ICAO CIRCULAR

CIRCULAR 79-AN/67

1967

PROVISIONAL ACCEPTABLE MEANS OF COMPLIANCE

GUST CRITERIA

Prepared by the Airworthiness Committee and published by authority of the Secretary General

INTERNATIONAL
CIVIL AVIATION
ORGANIZATION
MONTREAL • CANADA

Published in separate English, French and Spanish editions by the International Civil Aviation Organization. All correspondence, except orders and subscriptions, should be addressed to the Secretary General of ICAO, International Aviation Building, 1080 University Street, Montreal 3 (Quebec), Canada.

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FOREWORD

1. The Standards in Annex 8, Airworthiness of Aircraft, are of the nature of broad specifications stating objectives rather than methods of realizing those objectives. In order to indicate by example the level of airworthiness intended by the Standards of that Annex, some specifications of a more detailed and quantitative nature have been included in the same volume under the title "Acceptable Means of Compliance". The Foreword of Annex 8 indicates the obligation under the Convention, resulting from the introduction of Acceptable Means of Compliance.

2. When the Annex was adopted on 13 June 1957, the Standards on the subjects Aeroplane Performance, Strength under Flight Loads, Reciprocating Engines, Turbine Engines, Propellers, and Navigation Lights were supplemented by Acceptable Means of Compliance. The absence of provisions of that type pertaining to other subjects was considered either as recognition by the Council that the Standards in themselves defined a sufficiently accurate level of airworthiness, or as recognition by the Council that, due to the technical developments going on in a subject at the time of adoption of the Annex, it had not yet been possible to establish a more precise technical specification than that in the Standards themselves.

3. It is the essence of the Acceptable Means of Compliance that they permit variations in overall methods as well as in detailed application. Therefore, Contracting States, in establishing national codes that will ensure compliance with the Standards, will sometimes need guidance as to the departures from Acceptable Means of Compliance that are suitable for the certification of aircraft other than those specified in their Range of Validity, and also as to the use of methods developed too recently to have behind them the suitable background of experience deemed necessary for introduction of an Acceptable Means of Compliance.

4. The guidance material is established by ICAO as "Provisional Acceptable Means of Compliance", a class of specification that does not impose any obligation under the Convention. The Provisional Acceptable Means of Compliance are not, like the Standards or the full-fledged Acceptable Means of Compliance, established by agreement between Contracting States; instead, they reflect an agreement reached by an international body of experts to the effect that a specification is worthy of trial.

5. Trial application of Provisional Acceptable Means of Compliance in national regulations or practices is intended to build up the amount of experience that, eventuallv, could lead to the introduction of an Acceptable Means of Compliance on the same subject.

6. The Provisional Acceptable Means of Compliance presented in this Circular was developed by the Airworthiness Committee, a body of experts authorized by the Council and functioning under the Air Navigation Commission. The Airworthiness Committee recommended the issuance of this Provisional Acceptable Means of Compliance in its report of the Seventh Meeting which was held from 22 November to 15 December 1966. The Air Navigation Commission, after satisfying itself that this Provisional Acceptable Means of Compliance was properly co-ordinated with the ICAO Standards and related material and that the policies of the Organization had been followed, authorized issue of this Provisional Acceptable Means of Compliance at the Fourth Meeting of its Fifty-Fourth Session on 31 January 1967. It is to be noted that in so doing the Air Navigation Commission did not pass judgement on, or endorse, the technical contents recommended by the Airworthiness Committee.

7. This Provisional Acceptable Means of Compliance contains specifications to provide for a level of safety equivalent to that intended by the provisions of paragraph 3.3.2 of Part III of Annex 8 to the Convention, when applied to aeroplanes falling within the Applicability set out herein. They may also be applied to other aeroplanes at the discretion of the States concerned.

8. The Airworthiness Committee based this Provisional Acceptable Means of Compliance on the current practices in the major aircraft-manufacturing States. The requirements are based on the discrete gust method assuming the aeroplane to be a rigid body. An acceptable method is given for taking account of the flexibility effects and the attention of the certification authorities is directed to the need of investigation of critical parts of the structure using the continuous turbulence technique. The Committee is undertaking studies on the application of power spectral approach methods in the calculation of response of currently operating transport aeroplanes to continuous turbulence in order to help develop an appropriate criterion at a later date.

9. States are invited to use these specifications and to notify ICAO of the extent to which they are being applied. Should any State find it desirable or necessary to adopt any significant variations from the specifications, that State is invited to notify the Organization of such differences.

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APPLICABILITY

This Provisional Acceptable Means of Compliance (PAMC) is applicable to subsonic transport aeroplanes which do not operate above 15 200 metres (50 000 ft) altitude and which do not incorporate new or special features with regard to configuration or operational use, as compared to the aeroplanes currently operating or which are ready to start operations in the near future (1967). The specifications may also be applied to other aeroplanes at the discretion of the States concerned.

1. DEFINITIONS

Design Maximum Weight	The maximum aeroplane weight used in structural design for flight load conditions.
Design Minimum Weight	The minimum aeroplane weight used in structural design for flight load conditions.
Design Wing Area	The area enclosed by the wing outline (including wing flaps in the retracted position and ailerons but excluding fillets or fairings) on surface containing the wing chords. The outline is assumed to be extended through the nacelle and fuselage to the plane of symmetry in a reasonable manner.
Load Factor - (Structural)	The total aerodynamic lift on the aeroplane, acting perpendicularly to the flight path, divided by the weight of the aeroplane. (Note - In steady level flight, the load factor is equal to unity.)
Limit Load	The highest load assumed to occur in the Anticipated Operating Conditions.
Ultimate Load	An ultimate load is the limit load multiplied by a prescribed factor of safety.
Mean Geometric Chord	The Design Wing Area divided by the wing span.
EAS (Equivalent Air Speed)	TAS $(\rho/\rho_0)^{\frac{1}{2}}$, where ρ_0 is the density of the air at sea level in the Standard Atmosphere, and ρ is the density of the air in the conditions under consideration.

TAS (True Air Speed)	The speed of the aeroplane relative to undisturbed air.
U_{de}	A design limit gust velocity appropriate to each altitude.
V_B	The design speed for maximum gust intensity.
V_C	A design cruising speed not expected to be deliberately exceeded in normal flight, unless higher speed is authorized for flight test in pilot training.
V_D	The design dive speed is sufficiently greater than V_C to make it unlikely that such a speed would be exceeded as a result of inadvertent speed increases in the Anticipated Operating Conditions taking into account the flying qualities and other characteristics of the aeroplane.
V_F	The design flap speed.

Note.- See Annex 8, Airworthiness of Aircraft, Part I, for other definitions.

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2. FACTOR OF SAFETY

2.1 The factor of safety is used in conjunction with ultimate loading conditions and provides for the possibility of load conditions greater than those expected in normal conditions of operations, uncertainties in the design and variation of structural strength including variation of strength resulting from deterioration in service.

2.2 The factor of safety should not be less than 1.5.

2.3 Where there is uncertainty about the strength of parts of the structure (e.g. fittings, castings, bonded parts) such parts are designed with factors of safety which can be expected to make them as reliable as the rest of the structure.

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3. STRENGTH AND DEFORMATION

3.1 For all critical loading conditions:

3.1.1 At all loads up to the limit load, no part of the aeroplane structure should incur detrimental deformations, and the functioning of moving parts essential for safety in the operating conditions corresponding with the loads should be satisfactory.

3.1.2 After removal of the limit load, no permanent detrimental deformation should be present in any part of the aeroplane structure.

3.1.3 The structure should be capable of supporting ultimate loads without failure. It should support the load for at least 3 seconds.

3.1.4 If deflection or deformation under the load would significantly change the distribution and magnitude of external or internal loads, such distribution should be taken into account.

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4. DESIGN AIRSPEEDS FOR GUST CONDITIONS

4.1 General

Design airspeeds are in terms of equivalent airspeeds (EAS). The design airspeeds V_F, V_B, V_C and V_D should be selected by the applicant but should not be less than the values denoted in this PAMC, except that they may be lower where the speeds are limited by consideration of compressibility effects.

4.2 Design flap speed V_F

V_F should be sufficiently greater than the minimum flight speed corresponding to the flap setting and particular weight to allow proper control in the event of flap retraction and also to provide an adequate margin of strength for the associated placarded speed.

4.3 Design speed for maximum gust intensity V_B

In the absence of better information V_B should not be less than the speed at which the aeroplane enters stall under the action of the maximum gust intensity given in paragraph 5.2.4.2, and should be suitably related to the operational turbulence penetration speed.

4.4 Design cruising speed V_C

V_C should be sufficiently greater than V_B to provide for inadvertent speed increases likely to occur as a result of severe atmospheric turbulence.

4.5 Design diving speed V_D

V_D should be sufficiently greater than V_C to provide for safe recovery from inadvertent speed increases occurring at V_C.

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5. GUST LOADS

5.1 General

5.1.1 The gust load requirements should be complied with:

(a) at all altitudes within the range selected by the applicant;

(b) at all weights from the design minimum weight to the maximum weight appropriate to each particular flight condition; and

(c) with any practical distribution of disposable load within the prescribed operating limitations stated in the Aeroplane Flight Manual.

5.1.2 The air and inertia loads resulting from the specified gusts are distributed so as to approximate actual conditions closely or to represent them conservatively.

5.1.3 Compressibility effects should be taken into account.

5.1.4 Where turbulence might produce transient stresses appreciably higher than those corresponding to gust loads in paragraphs 5.2 and 5.3, these effects should be considered in accordance with paragraph 5.4.

5.2 Symmetrical gust conditions

5.2.1 The aeroplane structure should have sufficient strength to withstand the loads corresponding with all combinations of airspeeds and load factors and within the boundaries of the limit V-n conditions shown in Figure 1.

5.2.2 A sufficient number of points on and within the gust V-n envelope should be investigated to ensure that the critical loads for each part of the aeroplane structure have been obtained.

5.2.3 The forces acting on the aeroplane should be placed in equilibrium in a rational or conservative manner.

Note.- In establishing such equilibrium it is normal to assume that:

(a) the loads on the wing and the horizontal tail surfaces are balanced by inertia forces;

(b) the pitching moments produced by the aerodynamic loads on the aeroplane are balanced by moments due to inertia forces.

5.2.4 Gust V-n envelope

5.2.4.1 For the purpose of determining limit loads, the aeroplane should be assumed to be subjected to symmetrical loading conditions resulting from encountering in straight level flight the up and down gusts prescribed in 5.2.4.2.

5.2.4.2 Gust velocities

5.2.4.2.1 The design limit gust velocities (U_{de}, EAS) at altitudes up to 6 100 metres (20 000 ft) should be not less than:

at speed V_B:	20.10 metres (66 ft) per second
at speed V_C:	15.25 metres (50 ft) per second
at speed V_D:	7.6 metres (25 ft) per second

5.2.4.2.2 At altitudes above 6 100 metres (20 000 ft) the V_C and V_D gust velocities may be decreased linearly from the given value at 6 100 metres (20 000 ft) to 50 per cent of that value at 15 200 metres (50 000 ft). The V_B gust velocity may be decreased linearly to 11.30 metres (38 ft) per second at 15 200 metres (50 000 ft) (see Fig. 1).

Note.- The application of a factor of safety of 1.5 on total limit load produces an asymmetry in required strength between positive and negative ultimate gust loads. If the negative gust could produce a critical design case, a suitable increase in the negative limit gust velocity should be considered.

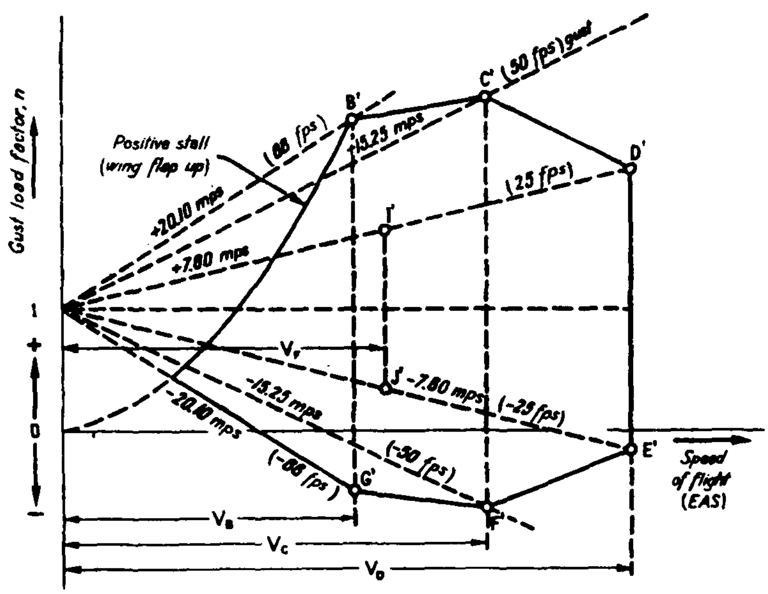

Fig. 1 - Gust V-n envelope

5.2.4.3 Effect of the design gusts

5.2.4.3.1 The load factor increment Δn due to gust encounter is obtained by the formula*:

$$\Delta n = \frac{1}{2} \rho_o V^2 \alpha_G \frac{a}{W/S}$$

where:

α_G = change in angle of attack due to gust given by the following formula:

$$\alpha_G = \arctan \frac{K_g U_{de}}{V}$$

K_g = an alleviating factor computed by the following formula:

$$K_g = \frac{0.88\mu_g}{5.3+\mu_g}$$

U_{de} = the design limit gust velocities (EAS) referred to in 5.2.4.2 in m/s (fps)

V = the flight speed (EAS) in m/s (fps)

μ_g = $\frac{2\ W/S}{\rho \bar{C} a\ g}$ = aeroplane mass parameter

W/S = the appropriate aeroplane design wing loading in kg/m^2 (lbs/sq. ft)

ρ_o = the air density at sea level in standard atmosphere in kg s^2/m^4 (slugs/cu. ft)

ρ = the air density in the conditions under consideration in kg s^{2}m/^{4} (slugs/cu. ft)

$\bar{C}$ = the mean geometric chord of the aeroplane's wing in metres (ft)

a = slope of the aeroplane normal force coefficient curve C_{NA} per radian if the gust loads are applied to the wing and the horizontal tail surface simultaneously by a rational method. It is acceptable to use the wing lift curve slope C_L per radian when the gust load is applied to the wings only, and the horizontal tail gust loads are treated as a separate condition.

g = acceleration due to gravity in m/s^2 (fps^2)

5.2.4.3.2 The altitude and speed of the aeroplane during gust encounter are assumed to remain constant.

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* For further details see NACA T.R. 1206.

5.2.4.4 Horizontal tail surface gust loads

5.2.4.4.1 In the absence of a rational investigation the horizontal tail surface loads should be calculated by adding to the initial tail load in steady level flight the airload increment due to the angle of attack increment as calculated by the method used for the wing but taking due account of wing downwash.

5.2.4.4.2 Equilibrium of pitching moments should be achieved by assuming appropriate pitching inertia forces.

Note.- The combination of the inertia and aerodynamic loads due to limit gusts on the tail may be less critical for the fuselage than those due to a lesser gust. In this case a reduced gust condition should be investigated.

5.2.4.5 Gust loads - flaps extended, low speed

When wing flaps or other auxiliary high lift devices are intended for use at relatively low airspeed, the aeroplane structure should have sufficient strength to withstand the following symmetrical gust conditions in straight level flight at speed V_F, with wing flaps in the landing position and also with wing flaps in any intermediate position which will produce critical loads in any part of the aeroplane:

(a) up and down limit gust velocity of 7.60 metres (25 ft) per second (EAS). For the purpose of determining design loads derived gusts should be used in accordance with 5.2.4.3. The gust conditions are represented by points I' and J' on Figure 1.

(b) rearward limit velocity of 7.60 metres (25 ft) per second along the flight path; no alleviating factor should be assumed.

5.2.4.6 Gust loads - flaps extended en route

For the flaps extended case en route, the design gusts of paragraph 5.2.4.2 should be used, together with appropriate numerical values of design speeds V_B, V_C and V_D.

5.3 Asymmetrical gust conditions

5.3.1 The aeroplane structure should have sufficient strength to withstand the loads resulting from an asymmetrical distribution of the vertical gust velocities as well as from lateral gusts.

5.3.2 Vertical gusts

Unless more accurate data are available it should be assumed that the aeroplane is subjected to the conditions of 5.2 whereby the airloads acting on the wing or the wing flaps on one side of the plane of symmetry correspond to the conditions of 5.2, and the air loads on the other wing or wing flaps are 80 per cent thereof. The difference is assumed to be caused by an appropriate reduction of the gust velocities.

5.3.3 Lateral gusts

5.3.3.1 The aeroplanes should be assumed to be subjected to the loads resulting from encountering in straight level flight the gusts normal to the plane of symmetry prescribed below (see note under 5.2.4.4.2):

(i) The design gust velocities and flight speeds should correspond to those prescribed in 5.2.4.2.

(ii) The effect of a lateral gust of maximum velocity U_{de} is assumed to be a change in the angle of attack of the vertical tail surfaces by an amount equal to:

$$\arc\tan \frac{K_{gt} U_{de}}{V}$$

where:

K_{gt} = an alleviating factor computed by the following formula:

$$K_{gt} \quad \frac{0.88\mu_{gt}}{5.3+\mu_{gt}}$$

U_{de} = the design limit gust velocities (EAS) referred to in 5.2.4.2, m/s (fps)

V = the flight speed (EAS) in m/s (fps)

$$\mu_{gt} = \frac{2 \quad W/S_t}{\bar{C}_t \rho \; a_t g}\left(\frac{i_z}{l_t}\right)^2 = \text{lateral mass parameter}$$

W = the appropriate aeroplane design weight in kg (lbs)

S_t = vertical tail surface in m^2 (ft^2)

ρ = the air density in kg s^2/m^4 (slugs/cu. ft)

g = acceleration due to gravity in m/s^2 (fps^2)

$\bar{C}_t$ = the mean geometric chord of the vertical tail surface in metres (ft)

a_t = slope of the lift curve of the vertical tail per radian

i_z = radius of gyration in yaw in metres (ft)

l_t = horizontal distance from aeroplane centre of gravity to lift centre of the vertical tail surface in metres (ft).

5.3.3.2 The attitude and speed of the aeroplane during gust encounter are assumed to remain constant.

5.4 Dynamic response to turbulence

5.4.1 Where turbulence is likely to produce transient stresses appreciably higher than the stresses corresponding to the gust loads of paragraphs 5.2 and 5.3, these effects should be considered.

5.4.2 The use of the simplified approach described in paragraphs 5.2 and 5.3 is based on previous experience. It can be considered as a comparison approach for use with aeroplanes with similar characteristics. In some cases, e.g. an aeroplane with high structural flexibility and/or lightly damped rigid body modes, the method may be insufficient to provide adequate strength. More appropriate analysis should be used when the relationship between rigid body modes and the various elastic modes, or when the damping in any modes, would result in significant increases in stresses. In these cases the national airworthiness authority is advised to require a more rational approach. It is the purpose of this paragraph to draw attention to these methods.

5.4.2.1 When effects of dynamic response to turbulence are assessed by use of derived gusts, the gust gradient distance H of the formula below should be varied over a sufficient range to ensure the most critical gradient for the configuration is covered. Response to all significant rigid body modes and elastic modes should be considered. Comparison with previous aeroplane types having similar characteristics which have had a satisfactory service experience from a structural point of view is acceptable. It should be acceptable to use the following gust form:

$U = 1/2\, U_{de}\, (1 - \cos \pi s/H)$ where

U_{de} = derived gust velocity in m/s (fps)

s = distance of penetration into gust in metres (ft)

H = gust gradient distance in metres (ft)

5.4.2.2 Where the degree of dissimilarity is unacceptable in considering the method of 5.4.2.1, the response of the aeroplane to vertical and lateral continuous turbulence should be considered. An acceptable model of the atmosphere for power spectral application is as follows:

$$\phi\, \omega = \frac{\sigma^2 L}{\pi} \; \frac{1 + \frac{8}{3}\left(1.339 L \frac{\omega}{v}\right)^2}{\left[1 + \left(1.339 \frac{\omega}{v}\right)^2\right]^{11/6}}$$

where:

ϕ = power-spectral density

σ = root-mean-square gust velocity in m/s (fps)

ω = frequency in rad/s

L = scale of turbulence [assumed to be 760 metres (2 500 ft)]

v = true airspeed m/s (fps)

- END -

ICAO TECHNICAL PUBLICATIONS

The following summary gives the status, and also describes in general terms the contents of the various series of technical publications issued by the International Civil Aviation Organization. It does not include specialized publications that do not fall specifically within one of the series, such as the ICAO Aeronautical Chart Catalogue *or the* Meteorological Tables for International Air Navigation.

INTERNATIONAL STANDARDS AND RECOMMENDED PRACTICES are adopted by the Council in accordance with Articles 54, 37 and 90 of the Convention on International Civil Aviation and are designated, for convenience, as Annexes to the Convention. The uniform application by Contracting States of the specifications comprised in the International Standards is recognized as necessary for the safety or regularity of international air navigation while the uniform application of the specifications in the Recommended Practices is regarded as desirable in the interest of safety, regularity or efficiency of international air navigation. Knowledge of any differences between the national regulations or practices of a State and those established by an International Standard is essential to the safety or regularity of international air navigation. In the event of non-compliance with an International Standard, a State has, in fact, an obligation, under Article 38 of the Convention, to notify the Council of any differences. Knowledge of differences from Recommended Practices may also be important for the safety of air navigation and, although the Convention does not impose any obligation with regard thereto, the Council has invited Contracting States to notify such differences in addition to those relating to International Standards.

PROCEDURES FOR AIR NAVIGATION SERVICES (PANS) are approved by the Council for world-wide application. They comprise, for the most part, operating procedures regarded as not yet having attained a sufficient degree of maturity for adoption as International Standards and Recommended Practices, as well as material of a more permanent character which is considered too detailed for incorporation in an Annex, or is susceptible to frequent amendment, for which the processes of the Convention would be too cumbersome. As in the case of Recommended Practices, the Council has invited Contracting States to notify any differences between their national practices and the PANS when the knowledge of such differences is important for the safety of air navigation.

REGIONAL SUPPLEMENTARY PROCEDURES (SUPPS) have a status similar to that of PANS in that they are approved by the Council, but only for application in the respective regions. They are prepared in consolidated form, since certain of the procedures apply to overlapping regions or are common to two or more regions.

The following publications are prepared by authority of the Secretary General in accordance with the principles and policies approved by the Council.

ICAO FIELD MANUALS derive their status from the International Standards, Recommended Practices and PANS from which they are compiled. They are prepared primarily for the use of personnel engaged in operations in the field, as a service to those Contracting States who do not find it practicable, for various reasons, to prepare them for their own use.

TECHNICAL MANUALS provide guidance and information in amplification of the International Standards, Recommended Practices and PANS, the implementation of which they are designed to facilitate.

AIR NAVIGATION PLANS detail requirements for facilities and services for international air navigation in the respective ICAO Air Navigation Regions. They are prepared on the authority of the Secretary General on the basis of recommendations of regional air navigation meetings and of the Council action thereon. The plans are amended periodically to reflect changes in requirements and in the status of implementation of the recommended facilities and services.

ICAO CIRCULARS make available specialized information of interest to Contracting States. This includes studies on technical subjects as well as texts of Provisional Acceptable Means of Compliance.

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(Doc 8554, AN-CONF/4). 309 pp. .... U.S. $5.00

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Montreal, 22 November - 15 December 1966.
(Doc 8653-AN/887). 153 pp. .... U.S. $2.50

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6th edition, April 1967. 38 pp. .... U.S. $1.00

Annex 8 - Airworthiness of Aircraft.
5th edition (incorporating Amendments 1-86).
April 1962. 62 pp. .... U.S. $1.00

PROCEDURES FOR AIR NAVIGATION SERVICES

Aircraft Operations.
(Doc 8168-OPS/611/2). 2nd edition, 1967. 164 pp. .... U.S. $3.00

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1965. 37 pp. .... U.S. $0.75

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Aeroplane Performance. 2nd edition, 1967. 34 pp. .... U.S. $0.50

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