SUB-SECTION D3—STRUCTURES

CHAPTER D3—7 PRESSURE CABIN LOADS

Revised, 1st July, 1956

A.C.D 1 GENERAL General requirements governing the design of pressure cabins are given in **D4—3**. They are presented in terms of a declared maximum working differential pressure, Δp, a negative differential pressure, Δp (neg), and a declared maximum altitude, h. Excess of internal pressure over external pressure is considered as a positive pressure differential.

2 STRENGTH

2.1 **Static Strength**

2.1.1 The pressure cabin and local structure shall have proof and ultimate factors of not less than 1·0 and 1·5 respectively, under the following combination of loads :—

(a) **Positive Differential Pressure**
Loads corresponding to all differential pressures from zero to Δp appropriate to the altitude considered up to the declared maximum altitude, h.

(b) **Flight Loads**
The flight loads of **D3—2**, appropriate to the altitude considered.

2.1.2 Where the stresses corresponding to the specified loads can be significantly affected by loads corresponding to the external pressure distribution over the cabin in flight, this shall be taken into account in conditions appropriate to the flight case considered.

2.1.3 Where a pressurised cabin is separated into two or more compartments by bulkheads or floors, the primary structure shall be designed to withstand any pressure differences which might exist between compartments and, in particular, to withstand the effects of sudden release of pressure in any compartment having external doors, which open outwards, or windows.

NOTE : In the case of external doors, which open inwards, consideration is to be given to the possibility of loss of pressure due to failure of the door seal.

2.2 **Fatigue Strength.** The pressure cabin and local structure shall have satisfactory fatigue characteristics which shall be confirmed by an appropriate programme of tests. (See 4.3 and Appendix No. 1 to this chapter.)

3 RELIABILITY OF COMPONENTS Where the maximum height and the characteristics of a pressure cabin aeroplane are such that failure of any one pressure-containing component (e.g. a window) would be likely to prejudice the safety of any occupant, then the integrity of each such pressure-containing component shall be beyond reasonable doubt.

A.C.D

3.1 **Windows***

3.1.1 **Mounting of Windows.** The design of the mounting shall be such that it will not transmit any load(s) to the panel over the maximum operating ranges of loading and climatic conditions.

3.1.2 **Strength of Windows.** The strength of transparent panels shall be established by tests of a suitable number of panels (normally six) which shall be such as to prove their integrity under the most adverse operating conditions. The mounting used in these tests shall be as representative as possible of that used in the actual aeroplane installation and the means of achieving this shall be agreed by the Board.

4 TESTS†

4.1 **Static Strength Test‡**

4.1.1 A representative specimen of the pressure cabin shall be tested to establish compliance with 2.1.

4.1.2 A representative specimen of the pressure cabin shall be tested to a pressure of 2·0 Δp.

4.2 **Acceptance Tests (Series)‡** A test shall be made on each aeroplane (including Series) to establish that the pressure cabin can withstand the application of a test pressure of at least 1·33 Δp and that all associated equipment will continue to function satisfactorily.

4.3 **Repeated Loading Test**

4.3.1 Repeated loading tests shall be made to establish compliance with 2.2. The tests shall be used either—

(a) to show that all possible failures are of a "safe" variety (i.e. the type and rate of propagation of cracks are such that they would be noted in normal inspection before they introduced any significant likelihood of catastrophic failure) ;

or

(b) if (a) cannot be shown, to establish "safe" lives for the pressure cabin as a whole or its components parts.

4.3.2 In addition to supplementary tests on detailed parts, compliance with this requirement will normally involve a repeated loading test on a complete pressure cabin which has not been used previously for strength test work, but which has been subjected to the pressure appropriate to the acceptance test of 4.2. In the test on the complete cabin the significant loading conditions encountered in operation shall be represented, repeated applications of pressure shall be made up to a pressure of 1·0 Δp, and appropriate applications of significant external loads shall be made in combination.

4.3.3 The factor(s) by which safe lives will be established from the cycles of load withstood on test, will be decided by the Board having regard to the scope and nature of the test evidence available.

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*See Appendix No. 2 to this chapter.

†See also Appendix No. 2 to this chapter.

‡It is intended by the design requirements and recommendations of this chapter that the static design factors used will exceed, by a considerable margin, those necessary to ensure ability to withstand this test safely.

APPENDIX No. 1 TO CHAPTER D3—7

Issued, 1st July, 1956

DESIGN OF PRESSURE CABINS FOR SATISFACTORY FATIGUE CHARACTERISTICS

1 INTRODUCTION In the present state of knowledge, the final confirmation of satisfactory fatigue characteristics in pressure cabins and in limitations of "life" of components or the cabin as a whole, depends on repeated loading tests. There is, however, some evidence that certain design practices will be of considerable assistance in producing satisfactory characteristics in a cabin.

2 DESIGN PRACTICES These design practices are aimed at producing the following main characteristics :—

2.1 Fuselage Skin Structure

2.1.1 Prevention of Fatigue Skin Cracks

A large part of the fatigue problem is solved if it can be ensured that a crack never starts in the cabin due to repeated loads. To this end, areas of high stress should be avoided, particularly in the region of cut-outs and stress raisers. This will help to ensure that the local raising of stress due to riveting and other manufacturing processes, will not result in excessive stresses. Further, careful attention should be given to the detailed design in the region of cut-outs and stress raisers.

The manufacturing and assembly processes required by the design should be such that the general level of stress is raised as little as possible at local points. The processes should also be such that the risk of accidental damage or scratching of sheets and detailed parts is minimised.

2.1.2 Prevention of Catastrophic Propagation of Skin Cracks

While it may be possible to reduce the risk of cracks by the methods given in **D3—7**, 4.3.1 (a), cracks may still be caused accidentally and a further part of ensuring satisfactory fatigue characteristics is to design so that any crack which has started due to whatever cause, is unlikely to grow at such a rate as to result in explosive failure before it has been noticed in inspection. A main factor influencing the rate of growth of cracks is the general level of normal working stresses in the cabin in areas away from cut-outs and stress raisers, and this should be kept to a suitably low value.

It may also be possible, in the design, to minimise the risk of accidental damage to cabin skinning by such methods as positioning equipment and furnishings with sufficient clearance from the skin, that rubbing or scratching under vibratory loads is unlikely. Further, it may be possible to so arrange the areas in which maintenance work is likely to be required, that the accidental mishandling of tools and equipment is unlikely to result in damage to the fuselage skin.

2.1.3 Special Processes

The recommendations given above are based on experience with built-up riveted structures and any structures using special assembly processes should be subject to such special tests as are necessary to substantiate the fatigue characteristics of the jointing method and to substantiate that no excessive local raising of stress is involved in the process.

2.2 Single Load Path Members

Where the structural integrity of the pressure cabin depends upon a single member (e.g. window frame) the static design factors of such members shall be so high as to

preclude the possibility of fatigue failure, taking into account the type and use of the member and the possible effects of operational factors, such as

(a) possibility of corrosion,
(b) the likelihood of cracks due to overtightening of bolts or other damage in maintenance operations.

Where the single load path member is a casting, the static design factors referred to here are additional to the normal factors specified for castings.

Where it is not possible to be assured that the possibility of fatigue failure has been removed by this method, special tests of these parts to give such assurance should be included in the supplementary tests referred to in D3—7, 4.3.2.

3 TESTS

3.1 In determining the extent of the programme for repeated load tests and in assessing the test results, due regard will be paid to the detailed design and to the stress levels both adjacent to and remote from cut-outs. Experience with aeroplanes having stress levels* of the order of 10,000 lb./sq. in. to 14,000 lb./sq. in., when associated with good general design, give reason to expect satisfactory fatigue properties.

3.2 A minimum of 10,000 cycles of load will have to be withstood satisfactorily on test before initial certification.

APPENDIX No. 2 TO CHAPTER D3—7

Revised, 1st July, 1956

PRESSURE CONTAINING WINDOWS

1 MOUNTING OF WINDOWS

1.1 Major factors to be considered in designing the mounting for suitability over ranges of loading and climatic conditions are :—

(a) differential contraction and expansion between the panel and the mounting due to varying ambient temperature,
(b) deflection of the panel due to temperature gradient across the thickness of the panel,
(c) deflection of the panel under pressure.

1.2 In mounting acrylic panels, methods which would induce stress concentrations in the panels (e.g. bolt holes, slots, cut-outs) should be avoided ; cemented joints should be avoided where possible.

2 DOUBLE WINDOW INSTALLATIONS

The following recommendations have been written primarily in terms of single windows; proposals for duplication of windows by using two panels, each capable of withstanding

*The stress levels referred to are those which would be present in the skin assuming no cut-outs or stress-raisers when the structure is subjected to loads corresponding to the positive differential pressure, Δp, and flight loads corresponding to steady level flight at cruising speed. They are related to structures using aluminium alloys having characteristics substantially similar to D.T.D. 546 and D.T.D. 610.

somewhat lower loads than those prescribed, should be discussed with the Board at an early stage in the design, the increased frequency of crazing of acrylic panels associated with any higher working stresses being taken into consideration.

3 TESTS

3.1 **General.** Transparent panels of conventional design complying with the requirements and other recommendations of this chapter, will normally be acceptable if the following tests are satisfactorily completed.

3.2 Functioning Tests

3.2.1 Tests should be carried out to establish the satisfactory functioning of the panel under the worst ground and flight operating conditions.

NOTE : Satisfactory functioning of the panel will have been established if no failure, cracking, delamination, loss of pressure or crazing occurs.

(a) **Ground Conditions**

Glass panels, which are equipped with an inter-layer or inter-space that can be heated, should be subjected to thermal shock cycling tests. The panel should be exposed to an ambient temperature, which should be the lowest for which the aeroplane is certificated, for a period long enough for conditions to stabilize. Full heat should be applied to the panel for a period of 5 minutes, the ambient air temperature being maintained at the outside surface. After each application of heat the panel should be allowed to return to the initial temperature conditions. The number of cycles are to be agreed with the Board.

(b) **Flight Conditions**

The panel should be subjected to the maximum working differential pressure and a representation of the maximum air loads around the panel. During this test, cycles of panel temperature representative of operational conditions should be applied. The initial conditions should correspond to the maximum of the climatic conditions for which the aeroplane is certificated* and the use of panel heating should correspond to the most adverse conditions from the point of view of the strength of the panel.

3.3 Strength Tests

3.3.1 **General**

(a) Tests should be carried out to establish that the strength of the weakest panel in the worst operating conditions is adequate to ensure complete reliability. Any means provided for heating the inter-layer of the panel should be functioning during the tests. For glass, this reliability is achieved by using high factors, and in the case of laminated glass panels a factor of 6·0 is required. In the case of acrylic panels a factor of 7·0 is required and also the maximum stress in the panel should not exceed 1,500 lb./sq. in. in order to ensure not only the reliability of the panel, but also that by keeping the working stresses to a low value, reasonable freedom from crazing is achieved. In this connection the importance of relieving all stresses which might be present due to forming and/or machining processes is emphasised. It is recommended that after all such manufacturing processes, panels should be annealed in accordance with Specification D.T.D. 925.

*If the conditions in which full pressure may be imposed on the ground is to be the subject of a limitation in the Flight Manual, the maximum temperature corresponding to such conditions may be used instead.

(b) For the purpose of these tests, any significant stresses induced in the panel by the temperature gradient, should either be determined independently, or calculated prior to the test. A load, in terms of applied pressure to produce the same stress should then be combined with loads due to other causes and the resulting design load multiplied by the relevant prescribed factor to obtain the ultimate test pressure which the panel is required to withstand.

NOTE : Failure of the panel is considered to have occurred when the panel fails to hold the pressure, or there is a drastic increase in deflection of the panel, or any of the laminations (other than a thin facing layer of annealed plate glass) breaks into fragments.

3.3.2 **Laminated Glass Panels.** The tests should establish that a mean factor of 6·0* is achieved, by the six panels tested, on the worst loads arising in flight or ground testing conditions. In the following test conditions the rate of application of load should be such that the ultimate load is reached in not less than 30 minutes.

(a) **Flight Conditions.** The panel is assumed to be subjected to the worst combination of loads due to :—

(i) the maximum working differential pressure ;
(ii) the air loads corresponding to external pressures around the panel ;
(iii) heating of the interlayer, if applicable, and any other significant temperature effects on the panel.

(b) **Ground Conditions.** The panel is assumed to be subjected to the loads due to maximum working differential pressure with the temperature on both sides of the panel equal to the maximum temperature of the climatic conditions for which the aeroplane is certificated.†

3.3.3 **Acrylic Panels.** Each design of acrylic panel should be subjected to the tests (a) and (b). In addition, panels which have bolt holes, cut-outs, or other forms of stress raisers, should be subjected to test (c).

(a) The tests should establish that, with a rate of application of load of the order of 5 lb. per sq. in. per minute a mean factor of 7·0 is achieved, by the six panels tested, on the worst combination of loads due to :—

(i) the maximum working differential pressure, and
(ii) the air loads corresponding to the external pressures around the panel. The panel shall be maintained at a temperature equal to the maximum temperature of the climatic conditions for which the aeroplane is certificated.†

(b) It should be established by means of strain gauge tests that, under the loads occurring in normal flight with maximum differential pressure applied, the stress in the acrylic panels does not exceed 1,500 lb. per sq. in.

(c) The panel and mounting should be built into a pressure box, which is exposed to the elements and is representative of the aeroplane structure. The panel and mounting should be subjected to loads corresponding to the maximum differential working pressure and any additional loads occurring in normal flight ; the loads should be maintained for a period not less than the maximum duration of the aeroplane, and then removed for the same period of time. The panel should be subjected to cleaning processes (with approved transparency cleaner) representative of operational practice.

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*The prescribed factor applies to laminated panels having "toughened" glass layers mounted by means of a vinyl interlayer which is capable of withstanding the maximum differential pressure. The Board should be consulted regarding the appropriate factors for laminated panels using other materials.

†If the conditions in which full pressure may be imposed on the ground is to be the subject of a limitation in the Flight Manual, the maximum temperature corresponding to such conditions may be used instead.

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