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Records of Major Strength Tests

By

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Summary.—The strength attained in major strength tests, made over a period of ten years, is given for twenty-four wing systems and ten fuselages. A preliminary analysis is also presented from the standpoints of safety and design efficiency. One third of all the wing systems tested are found to be seriously understrength as originally designed, and it is concluded that wing and fuselage testing for all new types is essential for safety. The majority of understrength aircraft, however, were brought up to the required standard by local strengthening, and it is concluded that this has an important bearing on design efficiency.

1. *Introduction and Main Conclusions*.—This report gives the overall results of major strength tests on the wing systems of twenty-four British aircraft and on ten fuselages. These tests were made at the Royal Aircraft Establishment during the last ten years. Distribution of strength attained in the various tests is shown diagrammatically (Figs. 1, 2 and 3). The values used to denote strength are the ultimate failing loads expressed as a percentage of the nominal design objective.

The first object of this report is to present factual information for use as may be required, and numerical values for analytical purposes are to be found in the accompanying table. A brief analytical review is also given, leading to certain general conclusions regarding safety and design efficiency which it is proposed to outline.

First, it is clear that routine strength testing of the wing systems and fuselages of all new aircraft is essential for safety. Calculations of strength are clearly insufficient. In the condition as first delivered for test, half the aircraft wing systems failed to reach the design figure, and one third of the total were seriously understrength. Data for fuselages are less extensive, and for reasons given below less reliable, but the indications are that the results and conclusions are broadly similar to those for wings.

Secondly, the results indicate a tendency for a rather high proportion of British aircraft to be unnecessarily heavy from the strength standpoint. Thus, one quarter of the total wing systems as originally designed are classed as seriously overstrength (12 per cent or more). It is important to note, however, that the overstrength aircraft are mainly among earlier types, and there are indications that modern aircraft are being designed with much greater regard to weight economy.

* R.A.E. Report Structures 44, received 3rd October, 1949.

Finally, there is firm evidence of the part that can be played by local strengthening in the attainment of a high standard of structural efficiency. The figures available show that two-thirds of the wing structures initially understrength were brought up to an entirely acceptable standard by one or two minor alterations involving only a small increase of weight. Similar benefits appear to be obtainable also from local strengthening of fuselages.

2. *Brief Analysis of Initial Wing Tests.*—The results of initial tests on wing systems as shown in Fig. 1 are perhaps most remarkable for the wide range of variation of percentage strength values (54 per cent to 143 per cent) and for the comparative evenness of the distribution over most of this range.

Detail consideration of these results requires some assumptions concerning what is acceptable and what is unacceptable. It is proposed to regard as entirely satisfactory results lying between 100 per cent and 110 per cent, as being just on the safe side of the nominal design figures. Any structure reaching 120 per cent or more is then regarded as unnecessarily strong, whilst any structure not achieving more than 90 per cent is classed as definitely understrength and ordinarily quite unacceptable.

Thus the conclusions are reached that for wing systems in their original design condition:—

(*a*) One fifth are entirely satisfactory (100 per cent to 110 per cent.);

(*b*) One quarter are unnecessarily strong (120 per cent or more);

(*c*) One third are seriously understrength (90 per cent or less).

The remainder lie within 10 per cent of the region classed as entirely satisfactory and are not specifically classified.

These results clearly indicate the need for strength testing all wing systems, since reliance cannot be placed on calculations alone.

3. *Variation of Nominally Identical Specimens.*—In one respect the data are incomplete. The figures relate to particular specimens and there is ordinarily no evidence of variation of nominally identical specimens of any one type. At one time such variation gave rise to special concern, though recently less attention has been given to it. The view is now widely held that the value of having an experimental check on calculations overshadows any doubts as to the accuracy of representation of a series of structures by a single specimen. This view is supported by the figures here made available. The errors in initial design calculations are on the whole much greater than any likely structural variations of nominally identical specimens.

In any case, it seems reasonable to ignore variation between nominally identical structures for the purpose of this overall statistical review. With as many as twenty-four results for wing systems, the effect may be regarded as 'averaging-out' and unlikely to affect general conclusions.

4. *Understrength Wings.*—Eleven out of the twenty-four wing systems initially failed to reach the nominal 100 per cent. Further consideration has been given to these cases (*see* Fig. 2), since for the majority a local modification was carried out to a higher standard of strength and a second test made. Nine out of eleven which initially failed to reach 100 per cent were so treated. Five out of the nine were at once rendered entirely acceptable (100 per cent to 110 per cent). A further one reached this standard after a second modification. Thus the general conclusion from these figures is that two-thirds of the wing systems initially understrength can be brought up to an entirely acceptable standard by one or two local modifications which usually incur only a minor increase of structure weight.

5. *Overstrength Wings.*—Six out of twenty-four wing systems tested attained 120 per cent or more as initially designed. Taken at its face value this result leads to the conclusion that an unduly high proportion of British aircraft are unnecessarily strong and hence unnecessarily

heavy. Further study of the individual cases, however, indicates that most of the overstrength aircraft are earlier types that were designed when the need for weight economy was not realised so acutely as it is now. There are grounds to suppose, in fact, that this early tendency to overstrength has been largely averted on modern types.

6. *Structural Efficiency and Local Strengthening.*—It is clear that the local strengthening process, which has been primarily used as a means of bringing weak structures up to an acceptable standard, merits special consideration from the standpoint of structural efficiency. An efficient structure is essentially one which is consistent in respect of its individual parts, with no one part appreciably weaker than the structure as a whole. Where local strengthening has been done, therefore, with small increase of weight, the structural efficiency of the design has in one respect at least been increased.

Consistency is not the whole of structural efficiency, however. An efficient structure must not be stronger than is required. The benefits of local strengthening may be largely lost if the result is merely to make a structure stronger than necessary. To obtain full benefit from local strengthening, therefore, the designer must anticipate it as a possibility from the start and design accordingly.

At the same time a considerable degree of caution is necessary, since not all structures benefit from local strengthening. Some of those which do not may be good examples of consistent structures, and yet fail to meet the requirements. Any solution of the problem of making best use of the principle of local strengthening, therefore, must be in the nature of a compromise. It is not unlikely that the present British practice approaches the best all-round compromise.

7. *Fuselage Tests.*—It is not considered advisable to attempt the same kind of analysis for fuselages as is done for wing systems. Results for only ten fuselages are available (Fig. 3), and four of the tests were not carried to the point of failure. The results taken collectively, moreover, are biased by a certain amount of selection. Fuselage testing has not always been done as a routine in the past, and there has usually been some special reason for having a test.

On the whole, however, there is nothing to suggest a large difference between fuselage and wing systems from the standpoint of deviation from the required standard of strength. A number are well understrength and, of four strengthened and re-tested, three reached an acceptable standard after modification. Evidence of a large proportion being seriously overstrength is not complete owing to many tests being stopped before failure, but there is no evidence to the contrary; and it is a reasonable assumption that the fuselages not considered to require testing would include a large number of overstrength cases.

The evidence for both wings and fuselages indicates that there are no grounds to justify dispensing with tests of fuselages in particular cases. For both safety and efficiency it would appear that all fuselages should be tested in future as a routine in the same way as wings have been treated for many years.

(60240) A*

TABLE

Test Results as Percentage of Required Strength

Wing Systems

Code letter	First test	Second test	Third test
A	73	74	75
B	82	95	
C	88	105	
D	143		
E	132		
F	70	78	103
G	88	104	112
H	54	103	
I	120		
J	112		
K	116		
L	100	108	

Code letter	First test	Second test	Third test
M	104		
N	125		
O	108		
P	91		
Q	98		
R	89	90	
S	80	105	112
T	134		
U	108		
V	102		
W	132		
X	93	104	

Fuselages

Code letter	First test	Second test	Third test
A	60	75	92
B	80	100*	
C	120*		
D	118		
E	120		

Code letter	First test	Second test	Third test
F	44	113	
G	124		
H	100		
I	100*		
J	50	149*	

* Indicates specimen unbroken.

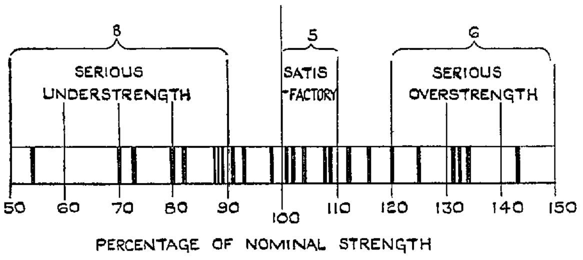

FIG. 1. Distribution for first tests (wings).

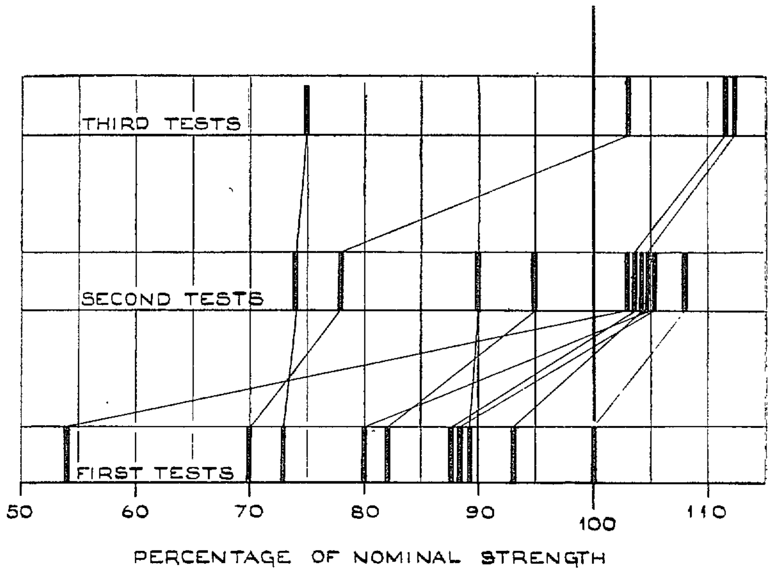

FIG. 2. Effect of local strengthening (wings).

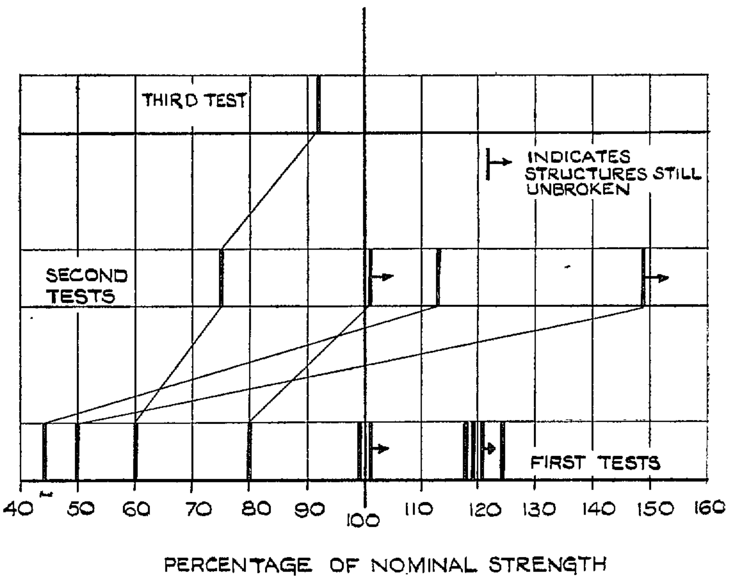

FIG. 3. Distribution for fuselages.

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