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Some Work on Tension Pads for Structural Tests

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SUMMARY

Sorbo rubber tension pads glued with Bostik adhesive have been developed for loading aircraft components during static and fatigue strength tests. The glueing technique, detail tests and pilot test on a typical component are described. A safe working stress for this type of pad is suggested. An account is given of some component approval tests in which tension pads were used.

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1 Introduction

Tension pads have been used successfully for a number of years on major strength tests of aircraft components in the U.S.A.[1] and Australia[2]. Each pad consists of a layer of soft rubber glued to a loading plate on the one side and to the metal covered surface of the test specimen on the other. The required tension load is applied to the loading plate and so to the specimen. The use of tension pads avoids the drilling of holes through the specimen for loading attachments and makes it easier to represent accurately the distribution of the aerodynamic loads, particularly the external suctions.

Tension pads have only recently come into use in this country and this note records some experimental work using types of rubber and adhesive which were readily available for preliminary trials of the method. The tension pads so developed have been found to be suitable for a working stress of 10 pounds per square inch (p.s.i.) of pad area and have shown a high degree of reliability in the tests so far made with them.

Detail development tests and component tests using these tension pads are briefly described.

2 Detail Development Tests

2.1 The majority of the development tests were made on rubber pads glued between two loading plates. The first objective was to develop a glueing technique which would exploit the full strength of the rubber that had been chosen. The second was to establish a safe working stress for the pads which would ensure a reserve factor of about 3 on the failing loads of the pads.

2.2 The final glueing technique and the materials used are described in Appendix I and a specimen test pad is shown in Fig. 1. Specimens were tested in tension and also in combined tension and shear. An average failing stress in tension of 45 p.s.i. was obtained and on the results of these tests a working stress of 10 p.s.i. was chosen. Other specimens were subjected to repeated applications of stresses of this order and to sustained loading at similar levels. It was found that 48 hours application of loads giving stresses in the rubber pad of 6 to 10 p.s.i. reduced the average tensile strength in a subsequent test to 32 p.s.i. Four pads have sustained loads of 5, 7, 9 and 11 p.s.i. for more than 3 weeks.

2.3 The possible effects of the skin of a test specimen buckling while under load were also investigated. Pads were glued to sheet-stringer panels which were then buckled by loading in compression. The pads were subsequently pulled off the buckled panels and it was found that buckling seriously weakened the adhesion of the pads. For example, one pad failed at 15 p.s.i. compared with 39 to 54 p.s.i. for pads tested between flat plates.

2.4 The full results are given in Appendix II.

3 Test of a Typical Component

3.1 Purpose of the experiment

An old tailplane was used for a pilot test to find the effect of loading a number of pads together under representative conditions. The tailplane had a semi-span of 122 inches and a root chord of 42 inches. It was of two spar sheet stringer construction with ribs at 12 inch pitch.

The skin was 24 ST alloy 0.025 inch thick with stringers at 5 inch pitch. Buckling of the skin might therefore be expected at about 1,000 p.s.i. which corresponds to 5% of the mean stress at the root at failure.

3.2 Test Conditions

The specimen was set at 10° dihedral and 5° incidence and loaded downwards. This introduced a shear component and also left the weight of the loading rig on the pads during the rigging period. There were 18 loading points, two on each rib, and the rig was arranged for equal loads to be applied through the pads at a working stress of 10.5 p.s.i. at the estimated failing load of the tailplane.

3.3 Preparation of Specimen

The glueing technique was as described in Appendix I except that one loading plate was glued to each pad as a preliminary operation before glueing the pad to the tailplane. The tailplane was cleaned and the pad positions were marked with a special paint recommended by Convair[1]*. The pads were glued directly over 3/32 inch mushroom headed rivets and lap joints, but to level the surface over the inspection panel screws an $\frac{1}{8}$ inch thick solid rubber sheet with holes to clear the screws was glued on first. A coating of glue was put around the sides of the pads and a 50 lb compression load was applied to each pad for 24 hours. After one week the pads were loaded individually to the maximum working load and showed no signs of failure.

3.4 The Test

The tailplane was rigged for test as shown in Fig. 2. The estimated failing load of 6,800 lb was applied in 10% increments at 10 minute intervals. At 50% load the front root pad started to peel away from the skin due to the local buckling of the skin.

The tailplane was unloaded and another pad was glued on. The test was resumed 4 days later and no further troubles developed. Failure of tailplane occurred at 95%. Figures (3) and (4) are photographs of the failure and they indicate the deep buckling of the compression surface.

After the tailplane test the pads were pulled off individually. To maintain skin buckling during this operation load was applied at the tip to produce a root bending moment of about 60% of the failing bending moment. The failing stress of the pads varied from 18 p.s.i. on the front root pad to 40 p.s.i. at the tip where there were no buckles. The average was 29 p.s.i. Rivets failed under eight of the pads and caused deep buckling of the skin and partial glue failures of the pads. The only complete glue failure was also associated with rivet failures and was at the front root pad.

4 Component approval tests using tension pads

Immediately following the pilot test described in para. 3, tension pads were used during approval tests on the wings and tail-unit of a large aircraft. No special precautions were taken, except that some of the loading plates near the leading edge were formed to fit the contour. The staff employed on the attachment of the pads had little previous experience

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* 16 gm Ethyl Cellulose, 32 m.l. Ethyl Alcohol.
250 m.l. Methyl Ethyl Ketone, 48 m.l. Phosphoric Acid 85%

of glueing techniques. Approximately 600 pads were used of which nearly 200 were used on the tail-unit components. Two pads only peeled off the specimen during the individual test to which each pad was subjected prior to the component test.

In the tail unit tests, i.e. tailplane, elevator, and fin and rudder, the pads were working at various stresses up to $13\frac{1}{2}$ p.s.i. There were no failures of the pads.

In the wing tests the most highly loaded pads were stressed to 10 p.s.i. No troubles were encountered with the pads during the initial tests, but leakage of water through rivet holes etc. when pressure was applied to an integral tank caused two pads to detach themselves from the specimen. As a precaution the working stress of the pads was restricted to 7 p.s.i. and all pads operating at higher stresses were bolted to the structure.

After the structural tests and after being glued to the specimens for about 8 months the ultimate strength of each pad on the tail-unit components was determined. Fig. 5 gives the results in the form of a histogram. Five pads indicated by cross hatching were adjacent to the crease in the skin which was formed by the compressive failure of the tailplane. It is thought that their strengths were lowered as a consequence; it is reasonable to ignore their low values and to conclude that the majority of the pads had a post-test strength greater than 30 p.s.i. but one or two pads had a post-test strength of little more than 10 p.s.i.

5 Conclusions

Tension pads at a maximum working stress of 10 pounds per square inch (p.s.i.) have been shown to be a reliable means of applying static loads to aircraft components. Preliminary tests indicate that they should also be satisfactory for fatigue tests up to 25,000 cycles of 0 to 10 p.s.i. Detail tests showed that the pressure during the setting of the glue should not be less than $1\frac{1}{2}$ p.s.i. for 24 hours, and, if possible, a week should elapse between the glueing and the loading of the specimen. It is advisable to test each pad individually to its maximum working load prior to the test.

Local buckling of the skin is a serious factor in reducing the adhesion of a pad, and water has been shown to reduce the strength of the glue.

6 Future Developments

Tests are proceeding to find an adhesive which can withstand the effects of water and which can be conveniently used under test laboratory conditions. There is also a necessity for a rubber-glue combination suitable for higher working stresses than 10 p.s.i. and an investigation of epoxy resins for this purpose is in hand.

LIST OF REFERENCES

No.	Author	Title, etc.
1	A.R. Vollmecke	Tension Pads for Structural Testing at Convair. Aircraft Engineering September, 1953
2	J.B. Belot	Static tests on a Mosquito Wing using Tension Pad Loading Australian Division of Aeronautics Report SM 97

APPENDIX I

The Method of Bonding Sorbo Rubber Tension Pads to the Loading Plates

1 The tension pads were made of Sorbo rubber, R.18, of 18 lb/ft^3 density. The rubber was cut in 6 inch squares from 1 inch thick sheets, and the sides were hollowed as shown in Fig. 1. The sides were so shaped to reduce the load at the edges, and this helped to prevent peeling when normal load was applied to the pad. The shaping was made with a wire scratch brushing wheel.

2 The plates were made of $\frac{1}{4}$ inch thick light alloy and were made $6\frac{1}{2}$ inch square to allow for the superficial expansion of the rubber caused by the pressure which was applied during the glue setting period. Two angles, attached by countersunk bolts to one side of the plate, provided the loading attachment to the tension pad.

3 Cleaning. The plates were degreased and roughened with No. $1\frac{1}{2}$ emery paper. A final cleaning with Trichlorethylene was made immediately prior to the application of the primer.

The rubber pad was roughened slightly with sand paper and then dipped in 90% concentrated sulphuric acid for 3 minutes. After this treatment the pad was washed thoroughly with running water and then dried in an air blast. This treatment broke the faces of the pad into fine cracks and produced a satisfactory key for the glue-rubber bond. Care was taken to avoid the contamination of these surfaces during the subsequent handling of the pad.

4 Glueing. After cleaning, the plates were coated with Boscolite 9245 primer, which hardened quickly. The rapid evaporation of the solvent in this primer made it essential that a newly opened tin should be used for each batch of specimens. The plates and the rubber were coated with Bostik 1410 and after 15 minutes open assembly time they were put together and a compression load was applied. The edge of the rubber was pressed into contact with the plates where necessary.

5 The fillet. A thick coating of Bostik 1410 was spread round the sides.

APPENDIX II

Results of Detail Tests

The specimens were 6 inches square and were tested between $\frac{1}{4}$ inch thick light alloy plates as in Fig. 1 and failures were in the rubber except where stated otherwise.

1 Tension stress at failure p.s.i.

54 53.4 45.3 43.5 41 39.2 38.6 Average 45

2 10 inch square specimen tested between $\frac{3}{8}$ inch thick cadmium plated steel plates.

Tension stress at failure p.s.i. 34.5.

3 $\frac{1}{4}$ inch cadmium plated steel plate one side; light alloy plate the other side.

Tension stress at failure p.s.i.

52 50.2 49 47.8 Average 50

4 Tension and Shear

Angle of pull to normal	0	10°	20°	30°
Stress at failure p.s.i.	44.7 42.7 41.9	42.8 41.4 37.4	47.5 39.8 37.8	40.3 34.9 33.5*
Average	43.1	40.5	41.7	36.2

5 Sustained Load followed by Tension test

Stress for 48 hours p.s.i.	6	8	10
Stress at failure p.s.i.	32.5 29.3*	34.1 26.9	29.8* 37.4

Average 32
* Glue failure

6 Effect of storage time and repeated loading

A wing on test might be loaded 2 or 3 times, left for a week or more

	N_1 weeks	N_2 weeks	Stress at Failure p.s.i.
Tension only			51.5 46.5
Repeated tension and shear loads and ageing tests	0 0 2 2 4 4 6 6 8 8	0 10 0 14 0 16 0 18 0 20	49.5 45.6 53.4 41.6 52.7 54.2 46.0 50.4 51.0 46.0

7 <u>Effect of Delay between Acid Treatment and Glueing</u>

Delay weeks	1	1	3
Tension stress at failure p.s.i.	46.6	61.3	46.6

8 <u>Effect of Lighter Pressure During Setting</u>

Clamps used in tests 1 to 7 and 9 and 10 applied a pressure during setting sufficient to compress the pads $\frac{1}{8}$ inch, about 6 p.s.i. For test 8 a 20 lb weight giving about $\frac{1}{2}$ p.s.i. was used.

Test condition	Stress p.s.i.
Tension	49.1*
Tension and shear 30° angle of pull	43.3*
Tension after 10 applications of 12 p.s.i.	43.7
As above but stored 8 weeks between repeated load and final test	39.5
Tension after 48 hours at 10 p.s.i.	37.8* 46.5

* Glue failure

/TABLE

9 Effect of Short Clamping Time and of Load Representing the Weight of the Loading System Suspended from the Pad during Rigging

Clamping time hours	Endurance under 40 lb load weeks	Test Conditions	Stress at Failure p.s.i.
29	1	Tension and shear 30° angle of pull	43.2
29	2	Tension	54.2
29	2	"	44.8
15	2	"	44
15	2	"	50
15	2	"	38.6

10 Effect of Short Curing Time

Curing time days	1	2	3	7	7
Tension stress at failure p.s.i.	41*	37.2	39.2	33	42.2

* Partial glue failure

11 Effect of Buckling of Skin under the Pads

The pads were glued to a sheet stringer panel. The panel was tested in compression to failure and the pads were then tested in tension.

Tension stress at failure p.s.i.

42 40 40 29* 27* 15½*

* Glue failure

The pad which failed at 15½ p.s.i. was over a deep buckle. There were smaller buckles under the other pads.

12 Fatigue Tests

Eight pads, glued between flat plates, sustained stresses of 0 to 10 p.s.i. tension for 100,000 cycles without failure.

13 Sustained loading Tension

Four pads have been subjected to sustained loading as listed below.

Stress p.s.i.	11	9	7	5
Endurance days	27½	50*	50*	50*

* Unbroken

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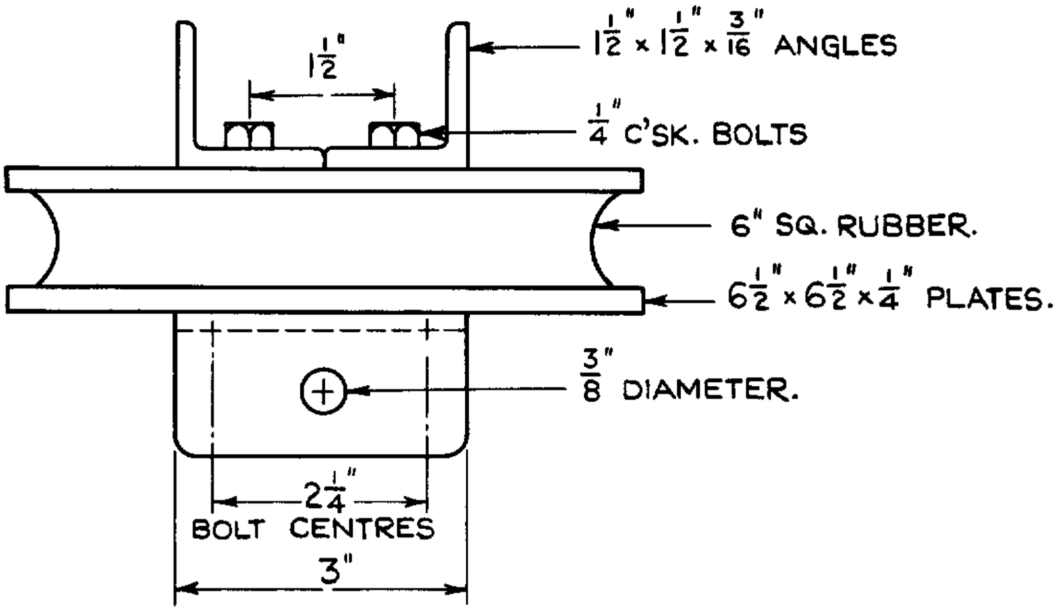

FIG. 1. TENSION PAD TEST SPECIMEN.

FIG.2

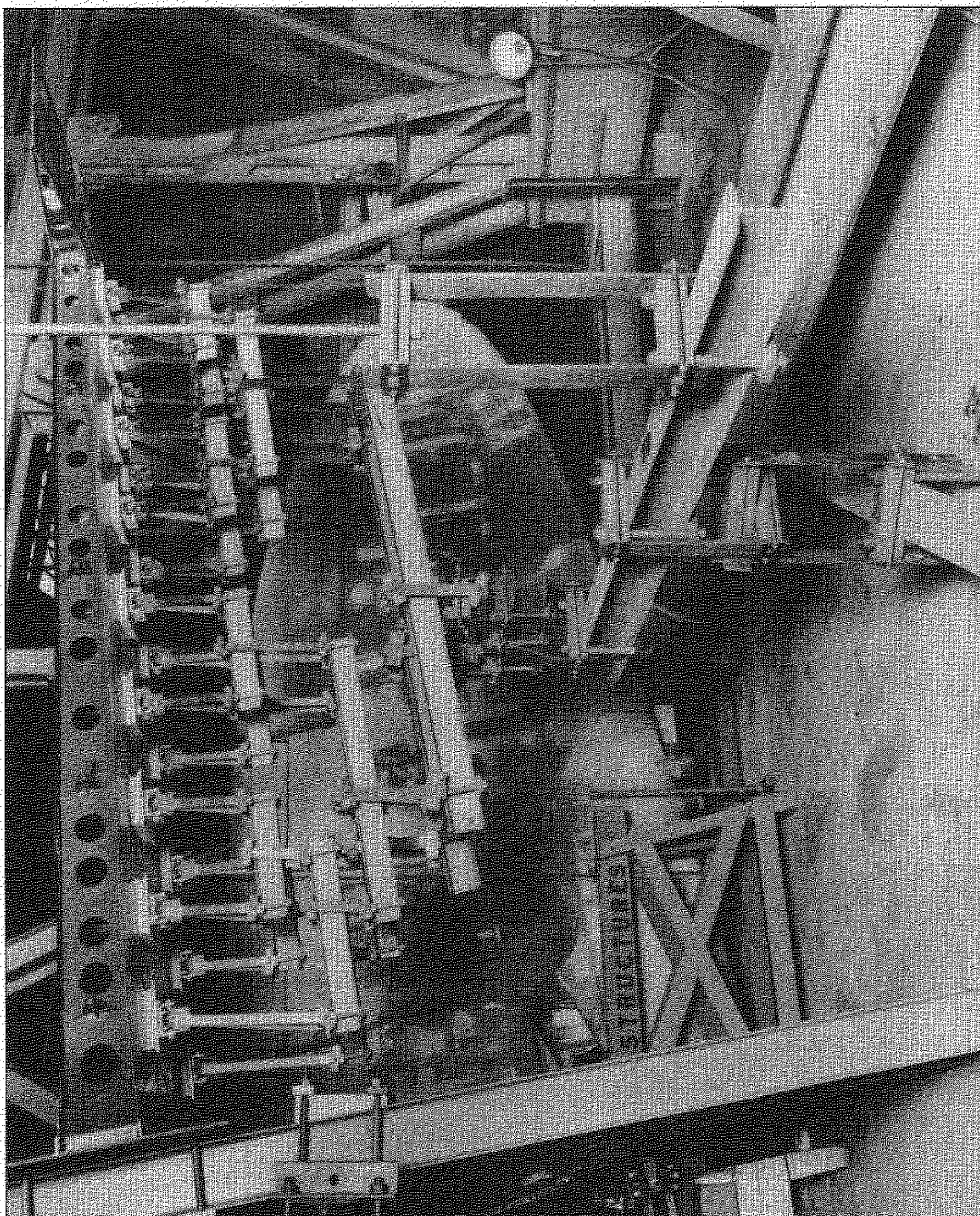

FIG.2. TAILPLANE RIGGED FOR TEST

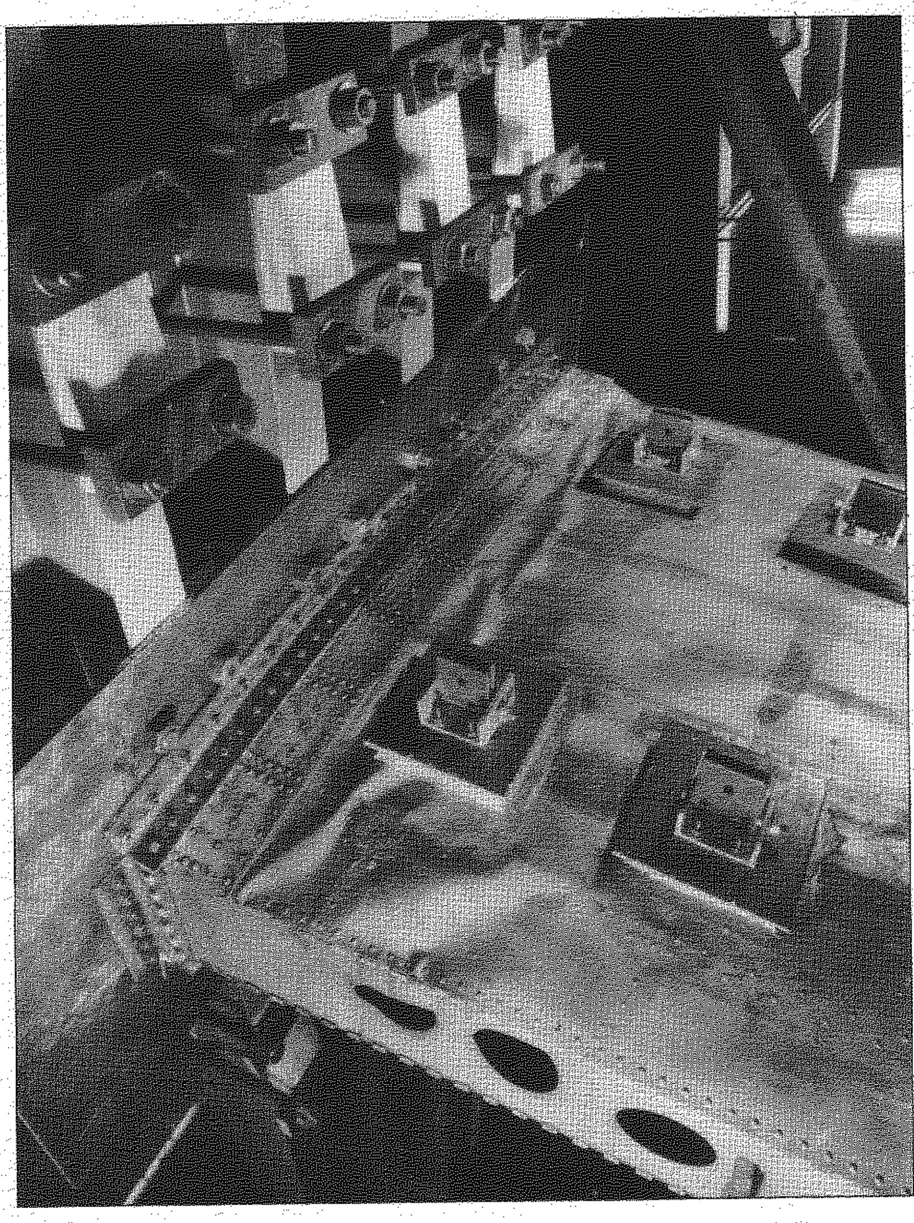

FIG.3. TAILPLANE FAILURE

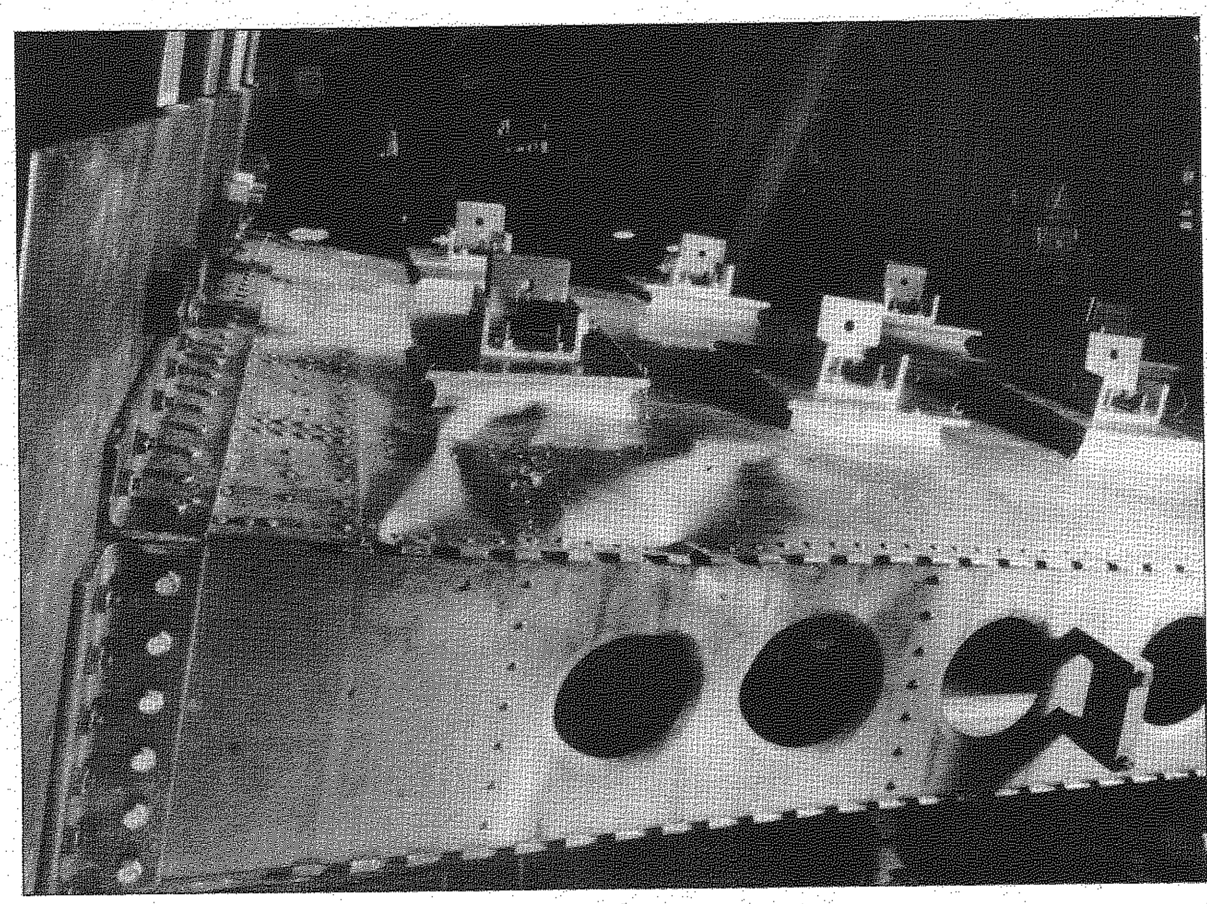

FIG.4. BUCKLING UNDER FRONT ROOT PAD

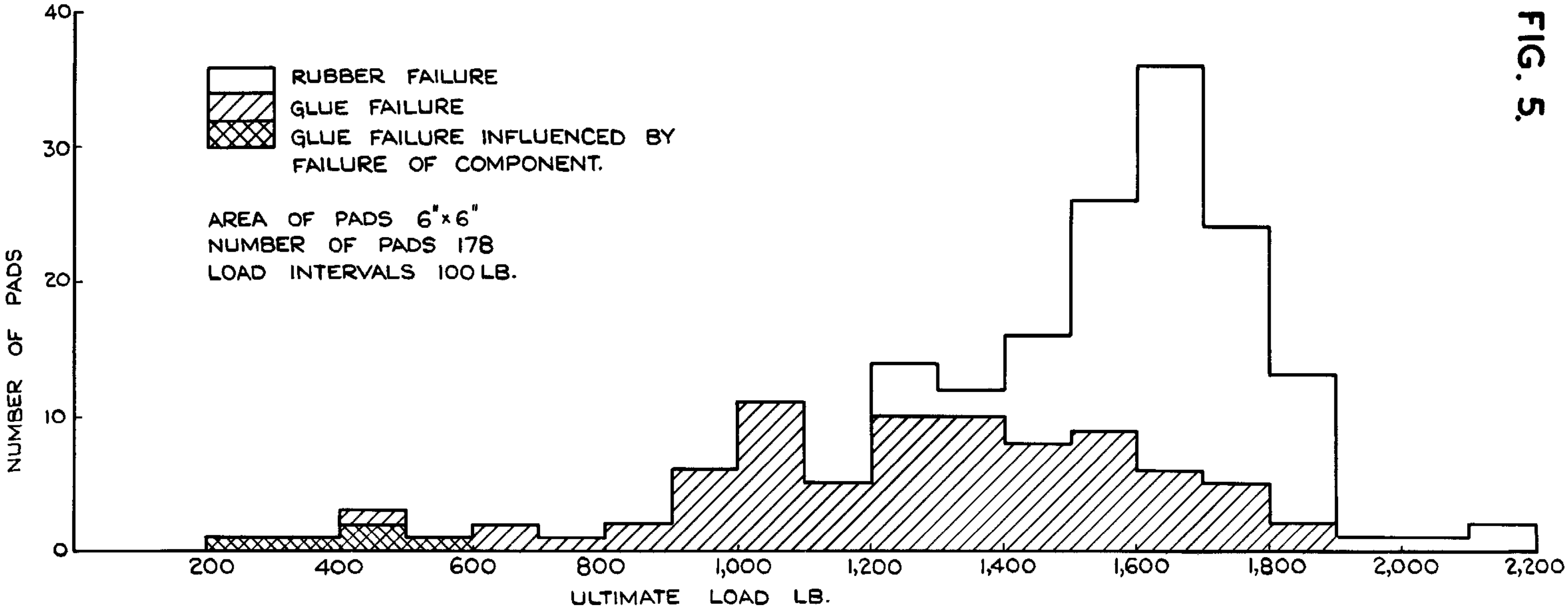

FIG. 5. HISTOGRAM OF FAILING LOADS OF PADS PULLED FROM COMPONENTS AFTER TEST.

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