The Practical Determination of Strength of Aircraft Fabric With Dope Removed

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THE PRACTICAL DETERMINATION OF STRENGTH OF AIRCRAFT FABRIC WITH DOPE REMOVED*

SUMMARY

A portable impact-type fabric tester was developed for use against doped aircraft fabric as an inspection aid to indicate whether or not the tensile strength of that fabric is above a predetermined value

Tests were conducted to calibrate the blow energy delivered by the tester versus tester adjustment and to determine the relationship between tester blow energy for penetration of doped fabric and the tensile strength of that fabric with the dope removed

Although the Civil Aeronautics Administration does not give formal approval status to aircraft fabric testers, the calibration results indicate that the tester covered by this report is a reliable device and that it may be used against doped fabric, both grade A and intermediate grade, to indicate whether or not the strength of that fabric with the dope removed is above predetermined minimum values, and to detect brittle dope Specific tester adjustments to provide properly for its use to test those fabrics are given

INTRODUCTION

Previous tests and studies were conducted at the Civil Aeronautics Administration (CAA) Technical Development Center (TDC) on a portable, impact-type fabric tester to determine if the tester could be used against the doped fabric covering of an aircraft to indicate whether or not the strength of the doped fabric is above an established minimum value The tests showed that the tester was suitable for such use[1] Although the tester has found wide use on the basis previously described, it could not be applied in connection with official CAA regulations because these regulations consider the strength of the fabric with dope removed[2]

Tests, therefore, were conducted during the spring and summer of 1955 to determine the accuracy and reliability of the tester as a means for delivering impact blow energy and to establish the relationship between tester adjustment for penetration of doped fabric and the tensile strength of the fabric with the dope removed This report describes these tests

DESCRIPTION OF FABRIC TESTER

Two impact-type fabric testers, shown in Fig 1, were supplied for test purposes by Steel City Testing Machines, Inc , 8817 Lyndon Avenue, Detroit 38, Michigan Essentially, these are identical with the tester described in Footnote 1

The tester is a tubular device approximately 13 inches long, terminating in a circular foot 2 inches in diameter When the foot is placed against the fabric and the tester handle is pushed, the handle telescopes over a tubular guide This pushes a coaxial hammer against a spring in the handle, thereby compressing the spring As the hammer moves into the handle,

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*Manuscript submitted for publication November 1957

[1] H Kendall King, Cecil B Phillips, and Alan L Morse, "The Practical Determination of Strength of Doped Fabric," CAA Technical Development Report No 129, November 1950

[2] "Maintenance, Repair, and Alteration of Airframes, Powerplants, Propellers, and Appliances," CAA Manual No 18, February 1957

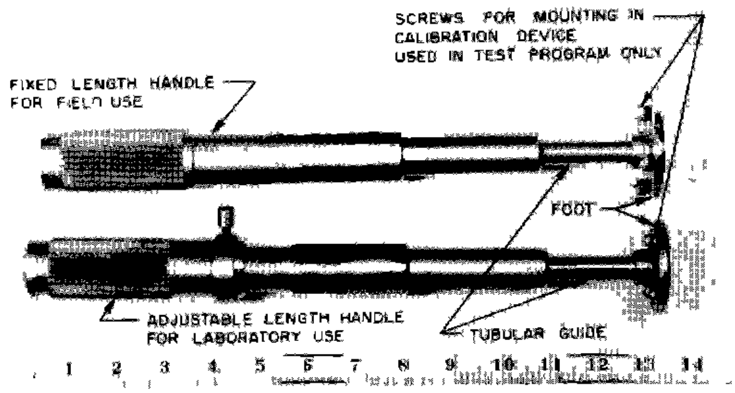

Fig 1 Impact-Type Fabric Testers

a reduction in the inside diameter of the handle causes a latch in the hammer to move in a transverse direction, thereby allowing the hammer to slide down over the guide The hammer, driven by the spring, impinges against a rod 3/16-inch in diameter This extends down through the guide and through the foot Its rounded end transmits the hammer blow to the fabric

Basically, the tester utilizes the impact force required to penetrate the fabric as a measure of fabric strength It was designed to minimize human technique errors in that the blow energy and rate of its application are automatically controlled A prestretching of the fabric also is automatic and occurs when the handle is pressed down The maximum degree of prestretching occurs just before the hammer is released

The energy of the blow against the fabric can be varied by adjusting the initial spring pressure This is accomplished either by inserting spacers in the handle behind the spring or providing a screwdown-type handle As shown in Fig 1, one of the testers provided by the manufacturer has a screwdown-type handle This was used for calibration purposes The other has a fixed-length handle in which spacers may be inserted to precompress the spring The fixed-length handle instrument is intended for use in the field It is preadjusted for the particular grade of fabric to be tested, and cannot be altered inadvertently

TESTS AND RESULTS

Tester Blow-Energy Characteristics

The calibration of the testers (adjustment versus blow energy) was accomplished in two steps

1 The blow energy, delivered by a ballistic pendulum, was correlated with the depths of the dents produced when the pendulum impinged against coupons of dead soft sheet aluminum (Aluminum Producers Specification No 1100-0)

2 The depth of dents produced when the tester was operated against identical coupons then was measured for various settings of the adjustable-handle tester and for various spacer thicknesses in the fixed-handle tester

The thickness of the aluminum sheet used for the coupons was 0 0163-inch plus or minus 0 0001-inch. This thickness tolerance was maintained through a process of coupon selection For blow energy test purposes, each coupon first was flattened such that flatness tolerances were held to within 0 002-inch, then it was held in the clamping device shown in Fig 2 This incorporates clamping rings that leave a disc area, 1 123 inches in diameter, free to be dented A dial gauge measures the depth of the dent

The ballistic pendulum is a basic and precise means for delivering specific values of blow energy [3] It was used to establish coupon denting as a means for measuring blow energy

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[3]Erich Hausmann, E E ScD , and Edgar P Slack, SBMS, "Physics," Third Edition, April 1949, p 188

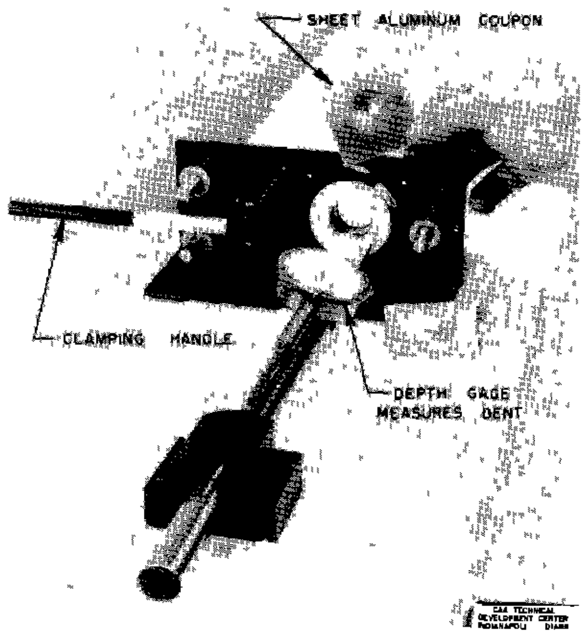

Fig 2 Clamping Device for Test Coupons

The setup is shown in Fig 3 As may be seen, the pendulum comprises a horizontal rod suspended by threads It terminates in a pin which is identical to the pin of the tester The pendulum was drawn back to successive increments of distance from the coupon and released to strike coupons clamped in the holder The multiplicity of tests were conducted at each increment and the resulting indentations were measured These tests established the fact that coupon denting will measure blow energy within plus or minus 0 04 per cent The curve of blow energy versus indentation is shown in Fig 4

Coupon denting then was used to measure the blow energy of the testers The test arrangement is shown in Fig 5 The same coupon clamping device and identical coupons were used to calibrate the fabric testers as were used in the ballistic pendulum tests Five dent

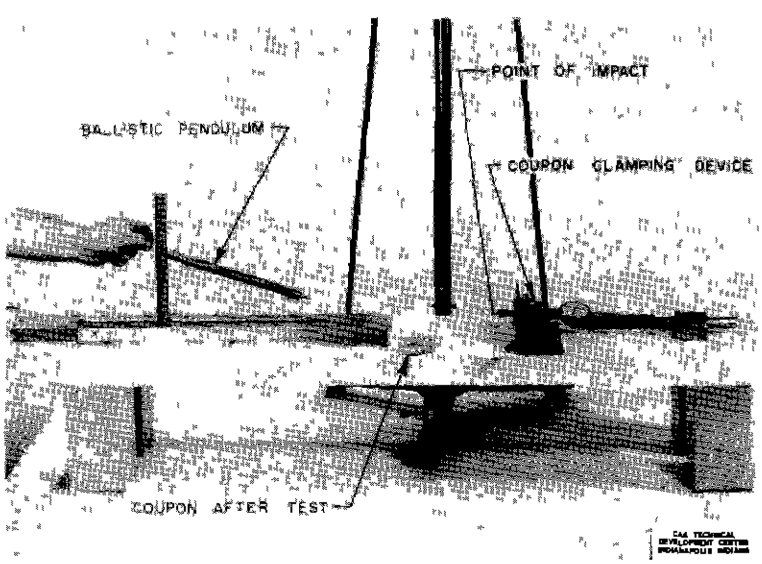

Fig 3 Coupon Dent Test - Ballistic Pendulum

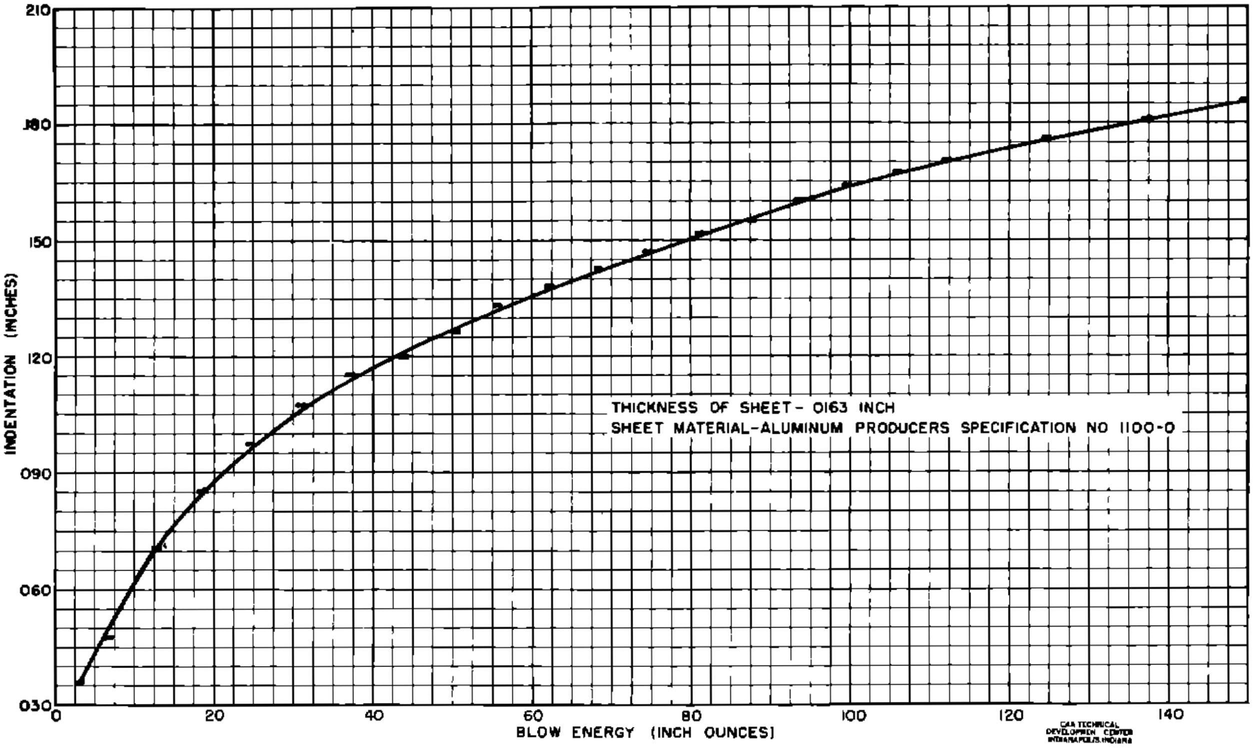

Fig 4 Ballistic Pendulum Blow Energy Versus Indentation of Sheet-Aluminum Coupon

tests were made at each setting of the adjustable-handle tester and for each increment of spacer thickness in the case of the fixed-handle tester The results are shown on Figs 6 and 7 From these it will be seen that, for a given setting, the tester can be depended upon to subject the fabric to a measured blow that is accurate to within plus or minus 4 5 per cent or within plus or minus 0 0035-inch depth of dent

Calibration of Tester Adjustment Versus Fabric Strength

To establish the relationship between tester adjustment for penetration of doped fabric and the corresponding strength of that fabric with dope removed, the tester with the adjustable handle was used on the fabric covering of a 1942 Waco biplane The airplane was made available through the cooperation of the Central States Aero Corporation, Shank Airport, Indianapolis, Indiana The fabric and its dope were ten years old A uniform calibration procedure was obtained through the use of a standard pattern 7 by 7 1/2 inches as shown in Fig 8 This includes four tensile strips, 1 inch wide and 7 inches long, each of which is flanked by a row of 13 spots for impact tests This pattern was stamped in ink at 42 locations on the top fabric surfaces of the upper and lower wings of the airplane to provide 2,730 impact test spots and 168 tensile test strips The patterns also were used as field data sheets The tester was applied at the pattern spots For each tensile strip, progressive changes in tester adjustment were made to determine the adjustment that would cause penetration of the doped fabric Tester adjustments and penetration results were noted on the corresponding pattern used as a data sheet, together with other pertinent data During the penetration tests in the field, the temperature varied from 70° to 73° F , and the relative humidity varied from 52 to 58 per cent

The fabric then was removed from the airplane and the four strips were cut from each pattern or sample A system of sample and strip numbering identified each strip with its sample and with its data sheet As each strip was tested, both the strength and the point of failure were noted on the corresponding data sheet The strip parts then were stapled together and to the pattern on the appropriate data sheet Figure 8 shows the utilization of the standard pattern as a data sheet and the tensile test strips attached to that data sheet

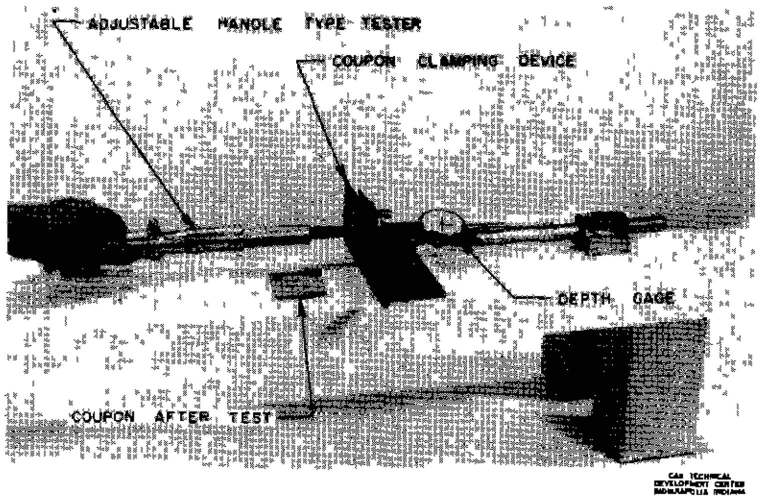

Fig 5 Tester Energy Tests - Coupon Dent

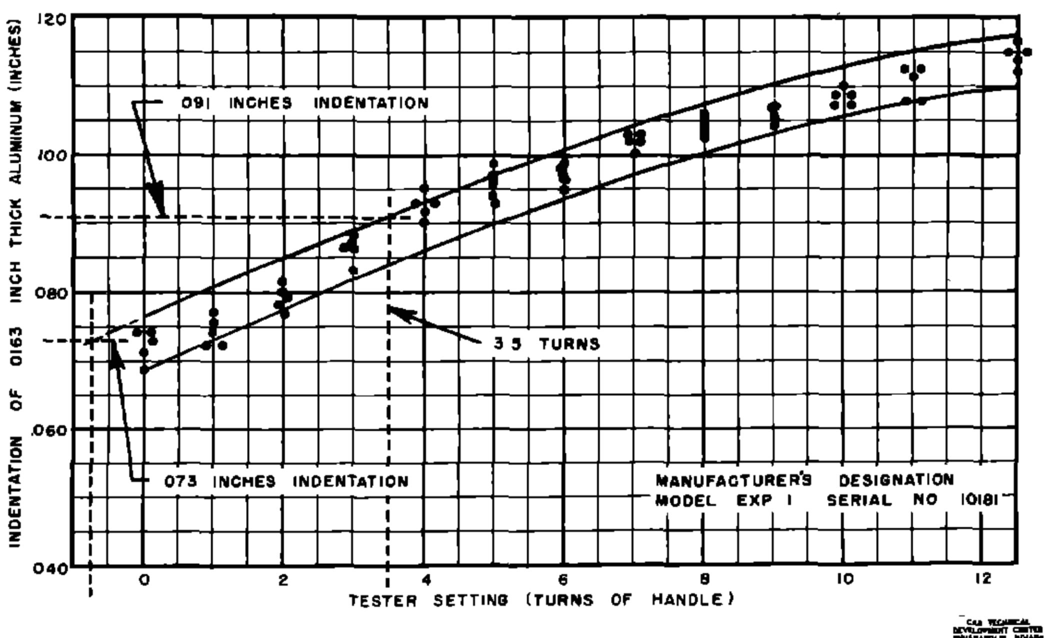

Fig 6 Impact Characteristics Aircraft Fabric Tester with Adjustable Handle

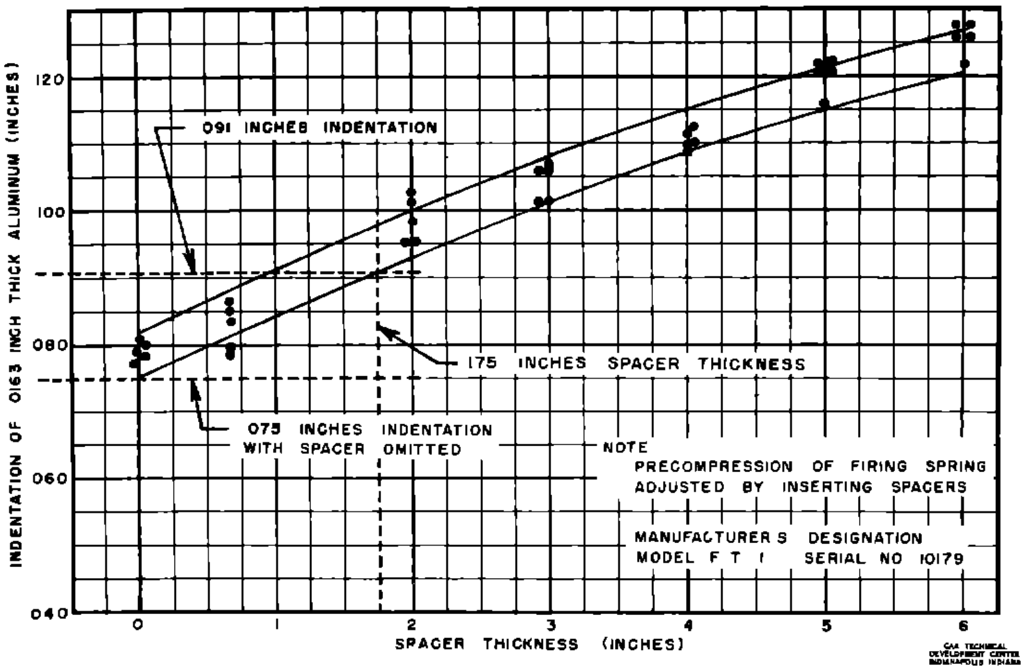

Fig 7 Impact Characteristics Aircraft Fabric Tester with Fixed-Length Handle

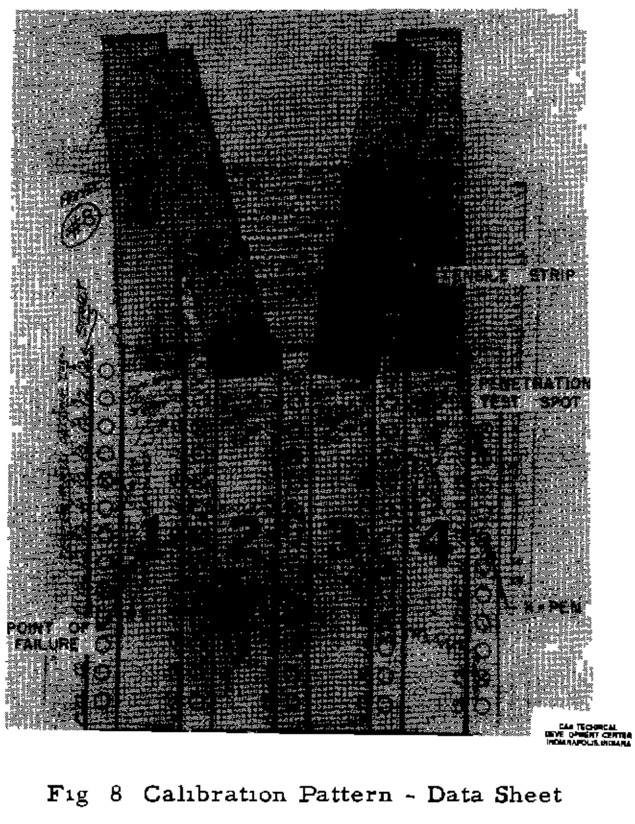

Fig 8 Calibration Pattern - Data Sheet

TABLE 1

RESUME OF TENSILE STRENGTH AND NONUNIFORMITY IN STRENGTH OF DOPED FABRIC

Test Sample of Strip	Dope	Upper Left-Hand Wing Min T S (lbs /in width)	Upper Left-Hand Wing Max T S (lbs /in width)	Lower Left-Hand Wing Min T S (lbs /in width)	Lower Left-Hand Wing Max T S (lbs /in width)
Includes all samples	On	47	90	64	140
	Off	28	57	42	76
Includes the four strips from 7-inch by 7 1/2-inch sample having greatest variation in tensile strength values	On	70	90	92	140
	Off	28	49	45	76

When the fabric was removed from the airplane and brought into the laboratory, the dope was removed from 17 of the samples (68 tensile strips) However, 25 of the samples were cut into 100 tensile strips without removing the dope The tensile strips were tested in a standard Model J-2 Scott fabric tensile testing machine which first was calibrated to insure precise operation During those tests the temperature varied from 73° to 78° F , and the relative humidity varied from 50 to 59 per cent Standard conditions include a temperature of 70° F and a relative humidity of 65 per cent [4] The tensile test results are shown in Fig 9

Figure 9 also shows an outline of the wings and the locations of the samples which incorporated the standard pattern The range of tensile strengths of the four strips taken from each sample is represented by a vertical bar which is aligned with the sample involved The strength of the fabric on the forward portion of the wings is represented by the bars in the upper half of Fig 9 The strength of the fabric on the rear portion is plotted in the lower half of Fig 9 The solid bars show the strength of the fabric with dope The dotted bars show its strength with dope removed

A resume of the tensile strength values is given in Table I From this it will be seen that the strength of the doped fabric and of fabric with dope removed is extremely nonuniform This also may be seen in Fig 10

Figure 9 also provides an indication as to the strength contributed by the dope Through a comparison of the bars showing the test results of samples Nos 3 and 4, rear, a dope strength of four pounds might be indicated, whereas the values shown by samples Nos 21 and 22, front, might be interpreted to show a dope strength of 57 pounds

The calibration of the tester was accomplished as follows go, no-go penetration tests were made by applying the tester to the spots on either side of the tensile strip. These are shown as small circles in Fig 8 While moving from one spot to the next, the tester adjustment was alternately increased and decreased as penetrations occurred or stopped In Fig 8, the tester adjustments are noted opposite each spot and a cross in the spot indicates penetration A process of averaging adjustments before and after penetration was employed to determine the penetration value However, only those spots adjacent to the point of tensile failure were considered The go, no-go values used are linked by curved lines in Fig 8 Referring to strip No 1 in Fig 8 and to the linked penetration values on either side of that strip, it will be seen that the following adjustments were involved 12 and 11, 12 and 12, 12 and 11, 11 and 12, 12 and 11, and 11 and 12 The average of those adjustment values is 11 6, which, together with the 73-pound tensile strength of strip No 1, locates one of the 68 points in Fig 10 A notation in that figure identifies this point

As will be noted, the points shown in Fig 10 are widely scattered. Each of these represents a value of tensile strength versus a penetration setting However, penetration

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[4] A S T M Specification D39-39

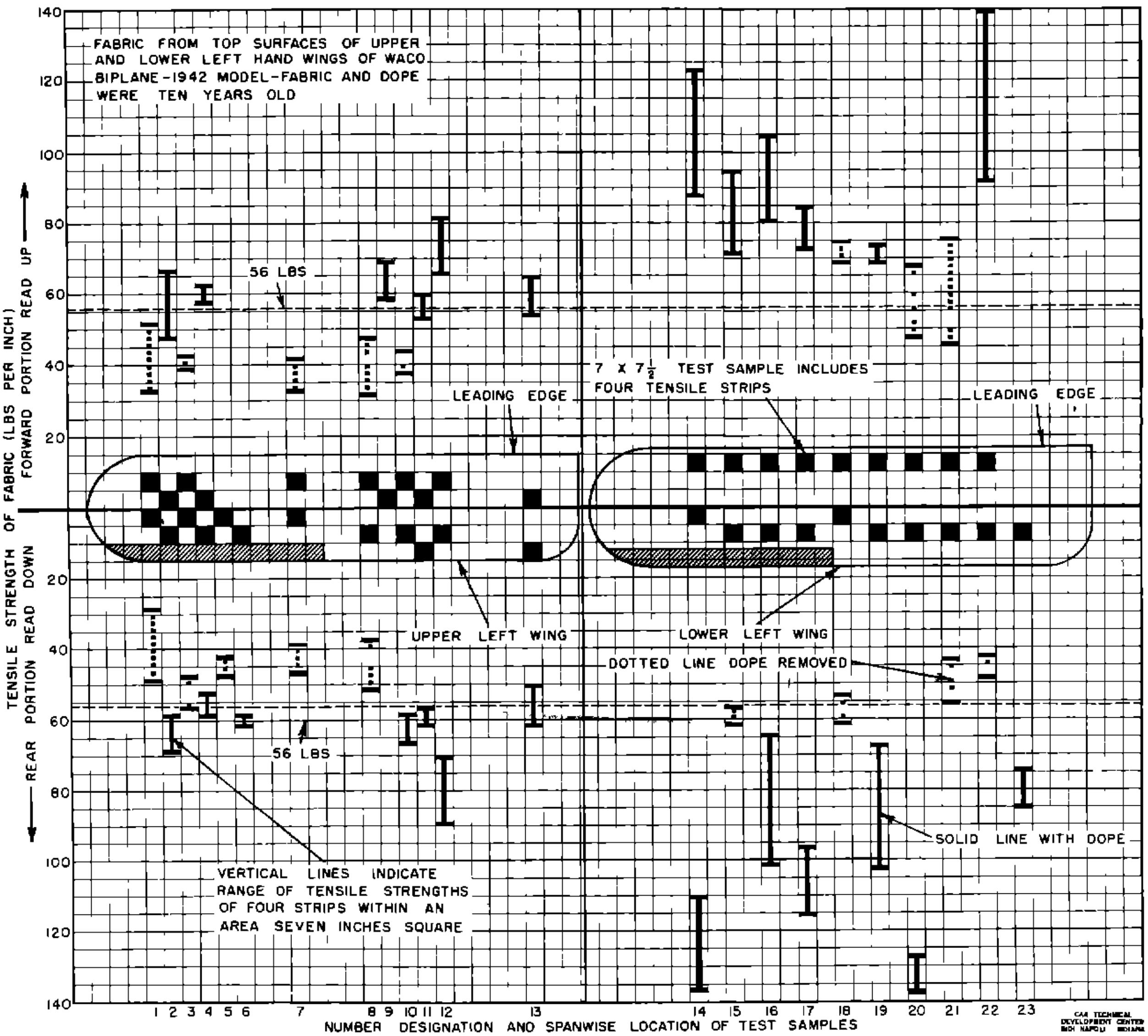

Fig 9 Tensile Strength Characteristics

tests cannot be made on the same portions of fabric that are subjected to tensile tests When this is considered in the light of the nonuniform characteristics of both the fabric and the dope, and since both testers are reasonably accurate in their delivery of impact blow energy (Figs 6 and 7), the scatter of points in Fig 10 must be attributed to the nonuniform characteristics of the fabric and dope

In spite of this scatter, however, it is possible to establish a penetration, no-penetration line This is shown on Fig 10 as the upper boundary of the calibration points This line may be used to establish an adjustment so that the tester may be employed to determine whether or not the tensile strength of an area of fabric less dope is greater than a predetermined value. Referring to Fig. 10, if the tester is adjusted to 3 5 turns of the handle, and if it is applied against an area of fabric a very large number of times and no penetration occurs, then the user can be reasonably sure that every portion of the fabric within that area will have a

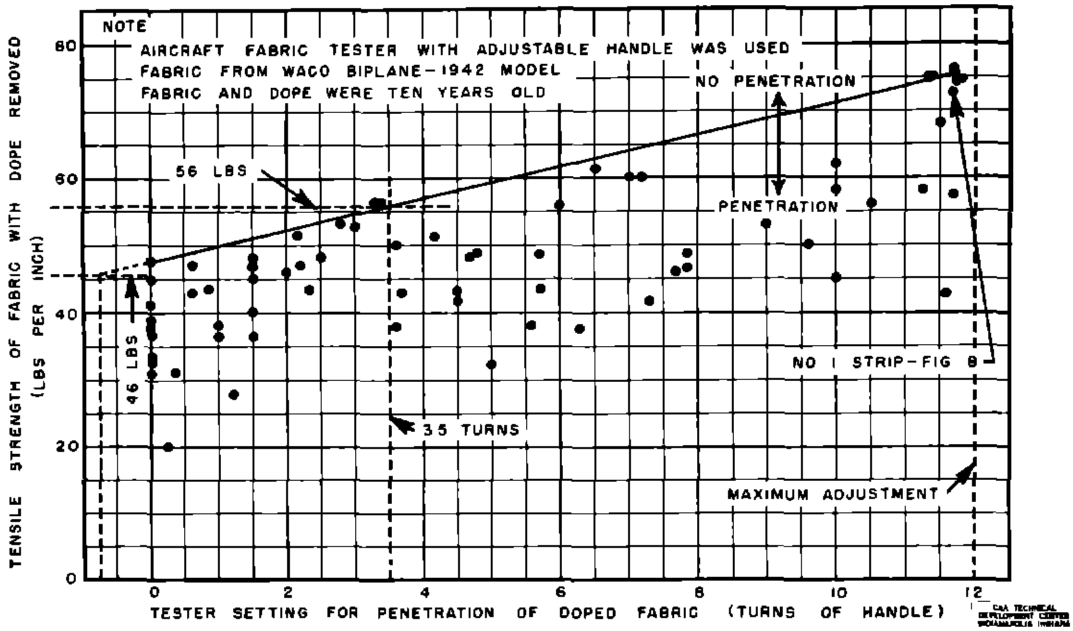

Fig 10 Fabric Tester Calibration Setting for Penetration of Doped Fabric Versus Tensile Strength of Fabric with Dope Removed

tensile strength of 56 pounds or more, with dope removed This value is the minimum allowable for grade A fabric [2]

Assuming that such limited indication is adequate, it then was desired to establish a means for determining the thickness of spacers to be inserted behind the springs of the fixed-handle or field-type testers so that they can be used for fabric testing

The spacer thickness to use in connection with grade A fabric was determined as follows referring to Fig 6, a setting of 3 5 turns of the handle can cause an indentation of the aluminum coupon of as much as 0 091-inch or as little as 0 083-inch The use of the higher value as a setting requirement is conservative This value was applied in Fig 7 for the fixed-handle tester From this figure, it will be seen that an indentation of 0 091-inch would be caused by spacer thicknesses varying from a low value of 0 100-inch to a high value of 0 175-inch In this case, the high value of 0 175-inch would be conservative, and if such a spacer were used in tester Serial No. 10197, the certainty of a reliable indication of adequate grade A fabric strength would be assured

Because of differences in manufacturing tolerances, it is considered more practical to specify field-tester adjustments in terms of coupon indentations, rather than in terms of spacer thicknesses This, plus the need for checking the tester's operating characteristics from time to time, has made it necessary to develop a calibration device for use in the field This is shown in Fig 11 Through its use, spacer thicknesses can be adjusted to cause a coupon indentation of at least 0 091-inch This would compensate for slight differences between individual testers.

In a similar manner to that described in the foregoing, Fig 10 indicates that the adjustable handle tester at minus 0 75 turns would provide an indication of fabric-less-dope strength of 46 pounds or more This is the minimum requirement for intermediate-grade fabric less dope Referring to Fig 6, a setting of minus 0 75 corresponds to a maximum indentation of 0 073-inch Referring to Fig 7, it will be seen that the omission of a spacer from that particular tester would insure an indentation value of at least 0 075-inch This would provide a slightly conservative indication as concerns intermediate-grade fabric

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[2] See footnote 2 on p 1

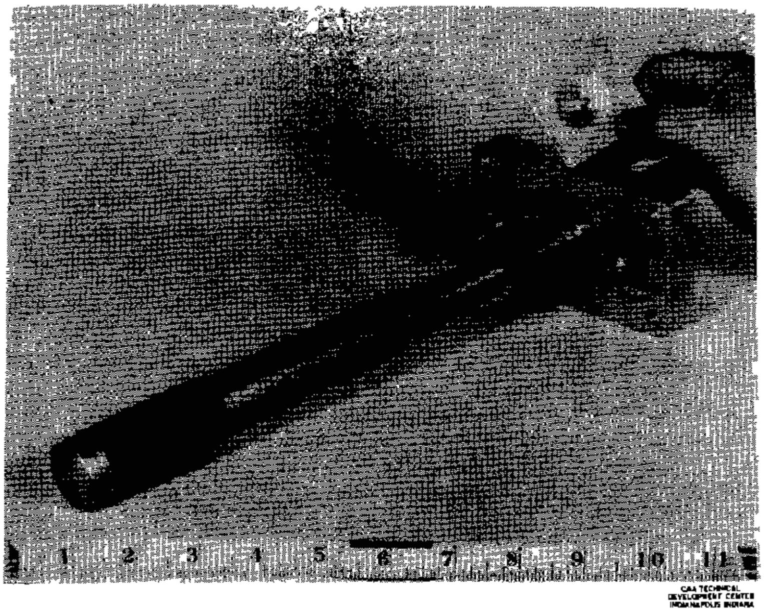

Fig 11 Field Calibration Device

The fabric testers adjusted and fitted with spacers as heretofore described have been used against aircraft coverings which comprised a combination of adequately strong fabric and brittle dope The dope showed cracking but the fabric was not penetrated

CONCLUSIONS

1 The depth of indentation of sheet aluminum provides an adequate means for measuring the blow energy delivered by the fabric tester

2 The test results presented in Fig 9 indicate significant variations in the tensile strength of deteriorated fabric both with and without dope

3 This portable, impact-type, fixed-handle fabric tester, when applied to the doped fabric covering of an aircraft, provides a reliable indication that the strength of that fabric with dope removed is above a predetermined minimum value

4 The test results indicate that this fixed-handle tester can be properly adjusted for use on either intermediate or grade A doped fabric

5 This portable, impact-type, fixed-handle fabric tester also is a suitable inspection device for detecting brittle dope.

6 The fixed-handle, impact-type fabric tester is better suited for use in the field than the adjustable-handle type

7 The blow energy requirements for the fixed-handle, impact-type fabric tester should be specified in terms of the depth of indentation produced when the tester is used against a sheet of dead soft aluminum having a thickness of 0 0163-inch plus or minus 0.0001-inch and having a flatness tolerance of 0 002-inch when it is clamped in such a manner that a circular area 1 123 inches in diameter is left free for denting

8 When the tester is to be used against grade A doped fabric, the depth of indentation mentioned in Item 7 should be at least 0 091-inch

9 When the tester is to be used against intermediate-grade doped fabric, the depth of indentation mentioned in Item 7 should be at least 0 073-inch