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CALIBRATION AND EVALUATION OF A PENETRATING-CONE TYPE FABRIC TESTER

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SUMMARY

Penetrating-cone fabric testers furnished to the Technical Development and Evaluation Center by the Bureau of Aeronautics, Department of the Navy and the Office of Aviation Safety of the Civil Aeronautics Administration, were used in a series of tests on the control surfaces of a DC-3 airplane. The results were correlated with laboratory tests of samples from the same areas. In the light of some general considerations of fabric properties and the results of the tests, it is concluded that the devices give an indication of fabric strength which may be interpreted within experimentally determined limits in terms of the minimum burst strength or the minimum tensile strength that may be expected in any sample for a given tester indication. However, the devices destroy the small area tested and are thereby limited in usefulness to the evaluation of those relatively small portions of the total fabric surfaces which have been judged to be doubtful by some other means. The validity of a testing procedure based on the use of this device is limited by the validity of the means used to select the areas of fabric to be tested.

INTRODUCTION

A penetrating-cone type fabric tester developed at the Naval Air Station, San Diego, Calif., was submitted to the TDEC in November 1947 by the Bureau of Aeronautics for testing and evaluation. Also, in February 1949, a Seyboth S-1 fabric tester, received from the Langley Corp., San Diego, Calif., by the Office of Aviation Safety of the CAA, was forwarded to this Center for test and evaluation. As this latter tester is a commercial duplicate of the Navy tester, this report applies to both devices, and gives the spring calibrations for each. The actual data on fabric strength were obtained with the Seyboth tester in connection with a survey of the strength of the fabric on the control surfaces of a DC-3 airplane.

Portable testers and two laboratory testers were used to obtain data, as described in a previously published report.[1] The evaluation of the penetrating-cone tester is based upon a comparison of the data obtained with the Seyboth tester and that obtained by laboratory tensile and burst tests. In addition, the evaluation considers some general properties of fabric and the strength factor of airworthiness as determined by the use of the tester in an inspection of the fabric surfaces of an airplane.

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

At present, an inspector evaluates many factors of airworthiness directly by a visual and tactile examination, interpreted in the light of his specialized training and experience. For the factor of fabric strength, however, it is generally agreed that the inspector can improve the accuracy and uniformity of his evaluations by using a suitable fabric strength test. The tester and the method of test must give an answer with respect to the strength of the entire fabric surface, beacuse aircraft fabric in service is highly nonuniform, and the strength of the fabric is different at different locations on the surfaces. Even when new and undoped, the material from the same bolt of cloth is not strictly uniform in strength. The various processes of doping and deterioration in service increase the variations in strength. The condition of the surface as a whole, therefore, cannot be predicted from the results of tests made on the original material before it was put on the airplane; neither can it be predicted from the results of laboratory tests of a few samples assumed to be representative of the highly nonuniform whole. Numerous tests that destroy the material as it is tested are obviously impractical for extensive use over large areas.

The evaluation of the penetrating-cone tester is based upon the considerations outlined; first, the correlation between the data obtained with the penetrating-cone tester and that obtained with the standard laboratory tests, and second, the usefulness of the tester in evaluating the strength of the fabric coverings on the surfaces of an airplane.

DESCRIPTION

The penetrating-cone tester consists of a spring-loaded, cylindrical plunger sliding through a sleeve having a flanged end. The conical, sharp-pointed end of the plunger projects from the flanged end of the handle, while the other end of the plunger and the encircling color bands are normally hidden within the handle. When the handle is grasped and the sharp tip of the plunger is pressed against the fabric, the point pierces the fabric and creates a free edge to start a tearing process. Further pressure slides the handle along the plunger, exposes the color bands and increases the spring load on the plunger until the flanged end of the handle contacts the fabric surface and stops further movement of the handle. In this position, a hole has been torn in the fabric, and the resistance of the fabric to further penetration balances the tearing component of the spring load on the plunger point. The color bands thus exposed give an indication of the tearing strength of the fabric-dope combination. Fig. 1 illustrates the use of the tester. Fig. 2 shows a tester fitted with an adapter and a precision dial indicator to facilitate recording and plotting the data on the displacement of the color-banded end of the plunger. A calibration of the displacement and the spring loading of the two testers, with the necessary corrections applied to compensate for the small added load of operating the dial indicator, is shown in Fig. 3.

TESTS

The ailerons, elevators and rudder as indicated diagrammatically in Fig. 4 were removed from the airplane preparatory to recovering them. About 100 test areas were selected, and the test pattern shown was stamped on 50 of the areas in the "as is" condition, and on 50 alternate areas after the dope had been removed by cleaning with a solvent. Within the central 5-inch square of each test pattern, 16 penetration tests were made with the penetrating-cone tester. The portable, penetrating-cone tester was applied to the fabric, as illustrated in Fig. 2, with a slight push and rotation of the handle as the point pierced the fabric and the cone continued to penetrate it, until the flange made contact with the fabric surface. The amount of the displacement of the color-banded plunger relative to the handle was read on the dial indicator. After the determinations with the portable tester were thus completed on all the selected areas, samples containing the test patterns and sufficient adjacent areas were cut from the fabric. These were used in the laboratory to obtain for each pattern eight determinations of tensile strength by the cut-strip method, and ten determinations of burst strength by pressure applied to the untreated side of the fabric with the Mullen tester. The relative location of the test areas and the average test values for each area are shown in Fig. 4.

RESULTS

It will be noted in Fig. 4 that the data obtained with the Seyboth tester increase the evidence that the value of fabric strength varies greatly from point to point on the surface. This is further confirmed by the data of the other tests. The general range of the average values over the whole surface is indicated in Table I. The extent of the correlation between the average values for the different tests on the same areas is shown in Fig. 5. The line of mean values shows the general trend and the minimum line shows the minimum standard test value to be associated with a given cone-penetration test value.

TABLE I

Range of Average Values Obtained on Samples From Same Plane

Average Test Value	Doped Samples Min.	Doped Samples Max.	Dope-Removed Samples Min.	Dope-Removed Samples Max.
Tensile, lb./in.	60	127	35	85
Burst, lb./in.^{2}	105	261	56	193
Cone Penetration (in.)	0.224	0.574	0.112	0.568

Table II shows appropriate values for the color bands obtained from the charts in Fig. 5 by correlations on both the mean line and the minimum line.

TABLE II

Comparison of Color Code and Burst Strength Values (Limits)
Seyboth Tester

Color Code	Burst Strength Test Values Obtained on Old Fabric			
	Doped		Dope Removed	
	Mean	Min.	Mean	Min.
Red	69-105	19-56	62-100	22-57
Yellow	105-125	56-76	100-116	57-75
Orange	125-161	76-113	116-148	75-108
First Green	161-176	113-128	148-163	108-121
Second Green	176-212	128-164	163-197	121-156
Third Green	212-245	164-197	197-226	156-185

Note: Attention is directed to close correlation of minimum values with dope and with dope removed.

DISCUSSION AND INTERPRETATION OF RESULTS

The comparison of penetrating-cone test data with tensile test and burst test data is essentially a comparison of tearing strength and tensile strength. With a fabric-dope combination, these are not strictly comparable, as doping increases the burst and tensile strength proportionately more than it increases the tearing strength. The correlation will be affected by the amount and condition of the dope, and may not be used for widely different combinations of fabric and dope.

Tearing of the fabric-dope combination cannot occur except from a free edge. A free edge in the covering of an airplane component does not normally exist, and would probably not be created except after failure in tension or bursting. The appropriate indication for resistance to failure would appear, therefore, to be the tensile strength or the bursting strength of the fabric-dope combination. This is recognized in the general acceptance of tensile tests and burst tests as standard tests for fabric and fabric-dope combinations.

The qualitative validity of an individual determination with the penetrating-cone tester, therefore, is established only for fabric-dope combinations similar to those used in obtaining the experimental correlation.

The quantitative validity for an individual determination is preferably established by the minimum line. This gives the lowest tensile strength or burst strength value which can be expected for a given penetration test value, and this is the practical answer sought. The range of numerical values corresponding to the color band correlation on the minimum line listed in Table II is suggested for use.

CONCLUSIONS

1. The penetrating-cone tester is mechanically sound, and provides a reproducible spring load on the plunger for a given mechanical displacement.

2. The tester gives an indication of fabric-dope tearing strength which may be interpreted in terms of burst strength or tensile strength only within experimentally determined limits on similar material.

3. The tester destroys the small area tested. Its use is therefore limited to the testing of areas judged by other means to be doubtful. It introduces into the inspection procedure the question of the degree of reliability of the "other means."

4. The tester is not suitable for use in an inspection survey of the entire fabric surfaces in inspection procedures designed to minimize the expense of repairs.

RECOMMENDATIONS

It is recommended that:

1. a mechanical, one-way friction catch be provided to retain the plunger in the position of the maximum reading until it is released for the next reading,

2. the minimum values of fabric strength obtained from the correlation charts be used rather than the mean values, and

3. other test means be used if the entire fabric surfaces are to be surveyed.

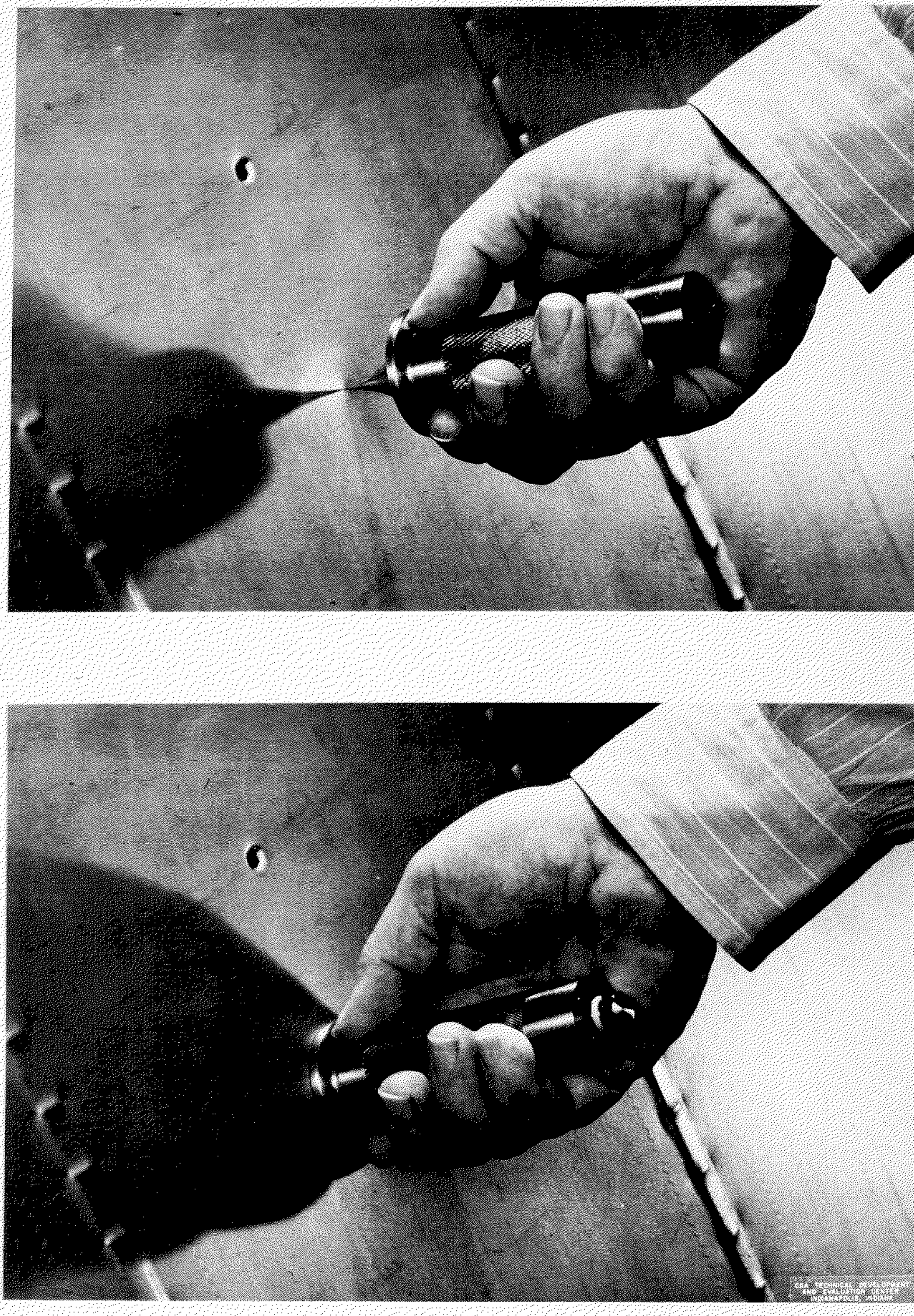
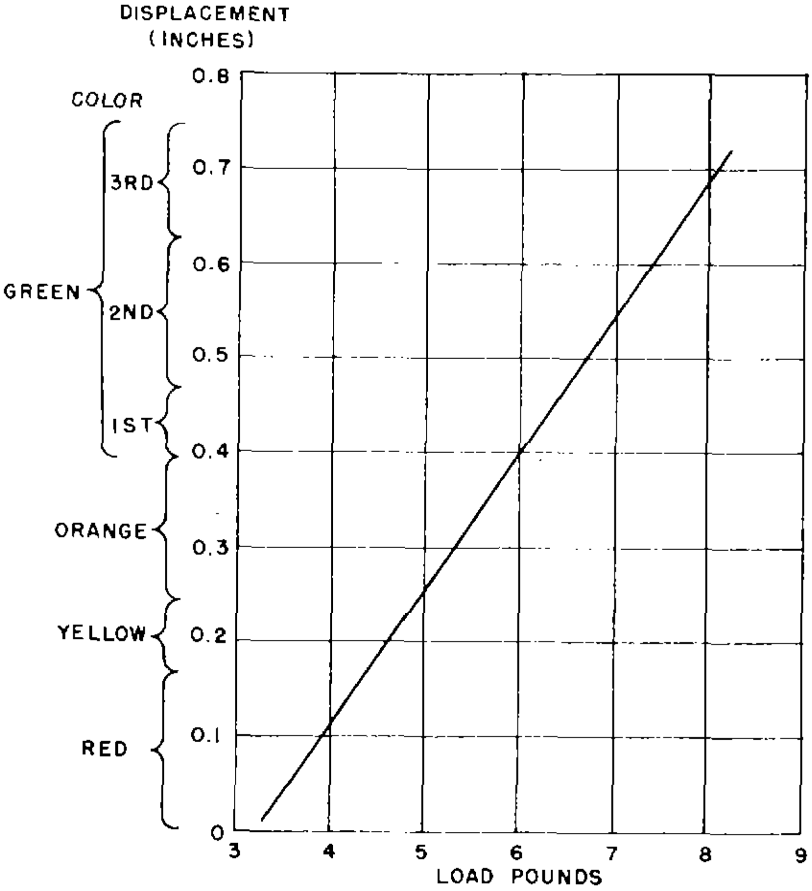
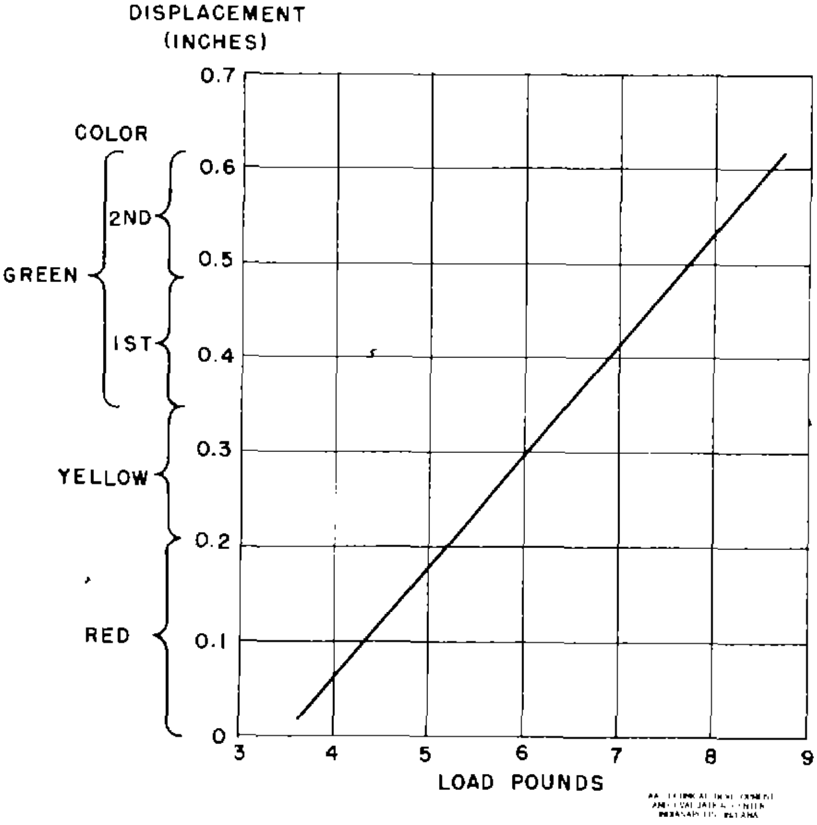


FIG. 1 PENETRATING-CONE TESTER

FIG. 2 PENETRATING-CONE TESTER WITH DIAL INDICATOR



CALIBRATION OF SEYBOTH TESTER



CALIBRATION OF SAN DIEGO TESTER

FIG. 3 CALIBRATION OF PENETRATING-CONE TESTERS

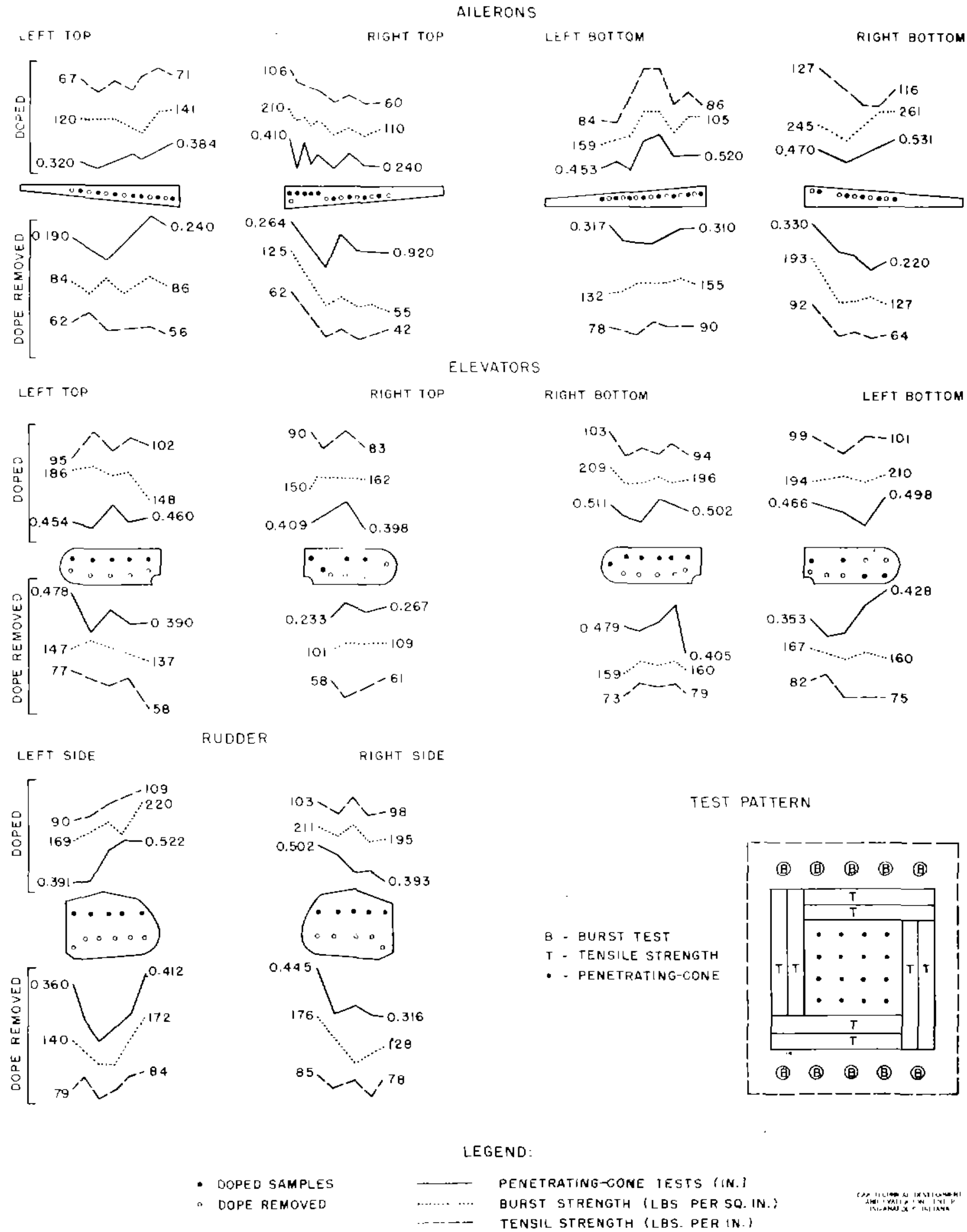


FIG. 4 LOCATION AND AVERAGE STRENGTH OF SAMPLES

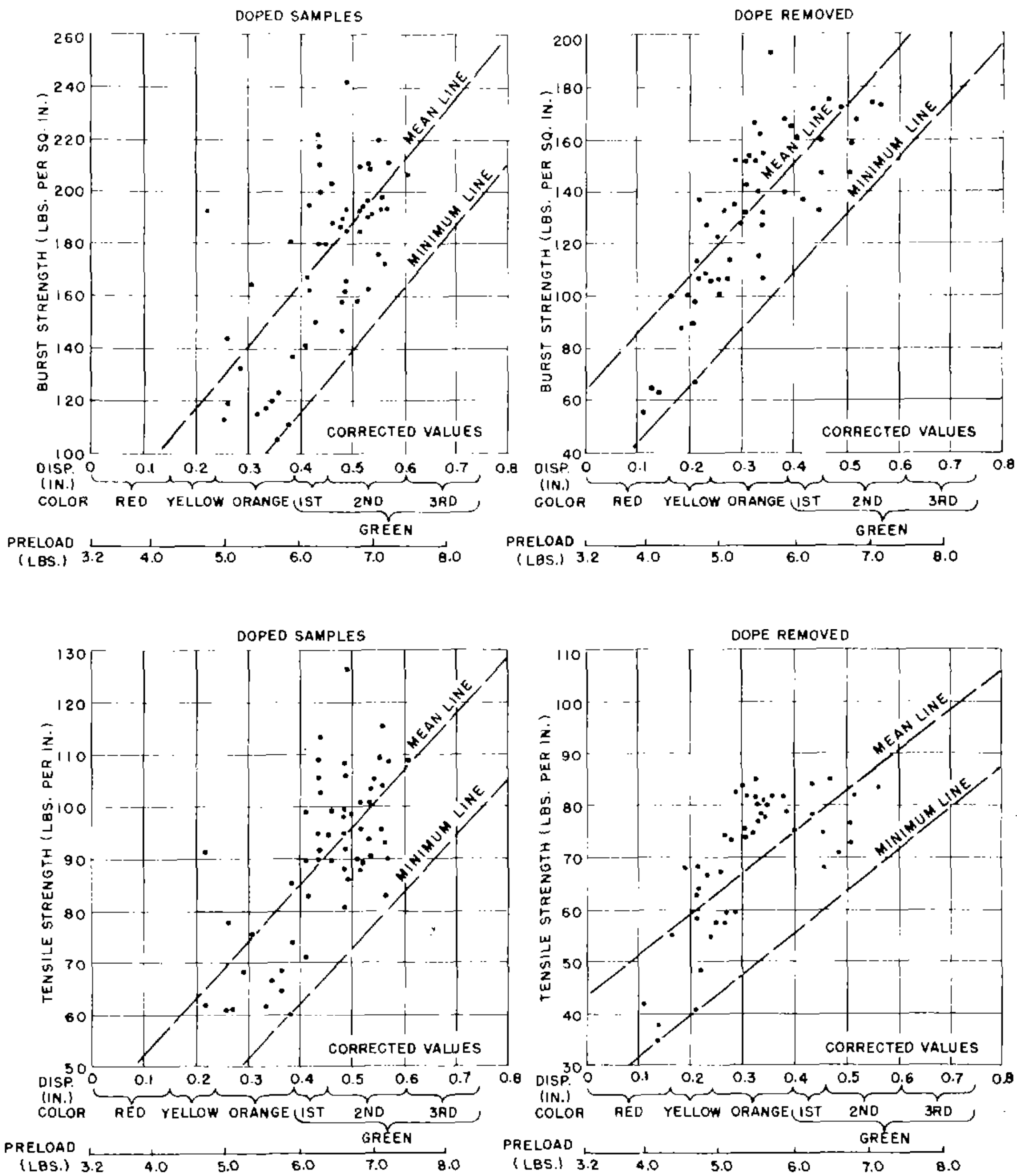


FIG. 5 CORRELATION OF SEYBOTH PENETRATING-CONE TESTS WITH LABORATORY BURST STRENGTH AND TENSILE STRENGTH TESTS