WADC TECHNICAL REPORT 54-52



# EVALUATION OF EXPERIMENTAL WOOL SYNTHETIC BLENDS IN AIR FORCE 18-OZ. BLUE SERGE

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# FOREWORD

This report was prepared by the Textiles Branch and was initiated under Project 7320, Air Force Textile Materials, Task 73202, AF Clothing Textile Materials (formerly RDO 612-13 Textile Materials for Air Force Clothing). The work was conducted and administered under the direction of the Materials Laboratory, Directorate of Research, Wright Air Development Center, with Mr. C. A. Willis and Lt C. W. Long acting as project engineers.

ABSTRACT

A group of twenty-one serge fabrics was evaluated in the laboratory to determine the effects on fabric properties when the fiber and percentage of fiber was varied. The fabrics included the 100% wool standard serge and twenty wool/synthetic blends. The fibers employed in the course of manufacture were wool, Dacron, Orlon, Acrilan, viscose rayon and Dynel. Each synthetic fiber was blended with wool in percentages of 10, 25, 40 and 60.

Comparative tests of the following properties versus wool percentage of the blends were conducted: warp breaking strength, filling breaking strength, warp percent shrinkage, filling percent shrinkage, warp abrasion, filling abrasion, flat abrasion, percent wrinkle recovery, flame time, char rate and wicking time.

Based on laboratory test results of the five synthetic fibers used and the four percentages blended with wool, Dacron, when blended in the fabric appears superior to the other four synthetics in increasing resistance to flat and flex abrasion, and increased breaking strength when used in higher percentages.

In all cases the rate of burning and wicking was increased, and the percent wrinkle recovery slightly decreased, by the addition of synthetic fiber.

Conclusions drawn from the laboratory tests are of interest; however, laboratory testing techniques are not to be considered an absolute measure when evaluating differences between wool and wool/synthetic blends.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

M. R. WHITMORE
Technical Director
Materials Laboratory
Directorate of Research

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# EVALUATION OF EXPERIMENTAL WOOL SYNTHETIC BLENDS IN AIR FORCE 18 OZ BLUE SERGE

## I. INTRODUCTION AND OBJECTIVES

The objective of this study of blended wool synthetic textile materials is threefold. The study was originated to conserve critical materials, to effect economics, and to improve wearing qualities in Air Force clothing by the selection of proper blend percentage and fiber type. Test results presented herein were determined in the laboratory and the results should be received with caution, unless they are confirmed by wear tests, since good correlation between laboratory tests and service conditions has not been established. While the results reported herein should be reproducible for serge fabrics of the general type tested, no claim is made that the trends shown would be assured in different types of fabrics.

## II. DISCUSSION

This report contains only data of laboratory tests. The primary objective of this phase of testing was to evaluate the physical properties of the various fabrics and to consider the results as criteria in selecting a fabric for future field wear evaluation.

Factors considered in selecting tests and test methods were general and were factors which would establish general qualities for a fabric of this type. Test methods used in screening the fabrics are outlined in Table 1 and are described in Federal Specification CCC-T-191 where applicable.

Examination of Table 1 reveals that thermal conductivity measurements were not conducted on the group of fabrics since it has long been established that warmth is chiefly dependent on thickness. The type of fiber does not appear to influence thermal insulation behavior; however, different fibers or blends of different fibers may have different bulking properties. The bulking property of a fiber is of importance since it is possible to weave two fabrics from different fibers having the same thickness and at the same time different densities. Densities of the various fabrics are presented in Table 2.

Wicking, or the rate of movement of water or perspiration in a fabric as applied to comfort, has not been clearly established and is dependent on many variables. Several factors that can affect the rate of wicking or the distance water moves in a fabric over a given period of time are: construction, finish, chemical treatments, whether laundered or cleaned, or tested as received from the mill, etc. Description of the test for wicking is presented below.

Table I Test Method

| Test for | Test method * | Specimens Tested |
|---|---|---|
| Width | 5020 | 5 |
| Weight | 5041 | 5 |
| Thread count | 5050 | 5 |
| Breaking strength | 5100 | 5 |
| Colorfastness to | | |
| Light | 5660 | 1 |
| Dry cleaning | CCC-T-191a, Sec. VI, par. 5a(2) | 1 |
| Perspiration | 5682 | 1 |
| Crocking | 5650 | 3 |
| Shrinkage in sponging | 5590 | 1 |
| Abrasion | | |
| Flat | 5302 (see description) | 5 |
| Flex | 5300 (see description) | 5 |
| pH | CCC-T-191a, Sec. VII, par. 1(a) | 2 |
| Air permeability | ASTM Method D737-46 | 5 |
| Wrinkle recovery | 5212 | 6 |
| Flame resistance | 5902 | 5 |
| Wicking | See description | 5 |

* Federal Specification CCC-T-191 unless otherwise stated.

Table 2 Fabric Composition Weight - Density

| Percent wool/synthetic | 100/0 | 90/10 | 75/25 | 60/40 | 40/60 |
|---|---|---|---|---|---|
| **DACRON** | | | | | |
| Ounces/yard square | 11.76 | 11.72 | 12.12 | 12.54 | 12.38 |
| Thickness (cm) | .0727 | .0744 | .0762 | .0754 | .0729 |
| Density (grams/cc) | .549 | .534 | .540 | .564 | .578 |
| **ORLON** | | | | | |
| Ounces/yard square | 11.76 | 10.92 | 11.07 | 10.02 | 10.25 |
| Thickness (cm) | .0727 | .0790 | .0734 | .0701 | .0686 |
| Density (grams/cc) | .549 | .469 | .512 | .485 | .570 |
| **RAYON** | | | | | |
| Ounces/yard square | 11.76 | 11.56 | 11.82 | 12.45 | 12.84 |
| Thickness (cm) | .0727 | .0722 | .0713 | .0746 | .0729 |
| Density (grams/cc) | .549 | .546 | .561 | .568 | .598 |
| **ACRILAN** | | | | | |
| Ounces/yard square | 11.76 | 11.23 | 11.06 | 11.11 | 10.88 |
| Thickness (cm) | .0727 | .0803 | .0746 | .0722 | .0666 |
| Density (grams/cc) | .549 | .473 | .502 | .520 | .555 |
| **DYNEL** | | | | | |
| Ounces/yard square | 11.76 | 11.65 | 11.38 | 11.10 | 10.56 |
| Thickness (cm) | .0727 | .0790 | .0785 | .0754 | .0706 |
| Density (grams/cc) | .549 | .500 | .492 | .500 | .505 |

Test data presented in Tables 3, 4, 5, 6, and 7 were obtained from fabrics just as received from the mill.

Wicking test *

1. Test specimen -

Test specimens were cut 1 inch by 2-1/2 inches with the long dimension in the direction of the warp.

2. Apparatus -

Ohm meter with a scale deflection of 0 to ∞ (scale used ratio 1/10,000 ohms), 600 ml. beaker, hose clamp, weight approximately 25 grams, ring stand and two clamps, and stop watch.

3. Procedure -

The beaker was filled to within 1/2 inch of the top with distilled water. The leads of the ohm meter were adjusted in the ringstand clamps so that one lead was in contact with the distilled water and the other in a horizontal position. The test specimen was then clamped to the horizontal lead making contact two (2) inches from the end of the specimen. The specimen was hung vertically, weighted with a 25 gram weight, so that it was perpendicular with the surface of the water.

The specimen was then lowered into the water so that one inch was submerged and one inch remained above the surface of the water and the horizontal contact. Time required for water to wick through the cloth from water surface to horizontal contact was noted and recorded as wicking time. The water in wicking one inch to the horizontal contact completed the circuit thereby causing the needle on the ohm meter to deflect.

* Modified method as reported in Quartermaster Corps Contract No. DA-44-109-qm-564.

Abrasion -

Flex abrasion was conducted in accordance with CCC-T-191 Method 5300 except that a 5 pound load was used on the flexing bar or blade and a 1 pound load on the pressure plate.

Diaphragm abrasion was conducted in accordance with Specification CCC-T-191, Method 5302, using a 4 pound diaphragm pressure, a 1 pound pressure plate load and #320 aloxite abradant paper.

Multidirectional abrasion was conducted on all samples.

Test data are presented in tables 2 through 7 and figures 1 through 11.

General comment based upon the various tests performed on the blended fabrics from data plotted as curves on Figures 1 through 11, and from Tables 3 through 7, is presented, with each factor being considered separately.

With respect to breaking strength, it is noted, from Figures 1 and 2, that an increasing percentage of Dacron provides much greater strength than the all wool fabric. Acrilan blends gave higher strength than the all wool (but less than Dacron blends); however, strength decreased with increase of synthetic fiber content. Only in percentages greater than 60% did Orlon and Rayon indicate improvement, and Dynel blends rapidly lowered the strength.

Warpwise shrinkage showed significant improvement (Figure 3) for all Orlon and Dacron blends. Acrilan at 60% indicates promise while Rayon and Dynel had little noticeable effect.

With the exception of Rayon blends, all fabrics evaluated exhibited a large degree of filling shrinkage (Figure 4) as percentage of synthetic fiber increased.

Figures 5 and 6 show warp and filling abrasion curves. All blends with the exception of Acrilan indicated better resistance than the all wool control. However, it is noted that Dacron is outstanding in this respect.

With respect to flat abrasion (strokes)(Figure 7) all of the Dacron blends greatly increase the fabric resistance, and high percentages (over 35%) of Dynel show slight improvements. No benefit is noted for the other blends.

From Figure 8 it can be seen that all of the blends were inferior to the all wool control in Wrinkle Recovery. Of the blends tested, those of Orlon appear best.

Flame Time (Figure 9) and Char Time (Figure 10) can be considered together for it is observed that in all cases for each test, addition of synthetic fibers to wool increases the flammability characteristics.

Wicking Time. This property has been mentioned previously. From Figure 11 the curves show that rate of wicking is increased with addition of synthetic fibers to wool. This effect is shown by the curves of all blends tested; however, since the curves appear erratic, the results should be viewed with caution.

Data presented in Tables 3 through 7 indicate that colorfastness properties, with the exception of fastness to light, were satisfactory for most of the blends. Improvement of the fastness to light of these fabrics, to a degree considered satisfactory for general issue uniform fabrics, should present no particular problem.

Based solely on results of laboratory tests, it appears that substantial improvement in many of the physical properties of 18 oz. serge fabric can be obtained by using selected percentages of Dacron fiber blended with wool. This does not rule out the use of other synthetic fiber - wool blends, for only by closely controlled service and wear tests can the merits of any fabric be realistically evaluated. A program has been initiated to consider this aspect of blended fabric evaluation and the results will appear in a future WADC Technical Report. Until this program is completed, 100% wool serge fabric should continue to be used for general issue service uniform fabric. However, if circumstances dictate the need for conservation of wool, blends of wool/synthetic fiber could be used to some degree.

Table 3

Properties of Wool Orlon Blended Fabrics

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Wool Percent | | | 100 | 90 | 75 | 60 | 40 |
| Orlon Percent | | | 0 | 10 | 25 | 40 | 60 |
| Width (inches) | | | 57-5/16 | 56-3/16 | 55-3/16 | 55-1/4 | 56-13/16 |
| Weight (oz/yd$^2$) | | | 11.76 | 10.92 | 11.07 | 10.02 | 10.25 |
| Thread count (per inch) | | Warp | 70 | 69 | 71 | 72 | 70 |
| | | Filling | 54 | 52 | 55 | 53 | 54 |
| Breaking strength (pounds)(Grab) | | Warp | 163 | 145 | 158 | 167 | 186 |
| | | Filling | 133 | 112 | 122 | 125 | 139 |
| Colorfastness to | Light (hours to break) | | 40 | 40 | 40 | 20 | 20 |
| | Dry cleaning | | Good | Good | Good | Good | Good |
| | Perspiration | Acid | Good | Good | Good | Good | Good |
| | | Alkaline | Good | Good | Good | Good | Good |
| | Crocking | Wet | Good | Good | Good | Good | Good |
| | | Dry | Good | Good | Good | Good | Good |
| Shrinkage in sponging (percent) | | Warp | 4.2 | 2.3 | 2.5 | 1.9 | 2.1 |
| | | Filling | 1.0 G* | .05 | 1.0 | .07 | 1.0 |
| Abrasion (Universal Wear Tester) | Flat (cycles) | | 423 | 420 | 394 | 2349 | 465 |
| | Flex (cycles) | Warp | 467 | 497 | 627 | 817 | 903 |
| | | Filling | 605 | 473 | 521 | 546 | 603 |
| pH | | | 4.8 | 8.6 | 7.2 | 8.0 | 7.9 |
| Air permeability (Gurley) | | | 11.0 | 13.3 | 7.7 | 9.2 | 5.8 |
| Wrinkle recovery (percent)(Monsanta Chemical Co.) | | | 89.5 | 87 | 86 | 84 | 76.6 |
| Rate of burning (sec/inch) | | | 7 | 4.2 | 5.3 | 3.8 | 3.9 |
| Wicking (min/inch) | | | 154 | 124 | 73 | 38 | 60 |
| Shade evaluation ** | | | A | N | N | N | N |
| Length of Char (inches)(Sample 2" x 12")*** | | | 4.5 | 4.6 | 5.4 | 12 C | 12 C |

* G = Gain  ** A = Acceptable, N = Not acceptable  *** C = Sample completely consumed

Table 4

Properties of Wool Dacron Blended Fabrics

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Wool Percent | | | 100 | 90 | 75 | 60 | 40 |
| Dacron Percent | | | 0 | 10 | 25 | 40 | 60 |
| Width (inches) | | | 57-5/16 | 56-15/16 | 56-5/16 | 56-1/2 | 56-1/2 |
| Weight (oz/yd$^2$) | | | 11.76 | 11.72 | 12.12 | 12.54 | 12.38 |
| Thread count (per inch) | | Warp | 70 | 70 | 70 | 69 | 69 |
| | | Filling | 54 | 52 | 55 | 54 | 55 |
| Breaking strength (pounds) Grab | | Warp | 163 | 197 | 239 | 290 | 323 |
| | | Filling | 133 | 141 | 195 | 233 | 266 |
| Colorfastness to | Light (hours to break) | | 40 | 40 | 20 | 20 | 20 |
| | Dry cleaning | | Good | Good | Good | Fair | Fair |
| | Perspiration | Acid | Good | Good | Good | Good | Good |
| | | Alkaline | Good | Good | Good | Good | Good |
| | Crocking | Wet | Good | Good | Good | Good | Good |
| | | Dry | Good | Good | Good | Good | Good |
| Shrinkage in sponging (percent)* | | Warp | 4.2 | 3.0 | 2.5 | 1.7 | 1.7 |
| | | Filling | 1.0G | 0.2 | 0.5 | 0.7 | 1.0 |
| Abrasion (Universal Wear Tester) | Flat (cycles) | | 423 | 536 | 702 | 936 | 1080 |
| | Flex (cycles) | Warp | 467 | 945 | 1241 | 2065 | 2143 |
| | | Filling | 605 | 1050 | 1582 | 1786 | 2312 |
| pH | | | 4.8 | 7.3 | 7.6 | 7.5 | 7.4 |
| Air permeability (Gurley) | | | 11.0 | 8.0 | 5.5 | 4.6 | 3.2 |
| Wrinkle recovery (percent)(Monsanto Chemical Co.) | | | 89.5 | 85.1 | 80.7 | 80.0 | 76.5 |
| Rate of burning (sec/inch) | | | 7 | 4.6 | 4.4 | 5.0 | 6.5 |
| Length of char (inches)(Sample 2" x 12") *** | | | 4.5 | 12C | 12C | 12C | 12C |
| Wicking (min/inch) | | | 154 | 22 | 65 | 43 | 35 |
| Shade evaluation ** | | | A | A | N | N | N |

* G = Gain   ** A = Acceptable  N = Not acceptable   *** C = Sample completely consumed

Table 5
Properties of Wool Rayon Blended Fabrics

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Wool Percent | | | 100 | 90 | 75 | 60 | 40 |
| Rayon Percent | | | 0 | 10 | 25 | 40 | 60 |
| Width (inches) | | | 57-5/16 | 57-1/4 | 57 | 55-5/8 | 55-15/16 |
| Weight ($oz/yd^2$) | | | 11.76 | 11.56 | 11.82 | 12.45 | 12.84 |
| Thread count (per inch) | | Warp | 70 | 69 | 69 | 70 | 70 |
| | | Filling | 54 | 52 | 55 | 53 | 56 |
| Breaking strength (pounds) Grab | | Warp | 163 | 136 | 145 | 163 | 182 |
| | | Filling | 133 | 98 | 112 | 122 | 125 |
| Colorfastness to | Light (hours to break) | | 40 | 20 | 20 | 20 | 40 |
| | Dry cleaning | | Good | Fair | Fair | Fair | Poor |
| | Perspiration | Acid | Good | Good | Good | Good | Good |
| | | Alkaline | Good | Good | Good | Good | Good |
| | Crocking | Wet | Good | Good | Good | Good | Good |
| | | Dry | Good | Good | Good | Good | Good |
| Shrinkage in sponging (percent) | | Warp | 4.2 | 4.2 | 4.3 | 4.2 | 3.8 |
| | | Filling | 1.0G | 1.6G | 1.0G | 0.7G | 0.5G |
| Abrasion (Universal Wear Tester) | Flat (cycles) | | 423 | 297 | 361 | 360 | 299 |
| | Flex (cycles) | Warp | 467 | 633 | 566 | 639 | 835 |
| | | Filling | 605 | 587 | 591 | 805 | 791 |
| pH | | | 4.8 | 7.4 | 8.1 | 6.8 | 6.7 |
| Air permeability (Gurley) | | | 11.0 | 11.9 | 8.0 | 9.0 | 8.0 |
| Wrinkle recovery (percent)(Monsanto Chemical Co.) | | | 89.5 | 84.4 | 86.1 | 82.6 | 78 |
| Rate of burning (sec/inch) | | | 7 | 5.4 | 5.3 | 4.3 | 4.8 |
| Length of char (inches)(Sample 2" x 12") | | | 4.5 | 4.8 | 3.9 | 10.3 | 12 |
| Wicking (min/inch) | | | 154 | 22 | 99 | 9 | 3 |
| Shade evaluation | | | A | A | A | A | A |

Table 6

Properties of Wool Acrilan Blended Fabrics

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Wool Percent | | | 100 | 90 | 75 | 60 | 40 |
| Acrilan Percent | | | 0 | 10 | 25 | 40 | 60 |
| Width (inches) | | | 57-5/16 | 59-1/4 | 58-3/4 | 58-1/8 | 57-3/4 |
| Weight ($oz/yd^2$) | | | 11.76 | 11.23 | 11.06 | 11.11 | 10.88 |
| Thread count (per inch) | | Warp | 70 | 68 | 69 | 67 | 68 |
| | | Filling | 54 | 54 | 55 | 51 | 51 |
| Breaking strength (pounds) Grab | | Warp | 163 | 244 | 227 | 203 | 180 |
| | | Filling | 133 | 196 | 181 | 163 | 156 |
| Colorfastness to | Light (hours to break) | | 40 | 20 | 20 | 20 | 20 |
| | Dry cleaning | | Good | Good | Good | Good | Good |
| | Perspiration | Acid | Good | Good | Good | Good | Good |
| | | Alkaline | Good | Good | Good | Good | Good |
| | Crocking | Wet | Good | Good | Good | Fair | Fair |
| | | Dry | Good | Good | Good | Good | Good |
| Shrinkage in sponging (percent) | | Warp | 4.2 | 4.5 | 3.8 | 4.2 | 2.8 |
| | | Filling | 1.0G | 0.5G | 0.3 | 0.5 | 1.4 |
| Abrasion (Universal Wear Tester) | Flat (cycles) | | 423 | 335 | 334 | 375 | 432 |
| | Flex (cycles) | Warp | 467 | 522 | 408 | 314 | 230 |
| | | Filling | 605 | 522 | 371 | 296 | 236 |
| pH | | | 4.8 | 9.4 | 9.1 | 9.1 | 8.6 |
| Air permeability (Gurley) | | | 11.0 | 11.7 | 7.3 | 6.5 | 5.8 |
| Wrinkle recovery (percent)(Monsanto Chemical Co.) | | | 89.5 | 86.2 | 83.0 | 77.9 | 76.3 |
| Rate of burning (sec/inch) | | | 7 | 5.9 | 5.9 | 5.2 | 4.4 |
| Length of char (inches)(Sample 2" x 12") | | | 4.5 | 4.2 | 4.6 | 7.2 | 12 |
| Wicking (min/inch) | | | 154 | 41 | 9 | 5 | 1 |
| Shade evaluation | | | A | A | N | N | N |

* G = Gain ** A = Acceptable N = Not acceptable *** C = Sample completely consumed

Table 7

Properties of Wool Dynel Blended Fabrics

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Wool Percent | | | 100 | 90 | 75 | 60 | 40 |
| Dynel Percent | | | 0 | 10 | 25 | 40 | 60 |
| Width (inches) | | | 57-5/16 | 58-1/8 | 58-1/4 | 58-1/2 | 58-1/2 |
| Weight (oz/yd$^2$) | | | 11.76 | 11.65 | 11.38 | 11.10 | 10.56 |
| Thread count (per inch) | | Warp | 70 | 68 | 67 | 67 | 68 |
| | | Filling | 54 | 56 | 54 | 56 | 53 |
| Breaking strength (pounds) Grab | | Warp | 163 | 193 | 166 | 144 | 138 |
| | | Filling | 133 | 138 | 122 | 120 | 118 |
| Colorfastness to | Light (hours to break) | | 40 | 20 | 20 | 20 | 20 |
| | Dry cleaning | | Good | Good | Good | Good | Good |
| | Perspiration | Acid | Good | Good | Good | Good | Good |
| | | Alkaline | Good | Good | Good | Good | Good |
| | Crocking | Wet | Good | Good | Good | Good | Good |
| | | Dry | Good | Good | Good | Good | Good |
| Shrinkage in sponging (percent) | | Warp | 4.2 | 4.5 | 4.7 | 4.5 | 4.3 |
| | | Filling | 1.0G | 0.3 | 0.5 | 1.9 | 3.1 |
| Abrasion (Universal Wear Tester) | Flat (cycles) | | 423 | 385 | 422 | 506 | 494 |
| | Flex (cycles) | Warp | 467 | 826 | 659 | 532 | 476 |
| | | Filling | 605 | 736 | 614 | 519 | 537 |
| pH | | | 4.8 | 9.3 | 9.2 | 9.2 | 9.1 |
| Air permeability (Gurley) | | | 11.0 | 7.5 | 7.3 | 6.5 | 6.8 |
| Wrinkle recovery (percent)(Monsanto Chemical Co.) | | | 89.5 | 83.3 | 82.7 | 76.5 | 75 |
| Rate of burning (sec/inch) | | | 7 | 4.8 | 5.2 | 5.9 | 6.4 |
| Length of char (inches)(2" x12" sample) | | | 4.5 | 5.8 | 6.8 | 3.7 | 2.8 |
| Wicking (min/inch) | | | 154 | 22 | 9 | 16 | 7 |
| Shade evaluation | | | A | A | N | N | N |

*G = Gain ** A = Acceptable N = Not acceptable *** C = Sample completely consumed

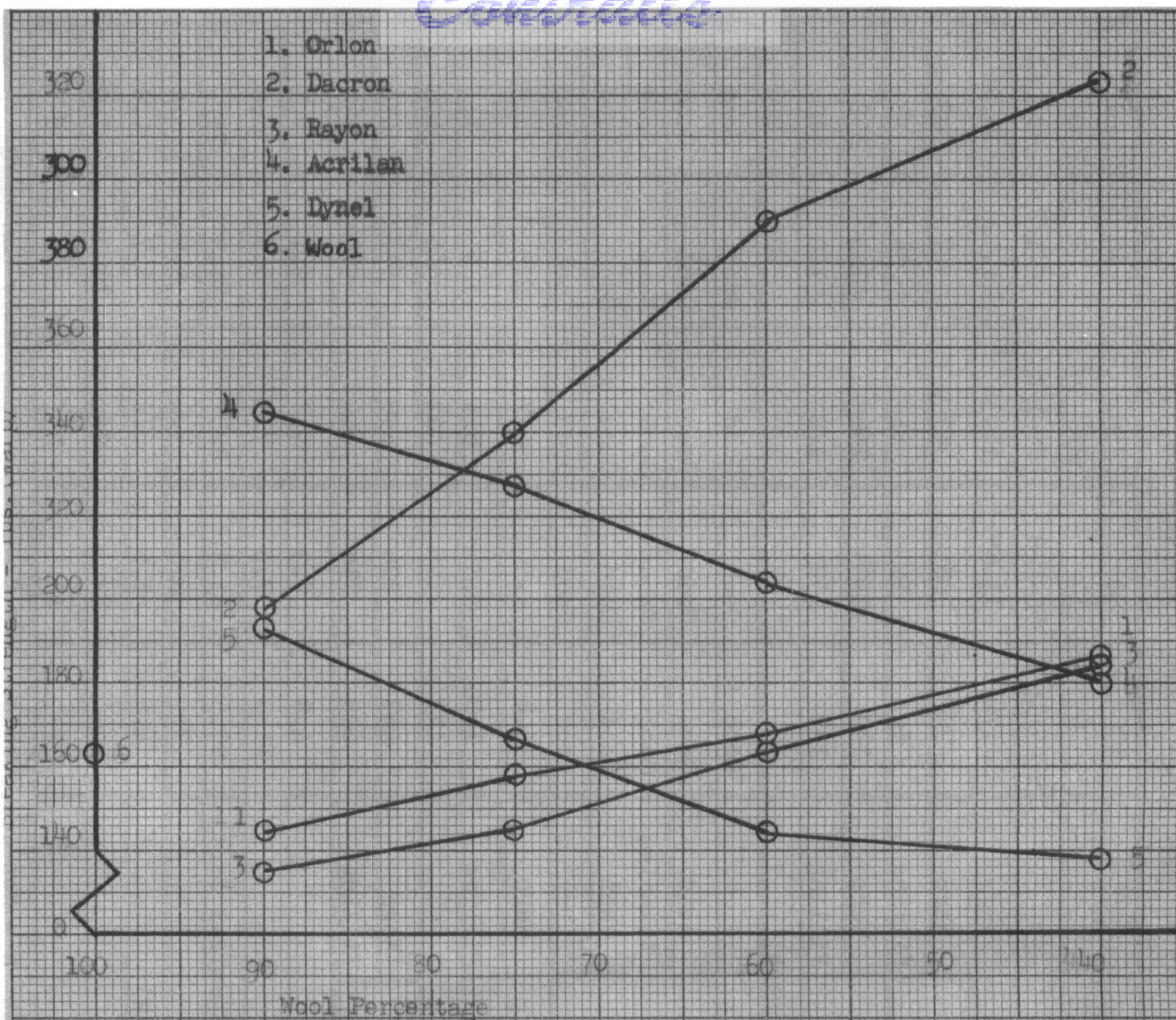


Figure 1

Warp Breaking Strength (Grab) VS Wool Percentage

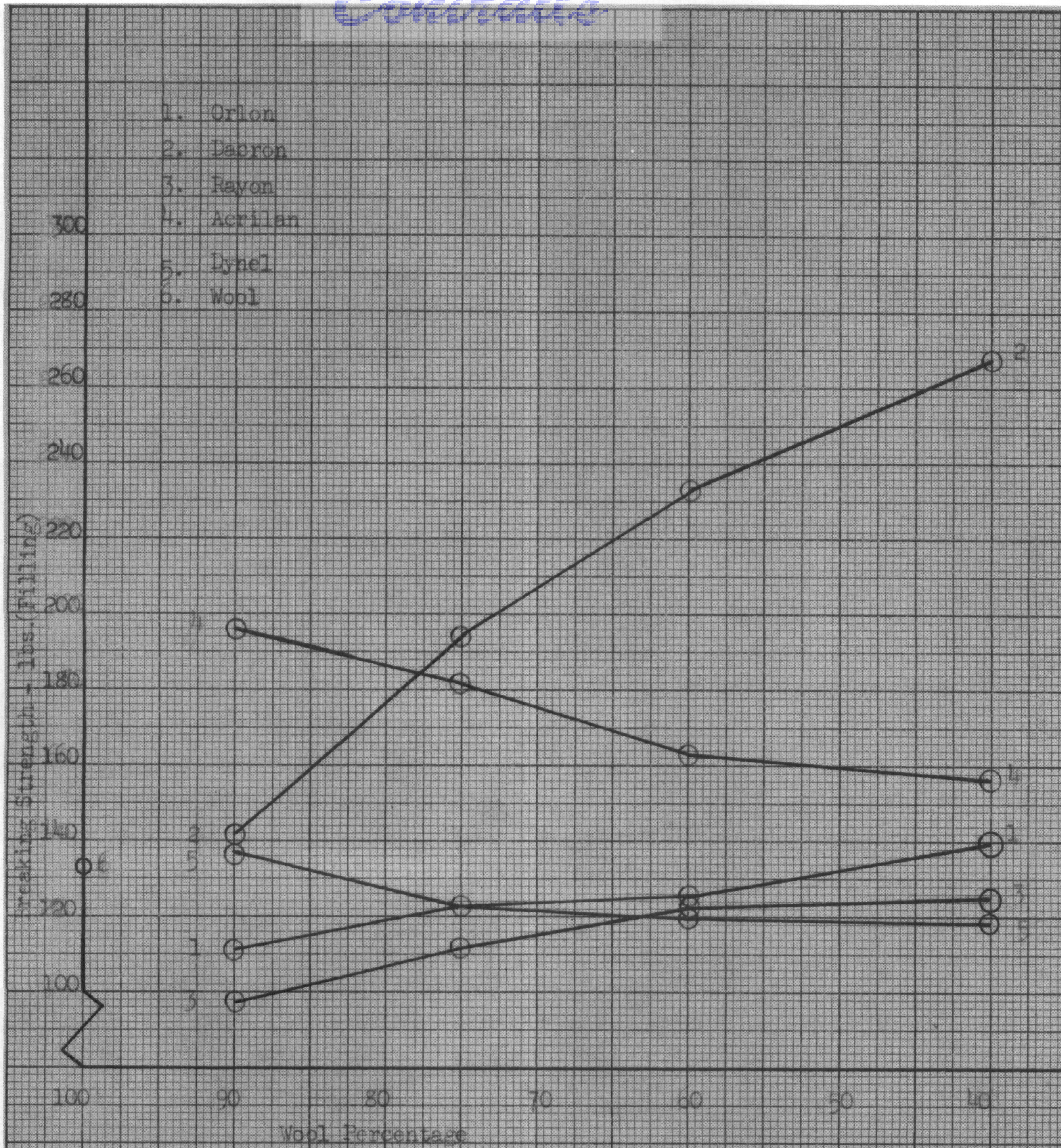


Figure 2

Filling Breaking Strength (Grab) VS Wool Percentage

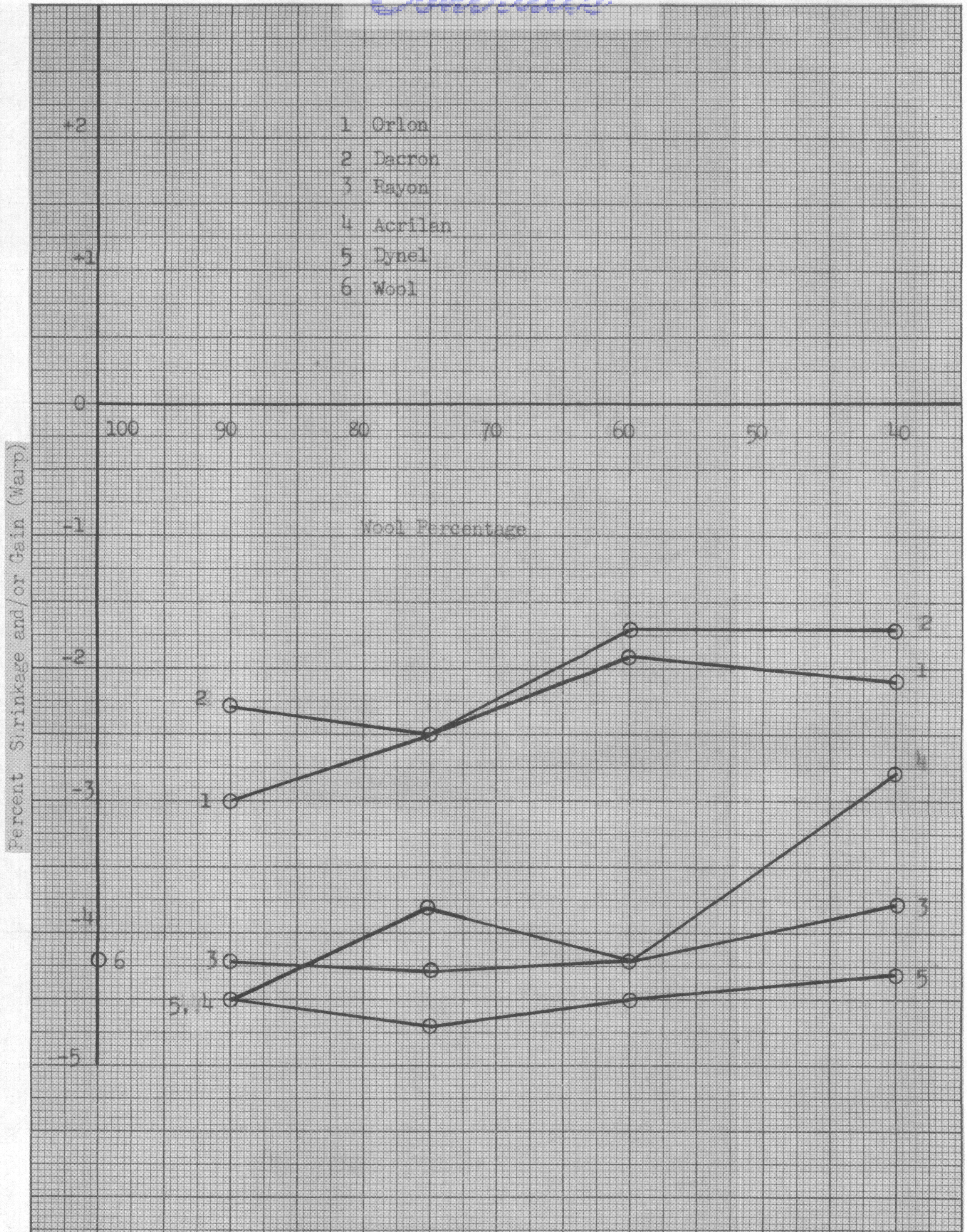


Figure 3

(Warp) Percent Shrinkage VS Wool Percentage Curves

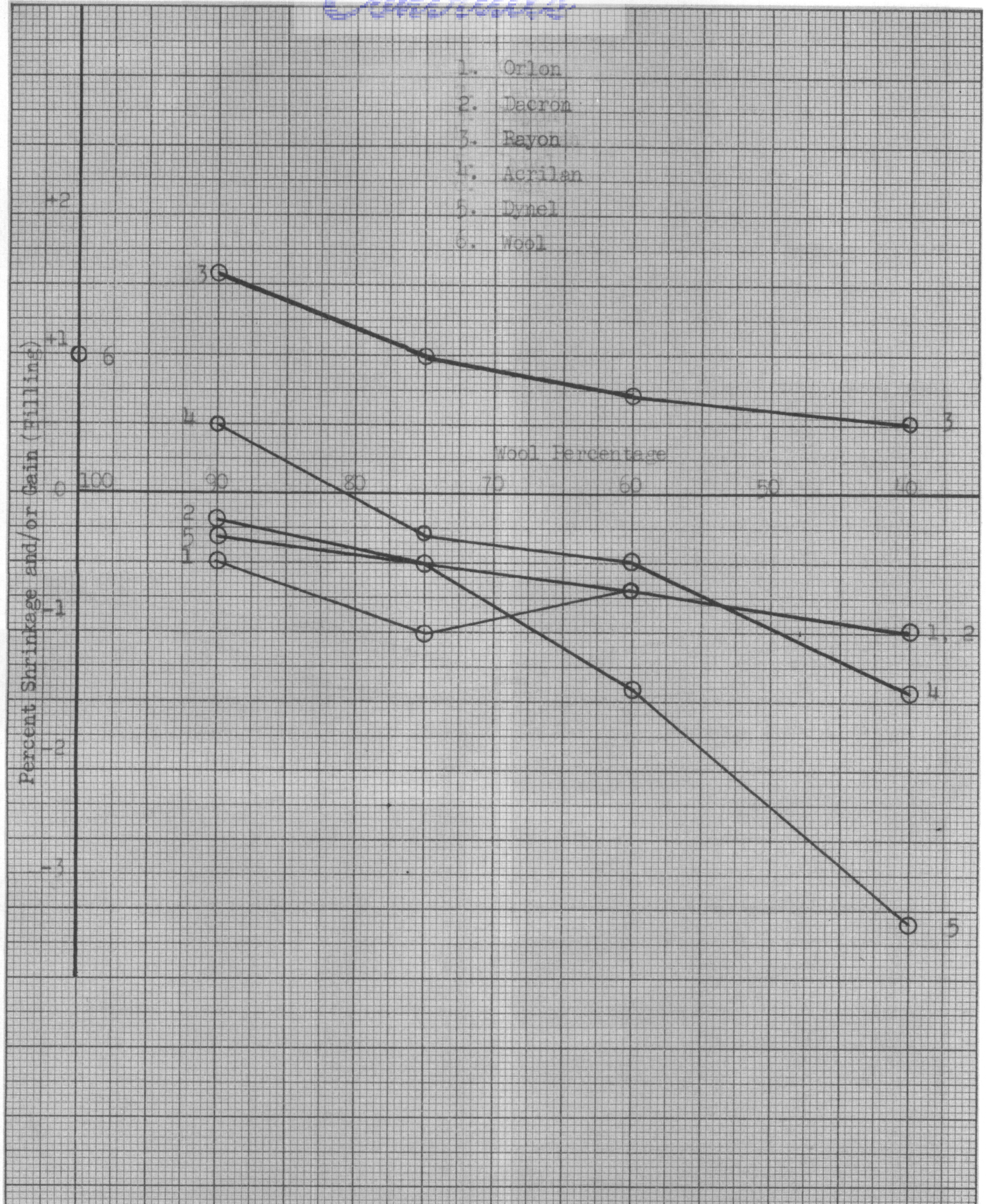


Figure 4

(Filling) Percent Shrinkage VS Wool Percentage

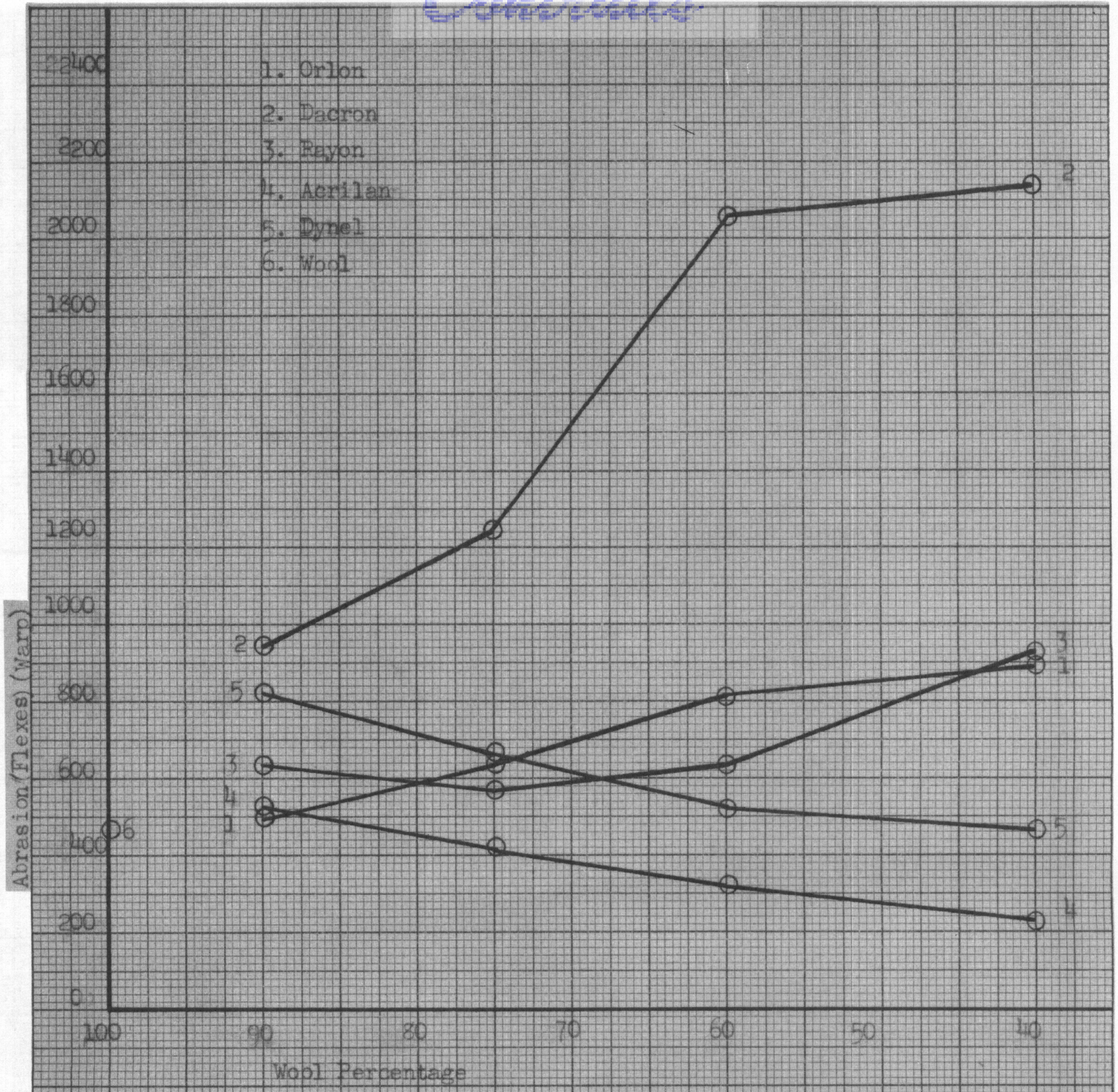


Figure 5

Warp Abrasion(Flexes) VS Wool Percentage

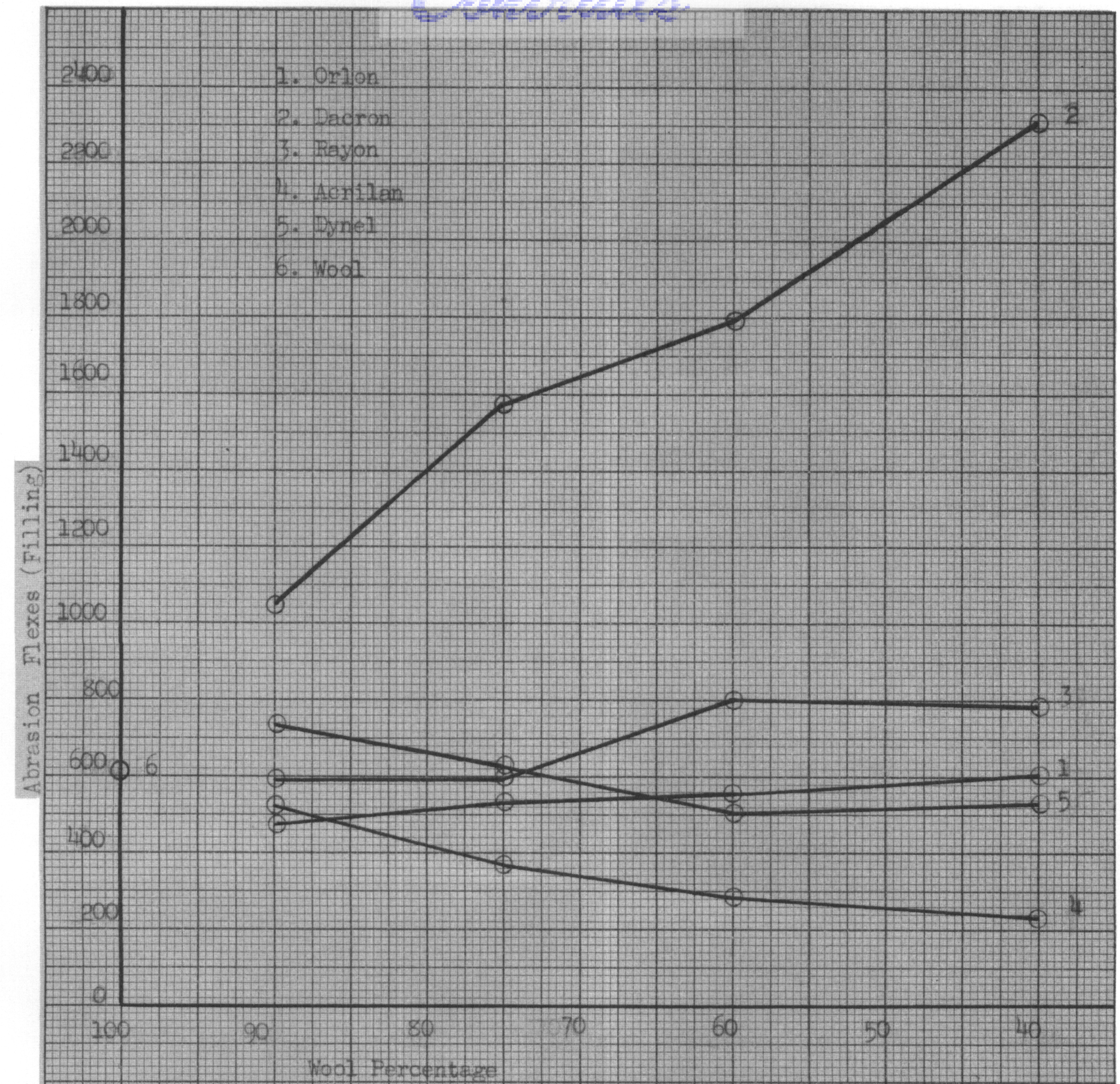


Figure 6

Filling Abrasion(Flexes) VS Wool Percentage

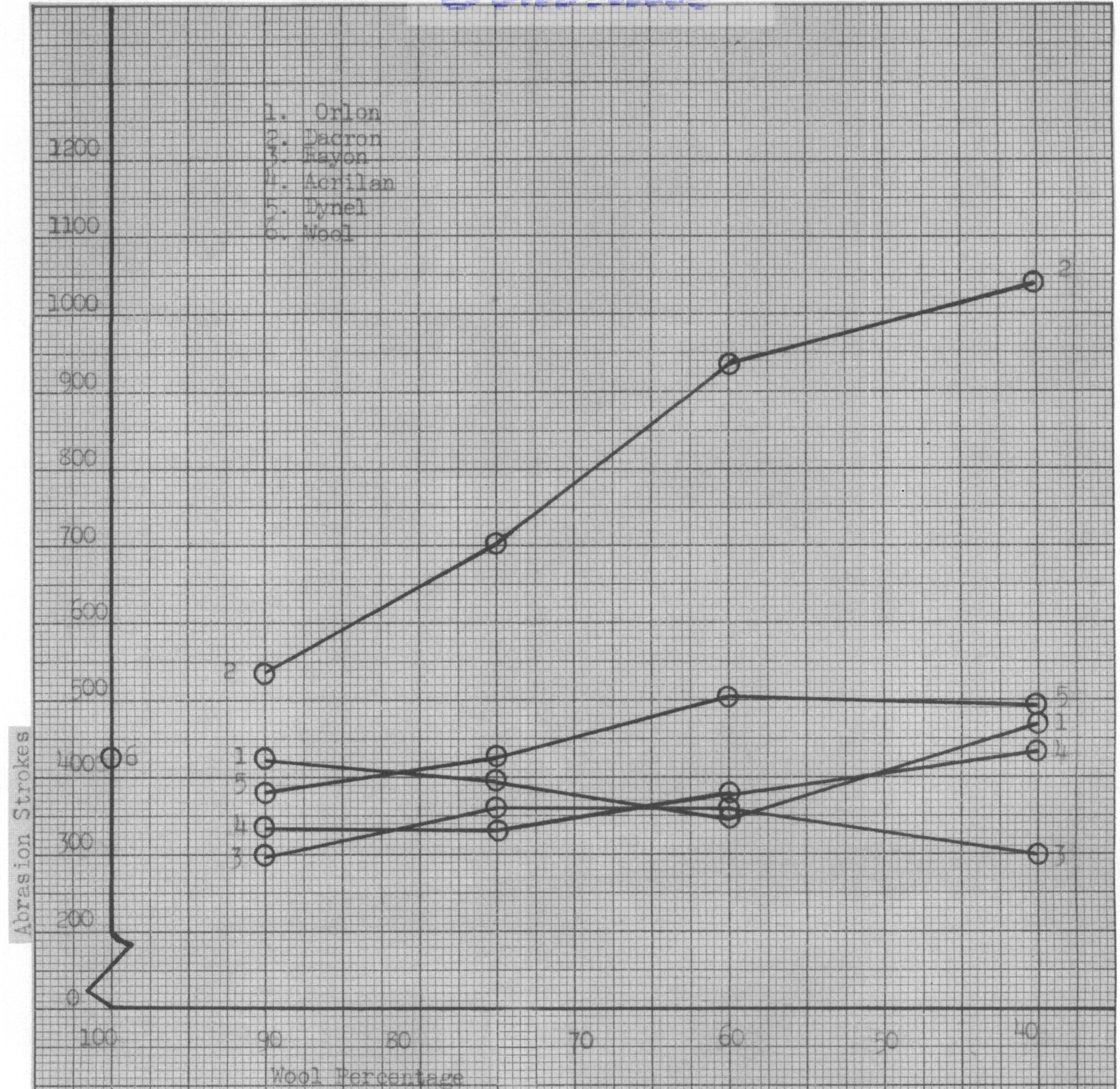


Figure 7

Flat Abrasion (Strokes) VS Wool Percentage

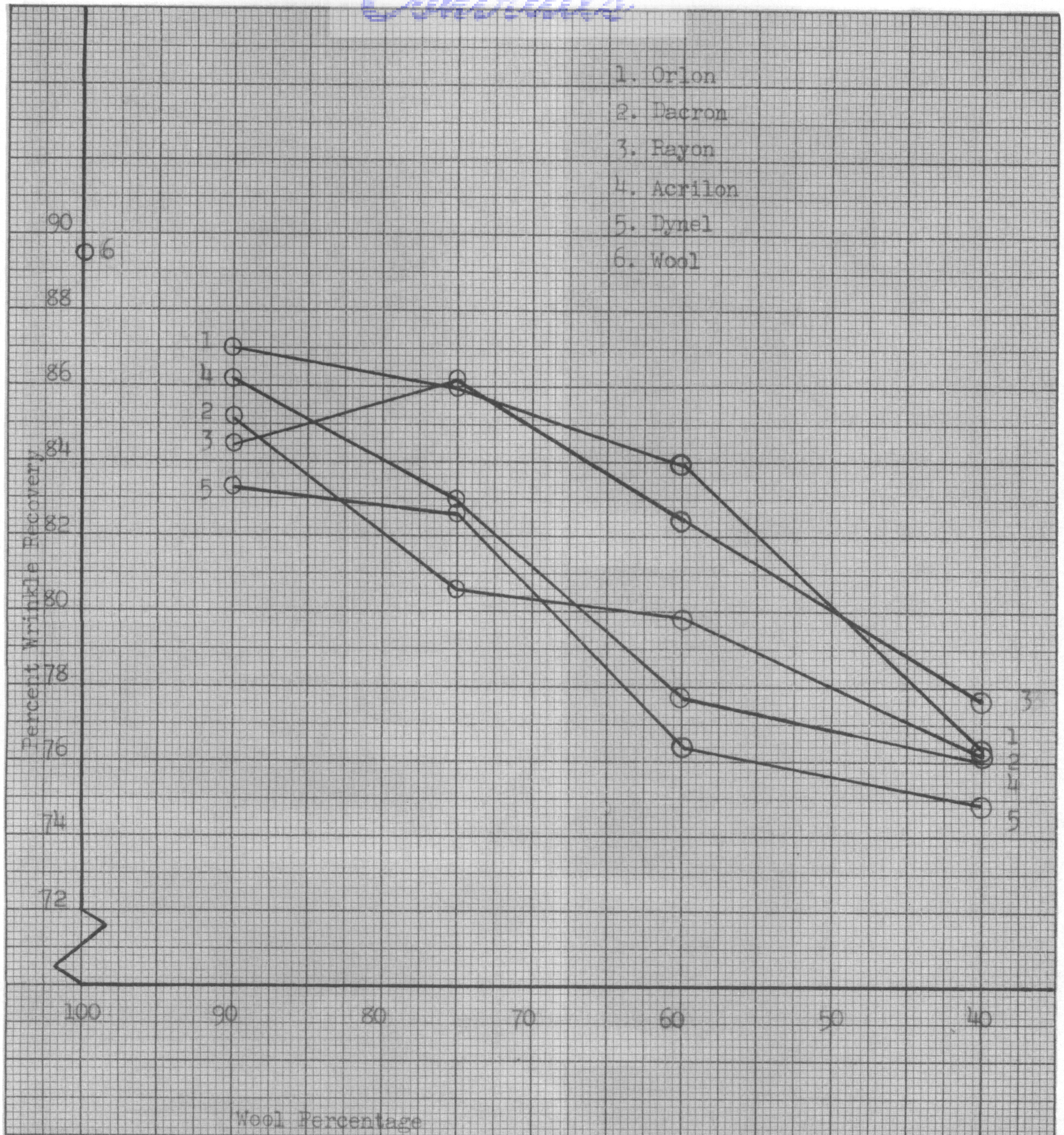


Figure 8

Percent Wrinkle Recovery VS Wool Percentage

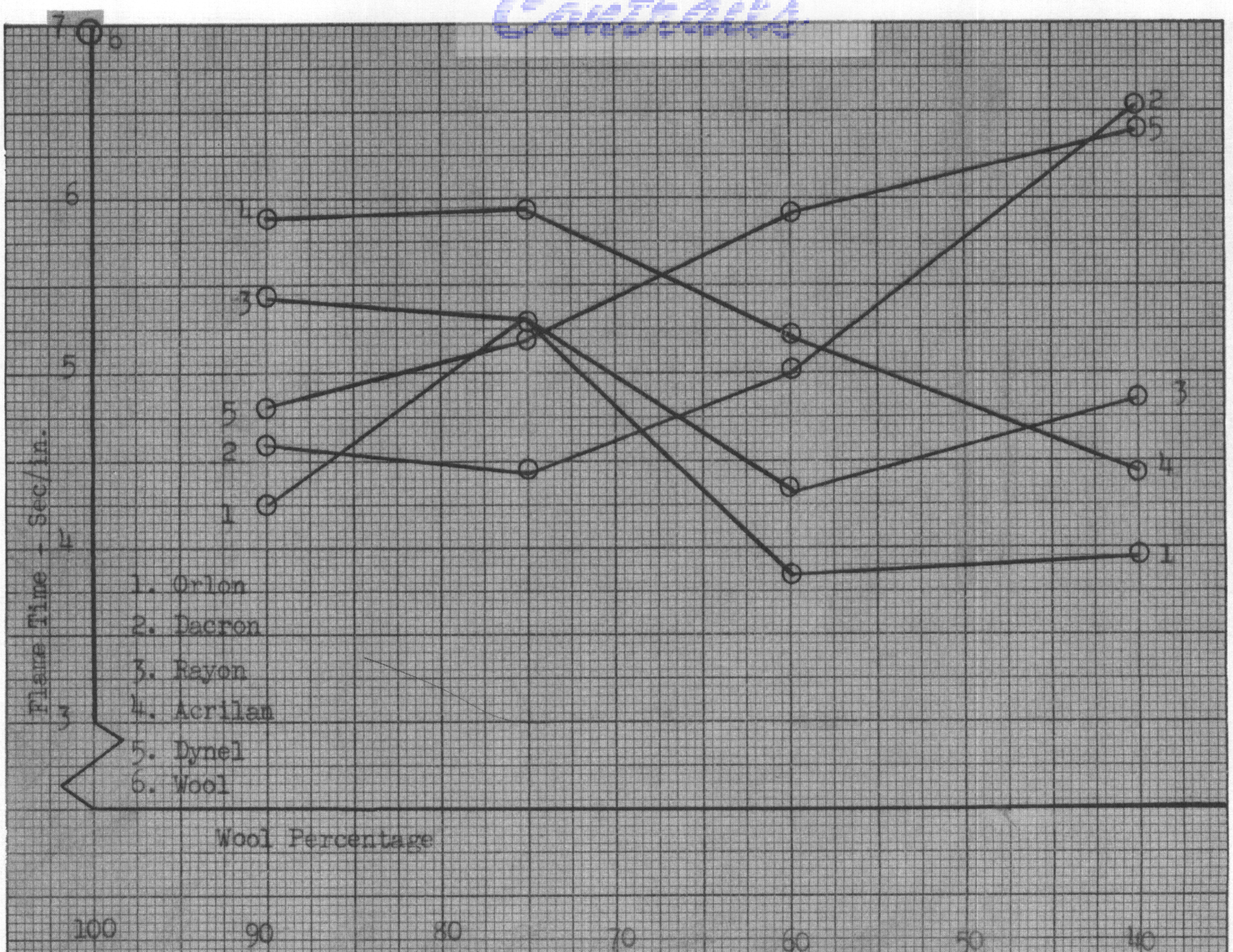


Figure 9

Flame Time - Sec/Inch VS Wool Percentage

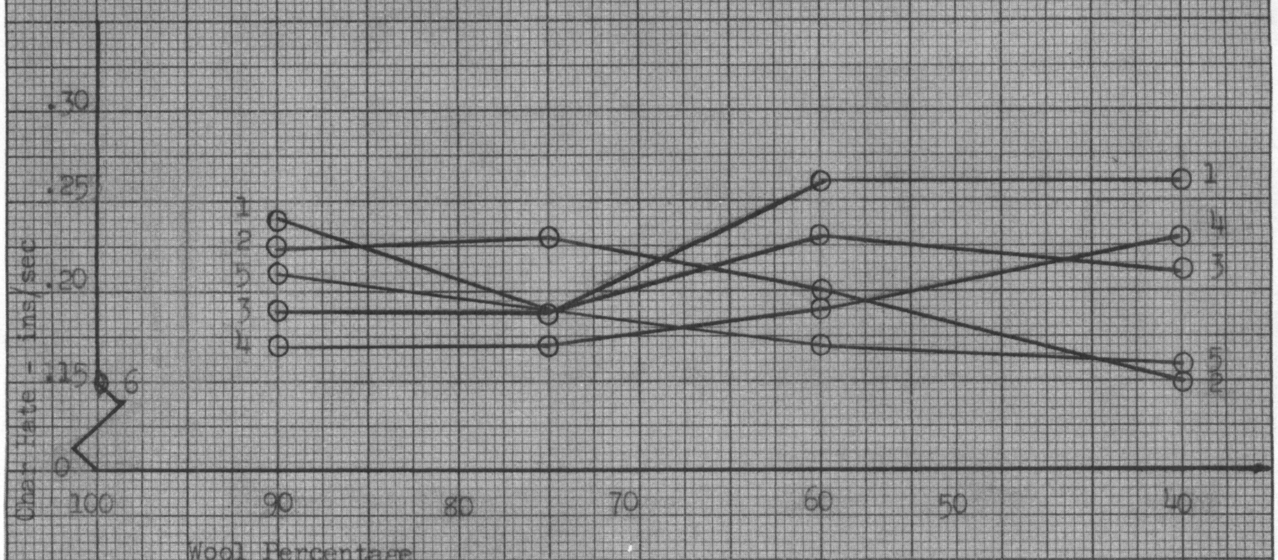


Figure 10

Char Rate VS Wool Percentage

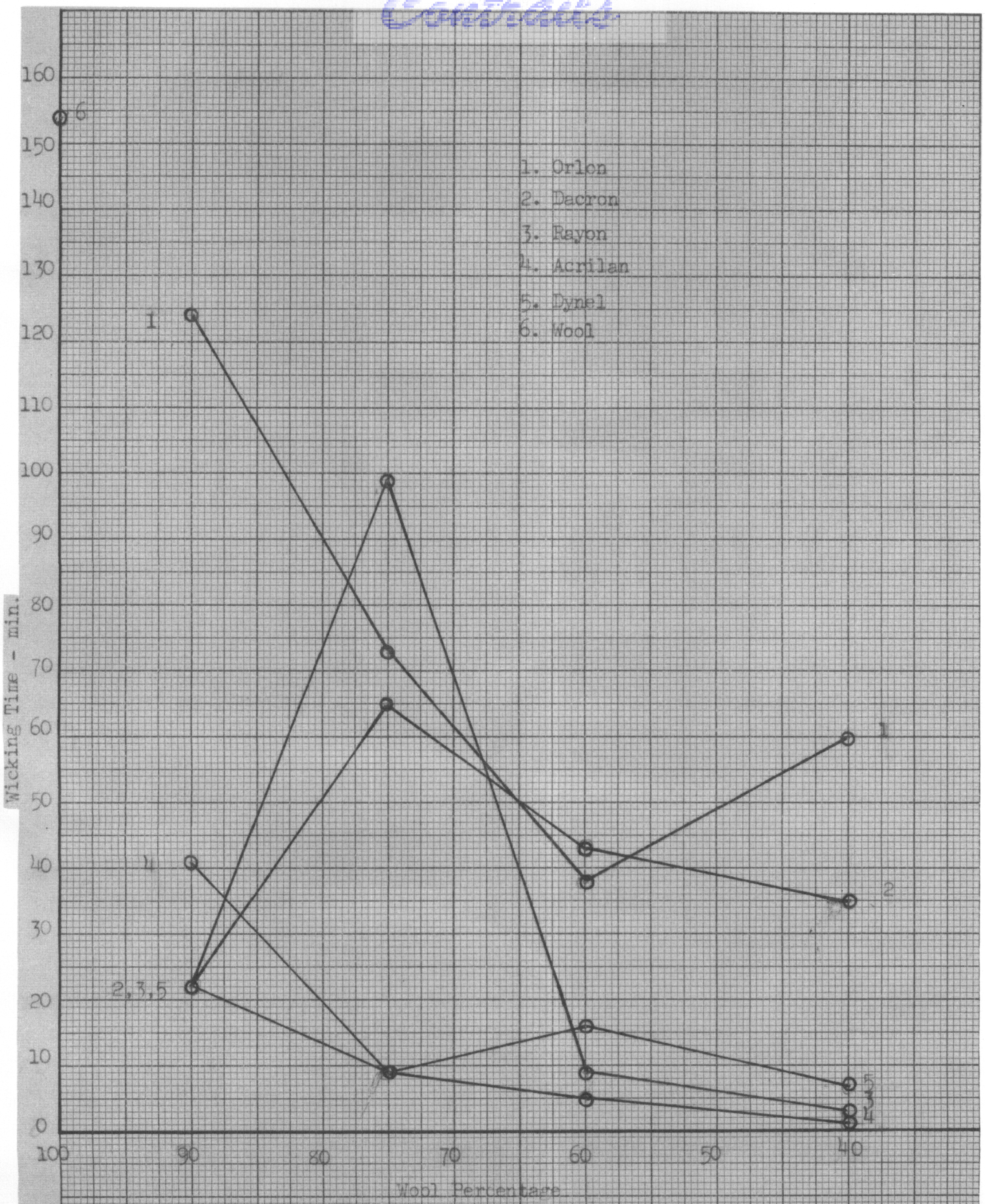


Figure 11

Wicking Time VS Wool Percentage