



The physical properties across a side and throughout a pack of leather

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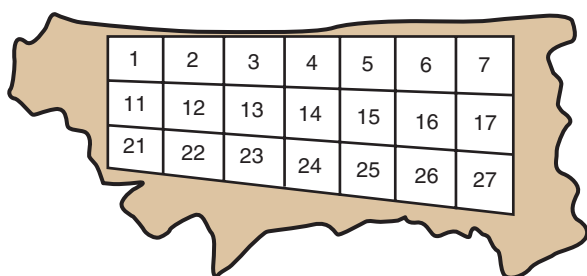
The information presented in this paper provides insight into the fundamental variations in the physical properties found throughout a pack of leather, and across a typical side/hide taken from that pack. The objective of the original study was to determine a location on a piece of leather where the properties could be best related to a complete pack of leathers. These investigations were complex, and produced a vast amount of information. This was presented in a condensed form within the original four papers: these in turn have been used selectively to produce this profile on cross-hide and intra-pack variation.

Background to the investigation

Cross-hide variations in terms of tensile strength and stretch under standard load were first investigated in detail and reported by Wilson in the early 1940s. These findings were the result of a most detailed investigation, and the findings have been reported in detail in *World Leather* November 2007⁽¹⁾.

However, considerably more insight into cross-side/hide variations was revealed in a series of studies made in the 1950s^(Legend 2,3,4). These were instigated by the Office of the Quartermaster General, USA, and related to the evaluation of military leathers. Whereas Wilson performed tests from many hundreds of samples taken across four hides, these new studies investigated the properties of rectangular specimen (*blocks*) cut from many sides throughout a pack at locations as indicated in *Panel 1*:

Panel 1 Sample locations and numbering for the investigation



These investigations were designed to find the optimum location on a side for sampling for analysis. This location would, therefore give the best guidance for the performance found within both an individual side/hide and throughout a batch of leather (see *Panel 2*).

Cross-side variability in physical performance

In these initial investigations⁽²⁾ the 7 x 3 blocks were cut from 30 sides from a pack of leather. After the 630 samples were analysed, the average value for each location (30 samples each) was calculated. These values are given in *Panel 3* where the variation between the different cross-side locations becomes clear:

Irrespective of the leather-making processes, these cross-side differences are directly associated with the structure within a

Panel 2: The predictive quality of test results

Physical tests generally result in the destruction of the tested area. The results are therefore only useful in so far that they give information regarding the performance of other untested areas on the same side or skin or in that location on another side in that pack. The actual test result is subject to variability and this means that any prediction is also subject to variability. By testing many locations on the same side it is possible to calculate the average for the side, thus the variability across the side. By taking more samples and carrying out more tests, the actual range of the predicted results can be narrowed and the prediction more "accurate". The papers summarised in this article give much information about the variability and enable us to judge what confidence we can have in the predictive quality of the test results.

single side/hide of leather. Other leathers will show different values - and greater or less degree of uniformity - but the underlying variability is fundamental. This provides considerable insight into the profile of any side/hide or skin in terms of physical properties.

RELATIONSHIP BETWEEN A SINGLE SAMPLE AND THE AVERAGE VALUE FOR A SIDE

Finding the typical variation across a side was the prime objective of the first investigation. However, the raw data was analysed (*at least in part*) for other purposes. In particular, the tongue tear test was investigated at various locations across each of the 30 sides to see if relationships could be found between individual results and the average performance for that side. The findings are given in *Panel 4*.

The trends within these two graphs have been evaluated using correlation coefficients, and this is not the same as average values.

The correlation coefficient is a concept from statistical analysis that measures the relationship between two values, then gives them a rating. A perfect relationship (*a straight line on a graph with all points placed on that line*) would have a value of 1.0. If there was no relationship - the points being random - then the rating would be 0.

It is a measure of predictability. For example, in the graphs shown in *Panel 4* the individual test results represent one value,

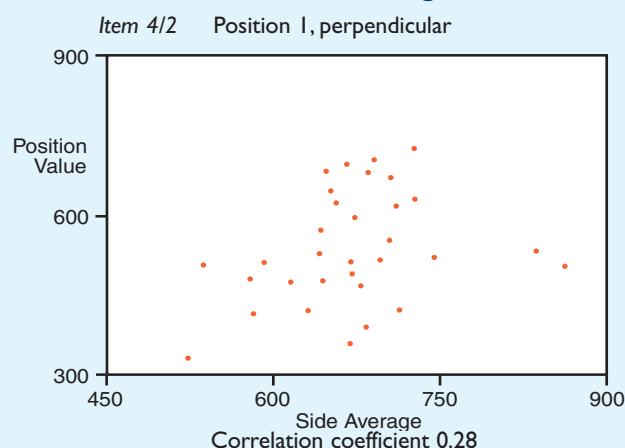
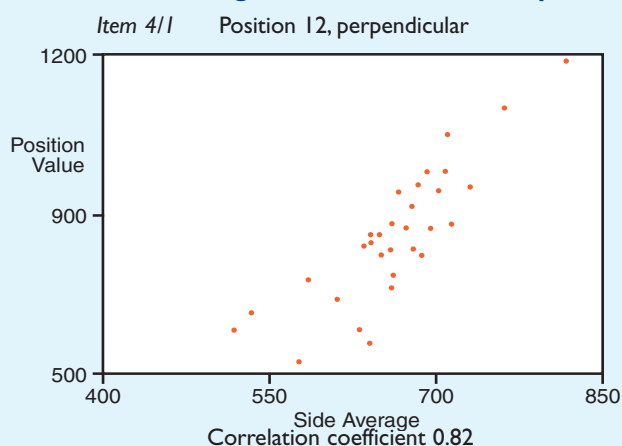


Panel 3 Average of 30 results on the same location on 30 sides of 1 pack

Location	Tensile strength		Stitch Tear strength		Tongue Tear strength		Elongation %		Burst strength
	Parallel	Perp.	Parallel	Perp.	Parallel	Perp.	Parallel	Perp.	
1	5710	3040	1520	1060	440	540	9	53	135
2	5400	3280	1440	1140	420	520	12	37	127
3	5750	3720	1300	1120	410	600	17	31	120
4	5020	3450	1290	1120	460	560	26	33	123
5	5240	3310	1170	1010	440	530	24	35	123
6	4200	2950	1040	950	400	410	28	34	127
7	2760	3880	920	1940	420	530	35	28	84
11	3740	4200	1690	1370	880	890	14	28	158
12	5090	5100	1740	1640	820	860	14	24	148
13	6620	5140	1370	1400	730	800	16	20	172
14	6290	4410	1360	1360	620	700	12	24	143
15	6610	4520	1390	1320	580	680	19	24	149
16	4610	3860	1180	1160	510	460	23	24	138
17	4650	4100	1330	1060	430	460	21	29	101
21	2170	2920	1420	1240	830	810	57	43	129
22	4400	3670	1490	1460	880	920	24	36	144
23	3570	5880	1590	1590	910	840	33	25	164
24	7310	5510	1490	1380	770	850	13	29	176
25	7510	5280	1730	1360	810	890	14	33	169
26	3670	4290	1740	1360	740	700	35	34	171
27	4830	4730	1270	1330	680	740	22	30	140
Max value	7510	5880	1740	1640	910	920	58	53	176
Min value	2170	2920	920	950	410	410	9	20	84

Note: Tensile Strength, Stitch Tear Strength, Tongue Tear Strength values as lbf/in²:
Elongation at load of 100 lbf/in width: Burst Strength at x 100 lbf/in thickness

Panel 4: Tongue Tear Test: relationships between individual results and the side average



Item 4/1: Samples taken from the 30 sides perpendicular to the backbone at location 12. This shows a linear relationship to the side average and is said to be typical of many of the findings.

Item 4/2: Samples taken from the 30 sides perpendicular to the backbone at location 1. This shows a non-linear relationship to the side average and is also said to be typical of many of the findings.

and the side averages the other. The relationships are shown as the scatter of findings; for example, in *Item 4/1* the correlation coefficient is calculated as 0.82. This means that a high level of test results could be expected to fit into this pattern of results. Some would be outside this pattern and might show no relationship, but the vast majority - perhaps 90% - would fit into this pattern. On the other hand *Item 4/2* has been evaluated at 0.28. This is a very low reading, and means for practical purposes that there is no

significant relationship between values, and that placing of test finding is almost random.

The better the correlation, the better the predictive quality of the test result.

Intra-pack variations (variations throughout a pack)

These initial findings were supported by a second set of investigations⁽²⁾. The leathers were similarly sampled, but the



exercise was more complex as it involved:

- matched pairs of sides from 30 steer hides as chrome tanned leather
- An additional 15 chrome retanned steer sides, and 15 chrome-retanned cow hides.

Since it was impossible to publish all of the large mass of data obtained, the data in the original reports was presented in condensed form. The findings considered to be pertinent are generalised:

- Although the cross-side/hide values were not (*and could not be*) the same as in the original investigations, the general patterns of variation in tensile strength found in the original investigations could be taken as typical.
- Several locations in the belly and shoulder areas have much greater tensile strength in the parallel than in the perpendicular direction.
- The average tensile strength and stitch tear strength in the parallel direction is higher than in the perpendicular direction - about 20% in the case of tensile strength.
- Tongue tear and stitch tear values are higher in the shoulders and belly areas than in the butt and backbone areas.
- The tongue tear value is roughly one-half of the values for stitch tear.
- Tongue tear shows little difference in the two directions of test.
- The correlation between the matched pairs of sides from the same hide for physical performance was good.
- The patterns of variation were similar irrespective of hide type or retannage.

Indications of the variability that might be expected within a side/hide have been given in *Panels 3 and 4*. However, the information extracted from the second investigation has been used to show intra-pack variations throughout a pack of 60 steer sides at each block location.

The values for the 7 x 3 locations across a side were determined for the 60 sides. The physical tests measured were tensile strength, stitch tear strength, tongue tear strength and bursting strength. The variation found between the 60 sides at each location was calculated as "average percent variation", and the findings are given in *Panel 5*.

These findings show that:

- The variations appear to follow the same pattern approximately.
- Within this pattern there are considerable variations at many of the locations.
- The blocks in the middle of each row, for example 5, 15 and 25, give the lowest variation for each of the tests.
- The blocks in the butt and shoulder areas give the highest variation.

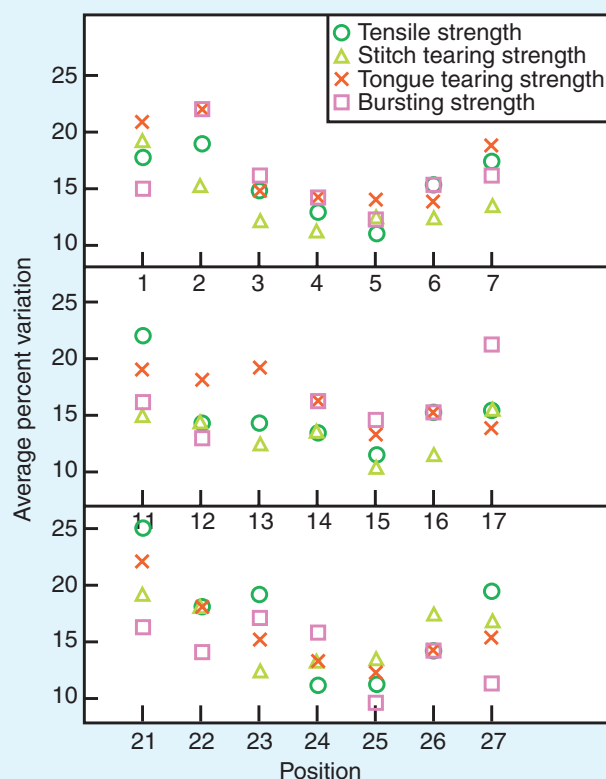
RELATIONSHIPS BETWEEN CROSS-SIDE AND INTRA-PACK VARIATIONS

Based on the information gained, the correlation coefficients were calculated to find the cross-side/hide and intra-pack variations for the various physical tests. These results are given as *Panel 6*.

This shows that in general the variation in physical tests is

Panel 5:

Average variation of properties across a side



These values are based on the averages of samples taken parallel and perpendicular to the backbone. The methodology is not the same as specified today in the Official Methods of Analysis. Nevertheless, the trends identified can be taken as typical. (Test details in the original papers)

greater between locations across a side/hide, than between the sides/hides within a pack.

Inconsistencies between physical properties according to location

The findings given so far show the variations in physical properties that might be found:

- at different locations across a side/hide.
- at the same location throughout a pack of sides/hides.

In a third paper⁽⁴⁾, based on the data that had already been collected, calculations were made to establish the optimum sampling position. A sample taken at this location when analysed should:

- provide meaningful information regarding the performance of the whole side
- be typical of the performance of the maximum number of sides within a pack

These calculations produced six rating levels (*between a maximum and minimum value*) at each of the 7 x 3 locations. It also shows the number of sides that must be sampled to show 10% difference between the sides/hides with a degree of

**Panel 6: Correlation coefficients for physical properties for cross-hide and inter-pack variations**

Parameter	Block averages (cross-side variations)	Side averages (Inter-pack variation)
Tensile Strength (Perp.) (Parallel)	0.86 0.89	0.89 0.72
Stitch Tear Strength (Perp.) (Parallel)	0.92 0.95	0.54 0.66
Tongue Tear Strength (Perp.) (Parallel)	0.94 0.59	0.97 0.65
Elongation at break (Perp.) (Parallel)	0.73 0.62	0.91 0.28
Bursting strength	0.95	0.47

Note: Tensile Strength, Stitch Tear Strength, Tongue Tear Strength values as lb/in²; Elongation at load of 100 lb/in width; Burst Strength at x 100lb/in thickness

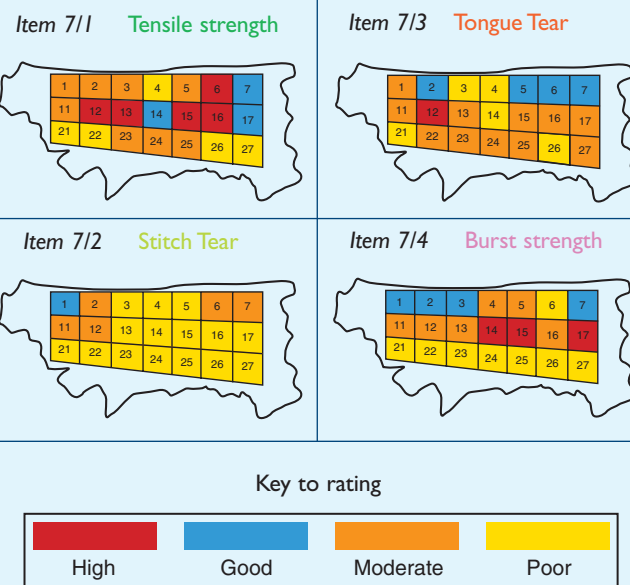
confidence of 90%.

The original six ratings have been reclassified as high, good, moderate and poor. Poor includes the ratings 4, 5 and 6 as the coefficient for variation was considered as unacceptable. The number of sides required to provide the 90% degree of confidence at the "high" rating varied between 18 and 28 (according to the physical test method), but for the "poor" rating ranged between 53 and 262. The findings are illustrated within Panel 7⁽⁵⁾.

These illustrations show that the optimum position for one analysis test is not necessarily the best for another test. However, the rankings considered best were provided by locations 12 and 7. For simplification of sampling block 7 was deemed the optimum sampling position. It later became a guide for the Official Sampling Position (OSP) for analysis.

Summary

- The original investigation determined the optimum point for sampling leathers so that the analysis would be the most meaningful for a side, and also, the minimum number of samples that would be needed when assessing the performance of that pack. The outcome resulted in a single location being identified as the optimum sampling position.
- The information gained has provided a profile of both cross-side and intra-pack variations that can be considered typical - assuming that the pack is processed as a single batch.
- In general, the variations found within a side are greater than the variations at a single location throughout a pack.
- The locations that provide the highest values for one test do not necessarily produce the highest values for another test. If the values are rated across a side/hide/skin, then the pattern of performance will vary according to the test method.⁽⁵⁾
- The OSP is not the best sampling position for all tests. It might be better regarded as the best compromise as a sampling position.

Panel 7: Rating of physical properties according to location on a side

- The Lastometer and Baumann Tear Tests were not developed until later. If it had been possible to apply these tests at the time, the findings could not have exactly followed the profile of any of the four tests that were investigated. However, it can be expected that in general those same trends would be found.
- The physical tests used in this investigation followed the test methods and procedures used on conventional military leathers at that time. Accordingly, the values will be different from leather manufactured today. However, the findings are fundamental to all leathers, and the trends and variations revealed remain typical.

This was a massive investigation, and together with Wilson's findings, provided the first detailed insight into the physical properties of leathers. It is highly unlikely that studies on this scale will ever be performed again. 🌐

References

- 1) *The properties of leather: Strength and stretch across the skin area and the effect of splitting:* J.A. Wilson, *World Leather*, June/July 2006, p27-29.
- 2) *The sampling of side upper leather:* C.W. Mann, E.B. Randall, J. Mandel, T.J. Kilduff, and A.M. Charles: *J. Am. Leather Chem. Assn.* p248-263 (1951).
- 3) *The variation of the physical and chemical properties of split and unsplit chrome-tanned leathers:* E.B. Randall, T.J. Carter, T.J. Kilduff, C.W. Mann, and J.R. Kanagy: *J. Am. Leather Chem. Assn.* p404-425 (1952).
- 4) *The sampling of side upper leather II:* C.W. Mann, J. Mandel, Mary N. Steel and J.R. Kanagy: *J. Am. Leather Chem. Assn.* p352-370 (1952).
- 5) *The different cross-side/hide performance profiles for the tests were discussed with experts familiar with the physical performance of different leathers. The findings were inline with their practical experience.*

Acknowledgements

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