SGS Wool Testing Services

IWTO RAW WOOL GROUP MEETING, Capetown, April 1996

Repeatability data on Length and Strength (IWTO-30) determined by the Agritest Staple Length and Staple Breaker model 2 instruments.

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Introduction

IWTO-30 describes the principles required for the measurement of staple length and strength. Currently one instrument is mentioned in an Appendix as being deemed to comply with the requirements, and therefore provides a useful benchmark. Data[1] was presented at the Nice 1995 meeting of this group to show the relationship between staple length and strength results from the Agritest Staple Length Meter and Staple Breaker model 2, and results from ATLAS. This report gives repeatability data from each of the two Agritest instruments.

Equipment

All the measurements reported here were carried out on an Agritest Staple Length Meter (SLM), or on two Agritest Staple Breaker model 2 (SB2) instruments. Descriptions of these instruments were given in the earlier report.

Repeatability procedures

Repeatability is difficult to measure in the IWTO-30 test method because of the very high variances associated with the sampling as compared to the measurement process. The sampling variances cannot be reduced by the commonly-used expedient of blending (which is used to reduce this source of variance in all core test methods), since the between-staples component of variance is extremely high. Additionally, of course, on the SB2, staple measurement is destructive, so the same staple cannot be remeasured.

In order to assess repeatability, two basic procedures were followed:

- Split staple comparisons - this procedure was used to allow direct comparisons to be made with similar work carried out by CSIRO. 10 lots of wool were chosen to cover a wide range of types - 5 were of Australian origin and 5 were from New Zealand. Both fleece and oddment samples were used. From each lot, 20 relatively thick staples were selected, and each staple was split into two approximately equal portions. The two portions of the staples were assigned in sequence to two sets, which were either tested on two instruments or on two different days.
- Split lot comparisons - staples from existing staple sample sets (comprising both fleece and oddment lines) were assigned alternately to the two SB2 instruments, thereby giving "subsamples" of 29 staples each.

Within-instrument repeatability

Assessment of within-instrument repeatability was carried out using the split staple method (i.e. splitting individual staples and testing on two separate days), and was only carried out on one instrument since it became clear that the results were dominated by the variances between the two halves of the staples rather than between the two days of measurement. The results are shown in table 1 and are reported for staple length in mm, for CoV SL in %, for staple strength in N/ktex, and for position of break in terms of the yield-corrected tip mass ratio %)

Table 1: Within-instrument differences (day 1 to day 2)

[1] B.P. Baxter. Comparative data on length and strength (IWTO-30) determined by ATLAS and Agritest Staple Length and Staple Breaker instruments, IWTO raw wool group meeting, Nice, Dec 1995, App. 9

SGS lot	SLM	SL	CoV SL	SS	PoB	CSIRO	SL	SS	PoB
101	-0.2	0.5	-0.3	-0.0	0.2	11	-0.5	-0.8	-0.7
102	-0.4	0.6	0.5	0.2	-1.7	12	-1.0	0.2	-0.2
103	-0.1	-0.3	0.2	3.2	0.9	13	-0.2	1.1	-0.3
104	3.2	***2.7***	-0.9	-0.0	-1.3	14	-0.1	0.3	0.1
105	-2.6	***-2.3***	-0.8	-2.3	-0.5	15	-0.5	0.2	-0.1
106	1.2	1.2	-0.9	-0.4	-2.9	16	0.4	0.4	-0.4
107	-2.3	-1.6	1.1	-2.4	-0.0	17	0.4	-0.4	-0.3
108	-2.4	0.3	-2.1	-0.2	-0.6	18	-0.9	0.8	1.2
109	-0.3	0.3	0.9	3.1	-2.9	19	0.1	0.9	-0.7
110	0.5	-0.9	-0.7	2.1	0.5	20	-1.2	1.5	0.6
						21	-0.4	0.2	0.1
						22	0.5	0.6	-1.1
Avg	-0.3	0.0	-0.3	0.3	-0.8	Avg	-0.3	0.4	-0.2
SD	1.8	1.4	1.0	2.0	1.3	SD	0.6	0.6	0.6

Comparison data to the right of the table (headed CSIRO) refers to ATLAS Repeatability trials, carried out in a similar manner with split staples, reported to the Australian Standards TX/12 committee in document TX/12/84-47.

Differences which are significant at the 0.05 level are shown in bold italic. Overall none of the average differences are significantly different to zero. The standard deviations of the differences on the left hand side of the table are all significantly larger than those shown on the right, but this is almost certainly due to the nature of the samples rather than the instruments. It will be seen when we look at between-instruments that the variances are statistically indistinguishable from the above.

Figures 1 through 4 show comparisons of the individual results on the two portions of the split staples. In these and later figures, each figure ‘a’ shows the results from one day or one instrument plotted against the other, figure ‘b’ shows the differences plotted against the mean, and figure ‘c’ shows the differences plotted on a normal probability plot. Figure ‘b’ is the clearest indicator of agreement or of a systematic difference between the two sets of measurements, whereas figure ‘c’ indicates whether the differences are normally distributed (in which case they lie on a straight line), or skewed or otherwise non-normal.

Figures 1 through 4 show no significant trends, as would be expected, since the only variable being compared is time. The regression constants in figures ‘b’ are all not significantly different to zero. The plots do, however, give an indication of the levels of variability to be expected between staple halves.

Between-instrument repeatability - split staples

Between-instrument repeatability was assessed using the split-staple method on 3 separate days but using the same lots (i.e. the two portions of each staple were measured on different SB2 instruments). The staple samples for measurement on the 3 separate days were themselves prepared on 3 separate days, so the between-day component includes both between-instrument over days as well as between-staple sets over days, although the same staple preparation operator was used in each case. Notwithstanding, analyses of variance all showed the between-days effect to be non-significant. Table 2 shows the results from day 1 compared against identical trials for ATLAS. In this case there are no significant differences in variance between the left and right hand sides of the table.

Table 2 - Between-instrument differences (day 1)

SGS lot	SLM*	SL	CoV SL	SS	PoB	CSIRO	SL	SS	PoB

101	-1.3	***-2.6***	1.0	-1.0	1.1	1	0.2	-0.3	-1.0
102	-0.1	-1.9	-0.1	0.3	-1.9	2	-0.7	***-3.3***	1.7
103	2.0	-2.5	2.9	-1.2	1.2	3	0.9	0.0	-3.6
104	-1.3	0.3	0.0	1.9	-1.0	4	-0.3	0.4	***-6.0***
105	0.2	-0.9	-0.8	0.0	0.6	5	-0.3	-1.8	***-2.2***
106	0.6	1.0	-0.5	3.1	1.6	6	1.6	0.9	-1.9
107	2.1	***1.2***	0.8	1.4	-0.1	7	0.9	-1.1	***-6.1***
108	-0.8	-0.1	0.1	***3.0***	-0.9	8	0.9	0.3	-1.7
109	0.3	***2.9***	0.0	0.3	-2.4	9	-1.5	-2.2	-1.9
110	-0.9	-1.3	1.0	2.3	-0.3	10	-1.4	***-3.7***	-4.2
Avg	0.1	-0.4	0.4	1.0	-0.2	Avg	0.0	-1.1	-2.7
SD	1.2	1.8	1.0	1.6	1.4	SD	1.0	1.6	2.4

It should be noted that in this case the figures under SLM are again the between-staple-halves differences, since all SLM measurements were carried out on the same instrument. The data in this column provides a check against the reference method (AS 2720). Table 3 shows the data for the other 2 days.

Table 3 - Between-instrument differences (days 2 and 3)

SGS lot	SLM* 2	SL 2	CoV SL 2	SS 2	PoB 2	SLM* 3	SL 3	CoV SL 3	SS 3	PoB 3
101	-0.2	-0.1	-1.0	0.8	1.7	0.1	***-1.9***	1.9	0.6	-1.2
102	-2.8	-1.3	-0.5	7.2	-2.6	-0.6	-1.4	1.7	1.2	-0.5
103	-1.0	-1.8	0.3	1.2	-0.5	-0.4	***-2.4***	1.4	1.0	-1.5
104	1.3	-0.7	1.8	1.0	0.3	0.4	-0.1	1.6	1.8	3.3
105	0.5	-0.1	0.3	0.6	1.1	1.2	-0.5	3.0	-2.2	0.3
106	1.7	2.1	-0.5	-1.3	0.7	-2.8	-0.2	1.2	1.8	3.6
107	-0.1	-0.8	***0.7***	***4.4***	0.4	1.3	-0.2	0.4	1.9	0.6
108	0.7	-0.4	1.3	0.8	0.0	1.9	0.8	0.2	2.2	-0.8
109	0.1	0.2	-0.1	0.4	-3.0	0.7	0.9	0.9	-0.9	-0.3
110	0.0	0.0	1.8	1.0	0.1	-1.6	-1.5	-0.6	-0.3	0.9
Avg	0.0	-0.3	0.4	1.6	-0.2	0.0	-0.6	***1.2***	0.7	0.4
SD	1.2	1.0	1.0	2.4	1.5	1.4	1.1	1.0	1.4	1.8

Only in one case (CoV SL day 3) was the average difference between instruments significant at the 0.05 level. In all cases the variances (SD^2) are not significantly different to those quoted in the TX/12 document when tested using the F test. In all cases also, there is no significant difference at the 0.05 level between the variances of the differences for the SLM and SB2.

The above data confirms that the SB2 has a similar level of between-instrument repeatability as the instrument deemed to comply with IWTO-30, and in length measurement, a similar level to the reference method AS 2710.

Figures 5 through 8 show the detailed staple by staple comparisons of the results from the two portions (instrument 1 against instrument 2) when all three days are combined. In figures 'b', the regression coefficients are significant for staple length, staple strength, and position of break. (The fact that they are not significant for the SLM is not surprising since these measurements were all carried out on the same instrument) Despite the statistical significance of the gradients of the regressions in the 'b' plots, in real terms the effects are small and of no commercial significance (individual staple measurements are not reported), as will be seen when we consider the split-lot comparisons.

Considering the entire set of staple by staple comparisons allows us to detect very small differences which are not apparent in the tables above. Whilst there was no significant difference in

PoB % between the two instruments, the average difference in staple length was 0.5 (sd 5.2) mm and the average difference in staple strength was 1.0 (sd 6.7) N/ktex.

These levels of differences between instruments were considered acceptable in all the published reports during development of the test method[2,3,4,5,6,7,8,9]. The literature refers to acceptable average staple length differences between instruments of 1 mm, and average staple strength differences of 2 N/ktex. In the between laboratory situation, average differences of up to 1.4 mm for staple length, 1.6 % for coefficient of variation of staple length, and 1.3 N/ktex have been considered "quite small"; and in one case differences of up to 3.1 N/ktex were considered by implication to be acceptable.

Between-instrument repeatability - split lot comparisons

Assessment of between-instrument repeatability was also assessed using the 'split-lot' comparison method outlined above, on 69 samples. Whilst the subsamples each only comprised 29 staples, this was adequate over the range of samples available to precisely evaluate the differences.

The measurements are summarised in figures 9 through 13, which follow a similar format to that used for the split-staple work.

Taking each comparison in turn:

- Staple length - the average difference was 0.3 mm (sd 2.6), which was not significant at the 0.05 level. The standard deviation of the differences is less than would be expected considering only the between-staple variances shown in IWTO-30. The regression coefficients in figure 9b are not significantly different to zero.
- Staple strength - the average difference was 0.9 (sd 3.1) N/ktex, which is significant at the 0.05 level, but within the acceptable range as defined in the literature. The standard deviation of the differences is less than would be expected considering only the between-staple variances shown in IWTO-30. The regression coefficients in figure 10b are not significantly different to zero.
- Coefficient of variation of staple length - the average difference was 0.7 (sd 2.2) %, which was significant at the 0.05 level. There is no information on which to base a judgement as to acceptability, but a review of the expected precision suggests that this is totally acceptable. The standard deviation of the differences is similar to the figure implied by the statements in IWTO-30. The regression coefficients in figure 11b are not significantly different to zero.
- Percentage of middle breaks - it should be noted that this is a measurement with particularly poor precision when only 29 staples are tested because of the way in which the figure is derived (the best sensitivity is only 1 in 29 or 3%). The average difference was 4.2 (sd 11.3) %, which is significant, but the data presented in figures 7 and tables 2 and 3 are probably much more relevant - they suggest that since there was no significant difference in PoB% (from which Mid % is directly derived) the difference in percentage middle breaks is probably an artefact of the

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[2] ATLAS and PERSEUS repeatability trial data, document TX/12/84-47, Standards Australia, 1984

[3] Comparisons between the CSIRO staple length meter and ATLAS, document TX/12/84-48, Standards Australia 1984

[4] Comparison of ATLAS prototypes for measurement of SL and SS, document TX/12/85-4, Standards Australia 1985

[5] Staple length data from 3 lots measured via existing system and ATLAS, document TX/12/85-15, Standards Australia 1985

[6] R.L. Thompson et al., The CSIRO Automatic Tester for Length and Strength (ATLAS), J. Text. Inst., 1988, 66 - 78

[7] J.W. Marler, Between-laboratories staple measurement round trials, IWTO Paris, Dec. 1989

[8] M.A. Jackson and A.J. Steer, Investigations on staple conditioning time, IWTO ?, ?

[9] C.G. Stubbs, J.W. Marler and M.R. Bow, The precision of average staple length and average staple strength measurements, IWTO Nice, Dec. 1991

comparison method rather than a reality. There is no obvious data on which to base a judgement of acceptability, but common sense suggests that the comparison outcome is satisfactory. The regression coefficients in figure 12b are not significantly different to zero.

- Figures 13 are comparisons of the average staple lengths of the two subsamples, since only one SLM instrument was used. Only 60 pairs of comparisons were available. The average difference was 0.2 (sd 1.9) mm, which is not significant. The regression coefficients in figure 13b are not significantly different to zero.

Conclusions

The results reported here indicate a high level of agreement between the two SB2 instruments on staple length, coefficient of staple length, staple strength and position of break on both New Zealand and a limited sample of Australian wools. They also show excellent agreement on staple length with the SLM instrument (as reported previously).

Although between-instrument variances cannot easily be assessed using only two instruments, the data nevertheless indicates that the variances are likely to be small, and the measured differences are within those which have been previously reported as acceptable. Where variances can be compared, they are similar to those reported in the literature. None of the comparisons show significant slope differences, nor indicate any significant heteroscedasticity.

The results confirm that the Agritest instruments comply with the essential requirements of IWTO-30. It has been shown in this paper that the instruments give at least equivalent precision to the instrument deemed to be acceptable, and in the previous paper that the principles of operation and measurement are similar, and that a similar level of accuracy is achieved.

SGS Wool Testing Services

SPLIT STAPLE COMPARISONS - SAME INSTRUMENT

Figure 1a - Within instrument - LENGTH

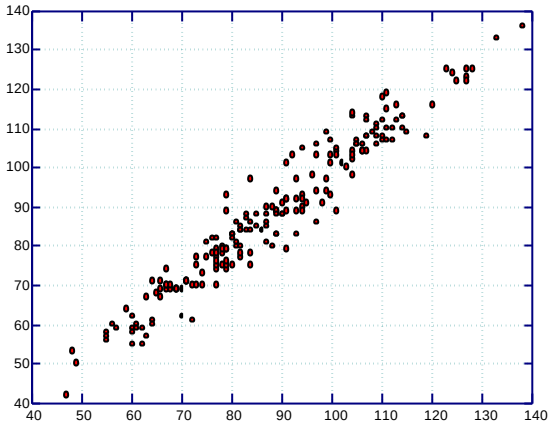


Figure 2a - Within instrument - STRENGTH

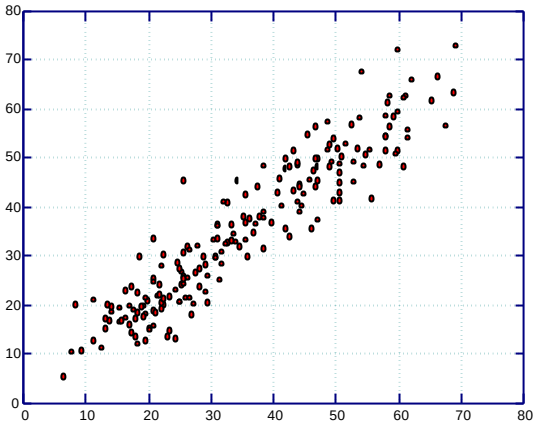
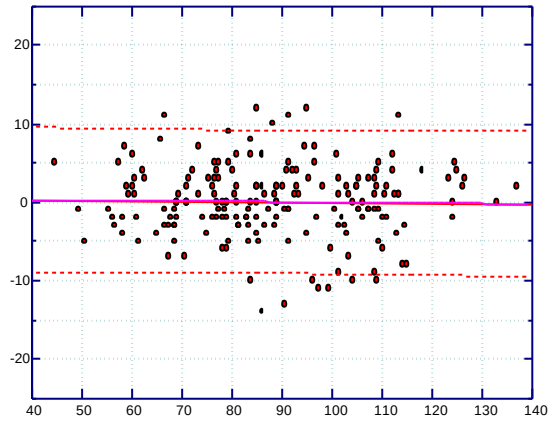
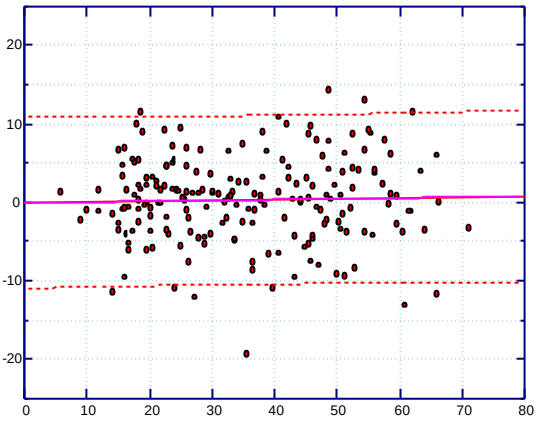


Figure 1b - Within instrument - LENGTH



R2 = 4.73344e-4 SE = 4.61248255 C0 = .521133088
C1 =-5.4011e-3

Figure 2b - Within instrument - STRENGTH



R2 = 9.12539e-4 SE = 5.43472004 C0 = -.110054481
C1 = .010881387

Figure 1c - Within instrument - LENGTH

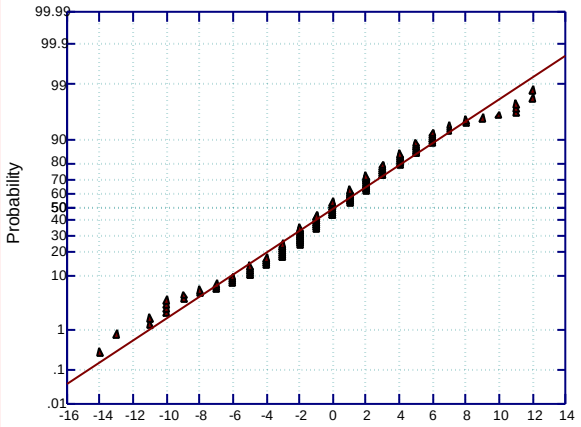
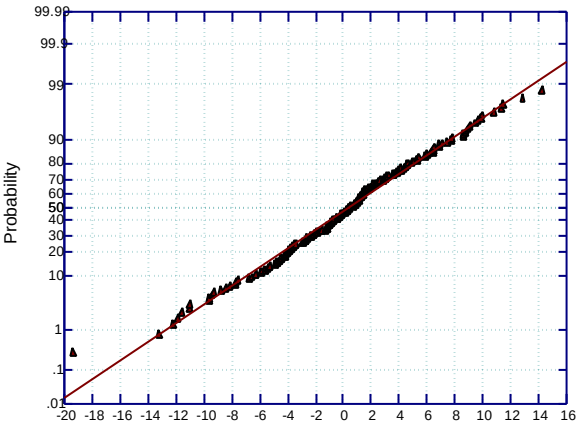


Figure 2c - Within instrument - STRENGTH



SPLIT STAPLE COMPARISONS - SAME INSTRUMENT

Figure 3a - Within instrument - PoB %

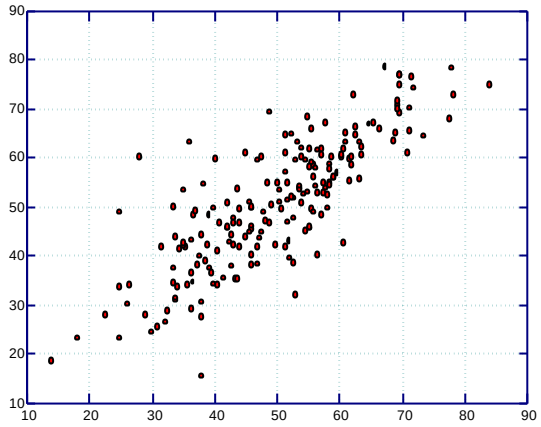


Figure 4a - Within instrument - SLM

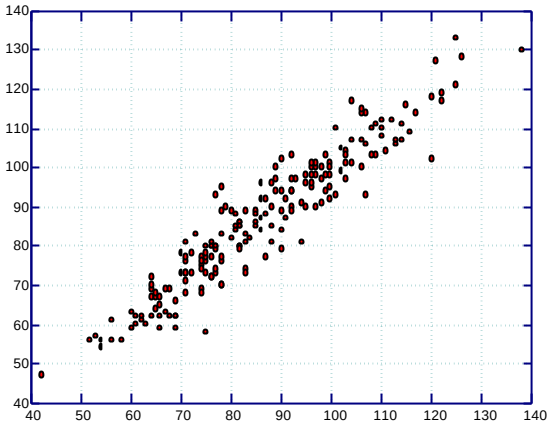
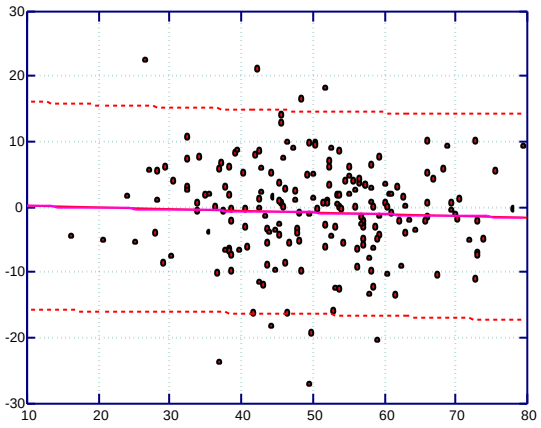
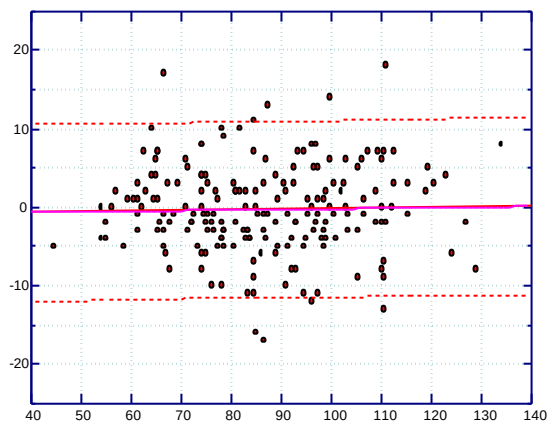


Figure 3b - Within instrument - PoB %



R2 = 1.50463e-3 SE = 7.86017752 C0 = .393577389
C1 =-.024890139

Figure 4b - Within instrument - SLM



R2 = 5.49826e-4 SE = 5.6668663 C0 = -.990417165
C1 = 7.63816e-3

Figure 3c - Within instrument - PoB %

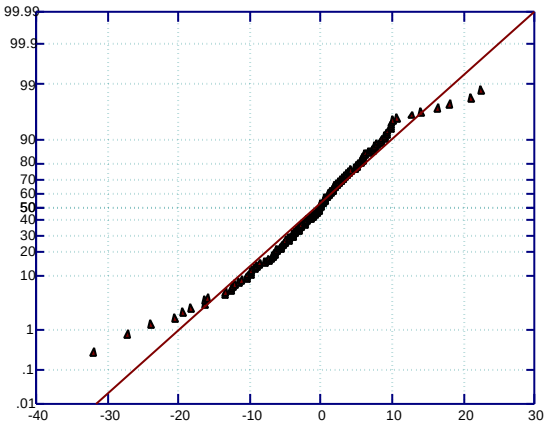
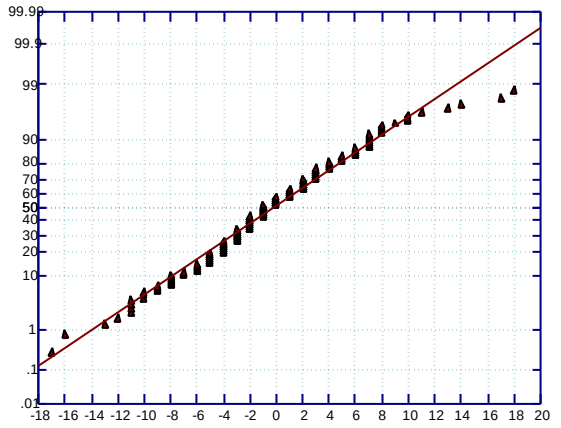


Figure 4c - Within instrument - SLM



SPLIT STAPLE COMPARISONS - DIFFERENT INSTRUMENTS

Figure 5a - Between instruments - LENGTH

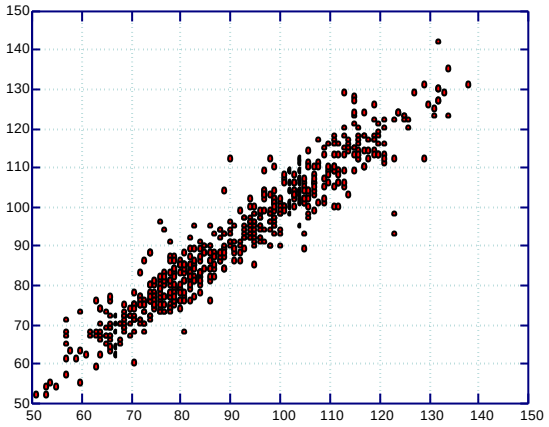


Figure 6a - Between instruments - STRENGTH

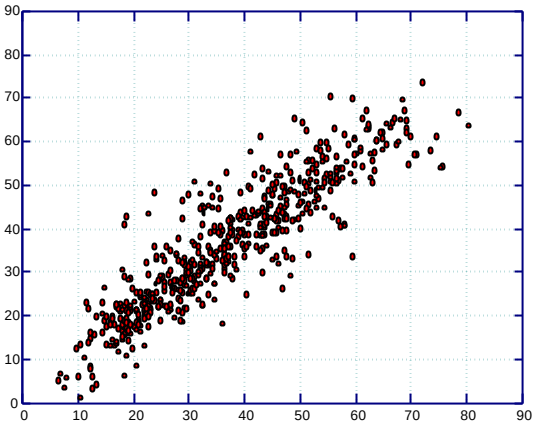
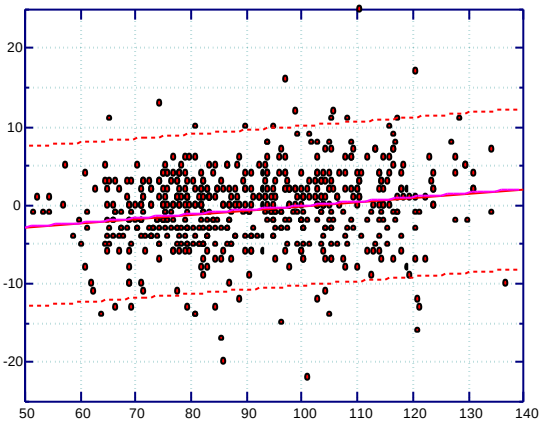
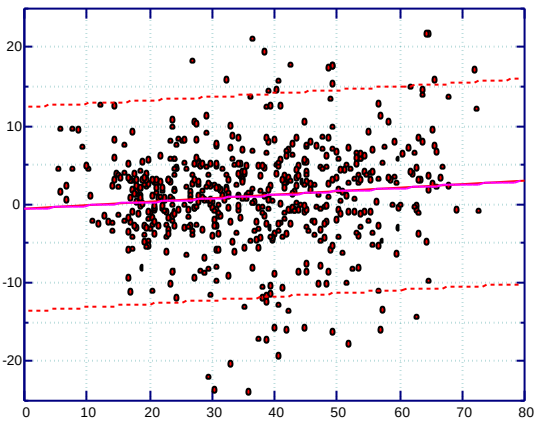


Figure 5b - Between instruments - LENGTH



R2 = .032440893 SE = 5.16719866 C0 = -5.45895083
C1 = .054097521

Figure 6b - Between instruments - STRENGTH



R2 = 7.53301e-3 SE = 6.59115458 C0 = -.626799819
C1 = .044520571

Figure 5c - Between instruments - LENGTH

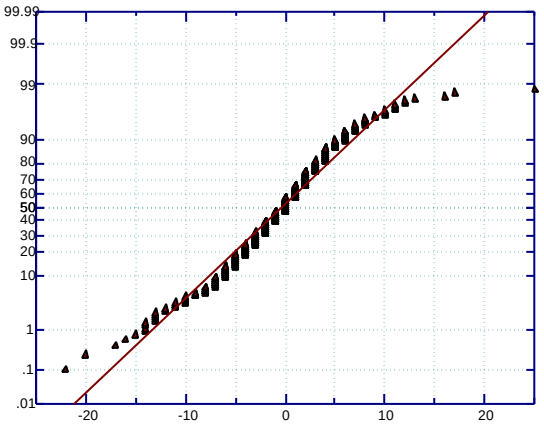
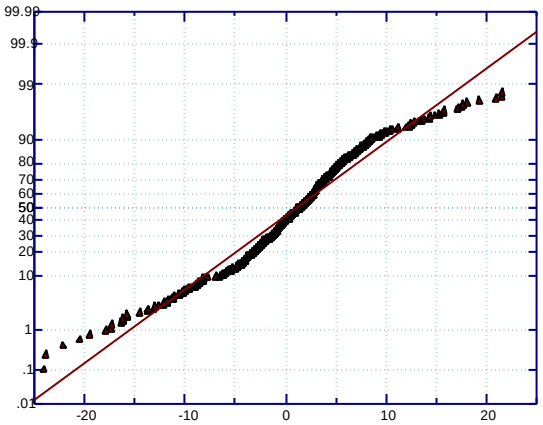


Figure 6c - Between instruments - STRENGTH



SPLIT STAPLE COMPARISONS - DIFFERENT INSTRUMENTS (fig 7 only)

Figure 7a - Between instruments - PoB %

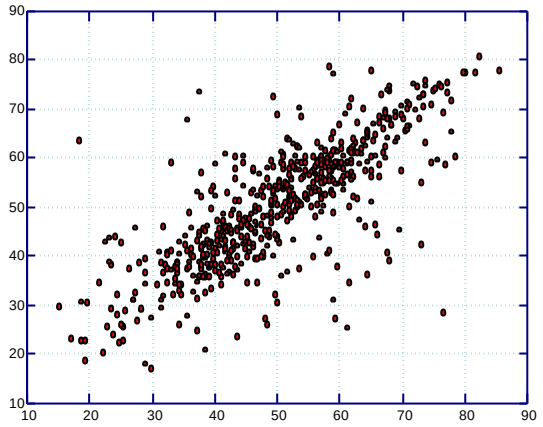


Figure 8a - Between instruments trial - SLM results

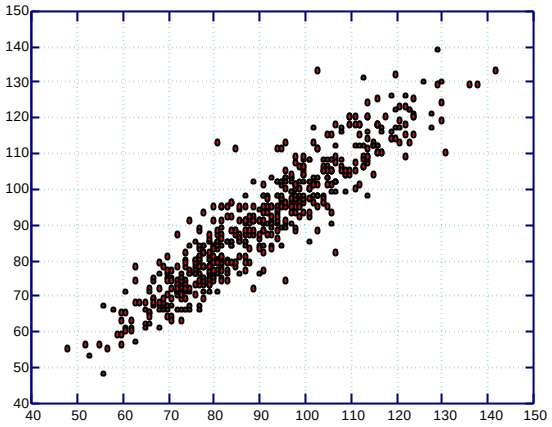
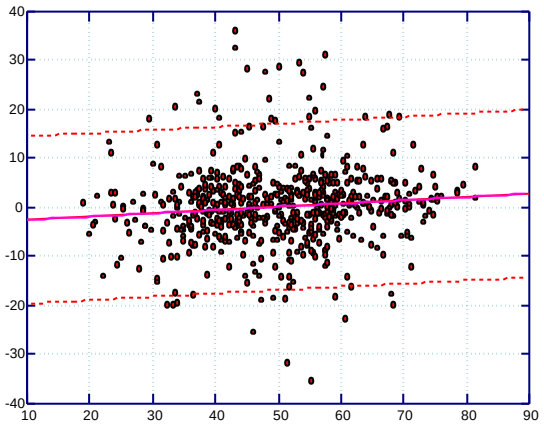
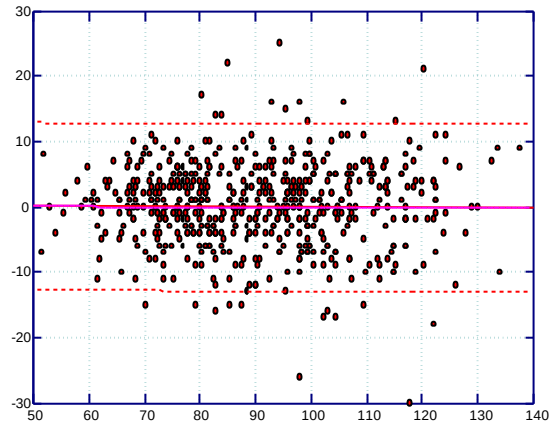


Figure 7b - Between instruments - PoB %



R2 = 9.02616e-3 SE = 8.63101578 C0 = -3.28036225
C1 = .067110965

Figure 8b - Between instruments trial - SLM results



R2 = 3.77301e-5 SE = 6.51107693 C0 = .20528922
C1 =-2.38214e-3

Figure 7c - Between instruments - PoB %

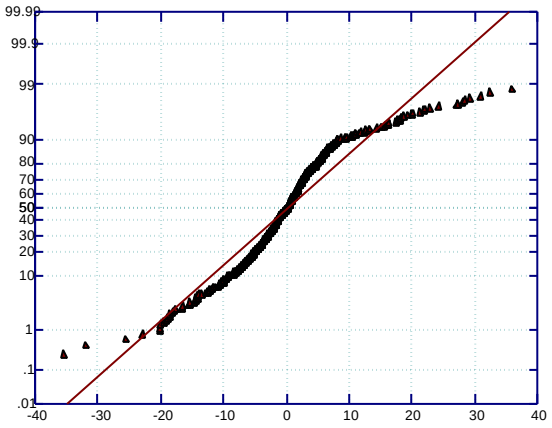
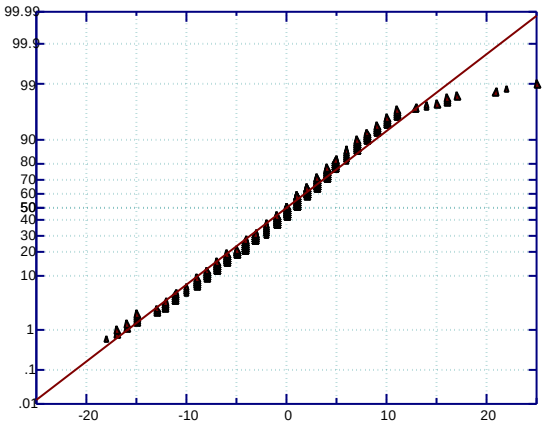


Figure 8c - Between instruments trial - SLM results



SPLIT LOT COMPARISONS - DIFFERENT INSTRUMENTS

Figure 9a - Between inst. (sets of 29) - Avg. LENGTH

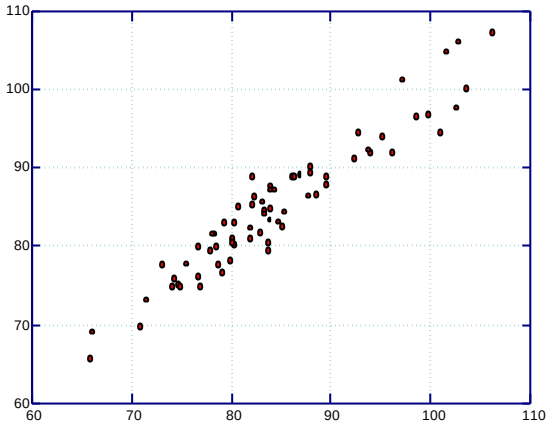


Figure 10a - Between inst. (sets of 29) - Avg. STRENGTH

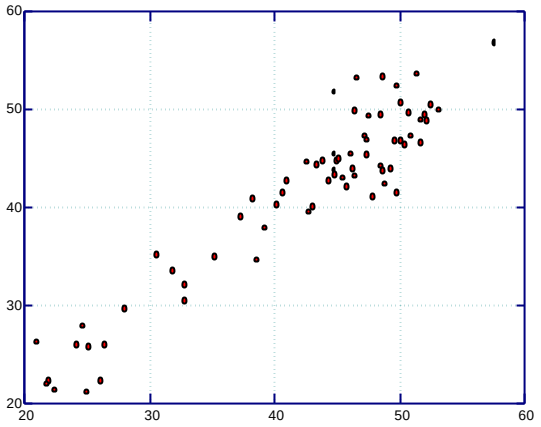
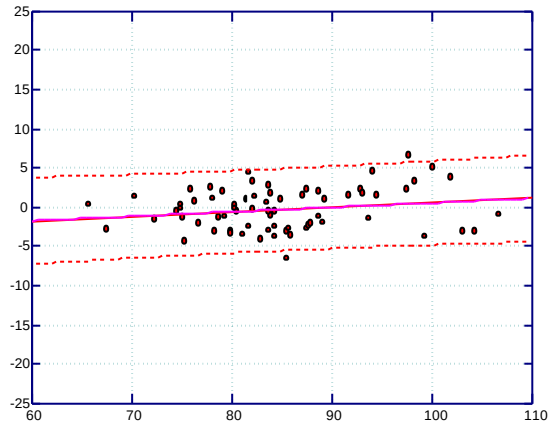
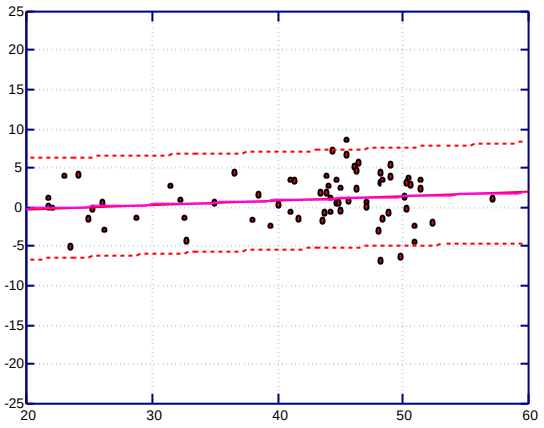


Figure 9b - Between inst. (sets of 29) - LENGTH



R2 = .035375949 SE = 2.60194159 C0 = -5.14279637
C1 = .056869667

Figure 10b - Between inst. (sets of 29) - STRENGTH



R2 = .023504231 SE = 3.09958124 C0 = -1.25065587
C1 = .052251012

Figure 9c - Between inst. (sets of 29) - LENGTH

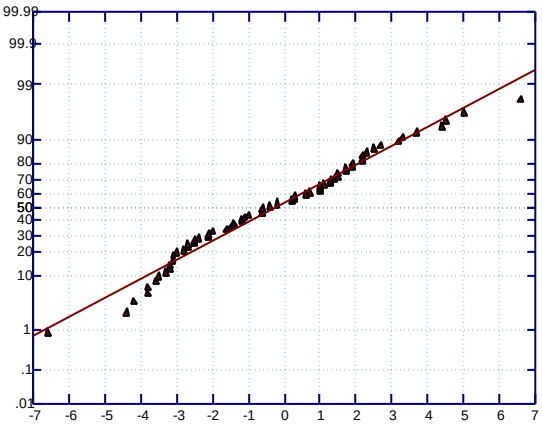
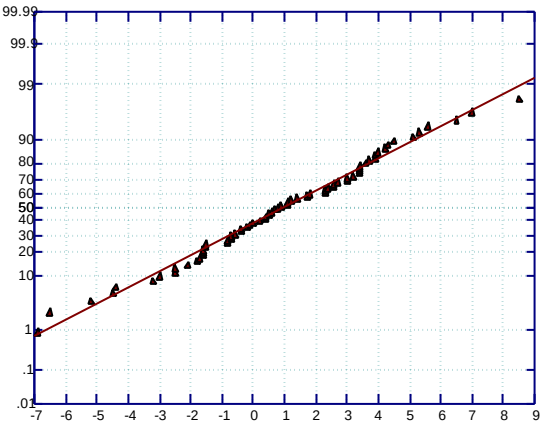


Figure 10c - Between inst. (sets of 29) - STRENGTH



SPLIT LOT COMPARISONS - DIFFERENT INSTRUMENTS

Figure 11a - Between inst. (sets of 29) - Avg. CoV SL

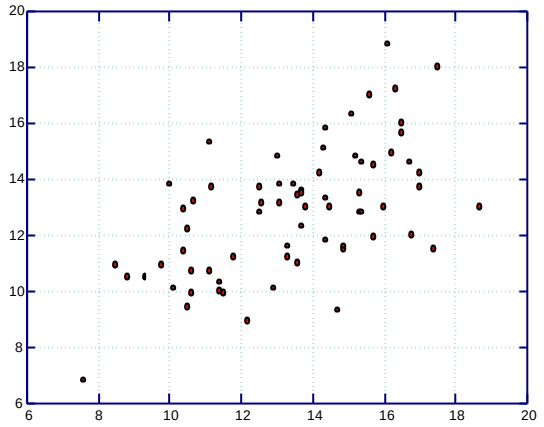


Figure 12a - Between inst. (sets of 29) - Avg. Mid %

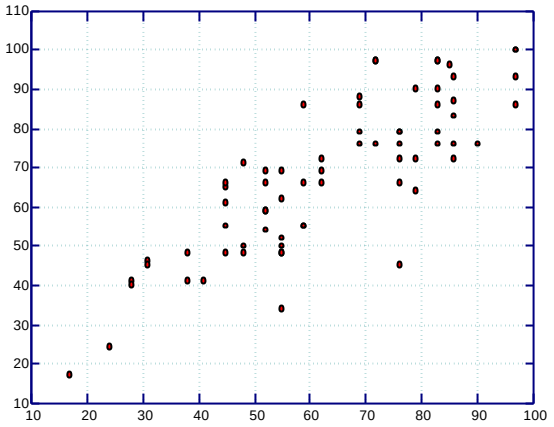
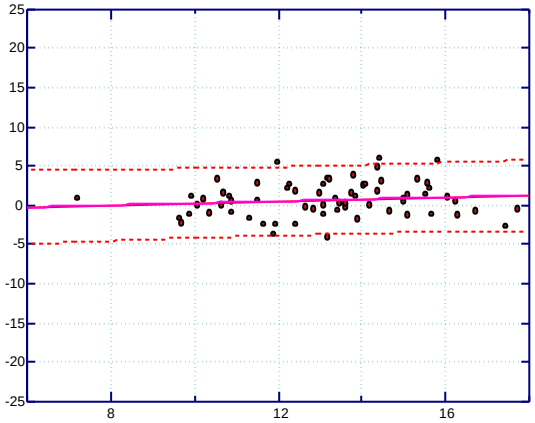
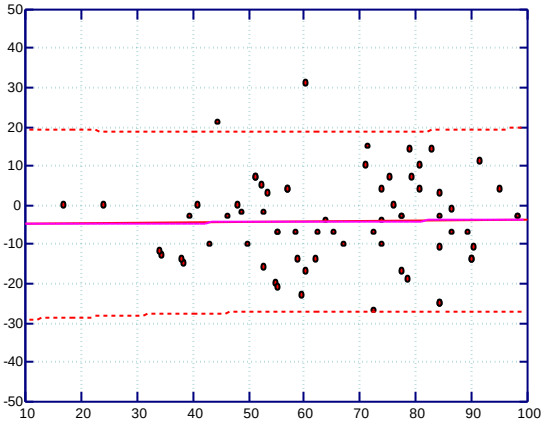


Figure 11b - Between inst. (sets of 29) - Avg. CoV SL



R2 = .015575011 SE = 2.16980648 C0 = -1.01042658
C1 = .126716765

Figure 12b - Between inst. (sets of 29) - Avg. Mid %



R2 = 3.9263e-4 SE = 11.3701916 C0 = -4.94365393
C1 = .011941327

Figure 11c - Between inst. (sets of 29) - CoV SL

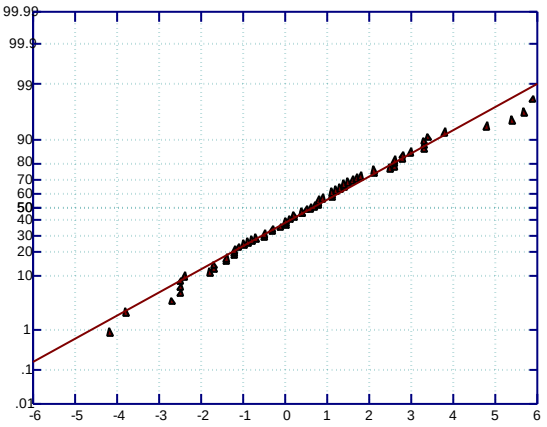
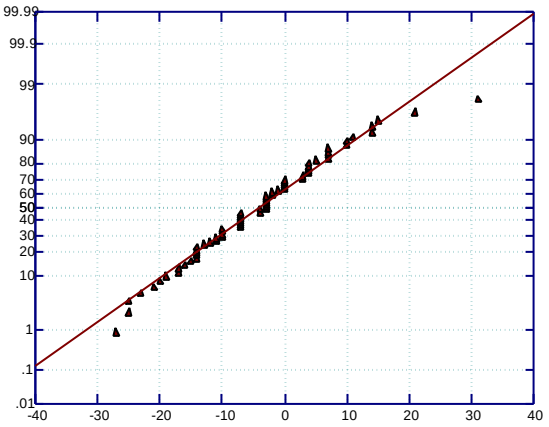


Figure 12c - Between inst. (sets of 29) - Mid %



SPLIT LOT COMPARISONS - Average staple length comparisons between subsamples

Figure 13a - Between sets of 29 - Avg. SLM

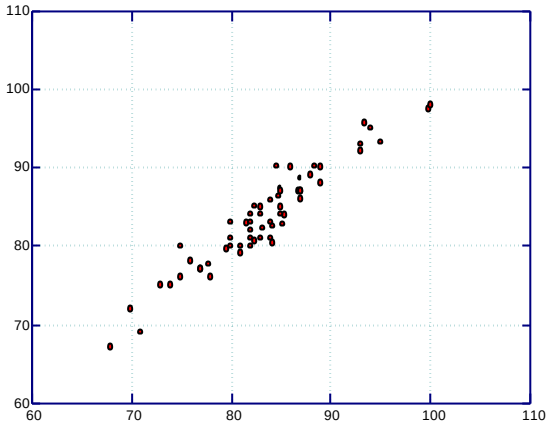
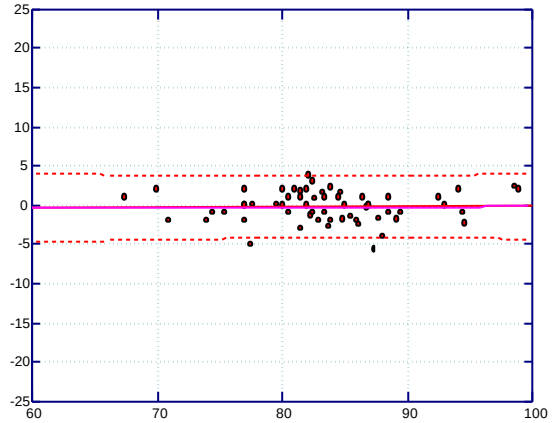


Figure 13b - Between sets of 29 - Avg. SLM



R2 = 2.19932e-4 SE = 1.95798576 C0 = -.617711749
C1 = 4.52151e-3

Figure 13c - Between sets of 29 - Avg. SLM