EVALUATION OF THE GAVARTI COMPREHENSIVE ABRASION TESTER (CAT)

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ABSTRACT

The Gavarti Comprehensive Abrasion Tester (CAT) is a relatively new instrument for determining the rub resistance of printed images. While there have been several published articles concerning its ability to duplicate damage found in the field, this paper examines the operating variables of the CAT and compares it to the Sutherland Rub Tester. Much of this work was done using folding carton type stock. Tests were conducted in accordance with manufacturers' specifications. This testing led to the development of standard test parameters for the CAT. In addition, a method of quantifying rub resistance is presented. This work showed that the Sutherland Rub Tester can be improved by using a Gavarti Standard Receptor.

<u>Summary</u>

Evaluation of the Gavarti GA-CAT consisted of the following areas:

1. Development of a method to quantify rub resistance.

2. Statistical analysis of the instrument variables.

3. Determination of standard test conditions.

4. Determination of operator error.

5. Comparison of the CAT to the Sutherland Rub Tester.

A Macbeth 1500 Plus Spectrophotometer using L*a*b* color space with illuminant C and a 10 degree observer was used to evaluate abrasion resistance.

Statistical analysis of the CAT shows that the variables of time, frequency, and span are significant for rub tests.

Results from the Sutherland can be made more repeatable and easier to interpret by using a Gavarti receptor.

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Correlation was not found between the Sutherland and the Gavarti CAT.

The Gavarti CAT was reproducible between operators.

The following represent recommendations for standard test procedures for the CAT:

Top Pressure	40 psi
Side Pressure	20 psi
Span	1 inch
Frequency	2 Hz.
Time	25 seconds
Receptor	Gavarti A-1

The type of receptor can be changed to accommodate different substrates. For instance, the Gavarti C-1 receptor is appropriate for lightweight coated stocks while the A-1 receptor is better for paperboard.

Applications

The Gavarti CAT has many uses. It can be used for abrasion testing of printed cartons, labels, magazines, periodicals, and book covers. This would be an improvement over another current test method, the Taber Test, which does not correlate to field damage (Vandermeerssche, 1987, 1988; Scarlett, 1986).

Experimental Methods

Samples were rubbed in the CAT as prescribed in the Gavarti owner's manual. The procedure is relatively simple. The sample is placed face-to-face with a receptor (either a Gavarti Standard Receptor or another sample) between the sample holders. The various machine parameters are then set accordingly. For most of the tests the frequency, span, and pressures were set the same. These settings are:

Top Pressure	40 psi
Side Pressure	20 psi
Frequency	2 Hz.
Span	1 inch

Time was varied on some of the tests to measure the effect of such a change.

Generally, a Gavarti A-1 receptor was used as the abrasion source. This is ideal, as it is abrasive enough to cause damage in a short period of time. The other major advantage to using a standard receptor is that it makes it easier to compare different samples to each other. By keeping the abrasion source constant, one is able to judge only the abrasion resistance. When a printed sample is rubbed face-to-face, there are two factors at work: the first is the abrasion resistance of the ink or coating, and the second is the abrasiveness of the ink or coating. While it can be argued that all samples should be rubbed face-to-face, it becomes very difficult to objectively evaluate the sample. By using the standard receptor, one can use reflectance spectroscopy to evaluate the amount of ink abraded from the sheet to the receptor.

This work used a Macbeth 1500 Plus spectrophotometer with a 20 mm diameter circular aperture. Measurements were made using CIE L*a*b* with illuminant C and a 10 degree observer. Results were expressed as DE (the color change between a blank receptor and one that was used as the abrasive source in a rub test). Generally, the higher the DE the less abrasion resistant the sample was. This technique allows for quantitatively evaluating abrasion resistance. A problem with this type of analysis is samples with small amounts of ink coverage will have a low DE. Consequently, a low DE doesn't always guarantee an abrasion resistant sample.

Discussion

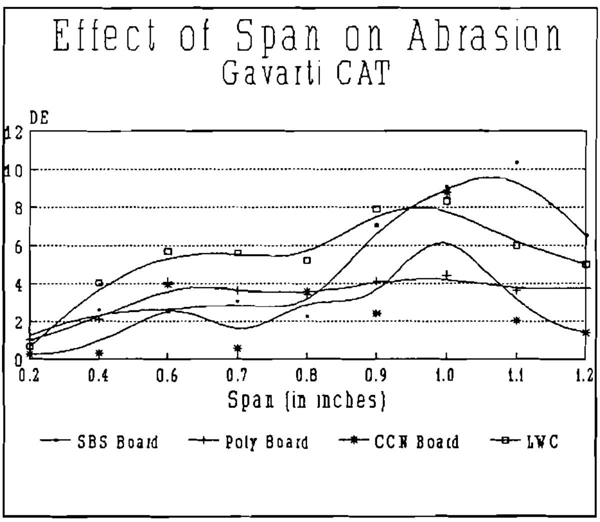
One of the original intents of this study was to develop industry standards for abrasion testing using the Gavarti GA-CAT. Before this could be done, it was necessary to evaluate the machine. This evaluation took the form of identifying the machine variables and their relative importance. The CAT consists of five adjustable parameters: top and side pressure, frequency, span, and time.

These variables were tested using a 2^5 factorial design (five factor at two levels). Appendix A is the analysis of this experiment. Of these variables, frequency, span, and time were statistically significant at the 95% confidence interval. Span was the most important followed by frequency. The longer the span the more ink that was rubbed off the sample. Appendix A also shows the conditions for this experiment. The sheetfed offset litho printed samples were 4-color process on solid bleached sulfate (SBS) board.

It was surprising to find that changes in the pressure adjustment on the CAT did not affect ink rub-off. The range of pressure settings used in this test are shown in Appendix A. This implies that pressure is not a major factor in abrasion damage over the range tested.

The Gavarti owner's manual specifies 40 pounds per square inch (psi) top pressure and 20 psi side pressure. Based on the above experiment these settings are as good as any other. Further proof of this is observed during a rub test. The pressure varies dramatically as the sample slides back and forth. Gavarti Associates believe that this is the reason their machine successfully duplicates damage found in the field (Vandermeerssche, 1987).

The next variable tested was span. Span is the distance the sample holder moves during one cycle. Gavarti recommends using a one inch span. From this testing it was observed that at spans greater than 1.3 inches, the CAT would not function properly. The sample holders would lock together causing the rubbing action to stop. In an effort to keep test times short, the span should be chosen to maximize abrasion. The figure below illustrates the effect of span on abrasion. The maximum abrasion occurred between 0.8-1.1 inch span. From this data, 1 inch is an acceptable test parameter. This is also the CAT default value stored in its computer.



Frequency was the next variable to test. Gavarti recommends using 2 Hz as the standard test parameter. This is also a CAT default value. Frequencies greater than 2 Hz caused the CAT to vibrate. Operating the CAT at spans greater than 1 inch and frequencies greater than 2 Hz might shorten the life of the machine. Shorter frequencies reduce the amount of abrasion damage to the sample. Gavarti Associates claim that their future machines will have the frequency permanently set at 2 Hz. Therefore, 2 Hz is the value chosen for a standard test condition. The statistical analysis found in Appendix A shows that relative to span, frequency is not important.

The last machine variable to examine was time. The choice of a standard test time is arbitrary. The guidelines for this choice are a test that can be completed quickly and a test time long enough to cause measurable damage to the sample. Appendix B is a statistical analysis of abrasion (DE) and time. From this chart the letter B shows the equivalence of times between 25 and 55 seconds. At 25 seconds the damage to the substrate is easily visible and there is sufficient ink on the receptor to be measured by the spectrophotometer. Letter A would work but it is 10 seconds longer. Letter C has a shorter range (15-30 seconds) but at the lower end there isn't much damage to the sample. Therefore, 25 seconds is a satisfactory test time.

The next variable is not a machine variable. Rather, it is choosing the receptor for the test. Gavarti Associates sells three different receptors: the C-1, A-1, and the A-6. The C-1 is the least abrasive and is used mostly for lightweight coated papers. Attempts to use the C-1 on printed paperboard stock failed. This is the result of the sample abrading the receptor. The A-1 is sufficiently abrasive. The advantage to using a Gavarti receptor as the abrasion source is uniformity of its surface. It is easy to measure the receptor for ink transferred from the sample. The A-6 receptor is more abrasive than the A-1 and is more suited for the metal decorating industry or the plastic industry.

Samples also can be tested face-to-face. This is the technique used most frequently in the industry. In this case the length of the test time will depend on past experience and/or customer specifications. All other test parameters should remain the same. Evaluation of the sample for rub damage in this case is very subjective. A good starting point for such tests is 25 seconds. In addition to a face-to-face test, a test should be conducted with a standard receptor to develop a database comparing shipping damage to DE values. Ideally, this could lead to a DE value which would predict whether a sample will survive shipping damage.

From the above discussion, the following test conditions should be adopted as standard for measuring abrasion resistance of paperboard packaging type samples:

Top Pressure	40 psi
Side Pressure	20 psi
Frequency	2 Hz
Span	1 inch
Time	25 seconds
Receptor	Gavarti A-1

Measurement of the rubbed receptor is a matter of choice. This work used the Macbeth 1500 Plus spectrophotometer. Gavarti Associates uses a densitometer. Without either available, a subjective ranking system can be used. It is generally desireable to keep the analysis consistent to allow for comparison of results over time.

An important observation from the evaluation of the CAT is the inconsistent rub pattern obtained between samples. Abrasion damage with the CAT is more concentrated at the bottom of the sample. The board appears to be held tighter at the bottom of the sample holder than at the top. This effect was more pronounced on board stock than on lightweight coated (LWC) stock.

Another aspect of abrasion testing studied was operator error. This was tested by having four different operators perform the same series of tests. The test conditions were the same as those specified above except that time was varied in 10 second increments between 0-60 seconds. The samples were then measured on the spectrophotometer and statistically analyzed. The results are shown in Appendix C. It is concluded that variance due to different operators is minimal and not important.

A comparison of three CATs to each other and to the Sutherland Rub Tester used the standard conditions specified earlier and varied time in 5 second intervals from 5-60 seconds. The Gavarti A-1 receptor was measured on the Macbeth 1500 Plus spectrophotometer. The results, expressed as DE, were analyzed statistically to determine correlation between instruments. The test was conducted using clay coated news (CCN) board and SBS board. The test was then conducted on the Sutherland using a 4 lb. weight at 5 stroke intervals between 5 and 60 strokes (1 stroke is equal to 1.38 seconds). The receptor was cut to fit the weight, while the board was cut to 3 by 6 inches. A rubber pad similar to the one that comes with the Sutherland was cut to 2 by 4 inches and attached to the weight. The receptor was mounted to the rubber pad. A similar pad was cut and attached to the top of the base of the Sutherland. The sample was attached to the rubber and held in place by two-sided tape. This is similar to the modification reported by Saul (1974). Appendix D-1 is the test conditions and raw data, while Appendix D-2 is the statistical analysis.

Correlation is defined using a 95% confidence interval with the correlation coefficient of .60 or greater. The best correlation was found between machines 32 and 48 with SBS stock. Machines 32 and 49 also showed correlation with SBS stock. Machine 48 showed correlation with the Sutherland but the graph of the Sutherland vs. the CAT 48 shows the range of correlation to be very wide and the standard error of estimate is too large to be of any practical value. Appendix E-1 is a graph showing correlation between two Gavartis and E-2 shows the lack of correlation between the Gavarti and the Sutherland.

Table 1
Results of Correlation Testing

Machine 1	Machine 2	Stock	Correlation 95% confidence level
CAT 32	CAT 48	SBS	Yes
CAT 32	CAT 49	SBS	Yes
CAT 32	Sutherland	SBS	No
CAT 32	CAT 48	CCN	No
CAT 32	CAT 49	CCN	Yes
CAT 32	Sutherland	CCN	No
CAT 48	CAT 49	SBS	No
CAT 48	Sutherland	SBS	Yes
CAT 48	CAT 49	CCN	Yes
CAT 48	Sutherland	CCN	No
CAT 49	Sutherland	CCN	No
CAT 49	Sutherland	SBS	No

Clearly, these results show that the Sutherland and the Gavarti CAT are not correlated.

The previously mentioned tests were based on similar samples tested over a range of times. Another comparison was made between the two rub testers, this time measuring the abrasion damage at just one time. This was done using 50 repeats of two lightweight coated stocks and two SBS board stocks. The test time was determined to be the time necessary to give damage that was measurable to the spectrophotometer. From the statistical analysis found in Appendix F, the CAT and the Sutherland exhibited similar precision when comparing SBS samples of average rub resistance. The coefficient of variation (CV) was 21% for the CAT and 18% for the Sutherland. For the LWC sample of poor rub resistance the CAT had a CV of 19% compared with 28% for the Sutherland. For the good rub resistant SBS, the CAT had a CV of 33% to 108% for the Sutherland. In this case the CAT had more precision than the Sutherland. Table 2 is a brief summary of the statistics.

Table 2

Sample	Mean DE	Machine	CV	Rub Resistance
SBS	9.43	CAT	21%	Average
SBS	5.32	Sutherland	18%	Average
SBS	5.42	CAT	33%	Good
SBS	0.97	Sutherland	108%	Good
LWC	1.94	CAT	19%	Good
LWC	0.79	Sutherland	28%	Good
LWC	15.8	CAT	9%	Poor
LWC	10.1	Sutherland	10%	Poor

Each of the samples were carefully measured on the spectrophotometer with a template. This was done to eliminate changes in DE due to variation in the sampling location.

Conclusions

The above discussion describes a method for quantifying rub resistance using a spectrophotometer. This method will work for full coverage prints. Assessing rub resistance via DE is more difficult as the coverage decreases. Despite this limitation, the DE value can be used to compare like prints.

A standard test method for using the Gavarti CAT was presented. While most of this work was done with paperboard, this method will work with other substrates. The only difference found between board stock and LWC stock during this work was that LWC stock sometimes gave a more uniform rub.

The Gavarti CAT was found to be fairly repeatable. Reproducibility between four CATs tested was satisfactory. The Gavarti CAT was found to be free of operator error. No usable correlation was found between the Sutherland and the CAT. This is contrary to previously published work (Vandermeerssche, 1988).

One of the more important observations of this work is the need to test samples in a controlled environment. Work not reported in this paper has shown that high humidity and heat have deleterious effects on rub resistance. Samples should be handled as little as possible.

Finally, it should be noted that great care was taken to insure the uniformity of the samples tested. Variations in printing, ink, and substrates should account for more of the variation in the test results than the test methods.

Acknowledgements

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Selected Bibliography

Scarlett, Terry
January 1986 — "Aye. There's the Rub," Graphic Arts Monthly.

Saul, R. G.
August 1974 — "Improving Reproducibility of the Sutherland Rub Tester," American Ink Maker, vol. 52, no. 8, pp. 17-18.

Vandermeerssche, Gaston
June 1987 — Journal of Packaging Technology, vol. 1, no. 3.

Vandermeerssche, Gaston
May 1988 — "Abrasion and Ink/Rub Testing Correlation Studies with the CAT, the Sutherland, and the Taber," TAGA Proceedings

Vandermeersch, Gaston
August 1988 — Presentation from the GATF Paper and Ink Symposium

Appendix A

SAS
General Linear Models Procedure
Class Level Information

Class	Levels	Values
Freq	2	2.5 0.75 Hz
Top	2	30 50 psi
Side	2	15 25 psi
Span	2	0.5 1.4 in
Time	2	20 60 sec

Dependent Variable DE

Source	DF	Sum of Squares	Mean Square
Model	5	323.75479	64.7509
Error	26	171.94716	6.61335
Corrected Total	31	495.70195	

F Value	PR>F	R Square	C.V.	Root MSE	DE Mean
9.79	0.001	0.65312	45.26	2.57164	5.68125

Source	DF	Type I SS	F Value	PR> F
Freq	1	32.0400125	4.84	0.0368
Top	1	15.5961125	2.36	0.1367
Side	1	8.7780500	1.33	0.2598
Span	1	218.9278125	33.10	0.0001
Time	1	48.4128000	7.32	0.0119

Appendix B

Study of Rub Testers
General Linear Models Procedure

T Tests (LSD) for Variable: Response
Note: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha=0.05 DF=80 MSE=13.6862
Critical Value of T=1.99006
Least Significant Difference=3.6811

Means With the Same Letter are not Significantly Different

T Grouping			Mean	N	Time
	A		17.485	8	60
	A				
	A		16.372	8	50
	A				
B	A		16.076	8	55
B	A				
B	A		15.495	8	40
B	A				
B	A		14.476	8	45
B	A				
B	A	C	14.159	8	30
B	A	C			
B	A	C	13.990	8	35
B		C			
B		C	12.434	8	25
		C			
	D	C	10.692	8	20
	D	C			
	D	C	10.506	8	15
	D				
E	D		8.361	8	10
E					
E			5.644	8	5

Appendix C

SAS Variance Component Estimation Procedure

Dependent Variable DE

Source	DF	Type I SS	Type I MS
Time	5	616.963494	123.3926988
Operator	3	50.196611	13.7322037
Error	63	269.244805	4.2737270
Corrected Total	71	936.404911	

Source	Expected Mean Square
Time	Var(Error) + 12 Var(Time)
Operator	Var(Error) + 18 Var(Oper)
Error	Var(Error)

Variance Component	Estimate
Var(Time)	9.9265809
Var(Oper)	0.6921375
Var(Error)	4.2737270

Class Level Information

Class	Levels	Values
Time	6	10 20 30 40 50 60 sec
Operator	4	Deb Karl Kevin Mark

Appendix D-1

Study of Rub Testers
General Linear Models Procedure

Class Level Information

Class	Levels	Values
Machine	4	SU 32 48 49
Substrate	2	CCN SBS
Time	12	5 10 15 20 25 30 35 40 45 50 55 60

Number of Observation in Data Set = 96

Time	SBS-32	CCN-32	CCN-48	SBS-48	CCN-49	SBS-49	SBS1-SU	CCN1-SU
5	4.36	4.77	5.25	4.60	7.44	6.98	7.15	4.60
10	12.22	7.60	11.40	8.87	8.37	9.61	4.20	4.62
15	14.88	10.53	10.10	11.38	9.46	15.41	9.52	2.77
20	14.38	5.22	13.87	14.20	12.73	15.04	6.27	3.83
25	17.08	16.24	12.40	11.39	14.36	14.07	6.01	7.92
30	20.80	15.48	15.79	13.30	15.03	21.78	6.67	4.42
35	23.92	14.41	15.58	16.14	12.89	18.68	6.94	3.36
40	26.33	17.05	9.68	18.61	14.19	27.04	8.68	9.64
45	22.49	14.86	15.67	21.41	16.07	4.68	11.38	9.25
50	23.75	21.11	18.02	18.43	16.13	15.74	8.16	9.64
55	27.16	23.27	13.96	22.12	11.71	18.40	8.60	3.38
60	26.28	22.06	12.42	22.11	15.94	26.27	8.32	6.48

Appendix D-2

Variable	N	Mean	Std. Dev.	Sum	Minimum	Maximum
SBS_32	12	19.470833	6.9749219	233.65000	4.3600000	27.160000
SBS_48	12	15.213333	5.5864159	182.56000	4.6000000	22.120000
SBS_49	12	16.141667	6.9338535	193.70000	4.6800000	27.040000
SBS1_SU	12	7.658333	1.8657771	91.90000	4.2000000	11.380000

Pearson Correlation Coefficients / Prob > |R| Under H0:RHO = 0 / N = 12

	SBS_32	SBS_48	SBS_49	SBS1_SU
SBS_32	1.00000 0.0000	0.92318 0.0001	0.64525 0.0235	0.43902 0.1533
SBS_48	0.92318 0.0001	1.00000 0.0000	0.45114 0.1410	0.59609 0.0408
SBS_49	0.64525 0.0235	0.45114 0.1410	1.00000 0.0000	0.00377 0.9907
SBS1_SU	0.43902 0.1533	0.59609 0.0408	0.00377 0.9907	1.00000 0.0000

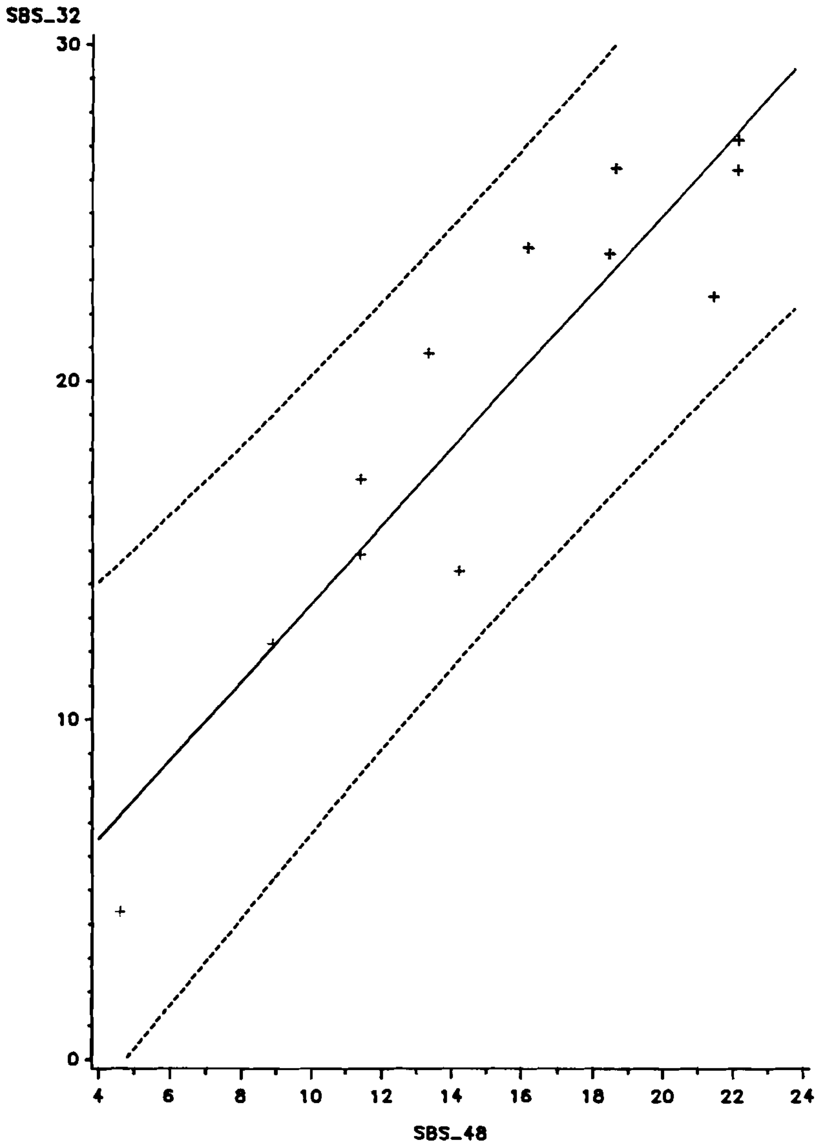
Variable	N	Mean	Std. Dev.	Sum	Minimum	Maximum
CCN_32	12	14.383333	6.2695923	172.60000	4.7700000	23.270000
CCN_48	12	12.845000	3.4497866	154.14000	5.2500000	18.020000
CCN_49	12	12.860833	3.0395139	154.33000	7.4400000	16.130000
CCN1_SU	12	5.220833	2.5024477	62.65000	2.3800000	9.640000

Pearson Correlation Coefficients / Prob > |R| Under H0:RHO = 0 / N = 12

	CCN_32	CCN_48	CCN_49	CCN1_SU
CCN_32	1.00000 0.0000	0.50791 0.0918	0.68030 0.0149	0.31112 0.3249
CCN_48	0.50791 0.0918	1.00000 0.0000	0.70970 0.0097	0.45167 0.1405
SBS_49	0.68030 0.0149	0.70970 0.0097	1.00000 0.0000	0.55474 0.0612
CCN1_SU	0.31112 0.3249	0.45167 0.1405	0.55474 0.0612	1.00000 0.0000

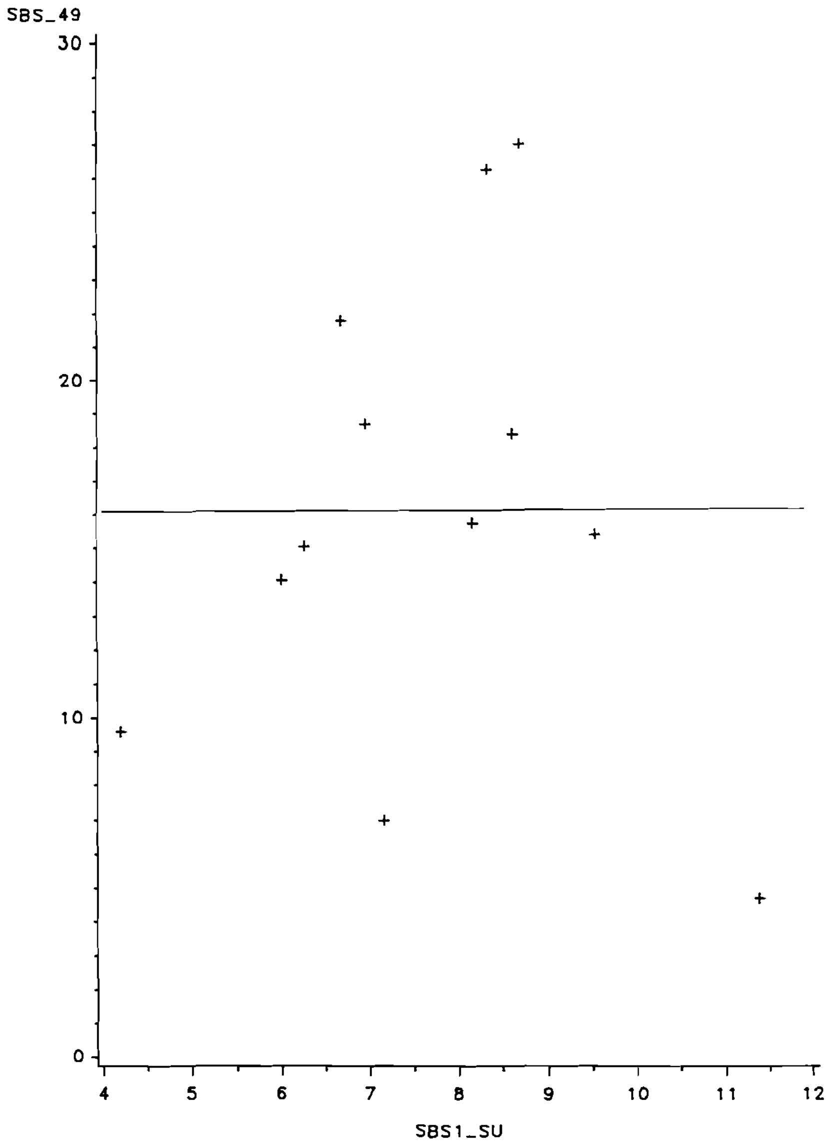
Appendix E-1

STUDY OF RUB TESTERS



Appendix E-2

STUDY OF RUB TESTERS



Appendix F-1

Gavarti CAT LWC-"Fish" 60 Sec.

N	50	Sum Wgts	50
Mean	1.944	Sum	97.2
Std Dev	0.373511	Variance	0.13951
Skewness	-0.17125	Kurtosis	-0.6426
USS	195.793	CSS	6.836
T:Mean=0	36.0826	Prob>T	0.0001
Sgn Rank	637.5	Prob>S	0.0001
CV	19.21	Std Mean	0.25038

Sutherland LWC-"Fish" 25 Strokes

N	35	Sum Wgts	35
Mean	0.7925	Sum	27.74
Std Dev	0.22530	Variance	0.0507
Skewness	2.86782	Kurtosis	12.3918
USS	23.7118	CSS	1.72587
T:Mean=0	20.8117	Prob>T	0.0001
Sgn Rank	315	Prob>S	0.0001
W:Normal	0.757797	Prob<W	< 0.01
CV	28.4267	Std Mean	0.03808

Gavarti CAT SBS "Bacon" 25 Sec.

N	49	Sum Wgts	49
Mean	9.3285	Sum	457.1
Std Dev	1.92896	Variance	3.72088
Skewness	0.76517	Kurtosis	1.0173
USS	4442.69	CSS	178.6
T:Mean=0	33.8525	Prob>T	0.0001
Sgn Rank	612	Prob>S	0.0001
W:Normal	0.95312	Prob<W	0.088
CV	20.678	Std Mean	0.27556

Sutherland SBS "Bacon" 100 Strokes

N	50	Sum Wgts	50
Mean	5.3248	Sum	266.24
Std Dev	0.98307	Variance	0.966434
Skewness	0.00614	Kurtosis	0.3910
USS	1465.03	CSS	47.3552
T:Mean=0	38.3003	Prob>T	0.0001
Sgn Rank	637	Prob>S	0.0001
W:Normal	0.9821	Prob<W	0.798
CV	18.462	Std Mean	0.13903

Appendix F-2

Gavarti CAT LWC "Bleach" 25 Sec.

N	75	Sum Wgts	75
Mean	15.821	Sum	1186.58
Std Dev	1.41	Variance	1.98809
Skewness	0.2066	Kurtosis	0.40535
USS	18920.1	CSS	147.119
T:Mean=0	97.1735	Prob>T	0.0001
Sgn Rank	1425	Prob>S	0.0001
D:Normal	0.0602	Prob>D	0.15
CV	8.91215	Std Mean	0.162813

Sutherland LWC "Bleach" 25 Strokes

N	50	Sum Wgts	50
Mean	10.055	Sum	502.76
Std Dev	1.00411	Variance	1.0082
Skewness	-0.1885	Kurtosis	0.30041
USS	5104.76	CSS	49.4036
T:Mean=0	70.8099	Prob>T	0.0001
Sgn Rank	637.5	Prob>S	0.0001
W:Normal	0.9586	Prob<W	0.176
CV	9.98598	Std Mean	0.142003

Gavarti CAT SBS "Ortega" 25 Sec.

N	50	Sum Wgts	50
Mean	5.42	Sum	271
Std Dev	1.77051	Variance	3.1347
Skewness	0.70618	Kurtosis	0.541256
USS	1622.42	CSS	153.6
T:Mean=0	21.6464	Prob>T	0.0001
Sgn Rank	637.5	Prob>S	0.0001
W:Normal	0.9596	Prob<W	0.198
CV	32.6662	Std Mean	0.25038

Sutherland SBS "Ortega" 100 Strokes

N	73	Sum Wgts	73
Mean	0.9977	Sum	71.39
Std Dev	1.05995	Variance	1.1235
Skewness	1.56314	Kurtosis	1.42049
USS	150.707	CSS	80.8918
T:Mean=0	7.88297	Prob>T	0.0001
Sgn Rank	1350.5	Prob>S	0.0001
D:Normal	0.2044	Prob>D	<0.01
CV	108.386	Std Mean	0.12405