GPO PRICE $ ________

CFSTI PRICE(S) $ ________

Hard copy (HC) 3.00

Microfiche (MF) .65

ff 653 July 65

JET PROPULSION LABORATORY

CALIFORNIA INSTITUTE OF TECHNOLOGY

PASADENA, CALIFORNIA

N68-15504

N68-15504 (ACCESSION NUMBER)	(THRU)
17 (PAGES)	1 (CODE)
CR#92519 (NASA CR OR TMX OR AD NUMBER)	15 (CATEGORY)

FACILITY FORM 602

Kinelogic Document 118001
Issued 10 November 1966
Copy Number ________

FINAL ENGINEERING REPORT
COMPARISON FATIGUE LIFE TEST OF SEAMLESS POLYESTER FILM BELTS FABRICATED BY AN ALTERNATE SOURCE
JPL PURCHASE ORDER DT-377029

Work Period: 1 July 1966 - 31 October 1966

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Pasadena, California

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This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, sponsored by the National Aeronautics and Space Administration under Contract NAS7-100.

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FINAL ENGINEERING REPORT
COMPARISON FATIGUE LIFE TEST OF
SEAMLESS POLYESTER FILM BELTS
FABRICATED BY AN ALTERNATE SOURCE
JPL PURCHASE ORDER DT-377029

1. CONTRACT FULFILLMENT

This final engineering report is submitted in fulfillment of Jet Propulsion Laboratory purchase order number DT-377029, item 2, by Kinelogic Corporation.

2. SUMMARY

During the period beginning 1 July 1966 and ending 31 October 1966, Kinelogic Corporation has performed work for the Jet Propulsion Laboratory of the California Institute of Technology in accordance with purchase order DT-377029.

In accordance with the purchase order, JPL provided a sample lot of seamless polyester film belts from an alternate source. Tests were conducted on the alternate source belts under conditions which duplicated tests performed as part of an earlier study of fatigue life of belts by Kinelogic Corporation. It was found that the alternate source belts had a significantly longer life than did the control group belts. It was determined that the variability of life within each sample lot does not differ significantly between samples. The alternate source belts may be expected to have a life approximately four times that of the control group belts when used under identical conditions.

2. SUMMARY (Continued)

The material sources and fabrication techniques and conditions of the alternate source belts were not disclosed by JPL and were not investigated as part of this program, and therefore, no discussion of the relative merits of the process is contained in this report.

3. TECHNICAL ACTIVITY

3.1 INTRODUCTION

Seamless polyester film belts have a finite life which is predictable based upon analysis of statistical data. This report is one of a continuing series of reports for programs in which data is collected and analyzed. This section of the report is divided into three subsections which discuss (3.2) the test procedure used in the testing program, (3.3) the results of the tests which were conducted, and (3.4) the interpretation of the data and conclusions drawn based upon that data.

3.2 TEST PROCEDURE

The fatigue life testers used for testing the alternate source belts have been adequately described in the final report of an earlier study[1]. The basic idea of the testers is to drive the belts at a relatively high surface speed with a large diameter drive pulley. The belt passes over a series of small-diameter test spindles to cause the fatigue stresses. Provision is made for automatic shut-down of the tester when the belt has failed. An elapsed time indicator in parallel with the motor measures the time to failure.

The severity of fatigue stressing may then be varied by the following three parameters:

1. The tension put into the belt at installation,
2. the size of the test spindles (which determines the bending stress),
3. the belt path which determines whether the bending stress is undirectional or bidirectional.

The test conditions which were used in the earlier test program[1] which were used as the control group for this program are as follows:

1.	Installed Stress:	4,375 PSI
2.	Material Thickness:	0.001 inch
3.	Test Spindle Diameter:	0.200 inch
4.	Stress Cycling Rate:	1,940 stress cycles per minute
5.	Threading Pattern:	Serpentine

This set of conditions was selected to provide a test at a stress level slightly above the endurance limit, thereby affording a compromise between

3.2 TEST PROCEDURE (Continued)

economy in testing time and testing significance.

The alternate source lot of belts were installed and operated to failure on the same equipment and under the same conditions as used in the earlier study[1].

3.3 TEST RESULTS

The life of each test belt from the control group tests are tabulated in Table I.

TABLE I

RANK	STRESS CYCLES x 10^6
1.	0.349
2.	2.24
3.	10.0
4.	10.3
5.	12.8

The cumulative failure plot for this test is shown in Figure 1. Also shown in Figure 1 are the best-fit straight-line and the prediction interval determined from these five test points. The best-fit straight-line is calculated by the method of leasts squares[2]; the usual method employed for fitting a curve to data which is varying in a random manner but, with an underlying functional relationship. The prediction interval is then calculated from the variability of the test points about the best-fit line.

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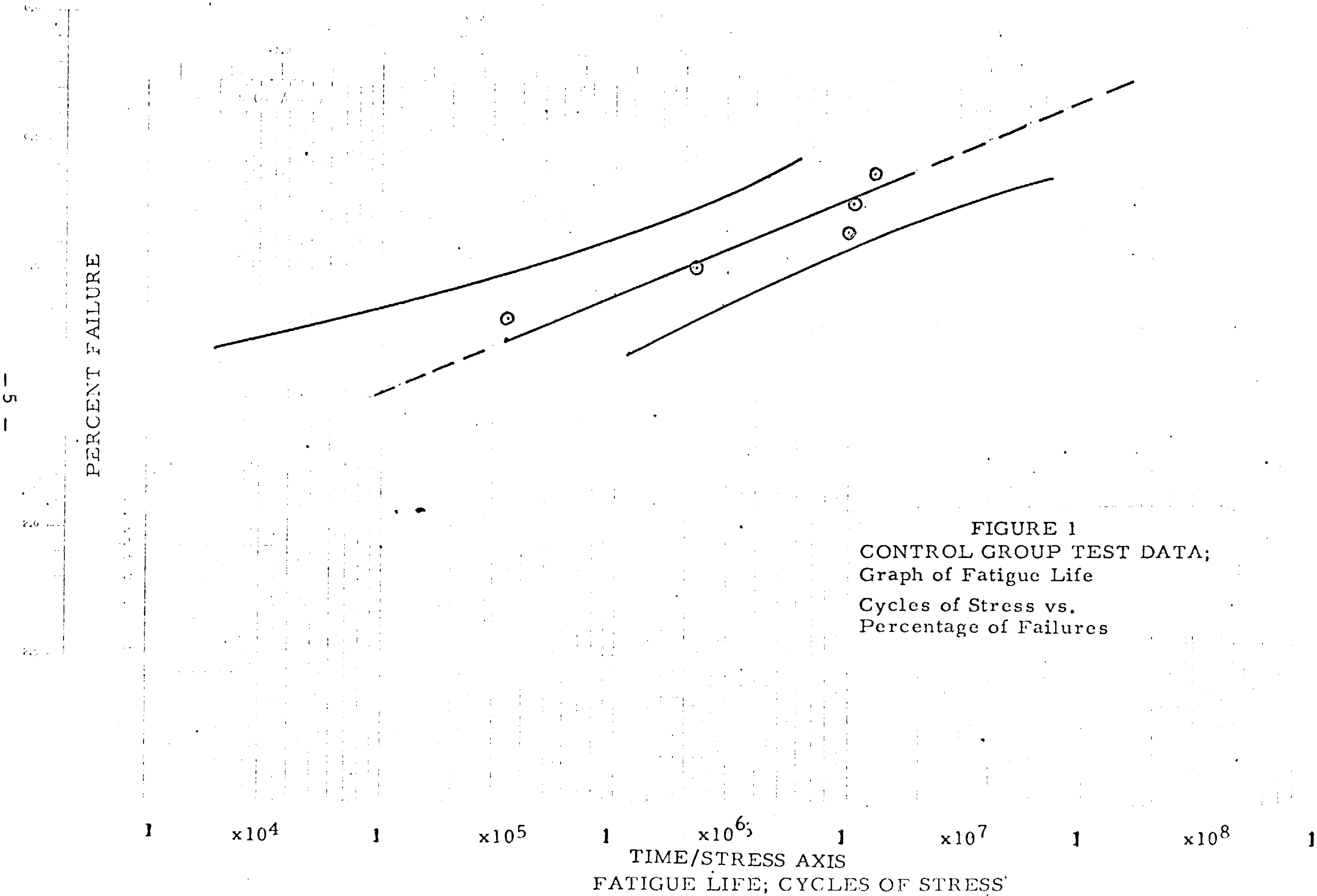

FIGURE 1
CONTROL GROUP TEST DATA;
Graph of Fatigue Life

Cycles of Stress vs.
Percentage of Failures

3.3 TEST RESULTS (Continued)

The prediction interval in Figure 1 is based upon a 90% confidence level. This means that at least 90% of all subsequent test points will fall inside the prediction interval of Figure 1, if the sample is basically unchanged from the original. Conversely, if the test points fall outside the prediction interval, it can be said that at the 90% confidence level, a significant difference exists between the two samples.

The lives of the ten belts tested in this study are tabulated in Table II, and are shown in the cumulative failure plot, Figure 2.

TABLE II

RANK	STRESS CYCLES x 10^6
1.	1.33
2.	4.82
3.	12.7
4.	15.6
5.	18.2
6.	18.6
7.	20.2
8.	27.2
9.	43.0
10.	60.4

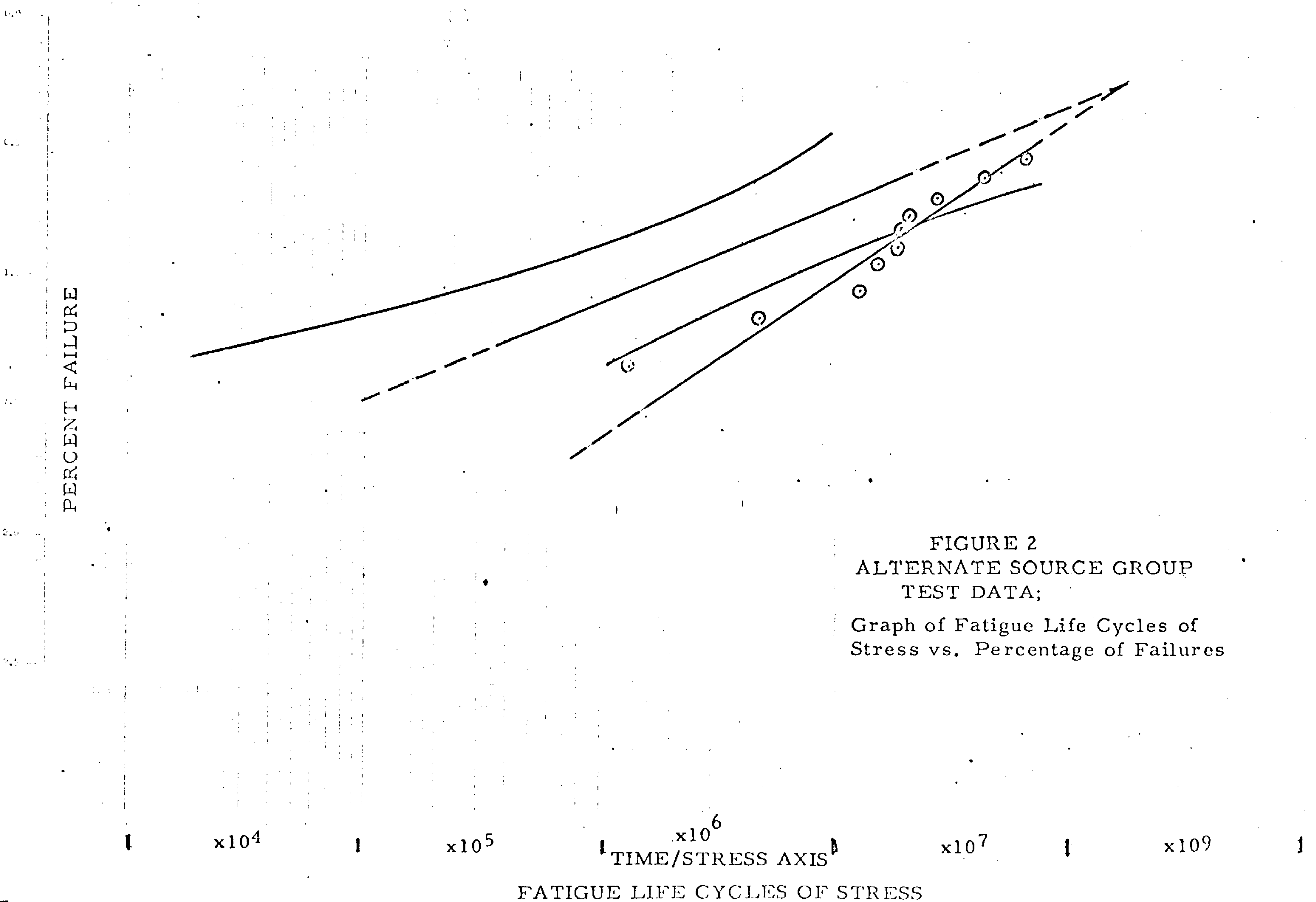

FIGURE 2
ALTERNATE SOURCE GROUP TEST DATA;

Graph of Fatigue Life Cycles of Stress vs. Percentage of Failures

3.3 TESTS RESULTS (Continued)

Also shown in Figure 2 are the best-fit straight-line and prediction interval of the control group lot. These are transferred from Figure 1. The best-fit straight-line for the alternate source lot is also shown in Figure 2. This line has been calculated by the method of least squares[2]. (See Appendix A.) The values for ordinate (x) and absissa (y) are measured on the uniform scales to the right and top of the graph grid pattern respectively. These scales are in units of standard deviation and the slope of the straight-line plot (measured in units of standard deviation) is the standard deviation of the test sample. The slope of the control group was 1.634 and the slope of the alternate source group was 1.067. The slope, determined by the average of all tests used in the earlier study[1], was 1.20.

The standard deviation is a quantified measure of the variability of the sample. The standard deviations determined by the two samples are not equal. The "F" test is utilized to determine whether the two values have a statistically significant difference[3]. If the value calculated from the ratio of the two sample variances(square of standard deviation) exceeds the tabular value, a statistically significant difference exists between the samples. The difference was found not to be significant when compared to the original test and also as compared to the grand average of all useable test data in the earlier study[1] at the 90% confidence level. (See Appendix B.)

3.4 INTERPRETATION OF RESULTS AND CONCLUSIONS

The comparison sample of seamless polyester film belts, which were fabricated by another source, was found to be significantly longer lived than the control group sample. The improvement was found to be a uniform four-fold increase throughout the life of the sample. The life of belts with fatigue life characteristics similar to this sample should be four times that predicted on the basis of the earlier study$_1$.

A four-fold increase in life, while not large, can make the difference between an acceptable and an unacceptable application. Since seamless polyester film belts are widely used in low power, low weight applications of instrumentation recorders, any increase in servicability or reliability should be identified and utilized. Any differences in materials or fabricating conditions between those used in the reference study and those used by this other source should be investigated to determined the cause of the improvement.

REFERENCES

1. Final Report on Fatigue Life of Polyester and Polyimide Film Belts, Tape Recorder Belt Study, JPL Subcontract No. 950899.

2. Page 262, Engineering Statistics, A. H. Bowker and G. J. Lieberman, Prentice-Hall, Inc.; 1963.

3. Page 186, ibid 2.

APPENDIX A

CALCULATIONS BY LEAST SQUARES METHOD

x_i	y_i	$x_i x_i$	x^2	y^2
0.67	0.59	0.3953	0.4489	0.3481
1.35	1.87	2.5245	1.8225	3.4969
1.85	1.87	5.3095	3.4225	8.2369
2.23	3.01	6.7123	4.9719	9.0601
2.50	3.21	8.0250	6.2500	10.3041
2.77	3.25	9.0025	7.6729	10.5625
3.00	3.32	9,9600	9.0000	11.0224
3.26	3.60	11.7360	10.6276	12.9600
3.52	4.06	14.2912	12.3904	16.4836
3.86	4.47	17.2542	14.8996	19.9809
Σx_i 25.01	Σy_i 30.25	$\Sigma x_i y_i$ 85.2105	Σx^2 71.5073	Σy^2 102.4555

APPENDIX A

$$\Sigma(x_i - \bar{x})^2 = \Sigma x_i^2 - \frac{(\Sigma x_i)^2}{n} = 71.5073 - \frac{(25.01)^2}{10}$$

$$= 71.5073 - 62.5500$$

$$= 8.95729$$

$$\Sigma(y_i - \bar{y})^2 = \Sigma y_i^2 - \frac{(\Sigma y_i)^2}{n} = 102.4555 - \frac{(30.25)^2}{10}$$

$$= 102.4555 - 91.50625$$

$$= 10.94925$$

$$\Sigma(x_i - \bar{x})(y_i - \bar{y}) = \Sigma x_c y_i - \frac{(\Sigma x_i)(\Sigma y_i)}{n}$$

$$= 85.2105 - \frac{25.01 \times 30.25}{10}$$

$$= 85.2105 - 75.65525$$

$$= 9.55525$$

$$\text{Slope} = b = \frac{\Sigma(x_i - \bar{y})(y_i - \bar{y})}{\Sigma(x_i - \bar{x})^2} = \frac{9.55525}{8.95729} = 1.066756$$

APPENDIX B

TEST FOR DIFFERENCE OF STANDARD DEVIATION (VARIANCE)

1. Comparison of Test of Control Group to Alternate Source Belts

Sample	S*	S^2*	F
Control Group	1.634	2.669956	2.345
Alternate Source	1.067	1.138489	

Maximum value of "F" caused by chance at 90% confidence Level:

$$F_{0.1, 4, 9} = 2.69$$

There is no significant difference in standard deviation between the two tests at the 90% confidence level.

2. Comparison of New Sample of Alternate Source Belts to the Average of the Earlier Standby Belts

Sample	S	S^2	F
Control Group	1.200	1.440000	1.34957825
Alternate Source	1.067	1.138489	

Maximum value of "F" caused by chance at 90% confidence level:

$$F_{0.1, 100, 9} = 2.19$$

There is no significant difference in standard deviation between the alternate source belt sample and the average of the control group belt sample at the 90% confidence level.

*S is the sample standard deviation and S^2 is the variance. In the "F" test the variances are compared.