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Ultimate tensile stress of K129 fabric used on the B5 window

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EXPERIMENT PLANNING and SUPPORT DIVISION

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ULTIMATE TENSILE STRESS OF K129 FABRIC USED ON THE B5 WINDOW

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This report contains a review of all currently available constant rate of strain to failure tests of k129. A description of the test, a chart of the data and a histogram are included for each type of test. The data indicates that there is considerable error in the tensile strength when comparing different rates of loading and varying sample widths. However this inconsistency is not nearly as apparent in the stress rupture tests or the hydrostatic tests. A reasonable explanation is that there exists two competing effects for the accommodation of localized stresses in the material. The first would be the fracture of individual filaments which results in a stress rise in adjacent filaments. The second is the formation and growth of micro voids. Since the voids are part of the volume of a filament an increase in void size also results in an increase in filament volume. This in turn slightly reduces the stress in that filament while increasing the stress in adjacent filaments. This redistribution of stress if it is slow enough will result in a reasonably uniform stress field albeit at the expense of some strength due to a reduction in cross-section.

The data indicates that equilibrium like loading will tend to favor micro voids and will result in greater consistency between samples. However faster loading will favor brittle rupture of individual filaments. However the fast loading will result in higher measured values due to a reduced probability of failure at load from stress rupture. Therefore the data contained in this report is probably not very useful for predicting variation from the mean lifetime for an actual window. This is in good agreement with the experimental data for stress rupture. Which shows relatively small variations in time to failure. As compared to the large variation in specific strength of these tests.

Test Description: Samples tested as received, carefully aligned but no compensation made for edge effects.

Material: Kevlar 129 weave (25 threads per inch Cross by 23 threads per inch fill)

Thickness: .017 inches

Rate of Loading: 20 mm/min (.81 in./min.)

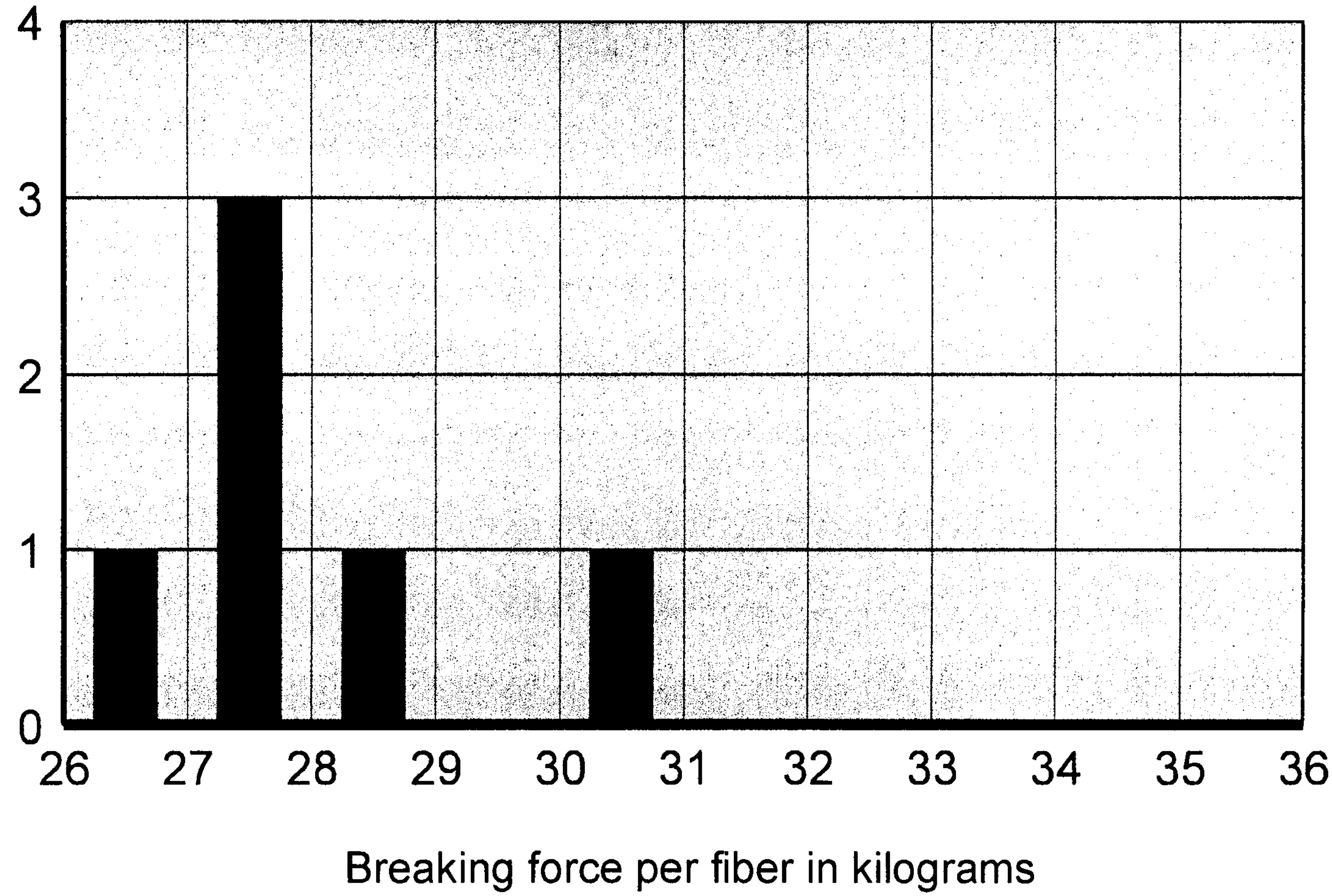
Gauge Length: 36 " 3 cm (14 " 1 inches)

Type of test: Load to failure sample cut from cross direction

TEST #	Width of Sample (cm)	Load at Failure (Kg)	Load at failure per fiber(Kg)
7/24/01	5.5	1450	26.8
7/24/02	5.9	1590	27.4
7/24/03	5.8	1600	28
7/24/04	5.7	1610	28.7
7/24/05	5.8	1600	28
7/24/06	5.4	1630	30.7
Average	5.68	1580	28.26

Comments: These tests yielded consistent results except for the first and last test which are very different for nearly identical tests. Future test would reveal the measured load at failure per fiber to be low.

Histogram of 5.68 cm wide Fabric tests of kevlar 129



File 1001.cch

Average Value = 28.26 Kg/fiber

Test Description: Samples tested by cutting in the center any fibers greater than 50. Typically an equal number from each side. Optically aligned. Hand tensioned.

Material: Kevlar 129 weave (25 threads per inch Cross by 23 threads per inch fill)

Thickness: .017 inches

Rate of Loading: 20 mm/min (.81 in./min.)

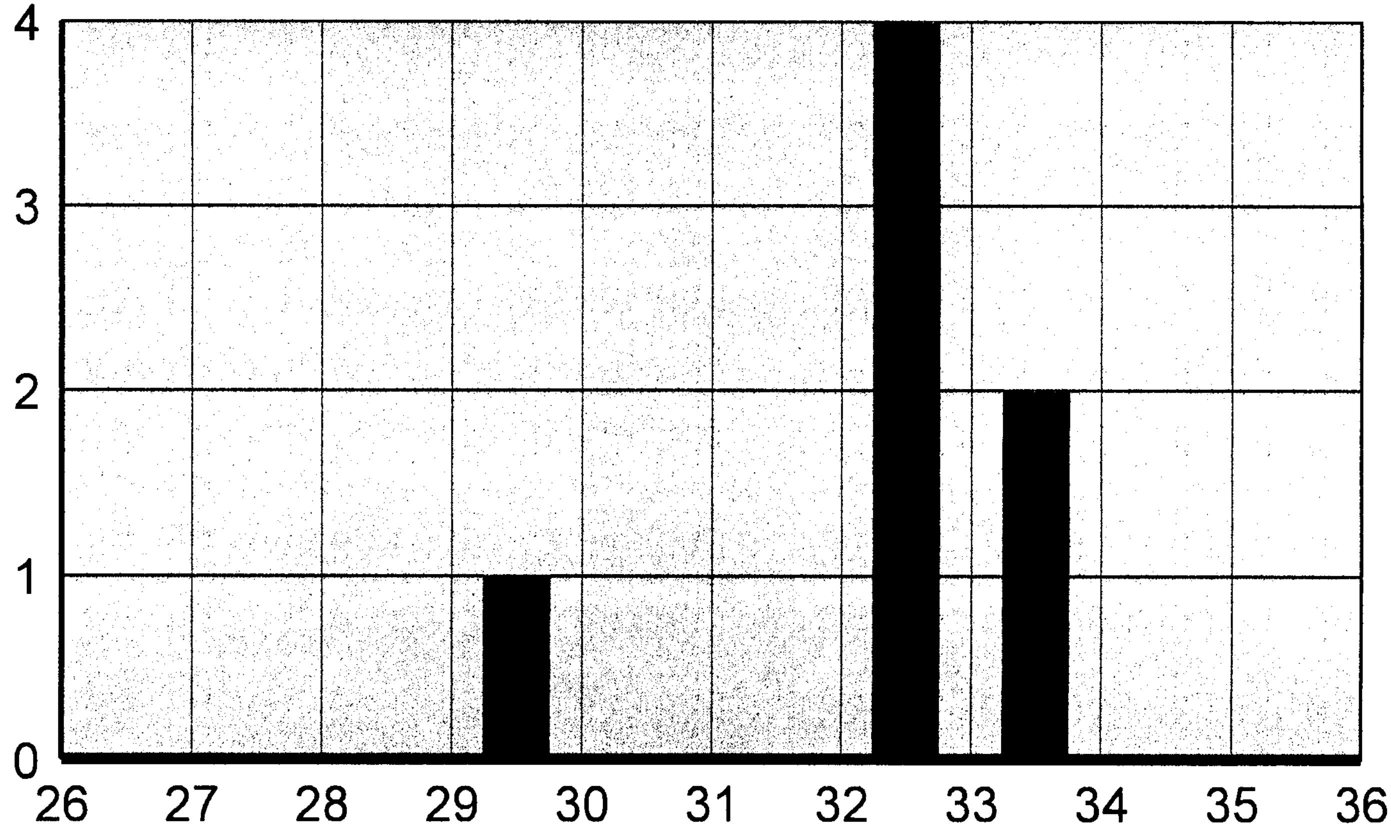
Gauge Length: 36 " 3 cm (14 "1 inches)

Type of test: Load to failure sample cut from cross direction

TEST #	Width of Sample Fibers	Load at Failure (Kg)	Load at failure per fiber(Kg)
8/5/01	50	1500	30
8/5/02	50	1675	33.5
8/5/03	50	1625	32.5
8/5/04	50	1650	33
8/5/05	50	1610	32.2
8/6/06	50	1680	33.6
8/6/07	50	1640	32.8
Average	50	1626	32.5

Comments: These samples excluding the first were far more consistent than the first series. Also the average specific strength went up by 13%. However for these tests the fabric was trimmed and aligned to 50 fibers which mini-Mized edge effects.

Histogram of 50 Fiber tests of kevlar 129 (second series)



File 1002.cch

Average Value = 32.50 Kg/fiber

Test Description: These tests represent unique data points collected to verify the validity of certain experimental presumptions.

Material: Kevlar 129 weave (25 threads per inch Cross by 23 threads per inch fill)

Thickness: .017 inches

Rate of Loading: 20 mm/min (.81 in./min.)

Gauge Length: 36 " 3 cm (14 "1 inches)

Type of test: Load to failure sample cut from cross direction

TEST #	Width of Sample Fibers	Load at Failure (Kg)	Load at failure per fiber (Kg)	Comments
8/21/01	48	1400	29.16	
9/6-36-1	36	1000	27.7	54 trimmed to 36
9/6-36-2	36	1000	27.7	54 trimmed to 36
10/2-1032	50	1540	30.8	strength after holding 909 Kg for 164.5 hours.

Comment: The 36 fiber samples started out with 56 fibers requiring that 10 fibers be cut from each side. The distortion created by pulling out fibers so close to the center of the weave may have resulted in a stress concentration. Which would account for the low values. The last test was a strength retention test.

Test Description: These tests were of narrower samples. This allowed the removal of only 4 or 5 edge fibers (per side) instead of 10. Sample was trimmed, optically aligned and hand tensioned.

Material: Kevlar 129 weave (25 threads per inch Cross by 23 threads per inch fill)

Thickness: .017 inches

Rate of Loading: 20 mm/min (.81 in./min.)

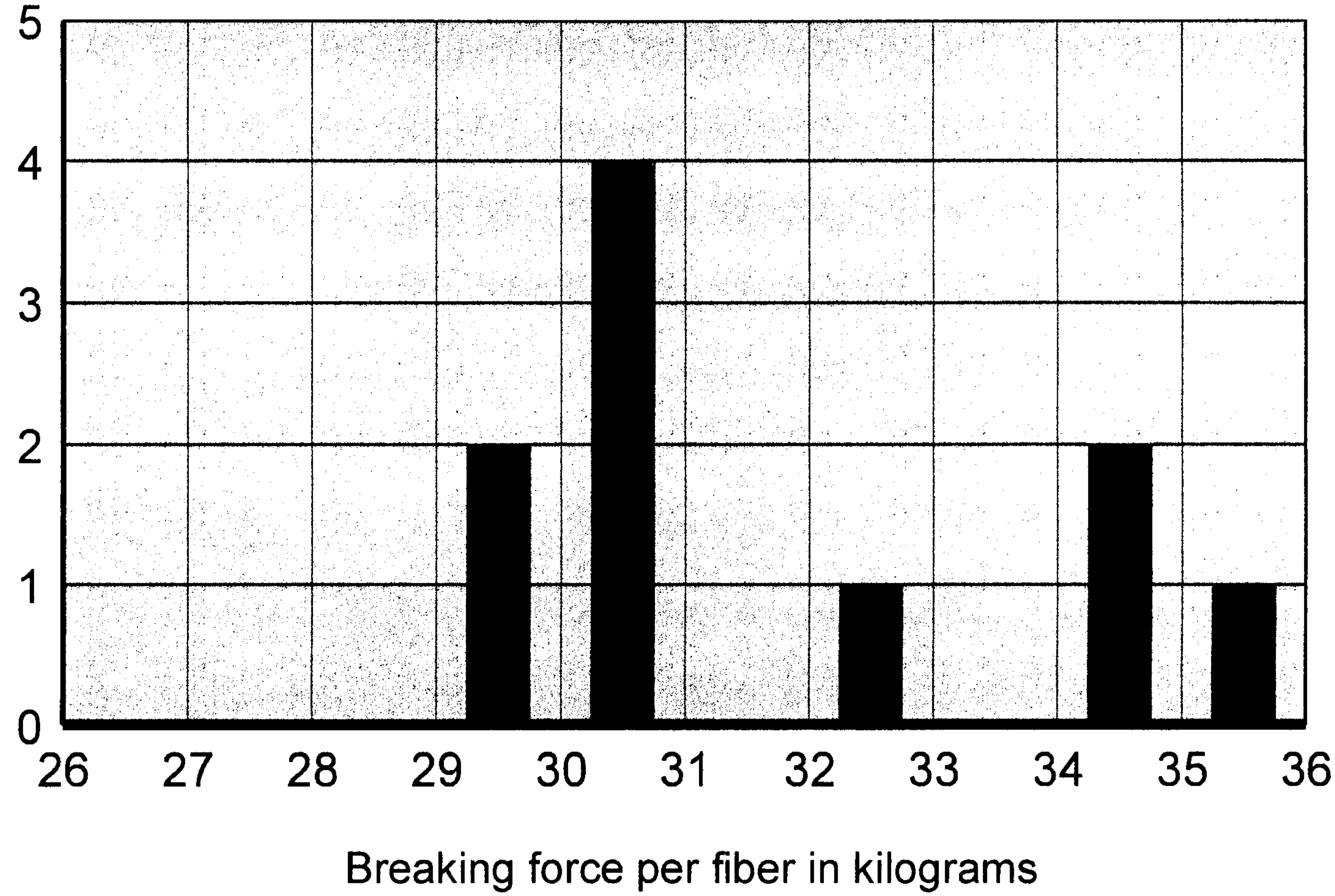
Gauge Length: 36 " 3 cm (14 "1 inches)

Type of test: Load to failure sample cut from cross direction

TEST #	Width of Sample Fibers	Load at Failure (Kg)	Load at failure per fiber (Kg)
10/2-1135	36	1100	30.55
10/2-1208	36	1275	35.41
10/2-1246	36	1075	29.86
10/7-1357	36	1100	30.55
10/7-1414	36	1225	34.02
10/7-1427	36	1075	29.86
10/7-1447	36	1100	30.55
10/8-1515	36	1250	34.72
10/8-1535	36	1175	32.63
10/9-1132	36	1100	30.55
Average			31.87

Comments: The average normalized strength for 36 fibers is slightly lower than the 50 fiber normalized value. However the difference is well within the experimental error.

Histogram of 36 fiber tests of kevlar 129



File 1003.cch

Average Value = 31.87 Kg/fiber

Test Description: Samples were loaded at various crosshead speeds to attempt to find a correlation between rate of loading and Ultimate tensile strength. Alignment and loading as before.

Material: Kevlar 129 weave (25 threads per inch Cross by 23 threads per inch fill)

Thickness: .017 inches

Rate of Loading: Variable

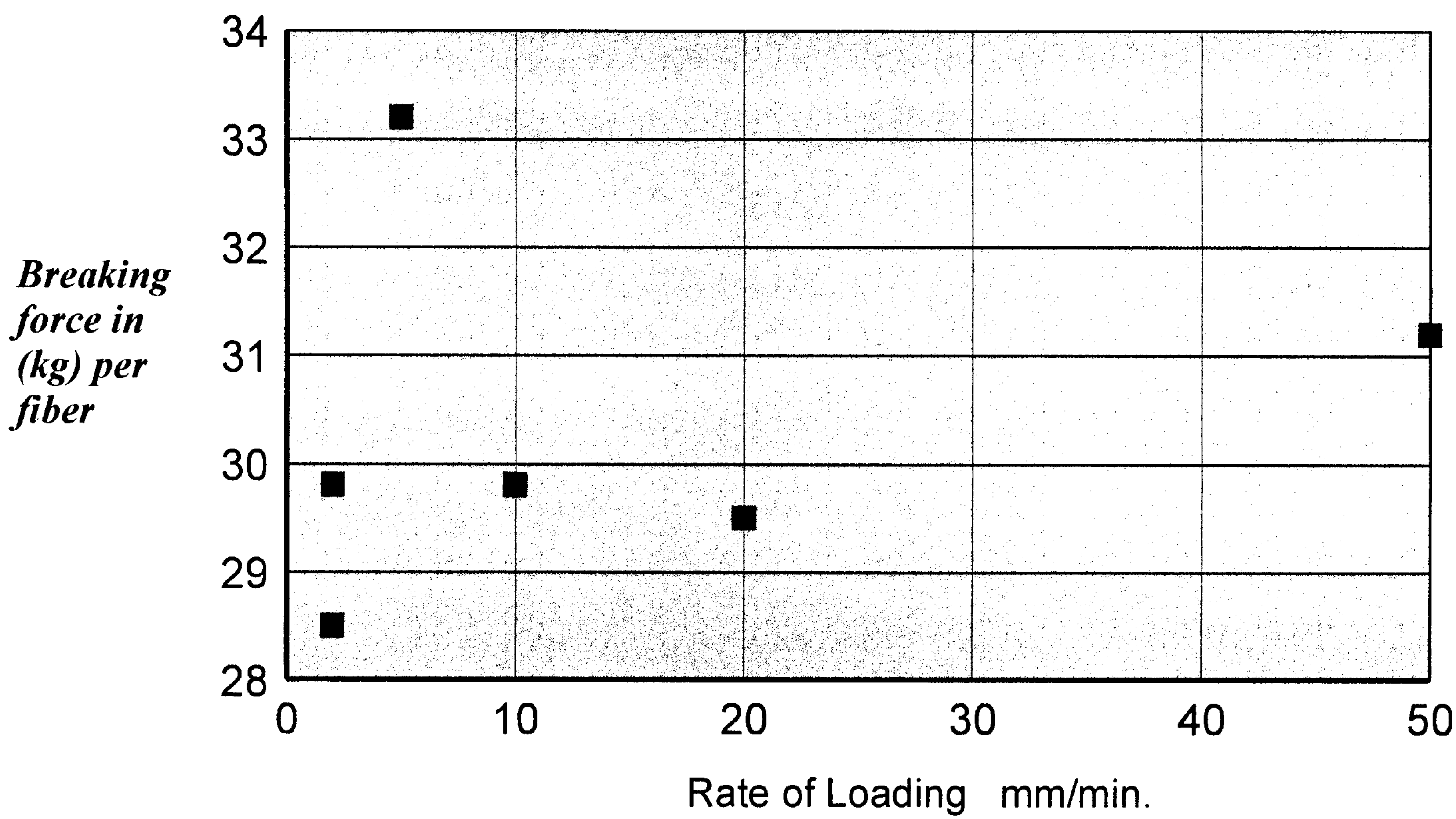
Gauge Length: 36 " 3 cm (14 "1 inches)

Type of test: Load to failure sample cut from cross direction

TEST #	Width of Sample Fibers	Load at Failure (Kg)	Load at failure per fiber (Kg)	Rate of Loading (mm/min.)
10/21-1335	50	1425	28.5	2
10/21-1455	50	1490	29.8	2
10/21-1432	50	1660	33.2	5
10/21-1400	50	1490	29.8	10
10/21-1525	50	1475	29.5	20
10/21-1422	50	1560	31.2	50

Comments: The data is plotted on the following page. If a correlation exists further data will be necessary to substantiate it.

Breaking Force Vs. Rate of loading for 50 fiber samples



File 1004.cch

Average Value = 30.33 Kg/fiber

Conclusion

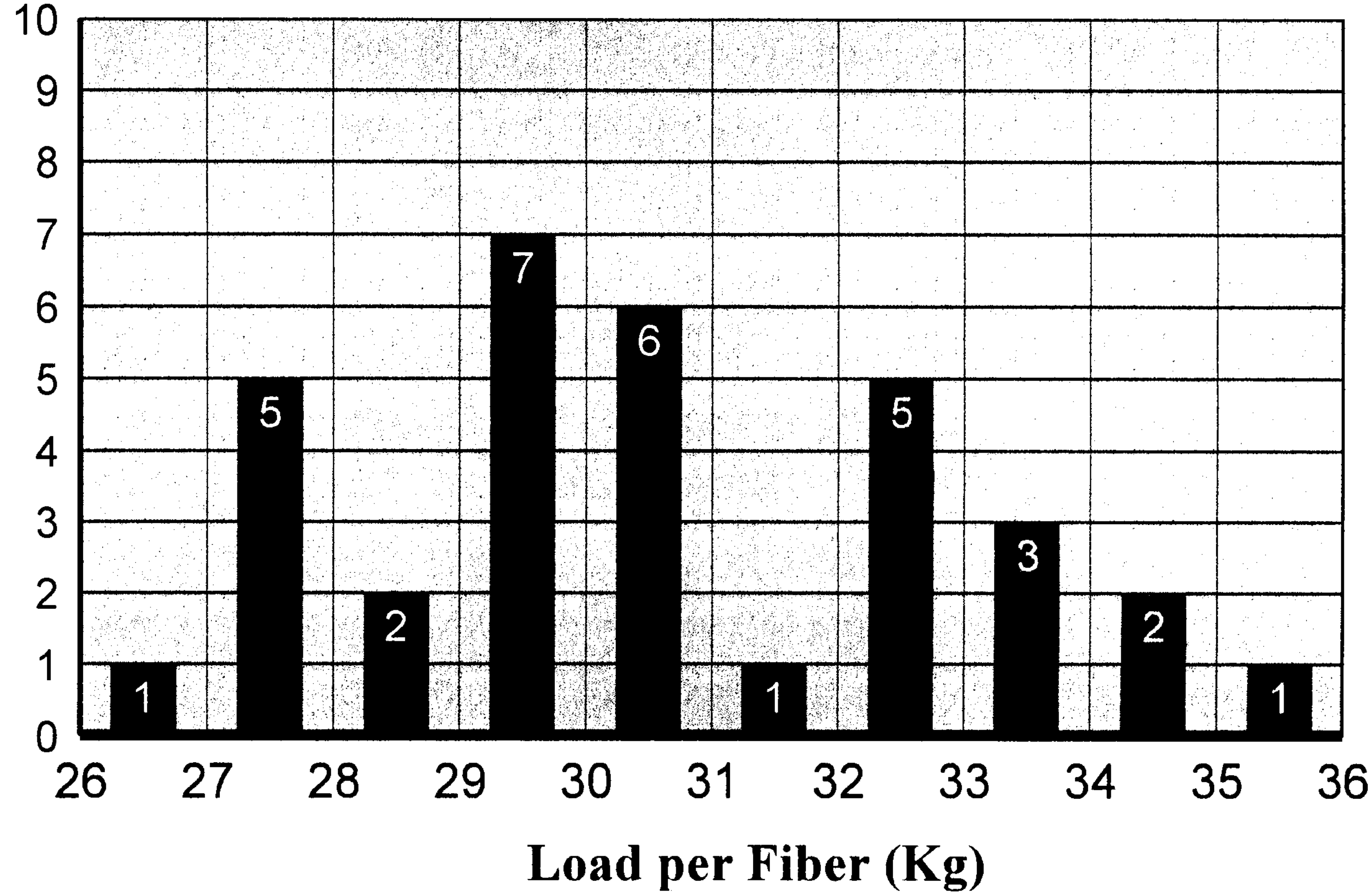
The collected data shows a maximum specific strength of 35.41 Kg /fiber. And an average of about 29 Kg/fiber. This difference is about 20%. In terms of stress rupture lifetime if the average test lasted 1 hour the maximum test should last 100,000 hours (i.e. a 20% difference in stress). However the actual stress rupture test uncertainty is probably more like 1 hour average to 10 hour maximum, this is equivalent to a 5% difference in stress.

Therefore testing only a few samples is a tenuous procedure that must not be relied upon too heavily. Perhaps a more valid test would be to load the sample very slowly and allow it to stress rupture around the 90% load level. This has been done with encouraging results on a few samples however more tests are needed before any conclusions can be drawn. This data has not been included in this report.

The rate of loading does not seem to have conclusive effect on the measured maximum load. However literature data is available on loading rate and it indicates that rate is not a significant factor. From the data collected here at Brookhaven this seems to be a crude first approximation. Albeit a reasonable approximation for safety purposes none the less.

The data presented represents the development of the current testing procedure. This data set will be appended to. However first strength values for other kevlar fabrics will be collected after which more K129 will be loaded to failure.

Histogram of all fiber tests of kevlar 129



File 1005.cch

Average Value = 29 Kg/fiber