ADHESION TESTING OF AIRCRAFT TIRES

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In December 1979 the FAA issued a new Technical Standard Order TSO-C62c to all users and manufacturers of aircraft tires. It was designed to upgrade the testing required to meet minimum airworthiness standards.

These changes to the testing requirements for new tires necessitated similar improved standards for retreads used in the national air carrier fleet.

Accordingly, an advisory circular (ref. 1) was prepared for comment which upgraded the testing standards for retreads to reflect the changes made in testing new tires under TSO-C62c. The advisory circular recommending the new dynamometer testing requirements called for testing every retread level of every tire size in an effort to accumulate sufficient tests and data to provide confidence that the retreading process including casing selection contained procedures which would provide for the continued airworthiness of the tires in service.

However, the number of tires to be tested to accumulate confidence would have presented an unacceptable and unrealistic cost to retreaders and their customers and an alternative approach was necessary.

For many years tire manufacturers and retreaders have been using laboratory adhesion tests as means for determining the effectiveness of the vulcanizing process in adhering the various tire components to one another. Adhesion testing appeared to offer a less burdensome alternative to replace some of the dynamometer tests recommended in the AC. Accordingly, test results and data were requested from retreaders who had used adhesion testing.

All of the American retreaders of aircraft tires submitted data, as did Goodyear, which obtained additional data from European adhesion tests. For some tires the Navy has required adhesion tests as a part of their purchasing procedure and this data was also made available. Such data was collected from various sources for over 700 tires, both commercial and military.

In meetings with industry, the FAA was presented with the industry consensus regarding the use of ply and tread adhesion tests to qualify tire retreading process specifications. The FAA has accepted this means of testing as one which can be used in the qualification of a tire retreading process specification.

The adhesion testing procedure used by most retreaders was a modification of the Hascar-Reiger method (ref. 2) in which a 1" strip of rubber is slit and introduced into a tensilometer. Variations of this method are described in references 1 and 3 to 6.

Figure 1 gives an example of the output from an adhesion test. The data is subject to wide variations in interpretation because of the stress-tear-relaxation characteristic of the rubber sample. Several methods of reporting the data have been adopted, including averaging all maximum values, averaging all minimum values and taking the mean of the maximum and minimum average values. The reporting sources usually list the method of recording and this is so noted in the data. Several other variations in method account for variations in test results, the three most important of which relate to sample preparation. Some laboratories attempt to cut the sample to the exact dimension, others correct for errors in size by normalizing the cut dimension to 25.4 mm (1 in.) width. Some laboratories cut the sample approximately 3.2 mm (1/8 in.) oversize and using a razor blade slit the intended path of travel of the tear line around the edge of the sample.

Several individuals have reported high values of adhesion when excess sample rubber thickness is not cut away, however laboratories as a rule do nothing to alter the thickness of the sample.

The location of the tear region varies depending upon the agency requesting the testing, and when it is known this information has been included in the data. Most organizations have reported buffline adhesion data, although some have reported maximum rather than average results.

Some organizations have reported adhesion data from the outside of the outer ply while some have reported between the second and third ply. Since there was no statistically detectable difference between these reported values they were lumped in the data.

The data was tabulated and placed in a data base called BANK (ref. 7). The fields are described in a listing. Most of the data on buffline adhesion is taken from TAV although TMX contains some buffline data. These two fields were separated because of uncertainty about the method of reading the primary recorder traces.

PAV gives values of outer ply adhesion. Some readings of maximum and minimum adhesion averages were available and these were recorded as PMX and PMN. Tire size is structured so that mathematical transformations such as linear regression or rank order correlation can be performed on the size variable.

Other information, such as R level, durometer tensile, and elongation measurements, is included where a sufficient amount of data was obtained.

The BANK program provides an interesting first level statistic printout of the data in each field (Figures 2 through 13). These include mean, standard deviation, and maximum and minimum values, as well as a data histogram.

In order to use simplified procedures for establishing minimum adhesion thresholds and realistic test sample sizes it is important to confirm the character of the distribution of the data. This may be accomplished by analysis of the data in terms of the probability that it fits on a normal distribution curve (Figure 14).

Figure 15 is a scatter plot of the probability that any given sample will lie below a given value, against ordinal value. To the extent that this plot is a straight line the distribution is normal. If the plot deviates greatly from a straight line the data does not have normal distribution. It may be seen that the plot in Figure 15 is a relatively straight line. A surer test is to use the log of probability and the log of the order value (Figure 16). This is useful to test the values lying in the skirts of the distribution curve. Since there is always a small number of data points in the region of the lower adhesion values, the use of the log plot highlights any abnormality of these values.

Our analysis of these data have allowed us to conclude that the data is fairly normally distributed and can therefore be used to establish criteria for minimum threshold levels based on normal distribution. These criteria have been determined using an algorithm giving the probability that any number R of adhesion values will fall below the n lowest values.

For the FAA we selected a test sample size of 20 tires and used the three lowest readings as the threshold criteria. Using the algorithm, we determined that, using values of 30, 33, and 36 for buffline adhesion and 20, 23, and 26 for ply adhesion, the probability that a retreader having good tires would fail the test was about fifteen percent. The probability of failing a retest was about 2%. One the other hand the probability of detection of a sample of tires having a mean less than the threshold values increases very rapidly to 98% at a value of 1 standard deviation away from the threshold mean (Figure 17).

Tread and ply adhesion values are a very good measure of tire production uniformity and can therefore be used as a monitor of quality during production in statistical QC devices such as control charts. The threshold values given represent tires taken from a fleet in which a very small number of tire related incidents have occurred. They can therefore be considered as representing a safe population of tires.

REFERENCES

1. Inspection, Retread, Repair, and Alterations of Aircraft Tires. Federal Aviation Advisory Circular AC 145-4, FAA, Sept. 1982.

2. Harscar, F. G.: Determination of Tire Components Adhesion. Test Engineering, November 1970, pp. 10-11.

3. Clark, S. K. (ed.): Mechanics of Pneumatic Tires. National Highway Traffic Safety Administration, U.S. Dept. of Transportation, 1981.

4. Adhesion to Flexible Substrate. ASTM D-413-76, 1981 Annual Book of ASTM Standards, p. 357.

5. Rebuilt Tire Aircraft Laboratory Quality Assurance Requirements, Military Standard MS3377. Paragraph 4.6.8, MIL-R-7726, Dept. of Defense, June 1975.

6. Standards for Retreading Aircraft Tires. Appendix 6, Association of European Airlines, Jan. 5, 1977.

7. Houchard, Richard: BANK DATA Management Package. Computer Center Library Program 3.9.1, Westerm Michigan Univ., Kalamazoo, Mich., Oct. 1974.

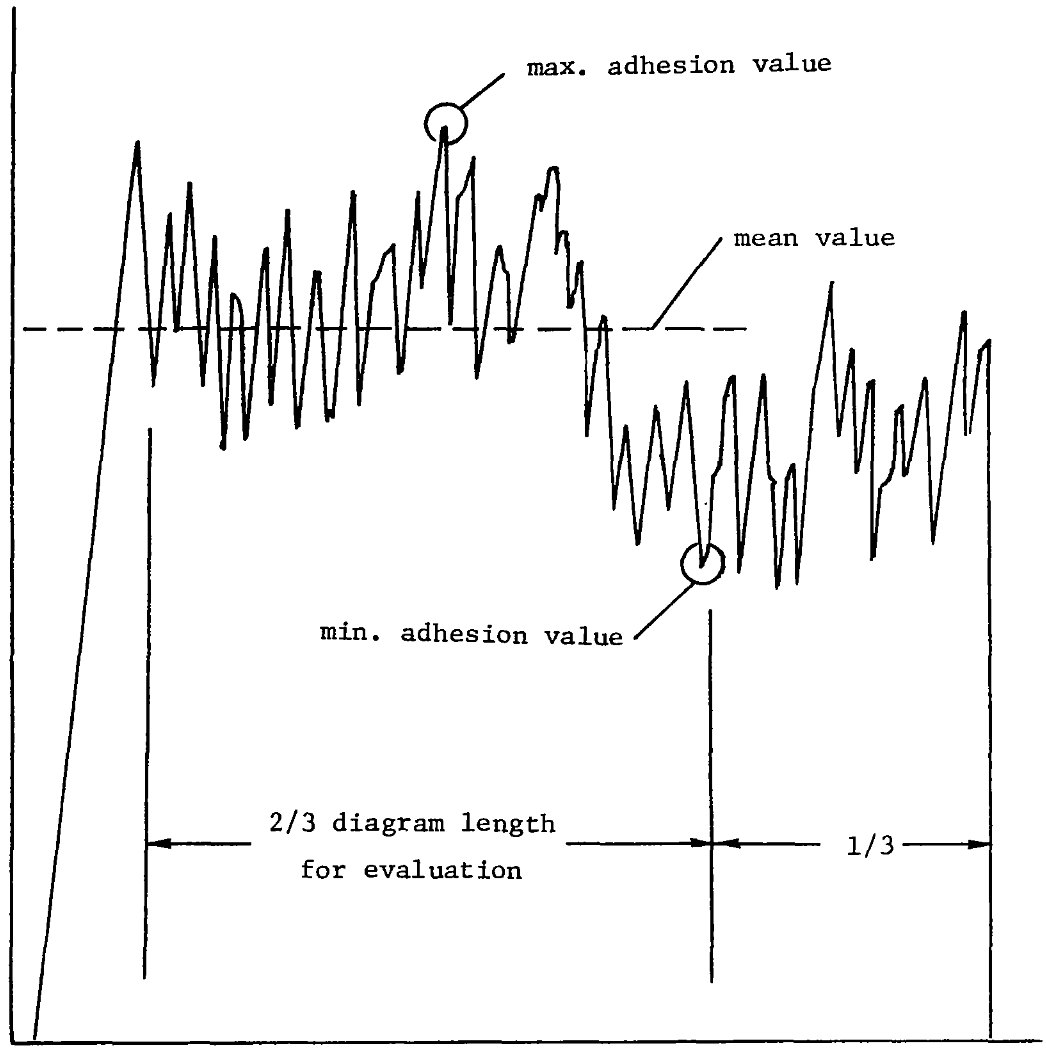
max. adhesion value
mean value
min. adhesion value
2/3 diagram length
for evaluation
1/3

Figure 1

VARIABLE: SIZE   NUMBER: 2   DESCRIPTION: VARIABLE TYPE: FLOAT
THERE WERE 706 OBSERVATIONS, WHICH INCLUDED 0 CASES OF MISSING DATA SELECTED FROM A TOTAL OF 706 OBSERVATIONS

SUM OF OBSERVATIONS = 23559.43	SUM OF OBSERVATIONS SQUARED = 838052.0	NUMBER OF OBSERVATIONS =
MEAN = 33.37030	MEDIAN = 29.50750	MODE = 24.55000
MAXIMUM = 56.16000	MINIMUM = 20.20000	RANGE = 35.96000
STANDARD ERROR OF MEAN = 0.3228110	STANDARD DEVIATION = 8.577303	VARIANCE = 73.57012
COEFFICIENT OF SKEWNESS = 0.5019920	COEFFICIENT OF VARIATION = 25.70341	KURTOSIS = 2.321392

VALUE	FREQUENCY	PERCENTAGE	CUMULATIVE PERCENTAGE
20.20000	1	0.142	0.142
20.55000	9	1.275	1.416
22.55000	50	7.082	8.499
24.55000	139	19.688	28.187
26.66000	17	2.408	30.595
28.77000	72	10.198	40.793
28.90000	65	9.207	50.000
30.11500	14	1.983	51.983
36.11000	94	13.314	65.297
37.11500	8	1.133	66.431
40.14000	129	18.272	84.703
41.15000	10	1.416	86.119
44.13000	18	2.550	88.669
44.16000	8	1.133	89.802
46.14000	2	0.283	90.085
46.16000	23	3.258	93.343
47.18000	1	0.142	93.484
49.17000	26	3.683	97.167
50.20000	3	0.425	97.592
52.20000	6	0.850	98.442
56.16000	11	1.558	100.000
	706		

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          5.0       10.0      15.0      20.0      25.0
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Figure 2

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VARIABLE:  RL      NUMBER:    3      DESCRIPTION:  R LEVEL                          VARIABLE TYPE: FIXED
THERE WERE  706 OBSERVATIONS, WHICH INCLUDED       623 CASES OF MISSING DATA SELECTED FROM A TOTAL  706 OBSERVATIONS

SUM OF OBSERVATIONS =  269.00                   SUM OF OBSERVATIONS SQUARED =  1201.000   NUMBER OF OBSERVATIONS =
MEAN =  3.240964                                MEDIAN =  3.000000                        MODE =  24.55000
MAXIMUM =  12                                   MINIMUM =  1                              RANGE =  35.96000
STANDARD ERROR OF MEAN = 0.2199233              STANDARD DEVIATION =  2.003597            VARIANCE =  73.57012
COEFFICIENT OF SKEWNESS =  1.395565             COEFFICIENT OF VARIATION =  61.82101      KURTOSIS =  2.321392
```

VALUE	FREQUENCY	PERCENTAGE	CUMULATIVE PERCENTAGE
1	19	22.892	22.892
2	13	15.663	38.554
3	17	20.482	59.036
4	16	19.277	78.313
5	11	13.253	91.566
6	3	3.614	95.181
7	1	1.205	96.386
8	1	1.205	97.590
9	1	1.205	98.795
12	1	1.205	100.000
	83		

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         5.0       10.0      15.0      20.0      25.0
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         5.0       10.0      15.0      20.0      25.0
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Figure 3

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VARIABLE:  MFG     NUMBER:   4      DESCRIPTION:  MANUFACTURER          VARIABLE TYPE:  ALPHA
THERE WERE   706 OBSERVATIONS, WHICH INCLUDED  430 CASES OF MISSING DATA SELECTED FROM A TOTAL OF  706 OBSERVATIONS

MAXIMUM =  TMS                          MINIMUM = AIR
```

VALUE	FREQUENCY	PERCENTAGE	CUMULATIVE PERCENTAGE
AIR	143	51.812	51.812
BFG	34	12.319	64.130
BRS	4	1.449	65.580
DLP	7	2.536	68.116
F	5	1.812	69.928
GYR	36	13.043	82.971
KC	6	2.174	85.145
TMS	41	14.855	100.000
	276		

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         15.0      30.0      45.0      60.0      75.0
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         15.0      30.0      45.0      60.0      75.0
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Figure 4

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VARIABLE:  TMX     NUMBER:    5     DESCRIPTION:  MAX TREAD ADHSN       VARIABLE TYPE:  FIXED
THERE WERE   706 OBSERVATIONS, WHICH INCLUDED   563 CASES OF MISSING DATA SELECTED FROM A TOTAL OF 706 OBSERVATIONS

SUM OF OBSERVATIONS =  12289.00              SUM OF OBSERVATIONS SQUARED =  1114039.     NUMBER OF OBSERVATIONS =
MEAN =  85.93706                             MEDIAN =  82.00000                          MODE =  80
MAXIMUM =  143                               MINIMUM =  50                               RANGE =  93
STANDARD ERROR OF MEAN =  1.689453           STANDARD DEVIATION =  20.20292              VARIANCE =  408.1580
COEFFICIENT OF SKEWNESS =  0.5453779         COEFFICIENT OF VARIATION =  23.50897        KURTOSIS =  2.987374
```

VALUE		FREQUENCY	PERCENTAGE	CUMULATIVE PERCENTAGE
50 -	53	5	3.497	3.497
54 -	57	3	2.098	5.594
58 -	61	6	4.196	9.790
62 -	65	7	4.895	14.685
66 -	69	12	8.392	23.077
70 -	73	7	4.895	27.972
74 -	77	11	7.692	35.664
78 -	81	18	12.587	48.252
82 -	85	10	6.993	55.245
86 -	89	11	7.692	62.937
90 -	93	7	4.895	67.832
94 -	97	5	3.497	71.329
98 -	101	10	6.993	78.322
102 -	105	9	6.294	84.615
106 -	109	5	3.497	88.112
110 -	113	4	2.797	90.909
114 -	117	2	1.399	92.308
118 -	121	2	1.399	93.706
122 -	125	1	0.699	94.406
126 -	129	3	2.098	96.503
130 -	133	1	0.699	97.203
134 -	137	3	2.098	99.301
138 -	141	0	0.000	99.301
142 -	145	1	0.699	100.000
		143		

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          5.0       10.0      15.0      20.0      25.0
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          5.0       10.0      15.0      20.0      25.0
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Figure 5

VARIABLE: TAV NUMBER: 7 DESCRIPTION: AVERAGE TREAD ADHSN VARIABLE TYPE: FIXED
THERE WERE 706 OBSERVATIONS, WHICH INCLUDED 213 CASES OF MISSING DATA SELECTED FROM A TOTAL OF 706 OBSERVATIONS

SUM OF OBSERVATIONS = 41810.00
MEAN = 84.80730
MAXIMUM = 149
STANDARD ERROR OF MEAN = 0.9643130
COEFFICIENT OF SKEWNESS = 0.6466109E-01

SUM OF OBSERVATIONS SQUARED = 3771346.
MEDIAN = 85.00000
MINIMUM = 20
STANDARD DEVIATION = 21.41122
COEFFICIENT OF VARIATION = 25.24691

NUMBER OF OBSERVATIONS =
MODE = 90
RANGE = 129
VARIANCE = 458.4405
KURTOSIS = 2.747826

VALUE		FREQUENCY	PERCENTAGE	CUMULATIVE PERCENTAGE
20 -	25	2	0.406	0.406
26 -	31	0	0.000	0.406
32 -	37	0	0.000	0.406
38 -	43	7	1.420	1.826
44 -	49	8	1.623	3.448
50 -	55	26	5.274	8.722
56 -	61	34	6.897	15.619
62 -	67	34	6.897	22.515
68 -	73	44	8.925	31.440
74 -	79	38	7.708	39.148
80 -	85	60	12.170	51.318
86 -	91	52	10.548	61.866
92 -	97	50	10.142	72.008
98 -	103	38	7.708	79.716
104 -	109	35	7.099	86.815
110 -	115	29	5.882	92.698
116 -	121	19	3.854	96.552
122 -	127	3	0.609	97.160
128 -	133	7	1.420	98.580
134 -	139	4	0.811	99.391
140 -	145	2	0.406	99.797
146 -	151	1	0.203	100.000
		493		

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         5.0       10.0      15.0      20.0      25.0
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         5.0       10.0      15.0      20.0      25.0
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Figure 6

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VARIABLE:   PMX     NUMBER:   8      DESCRIPTION:  MAX PLY ADHSN           VARIABLE TYPE: FIXED
THERE WERE    706 OBSERVATIONS, WHICH INCLUDED    538 CASES OF MISSING DATA SELECTED FROM A TOTAL  OF
                                                                                   706 OBSERVATIONS
SUM OF OBSERVATIONS =  6691.000              SUM OF OBSERVATIONS SQUARED =  280465.0
MEAN =  39.82738                             MEDIAN =  38.00000                   NUMBER OF OBSERVATIONS =
MAXIMUM =  73                                MINIMUM =  26                        MODE =  39
STANDARD ERROR OF MEAN =  0.7058958          STANDARD DEVIATION =  9.149456       RANGE =  47
COEFFICIENT OF SKEWNESS =  1.399312          COEFFICIENT OF VARIATION =  22.97278 VARIANCE =  83.71254
                                                                                  KURTOSIS =  5.195022
```

VALUE		FREQUENCY	PERCENTAGE	CUMULATIVE PERCENTAGE
26 -	27	5	2.976	2.976
28 -	29	6	3.571	6.548
30 -	31	12	7.143	13.690
32 -	33	15	8.929	22.619
34 -	35	20	11.905	34.524
36 -	37	20	11.905	46.429
38 -	39	23	13.690	60.119
40 -	41	13	7.738	67.857
42 -	43	14	8.333	76.190
44 -	45	9	5.357	81.548
46 -	47	8	4.762	86.310
48 -	49	3	1.786	88.095
50 -	51	2	1.190	89.286
52 -	53	4	2.381	91.667
54 -	55	0	0.000	91.667
56 -	57	3	1.786	93.452
58 -	59	3	1.786	95.238
60 -	61	1	0.595	95.833
62 -	63	1	0.595	96.429
64 -	65	1	0.595	97.024
66 -	67	1	0.595	97.619
68 -	69	1	0.595	98.214
70 -	71	2	1.190	99.405
72 -	73	1	0.595	100.000
		168		

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          5.0       10.0      15.0      20.0      25.0
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          5.0       10.0      15.0      20.0      25.0
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Figure 7

VARIABLE: PMN NUMBER: 9 DESCRIPTION: MIN PLY ADHSN VARIABLE TYPE: FIXED
THERE WERE 706 OBSERVATIONS, WHICH INCLUDED 681 CASES OF MISSING DATA SELECTED FROM A TOTAL OF 706 OBSERVATIONS

SUM OF OBSERVATIONS = 711.0000
MEAN = 28.44000
MAXIMUM = 44
STANDARD ERROR OF MEAN = 1.605283
COEFFICIENT OF SKEWNESS = 0.3450782

SUM OF OBSERVATIONS SQUARED = 21767.00
MEDIAN = 27.00000
MINIMUM = 14
STANDARD DEVIATION = 8.026415
COEFFICIENT OF VARIATION = 28.22227

NUMBER OF OBSERVATIONS =
MODE = 20
RANGE = 30
VARIANCE = 64.42333
KURTOSIS = 2.162221

VALUE	FREQUENCY	PERCENTAGE	CUMULATIVE PERCENTAGE
14	1	4.000	4.000
19	1	4.000	8.000
20	3	12.000	20.000
22	2	8.000	28.000
24	2	8.000	36.000
25	1	4.000	40.000
26	2	8.000	48.000
27	2	8.000	56.000
29	1	4.000	60.000
30	2	8.000	68.000
31	1	4.000	72.000
36	1	4.000	76.000
37	1	4.000	80.000
38	2	8.000	88.000
40	1	4.000	92.000
42	1	4.000	96.000
44	1	4.000	100.000
	25		

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          5.0       10.0      15.0      20.0      25.0
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          5.0       10.0      15.0      20.0      25.0
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Figure 8

VARIABLE: PAV NUMBER: 10 DESCRIPTION: AVERAGE PLY ADHSN VARIABLE TYPE: FIXED
THERE WERE 706 OBSERVATIONS, WHICH INCLUDED 188 CASES OF MISSING DATA SELECTED FROM A TOTAL OF 706 OBSERVATIONS

SUM OF OBSERVATIONS = 28109.00
MEAN = 54.26448
MAXIMUM = 114
STANDARD ERROR OF MEAN = 0.5346928
COEFFICIENT OF SKEWNESS = 0.6843333

SUM OF OBSERVATIONS SQUARED = 1601885.
MEDIAN = 54.00000
MINIMUM = 17
STANDARD DEVIATION = 12.16940
COEFFICIENT OF VARIATION = 22.42609

NUMBER OF OBSERVATIONS =
MODE = 53
RANGE = 97
VARIANCE = 148.0943
KURTOSIS = 5.372330

VALUE		FREQUENCY	PERCENTAGE	CUMULATIVE PERCENTAGE
17 -	20	1	0.193	0.193
21 -	24	0	0.000	0.193
25 -	28	3	0.579	0.772
29 -	32	9	1.737	2.510
33 -	36	19	3.668	6.178
37 -	40	37	7.143	13.320
41 -	44	36	6.950	20.270
45 -	48	41	7.915	28.185
49 -	52	77	14.865	43.050
53 -	56	92	17.761	60.811
57 -	60	62	11.969	72.780
61 -	64	52	10.039	82.819
65 -	68	42	8.108	90.927
69 -	72	23	4.440	95.367
73 -	76	5	0.965	96.332
77 -	80	5	0.965	97.297
81 -	84	4	0.772	98.069
85 -	88	3	0.579	98.649
89 -	92	1	0.193	98.842
93 -	96	2	0.386	99.228
97 -	100	1	0.193	99.421
101 -	104	0	0.000	99.421
105 -	108	2	0.386	99.807
109 -	112	0	0.000	99.807
113 -	114	1	0.193	100.000
		518		

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          5.0       10.0      15.0      20.0      25.0
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          5.0       10.0      15.0      20.0      25.0
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Figure 9

```
VARIABLE:  TENS    NUMBER:    10      DESCRIPTION:  TENSILE              VARIABLE TYPE:  FIXED
THERE WERE  706 OBSERVATIONS, WHICH INCLUDED   134 CASES OF MISSING DATA SELECTED FROM A TOTAL  OF
                                                                                   706 OBSERVATIONS
SUM OF OBSERVATIONS =  1538885.            SUM OF OBSERVATIONS SQUARED =  0.4200112E+10
MEAN =  2690.358                           MEDIAN =  2661.000                     NUMBER OF OBSERVATIONS =
MAXIMUM =  3697                            MINIMUM =  1495                        MODE =  2660
STANDARD ERROR OF MEAN =  13.54925         STANDARD DEVIATION = 324.0510          RANGE =  2202
COEFFICIENT OF SKEWNESS =  0.3102679       COEFFICIENT OF VARIATION =  12.04490   VARIANCE =  105009.1
                                                                                  KURTOSIS =  3.827942
```

VALUE		FREQUENCY	PERCENTAGE	CUMULATIVE PERCENTAGE
1495 -	1583	1	0.175	0.175
1584 -	1672	1	0.175	0.350
1673 -	1761	1	0.175	0.524
1762 -	1850	1	0.175	0.699
1851 -	1939	2	0.350	1.049
1940 -	2028	5	0.874	1.923
2029 -	2117	5	0.874	2.797
2118 -	2206	14	2.448	5.245
2207 -	2295	17	2.972	8.217
2296 -	2384	31	5.420	13.636
2385 -	2473	58	10.140	23.776
2474 -	2562	65	11.364	35.140
2563 -	2651	75	13.112	48.252
2652 -	2740	85	14.860	63.112
2741 -	2829	50	8.741	71.853
2830 -	2918	40	6.993	78.846
2919 -	3007	24	4.196	83.042
3008 -	3096	29	5.070	88.112
3097 -	3185	30	5.245	93.357
3186 -	3274	11	1.923	95.280
3275 -	3363	10	1.748	97.028
3364 -	3452	3	0.524	97.552
3453 -	3541	5	0.874	98.427
3542 -	3630	4	0.699	99.126
3631 -	3697	5	0.874	100.000
		572		

```
          5.0       10.0      15.0      20.0      25.0
+---------+---------+---------+---------+---------+
I
I
I
I
IX
IXX
IXX
IXXXXX
IXXXXXX
IXXXXXXXXXXX
IXXXXXXXXXXXXXXXXXXXX
IXXXXXXXXXXXXXXXXXXXXXXX
IXXXXXXXXXXXXXXXXXXXXXXXXXX
IXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
IXXXXXXXXXXXXXXXXX
IXXXXXXXXXXXXXX
IXXXXXXXX
IXXXXXXXXXX
IXXXXXXXXXX
IXXXX
IXXX
IX
IXX
IX
IXX
+---------+---------+---------+---------+---------+
          5.0       10.0      15.0      20.0      25.0
```

Figure 10

VARIABLE: ELONG NUMBER: 12 DESCRIPTION: ELONGATION VARIABLE TYPE: FIXED
THERE WERE 706 OBSERVATIONS, WHICH INCLUDED 133 CASES OF MISSING DATA SELECTED FROM A TOTAL OF 706 OBSERVATIONS

SUM OF OBSERVATIONS = 281707.0
MEAN = 491.6353
MAXIMUM = 670
STANDARD ERROR OF MEAN = 2.767603
COEFFICIENT OF SKEWNESS = -0.1577621

SUM OF OBSERVATIONS SQUARED = 0.1410076E+09
MEDIAN = 497.0000
MINIMUM = 274
STANDARD DEVIATION = 66.24928
COEFFICIENT OF VARIATION = 13.47529

NUMBER OF OBSERVATIONS =
MODE = 530
RANGE = 396
VARIANCE = 4388.966
KURTOSIS = 2.601573

VALUE		FREQUENCY	PERCENTAGE	CUMULATIVE PERCENTAGE
274 -	289	1	0.175	0.175
290 -	305	1	0.175	0.349
306 -	321	0	0.000	0.349
322 -	337	1	0.175	0.524
338 -	353	4	0.698	1.222
354 -	369	15	2.618	3.839
370 -	385	10	1.745	5.585
386 -	401	25	4.363	9.948
402 -	417	33	5.759	15.707
418 -	433	44	7.679	23.386
434 -	449	22	3.839	27.225
450 -	465	35	6.108	33.333
466 -	481	49	8.551	41.885
482 -	497	48	8.377	50.262
498 -	513	59	10.297	60.558
514 -	529	47	8.202	68.761
530 -	545	52	9.075	77.836
546 -	561	46	8.028	85.864
562 -	577	23	4.014	89.878
578 -	593	31	5.410	95.288
594 -	609	9	1.571	96.859
610 -	625	9	1.571	98.429
626 -	641	6	1.047	99.476
642 -	657	0	0.000	99.476
658 -	670	3	0.524	100.000
		573		

```
         5.0       10.0      15.0      20.0      25.0
+---------+---------+---------+---------+---------+
I
I
I
I
IX
IXXXXX
IXXX
IXXXXXXXXX
IXXXXXXXXXXXX
IXXXXXXXXXXXXXXX
IXXXXXXXX
IXXXXXXXXXXXX
IXXXXXXXXXXXXXXXXX
IXXXXXXXXXXXXXXXXX
IXXXXXXXXXXXXXXXXXXXXX
IXXXXXXXXXXXXXXXX
IXXXXXXXXXXXXXXXXXX
IXXXXXXXXXXXXXXXX
IXXXXXXXX
IXXXXXXXXXXX
IXXX
IXXX
IXX
I
IX
+---------+---------+---------+---------+---------+
         5.0       10.0      15.0      20.0      25.0
```

Figure 11

VARIABLE: DUR NUMBER: 17 DESCRIPTION: DUROMETER VARIABLE TYPE: FLOAT
THERE WERE 706 OBSERVATIONS, WHICH INCLUDED 276 CASES OF MISSING DATA SELECTED FROM A TOTAL OF 706 OBSERVATIONS

SUM OF OBSERVATIONS = 26392.00
MEAN = 61.37674
MAXIMUM = 69.00000
STANDARD ERROR OF MEAN = 0.1202394
COEFFICIENT OF SKEWNESS = -0.4979397

SUM OF OBSERVATIONS SQUARED = 1622522.
MEDIAN = 61.00000
MINIMUM = 50.00000
STANDARD DEVIATION = 2.493337
COEFFICIENT OF VARIATION = 4.062348

NUMBER OF OBSERVATIONS =
MODE = 61.00000
RANGE = 19.00000
VARIANCE = 6.216729
KURTOSIS = 5.129465

VALUE	FREQUENCY	PERCENTAGE	CUMULATIVE PERCENTAGE
50.00000	2	0.465	0.465
54.00000	1	0.233	0.698
55.00000	9	2.093	2.791
56.00000	2	0.465	3.256
57.00000	13	3.023	6.279
58.00000	14	3.256	9.535
59.00000	28	6.512	16.047
60.00000	70	16.279	32.326
61.00000	96	22.326	54.651
62.00000	56	13.023	67.674
63.00000	63	14.651	82.326
64.00000	38	8.837	91.163
65.00000	24	5.581	96.744
66.00000	8	1.860	98.605
67.00000	2	0.465	99.070
68.00000	1	0.233	99.302
69.00000	3	0.698	100.000
	430		

```
          5.0       10.0      15.0      20.0      25.0
+---------+---------+---------+---------+---------+
IX
I
IXXXX
IX
IXXXXXX
IXXXXXXX
IXXXXXXXXXXXXX
IXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
IXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
IXXXXXXXXXXXXXXXXXXXXXXXXXX
IXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
IXXXXXXXXXXXXXXXXXX
IXXXXXXXXXXX
IXXXX
IX
I
IX
+---------+---------+---------+---------+---------+
          5.0       10.0      15.0      20.0      25.0
```

Figure 12

VARIABLE: SG NUMBER: 18 DESCRIPTION: TREAD SPECIFIC GRAV 1.()() VARIABLE TYPE: FLOAT
THERE WERE 706 OBSERVATIONS, WHICH INCLUDED 279 CASES OF MISSING DATA SELECTED FROM A TOTAL OF 706 OBSERVATIONS

SUM OF OBSERVATIONS = 5376.000
MEAN = 12.59016
MAXIMUM = 16.00000
STANDARD ERROR OF MEAN = 0.5154423E-01
COEFFICIENT OF SKEWNESS = -0.2478130

SUM OF OBSERVATIONS SQUARED = 68168.00
MEDIAN = 13.00000
MINIMUM = 8.000000
STANDARD DEVIATION = 1.065109
COEFFICIENT OF VARIATION = 8.459850

NUMBER OF OBSERVATIONS =
MODE = 12.00000
RANGE = 8.000000
VARIANCE = 1.134457
KURTOSIS = 4.195873

VALUE	FREQUENCY	PERCENTAGE	CUMULATIVE PERCENTAGE
8.000000	1	0.234	0.234
9.000000	3	0.703	0.937
10.00000	7	1.639	2.576
11.00000	34	7.963	10.539
12.00000	161	37.705	48.244
13.00000	143	33.489	81.733
14.00000	65	15.222	96.956
15.00000	12	2.810	99.766
16.00000	1	0.234	100.000
	427		

```
          10.0      20.0      30.0      40.0      50.0
+---------+---------+---------+---------+---------+
I
IX
IXX
IXXXXXXXX
IXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
IXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
IXXXXXXXXXXXXXXX
IXXX
I
+---------+---------+---------+---------+---------+
          10.0      20.0      30.0      40.0      50.0
```

Figure 13

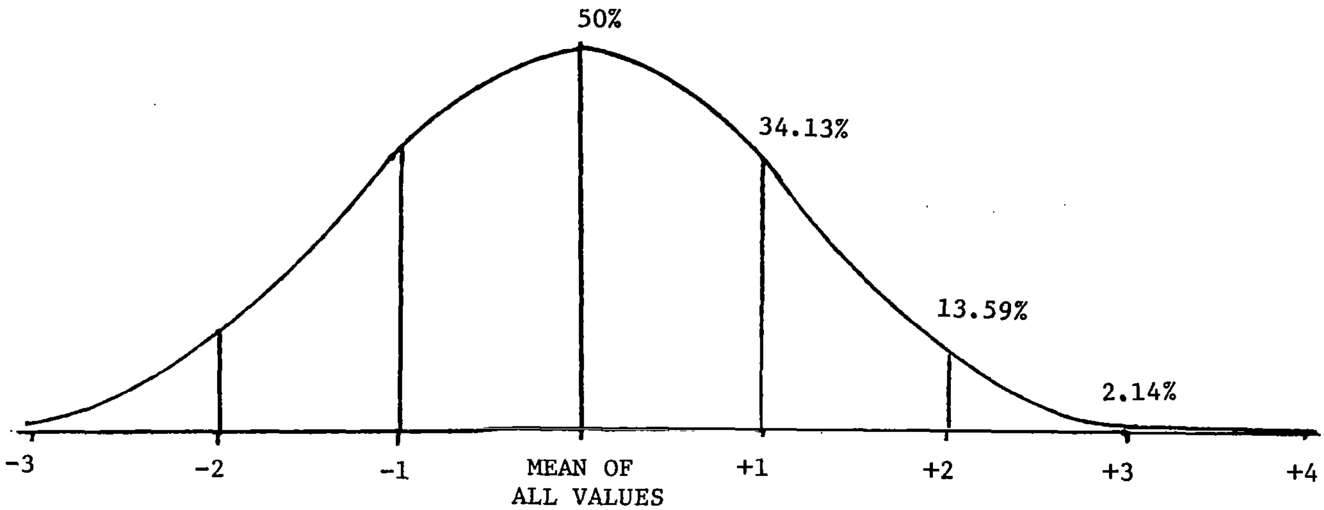

Figure 14

```
             PLOT OF VARIABLE:    1    (HORIZ.)  VS  VARIABLE:    3    (VERT.)

                    I---------+---------+---------+---------+---------+
  1.000             +                                      3B
                    I                                     CA
                    I                                  4CD
                    I                                AC9
  0.8000            +                              3C3
                    I                            2CA
                    I                          1CB
                    I                        2CC
  0.6000            +                      ACB
                    I                     93
                    I                  2CD3
                    I                 CB
  0.4000            +               6D
                    I             3D6
                    I            79
                    I          CC6
  0.2000            +       3DC1
                    I      79
                    I   6DC6
                    I BD6
  0.1863E-07        +71
                    I
                    I
                    I
 -0.2000            +
                    I---------+---------+---------+---------+---------+
                  201.5               451.5               701.5
                            326.5               576.5               826.5
```

Figure 15

```
PLOT OF VARIABLE:   VLOG1   (HORIZ.)  VS  VARIABLE:   VLOG3    (VERT.)

           I---------+---------+---------+---------+
 0.0000    +1   1                             YF
           I                                 **
           I                                3*I
           I                               B*
-0.4000    +                              I8
           I                             8E
           I                            BJ
           I                           IB
-0.8000    +                          A
           I                         66
           I                       9B6
           I                        5
-1.200     +                     5562
           I                   13
           I                  12
           I                131
-1.600     +
           I             112
           I
           I
-2.000     +        1 1
           I
           I
           I
-2.400     +
           I---------+---------+---------+---------+
      -0.8000E-01          1.520               3.120
                   0.7200              2.320
```

Figure 16

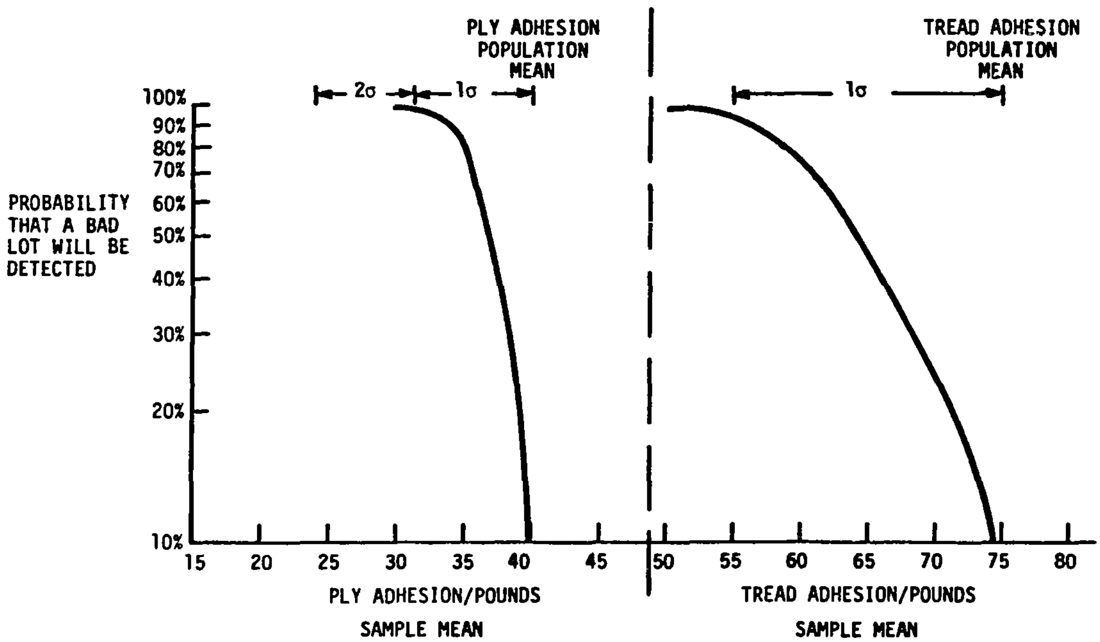

Figure 17