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O-RING TENSION TESTING CALCULATIONS

1. PURPOSE: To facilitate calculation of O-ring tension testing values.

2. DISCUSSION: The calculation of the values for tensile strength, ultimate elongation, and modulus at 100% elongation from raw data obtained on O-rings is outlined in its essentials in ASTM-D-1414-56T. This document provides tables which simplify these calculations. Notations and symbols used herein are not identical to those used in ASTM-D-1414.

2.1 Elongation: ASTM-D-1414 provides the following equation for calculation of ultimate elongation.

$$(1)\quad \%E = \left[\frac{C_f - C_o}{C_o}\right] 100$$

Where C_f = final inside circumference, C_o = original inside circumference, and E = elongation. The raw data consists of the inside diameter of the O-ring (denoted as D in the following), the spool diameter (S), and the spool center-to-center distance (d) at break. It should be noted that one spool must be driven and the other freely rotating in order that the stress be uniformly distributed around the entire ring. Use of non-rotating pins leaves the contact length(s) of the O-ring substantially unstressed because of friction between O-ring and pin(s), and yields consistently low and erratic results.

Equation (5) below is derived from equation (1) and, with Table I, is directly and simply applicable to the calculation of percent elongation.

$$(2)\quad C_o = \pi D$$

$$(3)\quad C_f = 2d + \pi S$$

$$(4)\quad E = \frac{C_f - C_o}{C_o} = \frac{2d + \pi S - \pi D}{\pi D}$$

$$(5)\quad E = \frac{2}{\pi D} d - \frac{D - S}{D}$$

The terms $\frac{2}{\pi D}$ and $\frac{D - S}{D}$ are constants for any given O-ring size and spool diameter. Table I gives values of these terms for "standard" ARP 568 dash numbers when tested on the ASTM specified .500 inch diameter spools. Similar tables for other spool dia-

meters can be constructed by using equation (5) above. In using the table, multiply the spool center to center distance, d, by the number in the column headed "multiply d by", and subtract from the result the number in the column headed "and subtract". This result must then be multiplied by 100 in order to obtain percent elongation. The table does not include values for small sizes which cannot be tested on .500 inch diameter spools.

2.2 Modulus at 100%: The value for modulus at 100% elongation is the tensile stress at this elongation. In order to note the tensile stress, the spool center-to-center distance must be pre-determined for 100% elongation. In order to do so, equation (5) is used, setting E = 1 in this case.

$$(6)\quad E = 1 = \frac{2}{\Pi D} d - \frac{D - S}{D}$$

$$(7)\quad d_{100} = \frac{(1 + \frac{D - S}{D})\ \Pi D}{2}$$

$$(8)\quad d_{100} = \frac{\Pi}{2}\ (2D - S)$$

The values for the spool center-to-center distance for 100% elongation, d_{100}, are calculated from equation (8) and given in Table II. The machine readings for modulus at 100% must be converted to psi in accordance with the following discussion on tensile strength.

2.3 Tensile Strength is defined as follows:

$$(9)\quad T = \frac{F}{A}$$

Where T is the tensile strength in psi, F the force in pounds (i.e. machine reading) and A is the area under stress. In the case of O-rings tested on spools the area A is equal to twice the cross-section area of the ring. The total area A, determined from the actual cross-section diameter, W, is

$$(10)\quad A = 2\Pi\ (\frac{W}{2})^2$$

$$(11)\quad A = \frac{\Pi W^2}{2}$$

Equation (9) may be restated as:

$$(12)\quad T = F\left(\frac{1}{A}\right) = F\left(\frac{2}{\pi W^2}\right)$$

The values for 1/A for each .001 inch interval within the ARP 568 tolerances are given in Table III. To obtain tensile strength simply multiply the machine reading, F, by the values given for 1/A in this table. This table is also used for calculation of modulus as mentioned in paragraph 2.2 above.

3. EXAMPLE:

Size ARP 568-218
Measured W = .141 in.

From Table II determine that stress for 100% modulus is to be noted when spool center-to-center distance (d_{100}) is 3.14 in.

If: machine reading at d_{100} = 21 lbs.
machine reading at break = 43 lbs.
spool center-to-center distance (d) at break = 5.6 inches.

Then: $\%E = [(.516)(5.6) - .596]\ 100$

$= [2.88 - .595]\ 100$

$\%E = 229\%$

The numbers .516 and .595 are taken from Table I opposite size -218.

$M_{100} = (21)(32)$

$M_{100} = 672$ psi

$T = (43)(32)$

$T = 1380$ psi

The number 32 is taken from Table III opposite W = .141.

TABLE I

ARP 568 Dash Nos.	I. D.	W.	Multiply d by	And Subtract
-022	.989 ± .006	.070 ± .003	.644	.494
-023	1.051 ± .006	.070 ± .003	.606	.524
-024	1.114 ± .006	.070 ± .003	.572	.551
-025	1.176 ± .006	.070 ± .003	.541	.575
-026	1.239 ± .006	.070 ± .003	.514	.596
-027	1.301 ± .006	.070 ± .003	.489	.616
-028	1.364 ± .006	.070 ± .003	.467	.633
-029	1.489 ± .010	.070 ± .003	.428	.666
-030	1.614 ± .010	.070 ± .003	.394	.690
-031	1.739 ± .010	.070 ± .003	.366	.713
-032	1.864 ± .010	.070 ± .003	.342	.732
-033	1.989 ± .010	.070 ± .003	.320	.749
-034	2.114 ± .010	.070 ± .003	.301	.764
-035	2.239 ± .010	.070 ± .003	.284	.777
-036	2.364 ± .010	.070 ± .003	.269	.788
-037	2.489 ± .010	.070 ± .003	.256	.799
-038	2.614 ± .010	.070 ± .003	.244	.809
-039	2.739 ± .015	.070 ± .003	.232	.817
-040	2.864 ± .015	.070 ± .003	.222	.825
-041	2.989 ± .015	.070 ± .003	.213	.833
-042	3.239 ± .015	.070 ± .003	.197	.846
-043	3.489 ± .015	.070 ± .003	.182	.857
-044	3.739 ± .015	.070 ± .003	.170	.866
-045	3.989 ± .015	.070 ± .003	.160	.875
-120	.987 ± .006	.103 ± .003	.645	.493
-121	1.049 ± .006	.103 ± .003	.607	.523
-122	1.112 ± .006	.103 ± .003	.573	.550
-123	1.174 ± .006	.103 ± .003	.542	.574
-124	1.237 ± .006	.103 ± .003	.516	.596
-125	1.299 ± .006	.103 ± .003	.490	.615
-126	1.362 ± .006	.103 ± .003	.467	.633
-127	1.424 ± .006	.103 ± .003	.447	.649
-128	1.487 ± .006	.103 ± .003	.428	.664
-129	1.549 ± .010	.103 ± .003	.411	.677
-130	1.612 ± .010	.103 ± .003	.395	.690
-131	1.674 ± .010	.103 ± .003	.380	.701
-132	1.737 ± .010	.103 ± .003	.366	.712
-133	1.799 ± .010	.103 ± .003	.354	.722
-134	1.862 ± .010	.103 ± .003	.342	.731
-135	1.925 ± .010	.103 ± .003	.331	.740
-136	1.987 ± .010	.103 ± .003	.320	.748
-137	2.050 ± .010	.103 ± .003	.311	.756
-138	2.112 ± .010	.103 ± .003	.301	.763
-139	2.175 ± .010	.103 ± .003	.293	.770
-140	2.237 ± .010	.103 ± .003	.285	.776
-141	2.300 ± .010	.103 ± .003	.277	.783
-142	2.362 ± .010	.103 ± .003	.270	.788
-143	2.425 ± .010	.103 ± .003	.263	.794
-144	2.487 ± .010	.103 ± .003	.256	.799
-145	2.550 ± .010	.103 ± .003	.250	.804
-146	2.612 ± .010	.103 ± .003	.244	.809
-147	2.675 ± .015	.103 ± .003	.238	.813
-148	2.737 ± .015	.103 ± .015	.233	.817

TABLE I (Cont'd)

ARP 568 Dash Nos.	I. D.	W.	Multiply d by	And Subtract
-149	2.800 ± .015	.103 ± .003	.227	.821
-150	2.862 ± .015	.103 ± .003	.222	.825
-151	2.987 ± .015	.103 ± .003	.213	.833
-152	3.237 ± .015	.103 ± .003	.197	.846
-153	3.487 ± .015	.103 ± .003	.183	.857
-154	3.737 ± .015	.103 ± .003	.170	.866
-155	3.987 ± .015	.103 ± .003	.160	.875
-156	4.237 ± .015	.103 ± .003	.150	.882
-157	4.487 ± .015	.103 ± .003	.142	.889
-158	4.737 ± .015	.103 ± .003	.134	.894
-159	4.987 ± .015	.103 ± .003	.128	.900
-160	5.237 ± .023	.103 ± .003	.122	.905
-161	5.487 ± .023	.103 ± .003	.116	.909
-162	5.737 ± .023	.103 ± .003	.111	.913
-163	5.987 ± .023	.103 ± .003	.106	.916
-214	.984 ± .006	.139 ± .004	.647	.492
-215	1.046 ± .006	.139 ± .004	.609	.522
-216	1.109 ± .006	.139 ± .004	.574	.549
-217	1.171 ± .006	.139 ± .004	.544	.573
-218	1.234 ± .006	.139 ± .004	.516	.595
-219	1.296 ± .006	.139 ± .004	.491	.614
-220	1.359 ± .006	.139 ± .004	.468	.632
-221	1.421 ± .006	.139 ± .004	.448	.648
-222	1.484 ± .006	.139 ± .004	.429	.663
-223	1.609 ± .010	.139 ± .004	.396	.689
-224	1.734 ± .010	.139 ± .004	.367	.712
-225	1.859 ± .010	.139 ± .004	.343	.731
-226	1.984 ± .010	.139 ± .004	.321	.748
-227	2.109 ± .010	.139 ± .004	.302	.763
-228	2.234 ± .010	.139 ± .004	.285	.776
-229	2.359 ± .010	.139 ± .004	.270	.788
-230	2.484 ± .010	.139 ± .004	.256	.799
-231	2.609 ± .010	.139 ± .004	.244	.808
-232	2.734 ± .015	.139 ± .004	.233	.817
-233	2.859 ± .015	.139 ± .004	.223	.825
-234	2.984 ± .015	.139 ± .004	.213	.832
-235	3.109 ± .015	.139 ± .004	.204	.839
-236	3.234 ± .015	.139 ± .004	.197	.845
-237	3.359 ± .015	.139 ± .004	.190	.851
-238	3.484 ± .015	.139 ± .004	.183	.856
-239	3.609 ± .015	.139 ± .004	.176	.861
-240	3.734 ± .015	.139 ± .004	.170	.866
-241	3.859 ± .015	.139 ± .004	.165	.870
-242	3.984 ± .015	.139 ± .004	.160	.874
-243	4.109 ± .015	.139 ± .004	.155	.878
-244	4.234 ± .015	.139 ± .004	.150	.882
-245	4.359 ± .015	.139 ± .004	.146	.885
-246	4.484 ± .015	.139 ± .004	.142	.888
-247	4.609 ± .015	.139 ± .004	.138	.892
-248	4.734 ± .015	.139 ± .004	.134	.894
-249	4.859 ± .015	.139 ± .004	.131	.897
-250	4.984 ± .015	.139 ± .004	.128	.900

TABLE I (Cont'd)

ARP 568 Dash Nos.	I. D.	W.	Multiply d by	And Subtract
-251	5.109 ± .023	.139 ± .004	.124	.902
-252	5.234 ± .023	.139 ± .004	.122	.904
-253	5.359 ± .023	.139 ± .004	.119	.907
-254	5.484 ± .023	.139 ± .004	.116	.909
-255	5.609 ± .023	.139 ± .004	.114	.911
-256	5.734 ± .023	.139 ± .004	.111	.913
-257	5.859 ± .023	.139 ± .004	.109	.915
-258	5.984 ± .023	.139 ± .004	.106	.916
-325	1.475 ± .010	.210 ± .005	.432	.661
-326	1.600 ± .010	.210 ± .005	.398	.688
-327	1.725 ± .010	.210 ± .005	.369	.710
-328	1.850 ± .010	.210 ± .005	.344	.730
-329	1.975 ± .010	.210 ± .005	.322	.747
-330	2.100 ± .010	.210 ± .005	.303	.762
-331	2.225 ± .010	.210 ± .005	.286	.775
-332	2.350 ± .010	.210 ± .005	.271	.787
-333	2.475 ± .010	.210 ± .005	.257	.798
-334	2.600 ± .010	.210 ± .005	.245	.808
-335	2.725 ± .015	.210 ± .005	.234	.817
-336	2.850 ± .015	.210 ± .005	.223	.825
-337	2.975 ± .015	.210 ± .005	.214	.832
-338	3.100 ± .015	.210 ± .005	.205	.839
-339	3.225 ± .015	.210 ± .005	.197	.845
-340	3.350 ± .015	.210 ± .005	.190	.851
-341	3.475 ± .015	.210 ± .005	.183	.856
-342	3.600 ± .015	.210 ± .005	.177	.861
-343	3.725 ± .015	.210 ± .005	.171	.866
-344	3.850 ± .015	.210 ± .005	.165	.870
-345	3.975 ± .015	.210 ± .005	.160	.874
-346	4.100 ± .015	.210 ± .005	.155	.878
-347	4.225 ± .015	.210 ± .005	.151	.882
-348	4.350 ± .015	.210 ± .005	.146	.885
-349	4.475 ± .015	.210 ± .005	.142	.888
-425	4.475 ± .015	.275 ± .006	.142	.888
-426	4.600 ± .015	.275 ± .006	.138	.891
-427	4.725 ± .015	.275 ± .006	.135	.894
-428	4.850 ± .015	.275 ± .006	.131	.897
-429	4.975 ± .015	.275 ± .006	.128	.899
-430	5.100 ± .023	.275 ± .006	.125	.902
-431	5.225 ± .023	.275 ± .006	.122	.904
-432	5.350 ± .023	.275 ± .006	.119	.907
-433	5.475 ± .023	.275 ± .006	.116	.909
-434	5.600 ± .023	.275 ± .006	.114	.912
-435	5.725 ± .023	.275 ± .006	.111	.913
-436	5.850 ± .023	.275 ± .006	.109	.915
-437	5.975 ± .023	.275 ± .006	.107	.916
-913	.986 ± .006	.116 ± .004	.645	.493
-914	1.047 ± .006	.116 ± .004	.608	.522
-916	1.171 ± .006	.116 ± .004	.543	.573
-918	1.355 ± .006	.116 ± .004	.469	.631
-920	1.475 ± .010	.118 ± .004	.431	.661
-924	1.720 ± .010	.118 ± .004	.370	.710
-928	2.090 ± .010	.118 ± .004	.304	.762
-932	2.337 ± .010	.118 ± .004	.273	.785

TABLE II

ARP 568 Dash Nos.	I. D.	W.	d_{100}
-022	.989 ± .006	.070 ± .003	2.32
-023	1.051 ± .006	.070 ± .003	2.52
-024	1.114 ± .006	.070 ± .003	2.71
-025	1.176 ± .006	.070 ± .003	2.90
-026	1.239 ± .006	.070 ± .003	3.12
-027	1.301 ± .006	.070 ± .003	3.30
-028	1.364 ± .006	.070 ± .003	3.50
-029	1.489 ± .010	.070 ± .003	3.89
-030	1.614 ± .010	.070 ± .003	4.29
-031	1.739 ± .010	.070 ± .003	4.68
-032	1.864 ± .010	.070 ± .003	5.09
-033	1.989 ± .010	.070 ± .003	5.46
-034	2.114 ± .010	.070 ± .003	5.85
-035	2.239 ± .010	.070 ± .003	6.25
-036	2.364 ± .010	.070 ± .003	6.64
-037	2.489 ± .010	.070 ± .003	7.03
-038	2.614 ± .010	.070 ± .003	7.43
-039	2.739 ± .015	.070 ± .003	7.82
-040	2.864 ± .015	.070 ± .003	8.26
-041	2.989 ± .015	.070 ± .003	8.61
-042	3.239 ± .015	.070 ± .003	9.39
-043	3.489 ± .015	.070 ± .003	10.18
-044	3.739 ± .015	.070 ± .003	10.96
-045	3.989 ± .015	.070 ± .003	11.75
-120	.987 ± .006	.103 ± .003	2.32
-121	1.049 ± .006	.103 ± .003	2.51
-122	1.112 ± .006	.103 ± .003	2.69
-123	1.174 ± .006	.103 ± .003	2.90
-124	1.237 ± .006	.103 ± .003	3.10
-125	1.299 ± .006	.103 ± .003	3.30
-126	1.362 ± .006	.103 ± .003	3.49
-127	1.424 ± .006	.103 ± .003	3.69
-128	1.487 ± .006	.103 ± .003	3.89
-129	1.549 ± .010	.103 ± .003	4.08
-130	1.612 ± .010	.103 ± .003	4.28
-131	1.674 ± .010	.103 ± .003	4.47
-132	1.737 ± .010	.103 ± .003	4.67
-133	1.799 ± .010	.103 ± .003	4.87
-134	1.862 ± .010	.103 ± .003	5.06
-135	1.925 ± .010	.103 ± .003	5.26
-136	1.987 ± .010	.103 ± .003	5.46
-137	2.050 ± .010	.103 ± .003	5.66
-138	2.112 ± .010	.103 ± .003	5.81
-139	2.175 ± .010	.103 ± .003	6.13
-140	2.237 ± .010	.103 ± .003	6.28
-141	2.300 ± .010	.103 ± .003	6.44
-142	2.362 ± .010	.103 ± .003	6.59
-143	2.425 ± .010	.103 ± .003	6.91
-144	2.487 ± .010	.103 ± .003	7.07
-145	2.550 ± .010	.103 ± .003	7.23
-146	2.612 ± .010	.103 ± .003	7.38
-147	2.675 ± .015	.103 ± .003	7.70
-148	2.737 ± .015	.103 ± .003	7.86

TABLE II (Cont'd)

ARP 568 Dash Nos.	I. D.	W.	d_{100}
-149	2.800 ± .015	.103 ± .003	8.01
-150	2.862 ± .015	.103 ± .003	8.17
-151	2.987 ± .015	.103 ± .003	8.64
-152	3.237 ± .015	.103 ± .003	9.42
-153	3.487 ± .015	.103 ± .003	10.21
-154	3.737 ± .015	.103 ± .003	11.00
-155	3.987 ± .015	.103 ± .003	11.78
-156	4.237 ± .015	.103 ± .003	12.57
-157	4.487 ± .015	.103 ± .003	13.35
-158	4.737 ± .015	.103 ± .003	14.14
-159	4.987 ± .015	.103 ± .003	14.92
-160	5.237 ± .023	.103 ± .003	15.71
-161	5.487 ± .023	.103 ± .003	16.50
-162	5.737 ± .023	.103 ± .003	17.28
-163	5.987 ± .023	.103 ± .003	18.07
-214	.984 ± .006	.139 ± .004	2.36
-215	1.046 ± .006	.139 ± .004	2.51
-216	1.109 ± .006	.139 ± .004	2.67
-217	1.171 ± .006	.139 ± .004	2.83
-218	1.234 ± .006	.139 ± .004	3.14
-219	1.296 ± .006	.139 ± .004	3.30
-220	1.359 ± .006	.139 ± .004	3.46
-221	1.421 ± .006	.139 ± .004	3.61
-222	1.484 ± .006	.139 ± .004	3.93
-223	1.609 ± .010	.139 ± .004	4.24
-224	1.734 ± .010	.139 ± .004	4.71
-225	1.859 ± .010	.139 ± .004	5.03
-226	1.984 ± .010	.139 ± .004	5.50
-227	2.109 ± .010	.139 ± .004	5.81
-228	2.234 ± .010	.139 ± .004	6.28
-229	2.359 ± .010	.139 ± .004	6.60
-230	2.484 ± .010	.139 ± .004	7.07
-231	2.609 ± .010	.139 ± .004	7.37
-232	2.734 ± .015	.139 ± .004	7.86
-233	2.859 ± .015	.139 ± .004	8.17
-234	2.984 ± .015	.139 ± .004	8.64
-235	3.109 ± .015	.139 ± .004	8.95
-236	3.234 ± .015	.139 ± .004	9.43
-237	3.359 ± .015	.139 ± .004	9.74
-238	3.484 ± .015	.139 ± .004	10.21
-239	3.609 ± .015	.139 ± .004	10.53
-240	3.734 ± .015	.139 ± .004	11.00
-241	3.859 ± .015	.139 ± .004	11.31
-242	3.984 ± .015	.139 ± .004	11.78
-243	4.109 ± .015	.139 ± .004	12.10
-244	4.234 ± .015	.139 ± .004	12.57
-245	4.359 ± .015	.139 ± .004	12.88
-246	4.484 ± .015	.139 ± .004	13.35
-247	4.609 ± .015	.139 ± .004	13.67
-248	4.734 ± .015	.139 ± .004	14.14
-249	4.859 ± .015	.139 ± .004	14.45
-250	4.984 ± .015	.139 ± .004	14.77