

Living Math

*Seeing mathematics in every day life
(and appreciating it more too).*

**...just the color figures for those who got the B&W
printed book...**

by D. James Benton

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Foreword

A friend once told me that he couldn't remember the last time he had used calculus. How sad. I can't remember the last time I didn't use calculus. Mathematics isn't just esoteric busywork. It's the language of cause and effect—a description of why things work the way they do. Mathematics connects the dots in the picture that is the world around us. Understanding the mathematical relationships between objects and events will give you a whole different perspective, like seeing color in a world where others see only black and white. Join me on this adventure, in which I will take you on a tour of *Living Math*.

*All of the examples contained in this book,
(as well as a lot of free programs) are available at...*

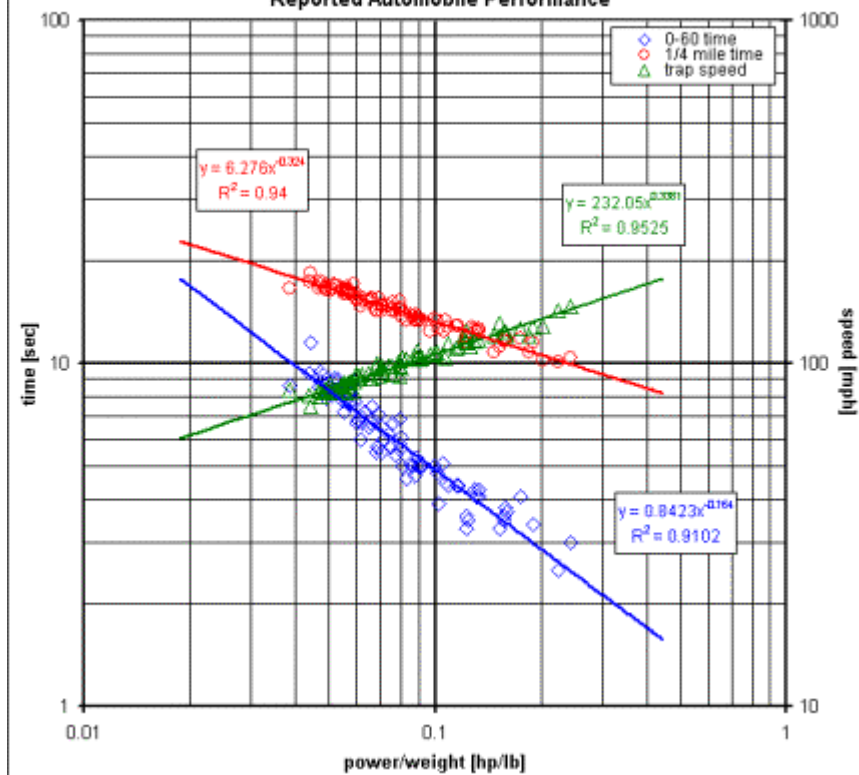
<http://www.dudleybenton.altervista.org/software/index.html>

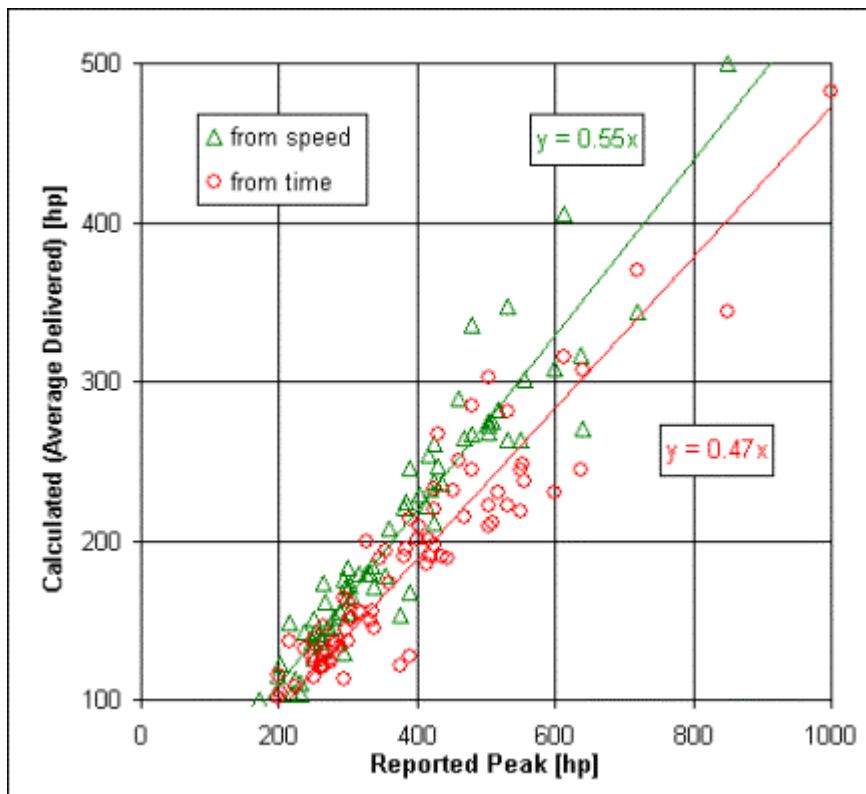




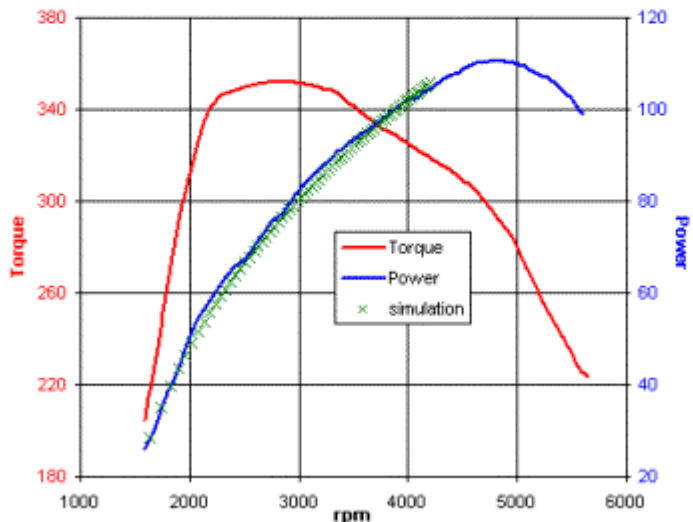


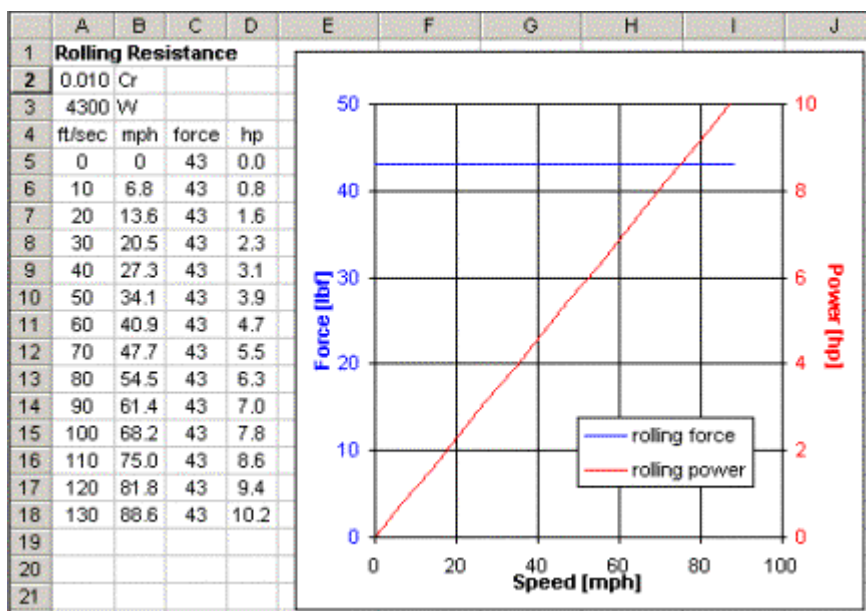
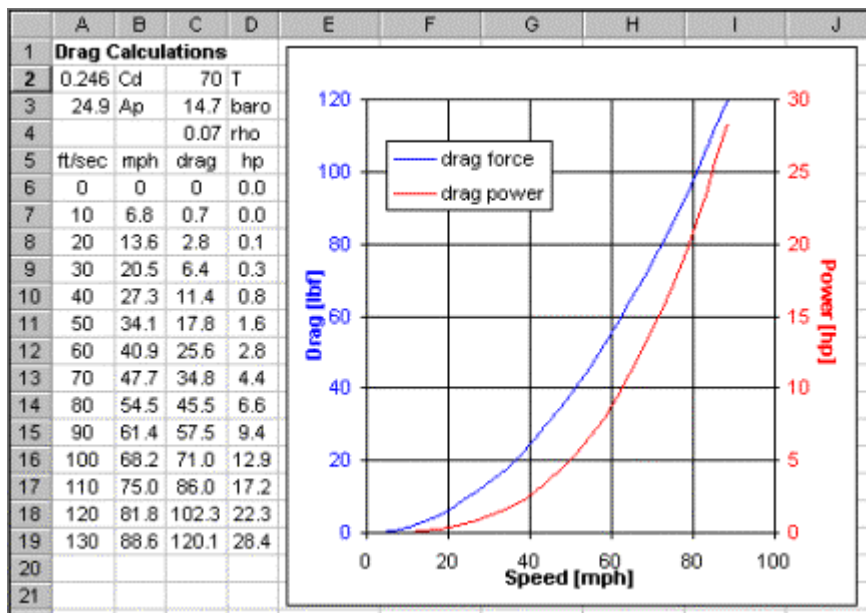
Reported Automobile Performance

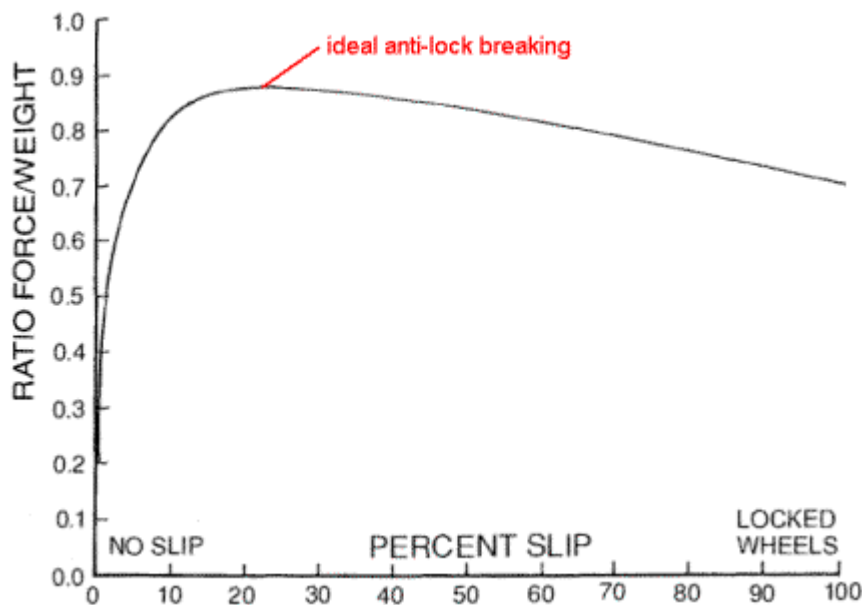




| | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
|----|---------------------|-------|----|------|------------|-----------------------------------|--------|-------|--------|------------|-----------------------|------|------|--------|
| 1 | 0-60 mph simulation | | | | | | | | | | | | | |
| 2 | t | eng | P | V | P | V ² | V | V | 60 | mph | typical engine curves | | | |
| 3 | sec | rpm | hp | mph | ft-lbf/sec | ft ² /sec ² | ft/sec | V | 88 | ft/sec | rpm | hp | rpm | torque |
| 4 | 0.00 | 1,500 | 0 | 0 | 0 | 0 | 0 | m | 3308 | lbm | 1587 | 26.0 | 1592 | 204 |
| 5 | 0.12 | 1,633 | 28 | 3.0 | 15,538 | 18.8 | 4.3 | m | 102.8 | slugs | 1617 | 27.3 | 1618 | 215 |
| 6 | 0.25 | 1,739 | 35 | 5.3 | 19,249 | 60.9 | 7.8 | eng | 4,200 | rpm | 1647 | 28.7 | 1647 | 221 |
| 7 | 0.37 | 1,823 | 40 | 7.2 | 21,817 | 110.6 | 10.5 | P | 150 | hp | 1677 | 30.3 | 1675 | 228 |
| 8 | 0.50 | 1,895 | 43 | 8.8 | 23,845 | 165.9 | 12.9 | P | 82,500 | ft-lbf/sec | 1706 | 32.3 | 1703 | 236 |
| 9 | 0.62 | 1,961 | 46 | 10.2 | 25,547 | 225.7 | 15.0 | tau | 8.95 | sec | 1736 | 34.3 | 1731 | 244 |
| 10 | 0.75 | 2,022 | 49 | 11.6 | 27,027 | 289.3 | 17.0 | alpha | 29579 | - | 1766 | 36.4 | 1759 | 252 |
| 11 | 0.87 | 2,079 | 52 | 12.9 | 28,345 | 356.3 | 18.9 | dt | 0.12 | sec | 1795 | 38.1 | 1787 | 259 |
| 12 | 1.00 | 2,121 | 54 | 14.1 | 29,500 | 437.4 | 20.0 | | | | 1822 | 40.0 | 1815 | 268 |
| 13 | 1.12 | 2,159 | 55 | 15.2 | 30,500 | 532.4 | 21.0 | | | | 1857 | 41.7 | 1843 | 276 |
| 14 | 1.25 | 2,193 | 56 | 16.3 | 31,350 | 641.4 | 22.0 | | | | 1891 | 43.3 | 1871 | 284 |
| 15 | 1.37 | 2,223 | 57 | 17.3 | 32,050 | 764.4 | 23.0 | | | | 1924 | 44.8 | 1899 | 291 |
| 16 | 1.50 | 2,250 | 58 | 18.3 | 32,600 | 901.4 | 24.0 | | | | 1956 | 46.2 | 1927 | 299 |
| 17 | 1.62 | 2,273 | 59 | 19.3 | 33,000 | 1052.4 | 25.0 | | | | 1987 | 47.5 | 1957 | 303 |
| 18 | 1.75 | 2,293 | 60 | 20.2 | 33,250 | 1217.4 | 26.0 | | | | 2017 | 48.7 | 1985 | 310 |
| 19 | 1.87 | 2,310 | 61 | 21.1 | 33,450 | 1396.4 | 27.0 | | | | 2046 | 50.0 | 2014 | 315 |
| 20 | 2.00 | 2,325 | 62 | 22.0 | 33,600 | 1589.4 | 28.0 | | | | 2074 | 51.1 | 2043 | 321 |
| 21 | 2.12 | 2,337 | 63 | 22.9 | 33,700 | 1796.4 | 29.0 | | | | 2101 | 52.1 | 2072 | 326 |
| 22 | 2.25 | 2,347 | 64 | 23.7 | 33,750 | 2017.4 | 30.0 | | | | 2127 | 53.0 | 2101 | 331 |
| 23 | 2.37 | 2,355 | 65 | 24.5 | 33,750 | 2252.4 | 31.0 | | | | 2152 | 53.8 | 2131 | 335 |
| 24 | 2.50 | 2,361 | 66 | 25.3 | 33,700 | 2501.4 | 32.0 | | | | 2176 | 54.5 | 2160 | 338 |
| 25 | 2.62 | 2,365 | 67 | 26.1 | 33,600 | 2764.4 | 33.0 | | | | 2200 | 55.1 | 2190 | 341 |
| 26 | 2.75 | 2,367 | 68 | 26.9 | 33,450 | 3041.4 | 34.0 | | | | 2223 | 55.6 | 2220 | 343 |
| 27 | 2.87 | 2,367 | 69 | 27.6 | 33,250 | 3332.4 | 35.0 | | | | 2245 | 56.0 | 2250 | 345 |
| 28 | 3.00 | 2,365 | 70 | 28.3 | 33,000 | 3637.4 | 36.0 | | | | 2266 | 56.3 | 2279 | 346 |
| 29 | 3.12 | 2,361 | 71 | 29.0 | 32,700 | 3956.4 | 37.0 | | | | 2286 | 56.5 | 2309 | 347 |
| 30 | 3.25 | 2,355 | 72 | 29.7 | 32,350 | 4289.4 | 38.0 | | | | 2305 | 56.6 | 2339 | 347 |
| 31 | 3.37 | 2,347 | 73 | 30.4 | 31,950 | 4636.4 | 39.0 | | | | 2323 | 56.6 | 2369 | 348 |
| 32 | 3.50 | 2,337 | 74 | 31.1 | 31,500 | 5007.4 | 40.0 | | | | 2340 | 56.5 | 2399 | 348 |
| 33 | 3.62 | 2,325 | 75 | 31.8 | 31,000 | 5402.4 | 41.0 | | | | 2356 | 56.3 | 2429 | 348 |
| 34 | 3.75 | 2,310 | 76 | 32.5 | 30,450 | 5821.4 | 42.0 | | | | 2371 | 56.0 | 2459 | 349 |
| 35 | 3.88 | 2,293 | 77 | 33.2 | 29,850 | 6264.4 | 43.0 | | | | 2385 | 55.6 | 2489 | 349 |

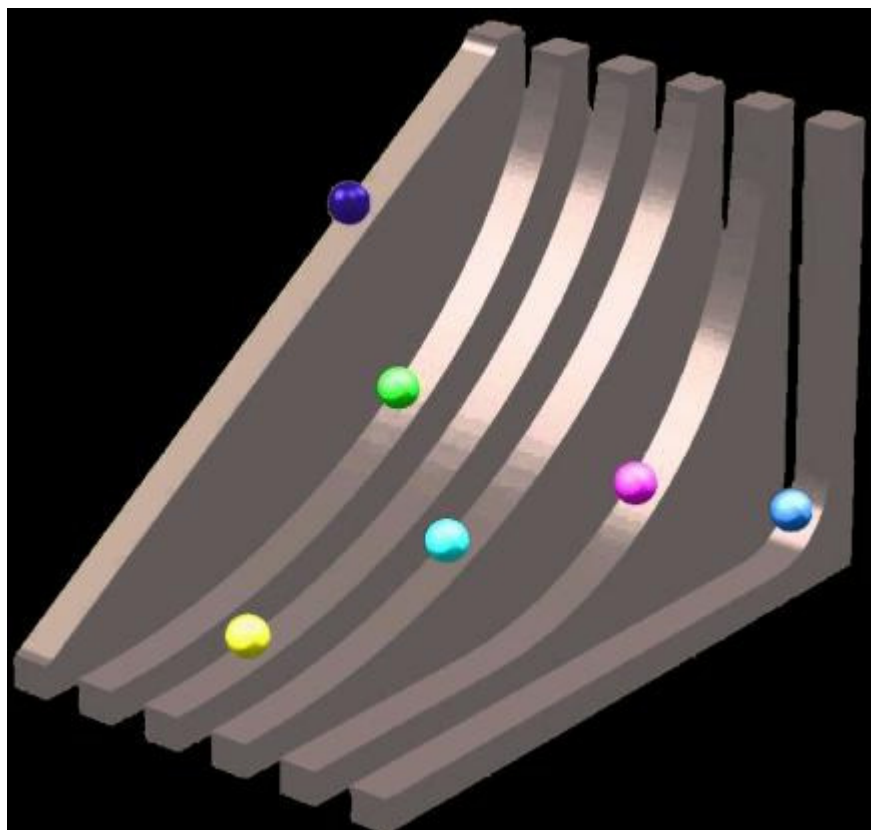


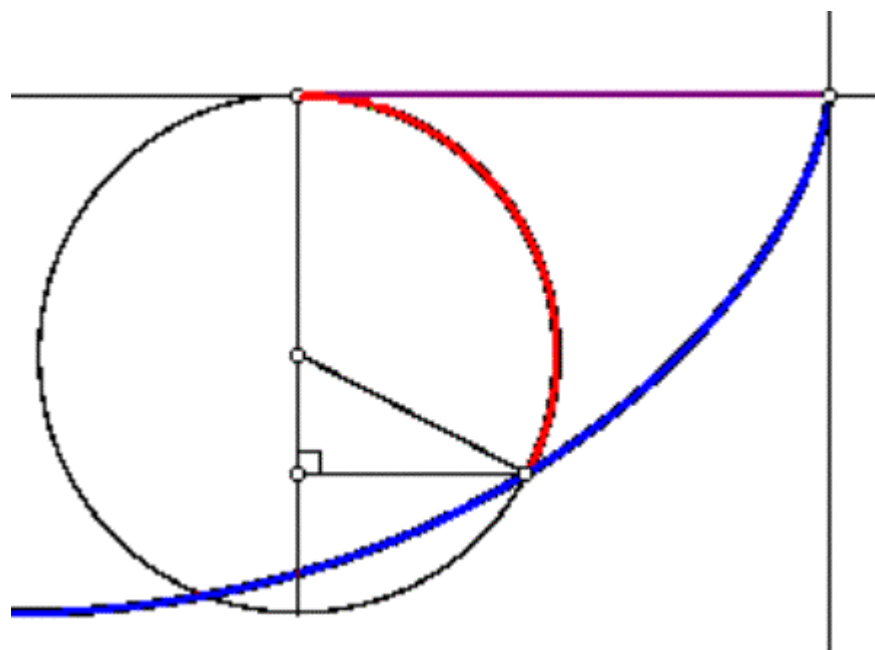


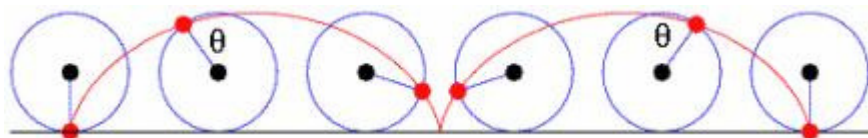


| | A | B | C | D | E | F | G | H | I | J | K | L |
|----|------------------|-----|--------|------|--------|------|---|---|---|---|---|---|
| 1 | Braking Distance | | | f= | 0.9 | NTSA | | | | | | |
| 2 | mph | ft. | adjust | fadj | ft.adj | ft | | | | | | |
| 3 | 0 | 0 | 1.36 | 1.00 | 0 | | | | | | | |
| 4 | 5 | 1 | 1.19 | 1.00 | 1 | | | | | | | |
| 5 | 10 | 4 | 1.07 | 0.96 | 3 | | | | | | | |
| 6 | 15 | 8 | 0.98 | 0.88 | 8 | | | | | | | |
| 7 | 20 | 15 | 0.92 | 0.83 | 15 | | | | | | | |
| 8 | 25 | 23 | 0.87 | 0.78 | 24 | | | | | | | |
| 9 | 30 | 33 | 0.84 | 0.75 | 36 | 43 | | | | | | |
| 10 | 35 | 46 | 0.81 | 0.73 | 51 | | | | | | | |
| 11 | 40 | 59 | 0.79 | 0.71 | 68 | 76 | | | | | | |
| 12 | 45 | 75 | 0.78 | 0.70 | 88 | | | | | | | |
| 13 | 50 | 93 | 0.77 | 0.69 | 111 | 119 | | | | | | |
| 14 | 55 | 112 | 0.76 | 0.68 | 137 | 144 | | | | | | |
| 15 | 60 | 134 | 0.76 | 0.68 | 165 | | | | | | | |
| 16 | 65 | 157 | 0.76 | 0.68 | 195 | 201 | | | | | | |
| 17 | 70 | 182 | 0.76 | 0.68 | 228 | | | | | | | |
| 18 | 75 | 209 | 0.76 | 0.68 | 264 | 268 | | | | | | |
| 19 | 80 | 238 | 0.76 | 0.68 | 302 | | | | | | | |
| 20 | 85 | 268 | 0.76 | 0.68 | 342 | 344 | | | | | | |
| 21 | | | | | | | | | | | | |

Graph showing Braking Distance (ft) (Y-axis, 0 to 350) versus Vehicle Speed (mph) (X-axis, 0 to 90). The graph compares two braking models: "adjusted f" (blue line) and "constant f" (green line). The "adjusted f" model shows significantly longer braking distances at higher speeds compared to the "constant f" model. Red triangles represent "NTSA" data points, which closely follow the "adjusted f" model.

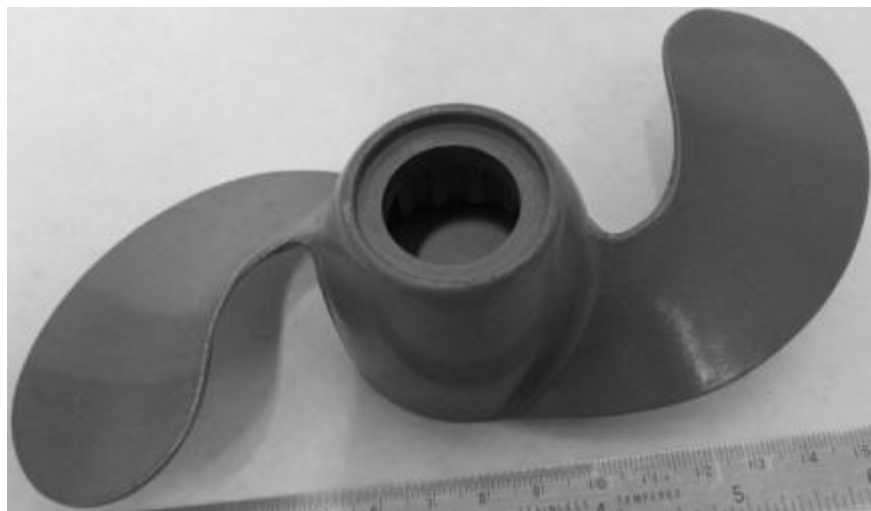




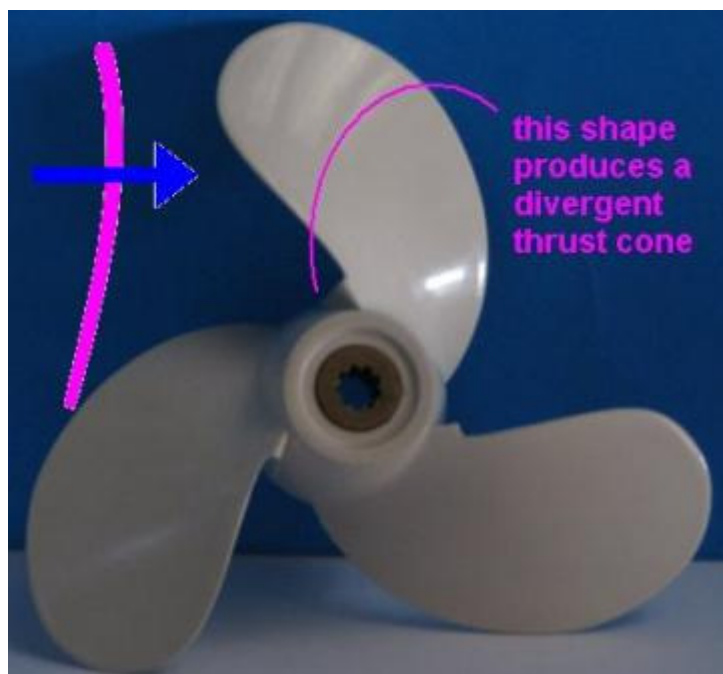
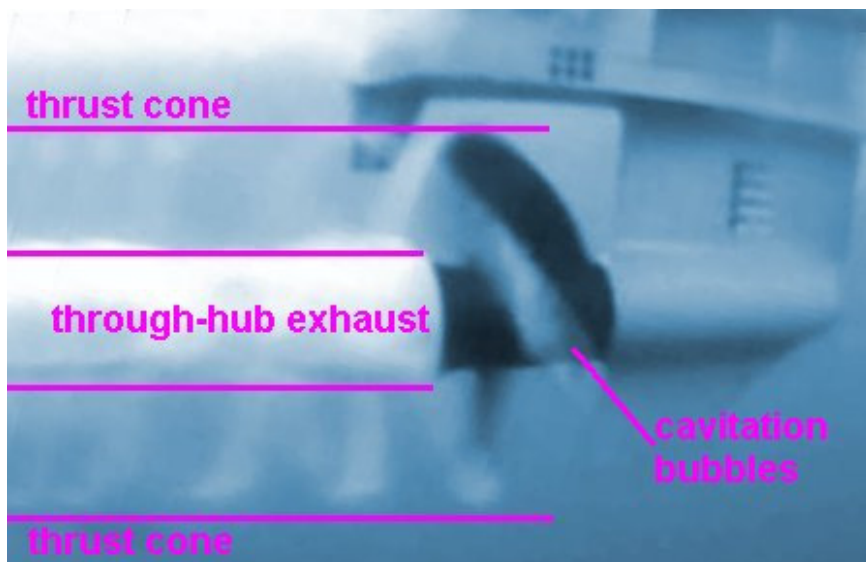


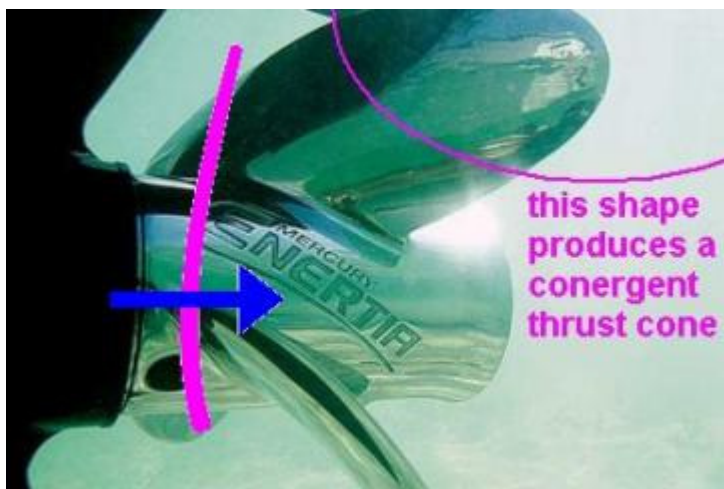


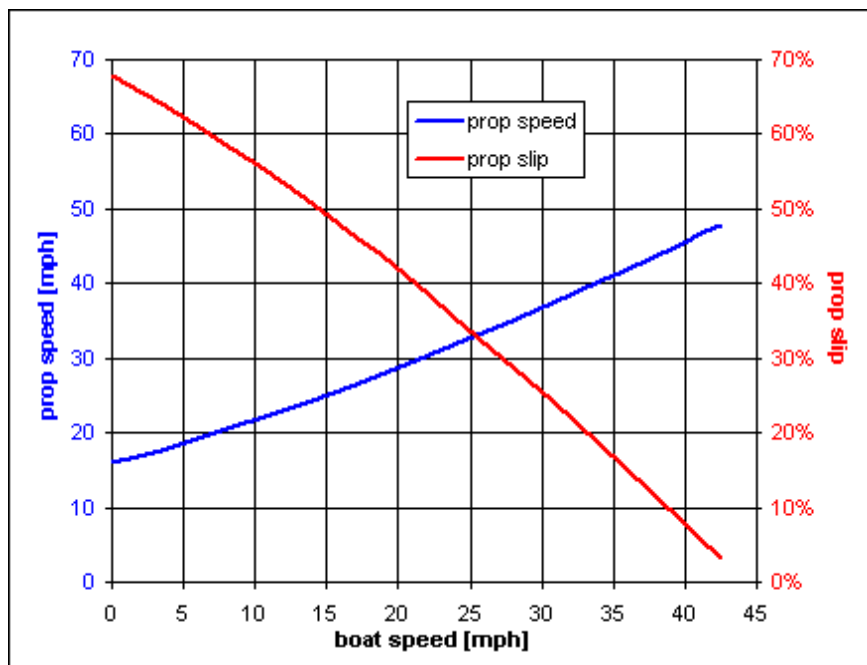








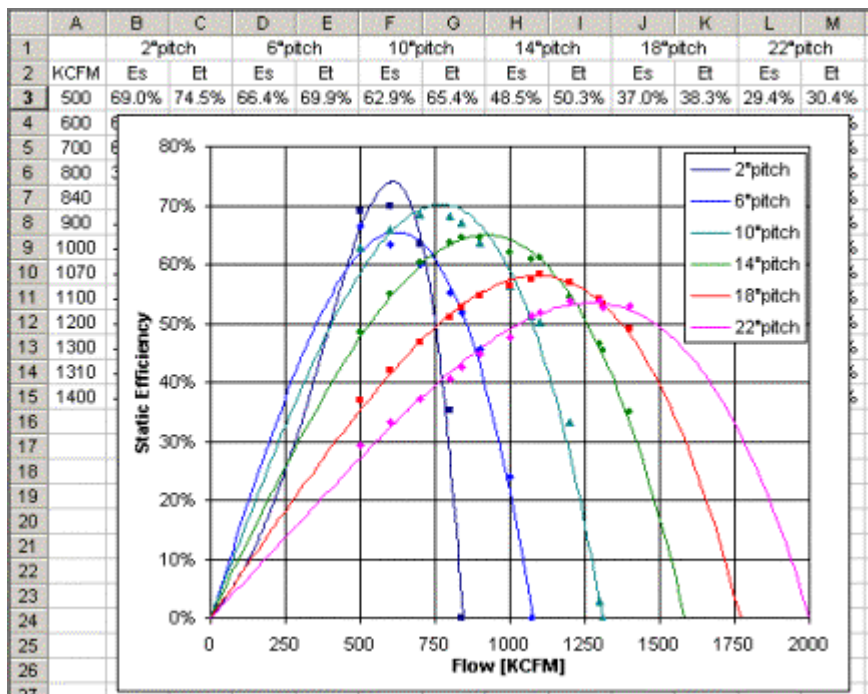


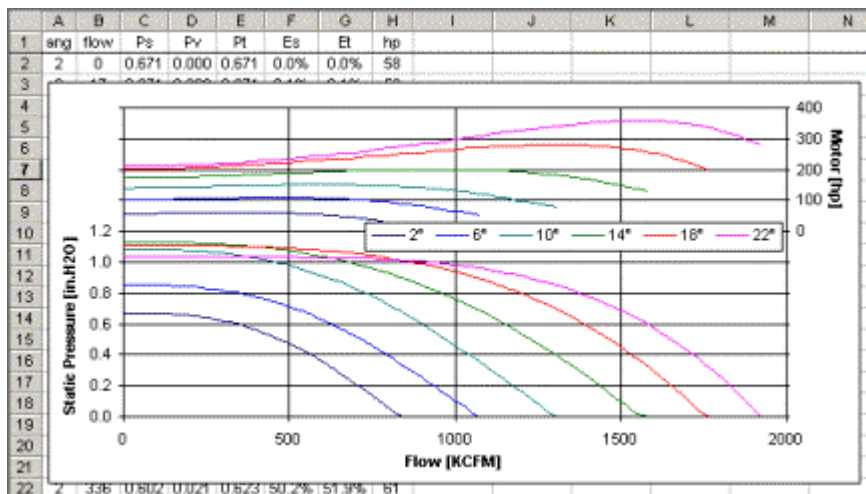
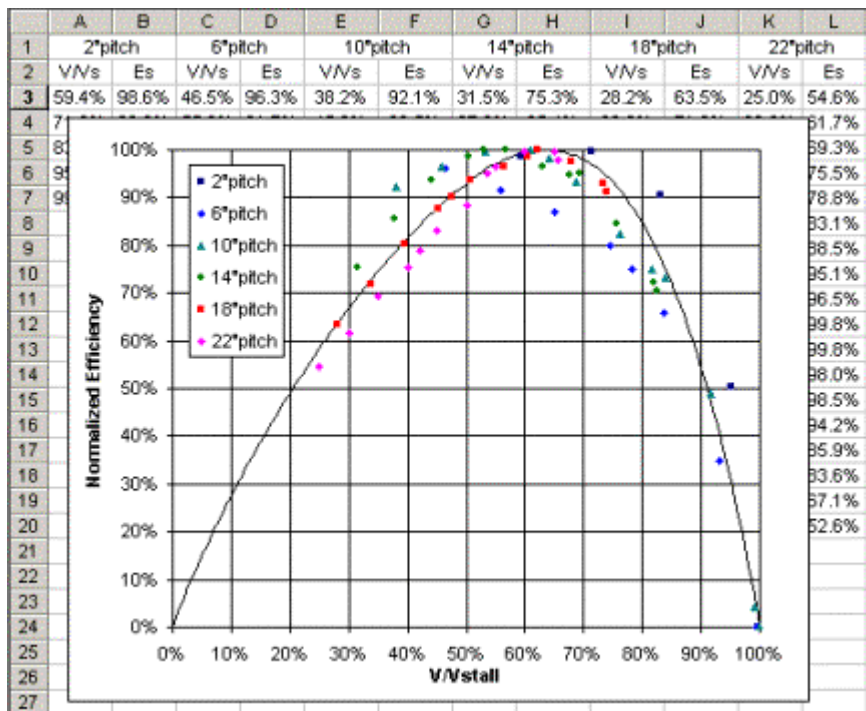






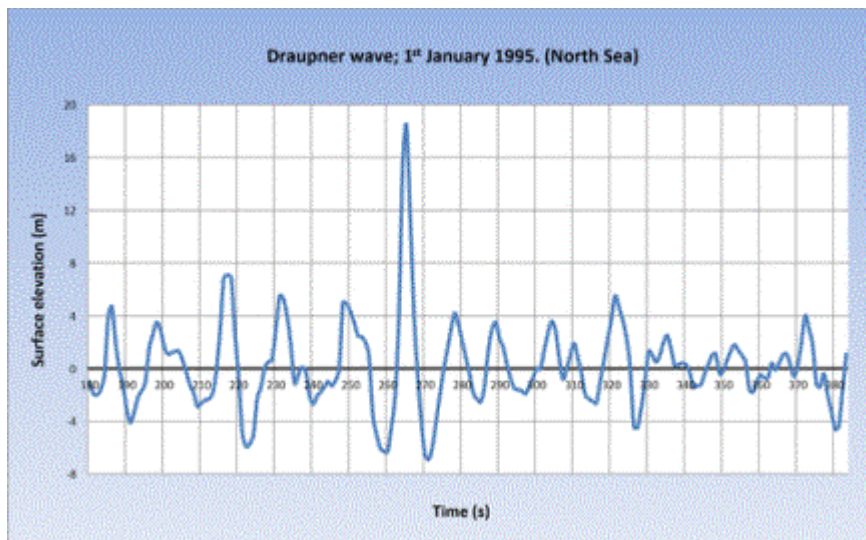




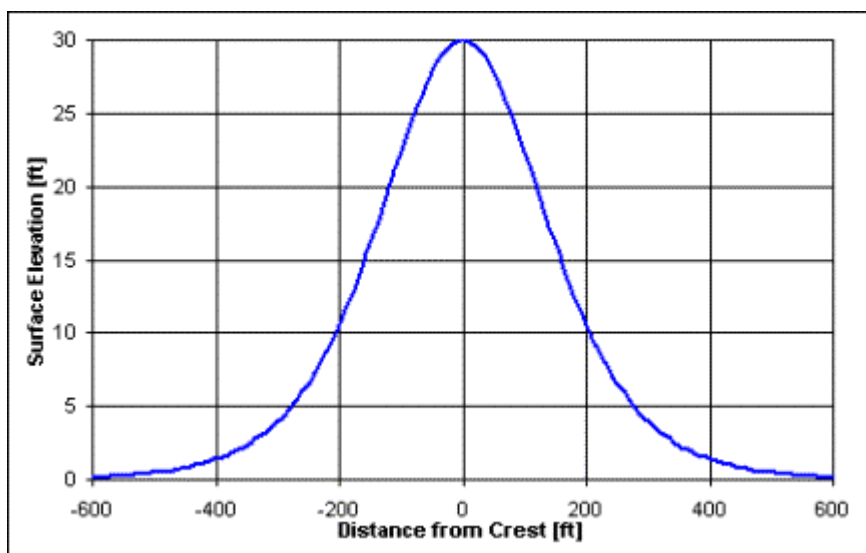


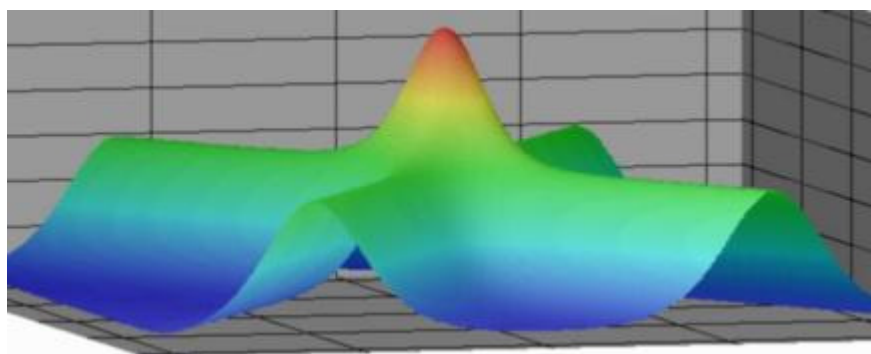
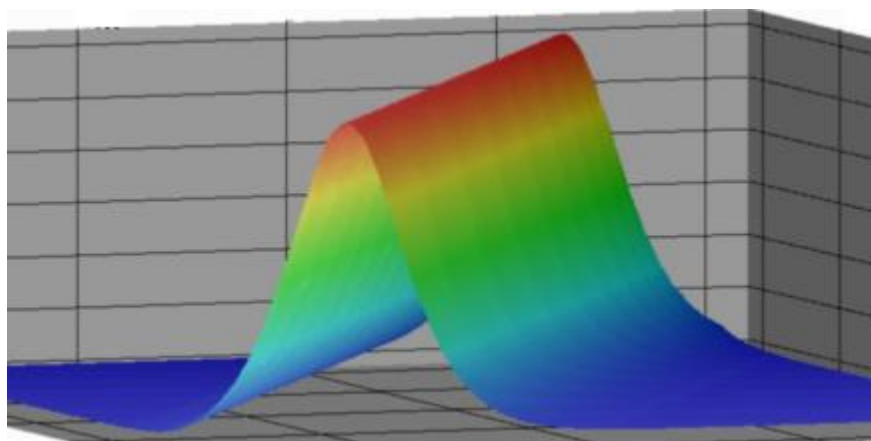


Rogue wave [image from BBC Horizons, 2002]



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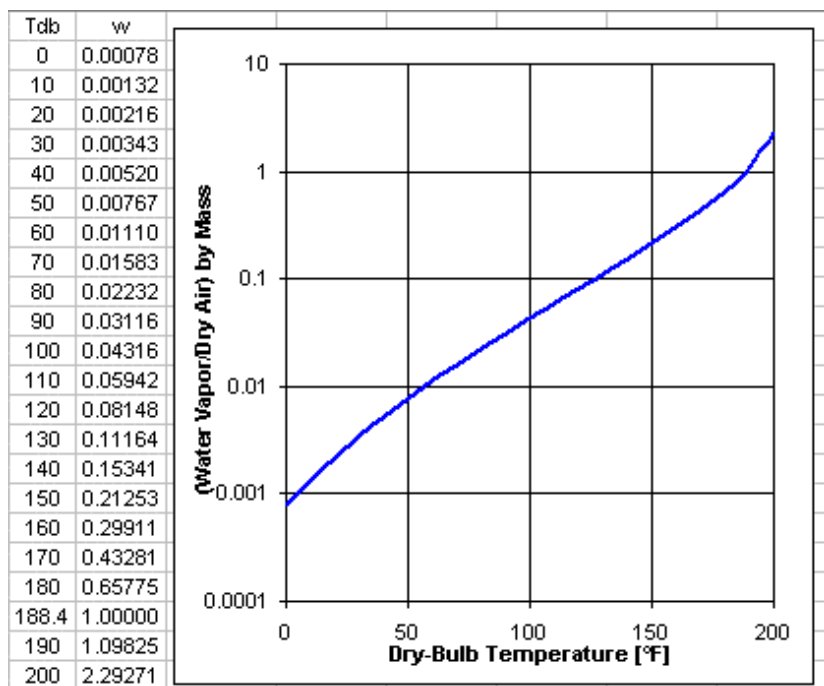




| The Heat Index | | | | | | | | | | | | | | | | | | | | | |
|----------------|-------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| Temp (°F) | Relative Humidity | | | | | | | | | | | | | | | | | | | | |
| | 0% | 5% | 10% | 15% | 20% | 25% | 30% | 35% | 40% | 45% | 50% | 55% | 60% | 65% | 70% | 75% | 80% | 85% | 90% | 95% | 100% |
| 135 | 120 | 126 | | | | | | | | | | | | | | | | | | | |
| 130 | 117 | 122 | 131 | | | | | | | | | | | | | | | | | | |
| 125 | 111 | 116 | 123 | 131 | 141 | | | | | | | | | | | | | | | | |
| 120 | 107 | 111 | 116 | 123 | 130 | 139 | 148 | | | | | | | | | | | | | | |
| 115 | 105 | 107 | 111 | 118 | 120 | 127 | 135 | 143 | 151 | | | | | | | | | | | | |
| 110 | 98 | 102 | 105 | 108 | 112 | 117 | 123 | 130 | 137 | 143 | 150 | | | | | | | | | | |
| 105 | 95 | 97 | 100 | 102 | 105 | 109 | 113 | 118 | 123 | 129 | 135 | 142 | 149 | | | | | | | | |
| 100 | 91 | 93 | 96 | 97 | 99 | 101 | 104 | 107 | 110 | 115 | 120 | 125 | 132 | 138 | 144 | 150 | | | | | |
| 95 | 87 | 88 | 90 | 91 | 93 | 94 | 96 | 98 | 101 | 104 | 107 | 110 | 114 | 119 | 124 | 130 | 135 | 140 | 150 | | |
| 90 | 83 | 84 | 85 | 86 | 87 | 88 | 90 | 91 | 93 | 95 | 96 | 98 | 100 | 102 | 105 | 109 | 113 | 117 | 122 | 126 | 131 |
| 85 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 93 | 95 | 97 | 99 | 102 | 105 | 108 |
| 80 | 73 | 74 | 75 | 76 | 77 | 77 | 78 | 79 | 79 | 80 | 81 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 |
| 75 | 69 | 69 | 70 | 71 | 72 | 72 | 73 | 73 | 74 | 74 | 75 | 75 | 76 | 76 | 77 | 77 | 78 | 78 | 79 | 79 | 80 |
| 70 | 64 | 64 | 65 | 65 | 66 | 66 | 67 | 67 | 68 | 68 | 69 | 69 | 70 | 70 | 70 | 71 | 71 | 71 | 71 | 71 | 72 |

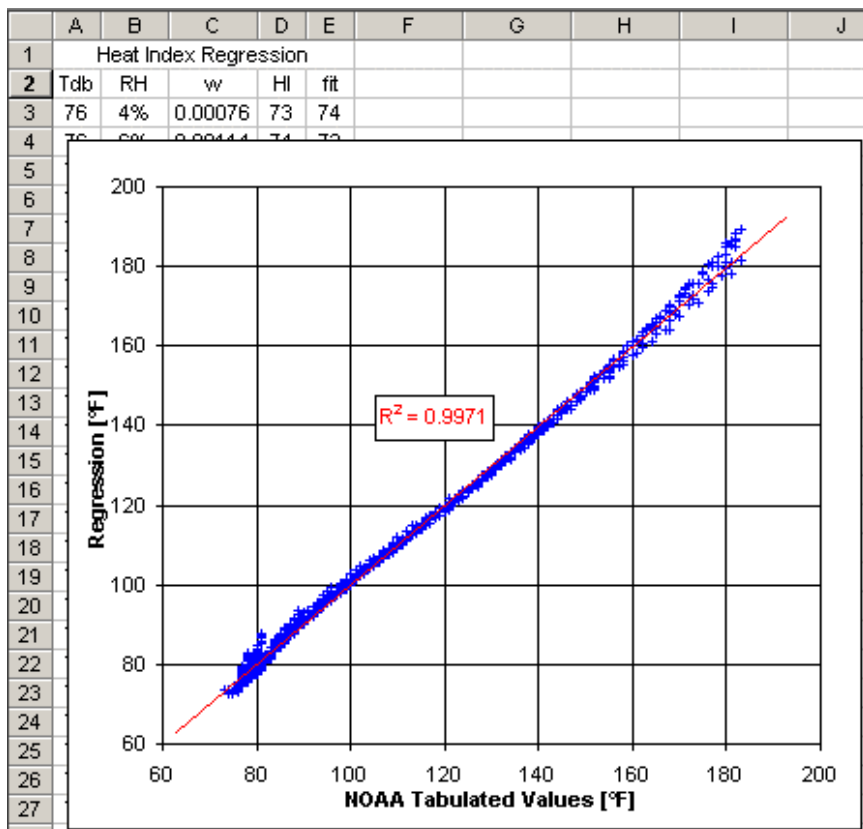
- Heatstroke risk extremely high
- Heat exhaustion likely, heatstroke possible
- Heat exhaustion possible
- Fatigue possible

:



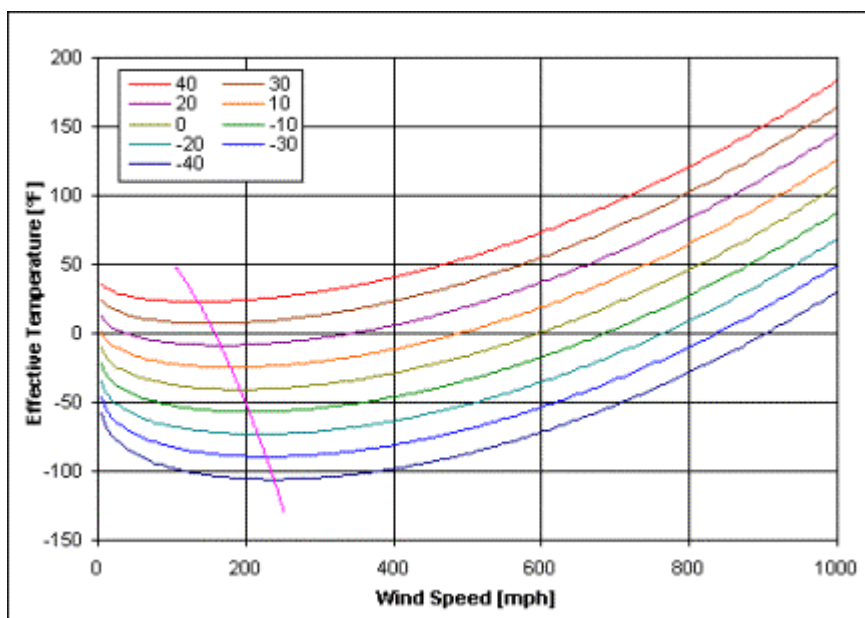
Fraction of Total Energy in Water Vapor Alone

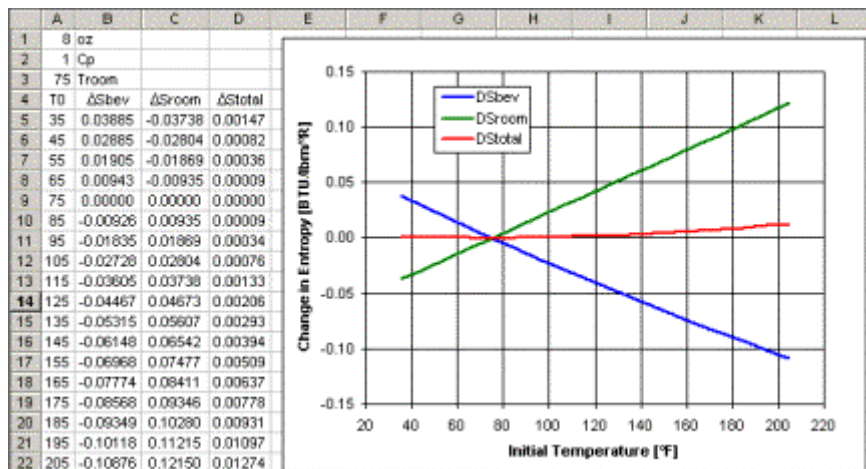
| Tdb | Relative Humidity | | | | | | | | | | |
|-----|-------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| | 0% | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100% |
| 30 | 0% | 5% | 9% | 13% | 17% | 20% | 23% | 26% | 29% | 31% | 34% |
| 40 | 0% | 5% | 10% | 15% | 19% | 23% | 26% | 29% | 32% | 34% | 37% |
| 50 | 0% | 6% | 12% | 17% | 22% | 26% | 29% | 33% | 36% | 38% | 41% |
| 60 | 0% | 8% | 14% | 20% | 25% | 29% | 33% | 37% | 40% | 43% | 46% |
| 70 | 0% | 9% | 17% | 23% | 29% | 34% | 38% | 42% | 45% | 48% | 51% |
| 80 | 0% | 11% | 20% | 27% | 33% | 38% | 43% | 47% | 50% | 53% | 56% |
| 90 | 0% | 13% | 23% | 31% | 38% | 44% | 48% | 52% | 56% | 59% | 61% |
| 100 | 0% | 16% | 27% | 36% | 43% | 49% | 54% | 58% | 61% | 64% | 66% |



NOAA Wind Chill Chart - Temperature [°F]

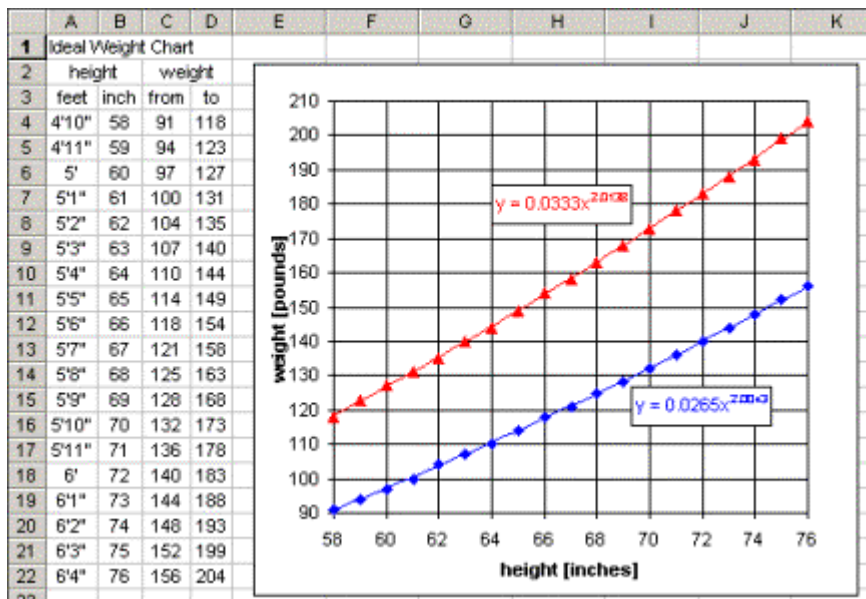
| mph | 40 | 35 | 30 | 25 | 20 | 15 | 10 | 5 | 0 | -5 | -10 | -15 | -20 | -25 | -30 | -35 | -40 | -45 | |
|-----------------|------------|----|----|----|----|------------|-----|-----|-----|-----|-----------|-----|-----|-----|-----|-----|-----|-----|--|
| 5 | 36 | 31 | 25 | 19 | 13 | 7 | 1 | -5 | -11 | -16 | -22 | -28 | -34 | -40 | -46 | -52 | -57 | -63 | |
| 10 | 34 | 27 | 21 | 15 | 9 | 3 | -4 | -10 | -16 | -22 | -28 | -35 | -41 | -47 | -53 | -59 | -66 | -72 | |
| 15 | 32 | 25 | 19 | 13 | 6 | 0 | -7 | -13 | -19 | -26 | -32 | -39 | -45 | -51 | -58 | -64 | -71 | -77 | |
| 20 | 30 | 24 | 17 | 11 | 4 | -2 | -9 | -15 | -22 | -29 | -35 | -42 | -48 | -55 | -61 | -68 | -74 | -81 | |
| 25 | 29 | 23 | 16 | 9 | 3 | -4 | -11 | -17 | -24 | -31 | -37 | -44 | -51 | -58 | -64 | -71 | -78 | -84 | |
| 30 | 28 | 22 | 15 | 8 | 1 | -5 | -12 | -19 | -26 | -33 | -39 | -46 | -53 | -60 | -67 | -73 | -80 | -87 | |
| 35 | 28 | 21 | 14 | 7 | 0 | -7 | -14 | -21 | -27 | -34 | -41 | -48 | -55 | -62 | -69 | -76 | -82 | -89 | |
| 40 | 27 | 20 | 13 | 6 | -1 | -8 | -15 | -22 | -29 | -36 | -43 | -50 | -57 | -64 | -71 | -78 | -84 | -91 | |
| 45 | 26 | 19 | 12 | 5 | -2 | -9 | -16 | -23 | -30 | -37 | -44 | -51 | -58 | -65 | -72 | -79 | -86 | -93 | |
| 50 | 26 | 19 | 12 | 4 | -3 | -10 | -17 | -24 | -31 | -38 | -45 | -52 | -60 | -67 | -74 | -81 | -88 | -95 | |
| 55 | 25 | 18 | 11 | 4 | -3 | -11 | -18 | -25 | -32 | -39 | -46 | -54 | -61 | -68 | -75 | -82 | -89 | -97 | |
| 60 | 25 | 17 | 10 | 3 | -4 | -11 | -19 | -26 | -33 | -40 | -48 | -55 | -62 | -69 | -76 | -84 | -91 | -98 | |
| Frostbite Times | 30 minutes | | | | | 10 minutes | | | | | 5 minutes | | | | | | | | |







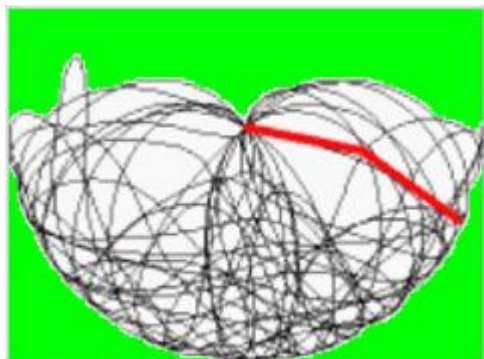









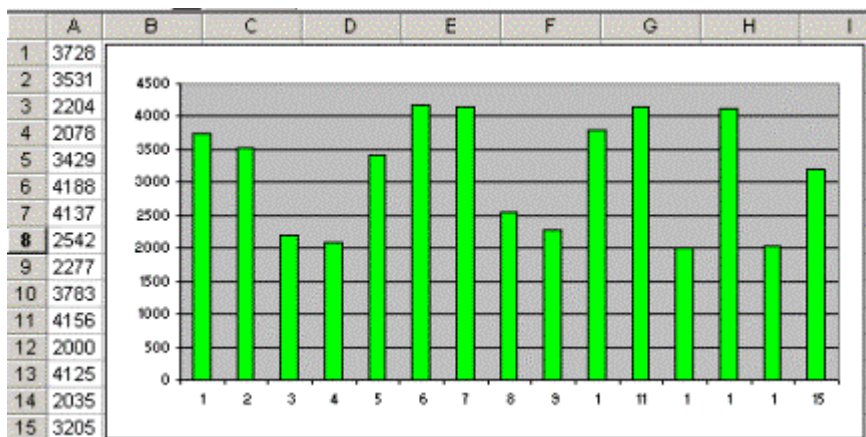




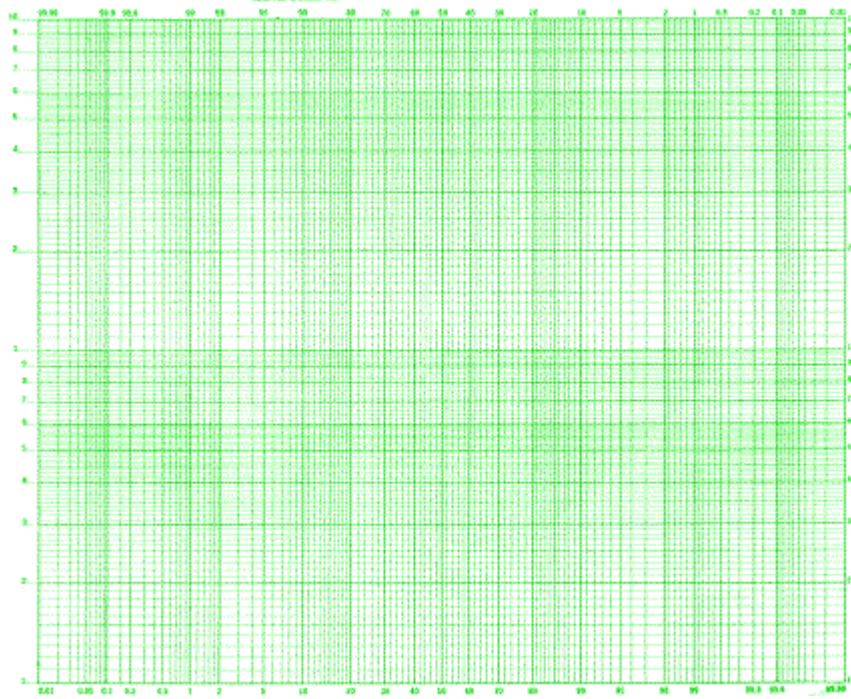
A double rod pendulum 



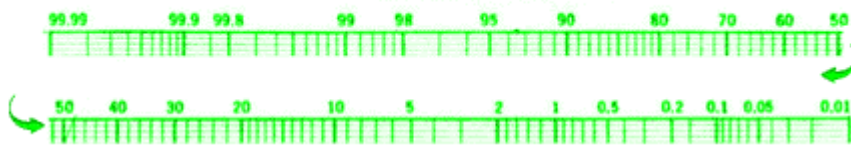
Barnsley fern created using 



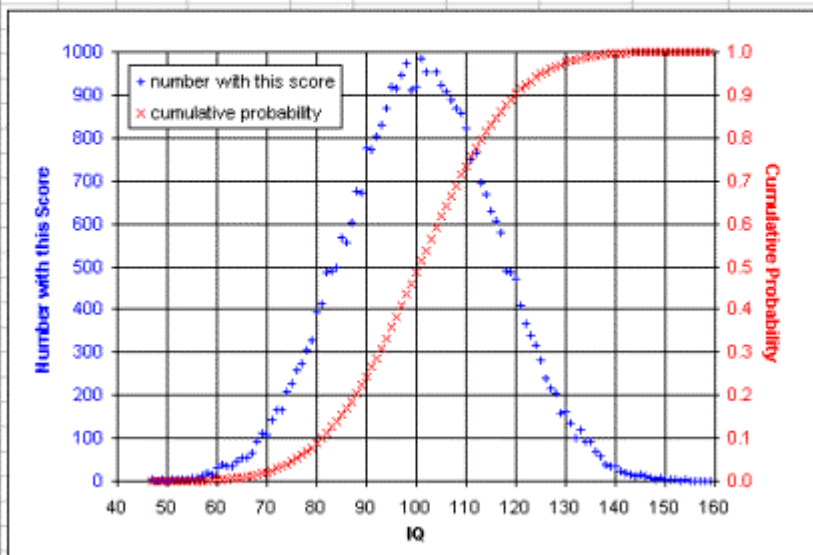
K·E PROBABILITY 46 8043
X 2 LOG CYCLES
NEUFFEL & ESSER CO.



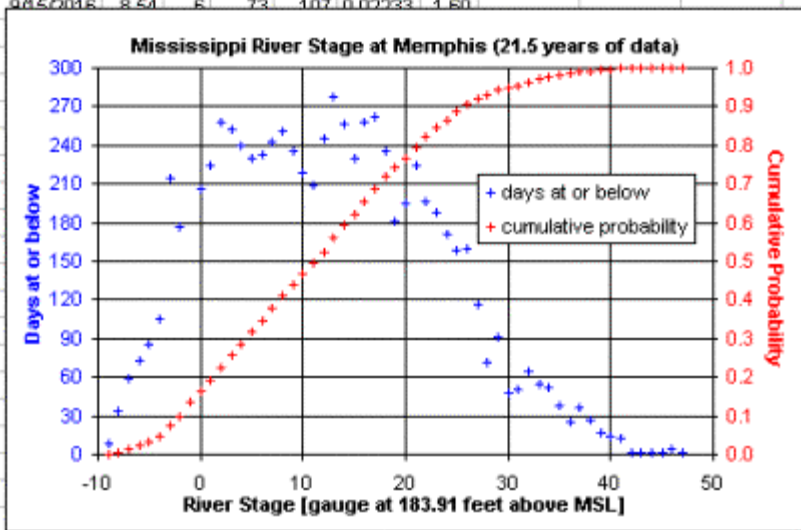
K·E PROBABILITY 46 8043
X 2 LOG CYCLES
NEUFFEL & ESSER CO.
MADE IN U.S.A.



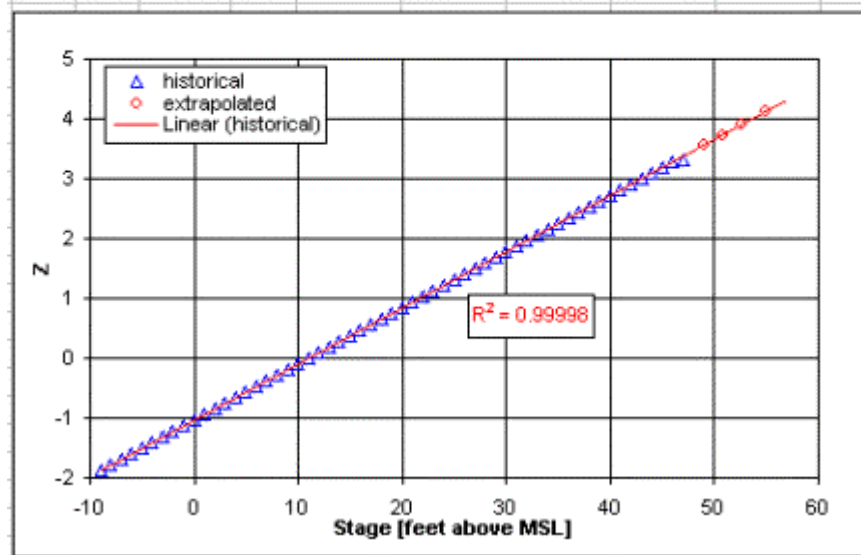
| | A | B | C | D | E | F | G | H | I | J |
|---|-----------|----|--------|-------------|-------|---|---|---|---|---|
| 1 | IQ Scores | | | cumulative | Z | | | | | |
| 2 | score | 46 | number | probability | score | | | | | |
| 3 | 80 | 47 | 2 | 0.0000545 | -3.56 | | | | | |
| 4 | 123 | 48 | 0 | 0.0000545 | -3.49 | | | | | |
| 5 | 104 | 49 | 4 | 0.0001634 | -3.42 | | | | | |



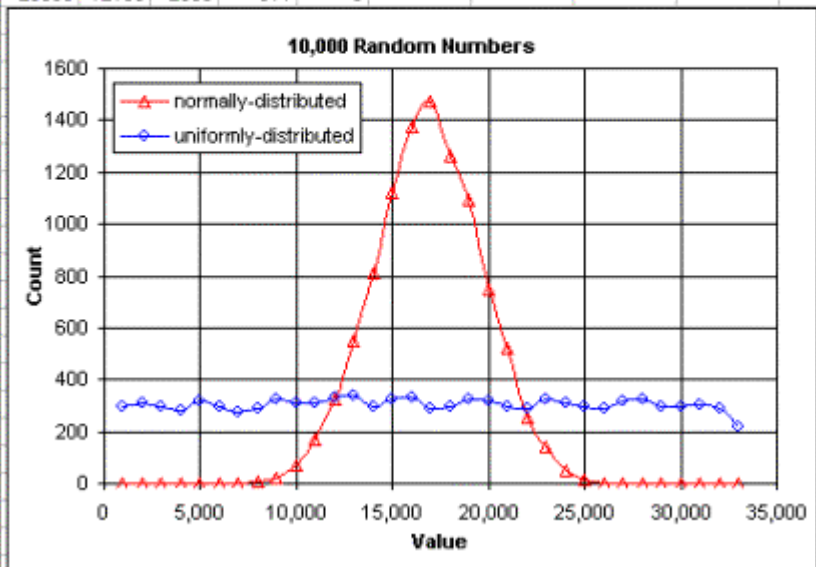
| | A | B | C | D | E | F | G | H | I | J |
|---|---|-------|------|-------|-------|---------|-------|---|---|---|
| 1 | Mississippi River at Memphis (21.5 years of data) | | | | | | | | | |
| 2 | date | stage | feet | days | recur | cum. | | | | |
| 3 | 9/19/2016 | 7.19 | -10 | above | days | prob. | Z | | | |
| 4 | 9/18/2016 | 7.60 | -9 | 9 | 871 | 0.00115 | -1.88 | | | |
| 5 | 9/17/2016 | 7.82 | -8 | 34 | 230 | 0.00549 | -1.79 | | | |
| 6 | 9/16/2016 | 8.61 | -7 | 59 | 133 | 0.01302 | -1.69 | | | |
| 7 | 9/15/2016 | 8.54 | 6 | 73 | 107 | 0.02233 | 1.60 | | | |



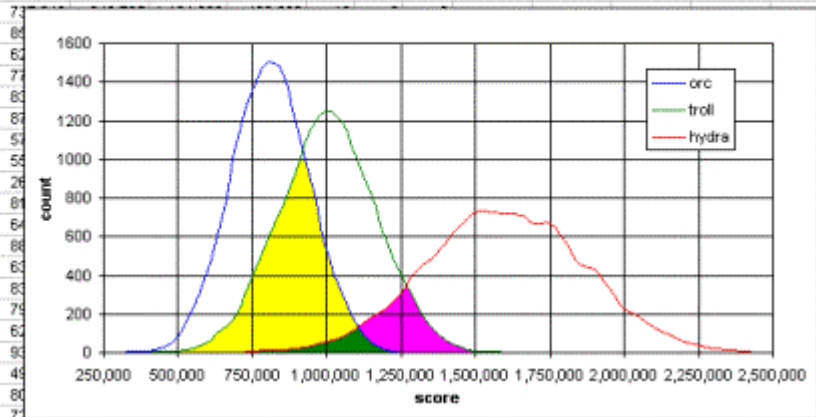
| L | M | N | O | P | Q | R | S | T | U |
|------------|-------|---------|-------|---|---|---|---|---|---|
| projection | | | | | | | | | |
| ft | Z | P | years | | | | | | |
| 48.98 | 3.555 | 0.99981 | 50 | | | | | | |
| 50.88 | 3.734 | 0.99991 | 100 | | | | | | |
| 52.70 | 3.905 | 0.99995 | 200 | | | | | | |
| 55.01 | 4.121 | 0.99998 | 500 | | | | | | |



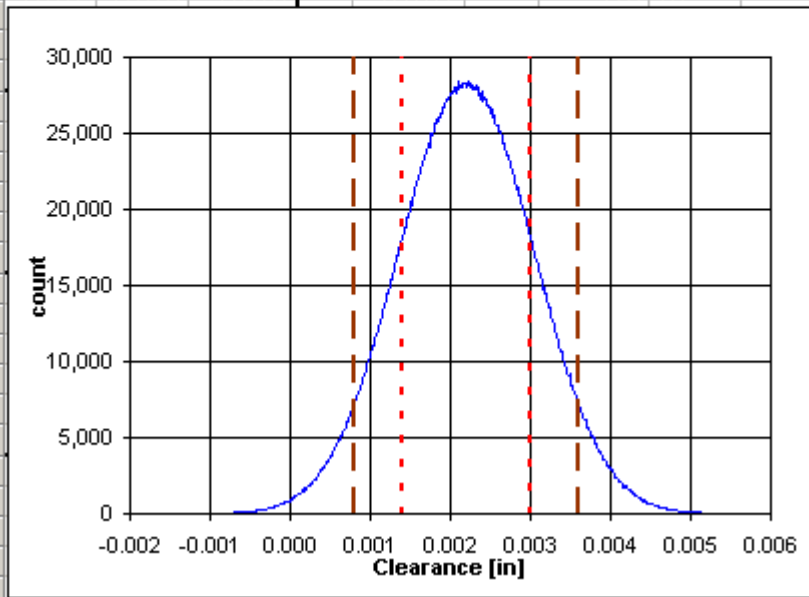
| | A | B | C | D | E | F | G | H | I |
|---|-----------------------|--------|-------|---------|--------|---|---|---|---|
| 1 | 10,000 Random Numbers | | | | | | | | |
| 2 | uniform | normal | range | count | | | | | |
| 3 | 12086 | 18579 | 0 | uniform | normal | | | | |
| 4 | 1638 | 18403 | 1000 | 298 | 0 | | | | |
| 5 | 29606 | 12160 | 2000 | 311 | 0 | | | | |



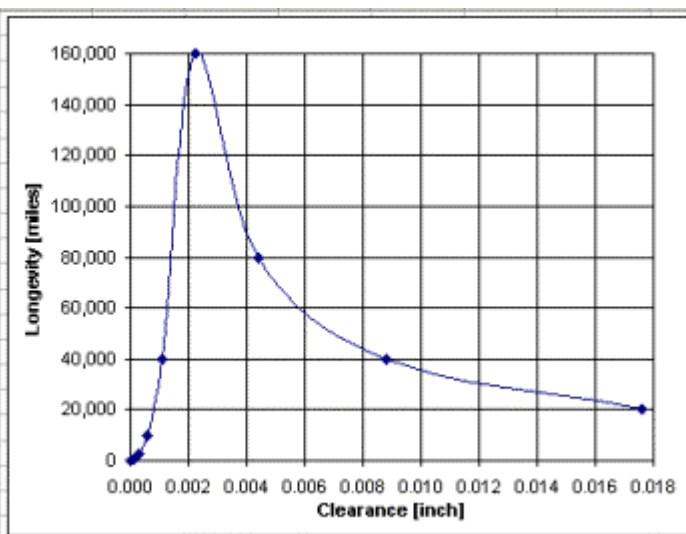
| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---------|-----------|-----------|---------|-----|-------|-------|---|---|---|---|---|
| 1 | score | | | | | | | | | | | |
| 2 | ork | troll | hydra | 250,000 | ork | troll | hydra | | | | | |
| 3 | 963,736 | 940,695 | 1,682,464 | 300,000 | 2 | 0 | 0 | | | | | |
| 4 | 495,184 | 1,083,980 | 1,561,696 | 350,000 | 4 | 0 | 0 | | | | | |



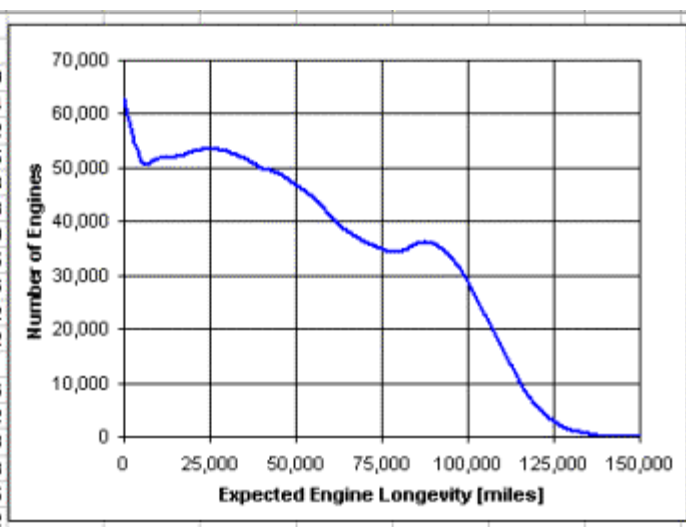
| | A | B | C | D | E | F | G | H | I |
|---|----------|---------|-----------|-----|-----------------|-------|-----------|-----------|---|
| 1 | cylinder | piston | clearance | | 6,000,000 units | | 1,023,169 | too small | |
| 2 | 3.73820 | 3.73600 | 0.00220 | | clearance | count | 1,023,166 | too large | |
| 3 | 0.00061 | 0.00058 | 0.00080 | | -0.00193 | 1 | 2,046,335 | outside | |
| 4 | 3.74023 | 3.73779 | 0.00436 | max | -0.00183 | 1 | 34.1% | bad | |
| 5 | 3.73620 | 3.73397 | -0.00056 | min | -0.00182 | 1 | 285,883 | too small | |
| 6 | 3.73788 | 3.73605 | 0.00183 | | -0.00174 | 1 | 285,853 | too large | |
| 7 | 3.73759 | 3.73546 | 0.00213 | | -0.00173 | 1 | 571,736 | outside | |
| 8 | 3.73811 | 3.73657 | 0.00155 | | -0.00171 | 1 | 9.5% | bad | |



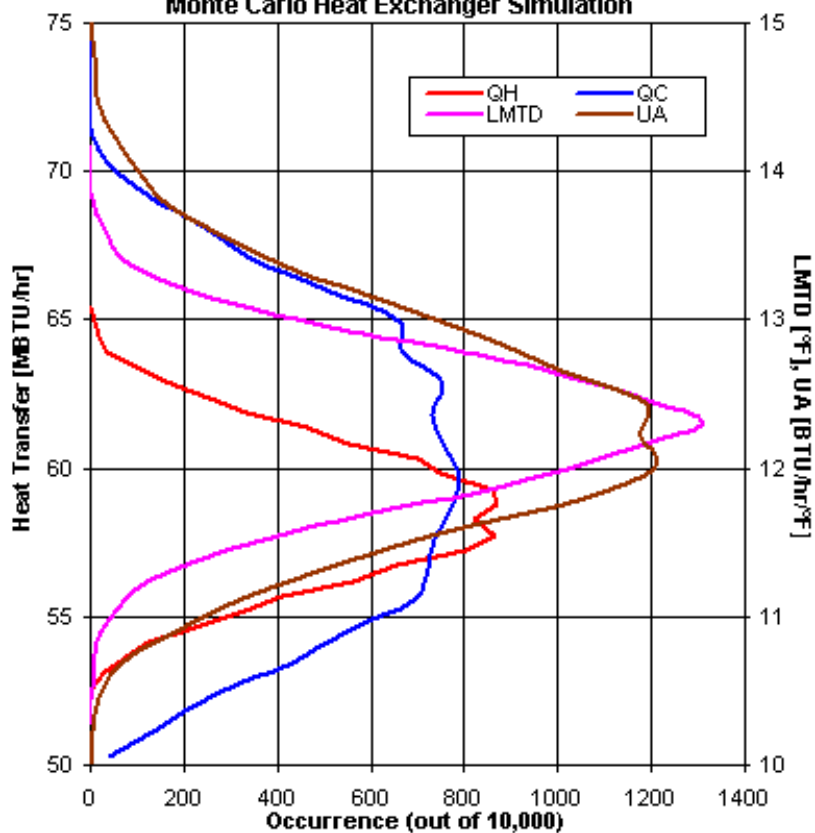
| engine longevity | clearance | miles |
|------------------|-----------|-------|
| 0.00002 | 10 | |
| 0.00003 | 39 | |
| 0.00007 | 156 | |
| 0.00014 | 625 | |
| 0.00028 | 2,500 | |
| 0.00055 | 10,000 | |
| 0.00110 | 40,000 | |
| 0.00220 | 160,000 | |
| 0.00440 | 80,000 | |
| 0.00880 | 40,000 | |
| 0.01760 | 20,000 | |

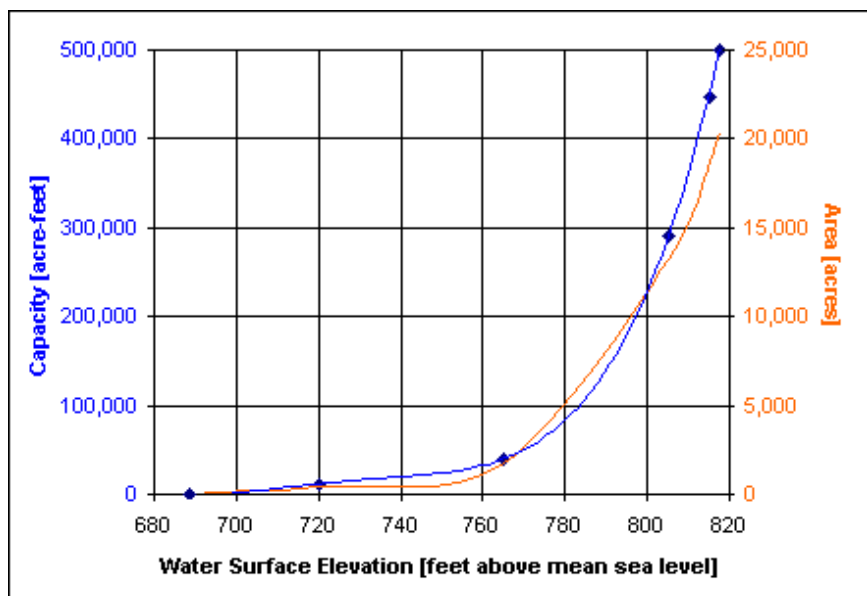


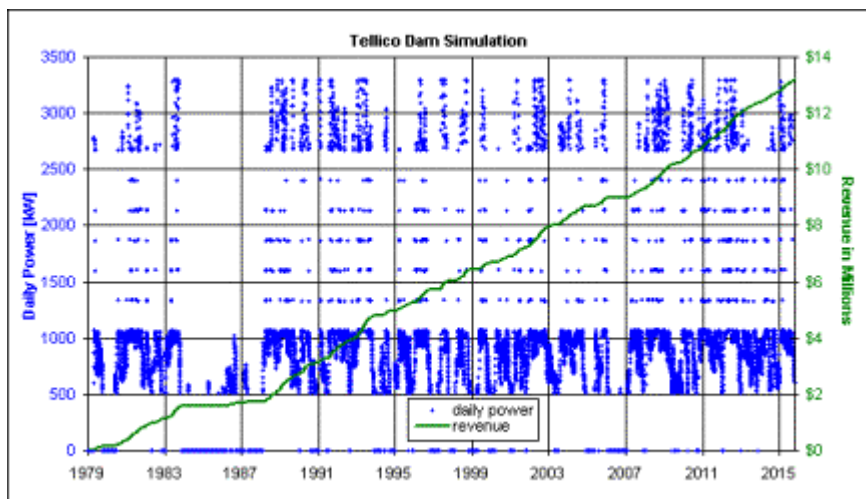
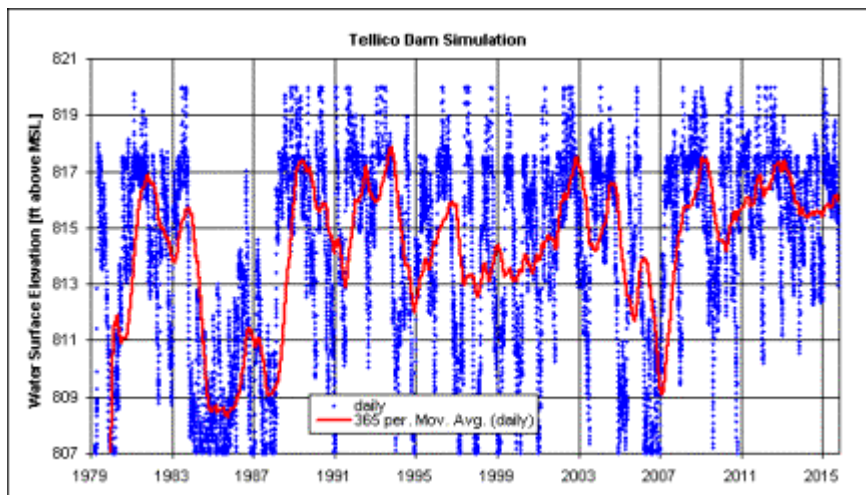
| expected longevity | miles | engines |
|--------------------|--------|---------|
| 0 | 63,139 | |
| 5,000 | 51,294 | |
| 10,000 | 51,922 | |
| 15,000 | 52,285 | |
| 20,000 | 53,233 | |
| 25,000 | 53,768 | |
| 30,000 | 53,129 | |
| 35,000 | 51,735 | |
| 40,000 | 49,856 | |
| 45,000 | 49,062 | |
| 50,000 | 46,632 | |
| 55,000 | 44,481 | |
| 60,000 | 41,126 | |
| 65,000 | 38,142 | |
| 70,000 | 36,428 | |
| 75,000 | 34,908 | |
| 80,000 | 34,325 | |
| 85,000 | 36,052 | |

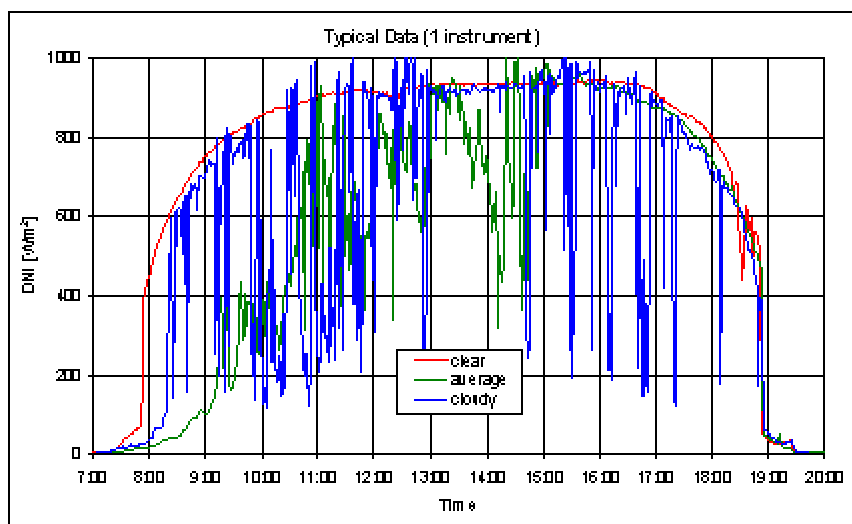
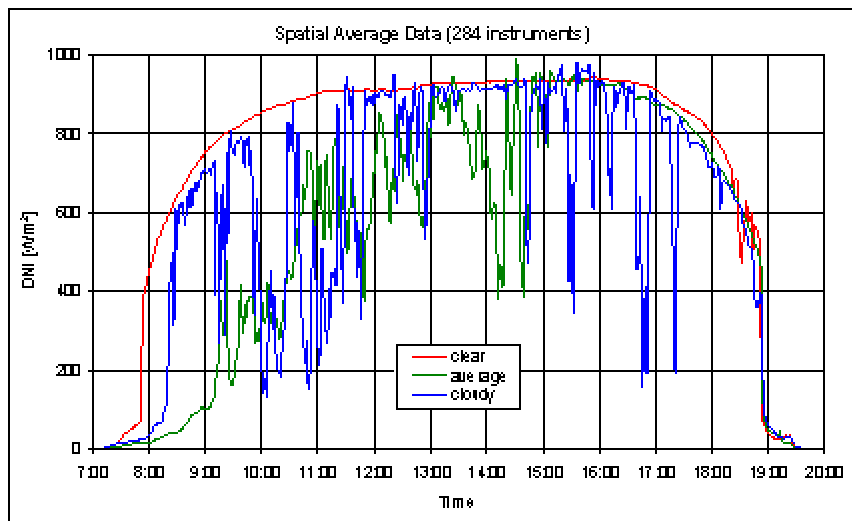


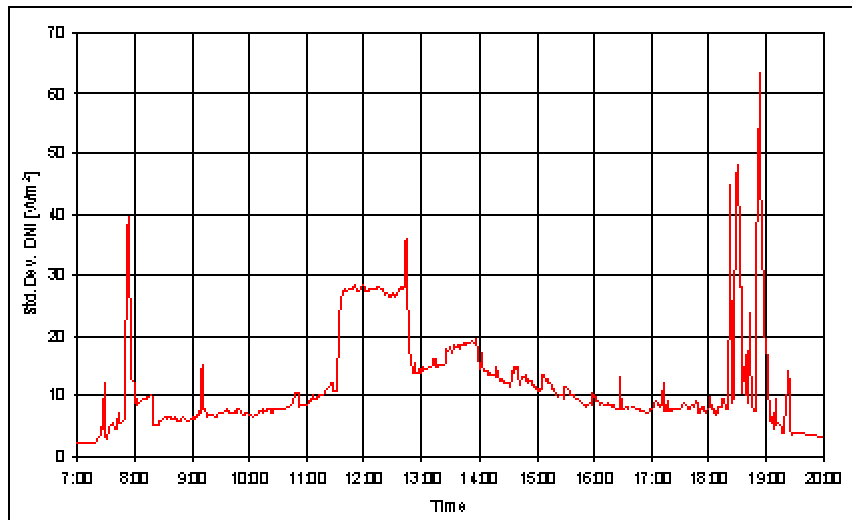
Monte Carlo Heat Exchanger Simulation











| | A | B | C | D | E | F | G | H | I | J | K |
|---|--|-------|--------|---------|---------------------|--------|---------|---------|------------|------------|-----|
| 1 | Spatially-Averaged DNI [W/m ²] | | | | Expected Power [kW] | | | | | | |
| 2 | time | clear | cloudy | average | clear | cloudy | average | clear | cloudy | 42,175,396 | |
| 3 | 12:00 AM | 1 | 1 | 1 | 0 | 0 | 0 | 0 | cloudy | 31,017,464 | 74% |
| 4 | 12:01 AM | 1 | 1 | 1 | 0 | 0 | 0 | average | 34,068,676 | 81% | |
| 5 | 12:02 AM | 1 | 1 | 1 | 0 | 0 | 0 | | | | |

