

# ***VERUS ENGINEERING***

# ***AERODYNAMIC VEHICLE***

# ***SETUP GUIDE***

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*PORSCHE 987 CAYMAN*

# OVERVIEW

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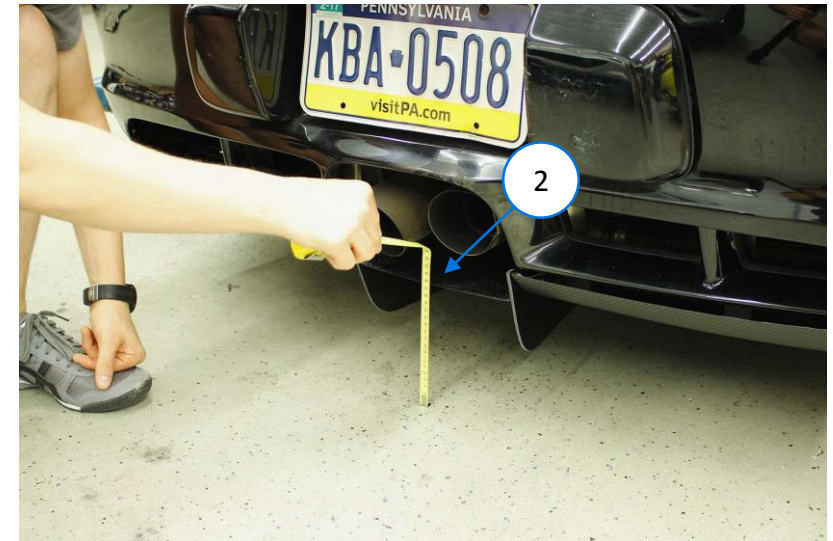
# CALCULATION INPUTS

All calculations were completed at standard temperature and pressure. Downforce and drag numbers will change depending on elevation, temperature, and humidity. How to calculate these force changes with the elevation, temperature, and humidity will be discussed at the end of the setup sheet.



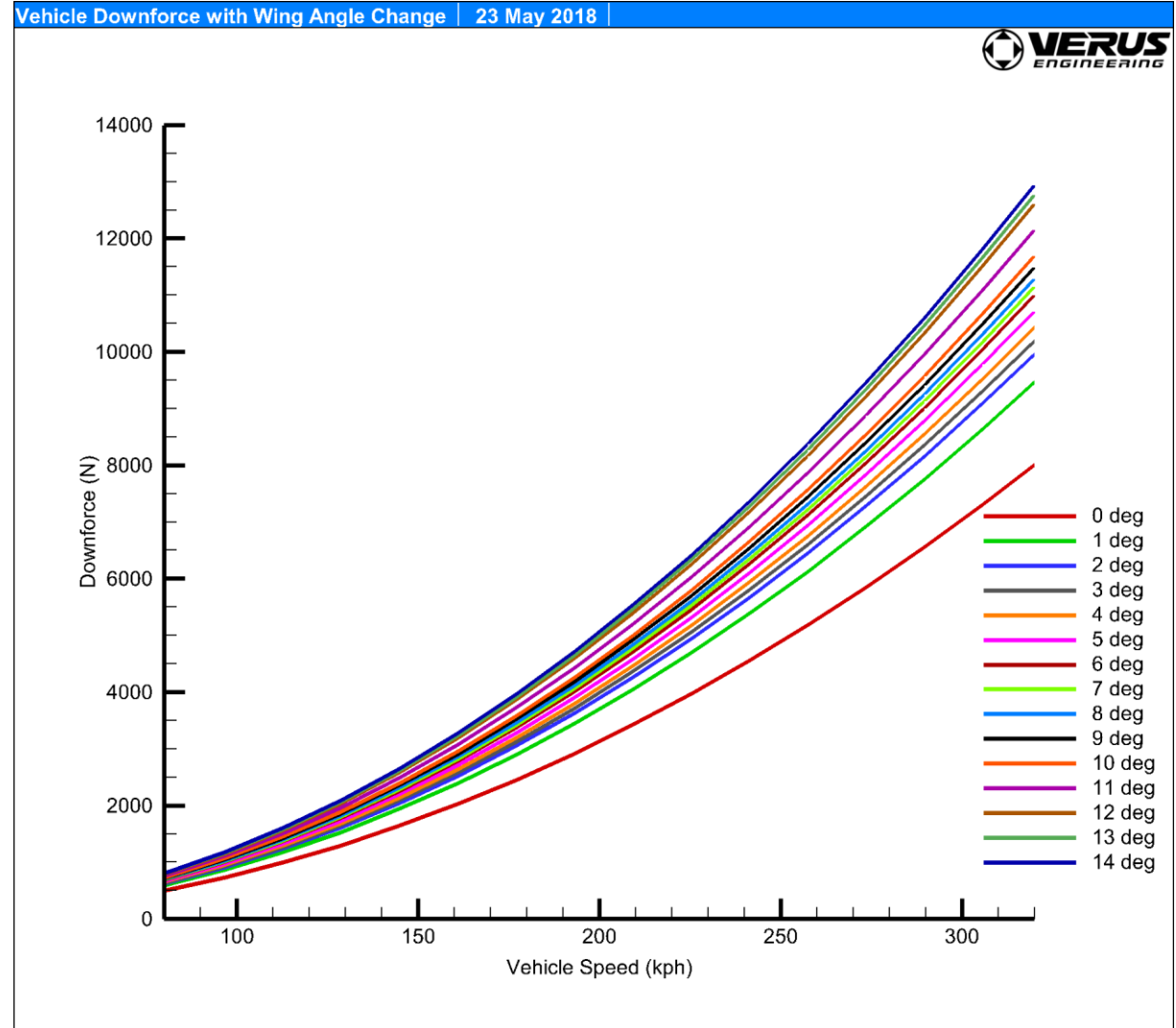
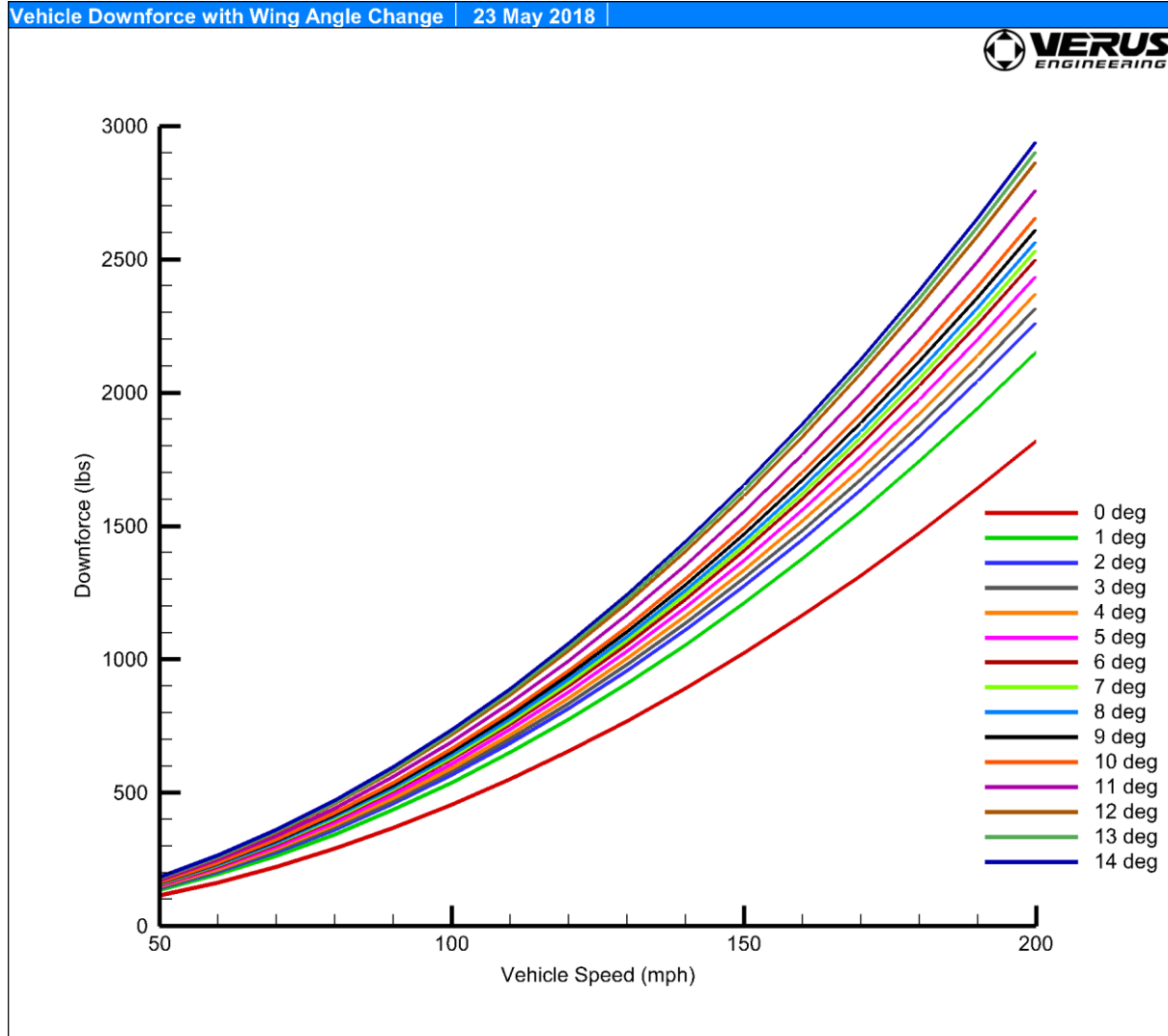
1. Front ride height is measured from the ground to the bottom side of the splitter.
2. Rear ride height is measured from the ground to the bottom side of the rear edge of the diffuser

Note: A metric tape measure is recommended so conversions do not need to be made.



The data was also calculated at a standard ride height; 90mm FRH / 205mm RRH. Downforce and drag also change with ride height changes. Since the vehicle is constantly changing ride heights front and rear, a ride height sensitivity chart will also be displayed in this packet.

# DOWNFORCE WITH WING ANGLE CHANGE



# DOWNFORCE WITH WING ANGLE CHANGE

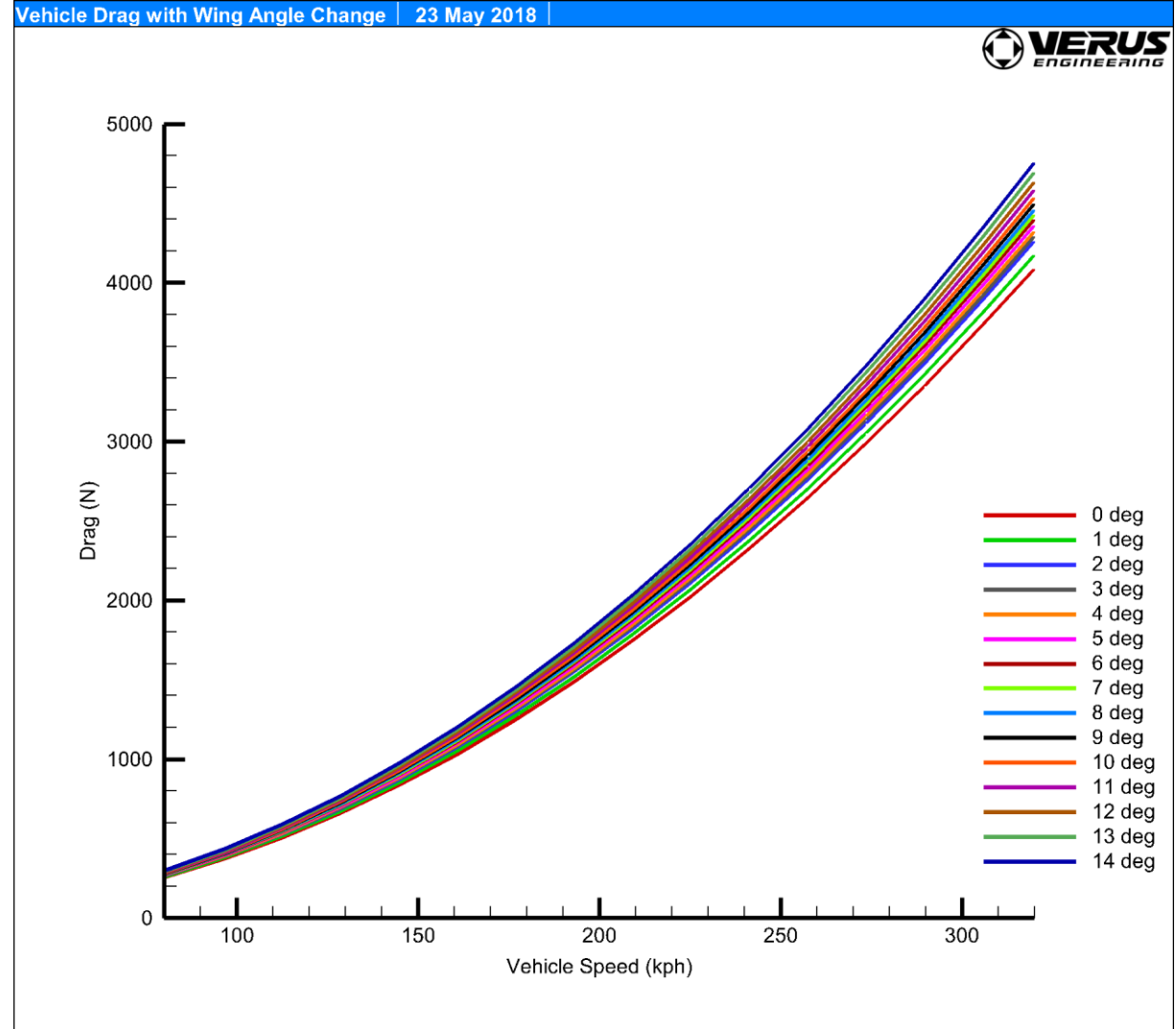
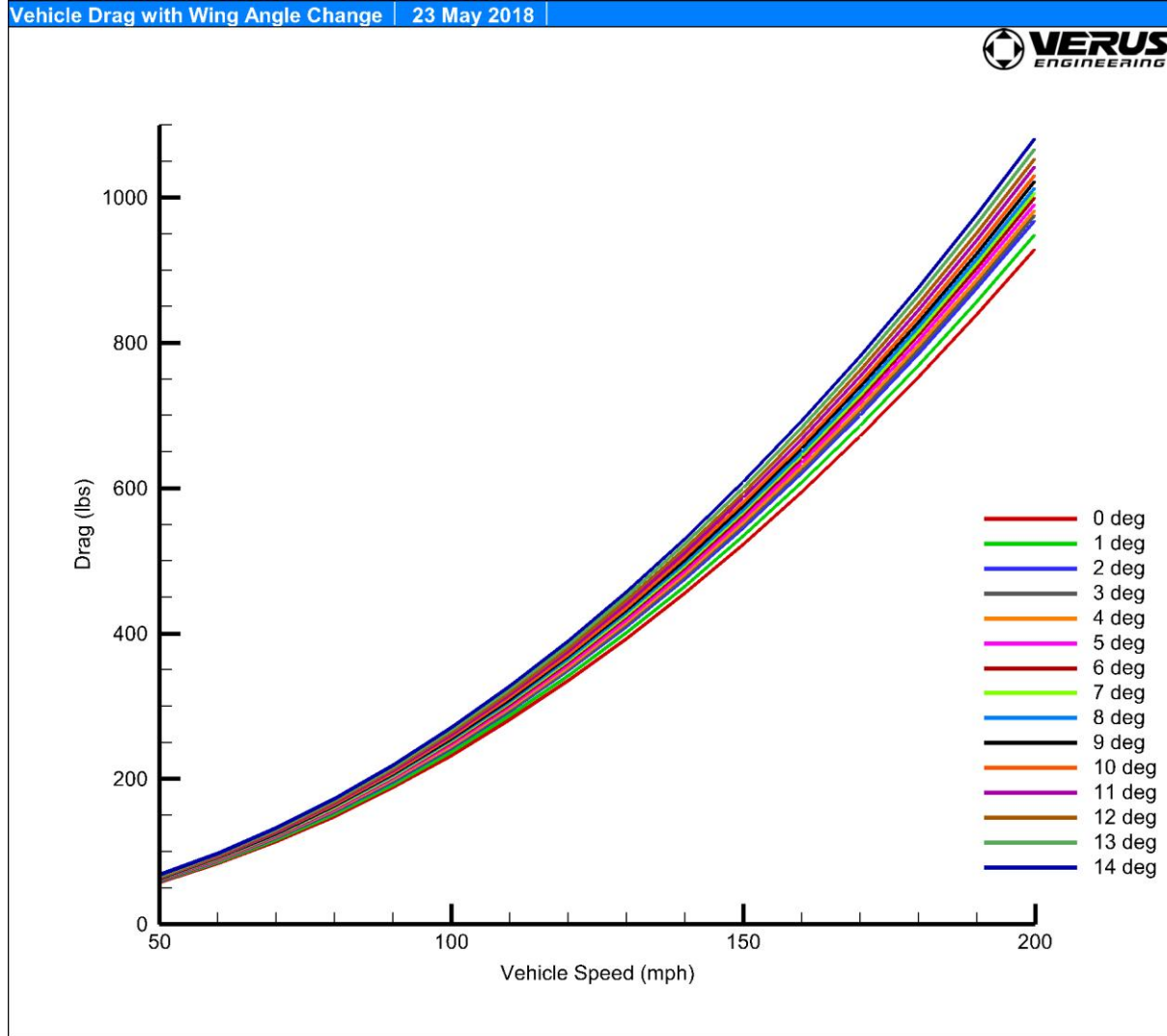
| Velocity(mph) | 0    | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   | 11   | 12   | 13   | 14   |
|---------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 50            | 114  | 134  | 142  | 145  | 148  | 152  | 156  | 158  | 161  | 163  | 166  | 173  | 179  | 182  | 184  |
| 60            | 164  | 194  | 204  | 209  | 214  | 219  | 225  | 228  | 231  | 235  | 239  | 249  | 258  | 261  | 265  |
| 70            | 223  | 264  | 277  | 284  | 291  | 299  | 306  | 311  | 315  | 320  | 326  | 338  | 351  | 356  | 360  |
| 80            | 291  | 344  | 362  | 371  | 380  | 390  | 400  | 406  | 411  | 418  | 425  | 442  | 459  | 465  | 471  |
| 90            | 368  | 436  | 459  | 470  | 480  | 493  | 507  | 513  | 520  | 529  | 538  | 559  | 581  | 588  | 596  |
| 100           | 455  | 538  | 566  | 580  | 593  | 609  | 625  | 634  | 642  | 653  | 665  | 691  | 717  | 726  | 736  |
| 110           | 550  | 651  | 685  | 701  | 718  | 737  | 757  | 767  | 777  | 791  | 804  | 836  | 867  | 879  | 890  |
| 120           | 655  | 775  | 815  | 835  | 854  | 877  | 901  | 913  | 925  | 941  | 957  | 995  | 1032 | 1046 | 1059 |
| 130           | 769  | 909  | 957  | 980  | 1002 | 1030 | 1057 | 1071 | 1085 | 1104 | 1123 | 1167 | 1211 | 1227 | 1243 |
| 140           | 892  | 1054 | 1110 | 1136 | 1163 | 1194 | 1226 | 1242 | 1258 | 1281 | 1303 | 1354 | 1405 | 1423 | 1442 |
| 150           | 1024 | 1210 | 1274 | 1304 | 1335 | 1371 | 1407 | 1426 | 1445 | 1470 | 1495 | 1554 | 1613 | 1634 | 1655 |
| 160           | 1165 | 1377 | 1450 | 1484 | 1518 | 1560 | 1601 | 1622 | 1644 | 1673 | 1701 | 1768 | 1835 | 1859 | 1883 |
| 170           | 1315 | 1555 | 1636 | 1675 | 1714 | 1761 | 1807 | 1831 | 1856 | 1888 | 1921 | 1996 | 2072 | 2099 | 2126 |
| 180           | 1474 | 1743 | 1835 | 1878 | 1922 | 1974 | 2026 | 2053 | 2080 | 2117 | 2153 | 2238 | 2323 | 2353 | 2383 |
| 190           | 1642 | 1942 | 2044 | 2093 | 2141 | 2199 | 2258 | 2288 | 2318 | 2359 | 2399 | 2494 | 2588 | 2622 | 2656 |
| 200           | 1820 | 2152 | 2265 | 2319 | 2373 | 2437 | 2501 | 2535 | 2568 | 2613 | 2658 | 2763 | 2867 | 2905 | 2942 |

Forces in lbs

| Velocity (kph) | 0    | 1    | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 11    | 12    | 13    | 14    |
|----------------|------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 80             | 506  | 598  | 630   | 645   | 660   | 678   | 695   | 705   | 714   | 727   | 739   | 768   | 797   | 808   | 818   |
| 97             | 728  | 861  | 907   | 928   | 950   | 976   | 1001  | 1015  | 1028  | 1046  | 1064  | 1106  | 1148  | 1163  | 1178  |
| 113            | 992  | 1172 | 1234  | 1264  | 1293  | 1328  | 1363  | 1381  | 1400  | 1424  | 1449  | 1506  | 1562  | 1583  | 1603  |
| 129            | 1295 | 1531 | 1612  | 1650  | 1689  | 1734  | 1780  | 1804  | 1828  | 1860  | 1892  | 1966  | 2041  | 2067  | 2094  |
| 145            | 1639 | 1938 | 2040  | 2089  | 2137  | 2195  | 2253  | 2283  | 2313  | 2354  | 2395  | 2489  | 2583  | 2617  | 2650  |
| 161            | 2024 | 2393 | 2519  | 2579  | 2638  | 2710  | 2782  | 2819  | 2856  | 2906  | 2956  | 3072  | 3189  | 3230  | 3272  |
| 177            | 2448 | 2895 | 3048  | 3120  | 3193  | 3279  | 3366  | 3411  | 3456  | 3517  | 3577  | 3718  | 3858  | 3909  | 3959  |
| 193            | 2914 | 3446 | 3627  | 3713  | 3799  | 3903  | 4006  | 4059  | 4113  | 4185  | 4257  | 4424  | 4592  | 4652  | 4712  |
| 209            | 3420 | 4044 | 4257  | 4358  | 4459  | 4580  | 4701  | 4764  | 4827  | 4912  | 4996  | 5193  | 5389  | 5459  | 5530  |
| 225            | 3966 | 4690 | 4937  | 5054  | 5171  | 5312  | 5452  | 5525  | 5598  | 5696  | 5794  | 6022  | 6250  | 6332  | 6413  |
| 241            | 4553 | 5384 | 5667  | 5802  | 5936  | 6098  | 6259  | 6343  | 6426  | 6539  | 6652  | 6913  | 7174  | 7268  | 7362  |
| 257            | 5180 | 6126 | 6448  | 6601  | 6754  | 6938  | 7121  | 7216  | 7312  | 7440  | 7568  | 7866  | 8163  | 8270  | 8377  |
| 274            | 5848 | 6915 | 7279  | 7452  | 7625  | 7832  | 8039  | 8147  | 8254  | 8399  | 8544  | 8880  | 9215  | 9336  | 9456  |
| 290            | 6556 | 7753 | 8161  | 8355  | 8549  | 8781  | 9013  | 9133  | 9254  | 9416  | 9578  | 9955  | 10331 | 10466 | 10602 |
| 306            | 7305 | 8638 | 9093  | 9309  | 9525  | 9783  | 10042 | 10176 | 10311 | 10492 | 10672 | 11092 | 11511 | 11662 | 11812 |
| 322            | 8094 | 9571 | 10075 | 10314 | 10554 | 10840 | 11127 | 11276 | 11425 | 11625 | 11825 | 12290 | 12755 | 12922 | 13089 |

Forces in N

# DRAG WITH WING ANGLE CHANGE



# DRAG WITH WING ANGLE CHANGE

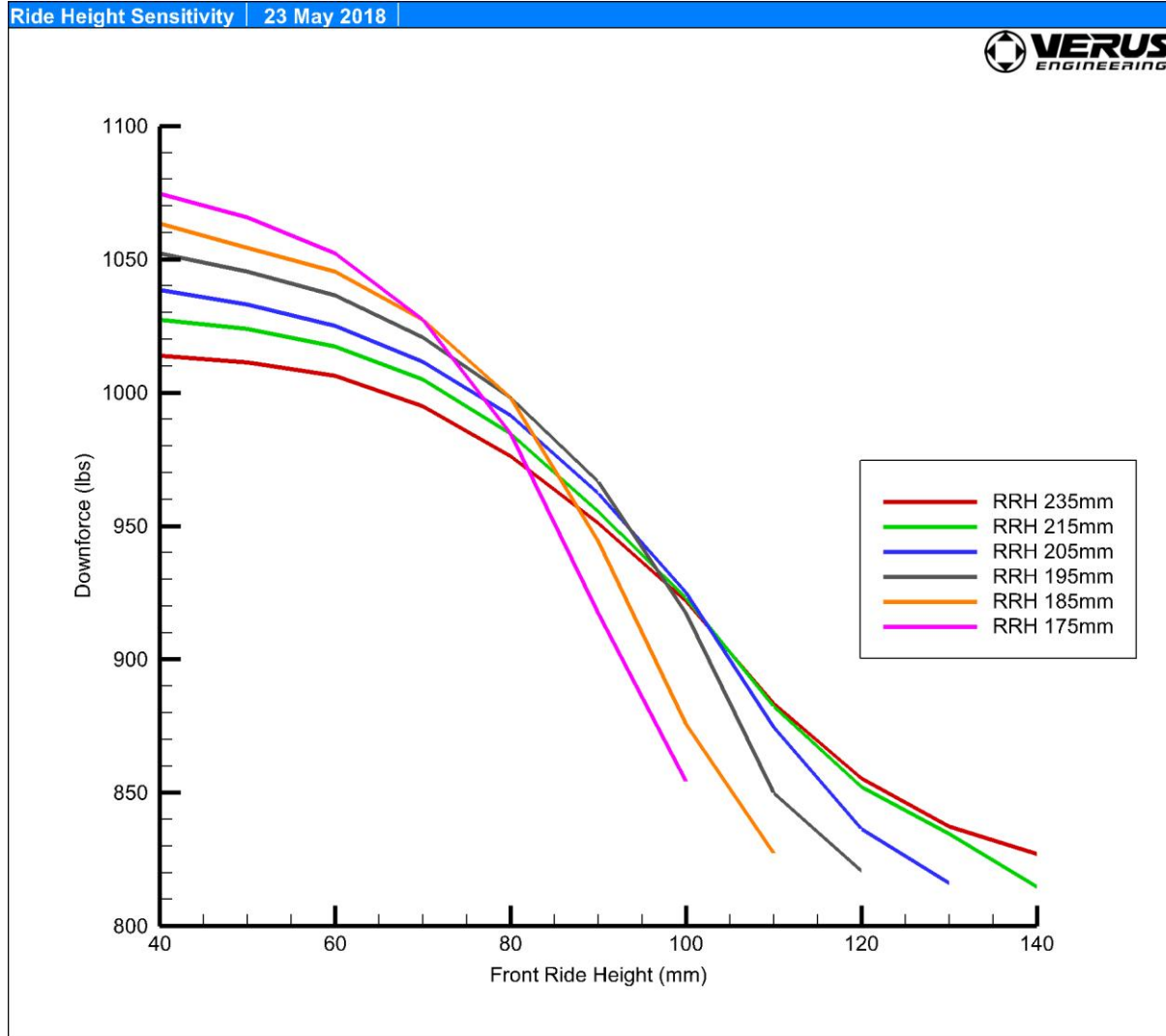
| Velocity(mph) | 0   | 1   | 2   | 3   | 4   | 5   | 6    | 7    | 8    | 9    | 10   | 11   | 12   | 13   | 14   |
|---------------|-----|-----|-----|-----|-----|-----|------|------|------|------|------|------|------|------|------|
| 50            | 58  | 59  | 61  | 61  | 61  | 62  | 63   | 63   | 63   | 64   | 65   | 65   | 66   | 67   | 68   |
| 60            | 84  | 85  | 87  | 88  | 88  | 89  | 90   | 91   | 91   | 92   | 93   | 94   | 95   | 96   | 97   |
| 70            | 114 | 116 | 119 | 120 | 120 | 122 | 123  | 123  | 124  | 125  | 126  | 128  | 129  | 131  | 133  |
| 80            | 149 | 152 | 155 | 156 | 157 | 159 | 160  | 161  | 162  | 164  | 165  | 167  | 169  | 171  | 173  |
| 90            | 188 | 192 | 196 | 198 | 199 | 201 | 203  | 204  | 205  | 207  | 209  | 211  | 214  | 216  | 219  |
| 100           | 233 | 237 | 242 | 244 | 246 | 248 | 250  | 252  | 254  | 256  | 258  | 261  | 264  | 267  | 271  |
| 110           | 281 | 287 | 293 | 295 | 297 | 300 | 303  | 305  | 307  | 310  | 312  | 316  | 319  | 323  | 327  |
| 120           | 335 | 342 | 349 | 352 | 354 | 357 | 360  | 363  | 365  | 368  | 372  | 376  | 380  | 385  | 390  |
| 130           | 393 | 401 | 410 | 413 | 415 | 419 | 423  | 426  | 429  | 432  | 436  | 441  | 446  | 451  | 457  |
| 140           | 456 | 465 | 475 | 478 | 482 | 486 | 490  | 494  | 497  | 501  | 506  | 511  | 517  | 524  | 530  |
| 150           | 523 | 534 | 545 | 549 | 553 | 558 | 563  | 567  | 571  | 576  | 581  | 587  | 593  | 601  | 609  |
| 160           | 595 | 608 | 621 | 625 | 629 | 635 | 641  | 645  | 649  | 655  | 661  | 668  | 675  | 684  | 693  |
| 170           | 672 | 686 | 700 | 705 | 710 | 717 | 723  | 728  | 733  | 739  | 746  | 754  | 762  | 772  | 782  |
| 180           | 753 | 769 | 785 | 791 | 796 | 804 | 811  | 816  | 822  | 829  | 836  | 845  | 854  | 865  | 877  |
| 190           | 839 | 857 | 875 | 881 | 887 | 895 | 903  | 909  | 916  | 924  | 931  | 942  | 952  | 964  | 977  |
| 200           | 930 | 950 | 970 | 976 | 983 | 992 | 1001 | 1008 | 1014 | 1023 | 1032 | 1043 | 1055 | 1068 | 1082 |

Forces in lbs

| Velocity(kph) | 0    | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   | 11   | 12   | 13   | 14   |
|---------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 80            | 259  | 264  | 270  | 271  | 273  | 276  | 278  | 280  | 282  | 284  | 287  | 290  | 293  | 297  | 301  |
| 97            | 372  | 380  | 388  | 391  | 394  | 397  | 401  | 403  | 406  | 410  | 413  | 418  | 422  | 428  | 433  |
| 113           | 507  | 518  | 528  | 532  | 536  | 541  | 545  | 549  | 553  | 558  | 562  | 569  | 575  | 582  | 590  |
| 129           | 662  | 676  | 690  | 695  | 700  | 706  | 712  | 717  | 722  | 728  | 735  | 743  | 751  | 760  | 770  |
| 145           | 838  | 856  | 873  | 880  | 886  | 894  | 902  | 908  | 914  | 922  | 930  | 940  | 950  | 962  | 975  |
| 161           | 1034 | 1056 | 1078 | 1086 | 1093 | 1103 | 1113 | 1121 | 1128 | 1138 | 1148 | 1160 | 1173 | 1188 | 1203 |
| 177           | 1251 | 1278 | 1305 | 1314 | 1323 | 1335 | 1347 | 1356 | 1365 | 1377 | 1389 | 1404 | 1419 | 1438 | 1456 |
| 193           | 1489 | 1521 | 1553 | 1564 | 1575 | 1589 | 1603 | 1614 | 1625 | 1639 | 1653 | 1671 | 1689 | 1711 | 1733 |
| 209           | 1748 | 1785 | 1822 | 1835 | 1848 | 1864 | 1881 | 1894 | 1907 | 1923 | 1940 | 1961 | 1982 | 2008 | 2034 |
| 225           | 2027 | 2070 | 2113 | 2128 | 2143 | 2162 | 2181 | 2196 | 2211 | 2230 | 2250 | 2274 | 2299 | 2329 | 2359 |
| 241           | 2327 | 2376 | 2426 | 2443 | 2460 | 2482 | 2504 | 2521 | 2538 | 2560 | 2583 | 2611 | 2639 | 2673 | 2708 |
| 257           | 2648 | 2704 | 2760 | 2780 | 2799 | 2824 | 2849 | 2869 | 2888 | 2913 | 2938 | 2970 | 3002 | 3042 | 3081 |
| 274           | 2989 | 3052 | 3116 | 3138 | 3160 | 3188 | 3216 | 3238 | 3260 | 3289 | 3317 | 3353 | 3389 | 3434 | 3478 |
| 290           | 3351 | 3422 | 3493 | 3518 | 3543 | 3574 | 3606 | 3631 | 3655 | 3687 | 3719 | 3759 | 3800 | 3849 | 3899 |
| 306           | 3734 | 3813 | 3892 | 3920 | 3947 | 3983 | 4018 | 4045 | 4073 | 4108 | 4144 | 4189 | 4234 | 4289 | 4344 |
| 322           | 4137 | 4225 | 4313 | 4343 | 4374 | 4413 | 4452 | 4482 | 4513 | 4552 | 4591 | 4641 | 4691 | 4752 | 4814 |

Forces in N

# RIDE HEIGHT SENSITIVITY



Ride height sensitivity is used to show how ride height changes impact overall downforce of the vehicle. Since the vehicle moves dynamically around a track, it is imperative to know how downforce changes with these movements. The data to the left was calculated at a 10 degree angle of attack with the wing and at 120mph. With wing angle changes, the trends will be similar since the rear wing is not very sensitive to ride height changes.



# ***SETUP STARTING POINT***

This is for a generic starting point on where to setup your car for its first track outing. This is generic and will need to be adjusted based on the track and driver's style.

## **Ride Height**

Front Ride Height : 90mm

Rear Ride Height : 205mm

## **Aerodynamic Adjustment**

Rear Wing Angle : 6-7 degrees

## **Suspension**

Set the starting point based on the specific manufactures recommendations

Our track car is running MCS 3-Way 550/800

Data acquisition is highly recommended to help properly setup the car. More than wing angle will need to be adjusted to get the setup where it is needed. The suspension will need to be tuned to optimize the car around the aerodynamic package.

# UNDERSTEER ADJUSTMENTS

Understeer - also known as pushing or tight, is when the front wheels are traveling in a larger arc than the rear wheels. This feels like the front of the car is not turning in and “plowing” through the corner.

**Aero Adjustment:** Reduce rear wing angle of attack

**Suspension Adjustment:**

| Corner Entry  | Mid Corner  | Corner Exit   |
|---|---|---|
| <ol style="list-style-type: none"> <li>1. Decrease front ride height (also changes aero loads)</li> <li>2. Increase front camber</li> <li>3. Increase toe-out</li> <li>4. Decrease front damper compression</li> <li>5. Decrease front ARB stiffness</li> </ol> | <ol style="list-style-type: none"> <li>1. Increase front spring pre-load</li> <li>2. Increase front spring rate</li> <li>3. Increase front ARB stiffness</li> </ol> | <ol style="list-style-type: none"> <li>1. Increase rear ride height (also changes aero loads)</li> <li>2. Increase rear damper compression and rebound</li> <li>3. Increase rear spring rate</li> <li>4. Increase rear ARB stiffness</li> </ol> |

# OVERSTEER ADJUSTMENTS

Oversteer - also known as loose, is when the front wheels are traveling in a smaller arc than the rear wheels. This feels like the back of the car is rotating around faster.

**Aero Adjustment:** Increase rear wing angle of attack

**Suspension Adjustment:**

| Corner Entry  | Mid Corner   | Corner Exit  |
|---|--|--|
| <ol style="list-style-type: none"> <li>1. Increase rear camber</li> <li>2. Increase rear toe-in</li> <li>3. Increase front damper compression</li> <li>4. Increase front ARB stiffness</li> </ol> | <ol style="list-style-type: none"> <li>1. Increase rear camber</li> <li>2. Decrease rear spring rate</li> <li>3. Decrease rear ARB stiffness</li> <li>4. Decrease rear ride height (changes aero loads)</li> </ol> | <ol style="list-style-type: none"> <li>1. Decrease rear damper compression</li> <li>2. Decrease rear ARB stiffness</li> <li>3. Decrease rear ride height (changes aero loads)</li> </ol> |

# ADJUSTING FOR ELEVATION, TEMPERATURE, & HUMIDITY

To correct data for atmospheric conditions like elevation, temperature, and humidity; density ratio should be used. To get a proper data, sign up for Davis Weather Station at [www.weatherlink.com](http://www.weatherlink.com).

$$\text{Density Ratio} = \frac{\rho_{humid}}{\rho_0}$$

$$\rho_{humid} = \frac{P_{dry}}{T * R_{dry}} + \frac{P_{vapor}}{T * R_{vapor}}$$

$$R_{dry} = 287.05 \frac{J}{kg * K}$$

$$P_{dry} = 101,325 Pa$$

$$T = Kelvin = ^\circ C + 273.15 = \frac{(^{\circ}F - 32) * 5}{9} + 273.15$$

$$\rho_0 = 1.225 kg/m^3$$

$$R_{vapor} = 461.495 \frac{J}{kg * K}$$

$$P_{vapor} = Pa$$

$$1 \text{ in of Hg} = 3386.39 Pa$$

To adjust the downforce levels for the weather condition, multiply the density ratio by the nominal downforce number on the graphs or charts.