

Process for Generating Engine Fuel Consumption Map

(Ford F150 EcoBoost 2.7L Tier 2 Fuel)

Version: 06-20-2016

This document summarizes the process followed to utilize laboratory engine dyno test data and generate a full engine fuel consumption map which can be used by EPA's ALPHA vehicle simulations. The map generated defines the complete operating boundaries of the engine needed for ALPHA modeling, including idle, WOT, minimum torque, and maximum speed.

Gather Engine Physical Characteristics

Source:

https://media.ford.com/content/dam/fordmedia/North America/US/2015_Specs/2015_F150_Specs.pdf

```
engine.name = 'Ford F150 EcoBoost 2.7L Tier 2';  
engine.combustion_type = enum_engine_combustion_type.spark_ignition;  
engine.displacement_L = 2.694;  
engine.num_cylinders = 6;  
engine.bore_mm = 3.27 * convert.in2mm;  
engine.stroke_mm = 3.27 * convert.in2mm;
```

Source: Estimated from engine displacement

```
engine.inertia_kgm2 = 0.13;
```

Load Fuel Map Test Data from Core Test Dataset

Source: 2015 Ford F150 2.7L Tier 2 Fuel - Core Test Data.xlsx

Note: Load data from core test data for fuel map generation.

```
datagrabber('../data/engine_data/2015 Ford F150 Tier 2 Fuel - Core Test  
Data.xlsx', 'structure', 'core_data', 'headerline', 3, 'dataline', 5, 'quiet');  
  
fuel_data.speed_rpm = core_data.Speed;  
fuel_data.torque_Nm = core_data.Torque;  
fuel_data.fuel_gps = core_data.Fuel_Flow;
```

Obtain Maximum Torque (WOT) Curve Data

Source:

https://media.ford.com/content/dam/fordmedia/NorthAmerica/US/2015_Specs/2015_F150_Specs.pdf

- 325 HP @ 5750 RPM
- 375 lbs*ft @ 3000 RPM

Note: Shape of curve estimated from other turbocharged engines.

```
WOT_data.speed_rpm = [ 1000, 1750, 2000, 2500, 3000, 4500, 5750, 6500 ];  
WOT_data.torque_Nm = [ 230, 420, 460, 490, 508, 508, 464, 415 ];
```

Obtain Minimum Torque (Motoring) Curve Data

Source: E09_2016-1-11_12.avg.d

```
datagrabber('../data/engine_data/F150_tier_2_SS_map_1-11-16/E09_2016-1-11_12_avg.d', 'structure', 'motoring_data', 'headerline', 7, 'dataline', 10, 'unitline', 'none', 'quiet');
```

```
CT_data.speed_rpm = motoring_data.DYN0_Speed;  
CT_data.torque_Nm = motoring_data.DYN0_shaft_torque;
```

Obtain Properties of the Fuel Used When Mapping the Engine

Source: FTAG 24670 Referenced in 2015 Ford F150 2.7L Tier 2 Fuel - Core Test Data.xlsx

Note: When using ALPHA to conduct specific technology assessments, the fuel properties and associated fuel consumption map for this engine definition are adjusted to suit the standard fuel being used during the specific assessment. For example, fuel rate is adjusted for LD GHG assessments to represent a suitable fuel rate with Tier 2 Certification fuel.

```
%Load from fuel database  
engine.fuel = class_REVS_fuel('FTAG 25278');  
disp(engine.fuel);
```

```
class_REVS_fuel with properties:  
    id: 'FTAG 25278'  
    description: 'Tier 2 Cert'  
    density_kgpl_15C: 0.74245  
    energy_density_MJpkg: 42.908  
    carbon_weight_fraction: 0.8664  
    anti_knock_index: []  
    research_octane_number: 96.6  
    motor_octane_number: 88.9  
    cetane_number: []  
    alcohol_pct_vol: 0  
    gCO2pgal: 8922.3  
    energy_density_BTUplbm: 18447  
    specific_gravity: 0.74316
```

Calibrate Idle Fuel Consumption and Define Idle Speed

Fuel consumption in the idle region of the map is calibrated using vehicle benchmarking data collected on a vehicle chassis dyno. Actual idle fuel consumption during an ALPHA simulation would depend on the transmission drag and accessory loads.

Source: EPAFordF150_2016-03-31_13_46_14.csv

Note: Idle speed is determined from chassis test data.

```
engine.idle_speed_radps = 590 * convert.rpm2radps;
```

Process for Generating Engine Fuel Consumption Map

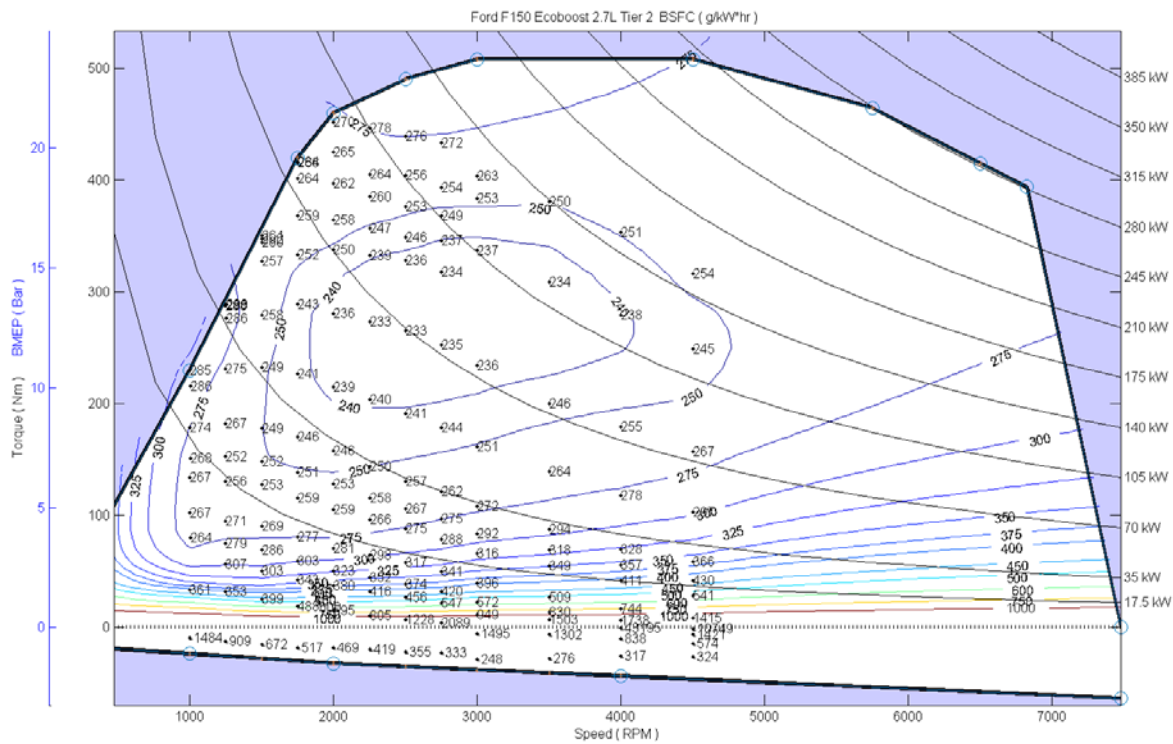
(Ford F150 EcoBoost 2.7L Tier 2 Fuel)

Version: 06-20-2016

Build Fuel Consumption Map

Note: Generate fuel map and WOT curves using REVS_build_engine with default settings. This map defines the complete operating boundaries of the engine needed for ALPHA modeling, including idle, WOT, minimum torque, and maximum speed.

```
engine = REVS_build_engine(engine, fuel_data, WOT_data, CT_data);
```



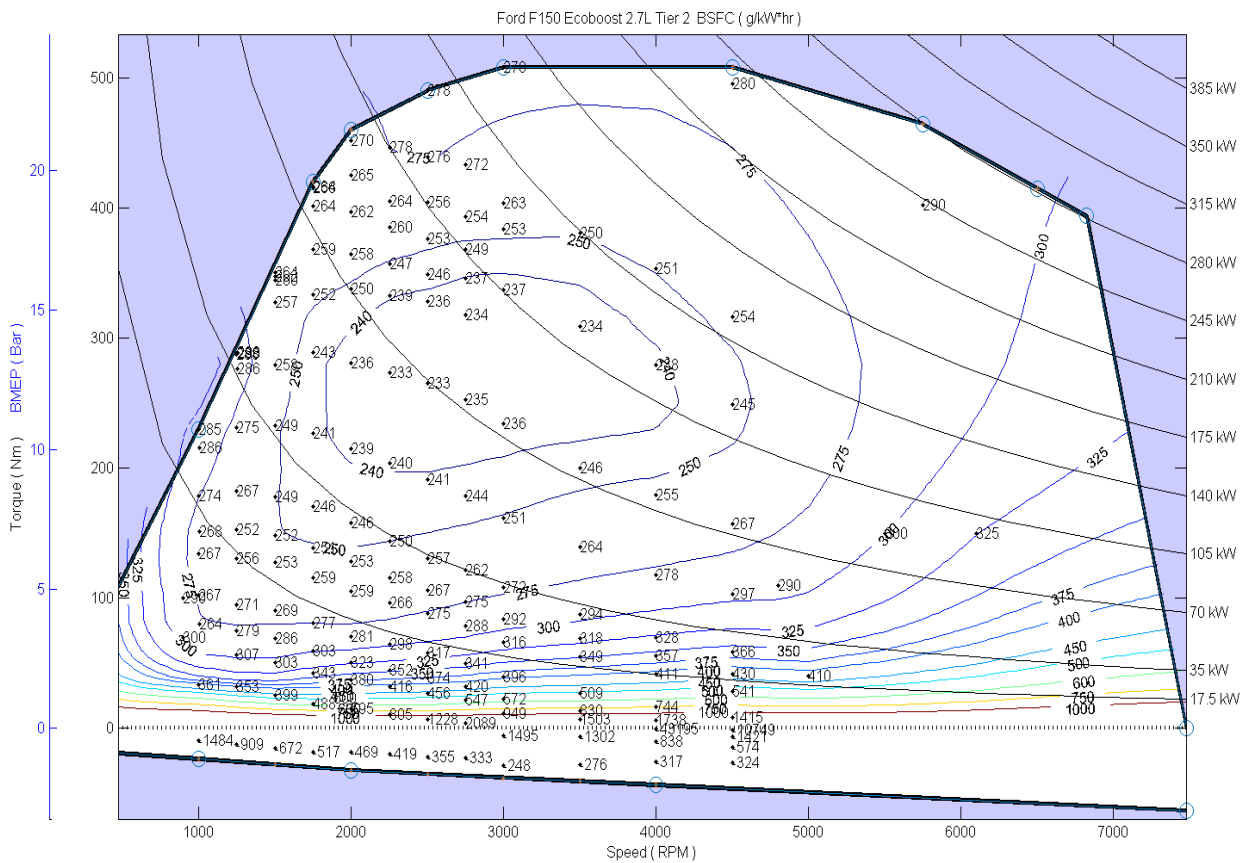
Adjust Extrapolated Region and Build Fuel Consumption Map

Note: Add data points to stabilize extrapolation behavior & regenerate fuel consumption map beyond the two-cycle operation range.

```
add_data.speed_rpm = [ 4800, 5000, 900, 900, 2500, 3000, 4500, 5750, 5500, 6100]';  
add_data.torque_Nm = [ 110, 40, 70, 100, 490, 508, 495, 402, 150, 150]';  
add_data.bsfc_gpkWhr = [ 290, 410, 300, 290, 278, 278, 280, 290, 300, 325]';  
add_data.fuel_gps = add_data.bsfc_gpkWhr .* ( add_data.speed_rpm .* convert.rpm2radps .*  
    add_data.torque_Nm ) / (1000 * 3600);
```

```
fuel_data.speed_rpm = [fuel_data.speed_rpm ; add_data.speed_rpm];  
fuel_data.torque_Nm = [fuel_data.torque_Nm ; add_data.torque_Nm];  
fuel_data.fuel_gps = [fuel_data.fuel_gps ; add_data.fuel_gps];
```

```
engine = REVS_build_engine(engine, fuel_data, WOT_data, CT_data);
```



Set Model Calibration Options

Note: These parameters influence particular behaviors within the ALPHA model. They often do not have a corresponding value with test data, but are calibrated to match observed behavior.

```
engine.pedal_map_type = enum_engine_pedal_map_type.max_engine_power;
```

Save Engine Fuel Consumption Map

```
write_REVS_engine( 'engine_f150_ecoboost_2L7_tier2.m', engine);
```

Process for Generating Engine Fuel Consumption Map

(Ford F150 EcoBoost 2.7L Tier 2 Fuel)

Version: 06-20-2016

Display Summary of Engine Fuel Consumption Map Information

Note: The listing below shows only the engine's fuel consumption map related information contained in the ALPHA Engine Definition .m file for this engine. This information is a subset of the full engine definition .m file that adds vehicle level information related to dynamic fuel use, accessories, etc.

```
% ALPHA ENGINE DEFINITION
% Generated 14-Jun-2016 12:32:16
% Ford F150 EcoBoost 2.7L Tier 2

% Constructor
engine = class_REVS_engine();
engine.name = 'Ford F150 EcoBoost 2.7L Tier 2';

% Physical Description
engine.displacement_L = 2.6940000;
engine.num_cylinders = 6.0000000;
engine.inertia_kgm2 = 0.13000000;
engine.bore_mm = 83.058000;
engine.stroke_mm = 83.058000;

% Maximum Torque Curve
engine.full_throttle_speed_radps = [ 0.0000000, ; 104.71976, ; 183.25957, ; 209.43951, ;
261.79939, ; 314.15927, ; 471.23890, ; 602.13859, ; 680.67841, ; 714.71233, ;
782.78017, ];
engine.full_throttle_torque_Nm = [ 0.0000000, ; 230.00000, ; 420.00000, ; 460.00000, ;
490.00000, ; 508.00000, ; 508.00000, ; 464.00000, ; 415.00000, ; 393.76667, ;
0.0000000, ];

% Minimum Torque Curve
engine.closed_throttle_speed_radps = [ 0.0000000, ; 104.82447, ; 209.54423, ; 418.98374,
; 782.78017, ];
engine.closed_throttle_torque_Nm = [ -14.821320, ; -23.510000, ; -32.190000, ; -43.540000, ; -
63.254950, ];

% Fuel Map
engine.fuel_map_speed_radps = [ 0.0000000, 103.87724, 131.01650, 157.19183,
183.37127, 209.55470, 235.73464, 261.90411, 288.08405, 314.24903,
366.62386, 418.98374, 471.33959, 502.65482, 523.59878, 575.95865,
602.13859, 638.79051, 782.78017, ];
engine.fuel_map_torque_Nm = [ -69.580445, -17.578824, -0.59000000, 15.353824,
38.627083, 55.537778, 69.016429, 82.694375, 102.65550, 117.45000,
131.71571, 152.08500, 178.18167, 199.08167, 228.17643, 250.61500,
280.40500, 315.50833, 332.80083, 349.14571, 375.39571, 401.46571,
415.78500, 439.27000, 496.33333, 533.40000, ];
engine.fuel_map_gps = [
0.00000000, 0.00000000, 0.00000000, 0.00000000, 0.00000000, 0.00000000, 0.00000000,
0.00000000, 0.00000000, 0.00000000, 0.00000000, 0.00000000, 0.00000000, 0.00000000,
0.00000000, 0.00000000, 0.00000000, 0.00000000, ;
0.00000000, 0.16509983, 0.21834483, 0.26989966, 0.32317336, 0.36066342, 0.39692285,
0.44961130, 0.50475080, 0.58567360, 0.73583647, 0.88988045, 1.0727317, 0.97687393, 0.95447422,
1.0323436, 1.1226840, 1.2819983, 2.3892235, ;
0.030657858, 0.36666718, 0.41742857, 0.45950579, 0.50166293, 0.54525498, 0.58863361,
0.64188971, 0.71647794, 0.79907716, 0.97065559, 1.1528828, 1.3915265, 1.3901472, 1.3938909,
1.5535176, 1.6905040, 1.9149675, 3.2997936, ;
```

Process for Generating Engine Fuel Consumption Map

(Ford F150 EcoBoost 2.7L Tier 2 Fuel)

Version: 06-20-2016

0. 064255197,	0. 40266158,	0. 44498517,	0. 47899146,	0. 52579031,	0. 59130785,	0. 66839858,			
0. 75620886,	0. 86827006,	0. 99793176,	1. 1936175,	1. 4045652,	1. 6905587,	1. 7647424,	1. 8045328,		
2. 0599455,	2. 2436216,	2. 5312416,	4. 1629562, ;						
0. 11198204,	0. 39976003,	0. 47746738,	0. 56819715,	0. 69128624,	0. 82063773,	0. 94055600,			
1. 0561412,	1. 1905702,	1. 3481158,	1. 6201123,	1. 9142641,	2. 2550581,	2. 3467253,	2. 4023949,		
2. 8377179,	3. 0959732,	3. 4795814,	5. 4413310, ;						
0. 14854610,	0. 48597833,	0. 60294721,	0. 72269457,	0. 86383485,	1. 0022718,	1. 1475868,			
1. 2950088,	1. 4524552,	1. 6302762,	1. 9607251,	2. 3196095,	2. 7020059,	2. 8306493,	2. 9348078,		
3. 4477253,	3. 7544523,	4. 2073401,	6. 3856250, ;						
0. 17951848,	0. 57102327,	0. 70885113,	0. 85541309,	1. 0054857,	1. 1520808,	1. 3167412,			
1. 4875075,	1. 6671828,	1. 8658538,	2. 2388324,	2. 6474510,	3. 0582478,	3. 2335361,	3. 3776643,		
3. 9534428,	4. 2975517,	4. 8050779,	7. 1453943, ;						
0. 21284638,	0. 65899570,	0. 82156070,	0. 98750908,	1. 1520450,	1. 3133957,	1. 4944979,			
1. 6871063,	1. 8898660,	2. 1081448,	2. 5239030,	2. 9776798,	3. 4244235,	3. 6483926,	3. 8312276,		
4. 4799715,	4. 8625265,	5. 4254932,	7. 9220302, ;						
0. 26658643,	0. 81076696,	0. 98574922,	1. 1767378,	1. 3694636,	1. 5594885,	1. 7695441,			
1. 9969893,	2. 2290947,	2. 4678611,	2. 9484408,	3. 4555227,	3. 9765125,	4. 2579402,	4. 4985331,		
5. 2714502,	5. 7130552,	6. 3589861,	9. 0673298, ;						
0. 31080509,	0. 91480631,	1. 1090070,	1. 3166144,	1. 5347566,	1. 7483828,	1. 9805616,			
2. 2295214,	2. 4816254,	2. 7374744,	3. 2673430,	3. 8109965,	4. 3785182,	4. 7233731,	5. 0027299,		
5. 8688628,	6. 3555842,	7. 0669600,	9. 9244108, ;						
0. 35666745,	1. 0183845,	1. 2289150,	1. 4551310,	1. 6928220,	1. 9305586,	2. 1841696,			
2. 4520770,	2. 7223431,	2. 9976556,	3. 5756837,	4. 1581763,	4. 7713036,	5. 1821427,	5. 4938184,		
6. 4487466,	6. 9784460,	7. 7556564,	10. 755693, ;						
0. 42851079,	1. 1784398,	1. 4103600,	1. 6638914,	1. 9221357,	2. 1878022,	2. 4698332,			
2. 7609704,	3. 0595266,	3. 3671396,	4. 0124517,	4. 6587506,	5. 3434303,	5. 8340496,	6. 1956787,		
7. 2767634,	7. 8653646,	8. 7358255,	11. 950978, ;						
0. 53238536,	1. 4160313,	1. 7003808,	1. 9496356,	2. 2243057,	2. 5194987,	2. 8312667,			
3. 1520529,	3. 4834366,	3. 8316444,	4. 5604328,	5. 2900368,	6. 0678130,	6. 6523992,	7. 0794662,		
8. 3138885,	8. 9777173,	9. 9319101,	13. 496974, ;						
0. 62003970,	1. 6238319,	1. 9183732,	2. 1853701,	2. 4706845,	2. 7866198,	3. 1255548,			
3. 4716590,	3. 8307401,	4. 2024940,	4. 9860162,	5. 7501952,	6. 6298683,	7. 2983971,	7. 7821742,		
9. 1438348,	9. 8623125,	10. 881949,	14. 743170, ;						
0. 73834617,	1. 9069006,	2. 2446961,	2. 5053852,	2. 8086968,	3. 1551382,	3. 5306608,			
3. 9227417,	4. 3216216,	4. 7188013,	5. 5374490,	6. 3822032,	7. 4014758,	8. 2058973,	8. 7770301,		
10. 315248,	11. 105618,	12. 218034,	16. 486766, ;						
0. 81133384,	2. 2019477,	2. 5143300,	2. 7874030,	3. 0923430,	3. 4468715,	3. 8466616,			
4. 2722608,	4. 7088877,	5. 1224800,	5. 9802061,	6. 9260839,	8. 0480840,	8. 9582455,	9. 5908299,		
11. 248661,	12. 091025,	13. 273317,	17. 835112, ;						
0. 86446606,	2. 5962800,	2. 9363379,	3. 1719459,	3. 4665506,	3. 8454212,	4. 2785673,			
4. 7293920,	5. 1929396,	5. 6575626,	6. 6238133,	7. 7619783,	9. 1011582,	10. 072361,	10. 751382,		
12. 539621,	13. 445089,	14. 714278,	19. 627133, ;						
0. 81352997,	2. 7947442,	3. 2084350,	3. 5746388,	3. 9860482,	4. 4286645,	4. 8824317,			
5. 3635008,	5. 8771384,	6. 3990556,	7. 5440574,	8. 9156801,	10. 483894,	11. 540189,	12. 267965,		
14. 167915,	15. 132372,	16. 486650,	21. 736273, ;						
0. 74881004,	2. 8518442,	3. 3252162,	3. 7783417,	4. 2762935,	4. 7801062,	5. 2470964,			
5. 7683611,	6. 2866455,	6. 8434807,	8. 0741566,	9. 5424448,	11. 204851,	12. 295971,	13. 045839,		
14. 998772,	15. 989658,	17. 380873,	22. 772646, ;						
0. 67330933,	2. 9032309,	3. 4520434,	3. 9953409,	4. 5559480,	5. 1214510,	5. 6291826,			
6. 2012285,	6. 7188663,	7. 3073337,	8. 6012813,	10. 154563,	11. 895094,	13. 018836,	13. 789499,		
15. 793091,	16. 808541,	18. 232769,	23. 750937, ;						
0. 52091981,	2. 9999535,	3. 6723378,	4. 3296929,	4. 9913059,	5. 6607690,	6. 2834164,			
6. 8885775,	7. 5158232,	8. 1788290,	9. 5142652,	11. 172634,	13. 016788,	14. 192580,	14. 996957,		
17. 084155,	18. 139581,	19. 611830,	25. 318326, ;						
0. 34005740,	3. 1192337,	3. 8900967,	4. 6415209,	5. 3957580,	6. 1429624,	6. 8845757,			
7. 5448498,	8. 3052960,	9. 1408664,	10. 549810,	12. 226799,	14. 139921,	15. 362663,	16. 198700,		
18. 365712,	19. 462931,	20. 977739,	26. 868829, ;						
0. 23584744,	3. 1900620,	4. 0081970,	4. 8059004,	5. 6111976,	6. 4115155,	7. 2354206,			
8. 0002630,	8. 8086912,	9. 6376049,	11. 118405,	12. 811520,	14. 757438,	16. 004294,	16. 856630,		
19. 062362,	20. 175528,	21. 720934,	27. 718460, ;						
0. 060608148,	3. 3126954,	4. 2024486,	5. 0681204,	5. 9502973,	6. 8772188,	7. 9003781,			

Process for Generating Engine Fuel Consumption Map

(Ford F150 EcoBoost 2.7L Tier 2 Fuel)

Version: 06-20-2016

```
8. 8036188,    9. 6282883,    10. 428452,    12. 027171,    13. 771833,    15. 769502,    17. 054298,    17. 931962,
20. 195265,    21. 334716,    22. 929412,    29. 109172, ;
0. 00000000,    3. 6684887,    4. 7528626,    5. 8054376,    6. 8667926,    7. 9358826,    9. 0054209,
10. 033016,    11. 037581,    12. 023212,    14. 014873,    16. 049991,    18. 207780,    19. 583956,    20. 517698,
22. 898854,    24. 100049,    25. 786829,    32. 462187, ;
0. 00000000,    3. 9346875,    5. 1342764,    6. 2881062,    7. 4352783,    8. 5717531,    9. 6948232,
10. 812758,    11. 926053,    13. 036586,    15. 270681,    17. 524578,    19. 834334,    21. 252819,    22. 211364,
24. 651854,    25. 887346,    27. 626574,    34. 632417, ];
```

% Fuel Properties

```
engine.fuel = class_REVS_fuel('FTAG 25278');
```

% Idle Speed

```
engine.idle_speed_radps = 61.784656;
```

% Pedal Calibration

```
engine.pedal_map_type = enum_engine_pedal_map_type.max_engine_power;
```

Published with MATLAB® R2014a