



## **MGL EFIS**

### **Engine Monitoring Addendum**

- **G2 Engine Horse Power Calculation Parameters**
- **Engine Lean Mode**
- **GAMI spread**

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# 1 Introduction

This document is an addendum to the main MGL EFIS Installation and Operating manuals and covers changes made in March 2012 to the calculation of engine horsepower, use of the Engine Leaning window, and indication of the GAMI spread.

## 2 Engine Horsepower Calculation

### 1.1 Formulae revisions

The formula used in EFIS software versions up to G2 1.0.3.1 to determine the engine horsepower or % horsepower had been found to be inaccurate for a number of engines. The formula was reviewed, modified and tested against the published power data sets for three engines – Lycoming IO540, Lycoming IO360 and Continental IO550. A match of at least better than +/- 1 or 2% can be achieved for these three engines over a range of pressure altitudes and OATs.

The prior formula has been replaced in software version G2 1.0.3.2 and above.

The previous formula addressed Rich of Peak (RoP) operation, whereas the revised method provides for calculation of engine horsepower under both RoP and Lean of Peak (LoP) operating modes. The engine horsepower or % horsepower indicated on the EFIS is now suffixed with either "R" or "L" (RoP and LoP respectively) to indicate the basis upon which the power is being calculated; see more on this below.

As with the previous version, entries for max. rated engine parameters must be entered into the EFIS, whilst engine and atmospheric parameters are acquired directly from within the EFIS.

"Tuning" of the formula to suit specific engines is achieved through the use of three "Engine Constants", each of which can be derived using a macro driven spreadsheet developed specifically for this application.

At minimum, Sea Level ISA (nominally 0ft press altitude and 15degC) engine performance data must be entered into the "Engine Constant Derivation" spreadsheet. Ideally, ISA data sets at a number of pressure altitudes should be entered, as this will improve the accuracy of the horsepower calculations.

The formulae are as follows:-

#### RoP formula

$$\left( \frac{\left( \left( \left( \text{RatedMAP} - \left( \left( \text{RatedMAP} - \text{ActualMAP} \right) * \text{EngineConstant1} \right) \right) / \text{RatedMAP} \right) * \text{ActualRPM} / \text{RatedRPM} \right)^{\text{EngineConstant2}}}{\left( \left( 1 + \text{EngineConstant3} \right) * \left( \text{QNH} / \text{ActualPressAlt} \right) - \text{EngineConstant3} \right) * \text{SQRT} \left( \left( 519 - \left( 3.58 * \text{ActualPressAlt} / 1000 \right) \right) / \left( 460 + \text{ActualTemp} \right) \right)}$$

\*  $\left( \left( 1 + \text{EngineConstant3} \right) * \left( \text{QNH} / \text{ActualPressAlt} \right) - \text{EngineConstant3} \right)$

\*  $\text{SQRT} \left( \left( 519 - \left( 3.58 * \text{ActualPressAlt} / 1000 \right) \right) / \left( 460 + \text{ActualTemp} \right) \right)$

where atmospheric units are in hPa and degF

## LoP formula

Fuel rate \* LoP constant

### 1.2 Engine Constant Derivation spreadsheet

The spreadsheet provides for the entry of up to six engine performance data sets for a variety of ISA conditions. Given these data, which must comprise a range of engine horse power vs RPM and MAP combinations at certain ambient pressure and temperature conditions, and the basic max. rated engine parameters, a macro driven function automatically derives the engine constants. At minimum, an engine performance data set for "Sea Level" conditions is required.

As some engine manufacturers do not provide engine performance data sets for anything other than "Sea Level" conditions, for example Continental, the engine constants for some engines can only be derived on the basis of a single data set. In these circumstances, one of the three engine constants which relates to variation in pressure altitude cannot be determined and hence two calculation options are available in the spreadsheet:-

- Calculate "A" – derives all three engine constants; requires 2 but ideally 3 or more data sets spanning from Sea Level to your highest intended operating pressure altitude
- Calculate "B" – derives the two engine constants necessary to define the Sea Level reference performance curves; Engine Constant 3 can be independently derived and manually entered – in the absence of any other data, a value of -0.695 is recommended

The quality of the match with the inputted data sets is described for each data set as the average % difference in calculated % power, and maximum deviation in calculated % power for a selected area of desired "normal operating" conditions – meaning MAP and RPM combinations.

The constant derivation routine aims to optimize the derived constants to minimize the maximum absolute deviation for all data sets. In the case of a Lycoming IO540 manufacturer published data set, the average and maximum absolute differences in calculated % power using the revised MGL formulae were -0.2% and 1.67% for the selected normal range of MAP / RPM combinations. Note, the ranges of normal (or typical) MAP / RPM combinations can be selected for each data set. For example, for a Sea Level data set, one might select 2200 – 2500rpm and 18 – 25" MAP; whereas for a 15,000ft data set, one might select 2200 – 2500rpm and 12 – 16" MAP. In other words, there is no point in trying to optimize the constants for operating conditions that you will either never use, should not use, or can't achieve.

Once the parameters have been derived, there is a separate window for spot calculations so you can check / see what the formula is actually doing for a specific set of operating conditions.

The spreadsheet is "non-password protected"; however, all cells where entries are allowed are unlocked. The spreadsheet uses the Solver function to derive value solutions and hence when the "Calculate" macros are run, the sheet is auto-unprotected (so the Solver routine can run) and then auto-protected again once a solution is found.

It is recommended that the spreadsheet is always operated in "protection mode" so as to avoid inadvertent corruption of the spreadsheet.

If your version of Excel is already set-up to run the Solver function, there should be no issues. If Solver is not set up, this will soon be apparent and you will have to take to steps to activate Solver – these vary in detail between the various versions / vintages of Excel for Windows or Mac but are similar in principle.

The steps to use the spreadsheet are as follows:-

1. Enter your engine's max. rated parameters; you will notice in this area the entry for calculation of LoP horsepower (the equivalent value to enter in the EFIS if operating in Litres is 3.94 HP/litre)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	
1	Engine:		Continental IO550N8B														
2																	
3	Common parameters:					RatedMAP: 28.60 inHg					LOP HP: 14.9 HP/USG						
4						RatedRPM: 2700 rpm					(3.94 HP/ltr)						
5						RatedHP: 310 HP					QNH: 1013 hPa						

2. Enter your engine's power performance data sets and associated definitions (pressure altitude and temperature). Be sure to delete all data in data set entry areas that are not relevant to your engine. The MGL supplied spreadsheet is populated with four data sets and two blank.

Engine constants derivation 2012026.xls																									
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q									
14	Data set ref: ISA conditions (15degC / 0ft PA)				Chart parameters:				Temp: 59 degF				Derived data set for ISA conditions (15degC / 0ft PA)												
15									Press alt: 0 ft				Selected parameter ranges for testing match occur												
16									(1013 hPa)				Min / max MAP: 19 25												
17													Min/max RPM: 2100 2500												
18	*HP ROP as per																								
19	Power Chart																								
20		40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17
21	2700												269	255	243	232	220	208	197	185	173	161	150	138	126
22	2600												260	246	236	225	214	203	191	180	169	158	147	135	124
23	2500												248	236	227	216	205	195	184	174	163	152	141	131	120
24	2400												239	229	218	207	196	186	175	165	154	144	134	124	114
25	2300												227	217	207	197	187	177	167	157	147	137	127	117	107
26	2200												215	206	196	187	177	168	158	149	139	130	120	111	101
27	2100												202	193	185	176	167	158	149	140	131	122	113	104	95
28	2000												191	182	174	165	157	148	140	131	123	114	106	97	89
29	1900												180	172	164	156	148	140	132	124	116	108	100	92	83
30	1800												169	161	153	146	138	131	124	116	109	101	94	87	79

3. Select the normal operating ranges for each data set

Engine constants d																									
Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI							
14	Temp: 59 degF				Derived data set for ISA conditions (15degC / 0ft PA)				Selected parameter ranges for testing match occur																
15	Press alt: 0 ft								Min / max MAP: 19 25																
16	(1013 hPa)								Min/max RPM: 2100 2500																
17									Aver																
18									Max																
19	*HP as per rev																								
20	Formula with pa&ta																								
21		40	39	38	37	36	35																		
22	2700																								
23	2600																								
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28	2100																								
29	2000																								
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31	1800																								

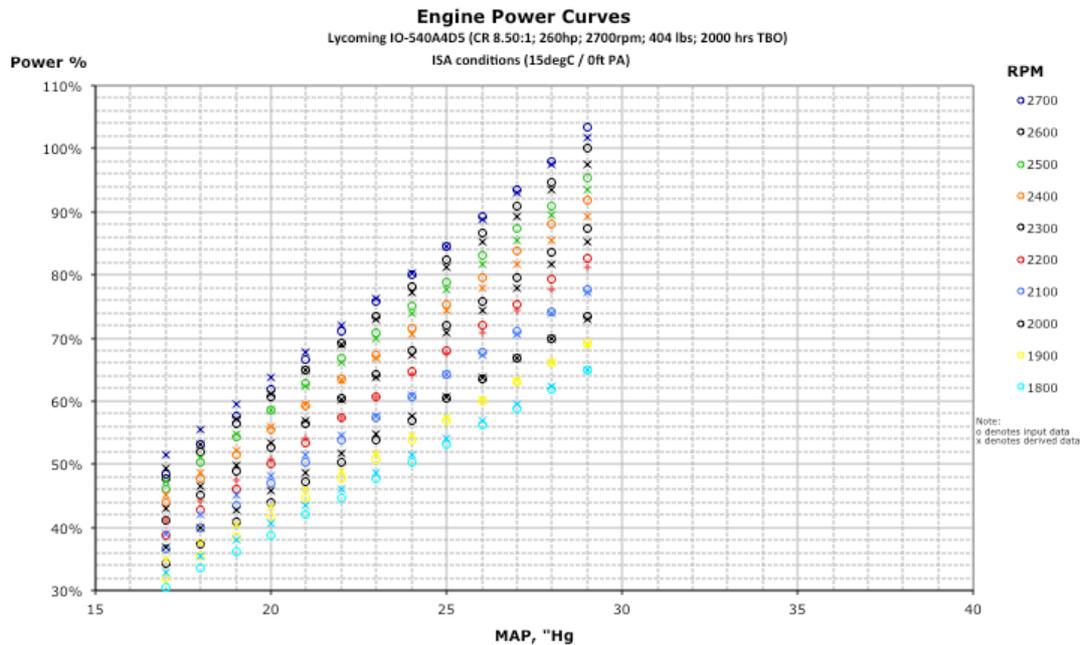
4. Press either the Calculate "A" or Calculate "B" button (refer above) to derive your engine constants. If you intend to use Calculate "B", now would be a good time to enter either your own derived value for Engine Constant 3 or the recommended value of -0.695

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z		
1	Engine:		Continental IO550N8B																								
2																											
3	Common parameters:					RatedMAP: 28.60 inHg					LOP HP: 14.9 HP/USG					EngineConstant1: 0.7334											
4						RatedRPM: 2700 rpm					(3.94 HP/ltr)					EngineConstant2: 1.7937											
5						RatedHP: 310 HP					QNH: 1013 hPa					EngineConstant3: -0.695											
6																											
7	Spot calculator:																										
8	MAP: 28.60 inHg			OAT: 59 degF			(15 degC)			Local QNH: 1013 hPa			Fuel burn: 48.0 Lt/hr			Power: 100%											
9	RPM: 2700 rpm			Press alt: 0 ft			(1013 hPa)			Lean mode: RoP						310 HP RoP											
10																											
11	Calculate "A"												Calculate "B"														
12	Optimize Engine Constants 1, 2 & 3												Optimize Engine Constants 1 & 2 (3 is fixed)														

- Check the overall accuracy match, and likewise for each data set – if there is a large error in any one or more of the data sets, there may be an inconsistency in your data set.

Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR																																											
										<table border="1"> <tr> <td>EngineConstant1:</td><td>0.7334</td> </tr> <tr> <td>EngineConstant2:</td><td>1.7937</td> </tr> <tr> <td>EngineConstant3:</td><td>-0.695</td> </tr> </table>										EngineConstant1:	0.7334	EngineConstant2:	1.7937	EngineConstant3:	-0.695																																													
EngineConstant1:	0.7334																																																																					
EngineConstant2:	1.7937																																																																					
EngineConstant3:	-0.695																																																																					
										<table border="1"> <tr> <td colspan="11">Summary of data set matching accuracies:</td> </tr> <tr> <td>Press alt</td><td>Data set 1</td><td>Data set 2</td><td>Data set 3</td><td>Data set 4</td><td>Data set 5</td><td>Data set 6</td><td>All charts</td> </tr> <tr> <td>Temp</td><td>0 ft</td><td>5000 ft</td><td>10000 ft</td><td>15000 ft</td><td>20000 ft</td><td>25000 ft</td><td></td> </tr> <tr> <td></td><td>59 degF</td><td>41 degF</td><td>23 degF</td><td>5 degF</td><td>-13 degF</td><td>-31 degF</td><td></td> </tr> <tr> <td>Avg. absolute % error:</td><td>-0.22%</td><td></td><td></td><td></td><td></td><td></td><td>-0.22%</td> </tr> <tr> <td>Max absolute % error:</td><td>2.16%</td><td></td><td></td><td></td><td></td><td></td><td>2.16%</td> </tr> </table>										Summary of data set matching accuracies:											Press alt	Data set 1	Data set 2	Data set 3	Data set 4	Data set 5	Data set 6	All charts	Temp	0 ft	5000 ft	10000 ft	15000 ft	20000 ft	25000 ft			59 degF	41 degF	23 degF	5 degF	-13 degF	-31 degF		Avg. absolute % error:	-0.22%						-0.22%	Max absolute % error:	2.16%						2.16%
Summary of data set matching accuracies:																																																																						
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Avg. absolute % error:	-0.22%						-0.22%																																																															
Max absolute % error:	2.16%						2.16%																																																															
										<table border="1"> <tr> <td>Fuel burn:</td><td>48.0 Lt/hr</td><td>Power:</td><td>100%</td> </tr> <tr> <td></td><td></td><td></td><td>310 HP RoP</td> </tr> </table>										Fuel burn:	48.0 Lt/hr	Power:	100%				310 HP RoP																																											
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			310 HP RoP																																																																			

Now check how your Sea Level (reference) input data set compares with the derived performance curves – select “Power chart” sheet. You should expect to see a good match for the selected MAP / RPM normal (or typical) combination ranges that you previously selected. You may see an increasing error outside of these selected ranges.



- Use the Spot Calculator to check for a few data points. You will note the option to select RoP or LoP operating mode. For the latter, you simply enter the fuel burn rate. Provided the spot check are satisfactory, record all the parameters and enter into the EFIS.

7	Spot calculator:										
8	MAP:	28.60 inHg	OAT:	59 degF	(15 degC)	Local QNH:	1013 hPa	Fuel burn:	48.0 Lt/hr	Power:	100%
9	RPM:	2700 rpm	Press alt:	0 ft	(1013 hPa)	Lean mode:	RoP				260 HP RoP

### 1.3 Setting up the EFIS

Armed with the parameters derived per above, enter the EFIS Menu system and proceed to the *Engine Monitoring Set Up Menu* [Menu – Menu – next page – Option 2 – Option 5]. Now select Option 3 *Engine HP Calculation Set Up*.

Enter all parameters and constants, being careful to make sure that values are correctly entered as +ve or -ve as required.

As guide to the quantum of values you will be entering, below are examples of values for a Lycoming IO540 and a Continental IO550. Note that as only Sea Level data are available for the Continental, the engine constants were derived using Calculate “B” option (for engine constants

1 & 2), and the value of -0.695 was used (as derived for the Lycoming engine, for which performance data up to FL150 were available).

	<b>Lyc IO550A4D5</b>	<b>Cont IO550N8B</b>
Max Sea Level HP	260hp	310hp
Max Sea Level RPM	2700rpm	2700rpm
Max Sea Level MAP	28.6"	28.6"
Engine Constant 1	1.117	0.733
Engine Constant 2	1.103	1.794
Engine Constant 3	-0.695	-0.695
Engine Constant LoP*	3.94hp/lit (or 14.9hp/USgal)	

\* Same for all engines

As other MGL clients develop parameters for other engines, it is hoped that these can be shared via the forum and incorporated into this guide when it is next updated.

## 2

### 2.1 **Setting up Excel to run the Engine Constants "Calculate" macro**

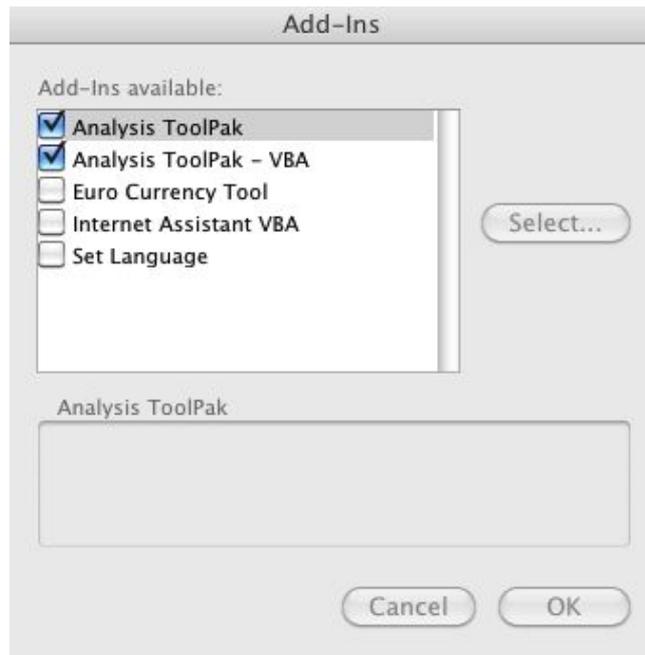
If your copy of Excel is not already set-up correctly to run the "Solver" function, which is the Excel add-in function run within the "Calculate" macros to derive the optimum engine constants, you will need to follow the steps (or similar steps) as per below.

The simplest thing to do first, is to find out if you need to do anything at all - open the spreadsheet, and hit one of the "Calculate" buttons on the spreadsheet.

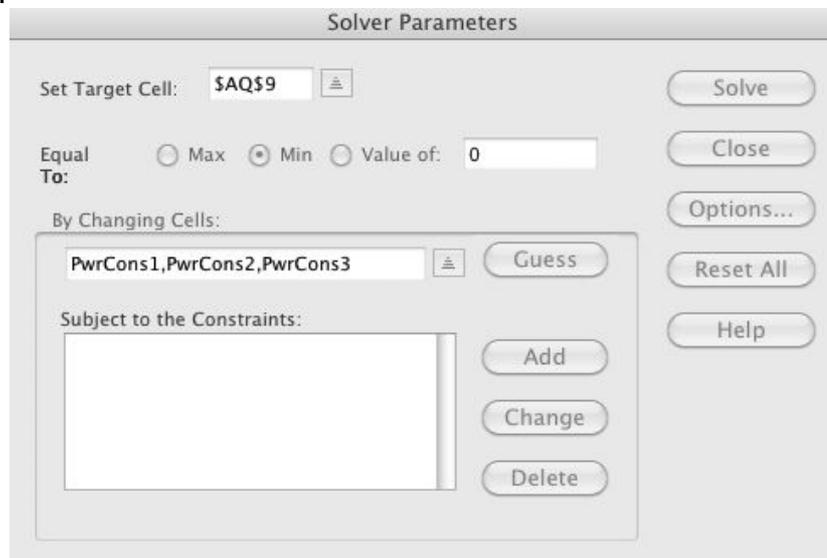
If "things start happening" and the process concludes, you are good to go. The fact that the process has run will be evident if you see the Engine Constants change, although they won't change if there have been no other data changes, and so the constants will already have been optimized - if that's the case, just change one of the constants to another number, and run the macro again to check that the optimization is occurring.

However, if you get a message such as "Compile error: Sub or Function not defined", then you have a few things to do:

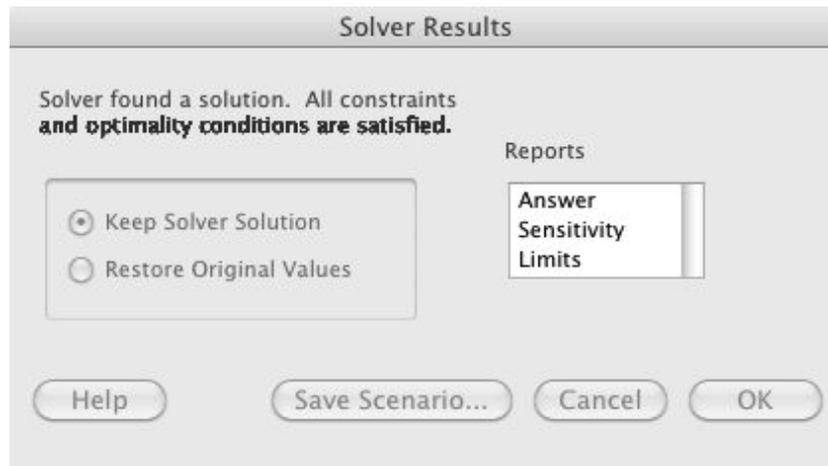
1. Try to run solver manually
  - a. Return the spreadsheet to "normal" mode, i.e. exit the VBA windows or, if this is troublesome, shut the spreadsheet down and re-open.
  - b. From the main menu along the top, select Tools and verify that "Solver" appears - about 2/3 down the list of options. If it does not appear, look for "Add-Ins" closer to the bottom of the list of options available under Tools, and make sure that "Analysis ToolPak" and "Analysis ToolPak - VBA" are both checked.



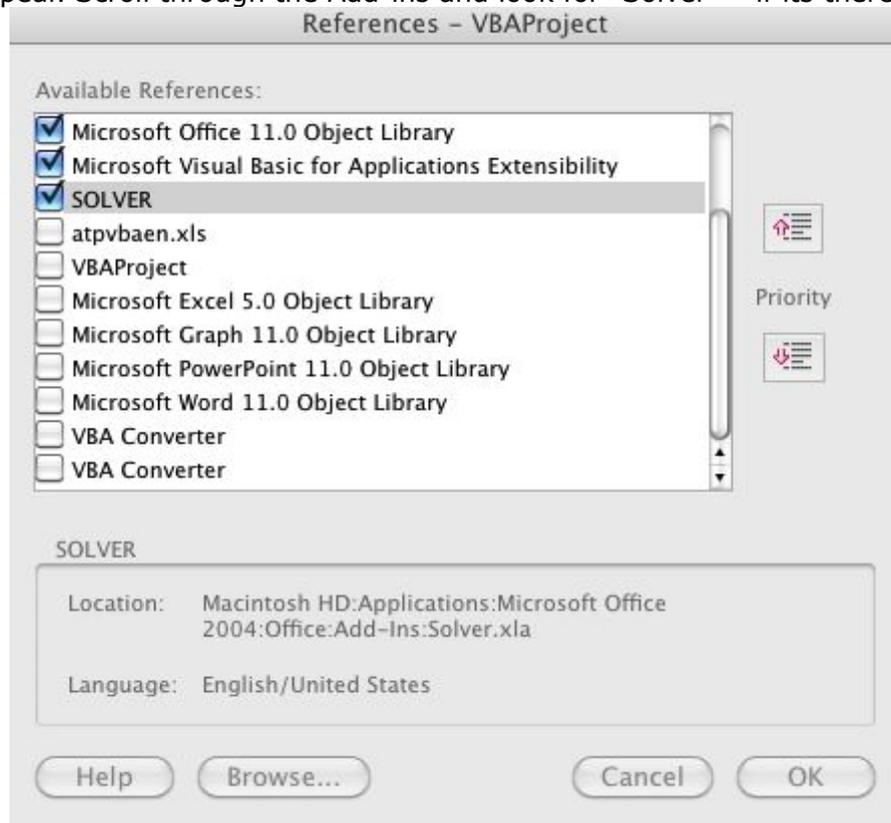
- c. Click OK in Add-Ins window, reselect the Tools menu and you should see "Solver" towards the bottom of the list of options.
- d. At this point, you need to manually unprotect the sheet before you can run Solver – again from the main menu, select Tools => Protection => Unprotect Sheet. Now back to the Tools menu, find the Solver option, select it and the "Solver" window should open and you will see the parameters already selected for the "Calculate" macro.



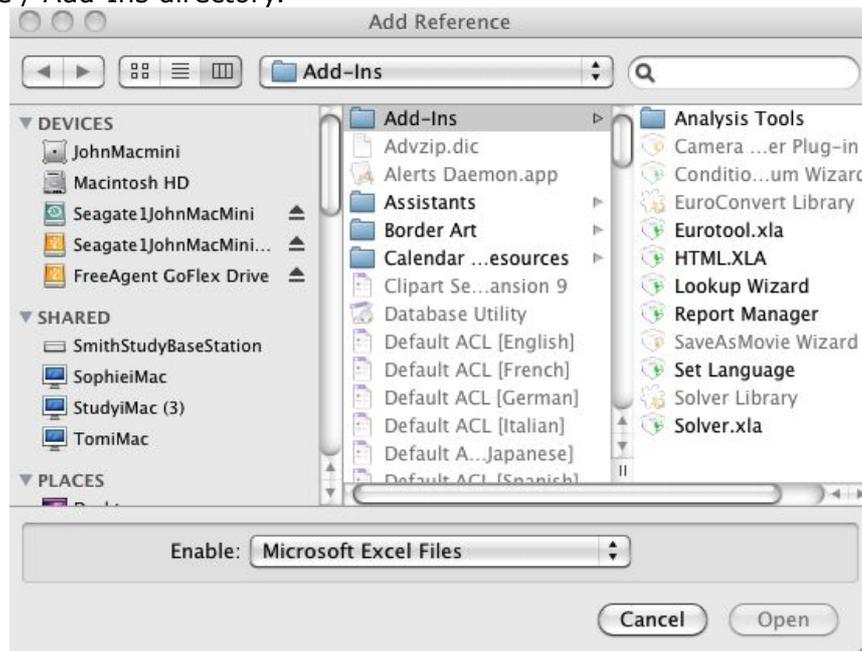
- e. Click "Solve" and the routine should run, and Solver Results window will appear and tell you that a solution has been found; select "Keep solver solution" and click OK



- f. You have now proven that the Solver function is installed and works on your version of Excel, and can be run in manual mode.
2. Now try to run the "Calculate" macro again – hit "Calculate". If the same or similar message as before such as "Compile error: Sub or Function not defined" appears again, you will need to make sure that Solver is referenced in the VBA Add-Ins. It may be that it is already registered in VBA and it just needs to be selected, or it needs to be installed and then selected – either way, the steps are quite simple and pretty much the same:
    - a. From the Excel Main menu, select Tools => Macro => Macros...
    - b. The Macro window will appear and within the list of Macros (should only be one, but some others may appear), highlight "Calc\_constants" and then select "Edit"
  - c. You have now entered VBA programming mode in Excel; note that the Main menu items along the top of your screen have changed
  - d. From this Main menu, select Tools => References and the VBA References window will appear. Scroll through the Add-ins and look for "Solver" – if its there, check it.



- e. If not, select Browse and go looking for a file "Solver.xla" in the Microsoft Office.... / Office / Add-Ins directory.



- f. Once the file is identified, double click it (or select it and press Open) and "Solver.xla" will be added to the VBA reference list – make sure it is checked, and then exit the VBA References window with OK.
- g. Close the VBA and windows and return to the Excel normal mode, and press the "Calculate" macro button on the spreadsheet. The routine will run and you will see the Engine Constants change as described at the beginning of this section.

Note: The screen shots shown here relate to Excel 2004 for Mac, as this was the platform used to initially develop the spreadsheet. The screens will appear slightly different for other / later versions of Excel for Mac running in Mac OS environments, and will also appear differently to various windows versions of Excel running in Windows OS environments. However, the general structure and steps should be similar.

The spreadsheet now provided to MGL clients has been converted and published in the 2010 / 2011 Office Excel formats. Running the spreadsheet in earlier versions may not work; in which case, a version for the spreadsheet designed to work with older versions of Excel can be developed (please make these requests through the MGL Users Forum).

### 3 Engine Lean Mode

The engine leaning function has been enhanced to auto-detect an "EGT peaking event" associated with leaning the mixture through to a lean of peak (LoP) condition. Detection of the event only occurs if the engine Leaning mode window is active. Once the peaking event has been detected, the horsepower calculation automatically switches to the LoP formula. At the same time, the horsepower or % power indication of the screen will change, for example: "63%" to "61% L".

Moving from LoP to RoP operations is not auto-detected.

However, there is also an option within the Engine Leaning menu to manually select "Normal" (RoP) or LoP method of calculation. This may be used under a variety of circumstances such as:-

- Intending to lean RoP, in which case after the EGT peaking event has been detected and the calculation mode auto-switches from RoP to LoP, all that is required is to manually select "RoP" and the method of calculation will revert back to the RoP basis. This will be confirmed with the power indication changing, for example from "59% L" to "62%"
- On descent, and having been operating LoP, you richen the mixture and move to RoP operation; again, all that is required is that you enter the engine Lean Mode function screen and manually select "RoP"
- You choose not to use the Engine Leaning and EGT tracing function, and simply employ the "big pull" and go straight to the fuel rate that you desire. In this circumstance, again, enter the Lean Mode screen, and manually select "LoP"

The default start-up mode is RoP.

The options to toggle between "Normal" (RoP) or LoP calculation will appear as indicated in the images below.





## 4 GAMI spread

Applicable only to fuel injected engines, and only determinable if EGTs can be monitored on all cylinders, the so-called GAMI spread refers to the change in total fuel rate when the first cylinder EGT peaks and the last cylinder EGT peaks when leaning. A "narrow spread" of better than around 0.5 gph or 2 lt/hr generally indicates a well-balanced engine, in the context of fuel/air mixture and fuel delivery to the injectors. A sudden change in the GAMI spread from the "norm" for a given engine is an indicator (but not the only indicator of course) of there being something astray with the fuel injection system – for example a partially blocked injector, or a leaking injector line (refer ADs on this subject for Continentals!). The GAMI spread therefore provides an indication of the balance and health of the fuel injection system.

The GAMI spread will now display in the Engine Leaning window once you have completed a leaning operation, and only if all cylinders' EGTs peak. The intended use is that each time you lean your engine, observation of the GAMI spread will give that "indication" that everything is either as its always been before, or whether something has changed – or even simply that your injectors could do with balancing.

On opening the Engine Leaning Window, you should see something like image below – with advice that the system is waiting for a leaning process to occur – specifically, waiting for the first cylinder to peak. Once a cylinder has peaked, system advises that it is now waiting for the last cylinder to peak and, once it has, the GAMI spread in the selected flow units is displayed.

