

Racing Systems Analysis

ENGINE Pro  
Version 3.1

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## CHAPTER 1: INTRODUCTION

### General

The ENGINE Pro software from RSA quickly estimates the maximum performance potential for a wide range of naturally aspirated, gasoline and methanol burning, spark ignition, internal combustion engines. It can be used with or without cylinder head flowbench data to provide accurate estimates of what an engine can develop in the way of power and torque, and what the expected RPM range of the engine will be.

Today, in this 21st century, motorsports and racing has attained a level of sophistication that makes the personal computer an essential tool for all racers to use, Professional and Sportsman alike.

The QUARTER Pro and QUARTERjr programs for drag racecar performance simulation started it all off, first becoming commercially available way back in 1985. Today, thousands of racers just like yourself, already have QUARTERjr in their "toolbox".

Now, ENGINE Pro unlocks the power and convenience of the personal computer for every racer who needs to know about their engine's performance, or how to modify it to make even more horsepower and torque.

The amount of power and torque a modern high performance engine makes is directly related to the volume and mass of air it pumps and traps. The larger the mass of air trapped in the cylinder at a given RPM, the more fuel that can be burned, and the more power and torque the engine will make.

Many factors - or design variables - have a strong influence on the trapped engine airflow rate including bore stroke ratio, connecting rod length, intake manifold length and flow capacity, and camshaft timing, to name just a few.

Fuel properties and compression ratio are key factors for determining the thermodynamic efficiency of the combustion and expansion processes of the four cycle internal combustion engine.

The ENGINE Pro software from RSA is one of the most accurate means of determining the effects of these engine design variables on overall engine performance. It has been calibrated using dyno data from hundreds of high performance engines, ranging from record holding 4 valve 77 cid Pro Stock motorcycle engines to championship 800+cid "Mountain Motor" Pro Stock engines, and everything else in between.

With competitive racing being a contest of hundredths, or even thousandths of a second, or just fractions of a MPH, only a computer can provide the necessary consistency and accuracy to help understand, predict and improve your engine's performance and durability.

RSA (Racing Systems Analysis) was started in 1978 by Patrick Hale, a local drag racer from Arizona. After drag racing several racecars while attending Mechanical Engineering school at Arizona State University; he developed the well known QUARTER Pro and QUARTERjr computer programs. Now, he has made ENGINE Pro available for overall engine performance simulation.

The services of RSA are also available to customize ENGINE Pro to your specific needs; and to write new, engineering analysis software for other applications. Give RSA a call or e-mail. We will be happy to discuss these possibilities, and future RSA products with you.

Web: [www.QUARTERjr.com](http://www.QUARTERjr.com)

## Installing your program disk

1. Start by inserting the ENGINE Pro program CD into the appropriate drive in your PC.
2. Use the mouse to select Run from the Start menu.
3. In the Command Line box, type `d:\setup.exe` depending on which drive you are using to read the ENGINE Pro setup disk.
4. Use the mouse to click the OK button.
5. Follow the instructions displayed on your computer monitor. When you are finished, remove the CD.
6. The setup process creates a folder named ENGINE Pro in the Program Files group. This folder contains the icon for the ENGINE Pro software. The ENGINE Pro program icon has the name `EngPro.exe`.
7. You can now create a Shortcut for the `EngPro.exe` file and Send it to the Windows desktop if you like. You normally do this by right-clicking the mouse on the `EngPro.exe` program icon and then choosing Create Shortcut from the drop-down list.

## CHAPTER 2: SAMPLE ENGINE Pro ANALYSIS

### Getting Started

In this chapter, we will walk you through a sample, hands on, engine performance analysis. So please sit at your computer while you read this chapter. ENGINE Pro is designed to be very easy to use, even for the first time or novice computer user.

You can begin using ENGINE Pro in one of two ways. For now, use the mouse to double-click on the application icon in the ENGINE Pro folder or the Windows desktop Shortcut you created for ENGPRO.exe. This process starts loading ENGINE Pro from the hard disk to the random access memory (RAM) and starts the program running.

The splash screen identifying the version of the ENGINE Pro program you have will now appear. This will be followed by the ENGINE Pro program screen including a menu of command options. By choosing one of the menu items from the two command menus (File and Help), you command ENGINE Pro to do whatever you choose.

ENGINE Pro can also be started by double-clicking on any ENGINE Pro data document that you have created and saved.

By double-clicking on an ENGINE Pro data document you can pick right up where you left off! However, you first need to "register" the ENGINE Pro application file with the "\*.eng" data documents using the Windows "File Types" manager.

The Windows "File Types" manager is selected by double-clicking on "My Computer" and selecting "Options" from the "View" command menu. The tab for setting the application "File Types" can now be selected.

### Sample ENGINE Pro Analysis

To begin with, let's take a quick look at the ENGINE Pro program screen before proceeding to the sample engine performance analysis that follows.

The ENGINE Pro program screen contains all the input design data necessary to accurately predict the performance potential of an engine. It includes those engine design variables that research and experience have shown to have the largest effect on the power and torque capabilities of an internal combustion engine.

Obviously, these variables include the bore and stroke of the engine design, the compression ratio, cylinder head flow capacity, and camshaft information. Other engine design variables include the number of intake valves per cylinder, fuel type and carburetor or throttle body size.

Any of these data values may easily be changed using the editing features of the ENGINE Pro program which are fully described in Chapter 4 of this manual.

Now slowly press the Tab key a few times and watch how the cursor moves around the ENGINE Pro program screen.

You can also use the mouse to select any input variable to modify. Single-clicking allows direct replacement of the input variable value. Double-clicking on the variable value allows you to insert and delete. You can quickly select any input variable to edit using your mouse in the normal Windows manner.

You might also try holding down the Tab key and see how you can rapidly get to any position on the program screen using this alternative method.

That's all there is to it! Try changing the compression ratio to 14.5. Remember to press the Tab key, (or the Return or Enter keys) after typing 14.5.

Whenever an input variable value is changed, the cursor will momentarily disappear while ENGINE Pro is calculating the new engine's design performance. After this very brief period of time, the calculated output parameters are updated on the program screen.

The calculated output from ENGINE Pro includes the predicted horsepower and torque peaks for the input engine design. Try pressing the Dyno Data command button located at the top of the program screen to see the complete engine dyno data chart.

Press the close box in the upper right-hand corner to return to the main program screen. Detailed descriptions of all the calculated output parameters are included in Chapter 5 of this manual.

How much more power can this 355 Chevy make? And at what RPM? What about trying a 1050 Dominator? A different cam? These are the type of questions ENGINE Pro was designed to answer, quickly and economically.

ENGINE Pro also includes powerful calculation worksheets available by pressing any one of three Worksheet buttons at any time. The Worksheet buttons are located next to their corresponding input variables. Try pressing the Compression Ratio button located at the compression ratio input variable location now.

The Compression Ratio Worksheet will now be displayed for easily calculating the engine compression ratio! The Compression Ratio Worksheet variables are described starting on page 4-8 of this manual.

The engine's Compression Ratio is automatically calculated as you enter the worksheet data. Press the close box in the upper right-hand corner of the Compression Ratio Worksheet to return to the ENGINE Pro program screen when you are finished using the worksheet.

Note that the calculated compression ratio from the worksheet does not automatically transfer to the main screen. You must still input any new value for yourself. However, if you double-click on the calculated value on the worksheet, the worksheet will close and the new value will be transferred to the main ENGINE Pro screen. The engine HP and torque are re-calculated any time any input variable on the main ENGINE Pro program screen.

Press the Recommendations button to display the recommended values for several intake and exhaust system design variables. Following these recommendations should provide a "tuned" intake and exhaust system to

maximize volumetric efficiency, and hence obtain the highest torque and horsepower possible from your engine.

Pressing the Mech Details button will display a special, very detailed screen where piston speeds are summarized and detailed calculations and graphs included for specific angles of crank rotation. Chapter 5 contains a complete description of the ENGINE Pro Recommendations and both the ENGINE Pro Mechanical and Intake Port Flow Details screens.

Selecting the Exit command from the File menu (or pressing the close box in the upper right-hand corner) will return your computer to the Windows desktop.

Good luck and have fun! The remaining chapters of this manual provide you with the detailed knowledge and skills necessary to fully exploit the power and versatility of ENGINE Pro and your Windows PC.

## CHAPTER 3: THE COMMAND MENUS

### The Command Menus

Two Windows command menus; File and Help, containing a variety of menu items are used with ENGINE Pro to specify the command option desired. These menu options may generally be selected anytime while running the program.

Three of the File menu options - Open, Save and Print are also available by using command buttons, located just below the Help menu near the top of the ENGINE Pro program screen.

#### File: Open

The Open command is used to retrieve from the disk and display on the ENGINE Pro program screen a previously saved engine design data document. Selecting Open from the File menu (or pressing the Open command button, the left button located near the top of the program screen) will cause a standard Windows dialog box to appear, awaiting the selection of an ENGINE Pro data document.

Once the input data document is selected, the data values are retrieved and displayed on the ENGINE Pro program screen as well as the calculated engine performance parameters for this data. The cursor is always left at the "Note:" position following this option.

The Open option can be used to open an existing data document so that it may be modified as desired. The retrieved input data can also serve as a base for building another data document to be saved using the Save As option described below.

#### File: Save

The Save command is used to save the current engine design data on your disk. Selecting Save from the File menu will save the data using the current document name. You may also press the Save command button to select this option.

#### File: Save As

The Save As command is used to save the current input data on your disk with a new document name. Select Save As in the File menu for this option.

#### File: Print

The Print option is used to make a complete, printed copy of both the input engine design data and the calculated output parameters from ENGINE Pro. The printout will also contain the data in the three ENGINE Pro calculation Worksheets as well as the complete Engine Dyno Data, Mechanical and Intake Port Flow Details, and Recommendations.

Selecting the Print command in the File menu (or the Print command button) at any time will cause the printer to start printing. The printer should be turned on and the paper aligned at the top of the page before the Print command is selected.

#### File: Exit

The Exit command in the File menu can be used at any time to exit the ENGINE Pro program and return to Windows.

## CHAPTER 4: INPUT VARIABLES

### How to Input

The ENGINE Pro program screen is where the editing required to build an engine design data document takes place. This chapter of the ENGINE Pro manual contains a complete, detailed description of all the input design variables.

Before getting into the definitions of the input variables, let's discuss how you provide input to ENGINE Pro via your computer keyboard and mouse. The mouse is used to select the input variable to be changed. Most of the input variables are edited by selecting them with the mouse and simply typing a new value.

If you make a mistake when typing, use the Back Space key to backup and erase, and then re enter your data.

Pressing the Tab key (or the Return or Enter keys) signifies the end of the variable entry. The Tab key will also advance the cursor to the next input data variable. Pressing the Return or Enter keys will hold the cursor in the current input variable location.

A maximum of five digits may be input for the numeric variables. If more than five digits are entered they will be ignored. Only numeric inputs are allowed.

Also, if you enter a value outside the range of acceptable engine design variable inputs, you will receive a warning message on the screen and ENGINE Pro will automatically change the value to be within the established program limits.

It is important to remember that pressing either the Tab, Return or Enter keys signifies the end of the entry, and only then are the calculations for the engine performance completed and the results displayed on the ENGINE Pro program screen.

Some of the data values are determined by selecting from a drop-down menu. An example of this type of input is the Camshaft Type. Use the mouse to click

the Camshaft Type list box and a menu will appear showing the possible selections. Click the mouse button on the Camshaft Type that you are modeling.

Some of the data values are determined by selecting option or check boxes. An example of this type of input is the Manifold Runner Style. Simply use the mouse to select either the Curved or Straight option button.

The remainder of this chapter of the ENGINE Pro manual contains a complete, detailed description for each of the input engine design variables. A complete description of the three ENGINE Pro worksheets is also included beginning on page 4-8.

### Engine Design Data

Note: = A descriptive string of up to 255 characters used to more completely identify the engine design data document.

Number of Cylinders = the number of cylinders that the engine design contains. Normal values for the Number of Cylinders are between 4 and 8.

Inline, Vee or Flat option? = a set of option check boxes to select either an inline, vee or flat type engine configuration. The flat option also includes all opposed engine configurations.

Bore Diameter = the measured cylinder bore diameter of the engine design expressed in either inches or millimeters. Normal values for the Bore Diameter are between 3.00 and 4.50 inches or 65 and 100 millimeters.

Stroke Length = the measured crankshaft stroke length of the engine design expressed in either inches or millimeters. Normal values for the Stroke Length are between 3.00 and 4.50 inches or 65 and 100 millimeters.

Rod Length = the measured center to center length of the engine connecting rods expressed in either inches or millimeters. Normal values for the Rod Length are between 5.0 and 6.5 inches or 100 and 150 millimeters.

Compression Ratio = the measured mechanical compression ratio for the engine design. Normal values for the Compression Ratio are between 9 and 16.

note: see page 4-8 for a description of the Compression Ratio Worksheet.

Camshaft Type: = a drop-down menu to select which type of camshaft and lifter design are to be modeled by ENGINE Pro.

- overhead cam
  - roller cam and lifter
  - mushroom tappet
- high rate-of-lift flat tappet
  - normal flat tappet and solid lifter
  - hydraulic roller cam and lifter
  - normal hydraulic cam and lifter

Intake Duration @ .050 inch = the intake cam lobe duration measured at .050 inch valve lift expressed in degrees. Normal values for the Intake Duration @ .050 inch are between 200 and 280 degrees.

Throttle CFM @ 1.5 inches Hg = the measured total flow capacity of the engine carburetor(s) or injector throttle body at 1.5 inches Hg pressure drop expressed in cubic feet per minute (CFM). Normal values for one carburetor are between 390 and 1150 CFM. Normal input values for two carburetors may vary from 1300 to 2600 CFM.

note: 1.5 inches Hg equals 20.4 inches H<sub>2</sub>O

note: see page 4-10 for a description of the Throttle CFM @ 1.5 inches Hg Worksheet.

Carb or EFI option? = an option check box to select either a carburetor, or a mechanical or electronic fuel injection type fuel delivery system.

Fuel Type: = a drop down menu to select which type of fuel is to be modeled by ENGINE Pro.

- gasoline
- racing gasoline
- methanol

Intake Manifold Type: = a drop-down menu to select which type of intake manifold design is to be modeled by ENGINE Pro.

- plenum style (most common)
- individual runner (IR)
- dual plane, 100% divided
- dual plane w/small slot

Manifold Runner Style option? = an option check box to select either curved or straight intake manifold runners. For example, single four barrel intake manifolds for V8 engines typically have curved intake runners between the carburetor and cylinder head. However, most dual four barrel sheet metal intake manifolds for V8 engines have straight intake runners.

Intake Manifold Flow Factor = is a measure of how the intake manifold affects the bare cylinder head flow. The Intake Manifold Flow Factor is the ratio of the intake flow with the intake manifold attached and the bare head flow, expressed as a percentage.

Both these flow values are measured on the flowbench at maximum net intake valve lift at the same Test Pressure and Reference Bore Diameter. Normal values for the Intake Manifold Flow Factor are between 90 and 98 percent.

Unported, cast intake manifolds can vary from 90 to 94 percent. Ported aftermarket, cast single four barrel manifolds can achieve 97 percent. State of the art aluminum sheet metal manifolds for two four barrel applications can exceed 99 percent.

Number of Intake Valves per Cylinder = the number of intake valves per cylinder for the engine design. Normal values for the Number of Intake Valves per Cylinder are either 1 or 2, but some racing motorcycle and Formula 1 engine designs currently have 3 intake valves per cylinder!

Intake Valve Diameter = the measured diameter of the intake valve head expressed in either inches or millimeters. Normal values for the Intake Valve Diameter are between 1.60 and 2.25 inches or 25 and 45 millimeters.

Maximum Intake Port Flow CFM @ Test Pressure inches H2O @ Reference Bore Diameter = the intake flow at maximum net intake valve lift determined

from the measured flowbench data expressed in CFM. You must also input the corresponding Test Pressure expressed in inches of H<sub>2</sub>O and the flowbench Reference Bore Diameter expressed in either inches or millimeters.

Normal values for the Maximum Intake Port Flow vary considerably based on the intake valve diameter and Test Pressure, but usually fall between 120 and 450 CFM. Normal values for the Test Pressure are between 10 and 28 inches H<sub>2</sub>O. Normal values for the Reference Bore Diameter should be within 2 percent of the actual engine cylinder bore diameter.

Note: Always input the total intake flow for engines having more than one intake valve per cylinder.

note: see page 4-12 for a description of the Intake Port Flowbench Data Worksheet.

### Compression Ratio Worksheet

The Compression Ratio Worksheet is displayed by pressing the Compression Ratio button located at the Compression Ratio input variable position. Control is returned to the main ENGINE Pro program screen by pressing the worksheet close box when you are finished using this worksheet.

The Compression Ratio Worksheet is included with ENGINE Pro to help you quickly determine what your current compression ratio is, or to determine what combination of engine variables will give you the compression ratio you desire. Each of the Compression Ratio Worksheet variables is fully described in the following paragraphs.

Combustion Chamber Volume = the measured volume of the cylinder head combustion chamber expressed in cubic centimeters (c.c.). This value may be obtained from the cylinder head manufacturer or accurately determined by direct measurement of the finished cylinder head. Normal values for the Combustion Chamber Volume vary greatly, but generally fall between 40 and 100 c.c.

Piston to Deck Height = the measured distance that the top of the piston is located below the block deck surface expressed in inches. If the top of the piston rises above the block deck surface, the Piston to Deck Height would be

input as a negative number. Normal values for the Piston to Deck Height are between 0.0 and .025 inches.

Head Gasket Thickness = the measured, compressed thickness of the cylinder head gasket expressed in inches. Normal values for the Head Gasket Thickness are between .018 and .048 inches.

Piston Dome Volume = the total measured volume of the piston dome expressed in cubic centimeters (c.c.). This value may be obtained from the piston manufacturer or accurately determined by direct measurement in the engine. Normal values for the Piston Dome Volume vary greatly, but generally fall between 10 and 25 c.c.

#### Throttle CFM @ 1.5 inches Hg Worksheet

The Throttle CFM @ 1.5 in Hg Worksheet is displayed by pressing the Throttle CFM @ 1.5 inches Hg button located at the Throttle CFM @ 1.5 inches Hg input variable position. Control is returned to the main ENGINE Pro program screen by pressing the worksheet close box when you are finished using this worksheet.

The Throttle CFM @ 1.5 inches Hg Worksheet is included with ENGINE Pro to help you quickly estimate what your carburetor or throttle body flow capacity is, or to determine what throttle and venturi diameters would be required to get the airflow you desire.

Each of the Throttle CFM @ 1.5 inches Hg Worksheet variables is fully described in the following paragraphs. The worksheet includes separate inputs for the Primary and Secondary parts of the throttle, since these may have different diameters for your specific application.

Number of Throttle Bores = the total number of throttle bores being modeled. Normal values for the Number of Throttle Bores is between 2 and 8.

Throttle Diameter = the diameter of the throttle bore measured in either inches or millimeters. Normal values for the Throttle Diameter are between 1.0 and 2.0 inches or 25 and 48 millimeters.

Venturi Diameter = the diameter of the throttle venturi measured in either inches or millimeters. Normal values for the Venturi Diameter are between .875 and 1.75 inches or 20 and 40 millimeters.

Throttle Type option? = an option check box to select which type of throttle design is to be modeled by ENGINE Pro.

- butterfly valve = this is the most common style, used in most carburetors and throttle bodies.
- slide valve = slide valve carburetors are typically found on motorcycles and do not have throttle shafts or butterfly valves in the throttle bore of the carburetor or throttle body.

Note: To display the equivalent Throttle CFM @ 3.0 inches Hg (a common rating for two barrel carburetors), move the mouse over the calculated Throttle CFM @ 1.5 inches Hg value.

#### Intake Port Flowbench Data Worksheet

The Intake Port Flowbench Data Worksheet is displayed by pressing the worksheet button located at the Maximum Intake Port Flow input variable positions. Control is returned to the main ENGINE Pro program screen by pressing the worksheet close box when you are finished using this powerful worksheet.

The Intake Port Flowbench Data Worksheet is included with ENGINE Pro for two primary uses:

- a) to help the engine designer without flowbench data estimate the intake flow capacity of a specific cylinder head design based on the intake valve diameter, lift, and valve job details.

b) to critique the flowbench data and intake flow capacity results obtained from a cylinder head porting shop.

Each of the Intake Port Flowbench Data Worksheet variables is fully described on the following pages. These definitions are then followed on page 4-16 by a description of how to use this powerful worksheet for the two situations listed above.

#### Intake Valve Seat Throat Data

Valve Seat Throat Diameter = the diameter of the valve seat throat measured in inches or millimeters. The Valve Seat Throat Diameter is always less than the valve head diameter (also displayed for reference).

Valve Seat Throat Percentage = the ratio of the Valve Seat Throat Diameter to the valve head diameter expressed as a percentage. Normal values for the Valve Seat Throat Percentage are typically between 85 and 88 percent for stock heads and 88 and 92 percent for racing heads.

Valve Seat Angle = the measured angle of the valve seat face expressed in degrees. The most common Valve Seat Angle is 45 degrees, however some cylinder heads may use a valve seat angle between 35 and 55.

Valve Seat Width = the width of the valve seat face measured in inches. Normal values for the Valve Seat Width are between .060 and .090.

Valve Stem Diameter = the diameter of the valve stem measured in inches or millimeters. Normal values for the Valve Stem Diameter are between .25 and .375 inches or 4 and 8 millimeters.

#### Flowbench Data

The next section on the Intake Port Flowbench Data Worksheet is for the actual flowbench data itself. A table providing for up to 10 pairs of lift (inches) and flow (CFM) values is provided. For each set of input data, the area and a number of flow velocity parameters are calculated.

Area = the calculated minimum cross section area of the intake port expressed in square inches. This may be controlled by either the valve curtain area or valve throat area depending on the input valve lift.

Please note that the intake port may be smaller at some other point. For example, on many small block Chevy heads, the area next to the pushrod can be a pinch point at very high valve lifts. The Cross-section Area Calculator may be useful to help you with this important calculation.

note: see page 4-18 for a description of the Cross-section Area Calculator.

Flow Velocity = the calculated average intake port flow velocity expressed in feet per second. Normal values for the Flow Velocity vary directly with the flowbench Test Pressure as shown below:

@ 10" H2O - 130 to 185 ft/sec

@ 20" H2O - 185 to 240 ft/sec

@ 25" H2O - 210 to 270 ft/sec

@ 28" H2O - 225 to 285 ft/sec

@ 45" H2O - 290 to 375 ft/sec

Flow Flux = the calculated intake port flow flux expressed in CFM per square inch of cross-section Area. Normal values for the Flow Flux vary directly with the flowbench Test Pressure as shown below:

@ 10" H2O - 55 to 70 CFM/sq in

@ 20" H2O - 80 to 100 CFM/sq in

@ 25" H2O - 90 to 115 CFM/sq in

@ 28" H2O - 95 to 120 CFM/sq in

@ 45" H2O - 120 to 155 CFM/sq in

Flow Velocity Index = the Flow Velocity expressed as a percentage of the maximum theoretical limit for the input flowbench Test Pressure. Normal values for the Flow Velocity Index are between 70 and 90 percent. State-of-the-art cylinder heads are currently able to achieve almost 100 percent of the theoretical limit.

At the bottom of the Flowbench Data section is an area to input the Maximum Intake Valve Lift for your engine design. After you input this value, ENGINE

Pro determines the corresponding intake port flow CFM and calculates all the flow velocity parameters described above for this max lift value.

Maximum Intake Valve Lift = the measured max net intake valve lift expressed in inches. This value can be calculated from the camshaft specs as the stated lift minus the recommended valve lash. Normal values for the Max Intake Valve Lift can vary greatly with intake valve diameter, but are usually between .450 and .750 inches.

Now, let's get back to the two situations described earlier and how to use the Intake Port Flowbench Data Worksheet.

a) For the case where you have absolutely no cylinder head flowbench data, start off by entering the actual Intake Valve Diameter on the main program screen. Use the Intake Port Flowbench Data Worksheet to estimate the valve seat dimensions and flowbench data for your engine design.

If the cylinder heads are totally stock enter a value of 65 percent for the Flow Velocity Index at the Max Intake Valve Lift. If some work has been done to the valve seat, throat and bowl areas a value of 70 75 percent might be appropriate. If the heads have been fully ported by a professional head porting shop, 80 85 percent Flow Velocity Index at maximum lift is not uncommon.

ENGINE Pro will now estimate the flowbench data values as well as the Maximum Intake Port Flow and display the result on the main program screen.

b) When critiquing cylinder head flowbench data, enter the Intake Valve Diameter and estimated Maximum Intake Port Flow on the main program screen. Use the Intake Port Flowbench Data Worksheet to enter all the valve seat details, actual flowbench data and Maximum Intake Valve Lift.

ENGINE Pro will calculate all the flow velocity parameters and the critical Flow Velocity Index. Professional port work should achieve a Flow Velocity Index of at least 85 percent at the Maximum Intake Valve Lift. State of the art port work can achieve over 10 percent more flow, approaching 100 percent for the Flow Velocity Index at maximum lift.

Cross-section Area Calculator

The Cross-section Area Calculator is displayed by pressing the Area Calculator button located along the top of the main program screen.

The Cross-section Area Calculator is included with ENGINE Pro to help you quickly determine what the cross-section area is for four different flowpath shapes. Each of the Cross-section Area Calculator variables is fully described in the following paragraphs.

All Cross-Section Area Worksheets use:

Stem Diameter = the diameter of the valve stem measured in inches or millimeters. Use this input only if the valve stem is actually present in the flowpath.

Circular Area Worksheet:

Diameter = the diameter of the circular flowpath measured in inches or millimeters.

Rectangular Area Worksheet:

Height = the height of the rectangular flowpath measured in inches or millimeters.

Width = the width of the rectangular flowpath measured in inches or millimeters.

Corner Diameter = the corner diameter of all four corners of the rectangular flowpath measured in inches or millimeters.

Elliptical Area Worksheet:

Major Diameter = the larger diameter of the elliptical flowpath measured in inches or millimeters.

Minor Diameter = the smaller diameter of the elliptical flowpath measured in inches or millimeters.

Annular Area Worksheet:

Outer Diameter = the outer diameter of the annular flowpath measured in inches or millimeters.

Inner Diameter = the inner diameter of the annular flowpath measured in inches or millimeters.

## CHAPTER 5: CALCULATED PARAMETERS

The calculated output from ENGINE Pro is separated into five parts - Estimated engine performance, Engine Dyno Data, ENGINE Pro Recommendations, and the ENGINE Pro Mechanical and Intake Port Flow Details. Please refer to the output of the sample case on your computer monitor to get a complete understanding of all the ENGINE Pro calculated output parameters.

### Estimated engine performance

ENGINE Pro estimates overall engine performance for the "standard" ambient conditions of sea level elevation, 29.92 inches Hg, 60 degrees F and no humidity. This is the same "standard" that most aftermarket, racing and high performance engine data is "corrected" to. Engine power and torque predictions are consistent with the SAE (Society of Automotive Engineers) J1349 Standard Method.

ENGINE Pro calculates the displacement of the engine and the eight key engine performance parameters described on the next page. These output parameters should be viewed as what's possible for the input engine design.

A few engines may be able to surpass these values using special exotic fuels, synthetic lubricants and dry sump oil systems, and variable length intake and exhaust systems . . . but not by much, usually no more than 2-3%.

Peak HP = the estimated maximum power (HP and kW) potential of the engine described by the input engine design data.

RPM @ Peak HP = the predicted RPM at which the Peak HP will occur.

Peak HP/CID = the calculated peak HP per cubic inch of engine displacement.

Peak Torque = the estimated maximum torque (ft lbs and Nm) potential of the engine described by the input engine design data.

RPM @ Peak Torque = the predicted RPM at which the Peak Torque will occur.

Peak Torque/CID = the calculated peak torque per cubic inch of engine displacement.

Shift RPM = the RPM that the engine should be shifted at for best performance. The recommended ENGINE Pro Shift RPM is simply 8 percent greater than the RPM @ Peak HP.

Redline RPM = the maximum RPM for engine operation. The ENGINE Pro recommended Redline RPM is based on mechanical stress limits for the crank, rod and piston assembly - it has nothing to do with valve train dynamics!

#### Engine Dyno Data

The Dyno Data button located at the top of the ENGINE Pro program screen is used to display the calculated horsepower and torque curves for the input engine design. This data is displayed over the entire RPM range of the engine, just like you get from an engine dyno.

#### ENGINE Pro Mechanical Details

The Mech Details button can be pressed at any time to display the ENGINE Pro Mechanical Details screen. Detailed engine parameters are organized into three distinct areas within this screen: Piston Speed Summary in the upper-left corner, Geometric Data Summary on the left-hand side, and Piston Details on the right-hand side of the screen.

#### Piston Speed Summary:

The Piston Speed Summary includes both the average and maximum piston speeds at the four engine rating points of peak TQ, peak HP, shift RPM and redline RPM - expressed in feet per minute (FPM). It also includes the crankshaft angle after top dead center (TDC) when the maximum piston speed occurs and the Estimated Cranking Compression.

Avg Piston Speed = the average speed of the piston expressed in feet per minute (FPM). Avg Piston Speed is a simple function equal to the crankshaft stroke (in inches), multiplied by the RPM, and divided by 6.

Max Piston Speed = the maximum speed the piston obtains expressed in feet per minute (FPM). Max Piston Speed takes into account the eccentric motion of the piston due to the crankshaft and connecting rod assembly. The Max Piston Speed will always be much greater than the Avg Piston Speed.

Geometric Data Summary:

The Geometric Data Summary includes a number of non-dimensional parameters that describe several key features of the overall engine design. These non-dimensional parameters allow a quick comparison as to the geometric similarity of two engine designs having vastly different displacements.

Bore to Stroke Ratio = the ratio of the bore diameter and crankshaft stroke length.

Rod to Stroke Ratio = the ratio of the connecting rod length and crankshaft stroke length.

Piston to Head/Rod Length = the ratio of the total piston to head clearance at TDC and the connecting rod length.

Intake Throat/Bore Area Ratio = the ratio of the intake port minimum cross-section area and the bore area. Normally, the intake valve throat is the section of minimum cross-section area.

Intake Valve Lift/Diameter Ratio = the ratio of the input maximum net intake valve lift and the intake valve head diameter.

Piston Details:

Piston Details are provided for a number of different crankshaft angles for each of the four engine rating points of peak TQ, peak HP, shift RPM and redline RPM.

The engine rating points and corresponding RPM are included in the Piston Speed Summary at the left of the Piston Details table as a menu list. You can

easily select among the four engine rating points by clicking the mouse on the desired rating point RPM.

deg ATDC = the crankshaft angle expressed in degrees after TDC (ATDC). The motion of the piston is assumed symmetric about TDC, thus the calculated piston depth and speed values will also correspond to crankshaft angles before TDC.

For example, at 45 degrees before and after TDC the piston will be in the same position relative to TDC and have the same speed and acceleration.

depth (inch) = the distance the piston is displaced from TDC along the cylinder expressed in inches.

Piston Speeds (FPM and FPS) = the actual piston speed along the cylinder at this crankshaft angle and rating point RPM, expressed in both feet per minute (FPM) and feet per second (FPS).

g's accel = the actual piston acceleration along the cylinder at this crankshaft angle and rating point RPM, expressed in g's. Positive g's result in tension in the connecting rod whereas negative g's result in compression.

note:  $1.0 \text{ g} = 32.174 \text{ ft/sec/sec}$

The graph located in the lower portion of the Mechanical Details screen includes the calculated Piston Speed and Depth details plotted against the crankshaft angle ATDC.

#### ENGINE Pro Intake Port Flow Details

The Flow Details button can be pressed at any time to display the ENGINE Pro Intake Port Flow Details screen. Detailed engine parameters are organized into three distinct areas within this screen: Piston Speed Summary in the upper-left corner, Camshaft Description on the left-hand side, and Flow Details on the right-hand side of the screen.

Piston Speed Summary:

The Piston Speed Summary includes both the average and maximum piston speeds at the four engine rating points of peak TQ, peak HP, shift RPM and redline RPM - expressed in feet per minute (FPM).

Avg Piston Speed = the average speed of the piston expressed in feet per minute (FPM). Avg Piston Speed is a simple function equal to the crankshaft stroke (in inches), multiplied by the RPM, and divided by 6.

Max Piston Speed = the maximum speed the piston obtains expressed in feet per minute (FPM). Max Piston Speed takes into account the eccentric motion of the piston due to the crankshaft and connecting rod assembly. The Max Piston Speed will always be much greater than the Avg Piston Speed.

Camshaft Description:

The Camshaft Description includes values that define both the cam lobe shape and orientation of the intake valve lift as a function of crankshaft angle. The initial values are set based on values from the ENGINE Pro main program screen, and the Intake Port Flowbench Data Worksheet and ENGINE Pro Recommendations.

Intake Duration @ .050" = the intake cam lobe duration measured at .050 inch valve lift expressed in degrees. Normal values for the Intake Duration @ .050 inch are between 200 and 280 degrees.

Intake Lobe Centerline = the location of the camshaft intake lobe centerline expressed in degrees ATDC.

Maximum Valve Lift = the measured maximum net intake valve lift expressed in inches. This value can be calculated from the camshaft specs as the stated lift minus the recommended valve lash. Normal values for the Maximum Valve Lift can vary greatly with the valve diameter, but are usually between .450 and .750 inches.

Flow Details:

Flow Details are provided for a number of crankshaft angle positions for each of the four engine rating points of peak TQ, peak HP, shift RPM and redline RPM.

The engine rating points and corresponding RPM are included in the Piston Speed Summary at the left of the Flow Details table as a menu list. You can easily select among the four engine rating points by clicking the mouse on the desired rating point RPM.

deg ATDC = the crankshaft angle expressed in degrees after TDC on the intake stroke.

Valve Lift (inch) = the valve lift for this crankshaft angle as determined from the Camshaft Description.

Flow Area (sq in) = the calculated flow area for this valve lift based on the Intake Valve Seat Throat Data on the Intake Port Flowbench Data Worksheet, at this rating point RPM.

Piston Speed (FPM) = the actual piston speed along the cylinder at this crankshaft angle and rating point RPM, expressed in feet per minute.

Piston Flow Demand (CFM) = the actual volumetric displacement rate at the intake valve throat due to the instantaneous piston speed at this crankshaft angle and rating point RPM, expressed in CFM. The Piston Flow Demand is the actual airflow demand (CFM) the moving piston within the cylinder is placing on the cylinder head!

Note that the peak Piston Flow Demand lags the maximum piston speed by a few degrees of crankshaft rotation. This is caused by the time lag as the piston flow demand signal traverses the cylinder from the piston dome to the intake valve throat at near sonic velocity.

Flowbench Velocity (FPS) = the calculated flow velocity at the intake valve throat for this crankshaft angle and rating point RPM, expressed in feet per second.

Flowbench Test (in H<sub>2</sub>O) = the test pressure required to accurately simulate this engine operating condition on the flowbench, expressed in inches of H<sub>2</sub>O. Note

that this test pressure may be much higher than that used for the actual input Flowbench Data.

The graph located in the lower portion of the Intake Port Flow Details screen includes the calculated Flow Area, Piston Flow Demand and Flowbench Velocity details plotted against the crankshaft angle ATDC for the intake stroke.

#### ENGINE Pro Recommendations

The estimated engine performance from ENGINE Pro should be viewed as the engine's power and torque potential based on the key input engine design variables. In order to achieve this engine performance level other design parameters must also compliment the overall engine combination and design.

The Recommendations button is used to display recommended values for these other significant engine design parameters. These design parameters have not shown as strong an influence on engine performance as the ENGINE Pro input design variables, but nevertheless, must be at or close to their optimum values to achieve the engine's performance potential.

The ENGINE Pro engine design parameter recommendation are based on research and analysis of a wide range of high performance and racing engine designs.

The ENGINE Pro recommendations for the Intake System and Camshaft should provide a free flowing intake track with "tuning" optimized for the calculated RPM range of the engine.

#### Intake System:

Intake Valve Lift = the maximum gross intake valve lift required stated in inches. This value considers the intake valve diameter, cylinder head flow capacity, camshaft and lifter type, and RPM range of the engine.

Minimum Flow Area = the minimum cross-section area to be found anywhere in the intake port stated in square inches.

Total Intake Track Length = the intake track length that provides the best "tuning" for the input engine design. The Total Intake Track Length is the length from the valve head to the first "abrupt opening". Typically, the first "abrupt opening" occurs under the carburetor(s) in the plenum area of the intake manifold. For IR systems the first "abrupt opening" is the open end of the air inlet stack of the carburetor or fuel injector.

Maximum Flow Area = the cross-section area at the first "abrupt opening" stated in square inches. The Maximum Flow Area is based on the optimum runner taper ratio and Intake Track Volume. Always utilize a smooth, gradual runner taper to achieve the Maximum Flow Area - do not create steep gradients anywhere in the intake track.

Total Intake Track Volume = the volume of the "tuned" intake track stated in c.c. The Total Intake Track Volume is the volume from the intake valve head to the first "abrupt opening". It is the sum of the intake port volume and intake manifold runner volume. For IR intake systems it also include the carburetor volume to the top of the velocity stack.

Plenum Volume = the recommended engine plenum volume stated in cubic inches.

Camshaft:

Lobe Separation Angle = the angle between the camshaft exhaust lobe and intake lobe centerlines stated in camshaft degrees.

Intake Lobe Centerline = The camshaft may need to be advanced or retarded from the straight-up setting but usually no more than 2 degrees in either direction.

Exhaust Duration @ .050 inch = the exhaust cam lobe duration stated in degrees.

The ENGINE Pro recommendations for the Exhaust Port and Exhaust System should provide a free flowing exhaust track with "tuning" optimized for the calculated RPM range of the engine.

#### Exhaust Port:

Exhaust Flow = the recommended exhaust flow stated in CFM at the input flowbench Test Pressure and Reference Bore Diameter. This value is also stated as a percentage of the input Maximum Intake Port Flow.

Note: There are two methods for flow testing exhaust ports in common use today. One is to flow the exhaust port bare, the other is to flow the exhaust port with a pipe attached to the header flange of the head. Flowing the exhaust port with a pipe normally increases the maximum lift flow about 10 percent.

The ENGINE Pro recommendations for exhaust flow assume the use of a pipe intended to simulate the engine's primary header tube. If a "stub" pipe is used on the flowbench, it's length should be at least 6 pipe diameters.

Exhaust Valve Diameter = the recommended exhaust valve head diameter stated in either inches or millimeters. For engine designs with two or more intake valves, ENGINE Pro assumes two exhaust valves will be used.

Exhaust Valve Lift = the maximum gross lift required at the exhaust valve stated in inches. This value considers the exhaust valve diameter, cylinder head flow capacity, camshaft and lifter type, and RPM range of the engine design.

Minimum Flow Area = the minimum cross-section area to be found anywhere in the exhaust port stated in square inches.

Maximum Flow Area = the maximum cross-section area at the exit of the engine exhaust port stated in square inches.

#### Exhaust System:

Primary Tube Length = the primary header tube length that provides the best overall "tuning" for the input engine design. The Primary Tube Length is the total length from the cylinder head flange to the first "abrupt opening". Typically, the first "abrupt opening" occurs in the collector of the exhaust header.

Primary Tube Diameter = the outer diameter of the primary header tube stated in inches. Multi-step headers may get larger than the Primary Tube Diameter as they approach the collector, but usually no more the 1/8" per step.

Collector Diameter = the recommended exhaust collector outer diameter stated in inches.