ProRacing Sim, LLC

DynoSim Racing Software

DeskTop Dyno
DeskTop Simulation Series

Engine Simulation And Analysis Software

Program Guide & Engine Builders Handbook

For Windows98/Me/2000/XP & Vista

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DeskTop Dyno5 and DynoSim5 Simulations

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ACKNOWLEDGMENTS, ETC.

ACKNOWLEDGMENTS: Larry Atherton of Motion Software wishes to thank the many individuals who contributed to the development and marketing of this program:

Lance Noller, Lead Programmer. A special thanks for his dedication to DynoSim5 project. His programming skills, tenacious troubleshooting and creative problem solving made DynoSim5 reliable and easy-to-use.

Brent Erickson, Lead Programmer on DynoSim-5 update project, Simulation Designer, Windows, C, C++, Assembler Programmer. Brent's positive "can-do" attitude is backed up by his ability to accomplish what many dismiss as impossible. Developed new mathematical models for DynoSim-5, and is principal architect of FastLapSim.

And special thanks are due to all the marketing and management personnel of ProRacing Sim, LLC., especially:

Ron Coleman, His enthusiasm for this software and the building of an outstanding marketing network made this entire project possible.

"Scooter" Brothers, He was the first to see special value in simulation software. A multi-talented engineer and camshaft expert, Scooter's insight and dedication to excellence is greatly appreciated.

And thanks to the many other individuals who have contributed to the successful development and marketing of this software.

Larry Atherton, Pres., CEO
Motion Software, Inc.

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INTRODUCTION

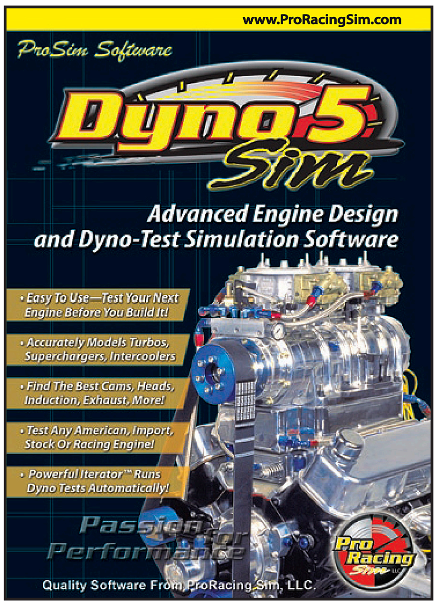
PROGRAM VERSION NOTE: While this manual primarily refers to the "DynoSim5," the descriptions herein also apply, in large part, to the DeskTop Dyno. For a detailed list of the feature differences between these products, refer to page 152.

Note: *If you can't wait to start this engine simulation, feel free to jump ahead to* **INSTALLATION** on page 13, *but don't forget to read the rest of this manual when you have time. Also, make sure you complete the Registration Form that appears when you first start your software. It entitles you to receive tech support, obtain discounts on future releases, and participate in exciting contests sponsored by ProRacing Sim.*

Thank you for purchasing the DeskTop Dyno5 or DynoSim5™ for PC computers. This software is the result of several years of development and testing. We hope it helps you further your understanding and enjoyment of engines, performance, and racing technology.

HOW IT WORKS

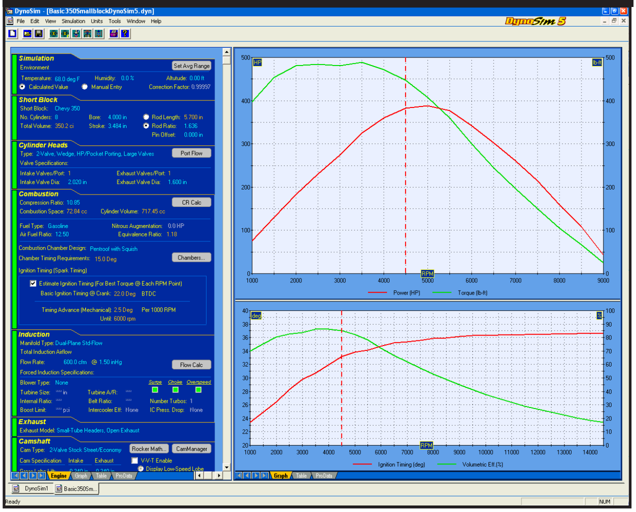
DeskTop Dyno5/DynoSim5 programs are 32-bit programs designed for Windows95/98/Me/2000/XP and Vista. They incorporate the *Filling-And-Emptying* method of engine power simulation. We chose this family of mathematical models because of their excellent power prediction accuracy and fast processing times. The DeskTop-Dyno5/DynoSim5 are *full-cycle* simulations. This means that they calculate the complete



DynoSim5 is the most advanced engine simulation ever offered to the performance enthusiast. It combines ease of use, rapid calculation times, powerful Iterative Testing™, and detailed graphics.

Introduction To DynoSim5

DynoSim5 Main Component Screen



DynoSim5 incorporates a clean, intuitive user interface. If you wish to change a component, simply click on the component name and select a new component from the drop-down list. The comprehensive data display graphs are fully customizable. Multiple engine and/or data value comparisons are possible. All components and graphics displays can be printed in full color.

fluid-dynamic, thermodynamic, and frictional conditions that exist inside each cylinder throughout the entire 720 degrees of the four-cycle process.

You will find that many other simulation programs on the market (even a few that sell for several times the price of these engine simulation packages) are not true *simulations*. Rather, they calculate the volumetric efficiency (VE) and then derive an estimate of torque and horsepower. There are many shortcomings to this technique. The two greatest drawbacks are: 1) since cylinder pressure is not determined, it is impossible to predict the pressure on the exhaust valve and the subsequent mass flow through the port when the exhaust valve opens, and 2) the inability to accurately determine the pumping horsepower (energy needed to move gasses into and out of the engine) from the predicted horsepower.

Since these ProRacing Sim simulations incorporate both filling-and-emptying *and* full-cycle modeling that includes frictional and pumping-loss calculations, extensive computation is required for each power point. In fact, the programs perform several million calculations at each 500rpm test point on the power curve (a full power-curve simulation consists of 41 test points). This in-depth analysis offers unprecedented accuracy over a vast range of engines. The DeskTop Dyno5/DynoSim5 has been successfully used to model single-cylinder “lawn mower” engines, light aircraft engines, automotive engines, modern Pro Stock drag-racing powerplants, and multi-thousand horsepower supercharged, nitrous-oxide injected “mountain motors.”

WHAT'S NEW IN DynoSim5

Note: From this point on, both the DeskTop Dyno5 and DynoSim5 will be referred to as the “DynoSim5” unless the features being described are unique to one program version, at which point the text will directly reference that program version.

The new features in DynoSim5 include substantial enhancements to simulation modeling over previous versions. Here is a “short list” of version-5 improvements:

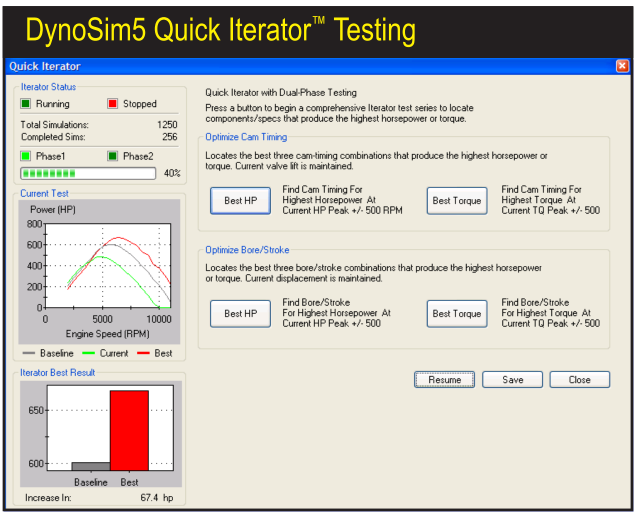
1) **New Interface Design**
2) **Environmental Parameters Can Be Varied**
3) **Combustion and Chamber-Shape Modeling**
4) **Ignition-Timing Modeling/Graphing/Advance Curves** (DynoSim5 Only)
5) **Support for All Domestic and Sport-Compact Engines**
6) **Latest, State-Of-The-Art Forced-Induction Modeling** (DynoSim5 Only)
7) **Hundreds of new Shortblocks in Engine menus**
8) **Enhanced ProPrinting Simulation Reports** (DynoSim5 Only)
9) **Extended Ranges for Bore, Stroke, and more**
10) **Rocker Ratio/Lash Advanced Calculator** (DynoSim5 Only)
11) **Increased Accuracy and Performance**
12) **Export RPM Data to Excel For Further Analysis** (DynoSim5 Only)
13) **Automatic, self-installing Internet updates**

In addition to these major enhancements, you will find hundreds of other improvements to DynoSim5. For a complete list of program features, see page 152 and visit our web at: www.proracingsim.com.

DeskTop Dyno5 and DynoSim5 REQUIREMENTS

Make sure you have the basic hardware and software required to run this simulation.

***Iterative Testing*™ is a powerful feature of DynoSim5. This screen illustrates a test that is evaluating a series of components (over 200 dyno tests were performed). Using this powerful tool it is possible to automatically run thousands or even hundreds of thousands of tests to find the best combinations. DynoSim5 keeps track of all the results and displays the best matches to your test criterion.**



Introduction To DynoSim5

- An (IBM™ compatible) PC with a CD-ROM drive.
- 32MB of RAM (random access memory) for Windows95/98/Me; 256MB for Windows2000/XP and 512MB for Vista.
- Windows95/98/Me or Windows 2000/XP or Windows Vista
- A video system capable of at least 800 x 600 resolution). Recommend 1024 x 768 or higher to optimize screen display of engine components and performance analysis graphics.
- A fast system processor (1GHz or faster) will improve processing speeds; especially helpful for Iterative analysis. However, DynoSim5 will operate on any Windows95/98/Me/NT/2000/XP or Vista system, regardless of processor.
- A mouse.
- Any Windows compatible printer (to obtain dyno-test printouts).

REQUIREMENTS
ADDITIONAL CONSIDERATIONS

Windows95/98/Me/NT/2000/XP and Vista: DynoSim5 is a 32-bit program designed for Windows95 through WindowsXP and Vista. DynoSim5 is also compatible with WindowsNT (we recommend that if you use WindowsNT, use version 4.0 with service pack 6 or later). If you use an early version of Windows95, make sure to install the latest service packs for both Windows and for Internet Explorer (use the Windows Update feature available in the Start Menu or visit www.microsoft.com to locate updates and service packs for your operating system).

Video Graphics Card And Monitor: An 800 x 600 resolution monitor/video card are required to use DynoSim5. Systems with 1024 x 768 resolution or higher provide more screen "real estate," and this additional display space is very helpful in component selection and power-curve analysis.
Note 1: See FAQ on page 158 for help in changing the screen resolution of your system and monitor.

System Processor: DynoSim5 is extremely calculation-intensive. Over 50 million mathematical operations are performed for each complete power-curve simulation. While the program has been written in fast C++ and hand-tuned assembler to optimize speed, a faster processor will improve data analysis capabilities. Furthermore, DynoSim5 incorporates powerful *Iterative Testing* that can perform an analysis of hundreds or thousands of dyno tests. To reduce calculation times and extend the modeling capabilities of the program, use the fastest processor possible.

Mouse: A mouse (trackball, or other pointer control) is required to use DynoSim5. While most component selections can be performed with the keyboard, several operations within DynoSim5 require the use of a mouse.

Printer: DynoSim5 can print a comprehensive "Dyno-Test Report" of a simulated dyno engine on any Windows-compatible printer. If you use a color printer, the data curves and component information will print in color (see page 147 for more information about DynoSim5 printing).

DynoSim 5 Advanced Engine Simulation

INSTALLATION

Software Installation

The installation for the DeskTop Dyno5 or DynoSim5 is a quick and easy process. Review these points and follow the installation steps below:

- Windows 95/98/Me® or Windows2000/XP/Vista® is required (see page 9 for more information about system requirements).
- A software SETUP program will install onto the **Windows-Install** drive in the **DeskTopDyno5** or **DynoSim5** directory. Placing program files within this directory will ensure that future upgrades and enhancements will install correctly. Please accept the default installation path for trouble-free operation.

Read and perform each of the following steps carefully:

1) Start Windows.

2) Insert the DeskTop Dyno5 or DynoSim5 CD-ROM into your CD drive.

3) An *Installation Menu* will be displayed on your desktop within 5 to 30 seconds (depending on the speed of your CD drive). From the options provided, click on **Install DeskTop Dyno**5 or **Install DynoSim5**.
Note: If the software *Installation Menu* does not automatically appear on your desktop within 30 to 60 seconds, choose ***Settings*** from the ***Start*** menu, select ***Control Panels***, then double click ***Add/Remove Programs***, finally click on ***Install***.

4) Click ***Next*** to view the ProRacing Sim/Motion Software, Inc. License Agreement. Read the Agreement and if you agree with the terms, click ***I Accept...***, then click ***Next*** to continue with the installation.

5) A *Readme* file includes the latest changes made to this software and information not available at the time this *Users Manual* was published. After you have reviewed the *Readme*, click ***Next*** to proceed with the installation.

Installing & Starting DynoSim5

6) Next you will be presented a dialog indicating the recommended install directory and/or path. If you cannot install the program on the recommended drive or at the location indicated, you can click **CHANGE**, and enter an alternate location. **Note:** If you do not install this software at the recommended location, updates or upgrades to this simulation released in the future may not install properly or function correctly on your system.

7) The **Ready To Install** screen gives you a chance to review installation choices. Press ***Back*** to make any changes; press ***Install*** to begin copying files to your system.

8) When main installation is complete, the **Setup Complete** screen will be displayed. Click ***Finish*** to close this window and a final dialog box will ask for permission to install a Camtasia™ Codec on your system (needed to display tutorial and help files). Choose ***Install*** to complete the installation.

Starting DeskTop Dyno5 or DynoSim5

9) To start the *DeskTop Dyno*: , open the Windows **Start** menu, select **Programs**, then choose ***ProRacing Sim Software, Engine Simulation***, and finally click on the ***DeskTop Dyno5 Engine Simulation*** or the icon displayed in that folder.

To start Dyno*Sim5*, open the Windows **Start** menu, select **Programs**, then choose ***ProRacing Sim Software, Engine Simulation***, and finally click on Dyno***Sim5 Engine Simulation*** icon displayed in that folder.

10) Before you first start the program, a ***Software Update*** dialog will be displayed. Please allow this *Motion Updater* to run before you start the engine simulation. Any updates released after your CDROM was manufactured will up automatically be transferred to your system. In the months ahead, *DeskTop Dyno5* and *DynoSim5* will periodically check for updated program files to make sure that you are always using the latest simulation technology.

10) When you first start the program, a Registration dialog will be displayed. Please fill in the requested information, including the serial number found on the back page of the QuickStart Guide included in the CD case. Then press the ***Proceed*** button. If you have an Internet connection, your registration will be submitted to ProRacingSim automatically. If you do not have an Internet connection, you will be presented with other registration options. If you do not register this simulation, you will not qualify for tech support.

11) You can access additional information about our simulation software and obtain technical support by visiting (www.ProRacingSim.com) or by opening the ***Start***

menu, select ***Programs***, ***ProRacing Sim Software,*** then click on ***Tech Support Website*** icons found in any of the application folders.

12) Please review the remainder of this Users Manual for more information on menu selections, program functions, and simulation tips.

13) If you experience installation problems, please review program requirements on pages 9-10 and take a few minutes to look over the following sources of information before you contact technical support:

- Make sure your program is up to date by selecting *Check For Updates* from the **HELP** menu in the program (requires Internet connection).
- The FAQs on page 158 provide additional installation and operational questions-and-answers.
- Visit the Tech Support section of the ProRacing Sim Software website for updates, patches, additional tips and FAQs.

If you cannot find a solution to your problem, please email support@proracingsim.com. Thoroughly explain the problems you are having. Provide as much detail as possible, including the program version you are running (found in the ***About*** dialog box available from the **Help** menu within the program).

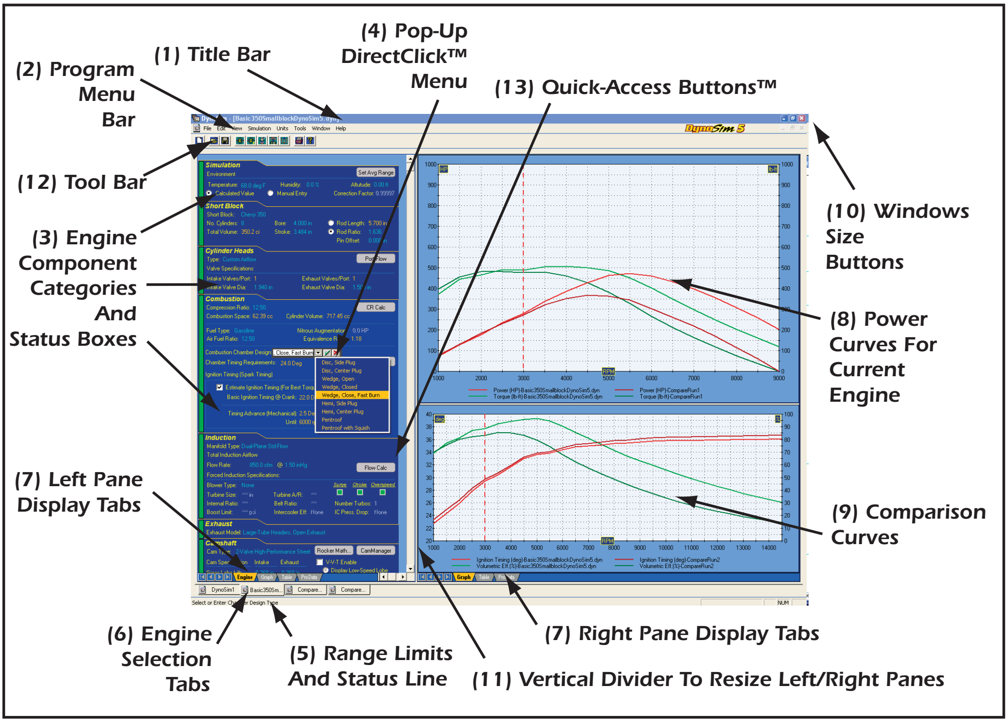
If you prefer, you can mail tech-support at:

ProRacing Sim Software, LLC.
3400 Democrat Road, Suite 207
Memphis, TN 38118
Tech: 901-259-2355, or visit our
Web: www.proracingsim.com
Email: support@proracingsim.com

Support Note1: Tech support will only be provided to registered users. Please complete the *Registration Form* that appears when you first start your software to qualify for technical support from the ProRacing Sim Software staff.
Support Note2: If you need to change your address or any other personal information after you have registered this software, simply select *Registration* from the **Help** menu, make any necessary address changes, then press ***Proceed*** to send your updated info ProRacing Sim.

Dyno Sim 5 Advanced Engine Simulation

OVERVIEW



THE MAIN PROGRAM SCREEN

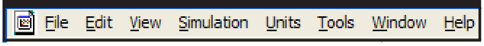
The **Main Program Screen** allows you to select engine components, dimensions, and specifications. In addition, engine power curves and/or simulation data is displayed in graphical and chart form. The Main Program Screen is composed of the following elements:

1) The **Title Bar** displays the program name followed by the name of the currently-selected engine.

2) The **Program Menu Bar** contains pull-down menus that control overall program function. Here is an overview of these control menus, from left to right (detailed

Program Overview

Program Menu Bar



Program Menu Bar contains eight pull-down menus that control overall program function.

information on menu functions is provided in the next section, beginning on page 22):

File—Opens and Saves dyno test files, imports previous version Dyno files, exports Data to other programs, prints engine components and power curves, allows the quick selection of the most recently used Dyno files, and contains a program-exit function.

Edit—Clears all component choices from the currently-selected engine (indicated by the *Engine Selection Tab* currently in the foreground; see **Engine Selection Tabs**, later in this section).

View—Allows you to turn the ***Toolbar***, ***Status Bar*** and ***Workbook*** layout on (default) or off and selects the current color scheme (DynoSim5 Exclusive Feature) for the program.

Simulation—***Run*** forces an update of the current simulation. ***Auto Run*** enables or disables (toggles) automatic simulation updates when any engine component is modified.

Units—Selects between US and Metric units.

Tools—Opens the *Iterative Testing* window, the *Cam Manager* screen, or one of the build-in, engine-math calculators.

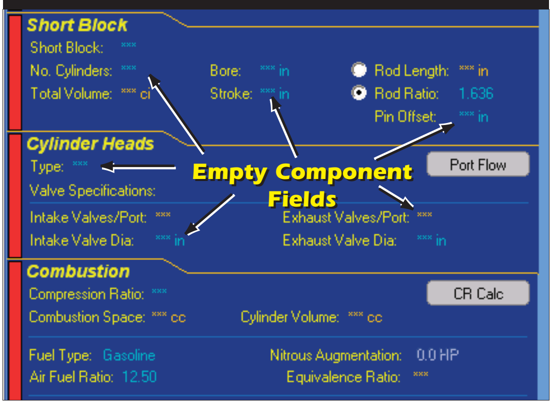
Window—A standard Windows menu for arranging and selecting engine display windows.

Help—Gives access to this Users Guide, Registration, and launches the Motion Program Updater.

3) The **Engine Component Categories** are made up of the following groups:

Component fields that do not yet contain valid entries are marked with a series of asterisks. This indicates that the field is empty and can accept data input. Most numeric fields accept direct keyboard entry and/or selections from the provided drop-down menus. Text selection fields (like the Cylinder Head choice menu) only accept selections from the associated drop-down menu. When a valid selection has been made, it will replace the asterisks and will be displayed next to the field names.

Incomplete Component Fields

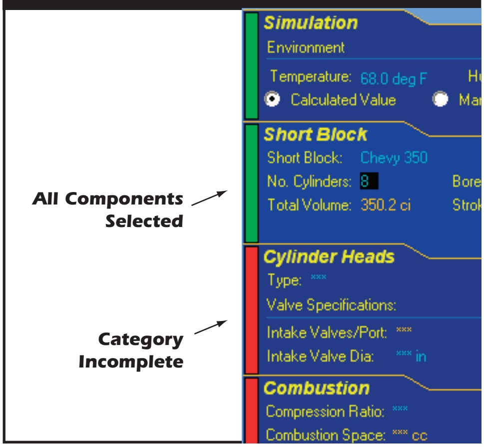


SIMULATION—Select RPM Range for average values on graphs and sets atmospheric conditions for dyno testing.
SHORTBLOCK—Select the bore, stroke, and number of cylinders in this category.
CYLINDER HEADS—Select the cylinder head type, port configuration, and valve diameters. Direct entry of flowbench data is also supported.
COMBUSTION—Selects the compression ratio. Select the type of fuel, air/fuel ratio, nitrous flow rate, combustion chamber design, and ignition timing.
INDUCTION—Selects the airflow rate through the induction system, the type of intake manifold, and a forced induction system.
EXHAUST—Selects the exhaust-system configuration.
CAMSHAFT—Selects the camshaft and allows direct entry of valve timing and lift data.
NOTES—Enter any comments about the current simulation. Notes are saved with the engine *.DYN* file.

Note1: Each component category is discussed in detail in the upcoming chapter ***Component Menus***, starting on page 24.
Note2: Each component category (except *NOTES*) contains a **Status Box** located at the left of the category. These boxes are either red, indicating that the category is not complete (inhibiting a simulation run), or green, indicating that all components in that category have been selected. When all component categories are green, a simulation will be performed and the results will be displayed in the graphs on the right pane of the Main Program Screen.

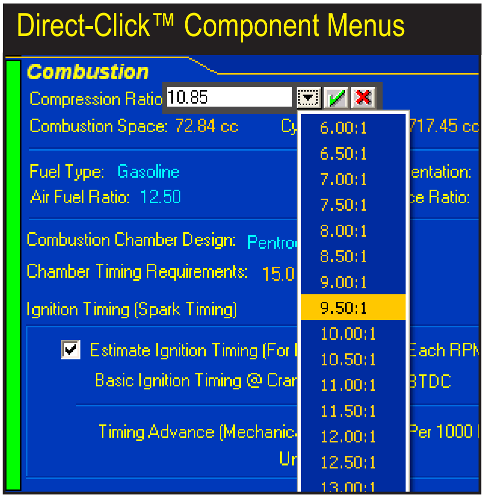
4) The **Drop-Down Component Menus** contain components and specifications for each of the Component Category choices. Click on any component specification to open its menu. The menu will close when a selection is complete. If you wish

Component Status Boxes



A Status Box is located in the left of each Component Category. These boxes are either red, indicating that the category is not complete (inhibiting a simulation run), or green, indicating that all components in that category have been selected.

Program Overview



The Direct-Click™ Component Menus contain components and specifications for each Component Category item. Click on any component specification to open its menu. The menu will close when a selection is complete (or accept the current selection by clicking on the green ✔). If you wish to close the menu before making a new selection, click the red X next to the drop-down box or press the Escape key until the menu closes.

to close the menu before making a new selection, click the red **X** next to the drop-down box or press the **Escape** key until the menu closes.

5) Several Component Category menus allow direct numeric entry. During direct data entry, the range of acceptable values will be displayed in a **Range Limit Line** within the **Status Box** at the bottom of the screen.

6) The DeskTop Dyno5 and DynoSim5 can simulate several engines at once. Switch between "active" engines by selecting any open engine from the **Engine Selection Tabs**, just above the **Status Box** (see photo, page 16). The currently-selected engine is indicated on the foreground Tab. The name of the currently-selected engine is also displayed in the **Title Bar**.

7) The Main Program Screen window is divided into two panes. The left and right panes contain **Screen Display Tab** groups. Use these tabs to switch the pane display to component lists, tables, graphics, or other data displays.

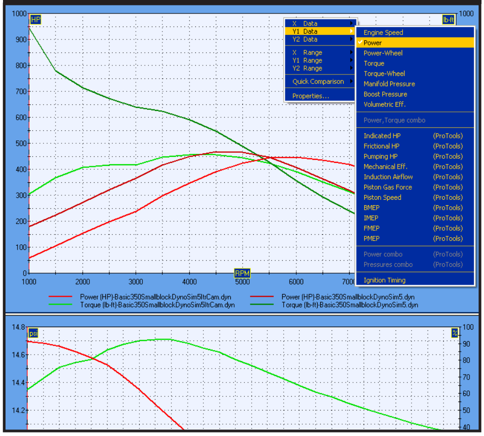
8) The **Current Engine Power Curves** upper window displays the horsepower and torque for the currently-selected engine. Horsepower and torque are the default curves, however, the graphic data display can be customized by right-clicking on the graph and reassigning each curve in the **Graph Options Box**.

9) Use **Properties...** in the **Graph Options Box** to create direct comparisons between up to four "open" engines.

10) The Main Program Screen also incorporates **Windows Size Buttons**. These buttons provide standard maximizing, minimizing, and closing functions common to all Windows applications. Refer to your Windows documentation for more

Program Overview

Graph Options Box



The Upper, Right-Hand *Power Curves Graph* displays the horsepower and torque for the currently-selected engine. Horsepower and torque are the default curves, however, the data displayed can be customized by right-clicking on the graph and reassigning each curve in the *Graph Options Box*. In addition, you can use *Properties...* to setup comparisons between any "open" engines. Note: A third, Left-Hand graph is available under the component selection screen (to activate this display, use the Left-Pane Screen Display *Graph* tab at the bottom of the component screen).

information on the use of these buttons.

11) The widths of all program panes are adjustable. Simply drag the V**ertical Screen Divider** to resize the Component-Selection and Graphics-Display panes. By dragging the **Vertical Screen Divider** to the left screen edge, the power-curve display can be enlarged to full screen for maximum resolution.

12) The **Tool Bar** contains a series of icons that speed up the selection of commonly used program functions and features. The **Tool Bar** in DynoSim5 contains the following icons: Create New Engine, Open Saved Engine, Open Quick Iterator, Open Pro Iterator (ProTool™), Open Cylinderhead Airflow (Port Flow) Dialog, Open Compression-Ratio Calculator, Open Airflow-Conversion Tool, Print Current Engine, Display Program "About Box."

13) Several component categories contain **QuickAccess Buttons**™ that give "one-click" access to important data-entry functions and calculators. For example, the **CYLINDERHEAD** category contains an ***Airflow*** button that opens the Port-Airflow dialog box, allowing direct entry of flowbench data; the **COMBUSTION** category contains a ***CR Calc*** button that opens the Compression-Ratio Calculator, a tool that can save time and improve accuracy in determining engine compression ratio; and the **CAMSHAFT** category contains a ***Cam Manager*** button (available in Advanced and ProTools versions) that opens the powerful Cam Manager dialog box giving unprecedented control over camshaft selection and timing specifications.

HOW TO BUILD A TEST ENGINE

A common starting point for an engine-design project using DynoSim5 is to "assemble" a test engine from component parts. For example, here's how to select bore and stroke specifications by using the **Short Block** pull-down menu. Activate the menu by:

1) If necessary, start DynoSim5; if DynoSim5 is already running, select ***New*** from the **File** menu. All component categories begin empty, as indicated by a string of asterisks (***) next to each incomplete component field.

2) Move the mouse cursor into the ***SHORTBLOCK*** component category and click the left mouse button on the asterisks in the highlighted ***Short Block*** field. (**Note**: all fields will automatically highlight when the mouse cursor passes over them).

3) When the component-menu bounding box appears (see photo, page 19), click on the ▼ symbol to open the SHORTBLOCK selection menu.

4) Move the mouse pointer through the menu choices.

5) When a submenu opens, move the mouse cursor over your selected choice in the submenu.

6) Click the left mouse button on your selection. This loads the engine name, bore, stroke, and number of cylinders into the ***SHORTBLOCK*** category. Note that the red boxed **X** (Component Category Status Box) on the left of the ***SHORTBLOCK*** category changed to a green-boxed checkmark ✔, indicating that all components in that category have been selected.

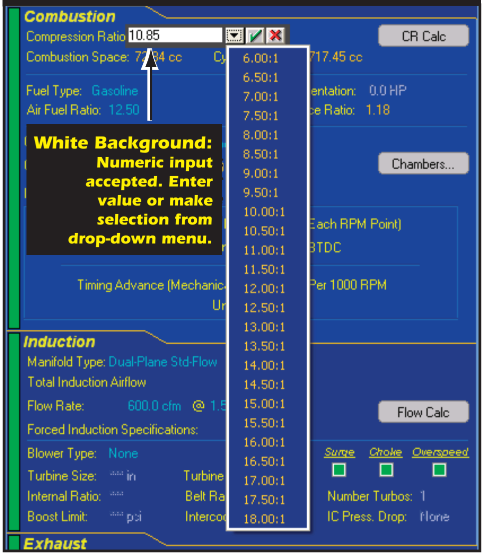
7) Alternatively, to close the menu without making a selection, click the red **X** on the right of the menu bounding box or press the **Escape** key until the menu closes.

8) Continue making component selections until all the ***Component Category Status Boxes*** have switched to green. At this point an engine simulation will be performed and the results will be displayed on the graph or chart on the right pane of the Main Program Screen.

DIRECT-ENTRY™ MENU CHOICES

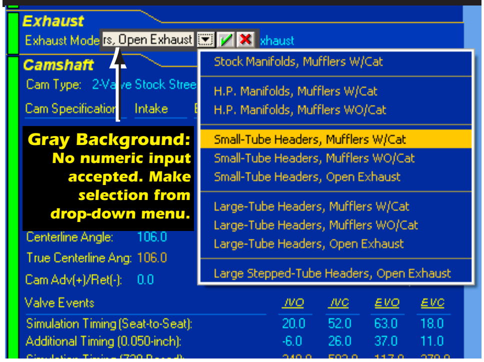
The Bore, Stroke, Number Of Cylinders, Valve Size, Compression Ratio, Induction Airflow, and several other menus permit direct numeric entry. When a component field supports direct entry, the bounding box will have a white interior. If the only entry possible is a choice from the drop-down menu, the bounding box will have a gray interior (see above photos). Choosing a new numeric value will replace the currently displayed value. When you press **Enter** the new value will be tested for acceptability,

Fields Accepting Direct/Numeric Input



Component fields that support direct numeric entry have white bounding boxes (left). When the only selection possible is a choice from the drop-down menu, the bounding box will have a gray interior (below).

Not Accepting Direct/Numeric Input



and if it passes, it will be used in the next simulation run. If you press **Enter** without entering a new value, the currently displayed value is left unchanged.

Data entry into any component field on the component-selection screen is limited to values over which DynoSim5 can accurately predict power. The range limits are displayed in the **Range Limit Line** within the **Status Line** at the bottom-left of the Main Program Screen (see page 14). If you enter an invalid number, DynoSim5 will play the Windows error sound and wait for new input.

THE MEANING OF SCREEN COLORS

The colors used on the component-selection screen provide information about various engine components and specifications. Here is a quick reference to screen color functionality:

White Component Names: Engine component names and specification fields are displayed in white. If the data in those fields is light blue, it can be changed or customized. If the data is yellow, it indicates values are automatically calculated by program and cannot be directly altered.

Yellow Numeric Values: Yellow engine specifications indicate that they are automatically calculated by program and cannot be directly altered. For example, the ***Total Volume*** shown in the ***SHORTBLOCK*** category is calculated based on the current bore and stroke. While you cannot directly alter ***Total Volume***, changing the bore or the stroke will alter the displayed value for ***Total Volume***.

Light Blue: All engine specifications that can be changed through direct data entry or through pull-down menus are displayed in light blue. For example, the cylinder ***Bore*** field in the ***SHORTBLOCK*** category will accept direct numeric input (within the range of values displayed in the ***Range Limit Line***).

Dyno Sim 5 Advanced Engine Simulation

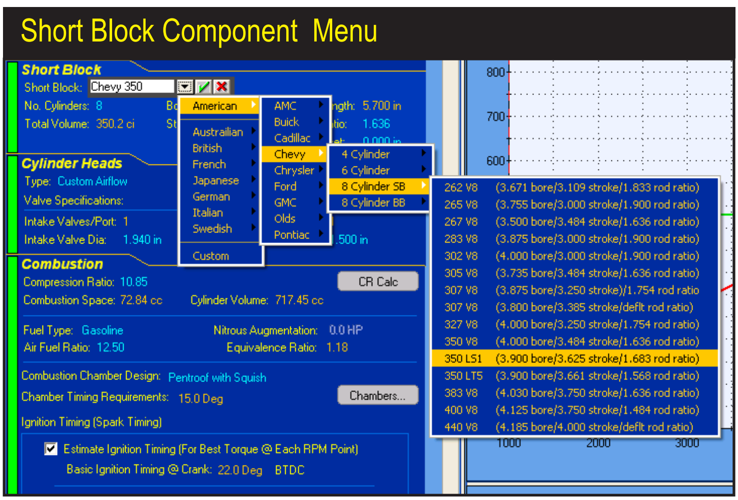
COMPONENT MENUS

THE SIMULATION COMPONENT CATEGORY MENUS

The **SIMULATION Category** is located at the top of the Component Selection Screen. Use this category to select ambient atmospheric conditions to which the dyno test will be corrected. The default values are standard temperature and pressure (STP) against which most dyno testing is corrected. You can enter specific atmospheric values (like ***Temperature***, ***Humidity*** and ***Altitude***) and let the program automatically calculate a correction coefficient, or you can directly enter a correction coefficient by clicking the ***Manual Entry*** radio button.

THE SHORTBLOCK COMPONENT CATEGORY MENUS

The **Short Block** menu is located on the upper-left of the **SHORTBLOCK** component category. By opening this menu, you are presented with a variety of domestic and import “predefined” engine shortblock configurations. If any one of these choices is selected, the appropriate bore, stroke, rod ratio, and number of cylinders will be loaded in the **SHORTBLOCK** category. In addition to selecting



The *Short Block* component menu contains over 600 bore and stroke combinations of popular domestic, import, and sport-compact engines that you can instantly use in any engine simulation. In addition, you can directly enter a custom description of any engine in the *Short Block* field.

any predefined engine configuration, you can directly enter any short block name (description) in the **Short Block** field (plus you can enter any Stroke, Bore, Rod Ratio, and Number Of Cylinders—within the acceptable range limits of the program indicated at the bottom of the screen in the **Range Limit And Status Line**—in these fields in the SHORTBLOCK category).

What's A SHORTBLOCK

When a particular engine combination is selected from the **Short Block** menu, the bore, stroke, rod ratio, and the number of cylinders are "loaded" into the **SHORTBLOCK** category. These values are subsequently used in the simulation. The menu choices presented in the **Short Block** menus should be considered a "handy" list of common engine cylinder-bore and crankshaft-stroke values, ***NOT*** a description of engine configurations (e.g., V8, V6, straight 6, V4, etc.), material composition (aluminum vs. cast iron), the type of cylinder heads (hemi vs. wedge) or any other engine characteristics. The **Short Block** menu only loads **Bore**, **Stroke**, **Rod Ratio**, and the **Number Of Cylinders** into the engine "parts" database.

Entering Rod Ratio And/Or Rod Length

Each of the **Short Block** menu selections will also load the exact (or a default) value for Rod Ratio; the length of the connecting rod divided by the stroke length. This value is commonly used to help determine rod angularity (rod angularity drives the piston into the cylinderwall producing the single greatest source of friction within the engine). By default, the **SHORTBLOCK** category will also allow direct entry of Rod Ratios and show a calculated value for Rod Length. But, by clicking the radio button next to the Rod Length, this field will become changable and allow direct entry of Rod Length data (the Rod Ratio field will switch to calculated values). If you know the exact Rod Length for a particular shortblock, "activate" the Rod Length field by clicking its radio button and directly enter the rod-length value.

Bore And Stroke And Its Effects On Compression Ratio

After selecting the Bore, Stroke, Rod Ratio, and Number-Of-Cylinders, the swept cylinder volume and the total engine volume (displacement) will be displayed. The swept cylinder volume measures the volume displaced by the movement of a single piston from TDC (top dead center) to BDC (bottom dead center). This "full-stroke" volume is one of the two essential values required in calculating compression ratio. We'll discuss compression ratio in more detail later, but for now let's take a quick look at how compression ratio is calculated:

$$\text{Compression Ratio} = \frac{\text{Swept Cylinder Volume} + \text{Combustion Space Volume}}{\text{Combustion Space Volume}}$$

The total volume that exists in the cylinder when the piston is located at BDC (this volume includes the Swept Volume of the piston plus the Combustion Space Volume) is divided by the Combustion Space Volume (the area above the piston at TDC).

Bore and stroke dimensions greatly affect cylinder volumes and, therefore, compression ratio. When the stroke, and to a lessor degree the bore, is increased while maintaining a fixed combustion-space volume, the compression ratio will rapidly increase. And if the compression ratio is held constant—as it is in DynoSim5, since the compression ratio is a ***fixed*** engine specification selected by you—the combustion space volume must be increased to maintain the desired compression ratio.

This may be easier to understand when you consider that **if** the combustion-space volume (volume at TDC) did **not** increase, a larger swept cylinder volume would be compressed into the same final combustion space volume, resulting in an increase in compression ratio.

THE CYLINDER-HEAD COMPONENT CATEGORY

The **Cylinder-Head Type** pull-down menu is located in the **CYLINDER HEAD** category, and selections from this menu allow DynoSim5 to model various cylinder head designs and airflow characteristics within both *Domestic* and *Sport-Compact* applications. Selections range from restrictive low-performance ports to high-performance four-valve cylinder heads. Each grouping of head/port designs includes several stages of modifications.

In addition to the provided choices, the **Custom Port Flow** selection at the bottom of the *Cylinder Head Type* menu lets you directly enter flowbench data, allowing DynoSim5 to model any cylinder head for which airflow-test data is available (for convenience, a **Port Flow** button in the Cylinder Head category provides fast access to the same custom-airflow, data-entry dialog). Custom port flow data entry will be detailed later (see page 37).

Valve Diameters And Basic Flow Theory

A selection from the **Cylinder Head** menu is the first part of a multistep process that establishes a baseline for the analysis of cylinder-head airflow. A *Cylinder-Head Type* selection (or entering custom flow-bench data) dictates the airflow restriction generated by the valves (and to some extent the ports, also). That is, flow data determines *how much less airflow than the theoretical maximum peak flow will pass through each valve*. This percentage of ideal flow is called the valve *Discharge Coefficient* and is always less than 100%.

An additional data point used to characterize cylinder-head and engine airflow capacity is the **Total Induction Airflow Rate**. This is typically the rated flow of the carburetor or throttle plates/valves. This establishes a "ceiling" flow-rate (actually a restriction for the entire engine).

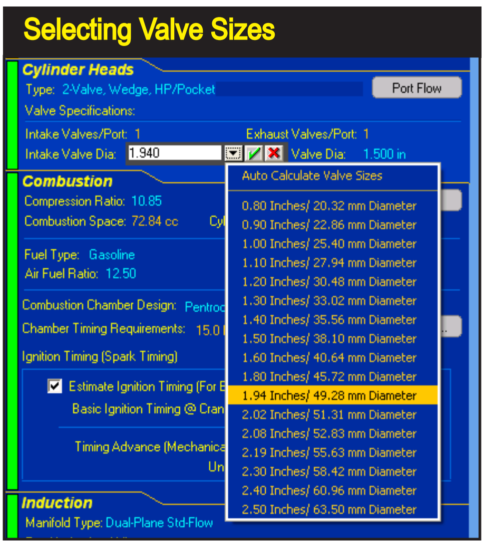
When this essential data has been specified, the mass flow within the ports still cannot be directly calculated. There are several reasons for this. The most important is that the flows generated in the ports of a running engine are vastly different than the flows measured on a flow bench. Airflow on a flow bench is steady-state flow, measured at a fixed pressure drop. A running engine will generate rapidly and widely varying pressures and port flow rates. These pressure variances directly affect—in fact, they directly cause—the flow of fuel, air, and exhaust gasses within the engine. To determine the instantaneous flow at any point during engine operation, DynoSim5 must calculate all internal port and cylinder pressures at closely-spaced, small increments in time throughout the four-cycle process. Overall mass flow into and out of the cylinders is determined from the sum of these instantaneous pressure differentials and calculated gas densities (that also vary as temperature and pressure gradients change within the passages). Finally, at the end of this long series of calculations (literally, millions of individual calculations), a few more steps sum the overall results and generate the desired numbers: Torque and Horsepower. (Not magic, but close!)

Sorting Out Cylinder Head Menu Choices

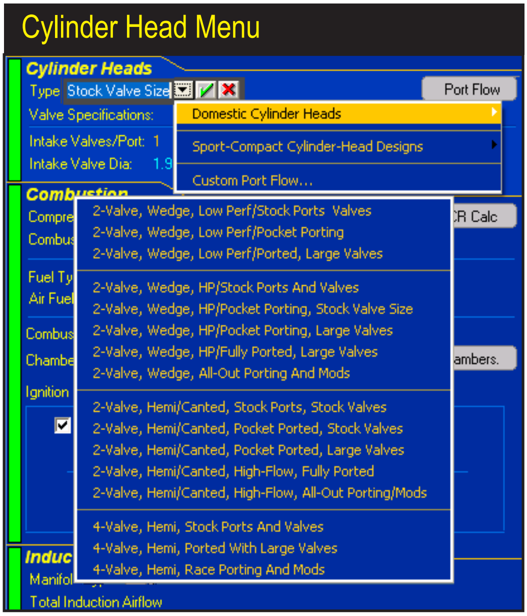
Now that some of the basic flow theory behind the choices in the **CYLINDER HEAD** category menus has been exposed, here's some practical advice that will help you determine the appropriate selections for your application.

Domestic Cylinder-Head Selections

Selecting a specific valve size fixes the theoretical peak flow of each port. Most cylinder heads flow only about 50% to 70% of this value. This percentage, called the *discharge coefficient*, has proven to be an effective link between flow-bench data and the calculation of mass flow moving into and out of the cylinders. In other words, the valve size and the derived discharge coefficient help establish a practical framework to accurately calculate actual mass flow within a running engine.



Cylinder Head Menu



The Cylinder Head Type menu contains a wide range of head/port choices. The main menu is divided into two groups: Domestic Cylinder Heads model typical 4-cylinder through V8 passenger car engines. The Sport-Compact Cylinder Heads selections primarily model newer, multiple-valve-per-port head designs.

Here is some basic information that will help you determine the appropriate cylinder-head selections (and port flow data) from the built-in menu selections for domestic engine applications.

Note-1: Each of the generic choices in the Cylinder Head menu has flowbench data associated with it. To view this test data simply select the cylinder head from the menu then click the **Port Flow** button.

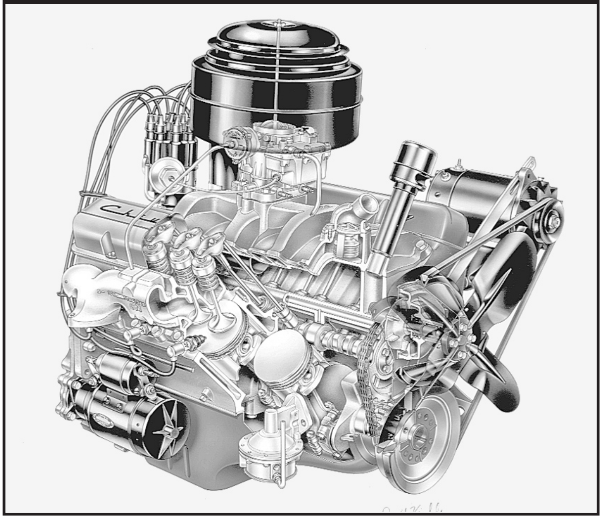
Note-2: *Domestic* head selections are shown below in **Red**; *Sport-Compact* cylinder heads follow in subsequent paragraphs titled in **Green**.

Domestic—2-Valve, Low Performance Cylinder Heads (Three variations: Stock, Ported, and Ported With Large Valves)—There are three ***Low Performance*** cylinder head selections listed at the top of the **Domestic Cylinder Head** menu. Each of these choices is intended to model cylinder heads that have small ports and valves relative to engine displacement. Heads of this type were often designed for low-speed economy applications, with little concern for high-speed performance. Early 260 and 289 smallblock Ford and to a lessor degree early smallblock Chevy castings fall into this category. These choices use the lowest discharge coefficient of all the head configurations listed in this menu. Minimum port cross-sectional areas are 60% of the valve areas or somewhat smaller and, if ***Auto Calculate Valve Size*** has been selected, relatively small (compared to the bore diameter) intake and exhaust valve diameters will be selected.

Note: These low-performance cylinder-head choices are a good option if you wish to model flathead (L-head & H-head) and hybrid (F-head) engines for which you do not have actual flow data. While the ports in these engines are quite

Cylinder Head Menu

Typical Low-Performance Cylinder Heads

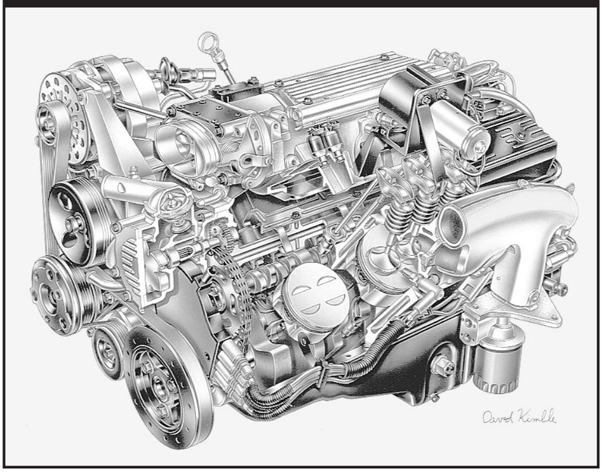


The *Low Performance* cylinder head choices are intended to model cylinder heads that have small ports and valves. Heads of this type were often designed for low-speed, economy applications, with little concern for high-speed performance. Early 260 and 289 smallblock Ford and to a lessor degree early smallblock Chevy castings fall into this category.

restrictive, by selecting ***Low-Performance*** and manually entering the actual valve sizes, DynoSim5 can provide a good approximation of power output from these early engines; further testing to evaluate changes in cam timing, induction flow, and other components will have good accuracy.

Domestic—2-Valve, Wedge Cylinder Heads (Three Variations: Stock, Ported, Large Valves)—The first three wedge cylinder-head selections model castings that have ports and valves sized with performance in mind. Ports are only somewhat restrictive for high-speed operation, and overall port and valve-pocket design offers

Typical Wedge Cylinder Heads



The *Wedge Cylinder Head* menu choices model cylinder heads that have ports and valves sized with performance in mind, like the heads on this LT1 smallblock Chevy.

a good compromise between low restriction and high flow velocity. The stock and pocket-ported choices are well suited for high-performance street to modest racing applications.

Domestic—2-Valve, Wedge/Fully Ported, Large Valves—The fourth wedge head moves away from street applications. This casting has improved discharge coefficients, greater port cross-sectional areas, and increased valve sizes. Consider this head to be an extensively modified, high-performance, factory-type casting that has additional modifications to provide optimum flow for racing applications. It does not incorporate "exotic" alterations, like raised and/or welded ports requiring custom-fabricated intake manifolds.

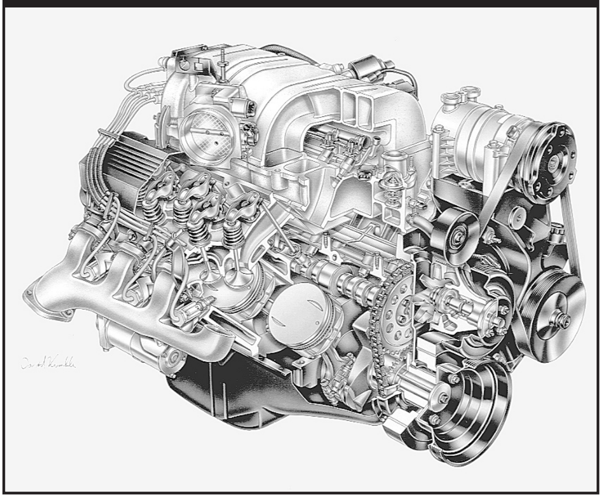
Domestic—2-Valve, Wedge/ProStock Porting And Mods—The last choice in the wedge group is designed to model high-flow, professional drag-racing cylinder heads. These heads are designed for one thing: Maximum power. They usually require hand-fabricated intake manifolds, have excellent valve discharge coefficients, and the ports have the largest cross-sectional areas in the smallblock group. This head develops sufficient airflow speeds for good cylinder filling only at high engine rpm.

The following *Hemi/Canted-Valve* ***Domestic*** selections are modeled after heads with valve stems tilted toward the outside of the cylinder heads to improve the discharge coefficient and overall airflow. All ports have generous cross-sectional areas for excellent high-speed performance.

Domestic—2-Valve, Hemi/Canted-Valve Cylinder Heads (Stock, Ported, Large Valves)—The first three choices best model oval-port configurations. These smaller

The *Canted-Valve Cylinder Head* selections have ports with generous cross-sectional areas and valves that angle toward the port mouths. The first three menu choices model oval-port designs. The final two selections simulate performance rectangular-port heads. This L29 bigblock Chevy would be best modeled by the second or third menu choice—the fourth menu choice models a head with flow capacity beyond the capabilities of L29 castings.

Typical Canted-Valve Cylinder Heads



cross-sectional area ports provide a good compromise between low restriction and high flow velocity for larger displacement engines. The stock and pocket-ported choices are suitable for high-performance street to modest racing applications.

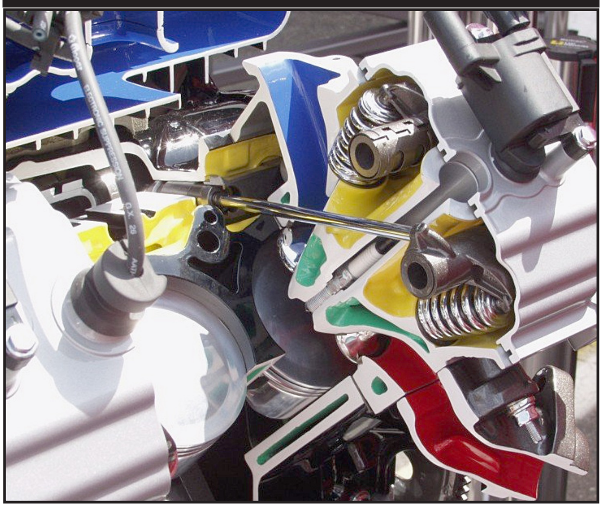
The next two selections best model extensively modified rectangular-port heads. These choices are primarily, all-out, bigblock heads, however, they also model other aggressive, high-performance designs, like the Chrysler Hemi head.

Domestic—2-Valve, Hemi/Canted-Valve, Rectangular Ports/Fully Ported—These rectangular-port heads have high discharge coefficients, large port cross-sectional areas, and increased valve sizes. This head is basically a factory-type casting but extensively improved. However, it does not incorporate "exotic" modifications, like raised and/or welded ports that require custom-fabricated manifolds.

Domestic—2-Valve, Hemi/Canted-Valve, Rectangular ProStock Ports/Mods—The last choice in the *Hemi/Canted-Valve* group is designed to model state-of-the-art, ProStock (and Hemi) drag-racing cylinder heads. These custom pieces, like their wedge-design counterparts, are more-or-less built from the ground-up for maximum power. They require custom-fabricated intake manifolds, have optimum valve discharge coefficients, and the ports have the largest cross-sectional areas in the entire 2-valve **Cylinder Head** menu. These specially fabricated cylinder heads only develop sufficient airflow for good cylinder filling with large displacement engines at high engine speeds.

The next three selections in the ***Domestic Cylinder Head*** submenu model 4-valve cylinder heads. These are very interesting choices since they simulate the effects of very low-restriction ports and valves used in some high-performance applications.

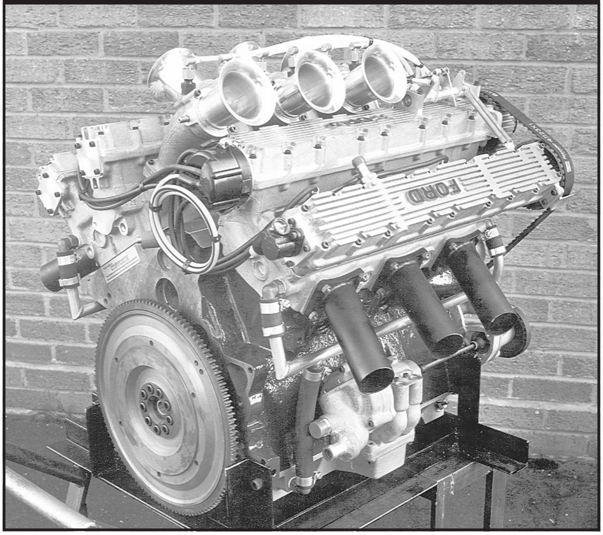
2-Valve, Hemi, HP Cylinder Heads



The *2-Valve, Hemi, HP Cylinder Head* selections have ports with generous cross-sectional areas and valves that angle toward the port inlets (the Dodge 5.7L Hemi is shown here). These heads have improved discharge coefficients and their high-performance designs typically offer the highest flow capability for 2-valve cylinder heads. Heads of this type have the greatest potential of producing the highest horsepower within the first three groups in the *Cylinder Head Type* menu.

Cylinder Head Menu

Typical 4-Valve Cylinder Heads



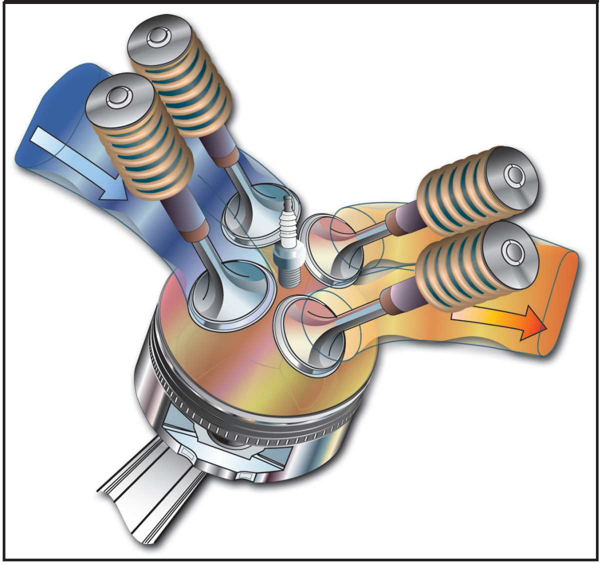
The *4-Valve Cylinder Head* selections model cylinder heads with two intake and two exhaust valves. These heads can offer more than 1.5 times the curtain area of the largest 2-valve heads. This large valve flow area, combined with high-flow, low-restriction ports greatly improves air and fuel flow into the cylinders at high engine speeds.
These Cosworth heads were designed for the English Ford V6. When they were raced in England, they regularly beat V8s.

The individual ports in 4-valve heads begin as single, large openings, then divide into two Siamesed ports, each having a small (relatively) valve at the combustion chamber interface. Since there are two intake and two exhaust valves per cylinder (by default, although DynoSim5 can model up to 3 valves per port). Valve curtain area (flow area exposed as the valve is lifted off the seat) is considerably larger than with the largest single-valve-per-port designs (at the same valve lift, despite larger valve diameters). In fact, 4-valve heads can offer more than 1.5 times the curtain area of the largest 2-valve heads. This large flow area, combined with high-flow, low-restriction ports, greatly improves air and fuel flow at low valve lifts *and* at high engine speeds. Unfortunately, the ports offer an equally low restriction to reverse flow (reversion) that often occurs at low engine speeds when the piston moves up the cylinder from BDC to Intake Valve Closing (IVC) on the early portion of the compression stroke. For this reason, 4-valve heads, even when fitted with more conservative ports and valves, can be a poor choice for small-displacement, low-speed engines, unless camshaft timing is carefully designed to complement the low-lift flow capabilities of these cylinder heads (as is the case in many V-V-T valvetrain designs). On the other hand, the outstanding flow characteristics of the 4-valve head puts it in another “league” when it comes to horsepower potential on high-speed racing engines.

Domestic—4-Valve, Hemi/Canted-Valve, Stock Ports And Valves—The first choice in the 4-valve group simulates a 4-valve cylinder head that would be “standard equipment” on factory high-performance engines. These heads offer power comparable to high-performance 2-valve castings equipped with large valves and porting work. However, because they still have relatively small ports, reasonably

Cylinder Head Menu

Two-Valves-Per-Port Cylinder Head



The *4-Valve Cylinder Head* selections model cylinder heads with two intake and two exhaust valves. These heads can offer more than 1.5 times the curtain area of the largest 2-valve heads. This large valve flow area, combined with high-flow, low-restriction ports greatly improves air and fuel flow into the cylinders at high engine speeds.

high port velocities, and good low-lift flow characteristics, they often show a boost in low-speed power over comparable 2-valve heads.

Domestic—4-Valve, Hemi/Canted-Valve, Ported With Large Valves—The next choice incorporates mild performance modifications. Larger valves have been installed and both intake and exhaust flow has been improved by porting work. However, care has been taken not to increase the minimum cross-sectional area of the ports. These changes provide a significant increase in power with only slightly slower port velocities. Reversion has increased, but overall, these heads generally show a power increase throughout the rpm range on most engines.

Domestic—4-Valve Hemi/Canted-Valve, Race Porting And Mods—The final choice, like the other Race-Porting-And-Mod choices in the **Cylinder Head** menus, models an all-out racing cylinder head. This selection has the greatest power potential. The ports are considerably larger than the other choices, the valves are larger, and the discharge coefficients are the highest possible. These heads suffer from the greatest reversion effects, especially with late IVC timing on low-speed, small-displacement engines.

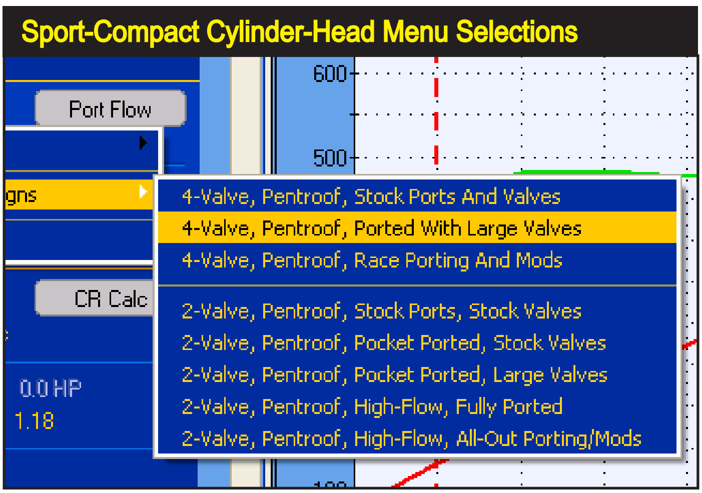
> **Note:** If the ***Auto Calculate Valve Size*** option is selected, these heads, like all choices provided in the **Cylinder Head** menu, use valves that are "scaled" to engine size, so that smaller engines automatically use appropriately smaller valves.
>
> **Domestic-Engine Simulation Tip:** If you would like to know what "hidden" power is possible using any particular engine combination, use the *4-Valve Hemi/Canted-*

Valve, Race Porting And Mods cylinder-head choice. It is safe to say that the only way to find more power, with everything else being equal, would be to add forced induction, nitrous-oxide injection, or use exotic fuels.

Sport-Compact Cylinder Head Selections

The first three selections in the **Sport-Compact Cylinder Head Type** submenu model the low-restriction ports and valves used in modern, 4-valve cylinder-heads; the basic mainstay of the Sport-Compact enthusiast. The individual ports in 4-valve heads begin as single, relatively large openings, then neck down to two Siamesed ports, each having a small (relatively) valve at the combustion chamber interface. Since there are two intake and two exhaust valves per cylinder, valve curtain area (area exposed around an open valve through which air/fuel can pass) is considerably larger than the largest single-valve-per-port designs. In fact, 4-valve heads can offer more than 1.5 times the curtain area of the largest 2-valve heads. This large flow area, combined with the high-flow, low-restriction ports greatly improves air and fuel flow into the cylinders at low valve lifts and high engine speeds. However, the ports offer an equally low restriction to reverse flow (reversion) that can occur at low engine speeds when the piston moves up the cylinder from BDC to Intake Valve Closing (IVC) on the early portion of the compression stroke. For this reason, 4-valve heads, even when fitted with more conservative ports and valves, can be a poor choice for small-displacement, low-speed engines, unless camshaft timing is carefully designed to complement the low-lift flow capabilities of these cylinder heads (as is the case in many VTEC engines). On the other hand, the outstanding flow characteristics of the 4-valve head puts it in another "league" when it comes to horsepower potential on high-speed performance engines.

Note-1: Each of the generic choices described below in the Cylinder Head menu



The *Sport-Compact Cylinder Head* selections are divided into two groups. The most common is the 4-Valve type with some version of a pentroof combustion chamber. The second group are 2-Valve heads, having good flow characteristics, but considerably lower power potential than the 4-Valve designs.

has flowbench data associated with it. To view this test data simply select the cylinder head from the menu, then click the **Port Flow** button.

Note-2: Sport-Compact head selections are shown below in **Green**; cylinder heads for Domestic applications precede this section and are titled in **Red**.

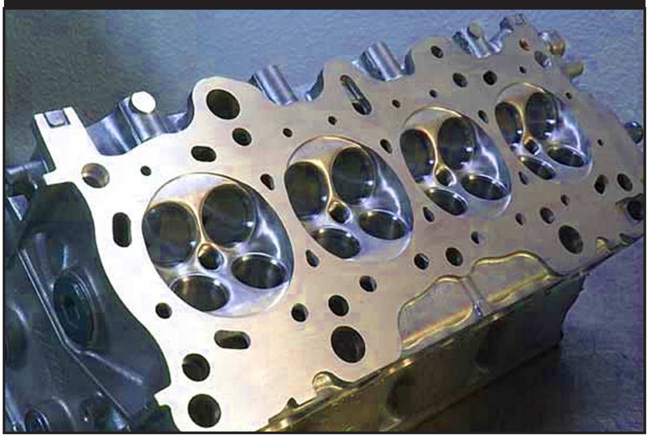
Sport-Compact—4-Valve, Pentroof, Stock Ports And Valve—The first choice in the 4-valve group simulates a 4-valve cylinder head that would be "standard equipment" on factory high-performance, sport-compact engines. These heads offer power comparable to high-performance 2-valve castings equipped with large valves and pocket porting. However, because they still have relatively small ports, reasonably high port velocities, and good low-lift flow characteristics, with proper cam timing they often show a boost in low-speed power over comparable 2-valve heads.

Sport-Compact—4-Valve, Pentroof, Ported With Large Valves—The next choice incorporates mild performance modifications. Larger valves have been installed and both intake and exhaust flow has been improved with porting work. However, care has been taken not to increase the minimum cross-sectional area of the ports. These changes provide a significant increase in power with only slightly slower port velocities. Reversion has increased, but overall, these heads will show a power increase throughout most of the rpm range on many engines.

Sport-Compact—4-Valve, Pentroof, Race Porting And Mods—The final choice, like other Racing options in the **Cylinder Head** menu, models a very efficient, high-flowing cylinder head. This selection has the greatest power potential of all. The ports are considerably larger than the other choices, the valves are larger, and the discharge coefficients are the highest possible. These heads suffer from the greatest reversion effects, especially with late IVC timing on low-speed, small-displacement engines.

Note: If the ***Auto Calculate Valve Size*** option is selected, these heads, like

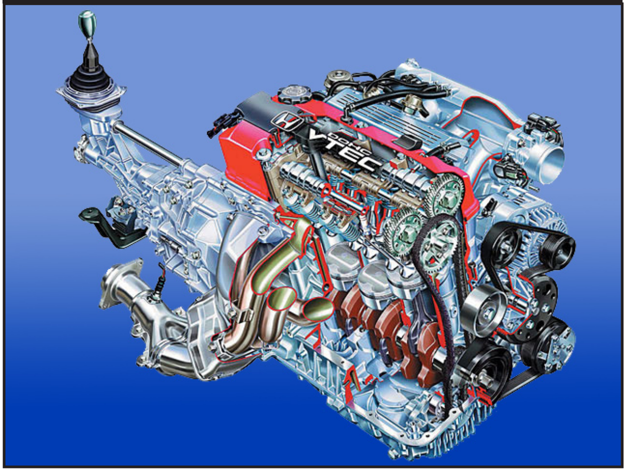
4-Valve, Pentroof, HP Cylinder Heads



The *4-Valve Cylinder Head* selections model cylinder heads with two intake and two exhaust valves. These heads can offer more than 1.5 times the curtain area of the largest 2-valve heads. This large valve flow area, combined with high-flow, low-restriction ports greatly improves air and fuel flow into the cylinders at high engine speeds.

Cylinder Head Menu

Honda VTEC, 4-Valve, Pentroof Engine



The *4-Valve Cylinder Head* selections can offer more than 1.5 times the curtain area of the largest 2-valve heads. This large valve flow area, combined with high-flow, low-restriction ports greatly improves air and fuel flow at high engine speeds. However, the ports offer an equally low restriction to reverse flow (reversion) that can occur at low engine speeds. Variable Valve Timing (like the VTEC system used by Honda) can reduce reversion at low speeds and improve engine efficiency.

all choices provided in the **Cylinder Head Type** menu, will use valves that are "scaled" to engine size, so that smaller engines (or 4-valve designs) automatically use appropriately smaller valves.

Sport-Compact Simulation Tip: If you would like to know what "hidden" power is possible using any particular engine combination, try this cylinder head choice. It is safe to say that the only way to find more power, with everything else being equal, would be to add forced induction, nitrous-oxide injection, or use exotic fuels.

The next five choices in the Sport-Compact Cylinder Head menu model pentroof-chamber, "canted-valve" heads with one valve per port, each tilted toward the port inlet. This orientation improves the discharge coefficients and overall airflow. All ports in this menu group have cross-sectional areas sized for performance.

Sport-Compact—2-Valve, Pentroof, HP Cylinder Heads (Stock, Ported, Large Valves)—The first three choices can be considered suitable for street/performance applications. These selections model smaller cross-sectional area ports (sometimes oval or round) that provide a good compromise between low restriction and high flow velocity for production engines. The pocket-ported choices are suitable for modest racing applications.

Sport-Compact—2-Valve, Pentroof, High-Flow, Fully Ported—The final two Pentroof, 2-valve selections simulate extensively modified, high-performance cylinder heads. These castings have high discharge coefficients, large port cross-sectional areas, and increased valve sizes. These heads are basically factory-type castings but incorporate improved porting and valve work. However, they do not use "exotic" modifications, like raised and/or welded ports that require custom-fabricated manifolds.

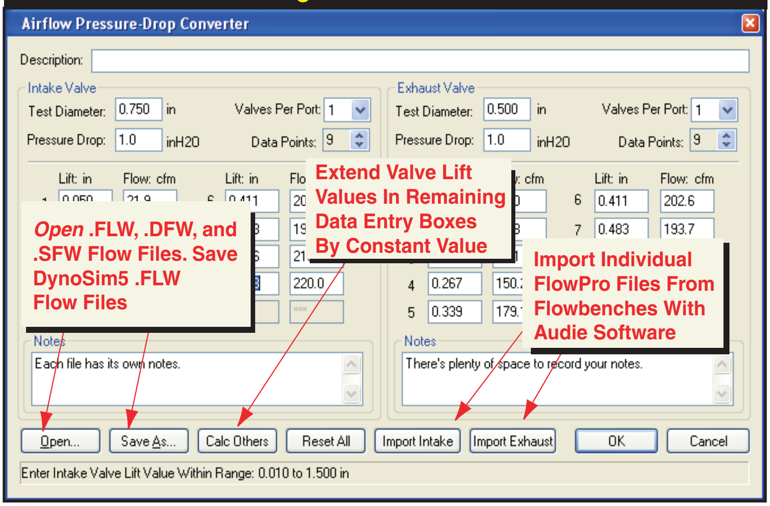
Sport-Compact—2-Valve, Pentroof, High-Flow, All-Out Porting/Mods—The last choice in this group is designed to model state-of-the-art, 2-valve, drag-racing cylinder heads. These custom pieces are extensively modified for maximum power. They require hand-fabricated or custom intake manifolds, have optimum valve discharge coefficients, and the ports have the largest cross-sectional areas of the 2-valve head designs. These cylinder heads only develop sufficient airflow for good cylinder filling at high engine speeds.

Note: If the ***Auto Calculate Valve Size*** option is selected, these heads, like all choices provided in the **Cylinder Head** menu, use valves that are "scaled" to engine size, so that smaller engines automatically use appropriately smaller valves.
Pro Simulation Tip: If you would like to know what "hidden" power is possible using any particular engine combination, try this cylinder head choice. It is safe to say that the only way to find more power, with everything else being equal, would be to add forced induction, nitrous-oxide injection, or use exotic fuels.

Custom Port Flow—DynoSim5 will accept flowbench data, determined from testing virtually any port, with any valve size, at any pressure drop. Selecting ***Custom Port Flow*** or clicking the ***Port Flow*** *Quick-Access™ Button* opens the port-flow dialog box (see photo, above).
Note: If you open the **Custom Port Flow** dialog after you have selected one of the "generic" heads from the **Cylinder Head** menu, the flow data for that cylinder head will be displayed.

To enter custom flowbench data from scratch, first enter a suitable name for the flow data in the ***Description*** field. Then select the number of data points in your

Custom Port Flow Dialog

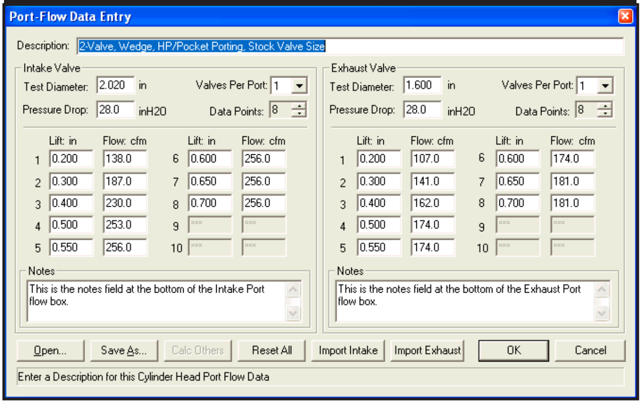


DynoSim5 will accept flowbench data from several sources. Basic flow data can be manually entered, in addition, you can load DynoSim5 Airflow files (ending in .FLW). You can also *Import FlowPro* flow files (using the Import buttons) generated on flow benches equipped with Audie Technology software.

Custom Port Flow Dialog

The *Custom Flow Dialog Box* allows the direct entry of flow bench data. From 4 to 10 data points for each port can be entered. Virtually any test-valve diameter, valve-lift and pressure-drop can be used with DynoSim5. For multiple valves-per-port, flow data is measured as both (or all) valves in each port are opened simultaneously.

Custom Port Flow Manual Entry



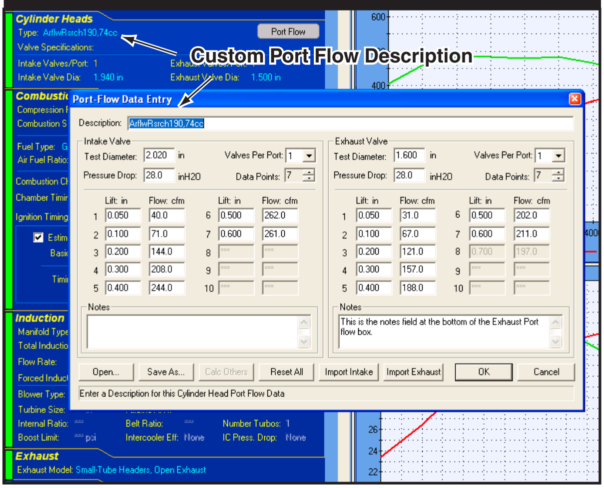
flowbench test into the ***Data Points*** field (click up to increase, down to decrease). Next, enter the valve ***Test Diameters***, the ***Pressure Drop*** (in inches of H_20) at which the tests were performed, and the number of ***Valves Per Port*** for both the intake and exhaust ports. Finally enter the ***Flow*** and ***Valve-Lift*** data obtained from flowbench testing.

Note 1: If you press the ***Calc Others*** button after entering two valve-lift points, DynoSim5 will fill in the remaining lift fields with the same "step" value that was established in the previous two fields.

Note 2: If you have fewer data points for one of the valves, simply repeat the highest measured flow value to "flush out" the remaining data points. This technique has been shown to produce accurate simulation results.

Note 3: For cylinder heads with more than one valve per port, the flow values

Custom Port Flow Description And Filename



When a cylinder head has been selected or an airflow file is loaded (using the *Port-Flow Dialog Box*) a short Description of the cylinderhead/flow-test is displayed in the Cylinder Head *Type* field. To load and save airflow data, click on the *Port-Flow Button*.

measured on the flowbench, and entered in the Custom Flow Dialog Box, assume that both (or all) valves in each port are opened to the same lift when the airflow rate is measured. *The recorded flow must be the combined flow for all valves in the port.*

You can save flow data in a separate file at any time by pressing the ***Save As*** button (data will be saved in a separate **.FLW** file of your choosing—however, even if you do not create a separate .FLW file, head flow data is saved with the current engine in its **.DYN** file). Recall previously saved flow data (**.FLW** files) with the ***Open*** button.

Pressing ***OK*** will load the new test data into the engine simulation database and display the ***Description*** of the flow test (entered in the **Description** field of the **Port-Flow Dialog Box**) in the **CYLINDER HEAD** category of the main component screen.

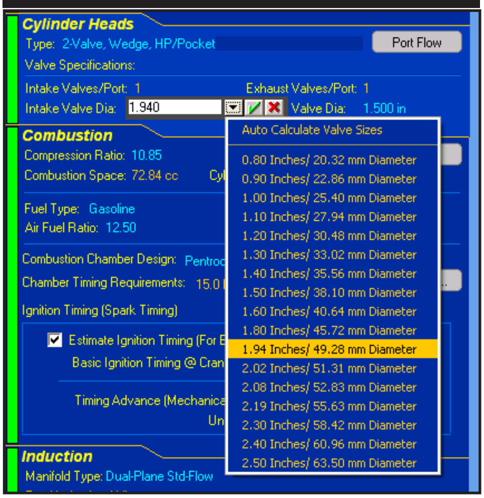
Valves-Per-Port And Valve Diameters

The ***Valves Per Port*** display-only fields in the **CYLINDER HEAD** category indicate the number of intake and exhaust valves located in each port. Four-valve heads typically have two intake and two exhaust valves per port, while three-valve heads designs often have two intake valves and one exhaust valve per port. Since multiple-valve-per-port cylinder heads are airflow tested by opening *<u>all valves in each port</u>* to the same lift before recording the flow rates, the number of valves-per-port is directly linked to (and stored with) the flowbench data for each cylinder head. **Note:** If you wish to change the number of valves-per-port, click the ***AirFlow Button*** to open the **AirFlow Dialog Box**; here you can modify all flow data, including the number of valves-per-port.

The ***Valve Diameter*** menus are located in the lower portion of the **CYLINDER**

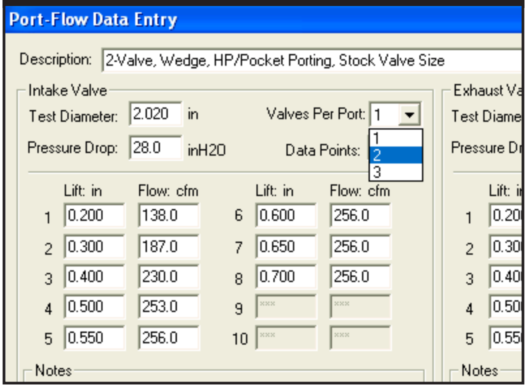
Select valve sizes for the intake and exhaust valves of the simulated engine from drop-down menus. These specs indicate the diameters of the valves used in the simulated engine; they need not be the same size as the valves used during flowbench testing and entered into the Airflow Dialog Box. If they are a different size than the flowbench test valves, airflow used in the simulation will be accurately scaled up or down to accommodate the actual valve sizes.

Intake And Exhaust Valve Sizes



Valve Size Menus

DynoSim5 will accept 1, 2, or 3 valves-per-port cylinderhead designs. Since multiple-valve-per-port cylinder heads are airflow tested by opening _all valves in each port_ to the same lift while recording the flow rates, the number of valves-per-port is directly linked to the flowbench data for any specific cylinder head. It is for this reason that the number of valves-per-port can only be changed by opening the Port-Flow Dialog Box (by pressing the *Port Flow Button* in the CYLINDER HEAD component category).



Select Number Of Valves Per Port

HEAD category. The first selections are ***Auto Calculate Valve Size***. This feature instructs DynoSim5 to determine the nominal intake and exhaust valve diameters for use with the current engine based on an assessment of the bore diameter and the cylinderhead selection. When the ***Auto Calculate*** function is activated, ***Auto*** will be displayed next to the calculated sizes, and it will remain active on the current engine until turned off (by selecting ***Auto Calculate*** a second time).

Note: ***Auto Calculation*** is turned **OFF** by default when DynoSim5 is started and whenever ***Clear Components*** is chosen from the **Edit** menu.

Auto Calculate Valve Size is especially helpful if you are experimenting with several different bore and stroke combinations or you're comparing different engine configurations. **Auto Calculate** will always select valves of an appropriate diameter for the cylinder heads under test and ensure that valve sizes (especially for multiple valves) are never too large for the current bore diameter (also, see page 102 for information on the related ***Auto Calculate Valve _Lift_*** feature).

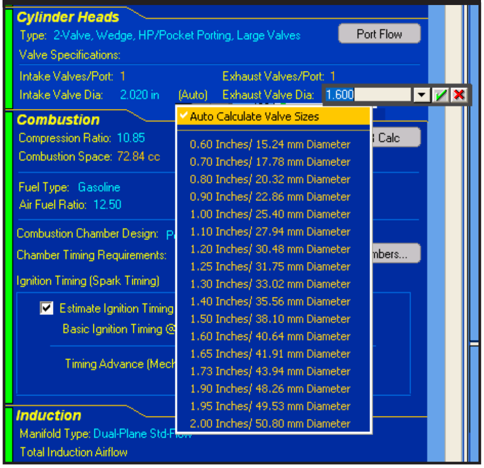
While ***Auto Calculate Valve Size*** is helpful during quick back-to-back testing, it may not "guess" the precise valve sizes used, and therefore, not simulate power as accurately as possible. In these situations refer to the additional choices on the ***Valve Diameter*** menus. Here you will find a list of exact diameters commonly used for automotive intake and exhaust valves. In addition, you can directly enter any valve-diameter dimension within the range limits of the program.

THE COMBUSTION CATEGORY

The Combustion Category is the location for all combustion-related components and specifications. Included are *Compression Ratio*, *Fuel Type*, *Air/Fuel Ratio*, *Combustion-Chamber geometry*, and *Ignition Timing (only available in DynoSim5)*. Each of these specifications directly affect how fuel is burned in the engine. This category also includes a *Compression Ratio Calculator*, and a *Chamber-Selection* dialog. Clicking the *Estimate Ignition Timing* checkbox will instruct DynoSim5 to determine the *MBT* (*Minimum Ignition Advance For Best Torque*) for the engine at

Valve Size Menus

Auto Calculate Valve Sizes



The first selection in the Valve Diameter Menus is *Auto Calculate Valve Size* (active when any of the "generic" cylinder heads have been selected). This feature determines the nominal intake and exhaust valve diameters based on an assessment of the bore diameter and the cylinderhead selection. *Auto Calculate Valve Size* will always select valves of an appropriate diameter for the cylinder heads under test and ensure that valve sizes (especially in multiple valves-per-port applications) are never too large for the current bore diameter. *Note: This selection is dimmed whenever custom airflow values have been entered in the AirFlow Dialog Box.*

each rpm point.

Compression Ratio

The calculation of compression-ratio, at its most basic, involves two variables: 1) swept-cylinder volume, and 2) combustion-space volume. *These volumes are the only two volumes that affect compression ratio.* However, each of these volumes is made up of multiple other volumes, so the first step in exploring compression ratio must be to understand these engine volumes in detail.

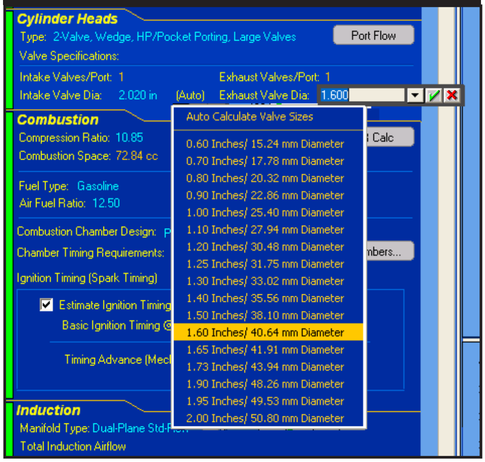
Swept cylinder volume is the most straightforward to understand. As you discovered previously, the swept cylinder volume is calculated by DynoSim5—and displayed in the **SHORTBLOCK** category—as soon as the bore and stroke have been selected for the test engine. Swept volume is simply the three-dimensional space displaced by the piston as it "sweeps" from BDC to TDC, and is determined solely by the bore diameter and stroke length.

The other main variable in the compression-ratio equation is *combustion-space volume*. This is the total volume that exists in the cylinder when the piston is positioned at TDC. This space includes the volume in the combustion chamber, the volume taken up by the thickness of the head gasket, plus any volume added by the piston not rising fully to the top of the bore plus any valve-pocket volume, less any volume displaced by the piston or piston dome protruding above the top of the bore. The complexity of volumes often is a stumbling block in understanding compression ratio. However, the following explanation should clarify these important concepts.

A good way to visualize these volumes is to imagine yourself as a "little guy" wandering around inside the engine. Let's take a walk inside the combustion space. Picture in your mind what you would see in the cylinder with the piston at TDC.

Combustion Category

Manually Selecting Valve Sizes



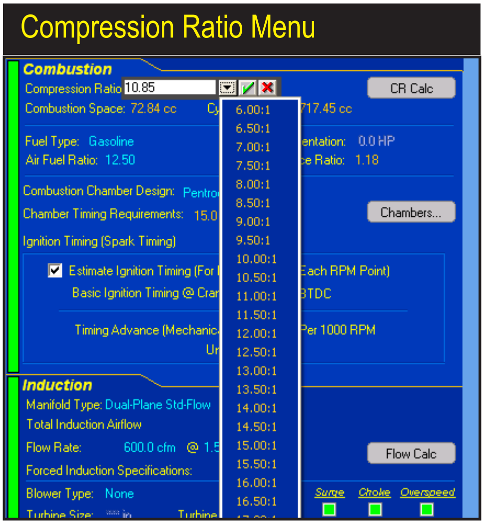
Selecting a specific valve size will disable the *Auto Calculate Valve Size* feature. You can select from the provided sizes (displayed in both US and Metric measurements), or you can directly enter any valve dimension within the range limits of DynoSim5 (range limits are shown in the *Status and Range Limit Line*, as described on page 16 and 19).

The combustion chamber would look like a ceiling above you. The floor would be the top of the piston. If the piston (at TDC) didn't rise completely to the top of the cylinder, you would see a bit of the cylinderwall around the edges of the floor, with the head gasket sandwiched between the head and block like trim molding around the room. There may be notches (valve pockets) in the top of the piston just under your feet (don't trip!). If the piston had a dome, it might act as a small room divider rising from the floor, to, perhaps, knee high. The combustion space would be larger if the piston was positioned lower down the bore or if the notches under your feet were deeper, and it would be smaller if the room divider (dome) volume was larger. This entire space is "home" for the compressed charge when the piston reaches TDC. This is the volume that makes up the combustion space, the denominator of the compression-ratio calculation equation. Now let's continue our "tour" of compression spaces, but this time we'll explore what we see inside the cylinder when the piston is located at BDC. The very same volumes that we just described (chamber, dome, notches, gasket, etc.) are still there, but are now located well above our head. It looks like the room has been stretched, like the elevator ride in the Haunted House at Disneyland. This "stretched" volume is described in the numerator of the compression-ratio equation. It's simply the original combustion volume plus the volume added by the "sweep" of the piston as it traveled from TDC to BDC. The ratio between these volumes is the compression ratio.

Changing Compression Ratio

A quick look at the compression-ratio equation reveals that if engine displacement (swept volume) is increased, either by increasing the bore or stroke, the compression ratio will rise. In fact, with everything else being equal, a longer stroke will increase compression ratio much more quickly than increasing bore diameter. This is due to the fact that a longer stroke not only increases displacement, but it tends

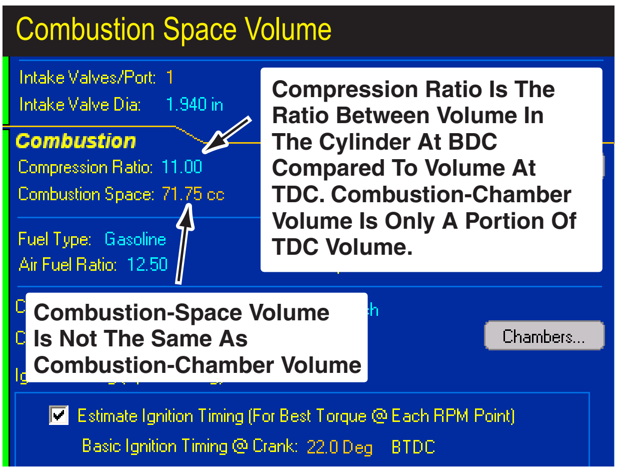
Compression Ratio Menu



The Compression Ratio of the engine is a comparison of the geometric volume that exists in the cylinder when the piston is located at BDC (bottom dead center) to the "compressed" volume when the piston reaches TDC (top dead center). Passenger car engines often have 8 to 10:1 compression ratio, while racing engines can have a compression ratio as high as 18:1.

to decrease combustion space volume, since the piston moves higher the bore (in our "little guy" example, raising the floor closer to the ceiling). This "double positive" results in rapid increases in compression ratio for small increases in stroke length. On the other hand, increasing cylinder-bore diameter also increases compression ratio but less significantly. This is due, in part, to the increase in combustion volume that often accompanies a larger bore (our "little guy" would see more floor space because of the increasing diameter of the room—plus a larger bore often accompanies an increase in the size of the ceiling, i.e., the combustion chamber), partially offsetting the compression-ratio increase from greater swept cylinder volume.

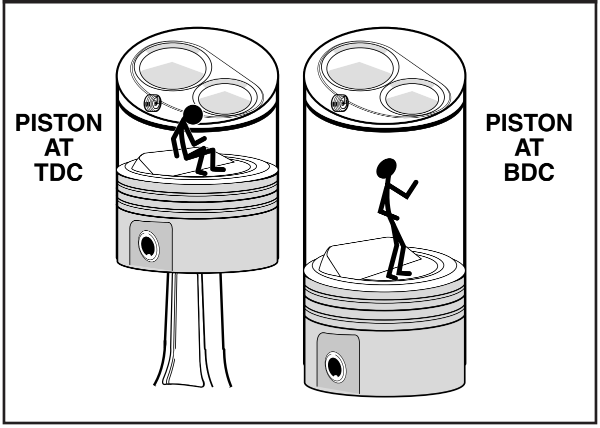
Changing combustion space, the other element in the compression-ratio equation, will also alter the compression ratio. Anything that reduces the combustion volume, while maintaining or increasing the swept volume of the cylinder, will increase the



An 11:1 compression ratio (as shown here) means that the sum of the Swept Cylinder Volume and the Combustion Space Volume is eleven times greater than the volume in the Combustion Space alone.

Compression Ratio Menu

Exploring Compression Ratio And Volumes



A good way to visualize compression ratio volumes is to imagine yourself as a "little guy" wandering around inside the engine. You would see the combustion chamber above you like a ceiling. Your floor would be the top of the piston (see text for a further description of cylinder volumes).

compression ratio. Some of the more common methods to accomplish this are decreasing the volume of the combustion chambers (by replacing or milling the heads), using thinner head gaskets, changing the location of the piston-pin or rod length to move the piston closer to the combustion chamber, installing pistons with larger domes, etc. These modifications and others can be explored in DynoSim5 using the built-in **Compression-Ratio Calculator**.

THE COMPRESSION-RATIO CALCULATOR
(The Compression-Ratio Calculator Is A DynoSim5 Exclusive Feature)

DynoSim5 engine simulation allows the selection and testing of virtually any compression ratio. But many engine builders need to directly enter combustion-chamber volumes, head-gasket thickness, etc., to determine their effects on compression ratio. The ***Compression-Ratio Calculator***, built-in to DynoSim5 (not available in the DeskTop Dyno5), quickly performs these functions. But this tool is more than a "enter-the-numbers-into-the-equation" calculator. This tool "intelligently" adjusts itself to the needs of the engine builder, changing the way it functions depending on whether combustion volumes are known ahead of time or need to be derived from measurement.

After you have specified the bore, stroke, and number of cylinders for the engine under test, activate the ***Compression-Ratio Calculator*** by selecting either ***Compression-Ratio Math*** from the **Tools** menu, or by clicking the ***Compression-Ratio Button*** in the **COMPRESSION** component category. When the calculator is first activated, it defaults to the *Known Volumes* mode. This is the most straightforward model for calculating compression ratio. Simply enter the needed values in the ***Compression-Ratio Calculator*** and the compression-ratio will displayed.

Using The Calculator With Known Dome/Dish/Deck/Chamber Volumes

Compression-Ratio Math Calculator

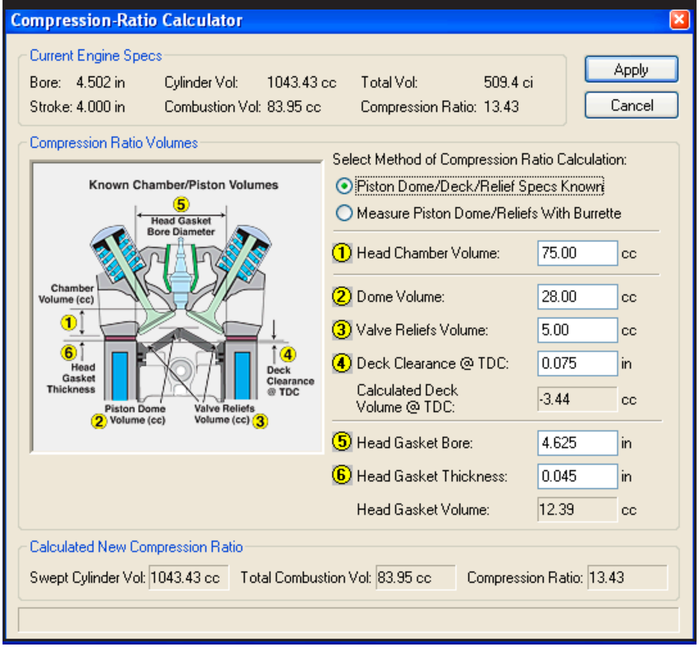
Note: The Compression-Ratio Calculator is not available in the DeskTop Dyno5; it is a feature of Dyno***Sim5 ProTools*** set.

If an engine builder is provided with the exact volumes displaced in the dome and valve pockets by the piston manufacturer, and the volumes of the combustion chamber, the deck height, and the specifications for the head gaskets are also known, a simple, numeric-only method can be used to calcuate the compression ratio. This proceedure is explained next. However, in those cases where piston specifications are unknown (not provided by the manufacturer or machine work has been performed on the dome/pockets), the engine builder must directly measure dome/pocket volumes. In these situations, refer to the next section for the ***Burrette-Measured Volume Mode*** of the *Compresssion-Ratio Calculator*.

Here is the procedure for using DynoSim5 compression-ratio calculator in the ***Known-Volumes Mode***. Start off by verifying that the calculator is in the ***Known-Volume Mode*** by ensuring that the upper radio button ***Piston Dome/Deck/Relief Specs Known*** is activated. Next, enter the combustion-chamber volume (in cubic centimeters—cc's) in the first ***(1) Head Chamber Volume*** data box. Next, enter the ***(2) Dome Volume*** and the ***(3) Volume*** displaced by all the ***Valve Reliefs*** in one piston. If your piston manufacturer provided one value for both of these volumes, enter the supplied volume in the ***(2) Dome Volume*** field and enter zero in field **3**.

Note: If any of these values are unknown, they must be manually measured (with a burrette (see the next section for *Burrette-Measured Volumes*).

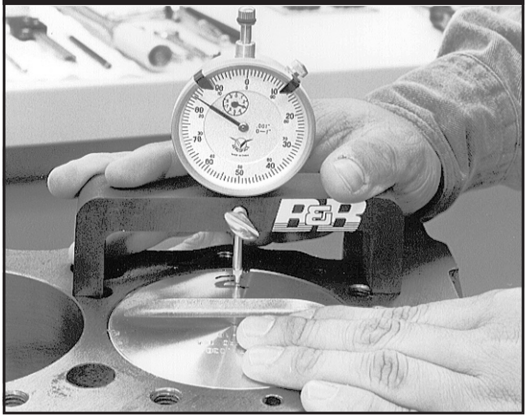
CR Math Calculator—Known Volumes Mode



When the *Compression-Ratio Calculator* is first activated, it defaults to the *Known Volumes* mode. This is the most straightforward model for calculating compression ratio. Simply enter the needed values in fields 1 through 6, and the *Compression-Ratio Calculator* will determine the compression ratio.

Compression-Ratio Math Calculator

Measuring Deck Height



Use a dial indicator and stand to measure how far down the bore the piston is positioned at TDC. Enter a positive number for "down-the-bore" distances and a negative number if the piston protrudes above the deck surface. A typical value might be +0.040, indicating that the piston comes to a rest at TDC 0.040-inch <u>below the deck surface</u>.

The next data entry field is ***(4) Deck Clearance @ @ TDC***. This dimension indicates how far down the bore the piston is located when positioned at TDC (see above photo). Enter a positive number for "down-the-bore" distances and a negative number if the piston protrudes above the deck surface. A typical value might be +0.040-inch, indicating that the piston comes to a rest at TDC at 0.040-inch <u>below the deck surface</u>.

Important Note: A positive ***Deck Clearance @ TDC*** indicates the piston is positioned below the deck surface and this volume <u>adds</u> to the combustion space at TDC; a negative number indicates the piston protrudes above the deck surface at TDC and <u>reduces</u> the combustion space.

The next two data-entry boxes are used to calculate the volume added to the combustion space by the head gasket that is compressed between the cylinder head and the block deck surface. The data box marked ***(5)*** accepts the ***Head Gasket Bore*** diameter (in the appropriate Metric or U.S. units system). Most head gaskets have a "bore-circle" or "bore diameter" larger than the cylinder-bore diameter. For gaskets with bore-circles of odd shapes, simply estimate the bore circle by averaging the larger and smaller dimensions. Next, enter the compressed ***(6) Head Gasket Thickness***. This dimension is often available from the head-gasket manufacturer. When the compressed thickness is entered, the ***Head Gasket Volume*** and the ***Compression Ratio*** are calculated.

At this point, you can move to any of the previous fields (by clicking in them or using the Tab and/or the SHIFT-Tab keys) and change any values to determine their effect on compression ratio. At any time, you can click on the **Apply** button to load the new calculated compression ratio into the **COMPRESSION** component category and save all entered values for the simulated engine. Alternately, you can press the **Cancel** button to discard all entries and leave any previously entered compression ratio value intact.

Using The Calculator With Burrette-Measured Volume

Compression-Ratio Math Calculator

If you are using pistons with domes, dishes, or valve-pockets/reliefs of unknown volumes, determing the compression ratio is a bit more complicated. Each of these volumes must be accurately determined so that the net effect of all “positive” (domes) and “negative” (pockets, reliefs) can be calculated.

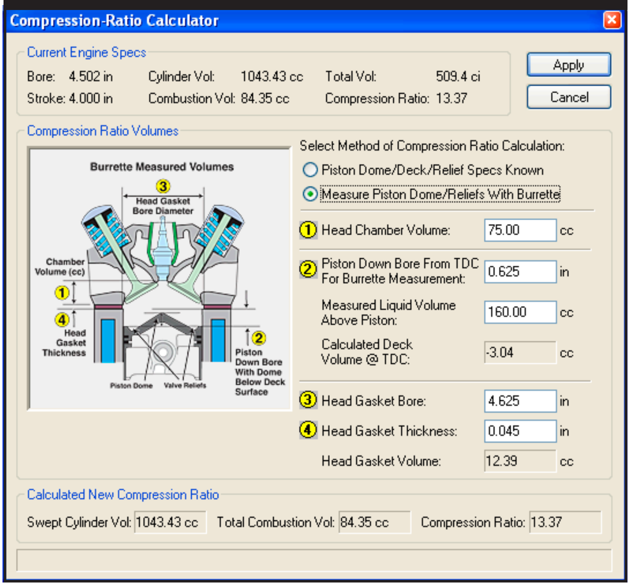
Start off by verifying that the calculator is in the ***Burrette-Measured Mode*** by verifying that the lower radio button ***Measured Piston Dome/Reliefs With Burrette*** is activated. Enter the combustion chamber volume (in cubic centimeters—cc’s) in the first ***(1) Head Chamber Volume*** data box.

Note: As mentioned earlier, if unknown, the combustion-chamber volume must be measured with a burette.

The next entry, ***(2) Piston Down From TDC For Burrette Measurement***, is a more-or-less arbitrary distance down the bore (measured from the deck surface) that you can position the piston at which the highest part of the piston dome is located below the deck surface. Typical values may be 0.100-inches or 0.250-inches depending on the height of the piston dome (any distance is acceptable as long as the entire dome resides below the deck surface). At this depth, a direct measurement is made of the ***Volume Above The Piston*** in the cylinder. This measurement is taken by the engine builder (see photo, above) using a burette to fill the space above the piston (a flat Plexiglas plate is often used to seal the top of the bore; grease is used to seal the piston to the bore). The volume of liquid dispensed typically will be less than the volume for a simple cylinder of the same height. The liquid volume dispensed from the burette is entered in field ***Measured Liquid Volume Above Piston***. The difference between this volume and the volume of a

When the Compression-Ratio Calculator is switched to the *Burrette Measured* Mode, the data fields are redefined to allow the engine builder to input the direct measurement of a volume (*Calculated Deck Volume @ TDC*) equivalent to the sum of the dome, dish, and relief volumes of the piston. To determine this volume, the piston is lowered down the bore until the dome is entirely below the deck surface (2), and a direct measurement is taken of the cylinder volume using a burette. After entering this volume and the head gasket specs, the compression-ratio is displayed.

CR Math Calculator—Burrette Measured Mode



Compression-Ratio Math Calculator

Measuring Dome/Deck Volume

Measure the volume above the piston while the highest portion of the piston dome is positioned below the deck surface. Enter this value in the *Measured Liquid Volume Above Piston* field. The difference between this volume and the volume of a simple cylinder [of a height equal to the value entered in field (2)] is the *Calculated Deck Volume At TDC*. This volume is equivalent to the sum of all the dome, dish, and relief volumes of the piston. A negative *Deck Volume At TDC* indicates that the dome reduces the combustion space and will increase the compression ratio over a flattop piston. A positive value indicates that the sum of all dome/dish/relief/deck volumes will increase the combustion volume and decrease the compression ratio over a flattop piston.

simple cylinder (of a height equal to the value entered in field **(2)**) is the ***Calculated Deck Volume At TDC***, a volume equivalent to the sum of the dome, dish, relief, and deck volumes of the piston.

Important Note: A negative ***Calculated Deck Volume At TDC*** indicates that the total dome/deck/relief volumes reduce the combustion space and will, therefore, increase the compression ratio over a flattop piston. A positive value indicates that the sum of all dome/dish/relief volumes will increase the combustion space volume and decrease the compression ratio over a similar flattop piston (with the same deck height at TDC).

The next two data-entry boxes are used to calculate the volume added to the combustion space by the head gasket that is compressed between the cylinder head and the block deck surface. The data box marked ***(3)*** accepts the ***Head Gasket Bore*** diameter (in the appropriate Metric or US units system). Most head gaskets have a "bore-circle" or "bore diameter" larger than the cylinder-bore diameter. For gaskets with bore-circles of odd shapes, simply estimate the bore circle by averaging the larger and smaller dimensions. Next, enter the compressed ***(4) Head Gasket Thickness***. This dimension is often available from the head gasket manufacturer. When the compressed thickness is entered, the ***Head Gasket Volume*** and ***Compression Ratio*** are calculated.

At this point, you can move to any of the previous fields and change any values to determine their effect on compression ratio. At any time, you can click on the **Apply** button to load the new calculated compression ratio into the **COMPRESSION** component category and save all entered values with the simulated engine. Alternately, you can press the **Cancel** button to discard all entries and leave any previously entered compression ratio value intact.

Combustion Category Fuel Menus

FUEL TYPE AND AIR/FUEL RATIO

DynoSim5 can model five automotive fuels plus Nitrous-Oxide injection with Gasoline or Methanol during a simulated dyno test. Select any of these fuels options from the ***FUEL*** menu:

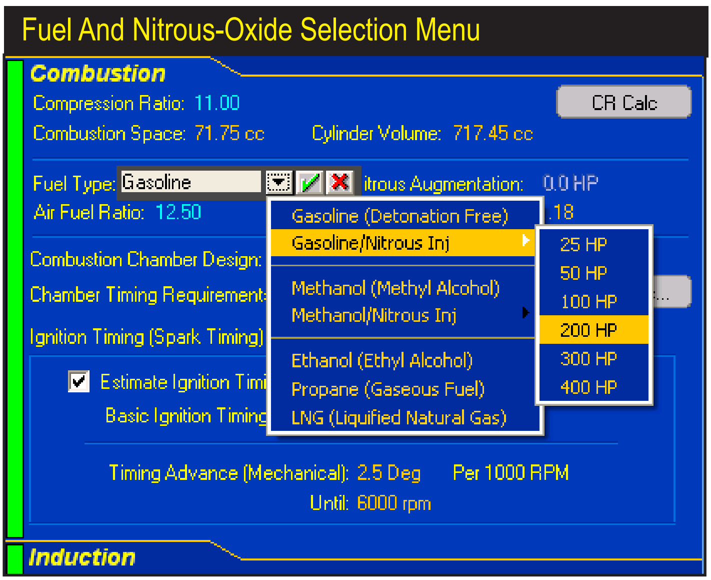
- **Gasoline (Detonation Free)**
- **Methanol (Methyl Alcohol)**
- **Ethanol (Ethyl Alcohol)**
- **LNG (Liquefied Natural Gas)**
- **Gasoline W/Nitrous Injection**
- **Methanol W/Nitrous Injection**
- **Propane (Gaseous fuel)**

When any of these fuels have been selected, DynoSim5 readjusts the air/fuel ratio for optimum power. This updated air-fuel ratio is displayed in the ***Air/Fuel Ratio*** field. Changes to the Air/Fuel ratio can be made at any time by making a selection from the Air/Fuel Ratio menu or by direct numeric entry.

Nitrous-Oxide Injection

DynoSim5 models typical constant-flow ***Nitrous/Gasoline*** and ***Nitrous/Methanol*** injection systems. During engine testing with nitrous augmentation, you should monitor cylinder pressures (BMEP) to make sure dangerously high pressures are avoided at lower engine speeds (a BMEP greater than 300psi is usually considered excessive).

One of the ways to reduce low-speed cylinder pressure is by altering cam timing. It has long been known that increasing valve duration and overlap will lower



DynoSim5 allows a selection of fuels for dyno testing. When any of these fuels is initially selected, the air/fuel ratio is automatically adjusted to ensure optimum power. Use the Air/Fuel Ratio menu to change the air/fuel ratio at any time.

Combustion Chamber Selection

Nitrous-Oxide vs. BMEP

This graphic comparison shows how cylinder pressures (BMEP shown by green line) increase after a 200-horsepower nitrous system is activated (this pressure comparison and the colored DataZones™ requires ProTools™ activation). Since DynoSim5 models a fixed-flow nitrous system, cylinder loads increase as engine speed decreases (the longer <u>time</u> the intake valve is open, the greater nitrous load is injected into the cylinder). Below 2700rpm, BMEP exceeds 300psi (shown as the top, orange band). To maintain engine reliability, nitrous-system activation should be delayed until 3000rpm.

cylinder pressures at lower engine speeds. This typically-unwanted phenomenon is a low-speed power killer, but combined with a nitrous-oxide injection system, it can permit earlier nitrous flow while optimizing power at higher rpms. Other variables that can decrease low-speed cylinder pressures are reduced compression ratios, increased exhaust-system back pressure, reduced induction airflow, less efficient induction manifolding, and larger engine displacements.

It is a simple matter to simulate and test a variety of component combinations with DynoSim5 to determine the maximum nitrous load that can be injected at any engine speed.

You can add nitrous injection by selecting ***Gasoline/Nitrous Injection*** or ***Methanol/Nitrous Injection*** from the induction menu. You will see the following choices:

- **25 HP** (~1 lb/min N_2O flow)
- **50 HP** (~2 lb/min N_2O flow)
- **100 HP** (~4 lb/min N_2O flow)
- **200 HP** (~8 lb/min N_2O flow)
- **300 HP** (~12 lb/min N_2O flow)
- **400 HP** (~16 lb/min N_2O flow)

These six selections allow nitrous flow rates from 25hp (~1-lb/min flow) to 400hp (~16-lb/min flow). You can also manually enter horsepower boosts from 0.0- to 500-horsepower in the ***Nitrous Augmentation*** field.

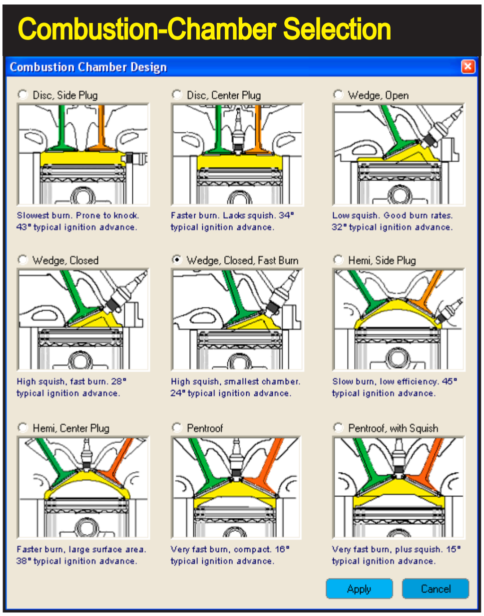
Combustion Chamber Design Selection

The **Combustion Chamber Design** category sets the fuel burn rate and adjusts the combustion efficiency for the physical geometry of the combustion space. In general, a "disc-shaped" chamber with a side-mounted sparkplug generates the lowest turbulence and flame speed. The burn-rate differences between this archaic chamber shape and a modern pentroof design with squish-assisted turbulence can require as much as 30-degrees of additional ignition timing "lead" to compensate for the slower-burn rate. A mathematical analysis of the burn process (that can be thought of as simply a rapid pressure rise) reveals that peak power would be obtained if the fuel burned instantly at an optimum crank angle. This would produce the greatest push on the piston at the point at which this pressure is most efficiently converted into the highest torque on the crankpin (approximately 20- to 30-degrees ATC in many applications). While an instant fuel burn (and pressure rise) is not possible for several reasons, including pressure knocking and mechanical shock damage, in general, the faster the pressure rises in the cylinder the more power the engine will produce. As a result, modern chamber designs are optimized for high turbulence and fame speeds within the constraints of limiting pre-ignition and detonation.

> **Note:** As always, there are exceptions. In a nitromethane-fueled engine, the slower burn-rate hemi chamber is often used. In this case, there are benefits to slowing down the burn rate and giving the flame front a symmetric volume in which to propagate. This results in a more uniform application of the considerable cylinder pressures produced by nitromethane across the piston surface. The overriding consideration here is reliability not peak power!

DynoSim5 provides nine combustion-chamber geometries from the slowest-burning disc shape, provided primarily for comparison purposes, to the fast-burn pentroof designs used in many modern high-performance and racing engines. Clicking on the ***Chambers*** Quick-Access™ button provides an overview of these chamber shapes, including the basic *Chamber Timing Requirement* of these designs (with gasoline as the baseline fuel).

The *Chamber Timing Requirement* is primarily based on the time lag between



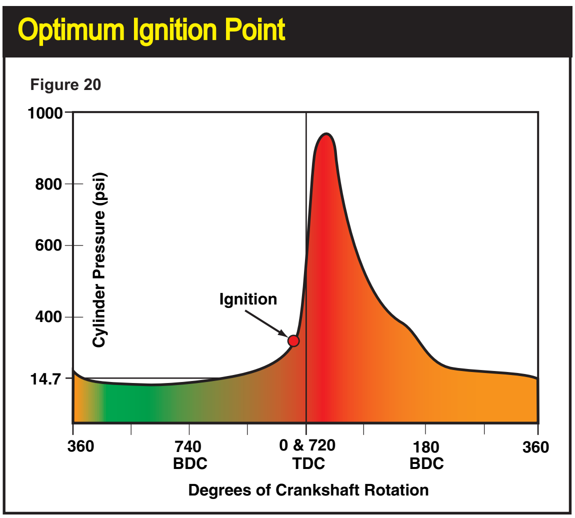
DynoSim5 provides nine combustion-chamber geometries from the slowest-burning disc shape to the fast-burn pentroof designs used in many modern high-performance and racing engines. Clicking the *Chambers Quick-Access™* button in the Combustion Category provides an overview of these chamber shapes, including the basic Chamber Timing Requirements of these designs (with gasoline as the fuel).

the sparkplug discharge, referred to as the "SparkPoint," and the beginning of cylinder pressure rise. This can be considered as the innate rate at which fuel burns in that chamber geometry. This is the *least timing advance* that the engine will need to produce optimum power with that chamber. As engine speed increases or if non-optimum air/fuel ratios are used, greater ignition lead will be required to regain optimum power. This minimum timing requirement for optimum power is often called ***MBT*** (or **M**inimum advance for **B**est **T**orque), and this timing point changes throughout the rpm range.

Ignition Timing Selection (Exclusive DynoSim5 Feature)

Optimum power production depends on the precise timing of the "ignition point," a term that is somewhat ambiguous. As mentioned, there is a significant delay in the initiation of measurable combustion after the *SparkPoint*, and even beyond that, may factors affect lag and the rate of combustion. So, what shall we call the actual point of ignition? Should it be: **1)** when the spark occurs, or **2)** when the fuel starts burning, or **3)** when pressure begins to rise in the cylinder? Rather than "splitting hairs," we will use other terms that have precise meanings and leave the "definition wars" to others.

To begin, let's establish the beginning of the *Combustion Cycle* at the ***SparkPoint,*** commonly know as the ***Ignition Timing Point*** of the engine. This will be the precise point, in crank degrees before top-dead center (BTDC), when the initiation of spark at the plug occurs. After the *SparkPoint* there is a delay before the pressure within the cylinder actually increases. This delay is somewhat exaggerated by the fact that this piston has begun to move down the bore after TDC, increasing combustion-space volume. At some point, however, the increasing volume is overcome by the rapid rise in pressure from accelerating combustion. The first indication of a pressure increase is usually defined as the ***Start Of Combustion***, even though



While an instantaneous fuel burn to produce peak pressures at the optimum crank angle (approximately 20- to 30-degrees ATC in many applications) is not possible for several practical reasons, in general, the faster the pressure rises in the cylinder the more power the engine will produce. Modern combustion chamber designs are optimized for high turbulence and fame speeds within the constraints of preventing pre-ignition and detonation.

it's obvious that the combustion process was already underway, but remained in a low-burn-rate initiation state.

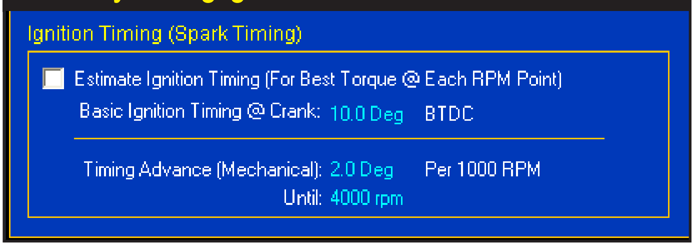
We mentioned that the *Ignition-Timing* requirement for optimum power is commonly called the ***MBT*** (Minimum advance for Best Torque). But this timing requirement changes as turbulence in the combustion chamber changes, since the burn rate is substantially linked to, among other things, the turbulence of the gasses in the combustion chamber. Furthermore, turbulence also changes when: **1)** Engine speed changes, **2)** Air/Fuel ratio changes, and **3)** When engine load (throttle position) changes. Plus there are subtle changes to burn rate from charge temperature changes, differences in compression ratio, and even bore size and stroke length affect the burn rate!

How do you take all these factors into consideration and determine the ***MBT*** for all engine speeds? Luckily, DynoSim5 handles these complex calculations and derives an *Optimum Ignition Timing* advance curve. To activate this feature, simply check the ***Estimate Ignition Timing*** checkbox in the Combustion Category (selected by default). You can view the calculated ignition timing values on the ProData table (see page 131), and you can plot the advance curve on the top-right RPM graph.

If you would like to enter a specific ignition timing value and/or an advance curve based on engine speed, that option is also available. Un-check the ***Estimate Ignition Timing*** box, and enter values for ***Basic Ignition Timing (BTDC).*** This is the SparkPoint relative to TDC measured in crank degrees. In addition, you can direct DynoSim5 to calculate an advance curve by specifying the number of degrees of advance for each 1000-rpm increase in engine speed. You can "flatten" the advance curve by specifying a limit rpm, after which no further advance is applied. After defining your own ignition values, you can quickly compare your curve with the *MBT* determined by DynoSim5 by re-checking the *Estimate Ignition Timing* box and noting the changes in engine power.

> **Note:** Depending on overall engine design, including chamber geometry, fuels, and several other factors, changes in ignition timing and the advance curve can have a marked to limited affect on engine power. Many of these effects are calculated in DynoSim5 and have been validated with dyno results. However, if you have ignition-timing test data that you would like to share with us, we are always interested in fine-tuning our simulation models to better predict engine performance.

Manually Setting Ignition-Advance



Enter an advance curve by specifying the number of degrees of advance for each 1000-rpm engine speed. You can "flatten" the advance curve by specifying a limit rpm, after which no further advance is applied.

Induction Component Category

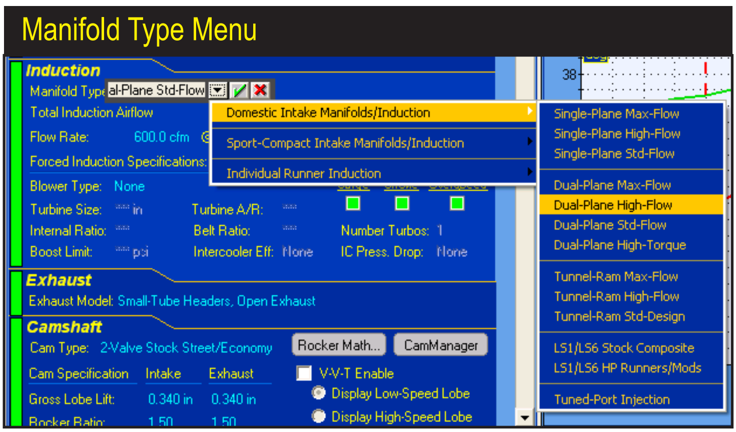
THE INDUCTION COMPONENT CATEGORY MENUS

The next main component category establishes an **INDUCTION** system for the simulated engine. An induction system, as defined in DynoSim5, is everything upstream of the intake ports, including the intake manifold, common plenums (if applicable), carburetor/fuel-injection-throttle-body, venturis (if used), any supercharger or turbocharger, and openings to the atmosphere. DynoSim5 induction menus are divided into two main groups: 1) ***Induction Airflow***, ***Pressure Drop***, ***Fuel***, and ***Manifold Type***, and 2) ***Forced Induction***. Next, we'll examine the choices in the first group, then forced-induction modeling will be discussed (on page 76).

The *Intake Manifold Design* Menu

The **Intake Manifold Design** menu consists of 32 intake manifold choices. Each of these selections applies a unique tuning model to the induction system. While these manifolds are only a small sample of the intake manifolds available for IC engines, this list of 32 models can accurately simulate many of the manifolds and induction systems available today for both street and racing applications.

The manifold models are divided into three main groups: 1) ***Domestic Intake Manifolds (13)***, 2) ***Sport-Compact Manifolds(14)***, and 3) ***Individual-Runner Inductions(5)***. These categories are intended as general classifications. In some cases, certain "domestic" engines (utilizing modern tuned-runner induction) are best modeled with selections from the Sport-Compact submenu. On the other hand, a racing Honda equipped with an individual-runner system, should have its induction chosen from the fourth (*Individual Runner Induction*) group. Finally, if you are interested in a manifold that falls "in between" two menu selections, you can use the ***trend*** method to estimate power for a hybrid design. For example, run a test simulation using manifold Type A, then set up a comparison and study the differences in power attributed to manifold Type B. The changes will indicate trends that



The 32 induction models comprise and extensive modeling set that can accurately simulate many of the manifolds and induction systems available today for both street and racing applications.

should give you insight into how a hybrid manifold Type A/B *might* perform.

Domestic Manifold Selections

The following sections provide an overview of each *Domestic* manifold model provided in the ***Manifold Type*** menu in the **INDUCTION** category. Here you'll find a brief description of the assumptions used in each model, and recommendations associated with that individual design.

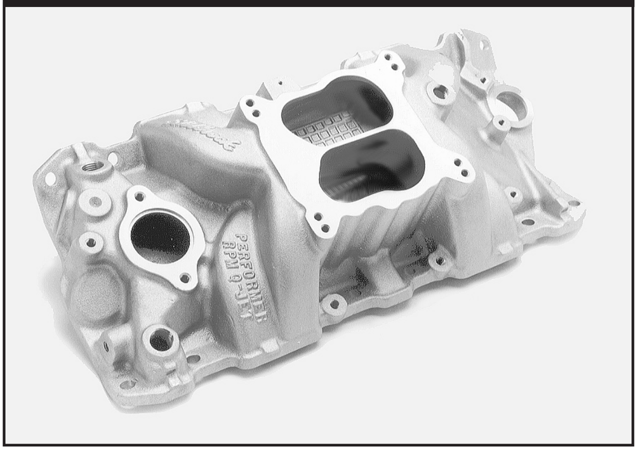
Note-1: Domestic induction selections are titles in **Red**; Sport-Compact induction systems are described in subsequent paragraphs titled in **Green**.

Domestic—Dual-Plane, (Four versions: Maximum-Torque, Standard-Flow, High-Flow, and Max-Flow Manifolds)—The ***Dual-Plane, Max-Torque Manifold*** models dual-plane manifolds with smaller runners, such as those designed for heavy vehicles, economy and other high-torque, applications. The *Dual-Plane Max-Torque* model will tune for a lower peak engine speed, due mainly to runner and plenum restrictions. The ***Standard-Flow, Dual-Plane Manifold*** selection represents the majority of street-oriented dual-plane manifolds available to performance enthusiasts (including many OEM manifolds). The *Standard-Flow* model will accurately simulate street and performance engines with "as-cast" dual-plane manifolds. The ***Dual-Plane, High-Flow*** and ***Max-Flow Manifold*** selections model modified, large-port, (and even custom-fabricated) dual-plane manifolds, as used on high-performance and all-out racing engines.

Dual-Plane Manifold Theory

Remarkably, the well-known and apparently straightforward design of the dual-plane manifold is, arguably, the most functionally-complex manifold to model. An

Dual-Plane Manifold



The Edelbrock Performer Q-Jet represents a typical dual-plane manifold design (of "Standard-Flow" capability). This manifold is said to have a 2nd degree of freedom. A powerful resonance multiplies the force of the pressures waves, simulating the effects of long runners, boosting low- and mid-range power.

intake manifold is considered to have an effective dual-plane configuration when 1) the intake runners can be divided into two groups, so that 2) each group alternately receives induction pulses, and 3) the pulses are spaced at even intervals. If all of these criteria are met, the manifold is said to have a 2^{nd} degree of freedom, allowing it to reach a unique resonance producing oscillations within the entire manifold. During this resonance, pressure readings taken throughout the manifold will be in "sync" with one another. Full-manifold resonance multiplies the force of the pressures waves, simulating the effects of long runners. Since longer runners typically tune at lower engine speeds, the dual-plane manifold is most known for its ability to boost low-end power.

The divided plenum is another common feature of dual-plane manifolds that boosts low-end power. Since each side of the plenum is connected to only one-half of the cylinders (4-cylinders in a V8), each cylinder in the engine is "exposed" to only one-half of the carburetor. This maximizes wave strength and improves low-speed fuel metering (these effects are less pronounced with throttle-body fuel-injection systems). However, the restriction inherent in a divided plenum can reduce peak power at higher speeds.

The main benefits of the dual-plane design are its low-speed torque-boosting capability, compact design, wide availability, and ease of use with both carburetors and injection systems. However, not all engines are capable of utilizing a dual-plane configuration. Typically, engines that do not have an even firing order or have too many cylinders to generate a resonance effect will not benefit from a dual-plane manifold. While there are exceptions, engines having 2 or 4 cylinders work best with this manifold. Since most V8 engines are basically two 4-cylinder engines on a common crankshaft, even-firing V8s benefit from the resonance effects of the dual-plane manifold. DynoSim5 does not prevent the selection of a dual-plane manifold on engines that will not develop a full resonance effect. For example, you can install a dual-plane manifold on a 5-cylinder engine, but the results—a low-end power boost—may not reproducible in the real world, since an effective dual-plane manifold cannot be built for this engine. The *Filling-And-Emptying* simulation is best utilized by modeling dual-plane manifolds combinations that already exist rather than testing theoretical fabrications.

Many dual-plane manifolds are hybrids, incorporating facets of other manifold designs. Especially common is the use of an undivided or open plenum typically associated with single-plane manifolds. These "mixed" designs are attempts at harnessing the best features of both manifolds while eliminating the drawbacks of each. Sometimes the combinations are successful, adding more performance without much sacrifice in low-speed driveability. With these designs, you can successfully use the "trend" method described earlier to estimate engine torque and power. Unfortunately, there is no shortage of manifolds that can reduce power without giving anything back in driveability or fuel economy. In fact, some of the worst designs are remarkably bad. It is impossible to determine which of these combo designs is better than others using DynoSim5 (a future multi-junction version of Dynomation, that models every segment of all intake passages, including the complex effects

Dual-Plane Manifolds

Many dual-plane manifolds are hybrids. This Edelbrock dual-plane manifold is designed for the 440 Chrysler engine and has a partially open plenum. In manifold such as this, the opening adds mid-range and high-speed performance with, typically, a slight sacrifice in low-speed torque. Not all hybrid designs are as successful as this one. In situations where you are not familiar with specific engine or manifold characteristics, it may be worthwhile to stick with "plane-vanilla" designs.

Hybrid Dual-Plane Design

of multi-cylinder interference, will be bale to perform this analysis). Unless you can perform actual dyno testing on these manifolds to determine what works and what doesn't, it may be worthwhile to stick with more "plain-vanilla" designs that produce predictable results.

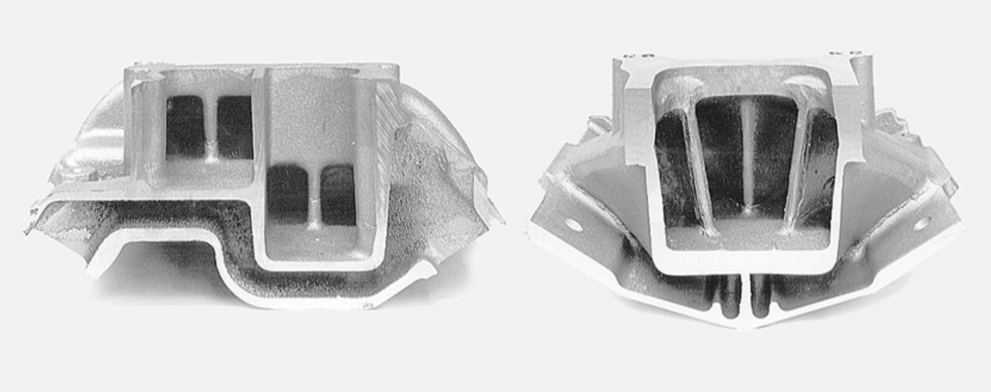
Domestic—Single-Plane (Three Versions: Standard-Flow, High-Flow, and Max-Flow Manifolds)—The ***Single-Plane, Standard-Flow Manifold*** selection represents the majority of single-plane manifolds sold to performance enthusiasts. The *Standard-Flow* selection accurately simulates street and performance engines with "as-cast," single-plane manifolds. The ***Single-Plane High-Flow*** and ***Max-Flow*** manifolds simulate modified, large-port, air-gap, and/or custom-fabricated single-plane manifolds, as used on high-performance and racing engines.

In a very real sense, a single-plane manifold, as used on most V8 engines, is simply a low-profile tunnel ram. The tunnel-ram manifold (discussed next) is a short-runner system combined with a large common plenum; a design that optimizes power on all-out racing engines where engine-compartment clearance is not an issue. The single-plane manifold combines short, nearly equal-length runners with an open plenum, but "lays" the entire configuration flat across the top of the engine.

The single-plane runner design prevents full-manifold resonance (found in dual-plane manifolds). This reduces low-speed torque, and depending on the size of the plenum and runners, single-plane manifolds can also reduce driveability and fuel economy. Furthermore, large-volume, undivided plenums often contribute to low-speed performance problems by presenting every cylinder to all barrels of the carburetor, lowering venturi signal and low-speed fuel metering accuracy (again, this drawback is minimized on fuel-injection systems). On the other hand, the single-plane manifold (like the tunnel ram) combines improved flow capacity, potentially higher charge density, and short runner lengths to build substantially more horsepower at

Single-Plane Manifolds

Dual-Plane vs. Single-Plane Design



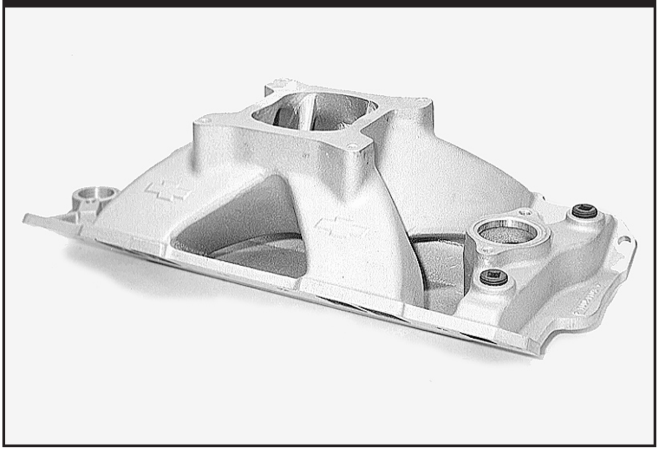
The basic differences between single- and dual-plane manifolds are clearly illustrated here. The dual-plane (left) divides the plenum in half, with the runners grouped by firing order. Each cylinder "sees" only one-half of the carburetor, transferring a strong signal to the venturis. This manifold design is said to have a 2nd degree of freedom, allowing it to reach a unique resonance that makes its short runners act as if they were longer and boosts low-speed power. The single-plane manifold (right) has short, nearly equal-length runners with a large open plenum, much like a tunnel ram laid flat across the top of the engine. The manifold has excellent high-speed performance, but its design prevents full-manifold resonance. That reduces low-speed torque, which can impair driveability and fuel economy.

higher engine speeds.

As a high-performance, high-speed manifold, the single-plane design has many advantages, however, it's compact, low-profile design also has drawbacks. The runners are connected to a common plenum like spokes to the hub of a wheel. This

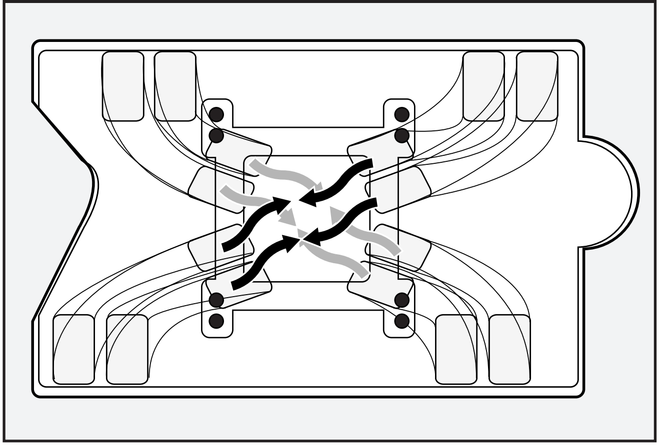
A single-plane manifold is simply a low-profile tunnel ram. The design combines short, nearly equal-length runners with an open plenum, but "lays" the entire configuration flat across the top of the engine. The single-plane manifold combines improved flow capacity, higher charge density, and short runners to build substantial horsepower at higher engine speeds.

Single-Plane Manifold



Single-Plane Manifolds

Single-Plane Pulse Interference



The typically compact, low-profile design of the single-plane manifold has some drawbacks. The runners are connected to a common plenum. This arrangement tends to create unpredictable interference effects as pressure pulses moving through the runners meet in the plenum and stir up a complex brew, sometimes creating irregular fuel-distribution.

arrangement tends to create unpredictable interference effects as pressure pulses moving through the runners meet in the plenum (or travel down the opposite runner) and stir up a complex brew. Large plenum volumes help cancel some these negative effects, but open-plenum, single-plane manifolds may produce unexpected anomalies in fuel distribution and pressure-wave tuning with specific camshafts, headers, or cylinder heads (to some degree, these effects are present in all manifold designs). Locating these will-o'-the-wisp anomalies requires dyno testing and the use of temperature and pressure probes and careful measurement fuel distribution accuracy throughout the rpm range.

Designers and engine testers have experimented with hybrid single-plane manifold designs that incorporate various dual-plane features. One common modification is dividing the plenum of a single-plane manifold into a pseudo dual-plane configuration. While this does increase signal strength at the carburetor, uneven firing pulses presented at each side of the plenum do not allow 2nd degree of freedom resonance. This modification can cause sporadic resonances to occur throughout the rpm range with unpredictable results. Spacers between the carburetor and plenum are also commonly used with single-plane manifolds often with positive results, particularly in racing applications. Spacers typically increase power for two reasons: 1) By increasing plenum volume they tend to reduce unwanted pressure-wave interactions, and 2) a larger plenum improves airflow by reducing the angle at which air/fuel must negotiate a transition from "down" flow through the carburetor to "side" flow into the ports. While there is no way to use trend testing to evaluate the effects of a divided plenum, spacers can be simulated. The increase in plenum volume tends to transform the single-plane manifold into a "mini" tunnel ram, so horsepower gains tend to mimic those obtained by switching to a tunnel ram design (i.e., performance improvements, when found, usually occur at high rpm).

Rule Of Thumb: Since a single-plane manifold typically reduces low-speed torque and improves high-speed horsepower, it is often the best compact manifold design for applications where wide-open-throttle engine speed rarely falls below 4000rpm. If the engine commonly runs through low speeds, a dual-plane, individual runner, sequential-fire injection system, or tuned-port injection system will usually provide better performance, driveability, and fuel economy.

Domestic—Tunnel-Ram (Three Versions: Standard, High-Flow, and Max-Flow Designs)—The ***Standard Tunnel-Ram Manifold*** selection represents a relatively small runner, tunnel-ram manifold with applications in high-performance street (roadster) and mild racing. This selection simulates performance applications with “as-cast,” tunnel-rams with dual- or single-carburetors or throttle bodies.

The ***High- And Max-Flow Custom Tunnel-Ram Manifold*** models simulate extensively-modified, large-port, and/or custom-fabricated tunnel-ram manifolds, as seen on ProStock and other “exotic” racing engines. The advantages of these tunnel rams derive from their combination of a large common plenum and short, straight, large-volume runners. The large plenum can accommodate one or two carburetors, potentially flowing up to 2200cfm or more. The large plenum also minimizes pressure-wave interaction and fuel distribution issues (especially with dual carburetors or fuel-injection throttle bodies). The short runners can be kept cooler than their lay-flat, single- and dual-plane counterparts, and they offer a straight path into the ports, optimizing ram-tuning and minimizing flow restriction.

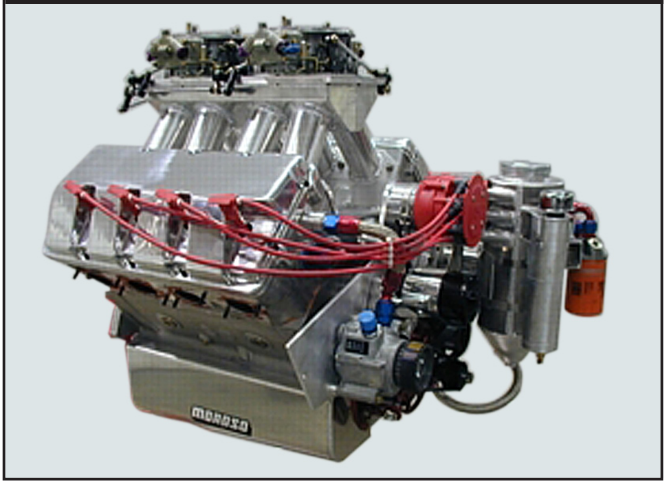
Tunnel-ram applications are limited because of their large physical size; vehicles using tunnel-ram manifolds usually require a hole in the hood and/or a hood scoop to provide manifold and carburetor clearance. While a protruding induction system may be a “sexy” addition to a street rod, in single-carburetor configurations, the tunnel ram offers very little potential power over a well-designed, single-plane manifold. Only at very high engine speeds, with multiple carburetors, will the advantages in the tunnel ram contribute substantially to power.

Tunnel-Ram Manifold

This Weiand/Holley BB Chevy tunnel ram manifold is a single-plane induction system designed to produce optimum power on all-out racing engines. It has a large common plenum and short, straight, large-volume runners. The tunnel ram manifold menu selection has the potential to produce the highest peak horsepower of all the naturally-aspirated manifolds listed in the *Induction* menu.

Tunnel-Ram Manifolds

Custom Fabricated Tunnel-Ram Manifold



This custom-fabricated tunnel-ram manifold (by Jon Kraase Racing Engines) has the potential to produce the highest peak horsepower of all naturally-aspirated induction systems. Combined with the proper cam timing, compression, and other components, the large cross-sectional areas, straight runners, and short tuned lengths make this custom manifold a "no compromise" racing design.

The ***Standard*** and ***Max-Flow Tunnel Ram*** manifold selections have the potential to produce the highest peak horsepower of all naturally-aspirated induction systems listed in the **Manifold Type** menu. The large cross-sectional areas, straight runners, and short tuned lengths make this manifold a "no compromise" racing design.

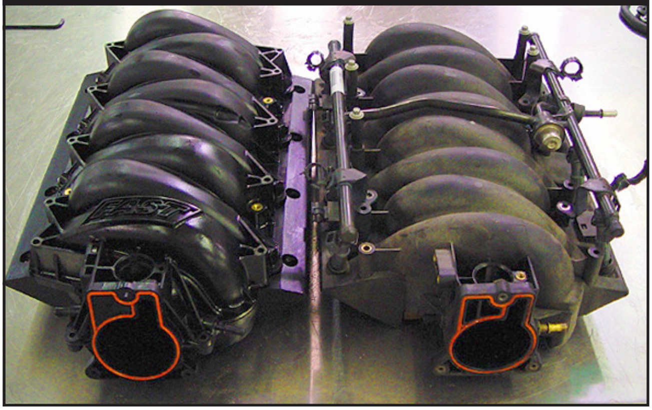
Domestic—LS1/LS6 Stock Composite and LS1/LS6 HP Runner/Mods Manifolds—Since the mid 1980's, engine simulation programs have been regularly used by engine designers and manufacturers to optimize wave dynamics developed inside the intake passages of the IC engine. These pressure waves can have a marked effect on engine performance. When unharnessed, they can produce non-uniform fuel distribution, prevent cylinder filling, and adversely affect driveability. On the other hand, when an induction system has been carefully designed to harness pressure-wave dynamics, the engine can benefit from improved airflow and cylinder filling at the desired engine speeds. Using this technology, manifolds can produce "designer" power and torque curves to optimize overall engine performance within specific rpm ranges and within fuel economy and emissions requirements.

The fully composite manifold developed by GM for their "new" smallblock engine is a good example of this design. It is biased toward producing power at higher rpms, while maintaining good torque throughout the rpm range. Installed in many performance vehicles, like the Z06, 405hp Corvette, the new composite design allows high power while maintaining good driveability and low emissions. This manifold can be modeled in DynoSim5 by selecting the ***LS1/LS6 Composite Stock*** from the Domestic selections provided in the **Manifold Type** menu. Despite the fact that this manifold packs its runners in a small package designed to fit under the low-profile hoods of modern vehicles, generous flow capacities produces good peak power.

Aftermarket companies have taken this concept a bit further to provide more performance for the automotive enthusiast. High-performance versions of this manifold

LS1-LS6 Manifolds

LS1/LS6 Composite FAST HP vs Stock Manifold



Composite intake manifolds have become standard equipment on many modern IC engines. They allow designs that could not be easily replicated in aluminum, and some offer unique performance opportunities. The stock GM LS1/LS6/Z06 induction, shown on the right, and the *FAST* version illustrates how changes in runner length and volume can improve power in HP applications.

have been shown to add from 3% to 12% more power with very little sacrifice in bottom-end torque. You can test a performance design with the ***LS1/LS6 HP Runner/Mod*** induction selection in DynoSim5. This induction model was based on the *FAST*™ manifold for the same engine.

Domestic—Tuned-Port Injection—This manifold design was introduced by automakers in the mid 1980's. It represents the first mass-produced induction system that clearly incorporates modern wave-dynamic principals. To optimize low-speed torque and fuel efficiency, the TPI manifold has very long runners (some configurations measure up to 24-inches from valve head to airbox). The runners on most TPI systems are also quite small in diameter—again, to optimize low-speed power—and, unfortunately, create considerable restriction at higher engine speeds. Characteristic power curves from this type of manifold are slightly to significantly above a dual-plane up to about 5000rpm, then runner restriction and an out-of-tune condition substantially lowers peak power.

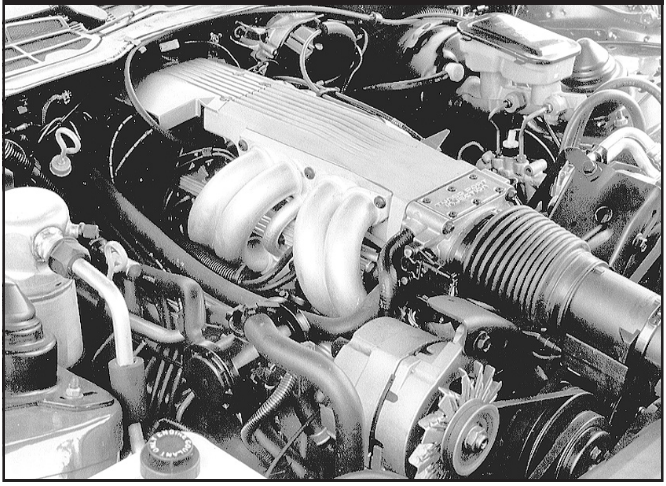
The TPI, included in DynoSim5 primarily as a comparison tool, is a "single-plane" design that functions like a long-runner tunnel ram. Each runner is completely isolated until it reaches the central plenum. This design tends to maximize pressure-wave tuning and minimize wave interactions. Since fuel is injected near the valve, the TPI system delivers precise air/fuel ratios with no fuel distribution or puddling problems.

The ***Tuned-Port Injection*** selection models a stock TPI. However, a wide range of aftermarket parts have been developed for the TPI system, including enlarged and/or Siamesed runners, improved manifold bases, high-flow throttle bodies, and sensor/electronic modifications. If you wish to model these higher flow systems, consider the ***Standard-Flow Single-Plane*** choice for small-runner systems or the ***High-Flow Single-Plane*** model for large-runner packages.

Sport-Compact Manifold Selections

Sport-Compact Manifold Models

Tuned-Port Injection Manifold



The TPI manifold was introduced by automakers in the mid 1980's. It represents the first mass-produced induction system that clearly incorporated modern wave-dynamic principals.

The following sections provide an overview of each of the 14 *Sport-Compact* manifold models in the **INDUCTION** category. Here you'll find a brief description of the assumptions used in each model, and recommendations associated with that individual design.

Note: Sport Compact induction selections are shown below in **Green**; Domestic induction systems are described in preceding paragraphs titled in **Red**.

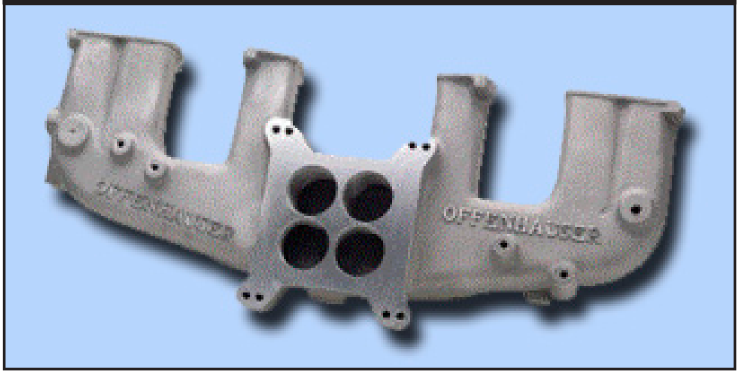
Sport-Compact—Non-Tuned Manifolds (Three Versions: Restrictive, Ported, Mods)—The ***Non-Tuned, Small Runner, Restrictive*** selection in the **Manifold Type** menu models an intake manifold with small-diameter runners that connect to a central plenum with little consideration for equal length or tuning characteristics, such as those designed for low-performance economy vehicles or other "basic" engine configurations. In naturally-aspirated applications, this manifold produces the least power and offers the least boost in torque from runner tuning.

The ***Non-Tuned, Small Runner, Ported Manifold*** selection provides a slight improvement in airflow that improves power at higher engine speeds. But the same non-tuned runners provide little pressure-wave tuning and low-speed torque boost.

The ***Non-Tuned, Larger Runner, Ported, Mods*** model represents an attempt to improve this simple manifold design as much as possible. By porting the runners, modifying the plenum, and even modifying and welding the runner passages, this is about as much as you can expect to improve this non-tuned intake manifold design. Even with this extensive work, however, this design simply cannot match the torque potential of a stock, OEM, tuned induction system. Primarily, this induction model has been included in DynoSim5 for comparison purposes, since such basic

Sport-Compact Manifold Models

Non-Tuned Manifold



The *Non-Tuned Manifold* selections model intake manifolds with small-diameter runners that connect to a central plenum with little consideration for equal length or tuning characteristics.

manifolds are rarely modified to this degree.

Sport-Compact—Long Tubing Runners, Common-Plenum Manifolds (Three Versions: Basic, HP, & MaxFlow) —The ***Long-Tubing Runners, Common-Plenum, Basic OEM Manifold*** models the induction system typically used on a flat-four and flat-six engines, like the original VW “Beetle” and lower-performance Porsches. The runner lengths and their relatively small diameters tune for good lower-speed torque, but offer restriction at higher engine speeds. These manifolds are particularly restrictive when used on larger displacement engines (such as those with larger cylinder liners or stroker cranks).

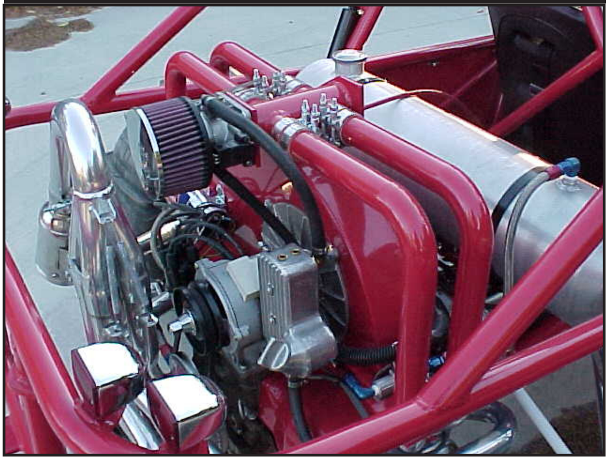
The ***Long-Tubing Runners, Common-Plenum, HP Manifold*** selection introduces a considerably different *Filling-And-Emptying* induction model. The larger diameter runners offer much less restriction at high engine speeds, but the increased volume dampens low-rpm tuning, often reducing bottom-end torque on all but large-displacement engines. This model closely simulates many naturally-aspirated Porsche 911 induction systems.

Finally, the ***Long-Tubing Runners, Common-Plenum, Max-Flow Manifold*** represents manifold designs used on very high-performance engines or in racing applications. The large runner cross-sectional area ensures cylinder filling at high engine speeds, however, the increased runner and plenum volume further reduces torque at low rpm.

Sport-Compact—Tuned Runner (Four Versions: Short-And-Long Runners, Large-And-Small Plenum)—All of the manifolds in this **Manifold Type** group model OEM (usually cast aluminum) induction systems. The longest runners produce copious torque at low to medium speeds, while the shortest runner manifolds are commonly used on high-performance, higher-rpm engines.

Sport-Compact Manifold Models

Long Tubing Runners With Common Plenum



The *Long-Tubing Basic OEM* manifold selection models induction systems often used on a flat-four and flat-six engines, like the VW and lower-performance opposed-six Porsche powerplants. The length of the runners and their relatively small diameters optimize torque output, but restrict airflow at higher engine speeds.

The ***Tuned, Long-Runner, Max-Torque, Small Plenum*** manifold is ideal for engines in heaver vehicles, like trucks and vans. The low-rpm tuning boosts efficiency, economy, and driveability in stock vehicles. However, while the runners are somewhat long, they are not overly restrictive and stock engines using this manifold will produce good horsepower.

The next selection (upwards within the group) is the ***Tuned, Long-Runner, Small Plenum*** manifold. The slightly shorter runners are capable of producing more horsepower, but torque below 3500rpm can suffer somewhat. This is still an excellent manifold for heavier performance vehicles.

The ***Tuned, Medium-Length Runner, Larger Plenum*** manifold is the first manifold in this group to offer a bias toward performance and higher engine speed. Manifolds

"Tubing," Max-Flow Manifold

The *Long-Tubing Runners, Common-Plenum, Max-Flow* selection models manifold designs used on high-performance engines or in racing applications, like this Porsche 928 V8. The large runner cross-sectional areas ensure cylinder filling at high engine speeds, however, the additional runner and plenum volume can reduce torque at low rpm, offset somewhat, in this case, by the length of the runners.

of this type are commonly found on 4, V6, V8, and V12 engines in performance sedans and sports cars.

The most performance oriented manifold, the ***Tuned, Short-Runner, Max-Flow, Large Plenum*** is an excellent choice on lightweight, performance vehicles. The tuned runners offer good pressure-wave tuning, while low restriction and large plenum volume give excellent horsepower potential. This manifold design is used on many performance-oriented sports cars, like Aston Martin, Maseratti, and Ferrari. The only manifolds that are superior in performance to this selection are the "***Honda Type***" listed in the next group that have the largest runner and plenum volumes. However, even "Honda" manifolds may not provide as broad a range of torque and power as the manifolds in this group.

Sport-Compact—Honda Type (Four Versions: Standard And Short Runner, Small And Large Plenum Designs)—While the manifolds in this group are designed to model the Honda induction systems used on 4-cylinder, high-performance engines, like the B16, B18, S2000 and others, this manifold model can be applied to any engine that uses straight, high-volume runners and a large-volume plenum. The power potential from this manifold model is similar to "all-out" induction systems, such as tunnel-ram manifolds used on racing engines.

Honda-Type, Large Plenum, Long And Short Runners

The Honda-Type manifold selections in DynoSim5 are designed to model the Honda induction systems used on 4-cylinder, high-performance engines, like the B16, B18, S2000 and others. This manifold model can be applied to any engine that uses direct, high-volume runners and a large plenum. The stock-length runner designs (like the Edelbrock Performer X, shown on the left) generate a characteristic broad and flat torque curve, and its large runners and plenum volume will supply all but the largest engines with adequate airflow to well beyond 7500rpm. Manifolds with shorter runners will often lower torque below 4000- 5000-rpm and offer slight-to-significant power gains above 7000- to 8000rpm.

Sport-Compact Manifold Models

The ***Honda Type, Standard-Length Runner, Factory*** *(Plenum)* ***Volume*** selection models the stock Honda manifold supplied on many of its B16A high-performance engines, like the Del Sol, Civic Si, the Integra GSR, and others. This induction system generates a characteristic broad and flat torque curve (with 4-valve heads), and its large runners and plenum volume will supply all but the largest engines with adequate airflow to well beyond 7500rpm. For many high-performance street vehicles, this is an excellent manifold with the only weak point being somewhat lower torque, usually below 3500- to 4000rpm, compared to the longer-runner manifolds in the previous group. But above these engine speeds, the *OEM Honda-Type* induction system with medium-length runners is virtually unbeatable.

The next “stage” in *Honda-Type* manifold designs is the shorter-runner version of the stock B16A intake, the ***Honda Type, Short Runner, Factory*** *(Plenum)* ***Volume***. These manifolds, supplied on the Type R (originally on the 1.8L, B18C5 engine) and available in many forms from aftermarket manufacturers, will often produce a slight reduction in torque below 4000- to 5000-rpm and offer a slight-to-significant gain in power above 7000- to 8000rpm. This is not the best manifold for a small-displacement street-stock engine, but for a modified or “stroker” engine it can offer more power with little or no loss in torque.

The third selection (working towards the top within this group), is the ***Honda Type, Standard-Length Runner, Large*** *(Plenum)* ***Volume*** manifold model. This choice simulates a manifold (only available from the aftermarket, such as the *Edelbrock Performer X* manifold) that has increased cross-sectional area runners of about factory length combined with a large-volume plenum. This manifold will show power gains above max-torque engine speeds, while the standard-length runners will usually maintain good torque at lower speeds. This may be the best manifold for a modified engine that will be operated on the street.

Finally, the ***Honda Type, Short Runner, Large*** *(Plenum)* ***Volume*** manifold model simulates many of the exotic induction systems used on racing all-motor and forced induction applications. This induction has the largest volume runners and plenum, and will reduce low-speed torque below about 5000rpm. However expect substantial gains on highly-modified engines, especially above 8000rpm.

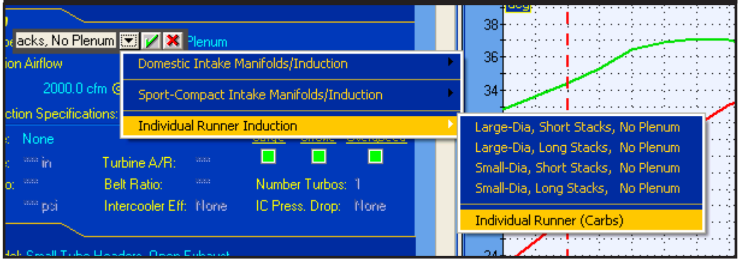
Individual-Runner Induction Selections

Individual Runner, No Plenum (Large And Small Diameter, Long And Short Stacks)—For naturally-aspirated, professional racing applications, individual- (or isolated) runner (I.R.) induction systems, with separate tubes containing their own throttle plates for each cylinder, can offer the ultimate in power potential at high engine speeds. The single element that sets the I.R. system apart from any other induction models is that each “barrel” or individual “stack” *does not share flow with other stacks through interconnecting passages* (like a plenum). This characteristic

Individual-Runner Modeling

Individual- (or isolated) runner (I.R.) induction systems, with separate tubes containing their own throttle plates for each cylinder, can offer the ultimate in power at high engine speeds.

Individual-Runner Induction Selections



means that the overall induction flow (as entered in the **INDUCTION** category, explained on page 71) is divided between all barrels (or cylinders).

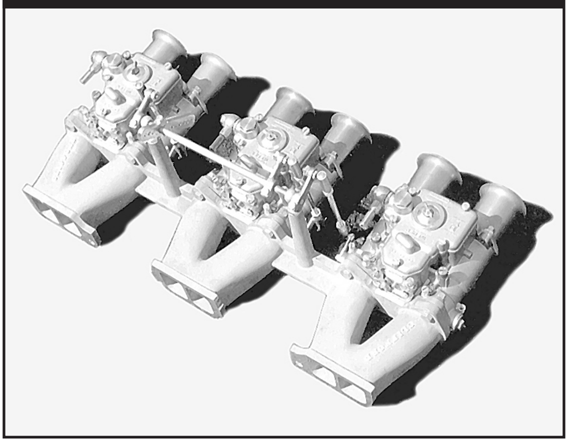
All of the manifolds in the **Manifold Type** submenus that we have discussed up to this point have shared-flow between cylinders, typically through a plenum. And the induction flow (***Flow Rate***) in the **INDUCTION** category specifies the maximum airflow that passes through the restriction common to all cylinders: the throttle body. On an I.R. system, however, the ***Flow Rate*** is the total airflow through all of the individual stacks. So, for example, if each I.R. stack has a rated flow of 400cfm, the induction ***Flow Rate*** needed to accurately simulate a 4-cylinder engine with four stacks would be 1600cfm (400cfm x 4-cylinders).

Note-1: An **Important!** message box will appear whenever any of the I.R. induction systems have been selected from the **Manifold Type** menu in DynoSim5. This message box will remind you that the induction ***Flow Rate*** must be entered as the sum of the individual flow values for each stack. If you mistakenly retain the flow that may have been used for a single throttle body, DynoSim5 will substantially under-predict power or it may not be able to complete the simulation calculations (due to instabilities generated from restricted induction flow).

Note-2: I.R. systems can only perform properly when each stack flows a suf-

A manifold that connects each cylinder to a single carburetor barrel *with no interconnecting passages that share flow* is considered an individual (or isolated) runner system (IR for short). Multiple Weber or Mikuni carburetor systems are well-known examples of this type of induction system. This IR manifold was designed for early OHC Pontiacs.

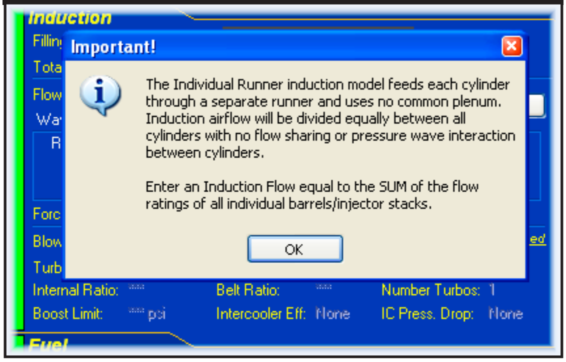
Individual Runner Manifold



Individual-Runner Modeling

An *Important!* message box will appear whenever any of the I.R. induction systems have been selected. This message box reminds you that the induction *Flow Rate* must be entered as the sum of the individual flow values for each stack. If you mistakenly retain an airflow that may have been used for a plenum manifold, DynoSim5 will substantially <u>under-predict</u> power (or it may not be able to complete the simulation).

Individual-Runner Flow Alert



ficiently large volume of air. When the ***Flow Rate***, specified in the **INDUCTION** category (the total flow through all stacks) is substantially greater than the flow rate through a typical single throttle body manifold (plenum), the engine can produce high top-speed power. To reach the full potential of the I.R. system, the total ***Flow Rate*** should be <u>*at least twice*</u> the flow rating of a high-performance throttle body (carburetor, injector throttle) that would feed <u>all cylinders</u> in a common-plenum induction.

The first manifold (located at the bottom of the I.R. group) is the ***Small Diameter, Long Stacks, No Plenum*** model. This selection produces a power curve similar to the *Honda Type, Standard Runner, Factory Volume* manifold discussed in the previous section. However, the improved flow potential over the factory manifold (see **Note-2**, above) at higher engine speeds offers improved power that will peak at a slightly higher rpm.

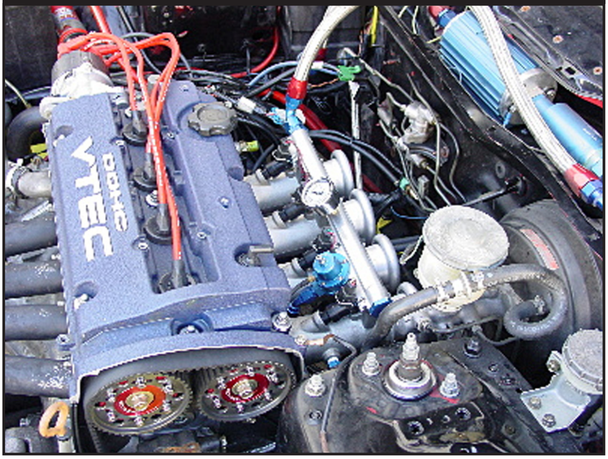
The ***Small Diameter, Short Stacks, No Plenum*** manifold is the shorter-runner version of the previous I.R. selection. It produces a power curve similar to the *Honda Type, Short Runner, Factory Volume* manifold discussed in the previous section. The improved flow potential (see **Note-2**, above) at higher engine speeds offers improved power that will peak at a slightly higher rpm. Expect this I.R. induction to produce good power levels beyond 8000rpm on a properly modified race engine.

The ***Large Diameter, Long Stacks, No Plenum*** selection produces a horsepower curve similar to the *Honda Type, Standard Runner, Large Volume* manifold. The improved flow potential (see **Note-2**, above) at higher engine speeds offers improved power that will peak at a higher rpm. Expect this I.R. induction to produce good power beyond 8000rpm on a properly modified race engine.

Finally, the ***Large Diameter, Short Stacks, No Plenum*** produces a horsepower curve similar to the *Honda Type, Short Runner, Large Volume* manifold. The improved flow potential (see **Note-2**, above) at higher engine speeds offers improved

Individual-Runner Modeling

Honda VTEC IR Induction



For naturally-aspirated, professional racing applications, individual- (or isolated) runner (I.R.) induction systems, with separate tubes containing their own throttle plates for each cylinder, offer the ultimate in flow potential and peak power at high engine speeds.

power that will peak at a higher rpm. Expect this I.R. induction to produce excellent power beyond 9000rpm on a properly modified race engine.

Individual Runner Manifold For Carburetors—Like the previous I.R. induction systems, individual- (or isolated) runners connect each cylinder to one "barrel" of a carburetor and *they do not share flow with other cylinders/barrels through interconnecting passages.* A multiple Weber or Mikuni carburetor system is a well-known example of this type of induction; once commonplace in drag racing, these systems are now limited to specific classes, such as methanol and fuel-burning, naturally-aspirated engine competition.

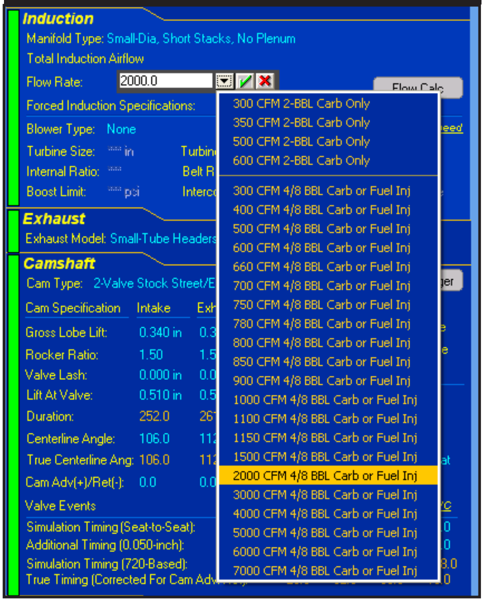
The one-barrel-per-cylinder carbureted I.R. arrangement can have horsepower limitations due to airflow restriction! A typical Weber 48IDA carburetor flows about 330cfm per barrel. While the sum total of all four barrels (on a 4-cylinder engine) is over 1200cfm, the important difference is that each cylinder can draw from only one 330cfm barrel. In a common-plenum manifold, each cylinder has access to the total flow potential of the entire throttle body, typically twice the flow of a single Weber venturi!

While I.R. induction can restrict peak flow, at low-speed the same one-barrel-per-cylinder arrangement transmits strong pressure waves to each carburetor barrel, producing ideal conditions for accurate fuel metering. Furthermore, the pressure waves moving in the runners are not dissipated within a plenum and don't interact with other cylinders. This allows the reflected waves to assist cylinder filling and, with optimum cam timing, reduce reversion. The combination of these effects makes individual-runner induction an outstanding induction choice for carbureted, low- to medium-speed engine applications.

The simulation model for ***Individual Runner (Carbs)*** is a slightly restrictive version of the *Small Diameter, Long Stacks, No Plenum* induction selection (discussed in the previous section).

Induction Airflow Modeling

Induction Airflow Menu



The Induction Airflow menu selects the flow rate and pressure drop through the induction system. It also establishes the airflow restriction for induction modeling. For the purposes of the simulation, everything upstream of the intake ports, including the intake manifold, carburetor/fuel-injection system, venturis, any supercharger or turbocharger, and the openings to the atmosphere is considered the induction system. The Airflow menu consists of four 2-barrel-carburetor selections (at 3.0-in/Hg) and thirteen 4-barrel-carburetor/fuel-injection choices (at 1.5-in/Hg). In addition, you can directly specify any rated airflow from 100 to 7000cfm.

Airflow Selection And Pressure Drop

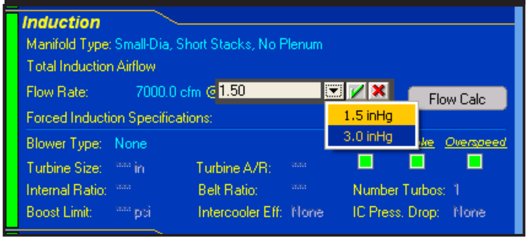
The first two **INDUCTION** menus select the rated airflow for the induction system and the pressure drop at which it's measured. The ***Induction Flow*** menu consists of four 2-barrel-carburetor selections and thirteen 4-barrel-carburetor/fuel-injection choices. In addition, you can directly specify any rated airflow from 100 to 4000cfm.

Note: The flow ratings for 2-barrel carburetors are measured at a pressure drop twice as high as the pressure used to rate 4-barrel carburetors and most fuel-injection systems. The higher pressure drop increases the measurement resolution for smaller carburetors and "shifts" the flow numbers toward the range commonly found in automotive applications (roughly, 100 to 700cfm). Rated airflow for 2-barrels is typically measured at a pressure drop of 3 inches of mercury (3.0-in/Hg), while the pressure drop for 4-barrel carburetors is 1.5-inches of mercury (1.5-in/Hg). This pressure drop is the pressure differential maintained across the carburetor during airflow measurement at wide-open throttle. The pressure drop is displayed as **3-in/Hg** or **1.5-in/Hg** in the **Pressure Drop** menu (**Hg** is the symbol for mercury as used in the Periodic Table). See the **Airflow Math Calculator** (next page 73) for quick conversions between any airflow measured at any pressure drop.

The two-barrel **Induction Flow** menu selections "install" a 300-, 350-, 500-, or 600-cfm 2-bbl carburetor on the test engine (at 3.0-in/Hg). These are the only 2-barrel selections directly available in the menu, however, you can manually enter

Induction Airflow Modeling

Induction Pressure-Drop Menu



Use the Induction Airflow Pressure Drop menu to select between 1.5-inches of mercury (1.5-in/Hg), a measurement standard for 4-barrel carburetors and injection systems, and the two-barrel carburetor standard of 3.0-inches of mercury (3.0-in/Hg).

any cfm flow rate (from 100 to 4000cfm). The last thirteen choices in the **Induction Flow** menu are labeled **4/8-Bbl Carb Or Fuel Inj**. These airflow selections set a pressure drop at 1.5-in/Hg. **4/8-BBL** indicates that the induction system can consist of single or multiple carburetors or a fuel-injection system capable of the rated airflow. Again, in addition to the menu selections, you can manually enter any cfm flow rate from 100 to 4000cfm.

Note: The important thing to remember about airflow selection is that DynoSim5 *makes no assumption about the type of restriction* used in the induction system. The airflow is simply a measure of the restriction of the entire induction system.

Airflow Menu Assumptions

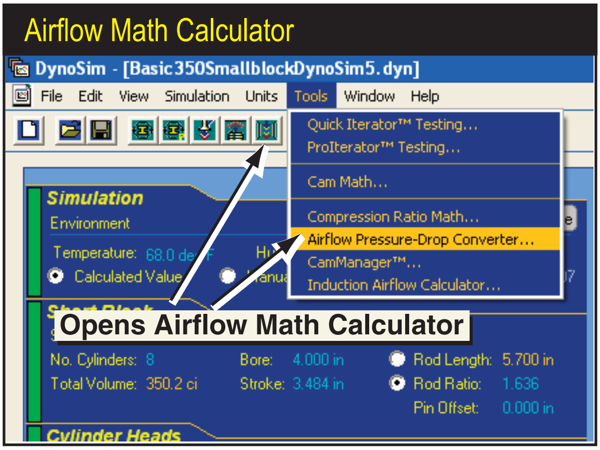
As higher airflow levels are selected from the **Induction Flow** menu, the simulation lowers the restriction within the induction system. This decrease in restriction increases charge density within the cylinders. To keep things consistent, DynoSim5 assumes that *the air/fuel ratio is always at the precise proportion for optimum power*. While optimum air/fuel ratios are more achievable with fuel-injection systems, a carefully tuned carburetor also can come remarkably close to ideal fuel metering. Regardless of whether the simulated engine uses carburetors or fuel injection, the power levels predicted by the simulation can be considered optimum, achievable when the engine is in “peak” tune and the induction system is working properly.

The airflow selected from the **Induction Flow** menu is the *total rated airflow into the engine*. On dual-inlet or multiple-carburetor systems, the Induction Airflow is the sum of all rated airflow devices. So a manifold equipped with twin 1100cfm Holley Dominators would have a rated airflow of 2200cfm. If an air cleaner is used, total airflow must be adjusted to compensate for the increase in restriction (contact the element manufacturer or flow test the carburetor/air-cleaner as an assembly).

Note About IR Manifolds: Keep in mind the unique way airflow capacities are handled on Individual Runner (IR) manifolds (additional details on page 67). On these induction systems, each cylinder is connected to a single “barrel” or injector stack with no connecting passages that allow the cylinders to “share” airflow from other barrels. The total rated flow for these induction systems is divided among the number of cylinders. For example, a smallblock V8 equipped with 4 Weber carburetors (having 8 barrels) may have a total rated flow of 2000cfm. To properly

Induction Airflow Modeling

The Airflow Math Calculator is a general-purpose tool that will convert airflow to/from any pressure-drop standard. Activate the Airflow Math Calculator by either selecting *Airflow Math* from the Tools menu or by clicking on the *Airflow Math Calculator Icon* in the Toolbar.



model this system, enter 2000cfm directly into the Induction Airflow field. When an **IR** manifold is selected from the **Manifold Type** menu, the airflow is equally divided into all cylinders (i.e., 250cfm per cylinder).

THE AIRFLOW MATH CALCULATOR

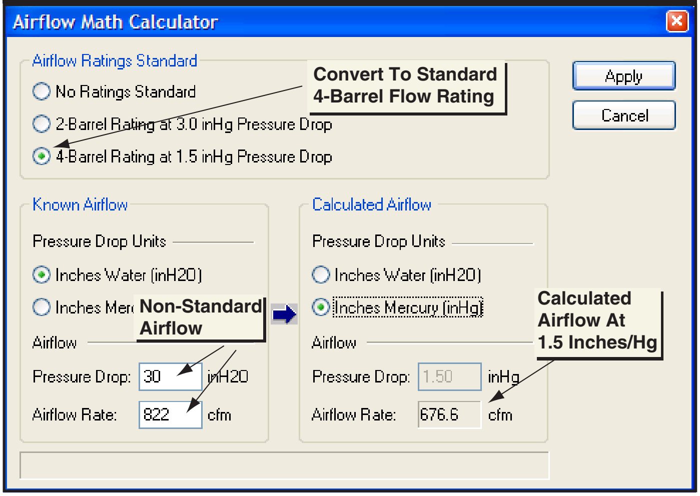
As discussed previously, DynoSim5 will accept induction airflow (cfm) measured at a pressure drop of either 1.5-In/Hg or 3.0-In/Hg. For those instances where an induction system, injector, or carburetor was flow tested at a different pressure drop, or whenever you would like to convert flow values from one pressure-drop rating to another, the **Airflow Math Calculator** easily performs these conversion functions. The **Airflow Math Calculator** can also convert flow ratings measured in inches-of-mercury (in/Hg) to and from airflow values rated in inches-of-water (in/H_2O). **Note:** A pressure drop of 1.5-in/Hg is equivalent to 20.3-in/H_2O.

The **Airflow Math Calculator** has three basic modes of operation: 1) Convert to the 4-Barrel Standard, 2) convert to the 2-Barrel Standard, and 3) calculate airflow between any two pressure drop ratings. Each of these methods are described below. Activate the **Airflow Math Calculator** by either selecting ***Airflow Math*** from the **Tools** drop-down menu or click on the **Airflow Icon** located in the **Toolbar**.

Using The Airflow Math Calculator
Mode 1: Convert Any Flow To 1.5-in/Hg, The 4-Barrel Standard.

When the calculator is first activated, the 1.5-in/Hg ***Airflow Ratings Standard*** "radio button" is selected. The ***Calculated Airflow*** category also defaults to a pressure drop of 1.5-in/Hg or 20.3-in/H_2O (these pressure drops are identical). To convert any known airflow measured at any pressure drop to the 1.5-in/Hg, 4-barrel standard, enter the measured airflow and pressure drop in the ***Known Airflow*** category (if needed, you can switch between Inches-of-Mercury(Hg) and Inches-of-Water (H_2O)

Airflow Math Calculator—Convert To 4-bbl Standard



When the calculator is first activated, the *Airflow Ratings Standard* is set to *1.5-in/Hg* (20.3-in/H_2O). To convert any known airflow to this flow (the standard for 4-barrel carburetors), enter the known airflow and pressure drop in the *Known Airflow* category. The calculated airflow will be displayed in the *Calculated Airflow* category.

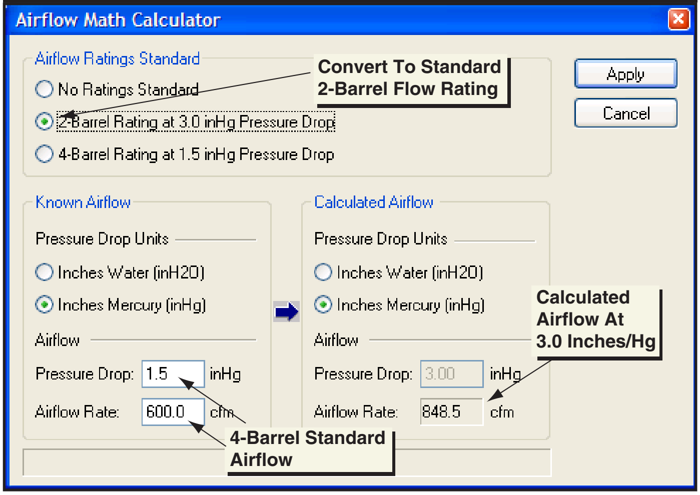
buy clicking on the appropriate radio buttons in the ***Known Airflow*** and ***Calculated Airflow*** categories). The converted airflow will be displayed in the ***Airflow Rate*** field (see photo, above). You can move to any of the previous fields (by clicking on them or using the Tab or SHIFT-Tab keys) to make changes and explore their effects on calculated airflow. At any time, you can click the ***Apply*** button to load the new calculated airflow into the **Induction Flow** field on the Component Selection screen, saving all entered values. Alternately, you can press **Cancel** to discard all entries and keep any previously entered flow values.

Using The Airflow Math Calculator
Mode 2: Convert Any Flow To 3.0-in/Hg, The 2-Barrel Standard.

Switch the ***Airflow Ratings Standard*** category selection to the radio button marked ***2-Barrel Rating of 3.0-in/Hg Pressure Drop***. This changes the “result,” or ***Calculated Airflow*** category to 3.0-in/Hg (40.7-in/H_2O). To convert any known airflow measured at any pressure drop to the 3.0-in/Hg, 2-barrel standard, enter the measured airflow and pressure drop in the ***Known Airflow*** category (you can switch between Inches-of-Hg and Inches-of-H_2O buy clicking on the appropriate radio buttons in the ***Known Airflow*** and ***Calculated Airflow*** categories). The calculated airflow at 3.0-in/Hg pressure drop will be displayed in the ***Airflow Rate*** field (see photo, next page). You can move to any of the previous fields (by clicking on them or using the Tab or SHIFT-Tab keys) make changes and explore their effects on calculated airflow. At any time, you can click **Apply** to load the new, calculated airflow into the **Induction Flow** field on the Component Selection screen, saving all entered values. Alternately, you can press **Cancel** to discard all entries and keep any previously entered values.

Induction Airflow Modeling

Airflow Math Calculator—Convert To 2-Bbl Standard



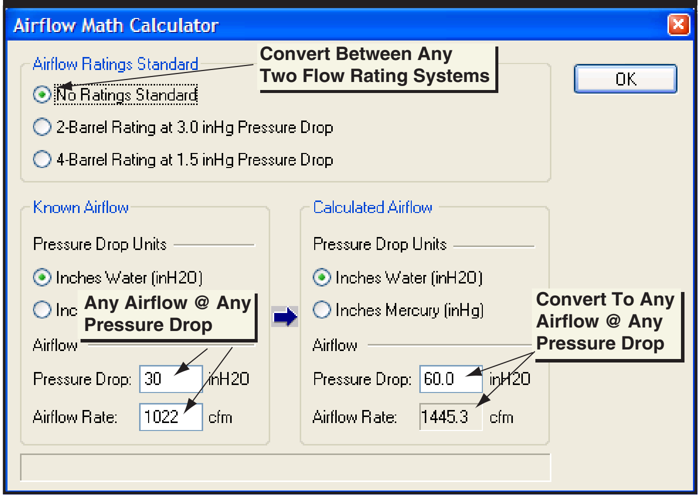
Switch the *Airflow Ratings Standard* to *3.0-in/Hg*. This the default pressure drop of 3.0-in/Hg (40.7-in/H_2O), a pressure drop commonly used for rating 2-barrel carburetors. Enter the measured airflow and pressure drop in the *Known Airflow* category. The new calculated airflow is displayed in the *Airflow Rate* field.

Using The Airflow Math Calculator
Mode 3: Convert Any Airflow To Equivalent Flow At Any Pressure-Drop.

Note: Since DynoSim5 **Induction Flow** field only accepts induction airflow rated at either 1.5- or 3.0-in/Hg (20.3- or 40.7-in/H_2O), the **Apply** button is not shown when the ***No Ratings Standard*** is selected. If you wish to use the new calculated values in a dyno test, select either the ***4-Barrel Rating at 1.5-in/Hg Pressure Drop*** or ***2-Barrel Rating at 3.0-in/Hg Pressure Drop*** choices in the ***Airflow Ratings Standard*** category.

Switch the ***Airflow Ratings Standard*** category selection to the radio button

Convert To/From Any Pressure Drop



Switch the *Airflow Ratings Standard* to *No Ratings Standard*. The *Calculated Airflow* can now be set to any pressure drop measured in Inches of Hg or H_2O. Select the desired *Pressure Drop Units* and enter the known airflow and pressure drop. Enter the desired pressure drop in the *Calculated Airflow* category. The equivalent airflow will be displayed in the *Airflow Rate* field.

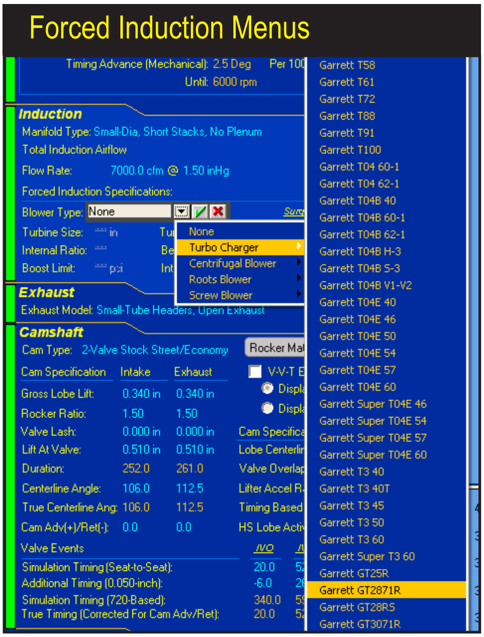
marked ***No Ratings Standard***. This allows the ***Calculated Airflow*** to be set to any pressure drop measured in Inches of Hg or Inches of H_2O. Enter the known airflow and pressure drop in the ***Known Airflow*** category. Then enter the desired pressure drop in the ***Calculated Flow*** category. The calculated equivalent airflow will be displayed in the ***Airflow Rate*** field (see photo, previous page). You can move to any of the previous fields (by clicking on them or using the Tab or SHIFT-Tab keys) to make changes and examine their effects on calculated airflow.

FORCED-INDUCTION MENUS
(Forced Induction Is A DynoSim5 Exclusive Feature)

The ***Forced Induction Selections*** included in the **INDUCTION** category (DynoSim5 only) considerably expands the modeling power of DynoSim5. In an instant you can add a positive displacement Roots- or Screw-type blower, a centrifugal blower (like a Paxton or Vortech), or a turbocharger to any engine. In addition, you can vary maximum boost—or blow-off (wastegate) pressure—***Belt Ratios***, ***Turbine Size***, ***Turbine A/R*** ratio, and more. And finally, you can test the effects of an intercooler on any of the forced-induction systems.

Note-1: When you apply any of the forced-induction systems, keep in mind that you are adding forced induction to the intake manifold selected in the ***Intake Manifold Design*** menu.

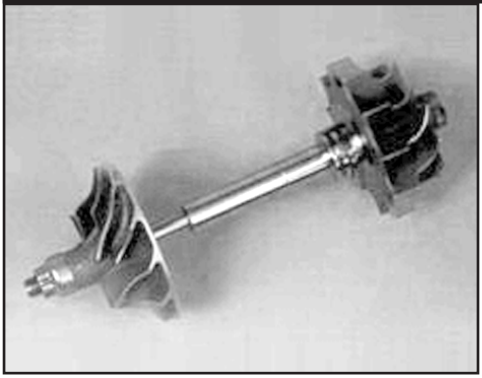
Note-2: Adding forced induction to the *Individual-Runner* selections, while theoretically possible, more or less converts the IR system to a common plenum



DynoSim5 includes over 100 forced induction choices (Turbos, shown here, Centrifugal, Roots and Screw blowers can all be modeled). Selecting a supercharger from any of the four submenus will load the modeling map data for that device into the INDUCTION category.

Forced Induction Modeling

Turbine & Compressor Impellers



The turbine (shown on the right) is placed in the exhaust stream of an engine and is driven by a combination of exhaust flow and exhaust pressure waves. Two parameters in DynoSim5 adjust the performance of the turbine: the *Turbine Wheel Size* and the *Turbine Housing A/R* ratio. Modifying the turbine wheel size will make large changes in the turbine speed; the smaller the wheel, the faster the turbine will rotate. The higher the turbine speed, the more airflow will be driven through the compressor (until the compressor blade tips reach supersonic speed).

configuration by the plumbing interconnections required to route airflow to each stack.

To select any of the forced-induction options, double click the **Blower Type** field to open a menu containing ***Turbocharger***, ***Centrifugal***, ***Roots***, and ***Screw*** blower choices. After a selection has been made from any of the nearly 100 forced-induction devices, specific fields will become active depending on the type of supercharger that was selected. You may modify these values at any time to determine their effect on engine power.

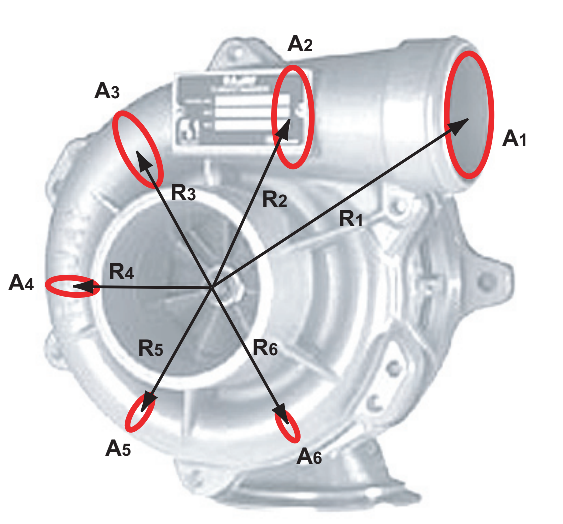
Here is a quick overview of these fields, the superchargers to which they apply, and how they affect forced-induction performance:

Turbine Size—(Turbos only) This is the diameter of the exhaust-driven impeller. The turbine is placed in the exhaust stream of an engine and is driven by a combination of exhaust flow and exhaust pressure waves. Two parameters adjust the performance of the turbine: the ***Turbine Wheel Size*** and the ***Turbine Housing A/R*** ratio (discussed next). Modifying the turbine wheel size will make relatively large changes in the turbine speed; the smaller the wheel, the faster the turbine (and the compressor) will rotate. The higher the turbine speed, the more airflow will be driven through the compressor. Smaller turbines generate boost earlier in the rpm range, however, if the turbine is too small for the application, the turbocharger shaft speed can exceed the manufacturer's recommendations (this is an ***Overspeed*** condition; see page 81).

Turbine Housing A/R Ratio—(Turbos only) This is a ratio of the cross-sectional area of the turbine housing inlet to the radius measured from the center of the turbine wheel (see photo). Unlike the *Turbine Size*, that has a dramatic affect on turbine speed, the **Turbine Housing A/R** ratio fine-tunes turbine speed. Changing *A/R* has many effects. By using a larger *Turbine Housing A/R*, the turbo produces less boost at lower engine speeds but develops more boost at a higher engine

Forced Induction Modeling

A/R Turbine-Housing Ratio



The Housing A/R ratio is a comparison of the cross-sectional area of the housing inlet passage to the radius, measured from the center of the inlet passage to the rotating wheel. Unlike the *Turbine Size* (that has a dramatic affect on turbine speed), the *Turbine Housing A/R* ratio fine-tunes turbine speed and helps establish where—in the engine rpm range—the turbo begins to produce induction pressure (boost).

speeds. The larger turbine housing increases exhaust flow capacity, reducing engine backpressure. Lower engine backpressure usually improves engine volumetric efficiency (VE) and can result in an overall power increase.

Number Of Turbos—(Turbos only) This selection divides the exhaust flow equally between all turbos (up to four turbos in parallel can be modeled). Compressed outflow from all turbos is directed into the induction system of the engine (through an intercooler, if selected). Multiple turbo applications are most successful when

Boost Limiter (Wastegate)

Boost Limit **is an arbitrary maximum induction pressure established by the wastegate setting. It is not a measure of the capability of the supercharger, i.e., the blower may not be able to develop sufficient pressure to activate the wastegate. DynoSim5 incorporates a wastegate model that modulates the size of its bypass passages when the** ***Boost Limit*** **is reached.**

the engine produces substantial exhaust-gas volume; e.g., in large-displacement or very high-speed engines.

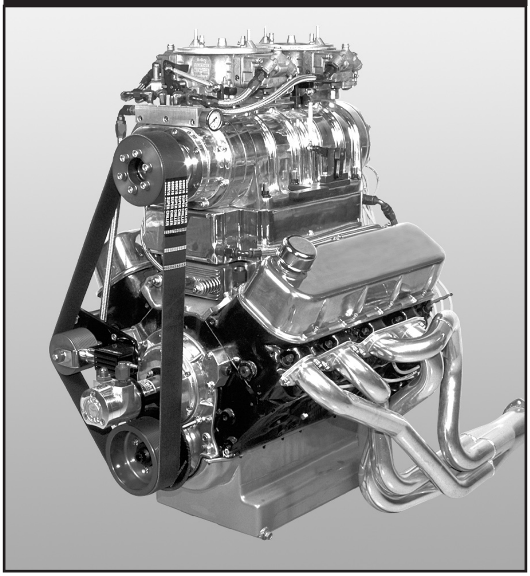
Boost Limit—(Turbos, Centrifugals, Roots, Screw) This is the pressure at which the wastegate or blow-off valve is activated, maintaining maximum induction pressure at or below this value.
Note: **Boost Limit** is an arbitrary pressure, set by you, for the simulation. It is not a measure of the capability of the supercharger. In other words, the blower, because mismatch and other factors, may not be able to develop sufficient airflow to reach the wastegate relief pressure.

Belt Ratio—(Centrifugals, Roots, Screw) Centrifugal, roots, and screw superchargers are mechanically driven by the engine. The **Belt Ratio** (external drive ratio) is the ratio of the mechanical connection between the engine crankshaft and blower input shaft. This value is multiplied by the **Internal Gear Ratio** on centrifugal superchargers to determine internal rotor speed.

Internal Gear Ratio—(Centrifugal) Centrifugal superchargers are driven by a mechanical connection to the engine crankshaft. Internal rotor speed is usually increased by the external *Belt Ratio* (described previously), but this speed increase is insufficient for most centrifugal superchargers to reach their optimum operating speeds (35,000rpm and higher). An internal gear train is commonly used to further increase rotational speed. The ratio of this internal gearing determines how much faster the turbine rotates over input-shaft rpm. To determine the internal speed

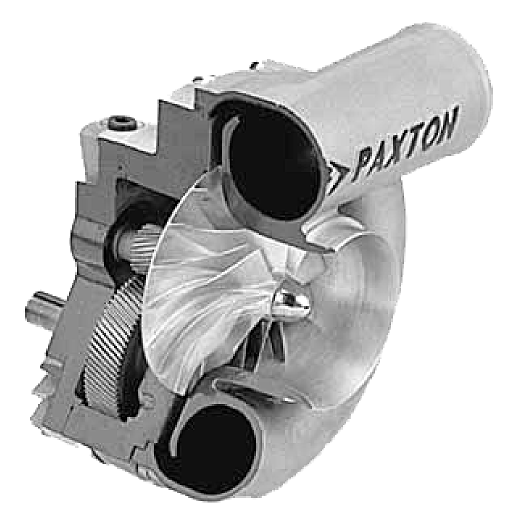
Both centrifugal and roots blowers are mechanically driven by the engine. The Belt Gear Ratio (external drive) is the mechanical connection between the engine crankshaft rpm and blower input rpm. This bigblock Chevy pulley setup provides an overdrive (a Belt Ratio of 1.20:1).

Belt Gear Ratio



Forced Induction Modeling

Internal Gear Ratio



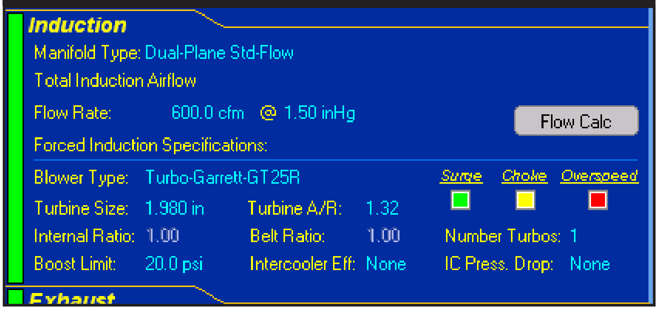
Centrifugal superchargers are driven through an external *Belt Ratio*, but this speed increase is insufficient for most centrifugal superchargers to reach their optimum operating speeds (35,000rpm and higher). An internal gear train is commonly used to further increase rotational speed.

of the centrifugal turbine, multiply crankshaft rpm by the **Belt Gear Ratio**, then multiply that by the **Internal Gear Ratio**.

Operational Indicators—(Turbos, Centrifugals) The forced-induction portion of the **INDUCTION** category includes three "indicators" that will help you select the correct turbocharger, turbine wheel size, and A/R ratio. Each indicator shows a potential operational problem, as follows:

Surge: (Turbo Only) This condition occurs when mismatched components cause unstable airflow through the compressor. If a turbo is operated consistently within surge, the additional loads can damage the turbines, shafts, and bearings. If surge is detected during a simulation run, the ***Surge*** indicator will display either yellow or red. A yellow *Surge* indicator means that the turbo has entered surge only twice during the full engine rpm range. This limited-surge operation is not considered unusual and is not normally

Operational Indicators

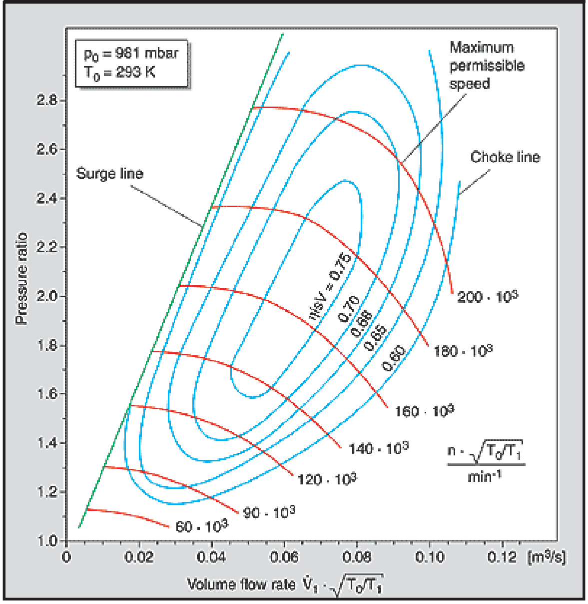


The *Forced Induction Specifications* group includes three "indicators" that will help you select the correct turbocharger, turbine wheel size, and A/R ratio. Each indicator reveals current operational conditions with the forced-induction system. See the text for tips on how to correct problems.

Forced Induction Modeling

This turbo compressor map shows how the compressor turbine performs at various flow rates, pressure ratios, and rpms. If engine demand (often called the "engine demand line") causes the turbo to operate "off the map" to the left, *Surge* can occur. If engine demand line falls off the right side of the map, the turbo is said to be in a *Choke* condition. And if the turbocharger speed exceeds the maximum speed on shown on the map (in this case 200,000rpm), an *Overspeed* condition exists. Each of these abnormal operating conditions trigger indicators in the *Forced Induction* portion of the INDUCTION category.

Turbocharger Compressor Map



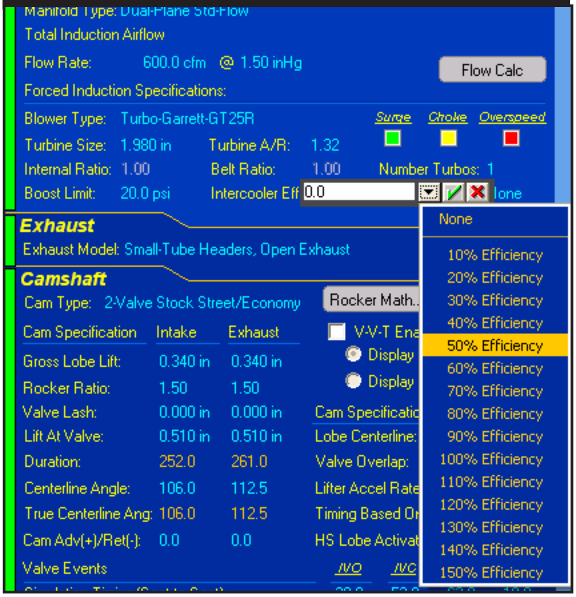
associated with shortened turbocharger life. If the indicator turns red, the turbo has entered into surge more than two times during the engine "dyno test." The turbocharger, *Turbine Size*, or *A/R* ratio should be changed to eliminate this condition.

Choke: (Centrifugals, Turbos) While ***Choke*** can apply to both the Compressor and Turbine impellers (in turbocharger applications), ***Choke*** most often refers to the point at which compressor wheel tips reach sonic velocity, preventing further flow. The choke line on a compressor map can be recognized by the steeply descending speed lines at the right side of the map. If choke is detected at any point during the engine rpm range, the ***Choke Indicator*** will turn from green to yellow, indicating a condition that should be corrected. However, choke problems are relatively easy to correct, often disappearing with a slight reduction in shaft speed (use a larger *Turbine Size* or increase the *A/R* ratio).

Overspeed: (Centrifugals, Turbos) If the shaft speed exceeds the manufacture's recommendations (the engine demand line travels off of the top of the compressor map), the ***Overspeed Indicator*** will change from green to yellow. If the overspeed condition exceeds the manufacturer's recommended speed by over 10%, the indicator will switch from yellow to red, indicating a potentially harmful condition to the turbocharger bearings and seals. If your simulation produces a red *Overspeed* condition, increase the *Turbine*

Intercooler Modeling

Intercooler Menu



DynoSim5 includes an intercooler model that can be activated with any forced-induction system. An intercooler reduces induction temperatures that, otherwise, substantially reduce performance.

Size and/or the *Turbine Housing A/R* ratio.

Intercoolers

One of the drawbacks to any method of supercharging is the resulting increase in induction-gas temperatures. High boost pressures can quickly raise charge temperatures more than 200-degrees(F)! These higher temperatures, common on blowers with pressure ratios of 2.0 or higher, cost more than just lost horsepower. Higher temperatures can lead to detonation, increase octane requirements, and usually require a reduction in ignition timing advance. While induction cooling can improve performance directly from increased charge density (more oxygen and fuel per unit volume of inducted charge), the additional benefits of reduced detonation and increased reliability make charge cooling an attractive addition to any supercharged high-performance engine.

Charge cooling is accomplished in the same way that heat is removed from the engine. A radiator, called an intercooler, is placed in the pressurized air ducting between the supercharger and the intake manifold. The efficiency of an intercooler determines how much of the heat generated by charge compression is removed. The lower the efficiency of the intercooler, the less heat is removed from the induction charge. An efficiency of 100% removes all extra heat (bring charge temperature down to ambient). An efficiency of over 100% (reduces charge temperatures below ambient) is possible with water or ice. Everything from outside air to ice water and even evaporating pressurized liquefied gas (like Freon or nitrous oxide) have been used to remove heat from an intercooler. The average efficiencies for these devices are:

Air-To-Air	**40%**	**Air-To-Cooler Ducted Air**	**50%**
Air-To-Water	**75%**	**Air-To-Cooled Water**	**100%**
Air-To-Ice Water	**120%**	**Air-To-Evaporating Liquid**	**120+%**

DynoSim5 includes an intercooler model that can be activated with any forced induction system. Simply double-click on the **Intercooler** field and select an intercooler efficiency from the drop-down list (or directly enter a custom value).

Every intercooler will produce a pressure drop from flow restrictions that are generated by its length, shape, and air passages. This pressure drop is usually small—in the range of 1 to 3 psi. You can adjust the Intercooler Pressure Drop by selecting a value from the ***IC Pressure Drop*** menu, however, DynoSim5 automatically calculates an appropriate pressure drop value based on the selected Intercooler.

Note-1: The ***IC Pressure Drop*** occurs after the Intercooler, so the ***Boost Limit*** may need to be increased to obtain the desired boost pressure at intake valve.

Note-2: When methanol evaporates, it cools the intake charge more than gasoline (the latent heat of vaporization of methanol is greater than gasoline). Therefore, intercooling is less needed and somewhat less effective as a power booster when methanol has been selected from the **Fuel Type** menu.

THE EXHAUST-SYSTEM COMPONENT CATEGORY MENU

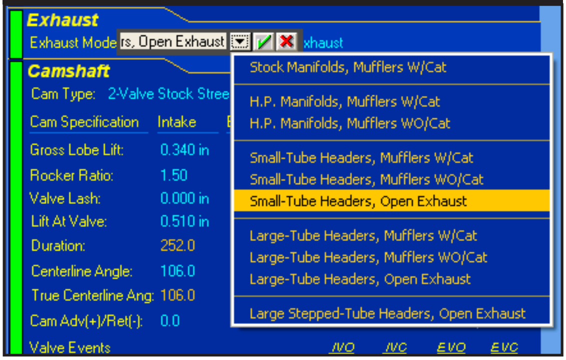
The **EXHAUST** category establishes a manifold or header exhaust system for the simulated test engine. Each menu selection applies a unique tuning model to the simulation. Ten selections are proviced; seven of which include mufflers, four include both mufflers and catalytic converters. Since DynoSim5 is designed to simulate the power levels for an engine mounted on a dyno testing fixture, the exhaust system for muffled engines ends at the outlet of the muffler and does not include additional tubing commonly used to route exhaust gasses to the rear of a vehicle.

The exhaust model in DynoSim5 cannot not resolve exact header dimensions, however, it can accurately predict engine power changes from various discrete selections of exhaust manifolds and headers of “large” and “small” tubing diameters (sizes are relative to the exhaust-valve diameters of the engine under test; more on this later).

Stock Manifolds And Mufflers W/Cat—The first choice in the *Exhaust Model* menu simulates the most restrictive exhaust system. It assumes that the exhaust manifolds are a typical, production, cast-iron, usually a “log-type” design, where all ports connect at nearly right angles to a common passage. These manifolds are designed more to minimize clearance problems and cost than to optimize exhaust flow. Exhaust manifolds of this type have widespread application on low-performance production engines. This exhaust-modeling selection assumes that the manifolds

Exhaust System Modeling

Exhaust System Menu



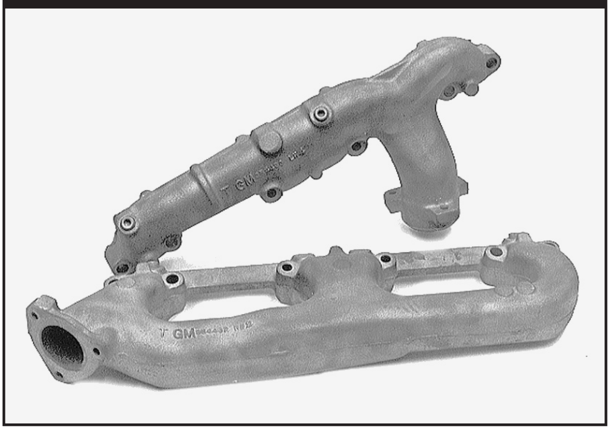
Exhaust-system flow restrictions (back pressure) are accurately modeled using "pressure-drop" techniques. DynoSim5 can also predict engine power changes from various exhaust manifolds and headers of large and small tubing diameters (these sizes are relative to the exhaust-valve diameter of the engine under test).

are connected to typical OEM mufflers and catalytic converters with short sections of pipe.

The exhaust manifolds and mufflers cancel all scavenging effects, and the system is a completely "non-tuned" design. Any suction waves that might be generated are fully damped or never reach the cylinders during valve overlap. The restriction created by this system mimics most factory muffler and/or catalytic-converter-with-muffler combinations. Back pressure levels in the exhaust system nearly cancel the blowdown effects of early EVO timing and increase pumping work losses during the exhaust cycle.

H.P. Manifolds And Mufflers W/Cat and WO/Cat—These choices in the *FE Exhaust Model* menu offers a significant improvement over the stock exhaust system discussed previously. The high-performance exhaust manifolds modeled are designed to improve exhaust gas flow and reduce system restriction. They are usually a "ram-horn" or other low-restrictive designs with fewer sharp turns and larger internal passages. The connecting pipes to the mufflers and catalytic converter are large

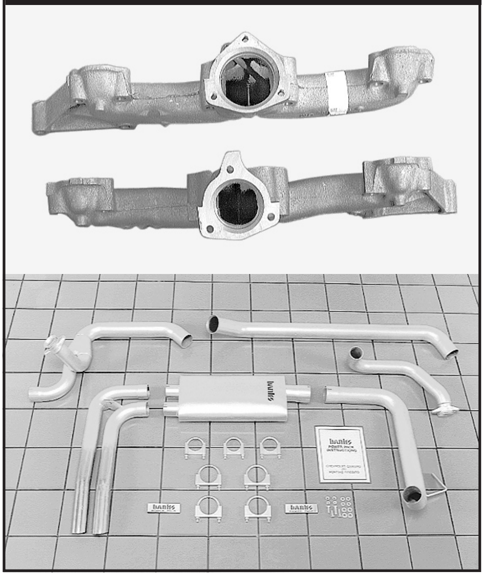
"Log-Type " Exhaust System Manifolds



The first choice in the Exhaust menu simulates typical, production, cast-iron, "log-type" exhaust manifolds, where all ports connect at nearly right angles to a common "log" passage. These manifolds are designed to provide clearance for various chassis and engine components and provide considerably less than optimum exhaust flow.

Exhaust System Modeling

HP Manifolds And Mufflers



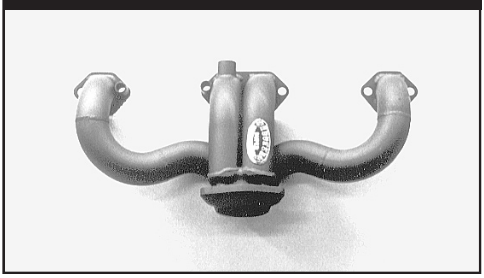
The *HP Manifolds And Mufflers* exhaust-system choice offers a measurable improvement over the stock-exhaust selection. High-performance exhaust manifolds are designed to improve exhaust gas flow and reduce system restriction. They are usually a "ram-horn" or other "sweeping" design with fewer sharp turns and larger internal passages. The connecting pipes to the mufflers are large diameter and the mufflers generate less back pressure.

diameter, the mufflers generate less back pressure and a louder exhaust note.

While this system is considered a "high-performance" design, it offers little tuning effects and virtually all suction waves are fully damped or never reach the cylinders during valve overlap. All performance benefits from this selection are due to a decrease in passage restrictions and lower system back pressure. System pressure levels mimic factory high-performance mufflers and/or catalytic-converter-with-muffler combinations. This exhaust system may allow some benefits from early-EVO timing blowdown effects (depending on the engine component combination) and overall pumping work losses are slightly reduced by lower back pressures.

> ***IMPORTANT NOTE ABOUT ALL HEADER CHOICES:*** *Some engines, in particular, 4-cylinder applications, can develop a "full resonance" in the exhaust system—a phenomenon similar to that of full-induction resonance seen in dual-plane*

Custom HP "Manifolds"



Here is an excellent example of high-performance "manifolds" from Hooker Headers. The low-restriction custom-built tubing design fits 1992-1995 Corvettes with an LT1 engine. When used with mufflers, model this system using the *H.P. Manifolds And Mufflers* menu selection.

manifolds; see the previous discussion of dual-plane manifolds for information about "full" system resonance (page 55). This phenomenon can derive scavenging benefits (although studies have revealed that the benefits, if they exist at all, are relatively small) from suction waves created in the collector by adjacent cylinders. This "one-cylinder-scavenges-another" tuning technique is not modeled in DynoSim5. Instead, the headers are assumed to deliver a scavenging wave only to the cylinder that generated the initial pressure wave.

Note About Tubing Sizes For All Filling-And-Emptying Header Choices: The following rules of thumb give approximations of tubing diameters used by the *Filling-And-Emptying* simulation: Headers with tubes that measure 95% to 105% of the exhaust-valve diameter are considered "small" for any particular engine (110% to 130% of the exhaust-valve diameter for two exhaust valves per port); tubes that measure 120% to 140% of the exhaust-valve diameter can be considered "large" tube headers (130% to 160% for two exhaust valves per port).

Small Tube Headers, Mufflers W/Cat and WO/Cat—This is the first exhaust-system model that begins to harness the tuning potential of wave dynamics in the exhaust system. These generic headers have primary tubes that connect each exhaust port to a common tube or collector. The collector—or collectors, depending on the number of cylinders—terminates into a high-performance muffler(s). Suction waves are created in the collector, but are somewhat damped by the attached muffler and catalytic converter, if used.

Note: Since exact tubing lengths are not resolved by the *Filling-And-Emptying* simulation model, the program assumes that the primary tube will deliver the scavenging wave to the cylinder during the valve-overlap period. The primary tubes modeled by this *Exhaust Model* menu selection are considered "small," and should be interpreted to fall within a range of dimensions that are commonly

Small-Tube Headers

This is the first exhaust-system selection that begins to harness the tuning potential of wave dynamics in the exhaust system. While the system pictured here is not a "true" header, this tubular exhaust system from Edelbrock for late model cars and trucks offers some wave-dynamic scavenging.

Exhaust System Modeling

Large-Tube Headers

Typical large-tube headers are designed for high-performance street and racing applications in mind. The better pieces have 3- to 4-inch collectors and 1-3/4- to 2-3/8-inch primary tubes (depending on whether they were designed for smallblocks or bigblocks).

associated with applications requiring optimum power levels at, or slightly above, peak-torque engine speeds. These headers show benefits on smaller displacement engines, and may produce less power on large displacement engines.

Small-Tube Headers, Open Exhaust—This menu selection simulates headers with primary tubes individually connecting each exhaust port to a common collector or tube. The collector—or collectors, depending on the number of cylinders—terminates into the atmosphere. Strong suction waves provide a substantial boost to cylinder filling and exhaust gas outflow. Since exact tubing lengths are not resolved, the simulation assumes that the primary tube will deliver the scavenging wave to the cylinder during the valve-overlap period.

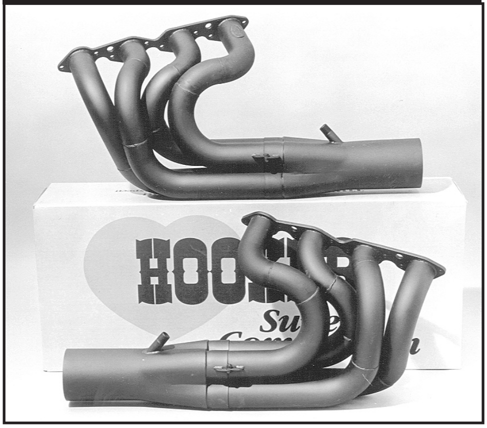
The primary tubes modeled by this menu selection are considered “small,” and should be interpreted to fall within a range of dimensions that are commonly associated with applications requiring optimum power slightly above peak-torque engine speeds. These headers show the greatest benefits on smaller displacement engines.

Large-Tube Headers, Mufflers W/Cat and WO/Cat—This **Exhaust Model** menu selection simulates headers with “large” primary tubes individually connecting each exhaust port to a common collector or tube. The collector—or collectors, depending on the number of cylinders—terminates into a high-performance muffler(s). Suction waves are created in the collector, but are somewhat damped by the attached muffler and catalytic converter, if used.

The primary tubes modeled by this selection are considered “large,” and should be interpreted to fall within a range of dimensions that are commonly associated with applications requiring optimum power at peak engine speeds. These headers typically show significant benefits on high-rpm or supercharged engines. These headers may not increase power as much on small-displacement engines operating in lower-rpm ranges.

Exhaust System Modeling

Large Tube Stepped Racing Headers



Large-tube stepped headers have large-diameter primary tubes with several transitions to slightly larger tubing diameters. These "steps" can reduce pumping work and improve horsepower on large displacement and/or high-rpm applications. These Hooker ProStock BB Chevy headers have 2-3/8-inch primary tubes that step to 2-1/2-inch as they reach the 4-1/2-inch collectors.

Large-Tube Headers, Open Exhaust—This menu selection simulates headers with "large" primary tubes individually connecting each exhaust port to a common collector. The collector—or collectors, depending on the number of cylinders—terminates into the atmosphere. Strong suction waves are created in the collector that provide a substantial boost to cylinder filling and exhaust gas outflow.

The primary tubes modeled by this menu selection are considered "large," and should be interpreted to fall within a range of dimensions that are commonly associated with applications requiring optimum power at peak engine speeds. These headers typically show benefits on high-rpm naturally-aspirated racing engines or supercharged engines. These headers may produce less power on small-displacement engines, particularly those operating in lower-rpm ranges.

Large Stepped-Tube Race Headers—This *Exhaust Model* menu selection simulates headers with "large" primary tubes individually connecting each exhaust port to a common collector. Each primary tube has several transitions to slightly larger tubing diameters as it progresses towards the collector. The collector—or collectors, depending on the number of cylinders—terminates into the atmosphere. Strong suction waves are created that provide a substantial boost to cylinder filling and exhaust gas outflow.

The primary tubes modeled by this menu selection are considered "large," and should be interpreted to fall within a range of dimensions that are commonly associated with applications requiring optimum power at peak engine speeds.

The "stepped" design of the primary tubes reduces pumping work on some engines. As high-pressure compression waves leave the port and encounter a step in the primary tube, they return short-duration rarefaction waves. These low-pressure "pulses" moves back up the header and assists the outflow of exhaust gasses. When rarefaction waves reach the open exhaust valve(s), they help depressurize the cylinder and lower pumping work. This can generate a measurable increase in horsepower on large displacement and/or high-rpm engines.

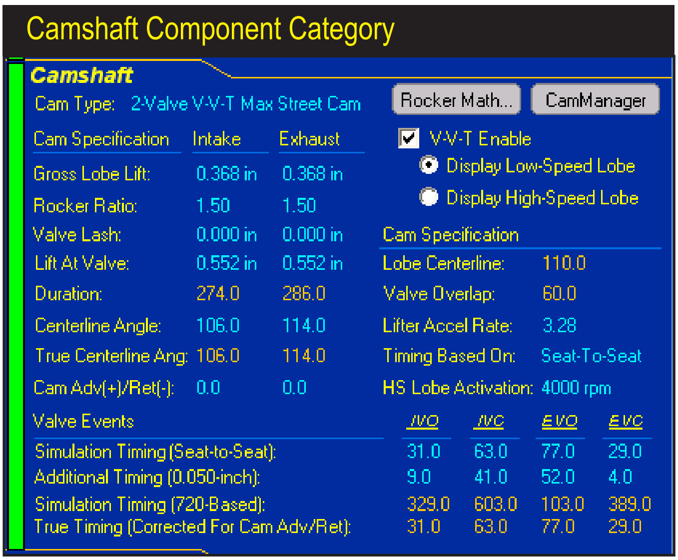
THE CAMSHAFT COMPONENT CATEGORY

The **CAMSHAFT** component category allows the selection of the single most important part in the IC engine: the camshaft. For many enthusiasts and even professional engine builders, the subtleties of cam timing defy explanation. Add in all the "standards" of measurement and advertising hype, and the reason for this confusion is understandable. The camshaft is the "brains" of the IC engine, directing the beginning and ending of all four engine cycles. Even with a good understanding of all engine systems, the interrelatedness of the physics within the IC engine can make the tuning results of cam timing changes read like a mystery story. In many cases there are only two ways to determine the outcome of a modification: 1) run a real dyno test or 2) run a simulation. Since the camshaft directly affects several functions at once, e.g., exhaust and intake scavenging, induction signal, flow efficiency, cylinder pressures, etc., using a computer-based engine simulation program is often the only way to *accurately predict* the outcome.

DynoSim5 makes it possible to test the effects of cam timing in seconds. The ability of the program to take the myriad elements that affect airflow and cylinder pressures into consideration and "add up these effects over time" is key to accurately predicting the results of camshaft timing changes.

Cam Basics

In the simplest terms, the camshaft is a straight steel or iron shaft with eccentric lobes. It is connected to the crankshaft with a chain or gear train and is usually

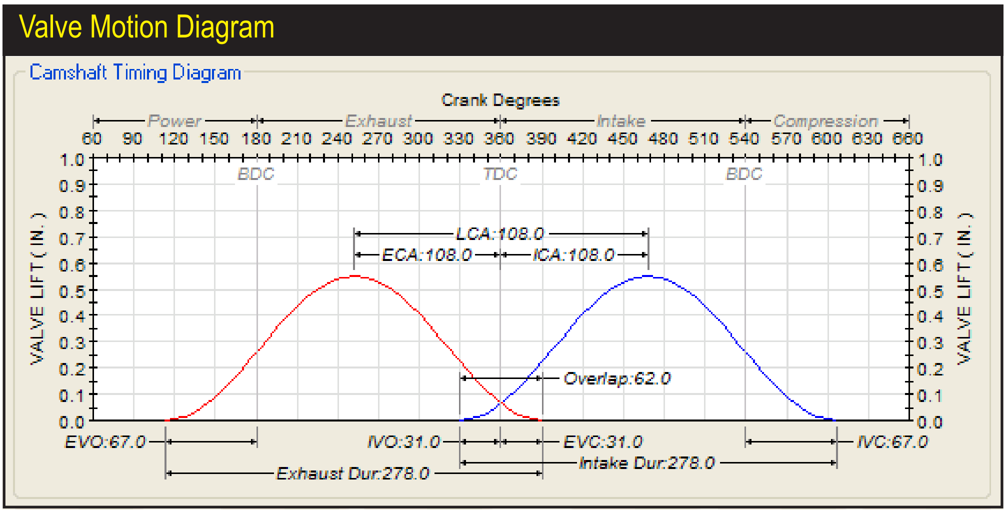


The CAMSHAFT component menus allows the selection of the single most important part in the IC engine: the camshaft, considered the "brains" of the IC engine. Cam timing directs the beginning and ending of all four engine cycles. DynoSim5 has hundreds of new enhancements and features that improve cam-timing and valvetrain motion analysis.

rotated at one-half crank speed. Lifters (or cam followers)—and in the case of in-block cam locations, pushrods, and rockerarms—translate the rotary motion of the cam into an up-and-down motion that opens and closes the intake and exhaust valves. This entire assembly must function with high precision and high reliability. Street engines driven hundreds-of-thousands of miles operate their valvetrain components *billions of cycles*. If the overall camshaft and valvetrain design is good, a precision micrometer will detect only negligible wear!

The camshaft controls the valve opening and closing points by the shape and rotational location of the lobes. Most cams are ground to a precision well within one crankshaft degree, ensuring that the valves actuate exactly when intended. Timing variations of several degrees can develop in the cam drive, especially in chain-drive systems, but racing gear drives reduce variations to within one or two crank degrees, or less, of indicated timing. Camshaft lobe height (heal-to-toe height) and the multiplying ratio of the rockerarms (if used) determines how far the valves will lift off of the valve seats. The rates at which the valves are accelerated open and then returned to their seats are also "ground into" cam lobe profiles. Only a very specific range of contours will maintain stable valve motion, particularly with high-lift, racing profiles. Unstable profiles or excessive engine speed will force the valvetrain into "valve float," leading to rapid component failure.

Valve Events

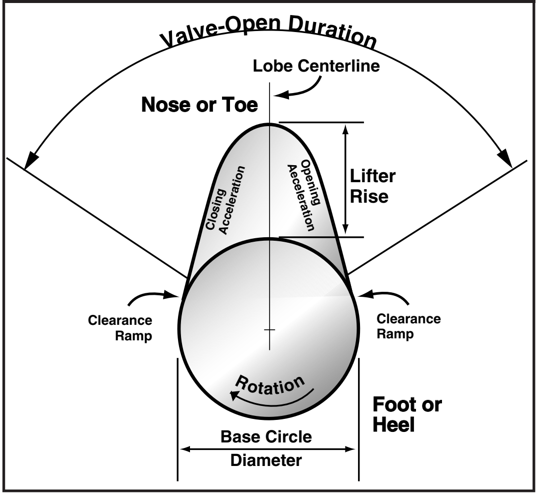


The best way to visualize camshaft timing is to picture this "twin-hump" event diagram (as drawn by Dyno*Sim5 CamManager*, described on page 115). It shows valve motion for the exhaust lobe on the left and the intake lobe on the right. Also illustrated are the valve-timing points, duration, valve overlap, valve lift, centerlines, lobe center angle, and "ideal" engine-cycle timing, all relative to TDC at the center of the drawing. Study this picture. It will help you evaluate cam timing and visualize how individual cam-timing events relate to one another.

Camshaft Modeling

The camshaft is a round shaft incorporating cam *lobes*. The *base circle diameter* is the smallest diameter of the cam lobe. *Clearance ramps* form the transition to the *acceleration ramps*. The lifter accelerates up the clearance and acceleration ramps and continues to rise as it approaches the *nose*, then begins to slow to a stop as it reaches maximum *lift* at the *lobe centerline*. Maximum *lifter rise* is determined by the height of the *toe* over the *heal*. *Valve-open duration* is the number of crankshaft degrees that the valve or lifter is held above a specified height (usually 0.006-, 0.020-, or 0.050-inch). A symmetric lobe has the same lift curve for opening and closing.

Cam Lobe Basics



There are six basic cam timing events ground into the lobes of every camshaft. These timing points are:

1—Intake Valve Opening (IVO) | **2—Intake Valve Closing (IVC)**
3—Exhaust Valve Opening (EVO) | **4—Exhaust Valve Closing (EVC)**
5—Intake Valve Lift | **6—Exhaust Valve Lift**

These six points can be "adjusted" somewhat (we'll discuss which and how cam timing events can be altered in the next section), but for the most part they are fixed by the design of the cam. Other timing numbers are often discussed, but they are always derived from the above, basic six events. Derivative events are:

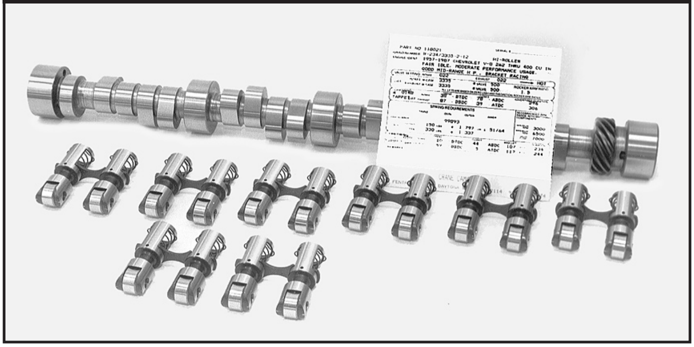
7—Intake Duration | **8—Exhaust Duration**
9—Lobe Center Angle (LCA) | **10—Valve Overlap**
11—Int. Center Angle (ICA) | **12—Exh. Center Angle (ECA)**

The first four basic timing points (IVO, IVC, EVO, EVC) pinpoint the "true" beginning and end of the four engine cycles. These valve opening and closing points indicate when the function of the piston/cylinder mechanism changes from intake to compression, compression to power, power to exhaust, and exhaust back to intake. For a more in-depth analysis of cam timing, refer to the *DeskTop Dynos* book available from Motion Software (www.motionsoftware.com).

Camshaft Menu Choices

Camshaft Modeling

Common “Cam Card” Timing



Long before engine simulations were widely used, cam manufacturers established a methodology for identifying and classifying camshafts. Unfortunately, these “catalog” specs place the emphasis on the span between the valve events rather than on the events themselves.

The **Cam Type** menu contains eighteen camshaft “grinds” in two menu groups for 2-valve engines and 4-valve engines (including Variable-Valve-Timing cams) that are listed by application. When any of these camshafts is selected, the ***Intake Lift At Valve*** and ***Exhaust Lift At Valve***, the seat-to-seat ***Cam Timing*** (the IVO, IVC, EVO, EVC), the ***Lifter Type***, and the ***Lifter Acceleration*** are loaded into the appropriate fields in the **CAMSHAFT** category. In addition, the ***Intake*** and ***Exhaust Centerlines***, the ***Lobe Center Angle***, the ***Intake*** and ***Exhaust Duration***, and the ***Valve Overlap*** are calculated and displayed.

2- And 4-Valve Non-Variable (Non-VVT) Cam-Type Selections

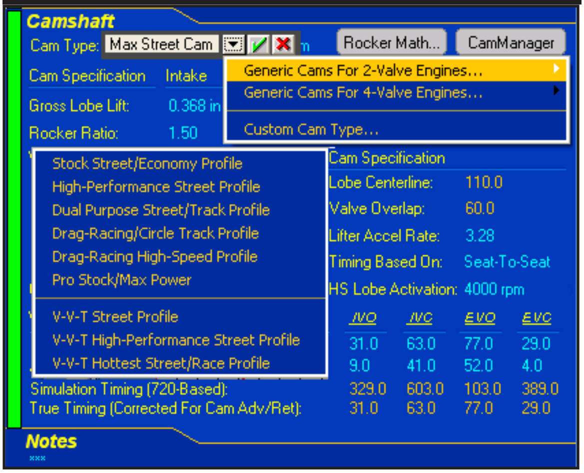
2- And 4-Valve, Stock Street/Economy Cams—These first cam selections are OEM-replacement street cams for 2- and 4-valve engines. The lifter acceleration rate (explained in detail on page 105) falls between 2.51 and 2.83 (on a 1.00-to-7.00 scale), which indicates that valve motion for these cams fall in the range of stock OEM to mild street performance applications. Rated valve lift is 0.510/0.510-inch for 2-valve engines and 0.305/0.305-inch for 4-valve engines (intake/exhaust).

The EVO timing maintains combustion pressure late into the power stroke and early IVC minimizes intake flow reversion. Late IVO and early EVC produce 38 degrees of overlap for 2-valve engines and 11-degress for 4-valve engines, enough to harness some scavenging effects but limited enough to prevent severe exhaust gas reversion into the induction system. The characteristics of these cams are smooth idle, good power from 600- to 5000-rpm for 2-valve engines and typically between 1500- and 6500-rpm for 4-valve engines. These generic cams produce good fuel economy and work well in high-torque-demand applications.

2-Valve And 4-Valve High-Performance Street Cams—These profiles are designed to simulate high-performance “street” camshafts for 2- and 4-valve engines. These cams produce lifter acceleration rates between 3.10 and 3.32, indicating that valve motion falls in the range of a typical, mild, street-performance camshaft. Rated

Camshaft Modeling

Camshaft Type Menu



DynoSim5 can evaluate cam timing changes in seconds. Several "generic" cam profiles are included in the Cam Type drop-down menu, plus you can easily input any custom timing and valve lift specifications. Test cams from specifications in manufacturer catalogs or load CamFiles directly using the new, built-in *CamManager™*. *Cam-Disk7™* (optional, see page 107) increases your test-cam library to over 6000+ profiles.

valve lift is 0.552/0.552-inch for 2-valve engines and 0.432/0.435-inch for 4-valve engines (intake/exhaust).

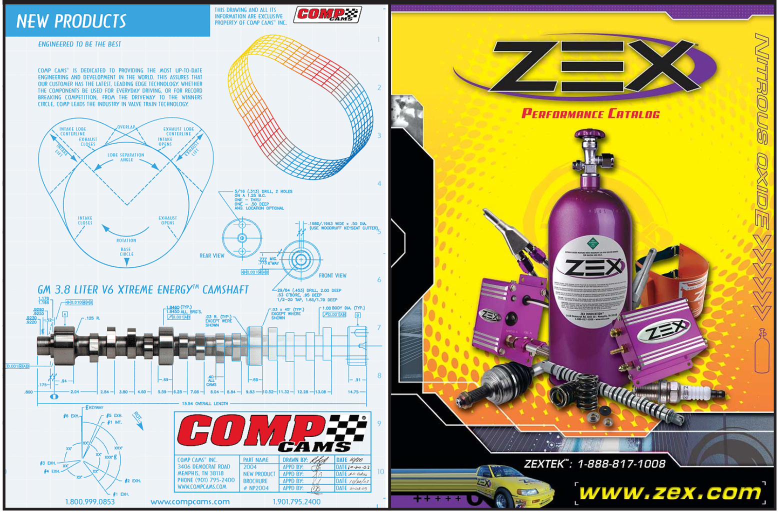
This camshaft uses relatively-late EVO to fully utilize combustion pressure and early IVC minimizes intake flow reversion (can be a serious problem on 4-valve engines, since low-lift flow can be substantial when both valves are open and expose large curtain areas). IVO and EVC produces between 54- and 60-degrees of overlap; profiles clearly intended to harness exhaust scavenging effects. The modestly-aggressive overlap allows some exhaust gas reversion into the induction system at lower engine speeds, affecting idle quality and low-speed torque. The characteristics of these cams are fair idle, good power from 1800- to 6000-rpm in 2-valve engines and between 2200- and 7500-rpm in typical 4-valve engines. Good fuel economy is still a by-product of the relatively "mild" cam timing. Both *High Performance Street* cams can be used with higher acceleration rates (typically up to about 4.00) to model more aggressive profiles.

2-Valve And 4-Valve Dual Purpose Street/Track Cams—These profiles simulates high-performance aftermarket camshafts designed for street and mild track applications in 2- and 4-valve valve engines. These cams produce lifter acceleration rates of approximately 3.90, indicating that valve motion falls in the range of a high-performance street and mild racing. Rated valve lift is 0.608/0.614-inch for 2-valve engines and 0.472/0.457-inch for 4-valve engines (intake/exhaust).

EVO timing on this camshaft is beginning to move away from specs that would be expected for optimum combustion pressure utilization, with more of an emphasis on blowdown and minimizing exhaust-pumping losses. The later IVC attempts to strike a balance between harnessing the ram effects of the induction system while minimizing intake flow reversion. IVO and EVC produce 63- to 65-degrees of overlap, profiles designed to harness exhaust scavenging. The modestly aggressive overlap

Camshaft Modeling

Cam Sources



The "generic" camshafts available in DynoSim5 *Cam Type* menu were modeled, in part, after profiles developed by CompCams, ZEX, and other manufacturers.

allows some exhaust gas reversion into the induction system at lower engine speeds, affecting idle quality and low-speed torque (can be a more substantial issue on 4-valve engines, since low-lift flow can be substantial when both valves are off their seats and expose large curtain areas). The characteristics of this cam are lopey idle, good power from 2500- to 6500-rpm in 2-valve engines and between 2500- and 7800-rpm in typical 4-valve engines. These cams develop considerable power at higher engine speeds and are especially effective in lightweight vehicles.

2-Valve And 4-Valve Drag-Race/Circle-Track (And Road-Racing) Cams—These profiles are designed to simulate competition, aftermarket camshafts for 2- and 4-valve engines. These cams produce lifter-acceleration rates of approximately 4.30, indicating that valve motion lies in the range normally used in competition-only engines. Expect somewhat reduced valvetrain life. Rated valve lift is 0.656/0.640-inch for 2-valve engines and 0.472/0.457-inch for 4-valve engines (intake/exhaust).

EVO timing places less emphasis on utilizing combustion pressure and more emphasis on beginning early blowdown to minimize exhaust-pumping losses. The later IVC attempts to strike a balance between harnessing the ram effects of the induction system while minimizing intake flow reversion. IVO and EVC produce 91-degrees of overlap (60-degrees for 4-valve engines) to harness exhaust scavenging. This aggressive overlap is designed for higher engine speeds with open headers and allows exhaust gas reversion into the induction system at lower rpm, affecting idle quality and torque below 3000- to 4000-rpm. The characteristics of these cams are very lopey idle, good power from 6600 to 8600rpm in 2-valve engines and between 3000- and 8000-rpm in typical 4-valve engines, with little consideration for fuel economy. These cams develop substantial power at higher engine speeds and are especially effective in lightweight vehicles.

Camshaft Modeling

2-Valve And 4-Valve Drag-Race/High-Speed Cams—These cam profiles simulate aftermarket high-performance competition camshafts for 2- and 4-valve engines. These cams produce lifter-acceleration rates between 3.94 to 4.60, valve motion that falls in the range normally used in competition-only engines. These camshaft produce good power while sacrificing some valvetrain life (especially considering the 2-valve cam acceleration rates of 4.60). Rated valve lift is 0.692/0.692-inch for 2-valve engines and 0.488/0.472-inch for 4-valve engines (intake/exhaust).

All timing events on this camshaft are designed to optimize power on larger displacement engines at very high engine speeds with large-tube, open headers, and high compression ratios. This camshaft may not be effective in small displacement engines. EVO timing places the utilization of combustion pressure on the "back burner" and focuses emphasis on beginning early blowdown to minimize pumping losses during the exhaust stroke. This technique will help power at very high engine speeds, especially on 2-valve, large-displacement engines that do not easily discharge the high volume of exhaust gasses they produce. The late IVC attempts to harness the full ram effects of the induction system while relying on intake pressure wave tuning to minimize intake-flow reversion. IVO and EVC produce 104-degrees of overlap (71-degrees for 4-valve engines), a profile that is clearly intended to utilize exhaust scavenging effects. This very aggressive overlap seriously affects idle quality and torque below 4500rpm. A 5000rpm stall torque converter is recommended for automatic transmission applications. The characteristics of this cam are extremely lopey idle, good power from 4500 to 7200rpm in 2-valve engines and between 5000- and 9500-rpm in typical 4-valve engines, with no consideration for fuel consumption.

Drag-Racing, High-Speed Cam Modeling

All-out drag-racing cams for 2- and 4-valve engines are designed to optimize power on larger displacement engines at very high engine speeds with large-tube, open headers, and high compression ratios. These camshafts are often not effective in small displacement engines.

Camshaft Modeling

2-Valve ProStock Camshafts

Optimizing power on very-large displacement engines at high engine speeds and with high compression ratios, requires EVO timing that focuses on early blowdown to minimize pumping losses. Late IVC helps harness the full ram effects of the induction system while relying on intake pressure wave tuning to minimize intake-flow reversion.

2-Valve ProStock/Max-Power Cam —(modeled after CompCams 11-728-9) This profile is designed to simulate an all-out, maximum-power competition camshaft for 2-valve engines (because of the inherent better breathing in a 4-valve design, a cam of this design—an all-out attempt to generate maximum blowdown at the very highest speeds—is not necessary). This cam uses roller-solid lifters and produces an acceleration rate of 5.40, indicating that valve motion falls in the high range normally used in competition-only engines. Valvetrain loads will be substantial, and frequent replacement of valvesprings and other components may be required. Rated valve lift is 0.867-inch for the intake and 0.816-inch for the exhaust.

This ProStock cam is designed for one thing: maximum power at all costs. It is designed to optimize power on very-large displacement engines at very high engine speeds with large-tube, open headers, and very-high compression ratios. EVO timing focuses on beginning early blowdown to minimize pumping losses, a technique that helps large-displacement engines discharge the high volume of exhaust gasses they produce. Late IVC attempts to harness the full ram effects of the induction system while relying on intake pressure wave tuning to minimize intake-flow reversion. IVO and EVC produce 110 degrees of overlap. This very aggressive overlap basically has no idle quality or torque below 6000rpm. The characteristics of this cam are extremely lopey idle, and awesome power potential from 7000 to 9000rpm.

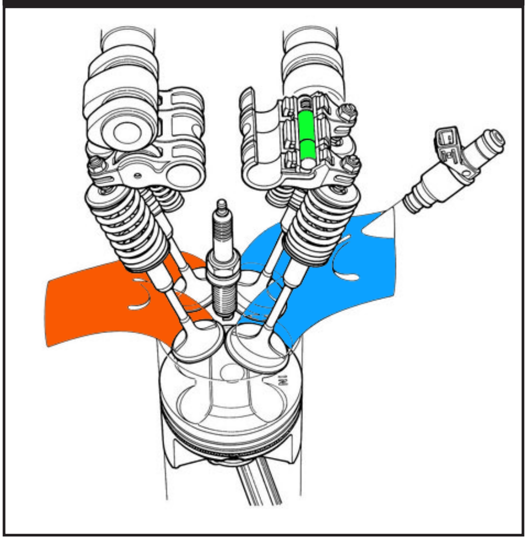
2- And 4-Valve Variable-Valve-Timing (V-V-T) Cam Selections

There have been two major engineering "enhancements" incorporated in modern automobile engines that have contributed to new levels of performance and the potential for even more. Getting more air and fuel in the engine has always been the bottom-line for performance, and 4-valve cylinderheads accomplish that goal with aplomb. While certainly not a "new" invention, it is only recently that 4-valve cylinder heads have become commonplace in showroom floors. But that's not the whole picture, for it's the combination of better breathing cylinder heads and Variable-Valve-Timing schemes that have brought power levels to such heights. These technologies have allowed the auto manufacturers to build a "one-two punch" into modern engines: 1) High flow potential with "aggressive," high-speed cam profiles combined with low-restriction ports and valves, and 2) Maintain low emissions and excellent low-rpm power with mild, low-speed cam timing. Variable valve timing lets car manufacturers have what they need—a "mild" engine that meets emissions and driveability requirements—while giving performance enthusiasts what they want—no-compromise valve timing and optimum power.

The Variable-Valve-Timing (V-V-T) model in DynoSim5 functions like the basic cam-control system used on many Honda automobile engines (called *VTEC™*, for *Variable Timing Electronic Control*). At low speeds, the engine operates on *Low-Speed Lobe* profiles designed to minimize emissions and optimize driveability. Then, at some higher engine speed (usually between 4000 to 6000rpm), the valvetrain "switches over" to *High-Speed Lobe* profiles that, primarily, are designed for performance. Without the V-V-T system, Honda and other car manufacturers wouldn't even consider using a cam with the timing specs of the high-speed lobes, since the engine would barely idle, have poor low-speed throttle response and torque, and generate plenty of unwanted emissions. But when that same cam is limited to high-rpm, wide-open-throttle use, power and driveability coexist.

Note-1: With more sophisticated electronic valvetrain systems, such as the Honda i-VTEC, the timing of individual intake valves is staggered at low rpm and their lift is asymmetric, which creates charge swirl within the combustion chambers, reducing emissions and improving fuel economy. At higher rpm, when more performance is desired—but before the valvetrain transitions to the High-Speed

V-V-T (VTEC) Camshaft Modeling



DynoSim5 will model variable valve timing (V-V-T) as used by Honda (in their VTEC system) and engines with similar valvetrain designs. This mechanism uses a discrete low-speed profile, and then at a particular engine speed switches to a high-speed cam profile. Honda uses a simple pin (shown in green) driven with oil pressure (timed with an electronic controller) that locks the outer two low-speed rockers (actuating the valves) to the center rocker that rides on the high-speed lobe. This allows the engine to maintain excellent driveability and fuel economy at low speeds, yet produce power similar to a "race" engine at higher speeds.

Lobes—both valves open in unison. Finally, at still higher speeds, the VTEC switches, as described previously, into high-lift, long-duration cam profiles.
Note-2: There are many variations of variable cam timing technologies. The most advanced of these designs can provide virtually "ideal" timing for every driving situation, from idle through full-throttle performance and every step in between.

Why have we included V-V-T cams for 2-valve, performance engines (aka the smallblock Chevy)? It's true that few 2-valve engines use variable valve timing. But wouldn't it be great if they did? We think so. It's in the spirit of encouraging interest and development of this technology that we include the ability to easily simulate variable valve timing on not only 4-valve (sport-compact) engines, but also 2-valve domestic powerplants.

Whenever you select any of the V-V-T cams from the *Cam Type* menu, V-V-T modeling will be activated, as indicated by a checkmark in the box next to ***V-V-T Enable*** in the **CAMSHAFT** category. Also, when V-V-T is activated, the box next to the ***Variable Valve Timing*** field in the *CamManager*™ (discussed on page 115) will display a checkmark.

4-Valve V-V-T Mild Street Cam—This profile is designed to simulate conservative OEM camshafts that are used in some 4-valve, V-V-T engines. This cam uses direct-rocker valve actuation (Overhead Cam) and produces an acceleration rate of 2.55 for the Low-Speed Lobe and 2.85 for the High-Speed Lobe, indicating that valve acceleration for these profiles fall well within the range of stock to mild-performance rates. Rated valve lift is 0.325-inch (8.25mm) on the Low-Speed Lobes and 0.420/0.416-inch (10.67/10.57mm) for the intake and exhaust on the High-Speed Lobes.

This camshaft uses very mild cam timing on the low-speed lobes, with only 15-degrees overlap. This profile is designed, primarily, to minimize emissions and maximize fuel economy up to the activation rpm of the high-speed lobes (typically 5000-to-5500rpm). The high speed lobe is of moderate performance design, with 30% more lift and a 6% increase in valve durations. Valve overlap is increased to 25-degrees, so exhaust scavenging effects will be minimal.

The overall characteristics of this cam are smooth idle, good power from 1000 to 7500rpm, and good part-throttle fuel economy.

2- And 4-Valve V-V-T Performance Street Cams—These profiles are designed to simulate mild-performance street camshafts commonly for 2- and 4-valve, V-V-T (VTEC) engines. These cams produce an acceleration rate of 2.83 to 2.41 for the Low-Speed Lobes about 3.15 for the High-Speed Lobes, indicating that valve acceleration for these profiles fall in the range of mild to performance rates. Rated valve lift is 0.510(2-valve)/0.335-inch(4-valve) on the Low-Speed Lobes and 0.552(2-valve)/0.459 & 0.416-inch(4-valve, intake/exhaust) for the High-Speed Lobes.

This camshaft uses mild cam timing on the low-speed lobes, with only 38-degrees overlap (2-valve cams) and 11-degrees (4-valve cams). These profiles are

Camshaft Modeling

V-V-T Best Of Both Worlds

Variable Valve Timing, like the VTEC system used on this B16 (1600cc) Honda engine, lets the engine build optimum power yet obtain good drive-ability and fuel economy (and much lower emissions) at lower engine speeds.

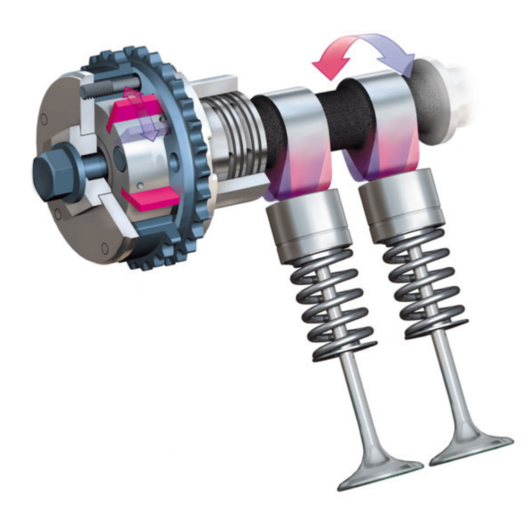
designed, primarily, to reduce emissions and optimize fuel economy up to the activation rpm of the high-speed lobes (typically 5000-to-5500rpm). The high speed lobe is of moderate performance design. Valve overlap is increased to 60-degrees (2-valve) and 46-degrees (4-valve), a sufficient amount to begin harnessing some exhaust scavenging effects. If the high-speed lobe was used below about 4000rpm, the modestly-aggressive overlap would allow exhaust-gas reversion into the induction system at lower engine speeds, affecting idle quality and low-speed torque. The overall characteristics of this cam are smooth idle, good power from 1000 to 7500rpm, and good part-throttle fuel economy.

2- And 4-Valve V-V-T High-Performance Street Cams—These profiles are designed to simulate high-performance street camshafts for 2- and 4-valve, V-V-T (VTEC) engines. These cams produce acceleration rates of 2.93 to 3.12 for the Low-Speed Lobes and 3.84 to 3.93 for the High-Speed Lobes, indicating that valve acceleration for this profile falls in the range commonly used for high-performance applications. Rated valve lift is 0.552(2-valve)/0.354-inch(4-valve) on the Low-Speed Lobes and 0.608 & 0.614-inch(2-valve, intake/exhaust)/0.472 & 0.457-inch(4-valve, intake/exhaust) for the High-Speed Lobes.

These camshafts use somewhat more aggressive cam timing on the low-speed lobes, with 60-degrees of overlap (2-valve cams) and 29-degrees (4-valve cams). These profiles will begin to harness exhaust scavenging effects even while running the low-speed cam timing. The increased overlap allows some exhaust gas reversion into the induction system at lower engine speeds, slightly affecting idle quality and low-speed torque. The high speed lobes are designed for performance, with 20% to 33% more lift and a 10% to 18% increase in valve durations. Valve

Camshaft Modeling

Porsche Boxter VarioCam™



The Porsche Boxter uses variable valve timing technology called VarioCam™. It alters the timing on the intake valves based on engine speed and load. As well as enhancing power and torque, the system offers smoother performance, improved fuel economy and lower emissions.

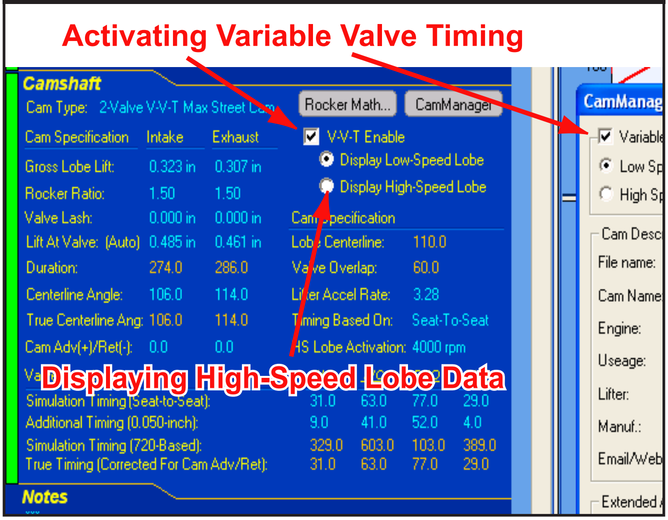
overlap is increased to 63-degrees (2-valve cams) and 65-degrees (4-valve cams), modestly-aggressive values that take advantage of free-flowing headers and mufflers (recommended for this cam). The narrow lobe centerline angle of 102-degrees on the 4-valve cam applications should be widened (with adjustable cam sprockets on dual-overhead cam engines) for turbocharged applications and even on some naturally-aspirated engines with low exhaust restriction. The overall characteristics of this cam are a slightly rough idle, good power from 2500 to 8500rpm, and moderate -to-good part-throttle fuel economy.

2- And 4-Valve Max Street/Race Cams—These profiles are designed to simulate maximum performance street camshafts for 2- and 4-valve, V-V-T (VTEC) engines. These cams produce acceleration rates of 2.69 to 3.12 for the Low-Speed Lobes and 4.09 to 4.27 for the High-Speed Lobes, indicating that valve acceleration for this profile falls in the range for high-performance applications. Rated valve lift is 0.552(2-valve)/0.380 & 0.370-inch(4-valve, intake/exhaust) on the Low-Speed Lobes and 0.656 & 0.640-inch(2-valve, intake/exhaust)/0.500 & 0.480-inch(4-valve, intake/exhaust) for the High-Speed Lobes.

These low-speed lobe profiles for 2-valve engines are the same as the previous *High-Performance Street Cam*. The 4-valve camshaft uses relatively mild cam timing on the low-speed lobes, with only 16-degrees overlap. This profile is designed to maintain a good idle and torque at low engine speeds. The high speed lobes are a high-performance design, with an 18% to 31% more lift and 9% to 20% increase in valve durations. Valve overlap is increased to an aggressive 91-degrees (2-valve cams) and 76-degrees (4-valve cams) that takes advantage of free-flowing headers and mufflers (headers, while not required, will significantly improve performance with

Camshaft Modeling

Activating V-V-T And Displaying High-Speed Lobe



When any of the V-V-T cams have been selected or a V-V-T CamFile has been loaded in the CamManager™, V-V-T modeling will be activated, indicated by a checkmark in the *V-V-T Enable* box in the CAMSHAFT category and in the *Variable Valve Timing* box in the CamManager™. To display High-Speed lobe timing, click the *Display High-Speed Lobe* radio button.

this cam). The lobe centerline angle (106- to 109-degrees) of the high-speed lobes can be widened somewhat (with adjustable cam sprockets) for turbocharged applications and even on naturally-aspirated engines with very low exhaust restriction. The overall characteristics of this cam are good to slightly-rough idle and excellent power from 1500 to 9000rpm, with good to moderate part-throttle fuel economy.

Note: Each of the previous application-specific cams can be modified in any way by directly entering custom valve-event timing or other cam specifications.

Variable Valve Timing (V-V-T) Activation And Custom V-V-T Modeling

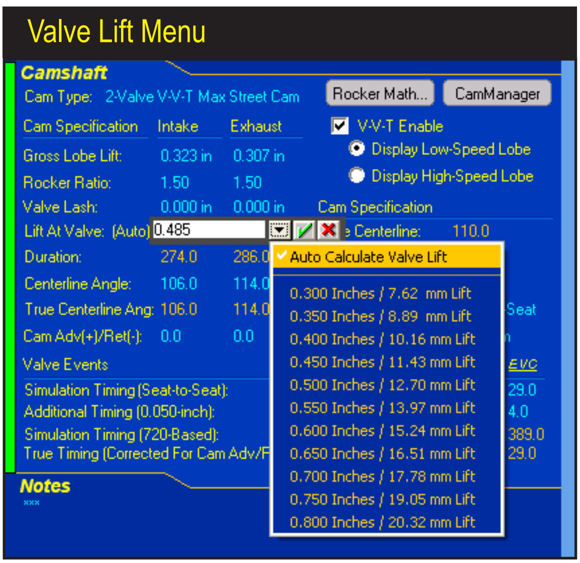
When you select a V-V-T cam from the **Cam Type** menu in the **CAMSHAFT** category, or you import/load a V-V-T cam (see the *CamManager™* on page 115), *Variable Valve Timing* modeling will be activated, as indicated by a checkmark in the **V-V-T Enable** box and next to the **Variable Valve Timing** box within the CamManager, however, you can activate or deactivate *Variable Valve Timing* at any time. When activated, *Low-Speed Lobe* timing will be used in the simulation until the engine reaches the *HS Lobe Activation* rpm, after which *High-Speed Lobe* timing will be used.

Note: When V-V-T is deactivated, by unchecking the **V-V-T Enable** checkbox, only the remaining *Low-Speed Lobe* timing will be used in the simulation.

You can also create a V-V-T cam from "scratch" to meet any requirement. For example, if you have found a non-V-V-T camshaft that produces good low-speed performance and another cam that produces good high-speed power, you can "combine" the two cams in DynoSim5. Here's how: First, import the low-speed lobe or enter the low-speed cam timing (see page 101). When all low-speed data has been entered, the simulation will be performed. Next, activate V-V-T camshaft modeling (by clicking the **V-V-T Enable** checkbox). The CAMSHAFT category indicator may switch to RED, indicating that the category is not complete. Now, click on the **Display High-Speed Lobe** radio button and enter the cam timing for the High-Speed Lobe. When complete, the simulation will model the original Low-Speed camshaft up to the **HS Lobe Activation** speed, after which High-Speed timing will be used.

The Valve-Lift Menus And The *Auto Calculate Valve Lift* Feature

Typically, the **Intake** and **Exhaust Lift-At-Valve** menus display the valve lift (maximum lift at valve) for the currently-selected camshaft, regardless of whether the cam was chosen from the **Cam Name** menu or loaded from as CamFile using the **CamManager** (see page 115). At any time you may manually enter custom valve-lift values in either menu and instantly see the results in the simulated power and torque curves displayed on the right side of the main program screen. You may select any of the predetermined valve lifts listed in the menus, or you may select ***Auto Calculate Valve Lift*** (turned off, by default) that is available as the first choice from either **Lift-At-Valve** menu. When Auto Calculate is enabled, DynoSim5 will automatically calculate intake and exhaust valve lifts, a useful feature if you wish to enter custom cam timing for which you do not know specific valve lifts, or if you wish to "scale" the valve lift of a known camshaft to better match the current engine (for example, if you use a bigblock cam in a smallblock engine). In these cases, ***Auto Calculate Valve Lift*** will provide the appropriate intake and exhaust valve lift heights based on current valve-head diameters and camshaft timing. The Auto-Calculation feature can be suspended and, instead, fixed lift values will be



Selecting (placing a check mark next to) *Auto Calculate Valve Lift* will automatically calculate appropriate valve lifts for camshafts listed in the Camshaft Type drop-down menu. To manually select valve lift from the drop-down menu, or to directly enter a custom value, make sure that the Auto Calculate Valve Lift feature is turned off (no check mark next to Auto Calculate).

used for any camshaft when you re-select **Auto Calculate Valve Lifts** (to turn it off by “unchecking” it).

Note 1: ***Auto Calculate Valve Lifts*** *will be turned off automatically when any CamFile is loaded, since each CamFile usually represents a “real-world” cam that has specific valve lifts associated with it (ground-in by the manufacturer).* However, you can turn valve lift Auto-Calculation back on at any time by reselecting it from the menus.
Note 2: If **Valve Diameters** are also being automatically calculated (see page 40)—cylinder-bore diameter and a cylinderhead selection must be completed before the program can calculate valve diameters and, consequently, valve lifts.

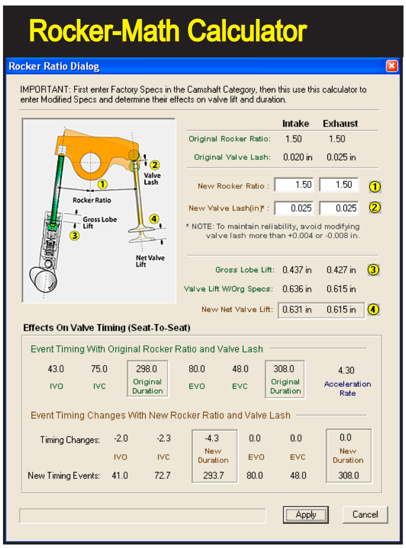
Rocker-Math Calculator (Exclusive DynoSim5 Feature)

The Camshaft Category includes a powerful ***Rocker-Math Calculator*** tool that can help you determine how and why changes in *Rocker Ratio* and *Valve Lash* affect engine output.

> **IMPORTANT:** It is important that you follow this simple rule when using *Rocker Math*: Enter the original manufacturer’s (baseline) specifications for *Rocker-Ratio* and *Valve Lash* in the Camshaft Category ***FIRST!*** Then, after the basic specs have been entered, use the *Rocker Math Calculator* to determine how CHANGES to these stock specifications will affect cam timing, valve lift, and engine power.

The *Rocker-Math Calculator* determines the changes to valve lift and valve-event timing that occur when valve lash and/or rocker-arm ratios are changed.
Rocker Ratio Changes: When rocker-arm ratio is modified, overall valve lift is affected directly by the increase or decrease in ratio. It is well known that an increase

It is important to follow a simple rule when using Rocker Math: *Enter the original cam manufacturer’s specifications for Rocker Ratio and Valve Lash in the Camshaft Category FIRST!* Then *use the Rocker Math Calculator to determine how CHANGES to these stock specifications will affect cam timing, valve lift, and engine power.*



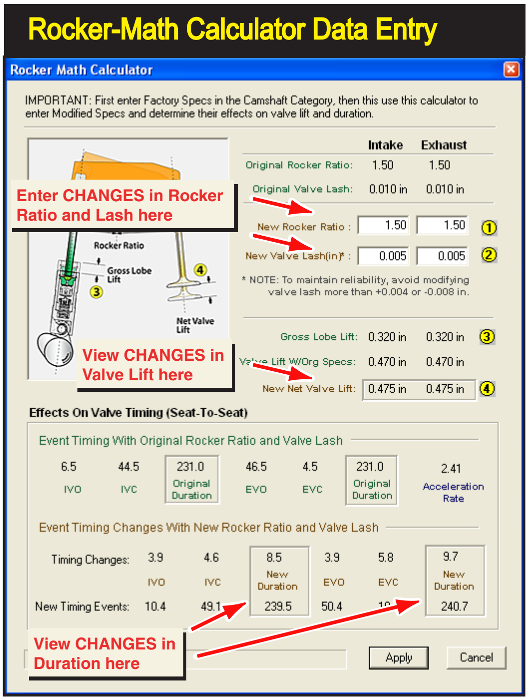
in rocker ratio will open the valve further and increase valve acceleration. But what is less known, is that rocker-ratio changes can also affect valve-open duration. Since rocker ratio directly controls "how fast" the running clearance is taken up before zero lash occurs, changes in rocker ratio changes the lobe-lifter contact position and, consequently, can slightly alter valve timing. Typically, rocker ratio changes from 1.5:1 to 1.6:1 can increase seat-to-seat duration by a degree or two, depending on the acceleration rates of the camshaft. The *Rocker-Math Calculator* will show you these subtle changes.

Valve Lash Changes: Interestingly, there are also two affects when changing valve lash. The first is the direct change in valve lift due to changes in lash. A reduction in lash opens the valve further by the same amount. But a more significant change is often overlooked entirely: Changing lash has a pronounced effect on seat-to-seat duration. Since the lifter is on the opening ramps when lash reaches zero, changes in lash affect *where* on the opening ramps the valvetrain reaches zero lash. And since the opening ramps are "shallow," slight changes in lash make a much larger change in the rotational position of the cam at the zero-lash point. In fact, reducing lash from 0.010-inch to 0.005-inch can add more than 10 degrees of seat-to-seat duration!

The *Rocker-Math Calculator* clearly shows the consequences of all changes made to lash and rocker ratios.

If you click **Apply** after entering rocker-ratio or lash changes, the new event timing and valve lift will be passed to the simulation.

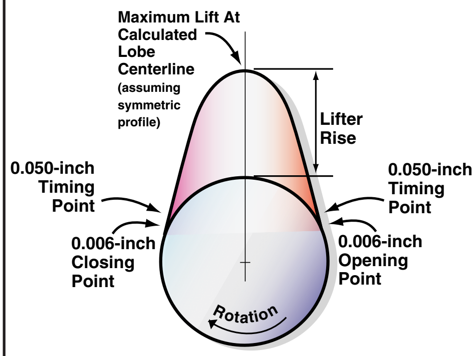
The *Rocker Math Calculator* will determine how CHANGES to valve lash and rocker ratio affect valve lift, event timing and engine power. Enter the CHANGED values of lash and rocker ratio in the four fields shown here (make sure you enter baseline "stock" values in the Camshaft Category first). The *Rocker Math Calculator* will determine new lobe-lifter contact positions (based on an analysis of lobe shapes and existing timing) and the new valve open duration will be calculated and displayed in the *Effects On Valve Timing (Seat-To-Seat)* area at the bottom of the dialog. If you click Apply, the new event timing and valve lift will be passed to the simulation.



Camshaft Modeling

DynoSim5 models valve motion and calculates valve acceleration from five data points for each lobe: 1) the seat-to-seat opening point, 2) the 0.050-inch opening timing point, 3) the point of maximum lift, 4) the 0.050-inch closing timing point, and 5) the seat-to-seat closing point. An exclusive feature of DynoSim5 is an entirely unique analysis of this data to accurately predict valvetrain acceleration. A simple range of valvetrain acceleration values from 1.00 (very low acceleration) to 6.00 (very high acceleration) let's you determine, at-a-glance, the performance characteristics of any cam profile.

Valve Motion Curves & Acceleration



Lobe Profiles Are Calculated From Seat-To-Seat and 0.050-inch Opening and Closing Points, And The Point Of Maximum Lift

Note: If you wish to "undo" changes made in the Rocker-Math Calculator (after they have been applied to the simulation), reopen the calculator and reenter the original rocker ratio and lash values; do not enter counter-acting values in the Camshaft Category.

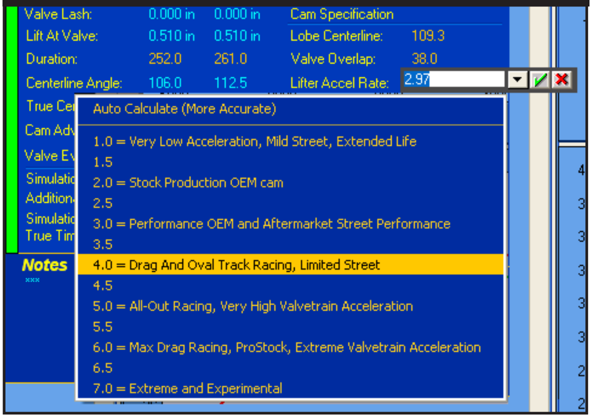
Lifter-Acceleration Menu

As mentioned, DynoSim5 uses an entirely new model to simulate lifter- and valvetrain acceleration. The ten common timing points associated with most camshafts (seat-to-seat and 0.050-inch valve opening and closing points plus peak valve lift points) are analyzed by the simulation to predict ramp-rate and overall valvetrain acceleration. From this analysis (and the valve opening an closing points, discussed in the next sections) DynoSim5 creates valve-motion curves that pinpoint valve position at each degree of crank rotation. The acceleration of the cam is rated with an overall value from 1.00 (very-low acceleration) to 7.00 (very-high acceleration). While previous models that produced only three steps of acceleration, the new technique provides a 500-step granularity that much more accurately models valvetrain acceleration rates generated by cams designed for street to ProStock applications. Using this easy-to-interpret value, you can determine, at-a-glance, the general performance characteristics of any camshaft.

Use the following guidelines to evaluate *Lifter Acceleration Rates* :

1.00 Very Low Acceleration, Mild Street, Extended Valvetrain Life
2.00 Stock Production, OEM Camshafts
3.00 Performance OEM and Aftermarket Street Performance
4.00 Drag and Oval Track Racing, Limited Street
5.00 All-Out Racing, Very High Valvetrain Acceleration
6.00 Maximum Drag Racing, Limited Valvetrain Life

Lifter-Acceleration Menu Selections



DynoSim5 can automatically determine the Lifter Acceleration rate by performing an analysis of valve timing specifications for the current camshaft. To enable this feature, select *Auto Calculate* from the Lifter Acceleration menu. If you cannot find all ten timing points, use the guidelines provided in the text to assist you in selecting the most appropriate rate (a value from 1.00 to 7.00).

7.00 Extreme And Experimental

Note: While the new algorithms used in this model have proven to be remarkably accurate, you should keep in mind that valve motion curves for both the intake and exhaust valves are calculated from only ten data points, five for the intake valve and five for the exhaust valve. Furthermore, DynoSim5 develops a valve motion curve that is biased toward symmetric (meaning that the "opening" side of the lobe has a nearly identical shape as the "closing" side). Asymmetric modeling is limited with only five data-input points per lobe, fortunately, performance differences between symmetric and asymmetric valve motions are often quite small. In most cases, the predicted ramp rates and valve motions within DynoSim5 are very accurate, but without knowing the precise shape of the cam at each degree of rotation, it is not possible to ensure accuracy 100% of the time.

Making The Best Lifter-Acceleration Choices

DynoSim5 can determine the Lifter Acceleration rate by performing an analysis of the valve-timing specifications for the current camshaft. To enable this feature, select ***Auto Calculate*** from the **Lifter Acceleration** menu. In order to complete the lobe-profile analysis, DynoSim5 must have all ten data points for the current cam (seat-to-seat and 0.050-inch opening and closing points plus peak valve lift points, entered in the **CAMSHAFT** Category, see photo on page 89). If all ten points are not available, the program will indicate a discrepancy. When all the points have been entered, Lifter Acceleration will be calculated and displayed in the **Lifter Acceleration** menu.

Note: All sample CamFiles provided with DynoSim5 and the 6000+ additional CamFiles included on ***CamDisk7™*** have complete cam specifications that allow DynoSim5 to automatically calculate Lifter Acceleration rates. For information on how to use

CamDisk7™ With 6000+ CamFiles

The new *CamDisk7*™ from ProRacing Sim Software includes 6000+ camfiles and all cam timing information required for DynoSim5 to automatically calculate the *Lifter Acceleration* rates. Use the new CamManager™ and Quick Iterator™ with CamDisk7 to automatically locate optimum profiles for any engine. CamDisk7 and DynoSim5 are, simply, the most powerful tools you can use to find the best cams for any application.

and search for CamFiles, refer to **Using The CamManager™** on page 115).

Manually Determining Lifter-Acceleration Rates

If you do not know all ten timing points for the current cam, DynoSim5 will be unable to automatically calculate the Lifter Acceleration, and therefore, it will not perform an engine simulation and display power and torque curves. In this case, you must manually enter Lifter Acceleration based on your understanding of the intended application of the camshaft. Use the guidelines provided in the previous section to assist you in selecting the most appropriate rate (a value from 1.00 to 6.00 must be entered in the **Lifter Acceleration** field in the **CAMSHAFT** component category).

If you are trying to determine the Lifter Acceleration for a specific camshaft (for which you lack timing specs), matching the intended application with the guidelines, as mentioned above, will generally give good results. However, testing has shown that some camshafts that "should" have higher acceleration (in the range of 3.5 to 4.5), in fact have considerable lower rates (from 2.5 to 3.5 or even lower). These camshafts will probably produce less power than similar cams with the same duration and lift, however, they may have been specifically designed for increased valvetrain reliability rather than optimum power. You may also come across camshafts that have actual acceleration rates considerably higher than you might have guessed by their application alone. In these circumstances, the acceleration value that you apply may produce as much as 10% higher (or lower) horsepower than real-world testing would reveal. Just because a camshaft has been given a name like "Ultimate High Performance" does not mean that it will have exceptional valvetrain acceleration. Similar cams from two different manufacturers may have very different acceleration values. So, if you have to "guess" the **Lifter Acceleration** value—and it is not possible to locate the missing timing points that would allow DynoSim5 to automatically calculate this value—keep in mind that you may be increasing potential variabilities in simulated power from ±5% to ±10% (even a really "bad guess" of Lifter Acceleration rarely affects power more than this).

If you are trying to determine Lifter Acceleration rates, don't be misled by the type of lifters the cam was designed to use. If the cam you're modeling is a street,

Comparing Cam Descriptions With Actual Acceleration Rates

Cam Type	Manufacturer Description	Guess Based On Guidelines	Calculated Acceleration	Comments
Solid-Roller For BigBlock Ford	Competition only, good upper RPM torque and HP, Bracket Racing, auto trans w/Drag Racing converter, 12.5 min. comp. ratio advised. Basic RPM 4400-7800.	4.5 to 5.2	5.0	The description of this cam is easy to analyze. Cam has acceleration that is typical for the application. Guess is accurate.
Solid Lifter For BigBlock Chrysler	Rough idle, performance usage, good upper RPM HP, Bracket Racing, auto trans w/3500+ converter, 11.0 to 12.5 compression ratio advised. Basic RPM 4200-7200.	4.0 to 4.5	2.5	This is a HP cam designed for drag racing. The low acceleration reduces potential performance but increases valvetrain life. Guess is too high.
Solid-Roller For BigBlock Ford	Rough idle, performance usage, good mid-range torque and HP, Bracket Racing, auto trans w/Drag Racing converter, 11.5 minimum compression ratio advised. Basic RPM 4000-7000.	4.0 to 4.5	5.6	This cam also requires high-stall converter, high-compression, etc. But this profile has very-high acceleration rates. A clue is the somewhat lower max rpm and claim of good mid-range. Guess is too low.
Hydraulic Lifter For Small Mopar	For street high performance and racing applications only, not heavy vehicles.	3.0 to 3.5	2.0	This is a HP cam designed for high performance. The low acceleration cuts a good chunk of power potential from this cam. Guess is too high.
Hydraulic Lifter For Small AMC	Good idle, moderate performance usage, good mid-range HP, Bracket Racing, 3200-3600 cruise RPM, 9.5 to 11.0 compression ratio advised. Basic RPM 2500-5500	2.3 to 3.0	2.4	The description fits the average acceleration for the category. Guess is accurate.
Solid Lifter For Ford Cleveland	Hot Street/E.T. Brackets. 10.5-11.5:1 compression using modified cylinder heads, large valves, Victor Jr. style intake, 750 cfm 4-barrel, and 3" diameter, free flowing exhaust produce good top end power. Automatic cars use 4,000 RPM converter and low gears. OK with nitrous!	3.5 to 4.2	2.7	Described as a performance camshaft requiring high compression, large valves, and a performance intake, you would expect this cam to have a more agressive acceleration rate. Will be low on mid-range power but easier on the valvetrain. Guess too high.
Solid Lifter For Small Chevy	Torque and mid-range power for Drag Racing and Oval Track. RPM Power Range: 2500 to 6500 / Redline: 7000 maximum.	3.8 to 4.5	4.1	Lower peak rpm and good mid-range power indicates higher acceleration. Wide rpm range suggets milder racing cam. Guess is accurate.
Solid-Roller For 351 Ford	Good for weekend cruiser w/9.0 comp, 2000 stall, and lower gears. Has noticeable idle. 2000-6000 RPM.	2.8 to 3.5	4.1	Here's a sleeper cam. But hints of good power with lower compression and limited top speed suggest higher acceleration. Guess too low.

DynoSim5 models valve motion and calculates Lifter Acceleration based on five timing points per lobe. If these timing specs are not available, you must "guess" an acceleration rate before the simulation can be completed. In many cases, you can accurately guess Lifter Acceleration (a value between 1.00 and 7.00) from a description of the intended application and from the guidelines presented in the text (cams that fall into this category are as shown in the green rows in above table). In some cases, the manufacturer's description may lead you to believe that the cam generates higher acceleration than it does (see the red rows). And in other cases, the camshaft description can understate the aggressive profiles used by the manufacturer (see the blue rows). If you cannot obtain the timing points required for DynoSim5 to perform a mathematical analysis of the cam (the most accurate method of estimating the Lifter Acceleration), keep in mind that estimates of acceleration may cause the simulation results to fall outside of the typical ±5% accuracy.

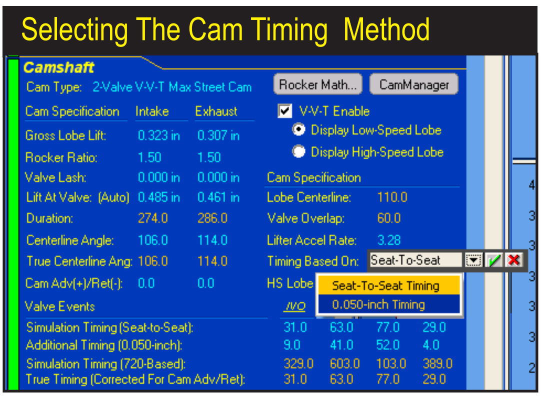
roller-lifter grind, it probably incorporates a low-acceleration profile. In these cases, keep acceleration values between 1.50 and 3.00. On the other hand, if the cam is a high-performance grind with roller lifters, acceleration is probably between 2.80 and 4.00. If you are modeling a solid-lifter racing cam, like some "mushroom" lifter grinds or a special SuperStock cam, the acceleration rates of these camshafts may be quite high, ranging from 4.0 to 5.5 or even higher. On the other hand, if the solid-lifter cam was developed as a replacement for a factory high-performance application, rates will be much lower, from 2.0 to 3.0.

Camshafts with high acceleration rates sometimes have a lower maximum rpm before valve float. If the engine is over-revved even slightly over the valvetrain limit, the damage from valve float can be severe. Since there are exceptions to just about everything, consider ProStock cams. Many of these cams have very high acceleration rates, but allow valvetrain speeds up to 9500rpm. How is this possible? Extreme valvespring pressures and constant valvetrain maintenance make this seemingly impossible situation, possible. However, if the performance cam you are analyzing is rated at a rather low peak speed, it may be an indicator that it has higher Lifter Acceleration rates than those indicated in the previous guidelines.

VALVE OPENING/CLOSING AND TIMING-METHOD MENUS

In addition to calculating (or manually entering) the acceleration rate of the lifter, and, therefore, categorizing the ramp rates of the cam profile, DynoSim5 must determine the opening and closing points of the intake and exhaust valves in order to accurately predict valve motion at each degree of crankshaft rotation throughout the entire four-stroke process (720-degrees of crank rotation). The simulation can determine the opening and closing points using two basic methods:

1) **Using *Seat-To-Seat cam timing* as the *Simulation* valve event timing to directly establish valve opening and closing points. This is the most reliable and accurate way to determine valve-event timing for simula-**



DynoSim5 will simulate camshaft motion for both Seat-To-Seat and 0.050-inch cam timing. However, the internal simulation requires seat-to-seat event timing to accurately calculate the beginning and end of mass flow in the ports and cylinders and must *derive* seat-to-seat timing from 0.050-inch figures. Unfortunately, this cannot be done perfectly. So, whenever possible enter seat-to-seat timing to obtain the most accurate simulation results.

tion purposes.

2) **Using *0.050-inch cam timing* as the *Simulation* valve events to *approximate* seat-to-seat timing that subsequently establishes valve opening and closing points. Only use this method when Seat-To-Seat timing values are not available. Since DynoSim5 must first "guess" the seat-to-seat timing from 0.050-inch values, this method inherently is less accurate.**

The method used to determine valve opening and closing points is selected with the **Valve Opening/Closing Based On:** menu. The notation "**Simulation**" will be placed next to either the **Seat-To-Seat** or **0.050-inch timing** groups (below the Valve Opening/Closing timing menu) to indicate the current timing used by the simulation. If you change the **Simulation** timing method, a warning message will be displayed and the ***Simulation*** notation will be moved to the other event-timing group. Changing the **Simulation** valve-event timing affects not only the simulation results, but also the calculated values displayed in the lower portion of the **CAMSHAFT** category: including *True IVO*, *True IVC*, *True EVO*, *True EVC*, *True ICA*, *True ECA*, *Intake Duration*, *Exhaust Duration*, *Intake Centerline (ICA)*, *Exhaust Centerline (ECA)*, *Lobe Center Angle (LCA)*, and *Valve Overlap*.

The following sections explain these common camshaft timing methods and gives useful advise on how to improve camshaft simulation accuracy by optimizing profile modeling in DynoSim5.

Seat-to-seat timing method—This timing method measures the valve timing—relative to piston position—when the valve or lifter has only just begun to rise or has *almost* completely returned to the base circle on the closing ramp. Unfortunately, there are no universal seat-to-seat measuring standards used in the camshaft-manufacturing industry. These are some of the more common seat-to-seat

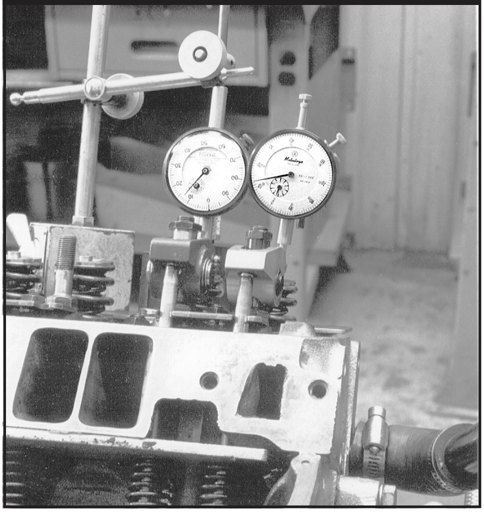
Seat-To-Seat and 0.050-inch Cam Timing Groups

Valve Events	IVO	IVC	EVO	EVC
Simulation Timing (Seat-to-Seat):	31.0	63.0	77.0	29.0
Additional Timing (0.050-inch):	9.0	41.0	52.0	4.0
Simulation Timing (720-Based):	329.0	603.0	103.0	389.0
True Timing (Corrected For Cam Adv/Ret):	31.0	63.0	77.0	29.0

Notes

DynoSim5 will accept both Seat-To-Seat and 0.050-inch cam timing specifications. The timing set that is currently used to determine valve opening/closing points is marked as *Simulation Timing*. If both sets of timing data and the intake- and exhaust-valve lifts are entered, DynoSim5 can automatically calculate the Lifter Acceleration rate, as discussed in the previous section.

Seat-To-Seat Timing Method



Seat-to-seat timing measures the valve timing—relative to piston position—when the valve has just begun to open. Here dial indicators are positioned on the valvespring retainers and are measuring valve rise, which is the most common technique used with seat-to-seat timing (0.020-inch LIFTER rise is a notable exception used for solid lifter camshafts to compensate for lash in the valvetrain). Timing specs measured using these methods are meant to approximate the actual valve opening and closing points that occur within the running engine. Because of this, seat-to-seat valve events are often called the *advertised* or *running* timing and will always produce the most accurate simulations.

timing methods:

- **0.004-inch LIFTER rise** for both intake and exhaust (SAE Standard)
- **0.006-inch VALVE rise** for both intake and exhaust (SAE Standard)
- **0.007-inch open/0.010-close VALVE rise** for both valves
- **0.010-inch VALVE rise** for both intake and exhaust
- **0.020-inch LIFTER rise** for both intake and exhaust (For Solid Lifters)

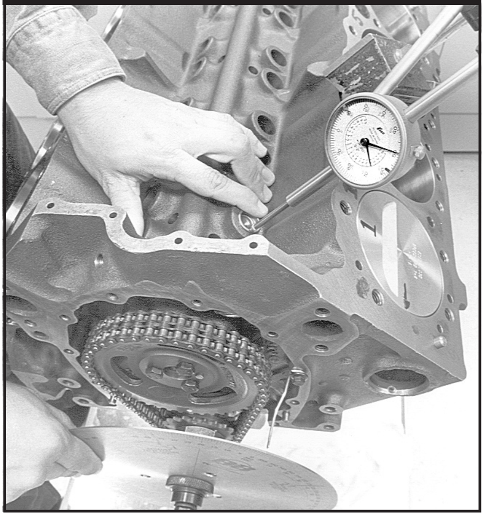
The timing specs measured using these methods are meant to approximate the actual valve opening-and-closing points that occur within the running engine. Because of this, seat-to-seat valve events are often called the *advertised* or *running* timing. DynoSim5 needs this event information to fix the beginning and end of mass flow into and out of the ports and cylinders, a crucial step in the process of determining cylinder pressures and power output. ***Because of this, selecting Seat-To-Seat timing specifications as the Simulation method to determine valve opening and closing will produce the most accurate results.***

Note: There is a seat-to-seat measuring standard (the SAE 0.004-inch Lifter Rise or 0.006-inch Valve Rise), but there is also a great deal of variation from this standard from cam manufacturers for “cataloging” or “advertising” purposes. These variations can easily confuse for anyone trying to enter timing specs into an engine simulation program. If you use seat-to-seat timing specifications that fall into any of the categories shown above, you should obtain accurate results. *Any timing specifications obtained at less than 0.004-inch lifter rise or 0.006-inch valve rise will not produce accurate results in DynoSim5.*

0.050-inch cam timing—This timing method is widely used and standardized

Camshaft Modeling

0.050-Inch Timing Method



The 0.050-inch lifter rise cam timing method measures valve timing when the lifter has risen 0.050-inch off of the base circle of the cam. In the setup pictured here, the dial indicator is positioned on an intake lifter; the 0.050-inch valve timing point can now be read directly off of the degree wheel attached to the crankshaft. Timing specs measured using this method <u>are not meant</u> to approximate the actual valve opening and closing points, instead their purpose is to permit accurate cam installation. All 0.050-inch timing specs entered into DynoSim5 are <u>internally converted</u> to seat-to-seat timing. Because there is no way to precisely perform this conversion, always try to obtain and use seat-to-seat event timing to optimize simulation accuracy.

by cam manufacturers. 0.050-inch cam timing points are always measured at:

0.050-inch LIFTER rise for both intake and exhaust.

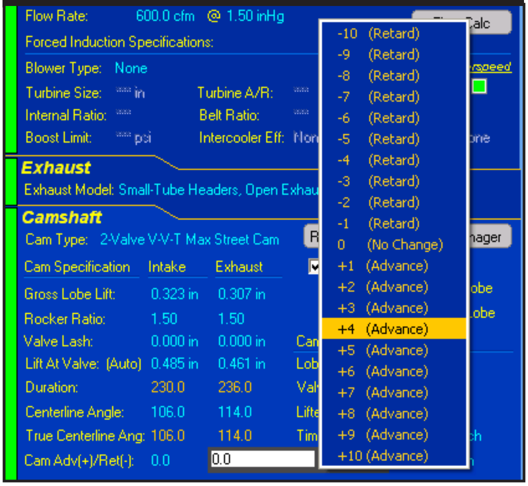
This measurement technique is based on the movement of the cam follower (lifter) rather than the valve. Since the lifter is well into the cam acceleration ramps at 0.050-inch lift, this technique provides an accurate "index" for cam-to-crank positioning, and is a wonderful way to verify the installation (index) of a camshaft. However, 0.050-inch timing does not pinpoint when the intake and exhaust valves open or close; the essential data needed to perform an engine simulation. While you will always find 0.050-inch-lifter-rise timing points published on the cam cards and in many cam manufacturer's catalogs, if you chose 0.050-inch timing as the ***Primary*** timing method, DynoSim5 must convert 0.050-timing to seat-to-seat values. And unfortunately, this often introduces some error into valve-motion calculations. ***Whenever possible, use Seat-To-Seat timing specifications as the <u>Primary</u> method to obtain the most accurate simulation results.***

DynoSim5 **CAMSHAFT** Category displays both the Seat-To-Seat and 0.050-inch cam timing points. As mentioned earlier, if you enter both sets of timing values, the simulation can automatically calculate **Lifter Acceleration** (select ***Auto Calculate*** from the **Lifter Acceleration** menu). The calculated lifter acceleration, combined with Seat-To-Seat ***Primary*** timing points (always use Seat-To-Seat for the Primary method when this data is available), allows DynoSim5 to most accurately model valve motion. This will produce the most accurate predicted power and torque for the simulated engine.

Camshaft Advance/Retard Menus

Camshaft Advance/Retard

Advance/Retard Menu



DynoSim5 allows direct entry of camshaft advance or retard. Changing this specification from zero (the default) to a positive value advances the cam; negative values retard the cam. See text for more information on how these changes affect engine output.

DynoSim5 allows direct entry of camshaft advance or retard. Changing these specifications from zero (the default) to a positive value advances the cam (in crank degrees) while negative values retard the cam.

Note: DynoSim5 will allow individual advance/retard values for intake and exhaust lobes to allow DOHC valvetrain modeling.

Why advance or retard a cam? For single-cam engines, it is just about the only valve-timing change available to the engine builder after the camshaft has been purchased. While it is sometimes possible to improve performance using this technique, let's investigate what happens when all valve events are advanced or

Single-Cam Advance And Retard

Race Car Dynamics **manufacturers this beefy adjustable cam drive that makes it relatively easy to vary cam advance and retard on engines with single camshafts. Most cam manufacturers recommend installing their camshafts "heads-up," or at the recommended specifications. In addition, advancing or retarding the cam will alter piston-to-valve running clearance. Make sure you have thoroughly tested the engine at cam advance/retard positions before you use it for tuning purposes.**

retarded in unison from manufacturer's recommended values (the only possibility in a single-cam engines).

Advancing Or Retarding A Single-Cam Engine

It is generally accepted that advancing the cam improves low-speed power while retarding the cam improves high-speed power. When the cam is advanced, IVC and EVC occur earlier and that can improve low-speed performance; however, EVO and IVO also occur earlier, and these changes tend to improve power at higher engine speeds, but to a lessor extent. The net result of these "conflicting" changes typically is a slight boost in low-speed power. The same goes for retarding the cam. Two events (later IVC and EVC) boost high-speed power and two (later EVO and IVO) boost low-speed performance, but again, to a lessor extent. The net result is a slight boost in high-speed power.

Advancing or retarding a camshaft in a single-camshaft engine has the overall affect of reducing valve-timing efficiency in exchange for slight gains in low- or high-speed power. Consequently, many cam manufacturers recommend avoiding this tuning technique. If advancing or retarding allows the engine to perform better in a specific rpm range, the cam profile was probably not optimum for the engine in the first place. More power can be found at both ends of the rpm range by installing the right cam rather than advancing or retarding the wrong cam. However, if you already own a specific camshaft, advanced or retarded timing may slightly "fine tune" engine output.

Advancing Or Retarding Camshaft Timing In DOHC Engines

Tuning DOHC engines with individual intake and exhaust cams is a straightfor-

DOHC Cam Sprockets

In DOHC engines, like the Honda VTEC and many other "sport-compact" engines, where separate cams are used for the intake and exhaust lobes, the advance/retard values can be set independently for the intake and exhaust lobes. In the real world, this same modification is easily accomplished with adjustable cam sprockets, like these from ZEX. Adjustable timing sprockets can also compensate for milled deck and head surfaces that can often result in retarded cam timing.

ward process in DynoSim5. While changing cam timing on an engine with a single cam forces you to change ALL lobes the same amount and in the direction—often reducing any benefits you may have gained—on DOHC engines with the ability to move each cam independently, cam tuning takes on a whole new significance. While properly selected cams often produce peak power (or torque) when installed "heads-up," or without any advance or retard, many engine builders have found improvements by advancing one cam and retarding the other. This is especially true in turbocharged applications, where advancing the intake cam and retarding the exhaust cam increases the Lobe-Separation Angle (also called the Lobe-Centerline Angle), reducing valve overlap, which sometimes improves forced-induction efficiency.

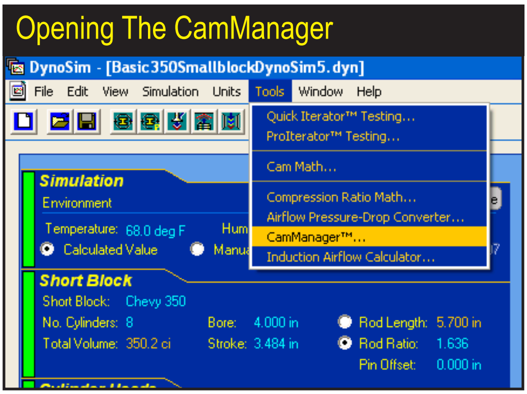
Dyno testing has shown that it is sometimes impossible to predict how the engine will respond to intake- or exhaust-cam advance and retard. This is may be due to subtleties in the induction and exhaust systems. While DynoSim5 will give you valuable feedback, this fine-tuning process should be confirmed on a real-world dynamometer.

> **Note:** DynoSim5 will let you alter cam timing by up to +/-15-degrees, so make sure you keep in mind that changing cam advance or retard on a real engine this much will radically alter valve-to-piston clearance. Changing cam timing by 4-degrees or less will rarely cause interference problems, however, it is always the engine builder/tuner's responsibility to check this important dimension, especially if you are using high-performance camshaft timing. Just starting and idling an engine with piston-to-valve interference can damage valves, break cams, and bend valvetrain components.

Using The CamManager™

The Advanced and ProTools versions of DynoSim5 incorporate a powerful, new tool: ***The CamManager*™**. This feature, available by clicking on the ***CamManager*** button in the **CAMSHAFT** category (or selecting ***CamManager*** from the **Tools** menu) will help you understand, analyze, create, and modify camshafts for any engine application. The *CamManager* is also the "central clearing house" through

Open the *CamManager* from the *Tools* drop-down menu or click the CamManager QuickAccess™ Button in the CamShaft Category. The CamManager will help you understand, analyze, create, and modify camshafts for any engine application.



which you can load, save, and search for *CamFiles*™ (camshaft data files ending in **.CAM** specifically designed for DynoSim5). Before we present a detail look into the capabilities of the *CamManager*, here is a quick overview of how to use the main features of this cam-analysis tool:

—Loading CamFiles: Open the *CamManager*, click on the ***Open*** button at the bottom of the dialog box, locate the **CamFile (.CAM)** folder (or one of its subfolders) and select the CamFile you wish to test. Press the ***Apply*** or ***OK*** button to load the CamFile into the **CAMSHAFT** Category and update the simulation with the new cam specs.

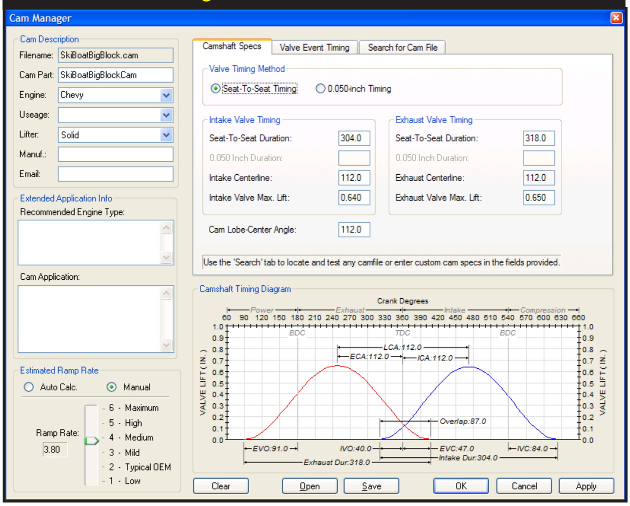
—Saving CamFiles: Open the *CamManager*, click on the ***Save*** button at the bottom of the dialog box, locate the **CamFile (.CAM)** folder (or one of its subfolders) and save the current CamFile to your hard drive.

Important Note: If you enter or change any cam specifications within the *CamManager* after saving or retrieving CamFiles, the *CamFile **data** will automatically be saved with the engine (.DYN) file* when you click on the ***Apply*** or ***OK*** buttons. However, the *CamFile itself will not be updated* unless you click on ***Save*** and update the CamFile on your hard disk.

—Entering or Modifying "Published" Cam Specifications: Open the *CamManager*, if necessary, click on the ***Camshaft Specs*** tab (top of screen), chose the ***Primary*** valve timing method by selecting either the ***Seat-To-Seat*** or the ***0.050-inch Timing*** radio button, enter or change any displayed ***Valve-Timing*** specifications. Press the ***Apply*** or ***OK*** button to load the new/modified cam specifications into the **CAMSHAFT** Category and update the simulation.

—Entering or Modifying Valve-Timing Events: Open the *CamManager*, if necessary, click on the ***Valve Event Timing*** tab (top of screen), chose the *Primary* valve timing method by selecting either the ***Seat-To-Seat*** or the ***0.050-***

The CamManager™



The new *CamManager*™ is a powerful "mini-application" built into DynoSim5. This comprehensive cam-analysis tool offers complete control and visualization of all cam timing specifications. Use this tool to convert published cam-timing specs (like duration) to valve-events (like IVO, IVC, etc.). Enter and modify any cam-related information or technical specifications. Select the Primary timing method. And use the powerful search features to locate a "real-world" camshaft that matches any range of timing values.

inch Timing radio button, enter or change any displayed ***Valve-Event Timing*** specifications. Press the ***Apply*** or ***OK*** button to load the new/modified cam specifications into the **CAMSHAFT** Category and update the simulation.

Important Note: If you enter or change any cam specifications within the *CamManager*, the *CamFile* ***data*** *will automatically be saved with the engine (.DYN) file* when you click on the ***Apply*** or ***OK*** buttons. However, the *CamFile itself will not be updated* unless you click on ***Save*** and update the CamFile on your hard disk.

—Searching For CamFiles: (This feature is only available in DynoSim5) Open the *CamManager*, if necessary, click on the ***Search For CamFile*** tab (top of screen), enter search terms if you would like to search for a specific filename or cam description, if you wish to locate cams that closely match the current valve timing leave the "***Find the following specs***" box checked, then press the ***Search*** button. Select a cam from the results list. Press the ***Apply*** or ***OK*** button to load the new CamFile into the **CAMSHAFT** Category and update the simulation.

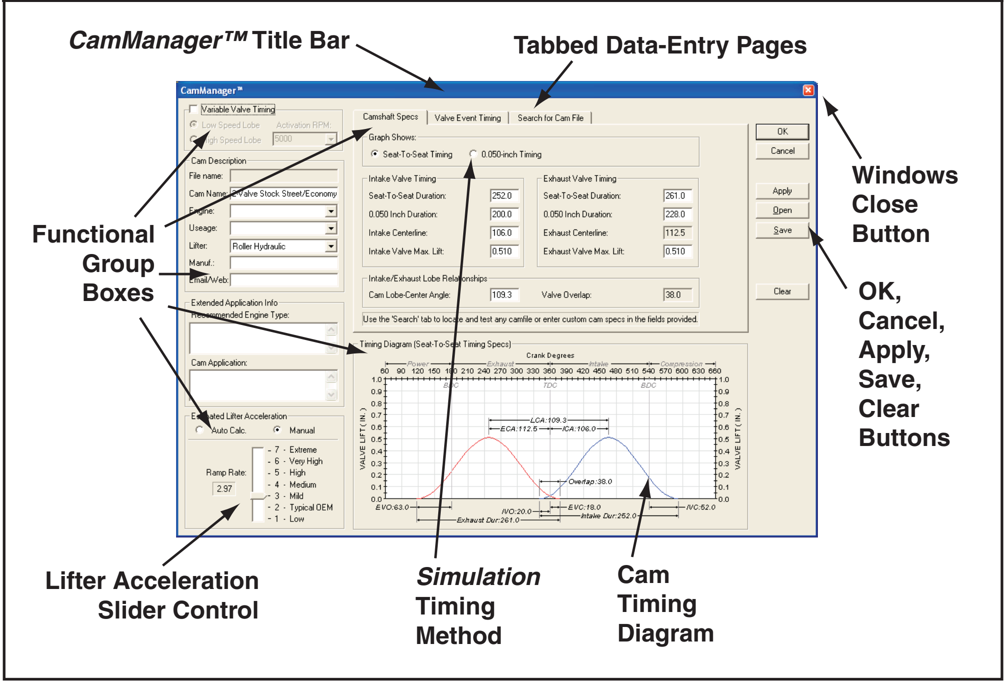
The *CamManager™* In Detail

The *CamManager* incorporates a wide range of functionality that has never been available to the performance enthusiast in one integrated package. In fact, the *CamManager* alone consists of more programming code than the entire first version of this engine simulation (DeskTop Dyno5 released in 1984). Great care was used in the design of this feature to make it as intuitive and easy-to-use as possible. To optimize usability, the *CamManager* is divided into functional "groups"; each group is displayed within a titled box or on a "tabbed" page 118. For example, when the *CamManager* is first opened (by clicking on the *CamManager* button in the CAMSHAFT category, or by selecting *CamManager* from the Tools menu, or by clicking on the *CamManager Icon* in the Toolbar), you will see the ***Cam Description*** group in the upper-left corner of the dialog box. Below that are the ***Extended Application Info*** and ***Estimated Lifter Acceleration*** groups. There are three ***Tabs*** available in the top-center of the dialog box that access the ***Camshaft Specs***, ***Valve-Event Timing***, and ***Search For CamFiles*** pages. In the lower portion of the dialog is the ***Camshaft Timing Diagram***. This dynamic graphic shows all critical valve-timing specifications and is updated immediately when any timing specification is changed. Each group within the *CamManager* has a distinct function that is detailed below:

Cam Description Group (upper-left corner)—Basic information about the current cam is displayed in this group. The ***Filename*** field contains the name of the displayed CamFile, if saved on your hard disk, the ***Cam Name*** is a short description, the ***Engine*** field indicates the engine family for which the camshaft was designed, the ***Usage*** field indicates the intended application, the ***Lifter*** field displays the lifter technology used with this cam (this is an information only field; it has no affect on the simulation), the ***Manufacturer*** field shows the

Using The *CamManager*™

The CamManager™ Features And Functional Groups



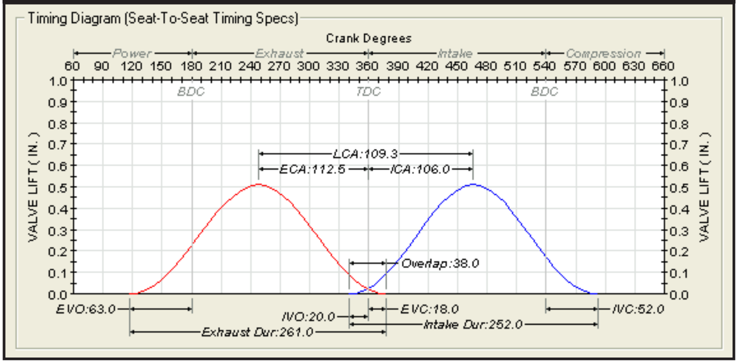
The *CamManager*™ incorporates a wide range of functionality that has never been available to the performance enthusiast as one integrated package. Great care was used in the design to make this tool as intuitive and easy-to-use as possible. To this end, the *CamManager* is divided into functional "groups"; each group is displayed within a titled box or on a "tabbed" page.

manufacturer/designer of the cam, and the ***Email/Web*** field provides a contact address. The ***Engine***, ***Usage***, and ***Lifter*** fields have suggested entries available in drop-down menus. And although you can enter any data into the fields in this group (except for the Lifter field), we recommend that you select choices from the drop-down menus whenever possible. This will help maintain consistency that will improve the accuracy of CamFile searches in the future.

Extended Application Info (left-center of screen)—A more detailed description of the intended usage and the operational characteristics of the cam and engine are provided in this group. The ***Recommended Engine Type*** field lists the specific engines for which the cam was designed. The ***Cam Application*** field contains detailed descriptions of cam specs, operation, requirements, and characteristics. The information in this group has often been obtained from cam manufacturer's catalog listings. You can edit, modify, or add information to both of these fields.

Using The *CamManager*™

"Twin-Hump" Valve Timing Diagram

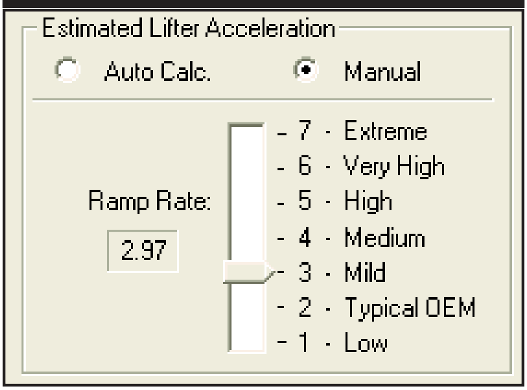


The "Twin-Hump" valve-motion diagram in the CamManager is dynamically updated whenever timing specifications are changed, including the Timing Method and *Lifter Acceleration Rate* (see text).

Camshaft Timing Diagram (lower-right on screen)—This graph, often called a two-hump diagram, shows valve position throughout the 720 degrees of crank rotation (Note: The 120-degrees of crank rotation during which the intake and exhaust valves are closed is not illustrated). Exhaust valve motion is shown on the left in red; the intake valve motion is in blue on the right. The valve timing points (IVO, IVC, EVO, and EVC), overlap, duration, centerlines, and lobe-center angle are all detailed on the graph. In addition, maximum valve lift is illustrated by the height of the curves. This dynamic graphic is updated immediately when any timing specification is changed, even *Lifter Acceleration*. To see the effects of changing *Lifter Acceleration*, click on the ***Manual*** button in the *Estimated Lifter Acceleration* group and move the ***Slider*** up and down. You will see the curves get "fatter" for higher acceleration valves and "thinner" for low acceleration.

Estimated Lifter Acceleration (lower-left of screen)—As discussed earlier, DynoSim5 can estimate Lifter (valve) acceleration. The acceleration is used to

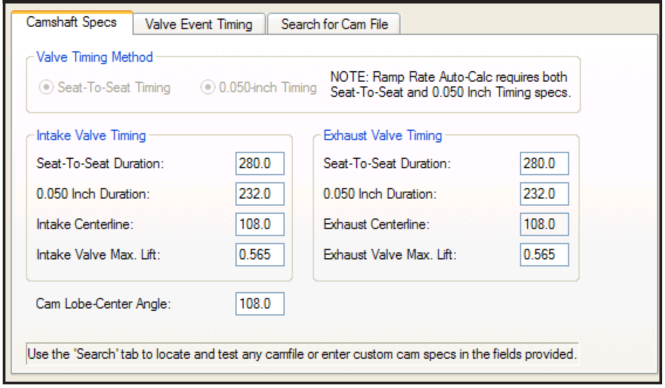
Estimated Lifter Acceleration



If DynoSim5 has sufficient data (all ten timing points, as mentioned in text), it will calculate and display the Lifter Acceleration (the *Auto Calc* radio button will be selected). You can disable automatic calculation by activating the *Manual* radio button. Then move the slider to any desired value. Changes in acceleration will be reflected in the valve-motion curves.

Using The *CamManager*™

Camshaft Specs "Tabbed" Data Page



This page, displayed by default whenever the *CamManager* is opened, shows seat-to-seat and 0.050-inch "published" cam specifications found in many manufacturer's catalogs. Included are *Duration, Centerline*, *Overlap*, and *Valve Lift* values. Data entered on this page will update the *Valve-Event Timing* (next) tabbed page.

determine the "shape" of the valve-motion curve. The greater the acceleration, the larger the area under the curve and the higher average valve lift throughout the valve-motion cycle. However, in order to calculate Lifter Acceleration, DynoSim5 needs both the *Seat-To-Seat* and *0.050-inch Valve-Event Timing* points, in addition to the maximum valve lift for both the intake and exhaust valves. If both data sets are available, the ***Auto Calc*** radio button can be activated and ***Lifter Acceleration*** will be calculated and displayed. If DynoSim5 does not have sufficient data, an error dialog will indicate the discrepancy. Regardless, you can click on the ***Manual*** radio button and directly select the Acceleration by dragging the ***Slider*** to the desired point. The results of changing the acceleration, as mentioned above, will be visible in the changing shape of the curves displayed in the **Camshaft Timing Diagram**.

Tabbed Data Pages (upper-right portion of screen)—Three data entry- and display-pages are available as tabbed screens at the top of the *CamManager*.

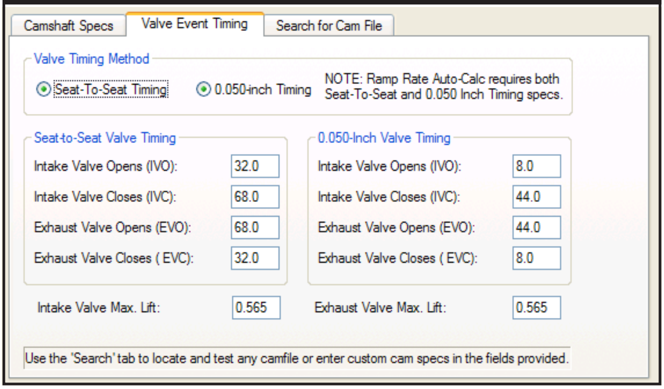
Camshaft Specs* Tabbed Page**—The first tabbed page, displayed as default whenever the *CamManager* is opened, shows the typical "published" cam specs found in manufacturer's catalogs. Included are ***Centerline, ***Overlap***, and ***Valve Lift*** values. If you enter this data (except *Overlap*, which is calculated), and *either* the seat-to-seat or 0.050-inch ***Duration*** values for both the intake and exhaust valves, DynoSim5 will calculate the valve-event timing (IVO, IVC, EVO, EVO, etc., displayed on the *Valve-Event Timing* tabbed page). If you enter *both* seat-to-seat and 0.050-inch ***Duration*** values (completing all data fields on this tabbed page), DynoSim5 will calculate ***Lifter Acceleration*** in addition to valve-event timing (***Auto Calc*** must be selected in the *Estimated Lifter Acceleration* group).

***Valve-Event Timing* Tabbed Page**—The second tabbed page shows the valve-event timing for both seat-to-seat and 0.050-inch timing methods. Included

Using The *CamManager*™

This data-entry page shows valve-event timing for both the seat-to-seat and 0.050-inch methods. Displayed are *IVO, IVC, EVO, and EVC*; in addition *Maximum Valve Lifts* are also displayed. When data is entered on this page, the *CamManager* will update the *Camshaft Specs* (previous) tabbed page.

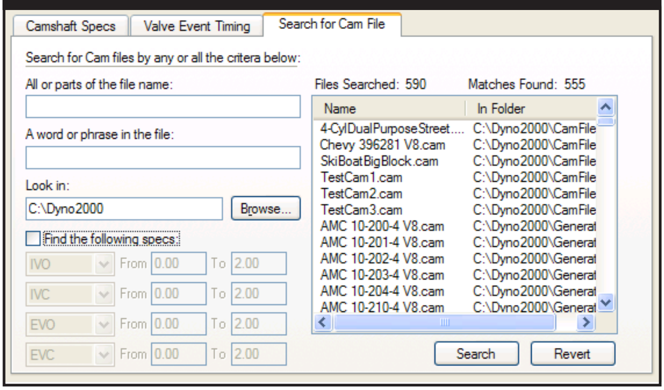
Valve-Event Timing “Tabbed” Data Page



are ***IVO***, ***IVC***, ***EVO***, *and* ***EVC***; in addition ***Maximum Valve Lifts*** are also displayed for convenience. If you enter this data for seat-to-seat and/or 0.050-inch timing values, DynoSim5 will calculate the Camshaft Specs (displayed on the previous *Camshaft Specs* tabbed page). If you enter both seat-to-seat and 0.050-inch valve timing values (completing all the data fields on this tabbed page), DynoSim5 also will be able to calculate ***Lifter Acceleration*** (***Auto Calc*** must be selected in the *Estimated Lifter Acceleration* group).

Simulation Timing Method* Selection**—As discussed earlier (see pages 109 to 112), the ***Simulation timing method establishes how the simulation determines valve opening and closing points. You an select the ***Simulation*** method from within the *CamManager* on either the *CamShaft Specs* or *Valve-Event Timing* Tabbed Pages (duplicates function of selecting ***Valve Opening/Closing Based On*** in the CAMSHAFT component category). Using ***Seat-To-Seat Timing*** as ***Simulation*** valve event timing directly establishes the valve opening and closing points. This is the most reliable and accurate way to determine valve-event

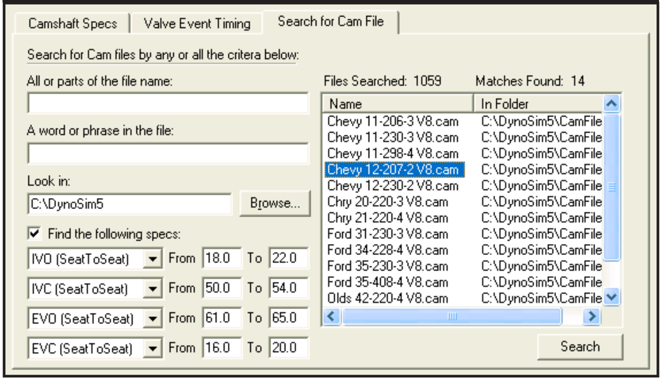
Search For CamFiles “Tabbed” Data Page



The *Search For CamFiles* data page (not available on the DeskTop Dyno5) helps you locate CamFiles for your test engine. Search through thousands of CamFiles and locate only those that meet your criterion. A powerful feature allows you to find “real-world” cams that match or nearly-match any custom timing you may have discovered using DynoSim5 *Iterator*™!

Using The *CamManager*™

Search For CamFiles Match Current CamSpecs



By checking *Find The Following Specs*, the *Search* function will only find CamFiles that fall within a range of timing values centered around current camshaft timing (current timing is the cam timing currently used in the simulated engine). This can be very helpful in finding a "real world" cam that matches timing specs you have determined work well in your engine.

timing for engine simulation purposes. Using ***0.050-inch Timing*** as ***Simulation*** event timing forces the simulation to perform *approximations*. Only use this method when *Seat-To-Seat* timing values are not available.

Note: Using ***0.050-inch Timing*** as ***Simulation*** event timing forces DynoSim5 to "guess" seat-to-seat timing from 0.050-inch values. This method is less accurate. Whenever possible, use *Seat-To-Seat cam timing* specifications as the ***Simulation*** timing method to obtain the most accurate simulation results.

Search For CamFiles* Tabbed Page**— (This feature is only available in DynoSim5) The third tabbed data page provides unprecedented versatility in locating CamFiles for your test engine. Search through thousands of CamFiles and locate only those that meet any criterion you establish. For example, find all the Bracket-Racing cams designed for a Smallblock Chevy, or locate all cams that closely match the specifications discovered in an ***Iterator™ test series (more on the *Iterator* on pages 132 and 135). To use this powerful tool, first (this step is optional) enter any search terms into the ***Criteria*** fields if you would like to search for specific filenames or cam descriptions. Next, if you would like to locate CamFiles that fall within a range of timing values centered around the current camshaft timing (the current cam is the cam currently installed in the simulated engine); if so, check the ***Find The Following Specs*** checkbox. Finally, click the ***Search*** button to locate all CamFiles starting in the folder listed in the ***Look In*** field *and in any folders that are nested below that folder* (a full *recursive* search is performed). When a list of matching CamFiles is presented, simply click on any file to view its characteristics (you may use the up-and-down arrow keys to quickly move through the results list). Transfer any CamFile into the **CAMSHAFT** component category on the *Main Program Screen* and into the simulated engine by clicking ***Apply*** ("installs" the cam and leaves the *CamManager* open) or ***OK*** ("installs" the cam and quits the *CamManager)*.

Note: If you would like to extend the search capabilities of the CamManager, the ***CamDisk7***™ will add more than 6000 CamFiles to those supplied with DynoSim5 (***CamDisk7*** is an optional data resource CD available from ProRacing Sim, LLC., see page 107 and www.ProRacingSim.com for more information).

Important Note: If you change any cam specification within the *CamManager* after saving or retrieving CamFiles, the new *CamFile **data** will automatically be saved with the engine (.DYN) file* when you click on the ***Apply*** or ***OK*** buttons. However, the *CamFile itself will not be automatically updated* unless you click on ***Save*** within the CamManager and update the CamFile on your hard disk.

The *CamMath QuickCalculator*™

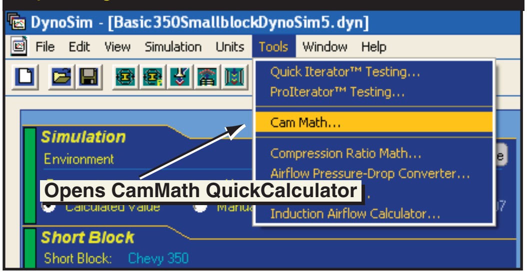
The basic four valve events (IVO, IVC, EVO, EVC) are required for DynoSim5 to pinpoint when the intake and exhaust valves open and close. The IVO and EVO signal the beginning of mass flow in the intake and exhaust ports. The closing points, IVC and EVC, mark the end of mass flow. Unfortunately, many cam catalogs and other printed materials ONLY publish the lobe center angles and duration values, leaving the conversion to IVO, IVC, EVO, and EVC up to the frustrated simulation user.

While these conversions can be accomplished in the powerful, new *CamManager*, DynoSim5 has an updated version of the simple-to-use calculator called the ***CamMath QuickCalculator***™. It instantly converts the lobe-center angle, intake centerline, and the duration values into IVO, IVC, EVO, and EVC valve events. By clicking the ***Apply*** button, the new event-timing values can be loaded into the **CAMSHAFT** Category and used in the simulation.

Note: In order for the ***CamMath QuickCalculator*** to determine all four valve events, BOTH the lobe-center angle AND the intake centerline must be available. Without the intake centerline, there is no way to determine how the cam is "timed" or "indexed" to the crankshaft. Many, unfortunately not all, cam manufacturer catalogs provide sufficient information to use the ***CamMath QuickCalculator*** to determine valve event timing. If you have a catalog that does not provide this information, try another cam manufacturer, or consider purchasing the ***CamDisk7*** from ProRacing Sim Software that provides over 6000 read-to-use CamFiles for DynoSim5 (see page 107 and www.ProRacingSim.com for more information).

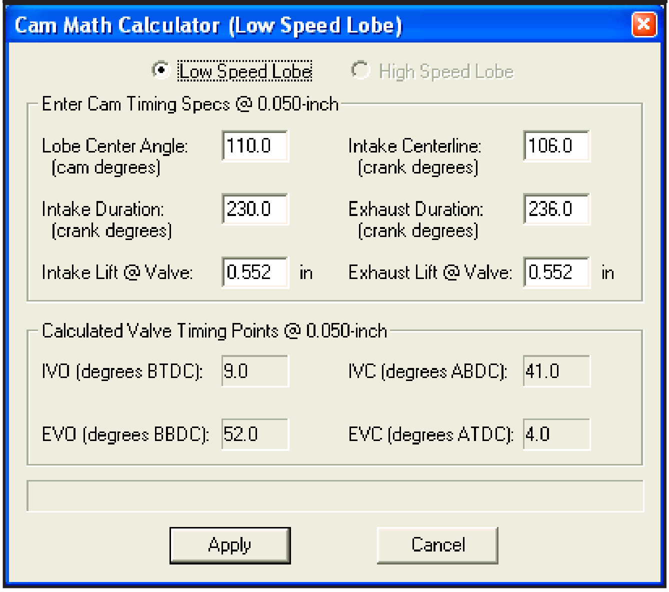
The *CamMath QuickCalculator* is available from the Tools menu.

Opening The CamMath QuickCalculator



The *CamMath QuickCalculator*™

Cam Math QuickCalculator—Without V-V-T



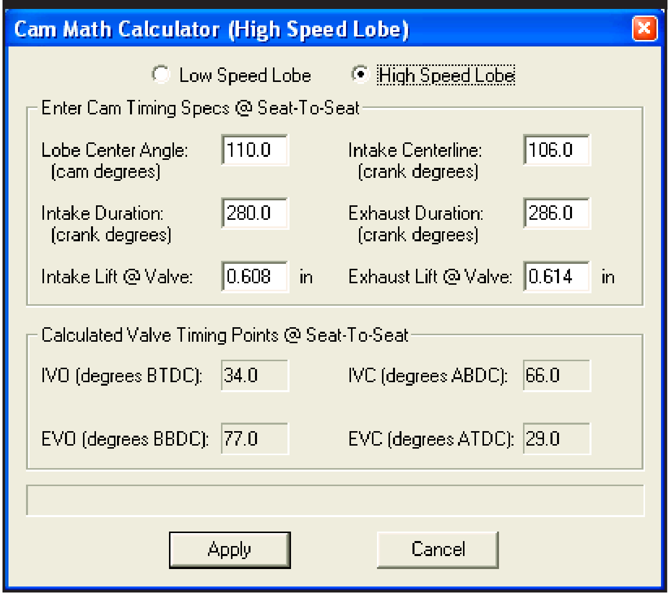
The *CamMath QuickCalculator* allows direct entry and conversion of cam data, as found in many cam manufacturer's catalogs. It simplifies changing lobe-center angle, intake centerline, intake and exhaust duration, into valve-event timing. This the CamMath QuickCalculator screen when a "normal," non-VVT cam is being used (no Variable Valve Timing)—note the High-Speed Lobe radio button is dimmed.

Opening And Using The *CamMath QuickCalculator*™

Open the ***CamMath QuickCalculator*** by selecting **CamMath** from the **TOOLS**

Here the *CamMath QuickCalculator* has been applied to a Variable Valve Timing, VVT, cam. You are given the option of calculating with Low- or High-Speed lobe timing values.

Cam Math QuickCalculator—With V-V-T



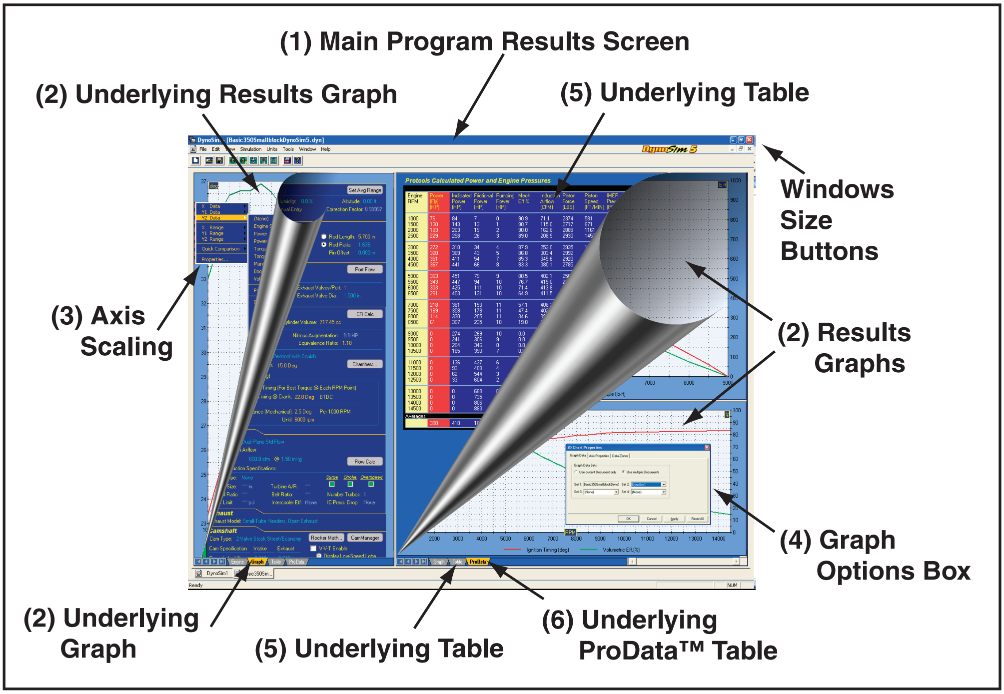
drop-down menu (see photo on page 123). If you are using a V-V-T cam, select the *Low-* or *High-Speed Lobe* radio button—the *High-Speed Lobe* radio button will be dimmed if the current engine is not using Variable Valve Timing.

> **Important Note:** The calculations performed in the ***CamMath*** calculator only apply to the current ***Simulation Timing*** (selected in the **CAMSHAFT** Category and in the *CamManager)*. For example, if **Seat-To-Seat** is the current ***Simulation Timing*** method, then all valve events and camshaft timing displayed in the ***CamMath*** calculator will be **Seat-To-Seat** based only.

If IVO, IVC, EVO and EVC cam timing values were already entered in the **CAMSHAFT** Category, the ***CamMath QuickCalculator*** will display the lobe-center angle, intake centerline, and duration values for the current cam and accept any changes you would like to make. On the other hand, if you have not yet entered camshaft timing, the ***CamMath QuickCalculator*** will display blank fields, and allow the input of centerline, duration, and valve-lift specs. As you fill in the fields, the corresponding IVO, IVC, EVO and EVC points will be calculated and displayed. You may then either accept the calculated values and transfer them to the **CAMSHAFT** Category by clicking the ***Apply*** button or discard the new values and close the ***CamMath QuickCalculator*** by clicking Close.

DynoSim 5 — Advanced Engine Simulation

SIMULATION RESULTS

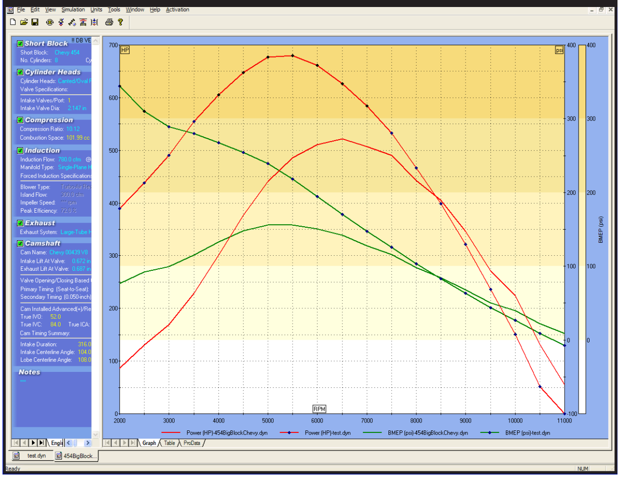


The speed and ease of engine component entry in DynoSim5 is complemented by the power and versatility of the simulation results displays. Almost the same instant that the component categories have been completed (all categories showing green Status Boxes) the simulation results will be displayed on fully-scalable precision graphs. The display graphs can be customized to display virtually any engine variable on any axis. Auto scaling or manual axis scaling are easily established by right-clicking the graph to display the *Graph Options Menu*. Right click on the graph and select ***Properties*** to setup side-by-side comparisons of up to four engines. And comprehensive "table" displays show exact horsepower, torque, rpm, induction pressure, cylinder pressure, engine friction, and more! DynoSim5 will show you the results you are looking for, fast!

The **Simulation Results** display is composed of several elements that will help you retrieve the most information from any simulation as quickly and easily as pos-

Simulation Results Displays

Moveable Vertical Screen Divider



The screen divider can be moved to allow the graph more display area. Drag it all the way to the left screen margin to display graph data "full screen."

sible:

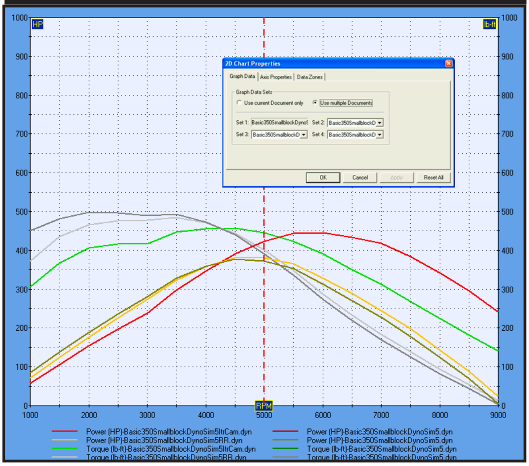
1) The *Main Program Screen* is divided into two sections (called panes), with the component selection categories on the left and the main results display on the right (by default). The center divider between each pane can be moved (click and drag) to resize the results screen to suit your requirements. The graph will redraw and rescale to take advantage of changes in display area.

2) The results graphs (there are three results graphs) each consist of three axis,

Three-Axis Graphs

All three results graphs consists of three axis, a left vertical, right vertical, and bottom horizontal axis. Each of these axis can be assigned an independent engine variable. Right click on the graph to display the *Graph Options Menu* to assign any engine variable to any of the three graph axis.

Compare Up To Four "Open" Engines

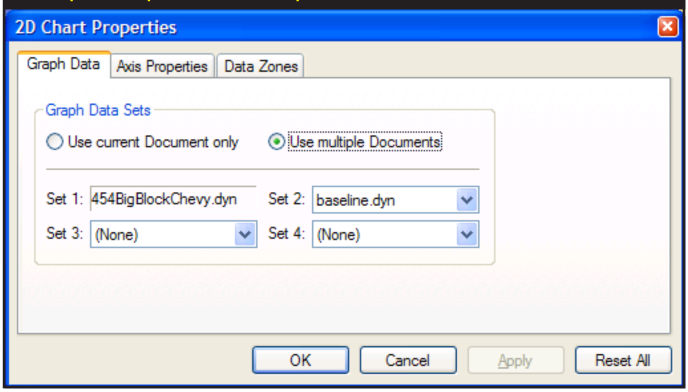


A comparison of four engines was setup using the Properties Box (DynoSim5 feature only). Up to four "open" engines can be compared on any graph.

a left vertical, right vertical, and bottom horizontal axis. Each of these axis can be assigned an engine variable. DynoSim5 will graph the following variables: Rpm, Horsepower, Torque, Intake Manifold Pressure, Volumetric Efficiency, Imep (Indicated Mean Effective Pressure), Bmep (Brake Mean Effective Pressure), and Fmep (Friction Mean Effective Pressure). Right click on the graph to display the *Graph Options Menu* to assign engine variables to graph axis.

3) The results graph supports several methods of axis scaling. Each axis will scale to a low, medium, and high value. Plus auto-scaling can be enabled for any axis. By default, auto-scaling is turned off. This maintains the axis values constant, establishing a fixed baseline so that changes in power or torque are easily distinguished. However, when component changes dramatically alter power (like nitrous-oxide injection or forced induction), the auto-scaling feature will ensure that the data curves are always visible and display at 80 to 90% of

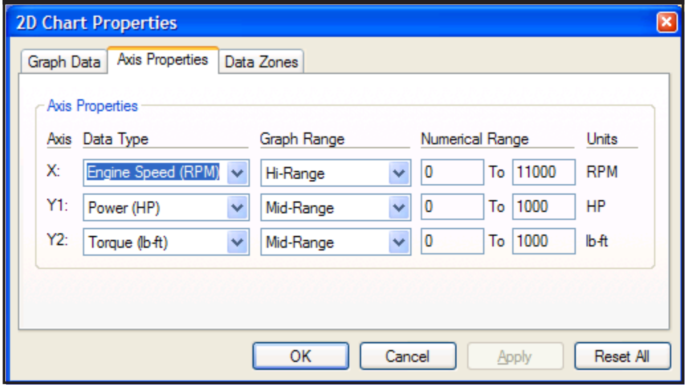
Graph Properties—Graph Data



Use the *Graph Data Properties* dialog box to establish on-graph comparison of up to four engines. Select the comparison engines from the *Graph Data Sets* drop-down menus.

Simulation Results Displays

Graph Properties—Axis Properties



The *Axis Properties* dialog box displays the current *Data Type*, *Graph Range*, and *Numerical Range* for the current graph. Change the characteristics of the display by modifying these properties. (*Numerical Range* modification is a *ProTool*-only feature)

full graph height for maximum resolution.

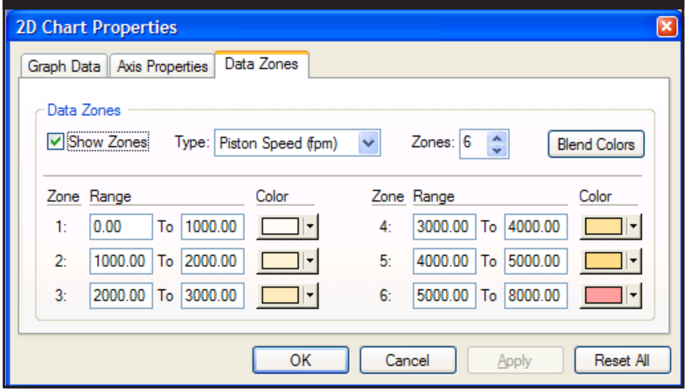
4) Right click on the graph to open the *Graph Options Menu*, then select ***Properties***. This will open a dialog box that has allows three tabbed data pages:

Graph Data—Use the Graph Data Sets page to establish on-graph comparison of up to four engines at once. The engines you wish to include in the comparison must be "open" with active tabs in the *Engine Selection Tabs* at the bottom of the *Main Program Screen*. Use the *Graph Data Sets* drop-down menus to select from currently-open engines. When you click ***Apply*** or ***OK***, the graph will redraw with the desired data comparisons. A legend at the bottom of the graph provides a key to all graph curves.

Axis Properties—This page indicates the current *Data Type* and *Graph Range*, (*Numerical Range* modification is a ***ProTools***™-only feature) for the current display. Change the characteristics of the display by modifying any of the graph properties.

Data Zones™—This DynoSim5-only feature displays additional data and

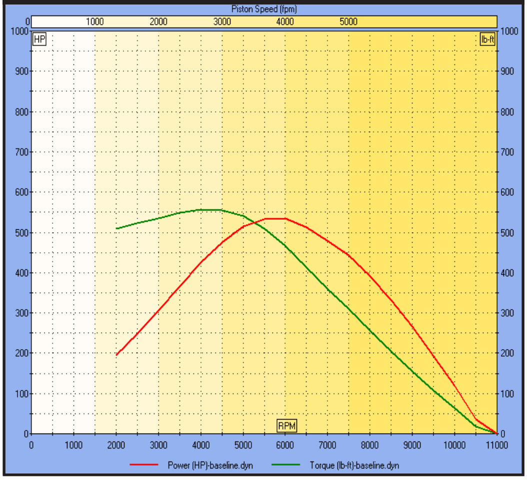
Graph Properties—Data Zones (ProTools™)



***DataZones* (*DynoSim5 only feature*) extend the graphic-display and data-analysis capillarities of DynoSim5. Using this feature, you can display additional engine data, show ranges, or clearly label dangerously high pressures, engine speeds, and more.**

Simulation Results Displays

DataZones Piston-Speed Display



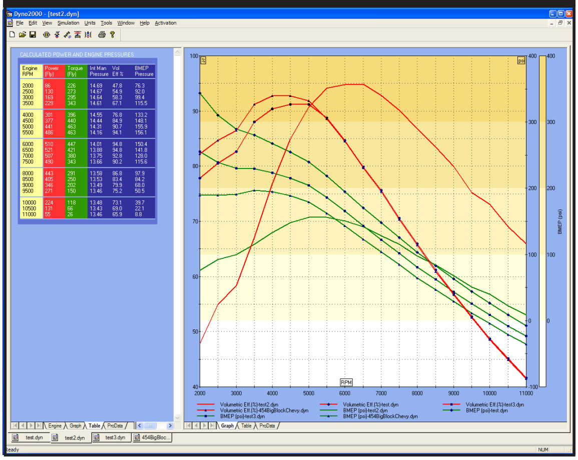
This *DataZone* display shows Piston-Speed bands drawn on the standard HP/Torque graph. The range values are indicated at the top of the graph, and the banded area colors were blended using the *Blend Colors* feature.

data-ranges on the graphs (see page 154 for more information on program features). ***DataZones*** extend the graphic-display and data-analysis capabilities of DynoSim5. Using this feature, you can display additional engine data and/or show ranges for target power values or clearly label dangerously high pressures, engine speeds, and more. To setup a *DataZone* display, first select the data that you would like to display from the ***Type*** drop-down menu.

Note: *DataZone* variables must be the _same as_, or _directly derived from_, one of the variables currently displayed on the graph. For example, you can display *Piston Speed DataZones* on standard Horsepower/Torque graphs since *Piston Speed* is directly calculated from engine rpm (stroke is held constant), but *Manifold Pressure* cannot be displayed, since it is not _directly calculated_

In addition to 2D graphing capability, a chart display is available by clicking the *Table* tabs located at the bottom of either the left or right pane. The chart lists engine variables recorded during the simulated dyno run. The exact data values are displayed in 500rpm increments from 2000 to 11,000rpm.

Table Shows Exact Test Results



Simulation Results Displays

Engine-Pressures Table (DynoSim5 only)

Protools Calculated Power and Engine Pressures

Engine RPM	Power (Fly) (HP)	Indicated Power (HP)	Frictional Power (HP)	Pumping Power (HP)	Mech. Eff %	Induction Airflow (CFM)	Piston Force (LBS)	Piston Speed (FT/MIN)	IMEP Pressure (PSI)	FMEP Pressure (PSI)	PMEP Pressure (PSI)	Ignition Timing (deg)
1000	58	65	7	0	89.1	63.1	1855	581	147.6	15.5	0.6	24.6
1500	105	117	12	1	89.3	105.1	2222	871	176.8	17.9	1.1	26.4
2000	155	174	18	1	88.9	153.5	2471	1161	196.6	20.3	1.6	28.1
2500	198	225	25	2	87.9	199.6	2560	1452	203.7	22.6	2.0	30.2
3000	238	274	33	3	86.8	244.9	2600	1742	206.9	24.9	2.5	32.0
3500	298	345	43	5	86.2	306.2	2802	2032	223.0	27.6	3.1	33.1
4000	347	407	54	7	85.3	363.1	2894	2323	230.3	30.3	3.7	34.5
4500	391	466	66	8	84.1	418.5	2940	2613	233.9	33.0	4.2	36.0
5000	424	513	80	10	82.5	468.7	2918	2903	232.2	36.0	4.6	36.7
5500	443	550	95	12	80.6	514.6	2844	3194	226.3	39.0	5.0	37.0
6000	446	572	112	14	78.0	548.7	2711	3484	215.7	42.3	5.2	37.6
6500	434	581	132	15	74.7	574.7	2540	3774	202.1	45.8	5.3	38.2
7000	418	588	153	16	71.1	601.7	2386	4065	189.8	49.5	5.3	38.4
7500	384	579	178	17	66.3	611.7	2193	4355	174.5	53.6	5.2	38.6
8000	342	565	205	18	60.6	623.5	2007	4645	159.7	57.9	5.1	38.9
8500	296	549	235	19	53.9	627.0	1836	4936	146.1	62.4	5.0	39.0
9000	241	528	268	19	45.7	628.3	1666	5226	132.6	67.2	4.8	39.2
9500	176	499	304	19	35.3	622.8	1492	5516	118.8	72.3	4.5	39.3
10000	117	480	343	19	24.4	618.3	1364	5807	108.5	77.6	4.3	39.4
10500	45	450	386	19	9.9	615.2	1217	6097	96.9	83.2	4.1	39.4
11000	0	426	433	19	0.0	607.2	1100	6387	87.6	89.0	3.9	39.4
11500	0	392	484	18	0.0	596.7	969	6678	77.1	95.2	3.5	39.5
12000	0	362	539	17	0.0	586.3	856	6968	68.1	101.5	3.3	39.5
12500	0	322	598	16	0.0	573.1	733	7258	58.3	108.1	2.9	39.5
13000	0	280	661	15	0.0	559.3	612	7549	48.7	115.0	2.5	39.6
13500	0	240	729	13	0.0	546.3	505	7839	40.2	122.1	2.2	39.6
14000	0	210	801	12	0.0	536.1	427	8129	33.9	129.3	1.9	39.6
14500	0	169	878	10	0.0	520.1	330	8420	26.3	136.9	1.5	39.7
Averages:	398	511	101	12	78.8	489.8	2692	3194	214.2	39.7	4.6	36.7

DynoSim5 displays an additional *ProData™* tab at the bottom of the left and right display panes. Activating this tab will generate a detailed listing of engine pressures, piston speeds, gas forces, induction airflow, and more. In addition, engine pressures can be drawn on any of the graphs.

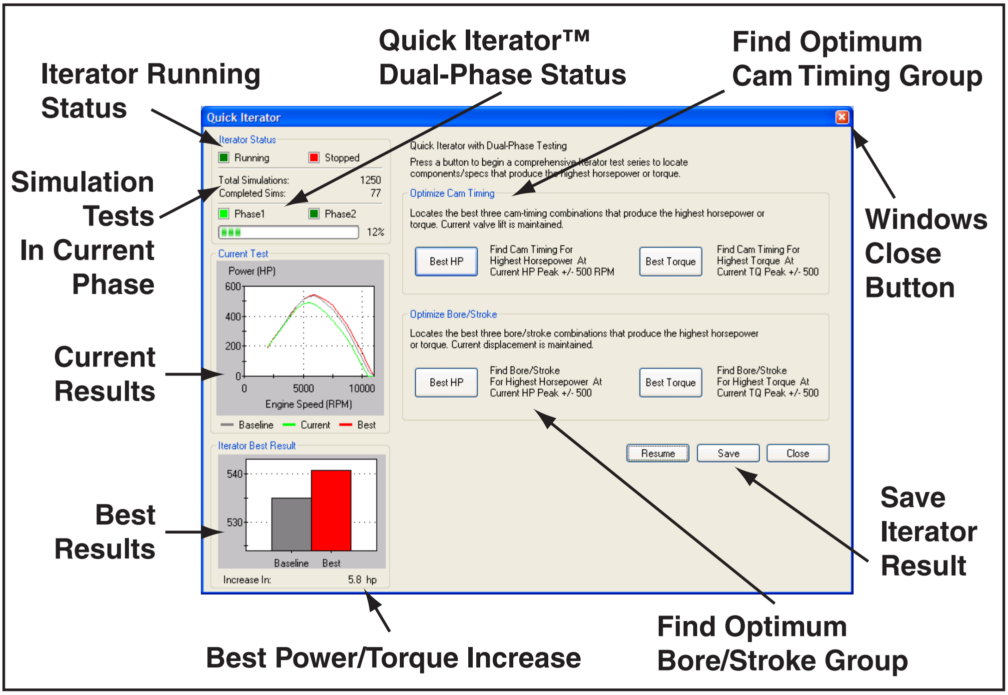
from engine rpm, power, or torque (the three main data sets displayed on the standard HP/Torque graph).

Next, select the number of *DataZones* you would like to display by clicking on the “up” or “down” arrows next to the ***Zones*** field. You can modify the ***Range*** values and ***Colors*** for each zone (if you set a starting and ending color, press ***Blend Colors*** to have DynoSim5 build a uniform transition between these colors for intermediate zones). Click on ***Apply*** or ***OK*** to draw the specified zones on the main graphic display.

5) In addition to the graphing capability described above, a table display is available by clicking on the ***Table*** tabs located at the bottom of the left or right display pane. The chart lists all engine variables recorded during the simulated dyno run. The exact data values are displayed in 500rpm increments from 2000 to 11,000rpm.

6) If you have DynoSim5, the additional ***ProTools™*** tab will be displayed at the bottom of the left and right display panes. Activating this tab will display a detailed listing of engine pressures, piston speeds, gas forces, induction airflow, and more. In addition, engine pressures can be drawn on any of the graphs.

QUICK ITERATOR™

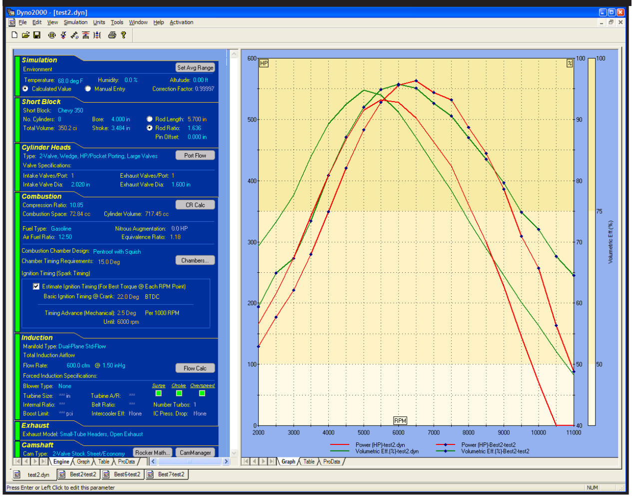


With the availability and low-cost of engine simulation software like DynoSim5, the ability to fill file cabinets with *simulated* dyno tests is available to just about anyone. In fact, many enthusiasts become "bogged down" in an overabundance of test data. Sorting through the results, analyzing the best power curves, and selecting promising component combinations can turn into a job nearly as difficult as old trial-and-error dyno testing.

The solution to the this problem was the introduction of *Iterative Testing*™, an exclusive feature of the Advanced and ProTools versions of ProRacing engine simulations. *Iterative* testing is a repeating series of simulation tests that methodically approach a final, optimum answer. DynoSim5 incorporates a completely new version of the *Iterator*: ***The Quick Iterator***™. Now, click on only one button, and DynoSim5 will perform a comprehensive test series to find optimum horsepower or torque for just about any application. The *Quick Iterator* uses an optimization

Using The *Quick Iterator™*

Quick Iterator™ Spawned Engine



When the *Quick Iterator* has completed its analysis, you can save the results (by clicking the *Save* button). The program will spawn a new simulated engine with the component combination that produced optimum power or torque. The new engine will be added to "open" engines included in the *Engine Selection Tabs* at the bottom of the *Main Program Screen* (arrow). *Quick-Iterator*-spawned engines can be analyzed, tested, and modified in any way, just like any other engine in DynoSim5.

process called ***Dual-Phase™*** testing to find the best combination in the shortest time. The first test phase uses a wider range of values. After the best result has been found from this wide-range test, a second testing phase is performed using a much narrower range of test values. This ***Dual-Phase*** approach greatly speeds processing time, allowing the *Quick Iterator*, for example, to perform a search for optimum cam timing in only 2500 simulation runs; typically, less than two minutes of processing time (on 1.5 Ghz or faster computer systems).

Using The *Quick Iterator™*

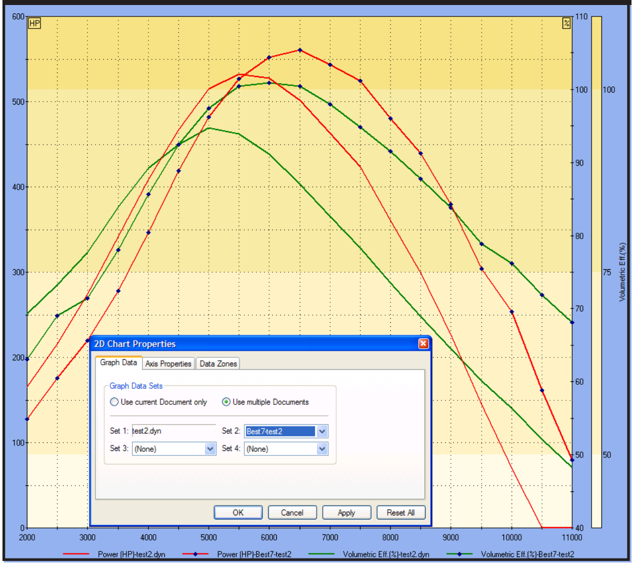
To perform a ***Quick Iterator*** analysis, first select all the components for the baseline engine. Make sure all *Status Boxes* in each Component Category are green, and turn off **Auto Calculate Valve Size** and **Valve Lift**, if necessary. There are two testing groups in the ***Quick Iterator***, and two buttons in each group. The upper group searches for optimum cam timing for either peak horsepower or peak torque. The lower group determines the best bore and stroke combination (maintaining current engine displacement) for either peak horsepower or peak torque.

Press either the ***Best HP*** or ***Best Torque*** button in the upper group to begin an analysis of valve-event timing that will optimize horsepower or torque within ±500rpm of the current power or torque peak. The ***Quick Iterator*** assumes that the current cam in the simulated engine is a "roughly" appropriate for the intended application and uses current cam timing as a starting point. You can follow the progress of the ***Quick Iterator*** by viewing the indicators in the ***Iterator Status*** group (upper-left of the ***Quick Iterator*** screen).

To perform an analysis of cylinder-bore and crankshaft-stroke dimensions, press either the ***Best HP*** or ***Best Torque*** button in the lower group. The ***Quick Iterator***

Using The *Quick Iterator*™

Comparison With Baseline Engine



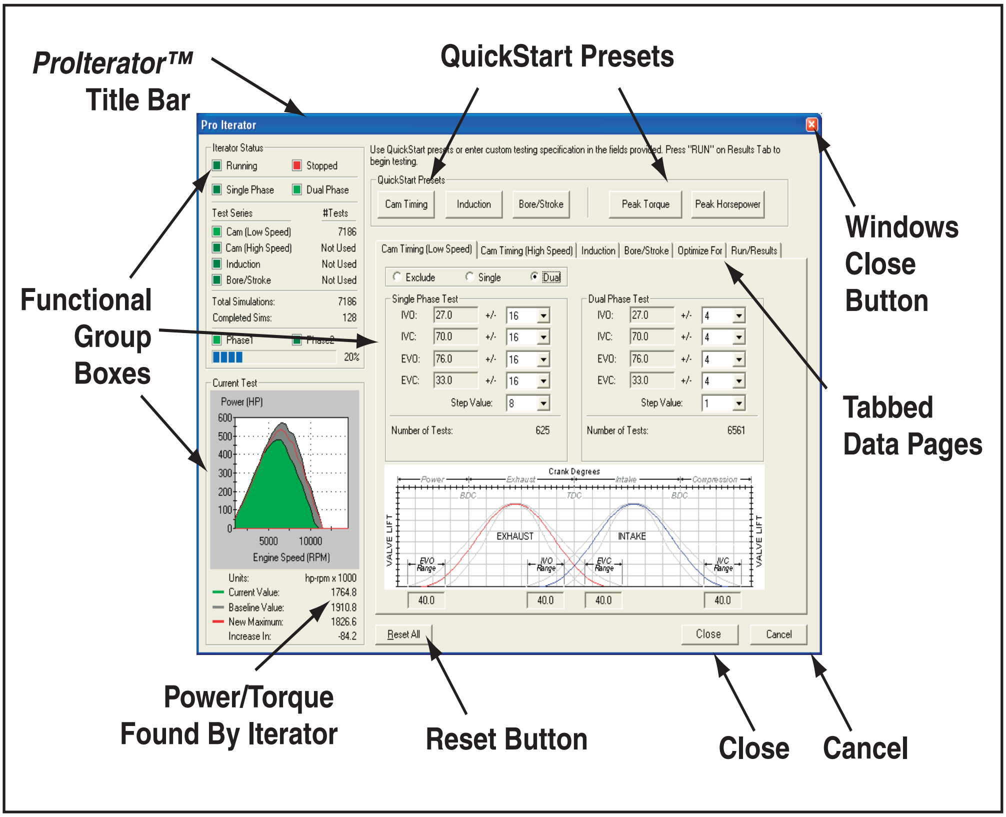
To pinpoint improvements located by the Iterator, you can setup back-to-back comparisons with the original, baseline engine. Right-click the graph, select *Properties*, then include the baseline engine in one of the *Data Sets*. The baseline engine curves will be drawn on the current graph, and the key-legend at the bottom of the graph will be updated.

will determine the best bore-and-stroke combination for optimum horsepower or torque within ±500rpm of the current horsepower or torque peak (current displacement will be maintained).

When *Iterative* testing is complete (you can stop testing at any time by pressing the ***Stop*** button; press ***Resume*** to continue testing), the ***Iterator Best Result*** graph will show the improvement in horsepower or torque found with the new component specifications. You can keep the results by clicking ***Save***. In a few seconds, DynoSim5 will “spawn” a new, simulated engine incorporating the component combination that produced optimum power or torque. Switch between the new engine and the baseline engine by using the ***Engine Selection Tabs*** at the bottom of the *Main Program Screen*. The *Quick-Iterator*-spawned engines can be analyzed, tested, and modified in any way, just like any other engine in DynoSim5. In fact, it is possible to begin a ***new*** *Quick Iterator* test to further “home in” on the desired results.

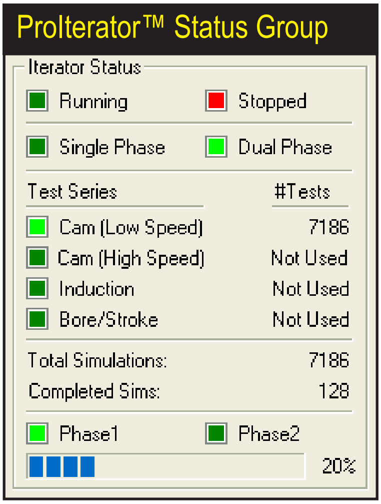
The *Quick Iterator* will almost always find more power or torque. To pinpoint the improvements, setup a back-to-back comparison with the original, baseline engine. Simply right-click on the power/torque graph of the newly-spawned engine, select ***Properties***, then include the baseline engine in one of the four ***Data Sets*** shown on the *Graph Data* page. The baseline engine curves will be included on the current graph, and the key-legend at the bottom of the graph will be updated.

PRO ITERATOR™ (Pro-Tool™)



The ***Quick Iterator™*** discussed in the previous chapter (available in both the DynoSim5 and the DeskTop Dyno5) is a powerful and easy-to-use tool that anyone can use to optimize engine components. While this capability will satisfy most enthusiasts, the more serious engine builder needs the ability to perform Iterative tests on more than one component at a time and include the *Induction* system in the testing criterion. This, combined with greater flexibility in Iterator setup, area under the curve analysis, variable power-band ranges, and much more, is offered in the ***ProIterator™*** (a DynoSim5 feature only).

Using The *ProIterator™*



Indicators within this group clearly show current testing status. *Running* and *Stopped* are located directly above the *Single-* and *Dual-Phase™* indicators; the *ProIterator™* can use *Single-* or *Dual-Phase™* optimization to find the best combinations in the shortest time. The *Test-Series* markers that show whether a particular engine component category will be included in the test series.

Using The *ProIterator™*

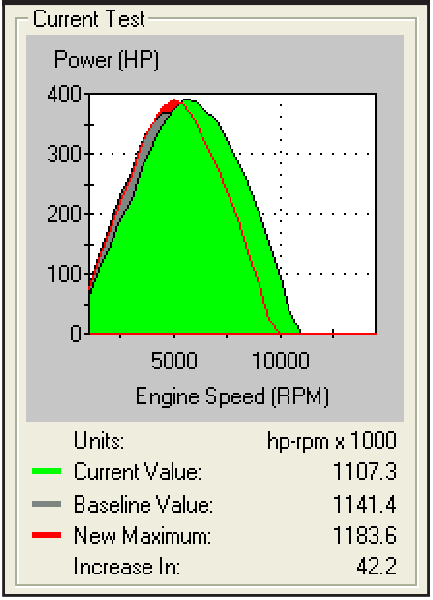
Open the ***ProIterator™*** by choosing the ***ProIterator™*** selection from the **Tools** menu or by clicking the ***ProIterator™ Icon*** in the **Toolbar.** The main screen consists of the following elements and groups:

Iterator Status Group (upper-left corner)—Indicators within this group clearly show current testing status. The Running and Stopped "lights" are located directly above the ***Single-*** and ***Dual-Phase™*** indicators. Like the *Quick Iterator*, the ***ProIterator™*** can use a *Dual-Phase™* optimization process to find the best combinations in the shortest time. The first phase tests over a wide range of values. After the best result is found, a second testing phase is performed using a narrower testing range. However, the ***ProIterator™*** extends this capability by allowing all variables in each Iterator phase to be fully customizable. *Dual-Phase™* and standard, *Single-Phase™* testing can even be toggled on and off as desired.

Below the phase indicators are three ***Test-Series*** markers that show whether a particular engine component category will be included in current tests. The three test groups, ***Cam Timing (High Speed)***, ***Cam Timing (Low Speed)***, ***Induction***, and ***Bore/Stroke*** correspond to the first four tabbed pages in the center of the dialog box. A light-green color indicates that this group will be included in the test series, and ***# Tests*** shows how many tests will be performed within this category. The total number of simulations is shown below, along with the number of completed test runs. At the bottom of the *Iterator Status* group are the ***Phase 1*** and ***Phase 2*** indicators (only visible when *Dual-Phase™* testing has been enabled) and a progress bar that indicates the progress of each phase in multiple-phase testing.

Using The *ProIterator*™

Current Test Group

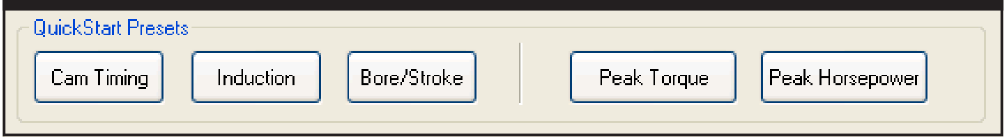


The *Current Test* group displays three horsepower or torque curves: The gray curve represents the baseline, the green curve is the current test, and the red curve is the highest power found. Exact values for the baseline, current, maximum, and gain-or-loss in power/torque are provided at the bottom of the group box.

Current Test Group (bottom-left corner)—The graph displays three horsepower or torque curves (and area under the curves, if selected). The gray curve represents the initial, baseline power/torque; the green curve is the current Iterator test result, and the red curve is the highest power discovered up to that point in the testing series. A key-legend is provided below the graph along with the exact values for the baseline, current, maximum, and gain-or-loss in power/torque.

QuickStart Presets Group (top center)—The convenience of one-button quick testing incorporated in the *Quick Iterator*™ also is part of the ***ProIterator*™**. While the ***ProIterator*™** does not begin testing when a *QuickStart* button pressed, instead, it loads a "typical" set of testing parameters in the appropriate tabbed data page (the five tabbed data pages are discussed next). For example, if you click the ***Cam Timing*** and ***Peak Horsepower*** presets, the ***Cam-Timing Page***

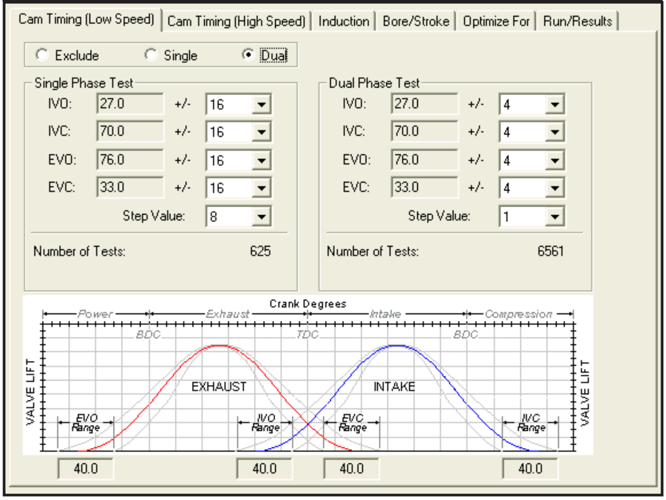
QuickStart Presets Group



The convenience of one-button quick testing has been incorporated in the *ProIterator*™. Click any preset button (e.g., *Cam Timing* and *Peak Horsepower)* to establish a testing series on the appropriate tabbed data page. Use the *Reset All* button to clear all Presets and return the tabbed-pages to their default setup.

Using The *ProIterator™*

Camshaft-Timing "Tabbed" Data Page



The *Cam-Timing* tabbed pages establishes a *Single-* or *Dual-Phase™* test of cam-timing changes (on Low and High-Speed Lobes when V-V-T cams are used) on power or torque output. Select either the *Single-* or *Dual-Phase* radio button and enter the testing criterion in the *Single- and/or Dual-Phase Test* boxes. The range of individual cam-timing values evaluated during *ProIterator™* testing are displayed just below the twin-hump cam-timing diagram.

establishes a *Dual-Phase™* cam-timing testing series based around the current camshaft and the ***Optimize-For Page*** selects *Peak Horsepower* as the principal search criterion. Use the ***Reset All*** button located at the bottom of the screen to clear all Presets and return the tabbed-pages to their default setup.

Tabbed Data Page Group (center of screen)—Five data entry- and display-pages are available as tabbed screens at the center of the ***ProIterator™***.

***Cam-Timing* Tabbed Pages (Low and High Speed lobes)**—The first two tabbed pages establish a *Single-* or *Dual-Phase™* test of cam-timing changes on power or torque output. If you are using *Variable Valve Timing* cam (see page 101 for more information on V-V-T cam modeling), select either the High or Low-Speed tabbed page(s). If you are using a "standard" non-V-V-T cam, only the Low-Speed Tabbed Page will be active.

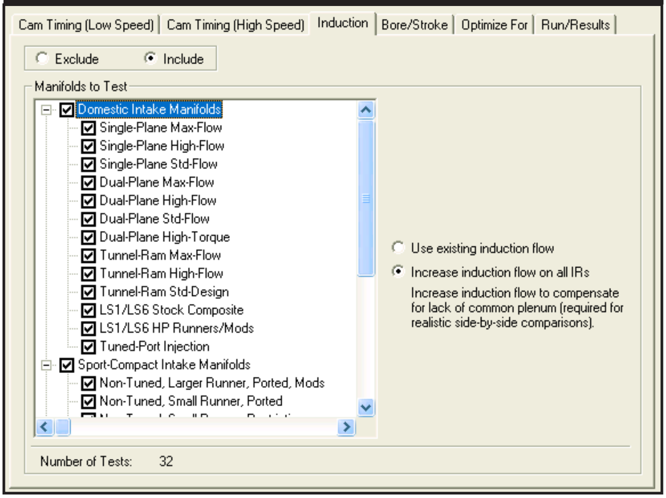
Cam-Timing Tabbed Pages by default are set to ***Exclude*** (perform no cam-timing tests) as indicated by the radio buttons at the top-left of the pages. To perform cam-timing Iteration, select either the ***Single-*** or ***Dual-Phase*** radio button and enter the testing criterion in the ***Single- and/or Dual-Phase Test*** boxes, located just below the radio buttons. The range of individual cam-timing values evaluated during ***ProIterator™*** testing are displayed just below the twin-hump cam-timing diagram.

You can quickly setup an thorough Iterative test through a relatively wide range of cam-timing values by clicking the ***Cam Timing*** button in the *QuickStart Preset* group (described previously). This will setup a *Dual-Phase* test of 8,962 simulations (takes about 5-to-10 minutes on a typical PC).

Using The *ProIterator*™

The *Induction* tabbed page sets up *Single-Phase* testing of various induction systems. Select the *Include* radio button and check the manifolds/induction-systems that you would like to add to the test series. If you select the *Increase Induction Flow* radio button, induction airflow will be modified using the following formula: (number-of-cylinders x airflow)/2. This puts IR manifolds on the same “playing field” with plenum inductions.

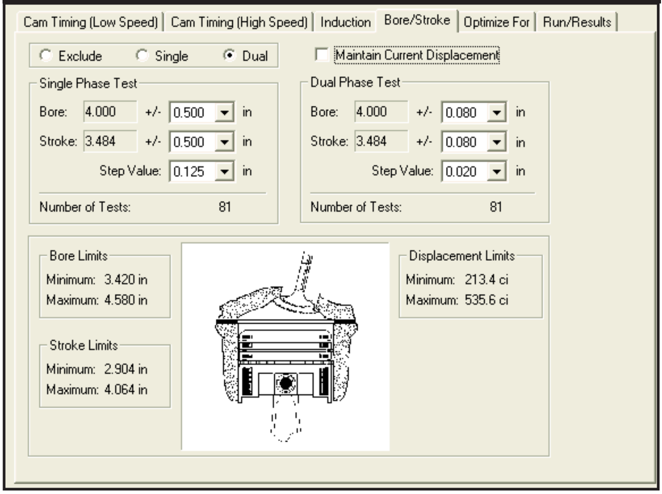
Induction “Tabbed” Data Page



Induction* Tabbed Page**—The third tabbed page sets up a *Single-Phase* test of the effects of various induction systems (up to 32) on power or torque output. By default, the *Induction Tabbed Page* is set to ***Exclude (perform no induction tests) with the radio buttons at the top-left of the page. To perform an Iterative test of induction systems, select the ***Include*** radio button and check the manifolds/induction-systems that you would like to include in the test series. You can quickly setup an exhaustive test of all induction systems by clicking on the ***Induction*** button in the *QuickStart Preset* group (described previously).
Note: The *Individual Runner* manifold has two additional radio-button selections: *Use Existing Airflow* and *Increase Induction Flow* to compensate for the lack of a common plenum in IR systems. If you select the ***Increase Induction Flow*** button, the induction airflow (as specified in the **INDUCTION** category, see page 54) will be modified using the following formula: (number-of-cylinders x airflow)/2. This formula only will be used when the IR manifold is being simulated. When other manifolds are tested, the baseline airflow will be used. Depending on the number of cylinders and the baseline airflow value, modified airflow for the IR system can increase to as high as 7000cfm (the maximum airflow limit in DynoSim5). If you select ***Use Existing Airflow***, the baseline airflow will be used at all times. This typically results in very poor performance for the IR system, since the baseline airflow is divided by the number of cylinders to determine individual port flow. We recommend that you enable ***Increase Induction Airflow*** whenever the IR system is included in Iterative tests of mixed induction systems.

***Bore/Stroke* Tabbed Page**—The third tabbed page establishes a *Single-* or *Dual-Phase*™ test of bore-and-stroke dimensional changes on power or torque

Bore/Stroke "Tabbed" Data Page



The *Bore/Stroke* tabbed page establishes an *Iterative* test of bore-and-stroke dimensional changes. Perform a Bore/Stroke *Iteration* by selecting either the *Single-* or *Dual-Phase* radio button and entering the testing criterion. You can chose to *Maintain Current Displacement* or let engine displacement vary throughout Bore/Stroke testing (see text for details).

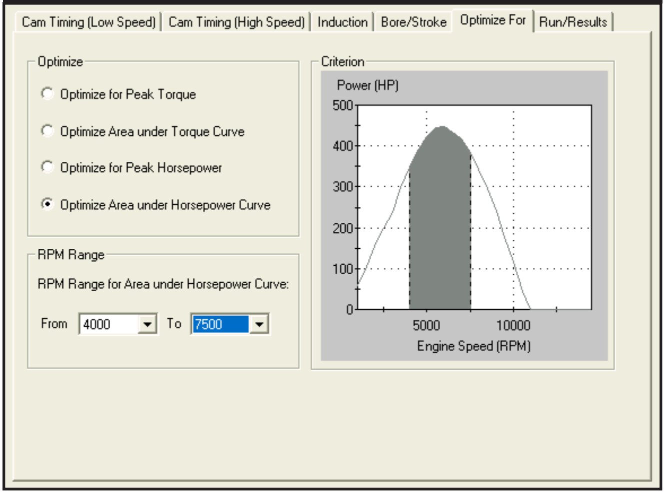
output. By default, the *Bore/Stroke Tabbed Page* is set to ***Exclude*** (perform no bore-and-stroke tests) with the radio buttons at the top-left of the page. To perform Bore/Stroke Iteration, select either the ***Single-*** or ***Dual-Phase*** radio button and enter the testing criterion in the ***Single- and/or Dual-Phase Test*** boxes, located just below the radio buttons. You can quickly setup an comprehensive test by clicking on the ***Bore/Stroke*** button in the *QuickStart Preset* group (described previously). This will establish a 242-test *Dual-Phase* simulation series (completed in about 1 minute on a 1Ghz or faster computer).

Note: You can chose to *Maintain Current Displacement* or let engine displacement vary throughout Bore/Stroke Iterative testing. By checking the ***Maintain Current Displacement*** box, the ***Stroke*** within both ***Phase-Test*** boxes will switch to ***(Auto)***, indicating that *Stroke* will be allowed to vary as much as required to keep displacement constant while the ***Bore*** varies from its current value throughout its indicated (±) Range. Alternately, you can chose to allow *Bore* (rather than Stroke) vary as much as required to keep displacement constant while *Stroke* changes from its current value throughout its (±) Range. Follow these steps to change ***(Auto)*** variables: With *Maintain Current Displacement* checked, set the *Bore (±) Range* value to zero, then set the *Stroke (±) Range* to any desired value (except zero). The ***(Auto)*** function will switch to *Bore*.

Optimize-For* Tabbed Page**—The fourth tabbed page establishes the desired result from Iterative testing. By default, the ***ProIterator™ will search for the combination of components that produces peak horsepower. Alternately, you can select *Optimize For Peak Torque*. In addition to these two options, two powerful new ***Optimize-For*** choices are available: *Maximum Area Under The Horsepower Curve* or *Torque Curve*. While the peak torque and horsepower choices will focus on absolute maximum values, the areas under the curves

Using The *ProIterator*™

Optimize-For "Tabbed" Data Page



The *Optimize-For* tabbed page establishes the testing range to obtain the desired result. By default, the *ProIterator*™ will search for peak horsepower. While peak torque and horsepower choices focus on absolute maximum values, the *Areas Under The Curve* selections locate parts that produce the greatest "volume" of horsepower or torque. Think of this as the maximum horsepower or torque throughout the rpm range.

selections will find parts combinations that produce the greatest "volume" of horsepower or torque within the selected rpm range. Think of this area as the maximum horsepower or torque throughout the rpm range (or over time). In general, peak horsepower searches may find optimum components for narrow-rpm-band racing (like drag-racing), and maximum area under the curve may find the best components for wide-rpm band racing (like road racing).

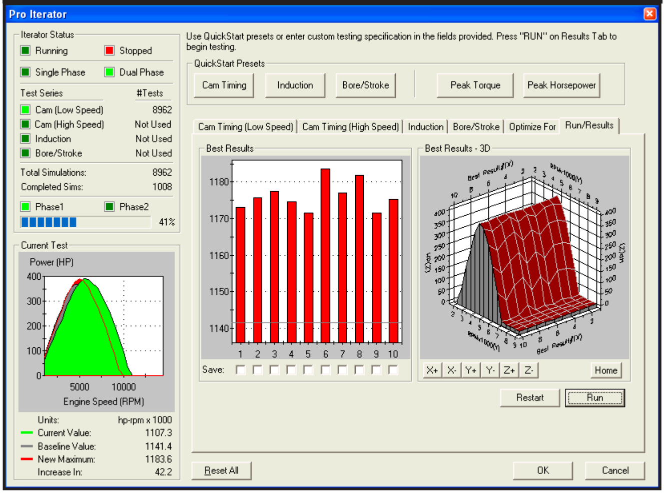
Below the *Optimize* settings box, the ***RPM Range*** choices let you set the lower and upper limits through which the *Iterator* will search for optimum power or torque combinations. When the *Iterator* is searching for peak values, the *RPM Range* will be illustrated as dotted lines on the *Criterion* graph. When either *Area Under The Curve* choice is selected, the *RPM Range* values will be displayed as a "bounded area" under the horsepower or torque curves.

Note: Optimizing engine components for maximum area under the curve is an entirely new way to look at engine power output. There is almost no published data on this method of evaluating engine power or torque, nor is there research available on which racing applications may benefit from this analysis. Rumor has it, though, that many of Formula-1, Indy, and other "very serious" racing teams have used this method to find a winning edge. Now you can use this powerful analysis method in Dyno***Sim5 ProIterator***™ to your advantage!

Run/Results* Tabbed Page**—The fifth tabbed page begins an *Iterative* test series, allows you to view testing progress, and displays the top ten results. Once you have selected the testing parameters (on the *Cam Timing*, *Induction*, and *Bore/Stroke* tabbed pages), click the ***Run button to begin an *Iterative* test. As the ***ProIterator***™ finds promising results, they are displayed in the ***Best Results*** graph as vertical bars. A horizontal "baseline" on the graph indicates the power level of the current engine (built from components on the

Using The *ProIterator™*

RUN/Results "Tabbed" Data Page



The *Run/Results* tabbed page begins *Iterative* testing, allows you to view testing progress, and lets you save any of the top ten results. When testing is complete, save any (or all) of the top ten results by clicking the *Save* boxes located below the vertical bars in the *Best Results* graph, then click the *OK* to spawn (create) these engines within DynoSim5.

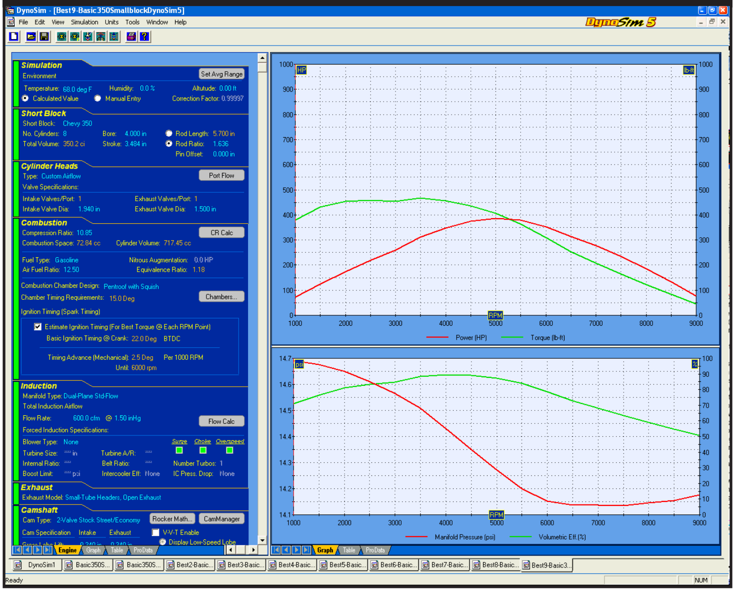
Main Component Screen). As the *Iterator* finds better and better component combinations, the bars continue to increase in height (and the graph axis will rescale as needed). If the *Iterator* finds combinations that produce more power or torque than the baseline engine, the vertical results bars will cross over the baseline indicator and grow taller (the baseline marker may rescale and move down the graph indicating a greater difference between the baseline engine and *Iterator* combinations). The top ten horsepower or torque curves that match the bar-chart results are displayed on the ***Best Results—3D graph***. You can view these curves from any prospective using the **X+**, **X-**, **Y+**, **Y-**, **Z+**, and **Z-** buttons (**Home** returns the 3D graph to its original position),

During *Iterative* testing, you can view the number of completed and remaining tests in the ***Iterator Status*** box, as discussed earlier (you can stop testing at any time by pressing the ***Stop*** button; press ***Run*** to continue testing or ***Restart*** to clear current results). When testing is complete, save any (or all) of the top ten results by clicking the ***Save*** boxes located below the vertical bars in the *Best Results* graph. After deciding which engines to save, click the ***OK*** button at the bottom of the ***ProIterator™*** dialog box. The *Iterator* will close and "spawn" new engines based on the components that were used in the selected tests. You can switch to any of these engines (and continue modification and testing as you can with any DynoSim5 engine) by clicking on the ***Engine Selection Tabs*** at the bottom of the *Main Component Screen*.

The ***ProIterator™*** will almost always find more power or torque. To pinpoint these improvements, setup back-to-back comparisons with the original, baseline engine. Simply right-click on the power/torque graph of any of the newly-spawned engines, select ***Properties***, then include the baseline engine in one of the four ***Data Sets*** shown on the *Graph Data* page. The baseline engine curves will be included on the current graph, and the key-legend at the bottom of the graph

Using The *ProIterator*™

Spawned Engines Displayed In Engine Selection Tabs



When you close the *Iterator* screen, new "spawned" engines will be created and displayed in the *Engine Selection Tabs* at the bottom of the Main Program Screen. Each new engine can be brought into the foreground by clicking on its *Selection Tab*. Iterator-spawned engines can be analyzed, tested, and modified in any way, just like any other engine in DynoSim5.

will be updated.

Reset All* Button** (bottom)—If you would like to return the ProIterator™ to the default state, resetting all tabbed pages to their original settings, press the ***Reset All button.

ProIterator™ Testing—A Quick Walkthrough

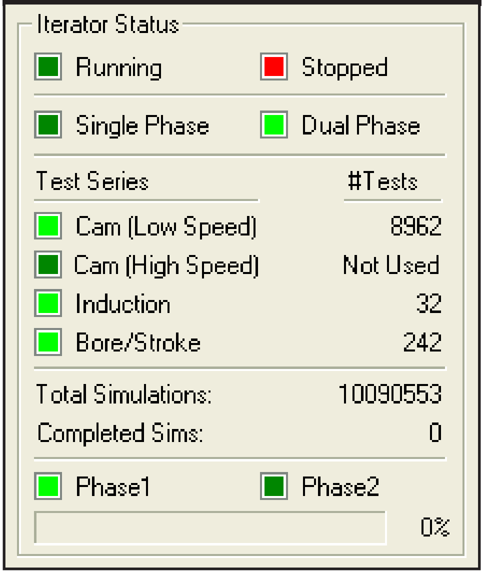
The first step in performing an *Iterative* test is to build the basic (or baseline) engine by selecting component parts from the *Main Program Screen Component Categories* (all component categories must display green status boxes) or by loading a completed engine (.DYN) file. When all parts have been selected, DynoSim5 will perform a simulation and display horsepower and torque curves in the right results pane.

When the baseline engine simulation has been performed, you may conduct an *Iterative* test. Open the *ProIterator*™ by choosing ***ProIterator*™** from the **Tools** menu or by clicking the ***ProIterator*™ *Icon*** in the **Toolbar**. The tabbed data-entry-and-display pages establish a component or engine-system for testing and specify a search criterion and rpm range (see the previous section for details on each tabbed data-and-setup page). As an alternative to setting up individual testing parameters, you can click on any of the *QuickStart Preset* buttons at the top of the *ProIterator*™ dialog box. Each button loads a "typical" set of testing parameters on the appropriate tabbed data page.

For Example: Click the ***Cam Timing*** and ***Peak Horsepower*** presets to setup a

Using The *ProIterator*™

An Extremely Long Iterator Test Series



Narrowly-focused or multiple-component tests may require several thousand, or even millions of test cycles to complete. A test series as large as the one shown here, can require several days of calculation time depending on the speed of your computer. Often the same results can be obtained by a more carefully designed test that takes less than 1% the time to complete. Use wide first-phase ranges and steps to keep the number of Iteration cycles to a minimum.

Dual-Phase™ cam-timing testing series on the ***Cam-Timing*** page that is based around current camshaft timing while the ***Optimize-For*** page establishes *Peak Horsepower* as the principal search criterion within an *Rpm Range* that extends below the torque peak and above the horsepower peak of the baseline engine. Use the ***Reset All*** button located at the bottom of the screen to clear all Presets and return the tabbed-pages to their program defaults.

As you make selections from either the *QuickStart Preset* buttons or the tabbed data pages, the *Iterator Status* box (upper-left of dialog) shows the component groups that have been included and the number of tests that must be performed to complete the current series. Since DynoSim5 will typically perform 10 to 20 simulation tests per second (depending on the speed of your computer), keep in mind that it will take about an hour to execute 45,000 tests. Keep testing criterion limited and the range and step values as large as possible to minimize testing time.

After you have selected the components that you wish to evaluate, the ***Optimize For*** tabbed page establishes the search criterion and the rpm range that the *Iterator* will use to find improved power or torque. By default, the ***ProIterator***™ will search for the combination of components that produces peak horsepower. Alternately, you can select *Optimize For Peak Torque*. In addition to these two options, two powerful new ***Optimize-For*** choices are available: *Maximum Area Under The Horsepower Curve* or *Torque Curve*. While the peak torque and horsepower choices will focus on absolute maximum values, the areas under the curves selections will find parts combinations that produce the greatest “volume” of horsepower or torque within the selected rpm range. Think of this area as the maximum horsepower or torque throughout the rpm range (or over time).

Using The *ProIterator™*

Once you have selected the testing parameters (on the *Cam Timing*, *Induction*, and *Bore/Stroke* tabbed pages), click the ***Run*** button to begin an *Iterative* test. As the ***ProIterator™*** finds promising results, they are displayed in the ***Best Results*** graph as vertical bars. A horizontal "baseline" on the graph indicates the power level of the current engine (built from components on the Main Component Screen). As the *Iterator* finds better and better component combinations, the bars continue to increase in height (and the graph axis will rescale as needed). If the *Iterator* finds combinations that produce more power or torque than the baseline engine, the vertical results bars will cross over the baseline indicator and grow taller (the baseline marker may rescale and move down the graph indicating a greater difference between the baseline engine and *Iterator* combinations). The top ten horsepower or torque curves that match the bar-chart results are displayed on the ***Best Results—3D graph***. You can view these curves from any prospective using the **X+**, **X-**, **Y+**, **Y-**, **Z+**, and **Z-** buttons (**Home** returns the 3D graph to its original position).

The ***Run*** button on the ***Run/Results*** tabbed page begins *Iterative* testing, allows you to view testing progress, and lets you save any of the top ten results. You can stop testing at any time by pressing the ***Stop*** button; press ***Run*** to continue testing or ***Restart*** to clear current results. When testing is complete, save any (or all) of the top ten results by clicking the ***Save*** boxes located below the vertical bars in the *Best Results* graph. After deciding which engines to save, click the ***OK*** button at the bottom of the ***ProIterator™*** dialog box.

When the *Iterator* closes, the newly spawned engines will be displayed in the ***Engine Selection Tabs*** at the bottom of the **Main Program Screen** (see page 16 and 19 for more information on Engine Selection Tabs). Each test engine can be brought into the foreground by clicking on its Tab. Iterator-spawned engines can be analyzed, tested, and modified in any way, just like any other engine in DynoSim5. In fact, it is possible to begin a *new Iterator* test using any of the spawned engines as a new baseline to further "home in" on the desired results.

Tips For Running Efficient Iterative Tests

Setting up an *Iterative* series only takes a few seconds, however, if you include too many parameters, ranges that are too wide, or step values that are too small, you will create an *Iterator* series that contains too many tests. If you create a series longer than 300 million tests (even fast computer systems will require one year or more to complete 300 million tests) DynoSim5 will request that you increase step values for selected parameters.

The best way to find optimum components, especially cam timing, is to setup a Dual-Phase™ test that uses large step values (20 degrees or more) to "get in the ballpark" on the first phase, then the second *Iteration* phase with a narrower range of values (perhaps just a 2 to 4 degrees) and a smaller step value (perhaps 1 degree) precisely locates the best timing.

Narrowly-focused tests may still require several thousand test cycles to complete.

Using The *ProIterator™*

A large test series may require several minutes, an hour or two, or even a day or two of calculation time depending on the speed of your computer. In these cases, you may continue to use your computer to perform other tasks. Simply use the ***Start*** menu to begin other applications or use ***Alt-Tab*** to switch between applications (see your Windows documentation for more information on program switching).

Note: If you are running Windows98/Me/2000/XP or Vista, you may also select the "DeskTop" icon (usually located close to the *Start* menu on the task bar) to "minimize" DynoSim5 and regain your desktop during an *Iterator* test.

PRINTING

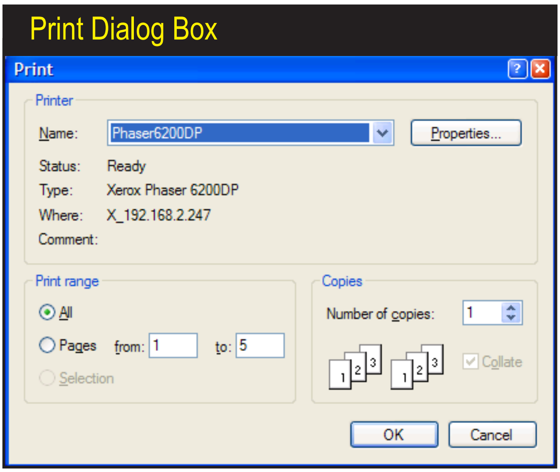
PRINTING DYNO DATA AND POWER CURVES

DynoSim5 is capable of printing a complete list of engine components, cylinder head airflow data, exact engine test result values, and 2D graphic curves of several engine-test variables. Each of these data sets print on separate pages that comprise a complete multi-page, dyno-test document of the currently-selected engine. You can determine which pages you would like to print, preview the pages before you print, and direct the output to any installed Windows printer.
Note: If you have DynoSim5 (not available on DeskTop Dyno5), ***ProPrinting™*** options are available that produce comprehensive "presentation" reports of dyno test results. ***ProPrinting™*** features include special page graphics, a cover page with the name of your business (or you personal name), additional engine-data values, pressures, forces, and more.

There are three choices in the ***File*** menu (located on the *Main Program Screen*) that will help you setup your printer and print dyno data. The choices are:

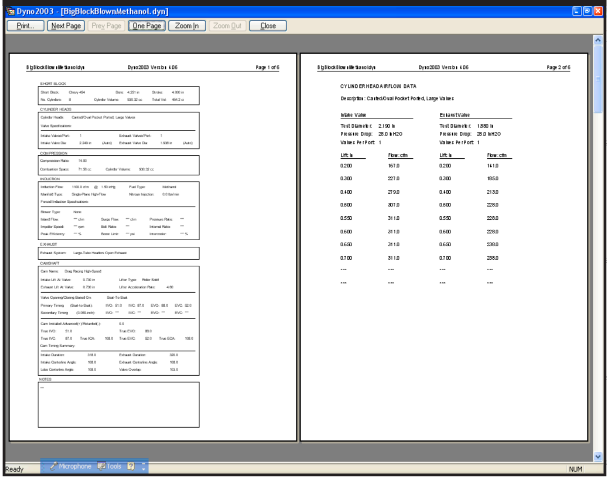
Print—Opens a dialog box that allows the selection of a printer, access to printer Properties, and the Print Range of dyno-test pages. Printing can be started from this dialog box.

The print dialog box, accessible from the *File* menu, allows the selection of a printer, access to printer Properties, and you can enter the range of dyno-test report pages. Printing can be started from this dialog box.



Printing Dyno Reports

Print Preview Dialog Box



Print Preview, accessible from the *File* menu, provides an on-screen rendering of what each page in the basic dyno-test printout will look like when printed on the selected Windows printer. Use this feature to determine which pages you would like to include in the printout.

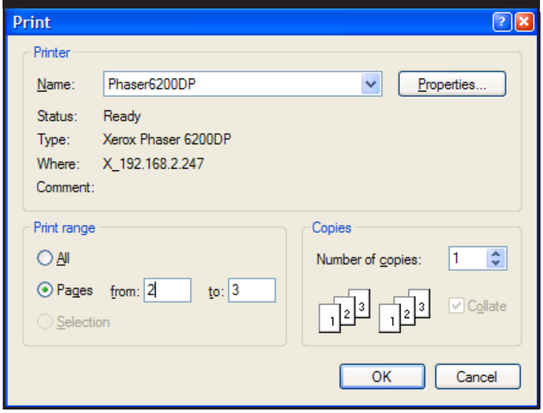
Print Preview—Opens the Print Preview Screen that provides an on-screen rendering of what each page in the dyno-test report will look like when printed on the selected Windows printer.

Printer Setup—Similar to the Print dialog box (allows printer selection), except printing cannot be started from this box.

The dyno-test report generated by DynoSim5 consists of up to 8 pages. Here is description of each page (varies with program version; this description applies to the DynoSim5):

Page 1 and 2—These pages print all the components selected for the current simulated dyno test. The appearance of the *Standard printout* is similar in layout to the *Component Selection* pane of the *Main Program Screen*.

Printing Specific Pages



The print dialog box allows you to specify a range of pages to print. Here only pages 2 and 3 will print.

Page 3—Displays cylinderhead airflow data used during the simulated engine test.

Page 4—All calculated engine power and pressures are provided in chart form. Values are listed for each 500rpm test point throughout the full test range.

Page 5—***ProTools™*** Advanced Power and Engine Pressure data is provided in chart form. Values are listed for each 500rpm test point throughout the full test range.

Page 6—The first of three engine-output graphs is reproduced on this page (this is the graph located on the left side of the *Main Program Screen* under the *Component Categories*—select the ***Graph Tab*** at the bottom of the left of the pane to display this graph). Full color printing is supported.

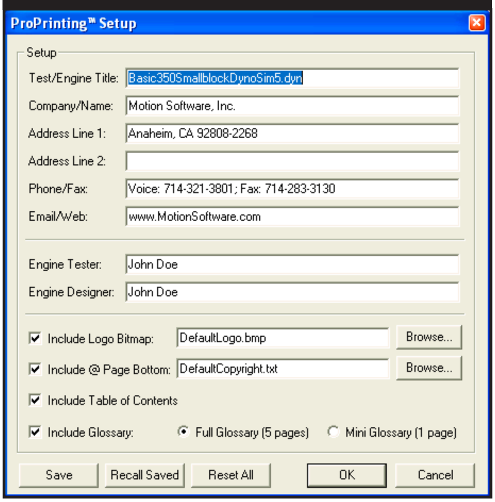
Page 7—The second of three graphs of engine output is reproduced on this page (this graph is located on the top right side of the *Main Program Screen*).

Page 8—The third of three graphs of engine output is reproduced on this page (this graph is located on the bottom right side of the *Main Program Screen*).

ProPrinting™ Features

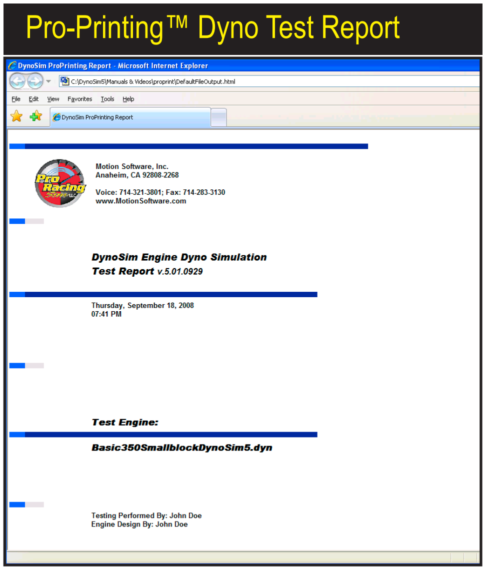
If you are using the DynoSim5, ***ProPrinting™*** is available that will generate a comprehensive "presentation" report of engine test data. ***ProPrinting™*** features include special page graphics, a cover page with the name and address of your business (or your personal name and address) and logo, a table of contents, optional text printed at the bottom of each page (can be a disclaimer, copyright notice or any other text you wish), optional comprehensive or "mini" glossaries, and a complete listing of all test data and results. This full-color report is assembled within DynoSim5 and delivered to your default Internet browser (e.g., Microsoft *Internet Explorer™*) for on-screen display and printing. To view a multiple-page print

Pro-Printing™ Setup



***ProPrinting™*, a *DynoSim5* feature, turns the results of any engine simulation into a professional test report. Use the *Pro-Printing™ Setup* dialog box, available from the *File* menu, to enable and customize *Pro-Printing™* features. You can add your name, address, your company logo, specialized (copyright) text, a table of contents, and even a short or long glossary to your *ProPrint* report. Use the *Default...* button to save your preferences that will be applied by default to new engine simulations. The files for the *DefaultLogo.bmp* and the *DefaultCopyright.txt* are located in Dyno*Sim5/Manuals & Videos/proprint* subdirectoy. You can modify these files to suit your requirements.**

ProPrinting™ Features



A *ProPrinting*™ report is assembled within DynoSim5 and delivered to your default Internet browser (e.g., Microsoft Internet Explorer™) for on-screen display and printing (or *print previewing* as shown in the photo below).

preview of this report, select *ProPrint Preview* from within DynoSim5, then select *Print Preview* from within your browser.

Note: Some browsers, like recent versions of Internet Explorer) do not print "background graphics" by default. This will prevent the printing of background colors in many of the data tables in the ***ProPrinting***™ report. To enable full-function printing, open the *Internet Options* menu (often located at the bottom of the *Tools* menu within Internet Explorer), choose the *Advanced* tab, and click the box (to enable) *Print background colors and images (see photo on next page)*.

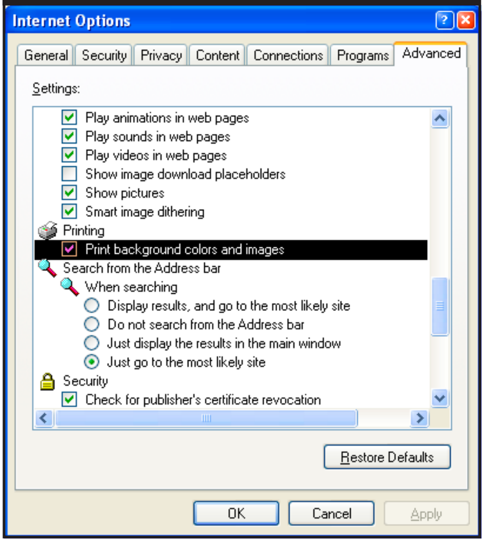
Use ***ProPrinting*™ *Setup***, available from the **File** menu within DynoSim5, to enable and configure ***ProPrinting***™ features. If you activate ***Include Logo***, the logo

A *ProPrinting*™ report includes "presentation" graphics, a cover page with the name and address of your business (or your personal name and address) and logo, a table of contents, optional text printed at the bottom of each page, optional "full" or "mini" glossaries, and a complete listing of all test data and results. The report is delivered to your default web browser for printing (or *print previewing* as shown here).

ProPrinting™ Features

Some browsers, like recent versions of *Internet Explorer)* do not print "background graphics" by default. This will prevent the printing of data table background colors in *ProPrinting*™ reports. To enable full-function printing, open the Internet Explorer *Options* menu (typically located at the bottom of the Tools menu within Internet Explorer), choose the *Advanced* tab, and click the box (to enable) *Print background colors and images*.

Pro-Printing™ IE Configuration



file must be a .BMP file (should be square with the size near 100 by 100 pixels). If you activate ***Include @ Bottom Of Page***, the included file must be non-formatted text only (for example, created in Notepad) and no longer than about 50 words. You will find these files located in *DynoSim5/Manuals & Videos/proprint* directory.

Dyno5 Sim Advanced Engine Simulation

OTHER FEATURES

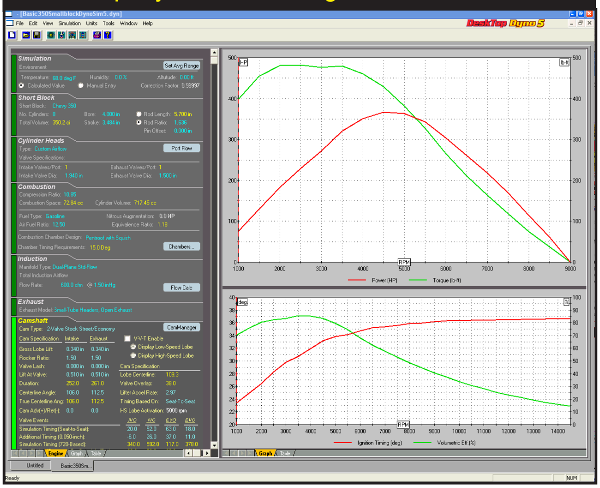
DeskTop Dyno5 and DynoSim5 Feature Sets

The DeskTop/Sim Series engine simulations are available in two versions: 1) **DeskTop Mode**, and 2) ***DynoSim* Mode including ProTools™*.***

DeskTop Dyno5—(Basic Version Of DynoSim5) The ***DeskTop Dyno****5* contains features that most enthusiasts will find more than sufficient to allow them to test components and determine optimum combinations for most applications. All essential simulation features and many powerful additional modeling and calculation features are included in the *DeskTop Dyno5*. Using the *DeskTop Dyno5*, anyone can measure and monitor various engine pressures and efficiencies, including Intake-Manifold Pressure and Volumetric Efficiency, enter custom cylinder-head airflow, and much more.

DynoSim5 Including ProTools™—(Most Advanced Version Of DynoSim5) If you are a serious enthusiast or racer you will find the additional tools and features supplied in ***DynoSim5*** a valuable addition to the *DeskTop* version.

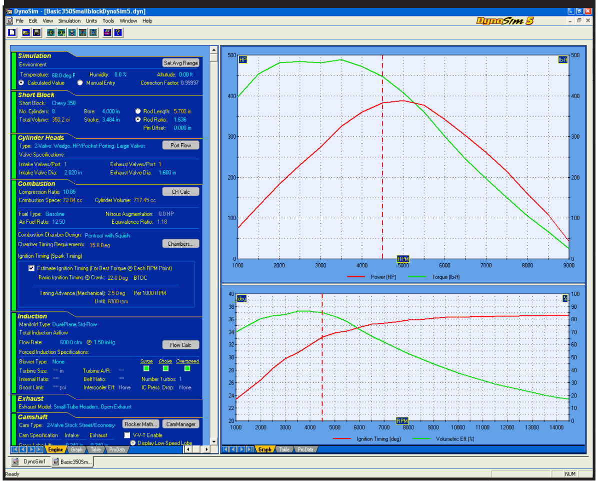
DeskTop Dyno5 Main Program Screen



The *DeskTop Dyno5* contains features that most enthusiasts will find more than sufficient to allow them to test components and determine optimum combinations for most engine applications*.*

DeskTop and Sim Program Versions

DynoSim5 Main Program Screen



DynoSim5 includes ignition and forced-induction modeling, CamFile™ rapid search/match capability, powerful ProIterator™ optimization, additional pressure and force measurements, plus the included *ProTools Kit* provides custom ProPrinting™, ProData™ tables, plus the ProIterator™ with the analysis of areas under the power and torque curves, and even more.

DynoSim5 includes ignition and forced-induction modeling, *CamFile*™ rapid search/match capability, powerful ProIterator™ optimization, additional pressure and force measurements, including Indicated HP, Frictional HP, Mechanical Efficiency, Gas Force On Piston, IMEP, BMEP, FMEP, PMEP, Induction Airflow, and more. Plus the included ***ProTools Kit*** provides custom *ProPrinting*™, *ProData*™ tables, plus the *ProIterator*™ with the analysis of areas under the power and torque curves, and even more.

Here is an abbreviated list of ***DynoSim5*** features:

ProIterator™—The one of the most powerful features of the ***ProTools™ Kit***. The *ProIterator*™ retains all the simplicity and ease-of-use of the ***Quick Iterator™*** (offered in the DeskTop program version), while adding powerful testing and analysis capability, including custom ranges, Induction-system Iteration, analysis of areas under the power and torque curves, and much more. For a complete description of ***ProIterator™*** features, refer to page 135.

Additional Simulation Data And Analysis—Adds additional calculated pressures, forces, and other data to the graphs and tables in DynoSim5. The additional data includes: *Indicated Horsepower, Frictional Horsepower, Pumping Horsepower, Mechanical Efficiency, Gas Force On Piston, Induction Airflow,* and *Piston Speed*. To support these additional variables, all graphs feature custom scaling and new multi-horsepower displays.

Data Export—Adds capability to export rpm-related data, like Horsepower, Torque, engine pressures, and more. Data is exported in a "CSV" format

DeskTop and Sim Program Versions

DeskTop/DynoSim5 Features

Engine Simulation Program Features	DeskTop Series(5.x) DeskTop Dyno5	DynoSim5 Series(5.x) DynoSim5 Includes ProTools™
Dyno-Testing RPM Range	1000 to 14500 rpm	1000 to 14500 rpm
Bore Range Limits	2.00 to 7.00-in	2.00 to 7.00-in
Stroke Range Limits	1.50 to 7.00-in	1.50 to 7.00-in
Alternate Fuels/Nitrous	Yes	Yes
AirFlow Calculator	Yes	Yes
CamMath QuickCalculator™	Yes	Yes
Cam Manager™	Yes	Yes
Test Multiple Engines	Yes	Yes
On-Graph Comparisons With Up To Four Engines	Yes	Yes
Custom Cylinder-Head Flow	Yes	Yes
Multi-Page Dyno Test Reports	Yes	Yes
DirectClick™ Menus	Yes	Yes
Real-Time Results Displays	Yes	Yes
U.S./Metric Units	Yes	Yes
One-Click Iterative™ Testing	Yes	Yes
Graph DataZones™ Displays	Yes	Yes
Advanced Compression-Ratio Calculator	No	Yes
Forced-Induction Modeling	No	Yes
Optimized High-Speed Simulation	No	Yes
Search For CamFiles™	No	Yes
Extended Color Display	No	Yes
Extended-Data Displays	No	Yes
ProPrinting™ Extended Dyno Reports	No	Yes
ProData™ Tables	No	Yes
ProIterator™ Advanced Dyno Testing	No	Yes
Analyze Area Under Power And Torque Curves	No	Yes

If you are a serious enthusiast, you will find the additional tools and features supplied in *DynoSim5* a valuable addition to the DeskTop Dyno5 Simulation. Many features have been enhanced with extended functionality. In addition, there are new features aimed directly at the serious enthusiast and professional, like the *ProIterator*™ and *ProPrinting*™ that generates a "presentation-quality" dyno test reports.

for easy import into Excel or other graphing and data analysis programs.

ProPrinting™—Turns simulation results into a comprehensive "presentation" report of dyno test data. ***ProPrinting™*** features include special page graphics, a cover page with the name and address of your business (or your personal name and address) and logo, a table of contents, optional text printed at the bottom of each page (can be a disclaimer, copyright notice or any other text you wish), optional comprehensive or "mini" glossaries, and a complete listing of all test data and results at each 500rpm point from 1000 to 14,500rpm, including additional engine-data values, pressures, forces, and more not included in a Advanced Mode. To view ***ProPrinting™*** displays, see page 149.

Advanced Forced Induction Modeling—Powerful new Roots, Turbo, Centrifugal, and Screw blower modeling allows you to find the potential for virtually any forced induction system. Change turbine housings, belt ratios, intercooler efficiency, pressure loss, and much more. See page 76 for more information on DynoSim forced-induction modeling.

One-Click QuickCompare™—Makes setting up side-by-side comparisons a snap! Compare with other engine files or setup baselines from which you can instantly see the changes in power and torque as you fine tune your engine application.

CamManager™ With CamFile™ Search—Search through thousands of CamFiles in just seconds. Let's you find the best cams by keyword, or valve-timing matches.

Rocker/Lash Advanced Math™—This powerful ***DynoSim5*** feature allows you to find the exact changes in not only lift but also valve timing as you vary rocker ratio and valve lash. Dramatically illustrates how valve timing can be dramatically altered as valvetrain components are modified.

Ignition Timing And Ignition Curve Modeling—Calculates and graphs optimum ignition timing advance for peak power. Let the program determine optimum timing or enter your own advance curve.

Compression-Ratio Calculator—Use this powerful calculator to determine any compression ratio from combustion-chamber, piston, gasket and block specifications.

DYNO FILE (.DYN) COMPATIBILITY

DynoSim5 allows you to simulate the building and dyno-testing of an engine, but in addition to this, you can install your simulated engine in a simulated drag-race vehicle using the DeskTop Drag5 or DragSim5. With these programs you can test your combination in 1/8- or 1/4-mile drag events. And using DeskTop FastLap or FastLapSim5 closed-course simulation, you can test any simulated engine on any track in any vehicle. To support this versatile testing "system," all version-5 simulations have full compatibility to allow the easy interchange of engine data to both drag-racing and road-racing simulations.

DeskTop Dyno5 and DynoSim5 engine files (xxxx.DYN files) can be directly loaded into the DeskTop Drag5, DragSim5, DeskTop FastLap5, and FastLapSim5; no file export or modification is required.

GENERAL SIMULATION ASSUMPTIONS

The ***DeskTop Dyno5*** and ***DynoSim5*** closely simulate the conditions that exist during an actual engine dyno test. The goal is to reliably predict the torque and horsepower that a dynamometer would measure throughout the rpm range while the engine and dyno are running through a programmed test.

Among the many interviews conducted during the research and development of ProRacing Sim Software, engine-simulation software, dyno operators and engine owners readily acknowledged the possibilities of errors in horsepower measurements. Unless the dyno operator and test personnel are extremely careful to monitor and control the surrounding conditions, including calibration of the instrumentation, comparing results from one dyno cell to another (or even one test run to another) is a futile task.

Controlling these same variables in an engine simulation program is infinitely easier but, nevertheless, just as essential. Initial conditions of temperature, pressure, energy, and methodology must be established and carefully maintained throughout the simulation process. Here are some of the assumptions within DynoSim5 that establish a modeling baseline:

Fuel:

1) The fuel is assumed to have sufficient octane to prevent detonation.
2) The air/fuel ratio is always maintained at the optimum power ratio.
3) The ignition timing is maintained at an optimum power setting.

Environment:

1) Air for induction is 68-degrees (F), dry (0% humidity), and of 29.92-in/Hg atmospheric pressure unless it is changed in the **Simulation Category**.
2) The engine, oil, and coolant have been warmed to operating temperature.

Methodology:

1) The engine is put through a series of “step” tests, during which the load is adjusted to “hold back” engine speed as the throttle is opened wide. The load is adjusted to allow the engine speed to rise to the first test point, 1000rpm in the case of this simulation. The engine is held at this speed and a power reading is taken. Then engine speed is allowed to increase to the next step, 1500rpm, and a second power reading is taken. This process continues until the maximum testing speed of 14,500rpm is reached.
   Note: Since some engines, especially those with cam timing designed for all-out drag racing, are not able to run at full throttle under load at very low engine speeds, the power generated at some of the lower rpm points may register as zero.
2) Since the testing procedure increases engine speed in 500rpm steps, and engine speed is held steady during the measurement, the measured power does not reflect losses from accelerating the rotating assembly (the effects of rotational inertia in the crank, rods, etc.). These processes affect power in most “real-world” applications, such as road racing and drag racing, where engine speed is rapidly changing throughout the race.

Simulation Assumptions

Air/Fuel Ratio Modeling:

1) Air/Fuel ratio has a strong influence on engine performance. Fuel and oxygen molecules combine during combustion to produce heat, pressure, and residual gases like carbon dioxide and water vapor. If all the carbon and oxygen atoms combine within the cylinder during combustion, no carbon monoxide or unburned hydrocarbons will remain. This “complete burning” is called stoichiometric combustion. The air/fuel ratio that allows complete combustion is called the *stoichiometric air/fuel ratio*, and it is approximately 14.6:1 for gasoline. However, for maximum power a richer mixture is required, typically around 12.5:1. You are able to set the air/fuel ratio used during simulated engine testing in the **Combustion Category**.

DynoSim5 Advanced Engine Simulation

FAQ's

FREQUENTLY ASKED QUESTIONS

The following information may be helpful in answering questions and solving problems that you encounter when installing or using DynoSim5. If you don't find an answer to your problem here, send an email to support@proracingsim.com. Thoroughly explain the problem and, if required, attach the engine file (.DYN) that caused the problem to your email *(ProRacing Sim Software provides Email technical service to registered users only—fill out the registration form that appears when you start the simulation or register on our website www.ProRacingSim.com).* We will review your problem and return an answer to you as soon as possible.

INSTALLATION/BASIC-OPERATION QUESTIONS

Question: Received an "Error Reading Drive D" (or another drive) message when attempting to install DynoSim5. What does this mean?

Answer: This means your computer cannot read the disk in your CD-ROM drive. The disk may not be properly seated in your drive, the drive may be defective, or the disk may be damaged. If you can properly read other CDs in your CD-ROM drive, but DynoSim5 distribution disk produces error messages, try requesting a directory of a known-good disk by entering **DIR X:** or **CHKDSK X:** (in a Command window, where **X** is the drive letter of your CD-ROM drive) and then perform those same operations with DynoSim5 CD. If these operations produce an error message only when using DynoSim5 CD, the disk is defective. Return the disk to Motion Software, Inc., for a replacement (mailing address available at www.motionsoftware.com). Replacement CD's are free for as long as you own our software (you must be the original purchaser). Just return the defective merchandise to Motion Software, Inc., and we will replace it at no charge. If you have lost the CD, please call for replacement pricing.

Question: Encountered "Could not locate DynoSim5 CD disk" error message when trying to run DynoSim5. Why?

Answer: Please insert DynoSim5 disk in your CD-ROM drive. Occasionally, DynoSim5 may need to access the CD. Please keep DynoSim5 disk handy while you use ProRacing Sim Software products.

Question: DynoSim5 produced an *Assertion Failure* error. What should I do?

Answer: Please note down all of the information presented in the error-message box, provide a quick synopsis of what lead up to the error, then send this information to ProRacing Sim Software. Thank you for your assistance in helping us improve DynoSim5.

SCREEN DISPLAY QUESTIONS

Question: Even though I have a 19-inch monitor, I can only see a small portion of DynoSim5 screen on my monitor. What can I do so that I don't have to scroll both horizontally and vertically?

Answer: The screen resolution of your monitor (not its size) determines how much of DynoSim5 you can see on screen without scrolling left and right. You can change screen resolution by ***RIGHT CLICKING*** on your desktop, then selecting ***PROPERTIES*** from the drop-down menu. Choose the ***SETTINGS*** tab and increase screen resolution by moving the ***Screen Area*** slider to the right. For more information about screen resolution, refer to the documentation that was supplied with your computer, your video graphics card, or with Windows.

BORE/STROKE/SHORTBLOCK QUESTIONS

Question: Everyone talks about longer rod lengths and potential improvements in power. Why isn't rod length one of the choices in the pull-down menus?

Answer: We realize that many actual dyno tests have shown power increases, but our simulation tests tell us that the power, when found, probably has little to do with piston dwell at TDC (and the associated thermodynamic effects) or changes in rod angularity on the crank pin. The measured power differences are most likely due to a reduction of friction on the cylinderwall from changes in side-loading on the piston. This can vary with bore finish, ring stability, piston shape, the frictional properties of the lubricant, etc. These variabilities are highly *unpredictable*. Some development, after all, can only be done in the real world on a engine dynamometer.

COMPRESSION-RATIO QUESTIONS

Question: DynoSim5 calculated the total Combustion Volume at 92ccs. But I know my cylinder heads have only 75ccs. What's wrong with the software?

Answer: This confusion comes from assuming that the calculated **Total Combustion Volume** displayed in the component-selection screen is the same as your measured combustion-chamber volume. The *Total Combustion Volume* is the entire volume that remains in the cylinder when the piston reaches top dead center. See page 41 for more information about compression volumes.

Question: When using the compression calculator in the "Piston - Has Dome, Dish, or Valve Reliefs" mode, item-4 should, but does not, allow a zero entry. Wouldn't this be the correct entry if I chose to run a zero deck clearance? Next is entry item-5: Although your manual states this is a measured amount, if I know my deck clearance is zero and I know the volume of the valve reliefs in my pistons, which I do, I should be able to enter that number and get the compression ratio. What is actually happening is when I enter .100 in item-4 and 5.00 in item-5, the compression is 13.69, much too high for my engine.

Answer: The assumption in the "domed/dished" option is that there is a volume (the combination of the displacements in the domes/dishes/pockets) that is unknown to the engine builder. The only practical way to measure this is to move the piston down the bore an arbitrary amount, say 0.250, and measure the volume in the cylinder (with a burette). This is then compared to the volume of a cylinder with the same bore diameter but of 0.250 inches high, the difference is the volume in the dome/dish/pockets.

However, on your engine, you know that the flattop pistons with valve pockets you have will produce a zero deck height at TDC, and the displacement of the valve pockets is 5cc. Knowing this, you can select the Flattop piston model, set the deck height at zero, and add 5cc to the combustion chamber volume (to allow for the valve-pocket volume in the pistons). This will yield the correct compression ratio.

You can also use the "Dome/Dish" model to determine compression ratio. Set the piston down the bore 0.100. Calculate the volume in a cylinder of the same bore diameter with a height of 0.100 and add 5cc. Plug this data in the model and you'll get the same compression ratio.

INDUCTION/MANIFOLD/FUELS QUESTIONS

Question: When I choose a carburetor that is too large for an engine (for example 1200cfm on a 283 Chevy), why does the power increase without a typically seen "bog" at low speeds?

Answer: DynoSim5, along with virtually any current computer simulation program, cannot model over-carburetion and show the reduction in low-end performance that this can cause. In reality, carburetors that are too large for an engine develop fuel atomization and air/fuel ratio instabilities, phenomena that is carburetor specific and extremely difficult to model. DynoSim5 assumes an optimum air/fuel ratio regardless of the selected CFM rating. While the program produces positive results from larger-and-larger induction flows (by the way, the predicted power increases are close to reality when optimum air/fuel ratios can be maintained, as is the case in electronic fuel-injection systems), you can't go wrong if you use common sense when selecting induction/carburetor flow capacities.

Question: The engine I am building uses two 660-cfm Holley carburetors. How can I simulate the airflow?

Answer: DynoSim5 will simulate induction airflow from 100 to 4000cfm, rated at either standard 4-barrel pressure drop of 1.5-inches of mercury or at standard 2-barrel pressure drop of 3.0-inches of mercury (a pressure drop of 1 inch of mercury is equivalent to 13.55 inches of water). To simulate two, 660cfm, 4-barrel carburetors, simply add the airflow and enter the total 1320cfm value into the component-selection screen (for four-barrel carburetors, make sure the pressure drop shown in the **INDUCTION** category is 1.5-in/Hg).

CAMSHAFT/VALVETRAIN QUESTIONS

Question: I built a relatively stock engine but installed a drag-race camshaft. The engine only produced 9hp @ 2000 rpm. Is this correct?

Answer: Yes. Very low power outputs at low engine speeds occur when racing camshafts are used without complementary components, such as high-flow cylinder heads, high compression ratios, and exhaust system components that match the performance potential of the cam.

Question: The horsepower produced when I enter the seat-to-seat timing on my cam card does not match the horsepower when I enter the 0.050-inch timing figures for the same camshaft. Why are there differences?

Answer: DynoSim5 uses the timing specs found on your cam card, and in cam manufacturer's catalogs, to develop a valve-motion curve (and from this curve it develops the instantaneous airflow for each port at each degree of crank rotation). Unfortunately, the seat-to-seat and/or 0.050-inch timing points do not precisely describe actual valve motion (these timing values constitute only five data points per lobe). However, using this data and a mathematical analysis of the differences between timing points, DynoSim5 "creates" a valve-motion curve for use in later calculations of power and torque. To optimize the accuracy of this process, always provide both seat-to-seat and 0.050-inch timing points. With both sets of timing points, DynoSim5 can automatically calculate a lifter acceleration rate. If you only have access to one set of data points, seat-to-seat timing will produce more accurate results, however, you'll have to manually guess the lifter acceleration rate.

Question: How does DynoSim5 allow for the different acceleration rate cams used with hydraulic, solid, and roller lifters?

Answer: DynoSim5 calculates a valve acceleration rate and a valve-motion curve from both the seat-to-seat and 0.050-inch cam timing specifications (see previous answer). Since the acceleration rate of cams is no longer directly linked to the type of lifters (mild street cams often used roller lifters), DynoSim5 does not use lifter-type to determine valve motion (and, subsequently, determine horsepower). See page 105 for more information about valve timing and acceleration modeling.

Question: I found the published factory seat-to-seat valve timing for a Pontiac engine that I am building. The IVC occurs at 112 degrees (ABDC). Something goes wrong when I enter the valve events into DynoSim5.

Answer: There are so many ways that cam specs can be described for cataloging purposes that it's confusing for anyone trying to enter can-timing specs into an engine simulation program. Your Pontiac is a classic example of a lack of standards. The Pontiac cam listed in the factory manual is a hydraulic grind with seat-to-seat timing measured at *0.001-inch lifter rise*. Because the cam is designed for long life and quite operation, it has shallow opening ramps. This is the reason for the large number of crank degrees between the opening and closing points. In fact, during the first 35 degrees of crank rotation, the lifter rises less than 0.010-inch. If this wasn't the case, and the valve opened and closed at the specified timing points listed in the factory manual, the cam would have over 350-degrees duration, and it's unlikely the engine would even start! DynoSim5 can use 0.004- or 0.006-inch valve rise, 0.007-open/0.010-close valve rise, or even 0.020-inch lifter rise for seat-to-seat timing. But the 0.001-inch lifter-rise figures published in your factory manual are useless for engine simulation purposes.

Question: My cam manufacturer's catalog does not list seat-to-seat, valve-event timing. But it does list seat-to-seat intake and exhaust duration, lobe-center angle, and intake centerline. Can I calculate the valve-event timing from these figures?

Answer: Yes. Use the *Cam QuickMath™ Calculator* built into DynoSim5 to calculate the intake and exhaust opening and closing points. You'll need the following information:

1) **Intake Duration**
2) **Exhaust Duration**
3) **Lobe-Center Angle** (sometimes called lobe separation angle).
4) And the **Intake Centerline Angle**.

See page 123 for more information on the *Cam QuickMath™ Calculator*.

Question: I have been attempting to test camshafts from a listing in a catalog. I can find the duration and lobe center angle. The cam manufacturer won't give me the seat-to-seat timing (they act like it's a trade secret!). Can I use the available data to test their cams?

Answer: No. As stated in the previous answer, you also need the intake-center angle to relate cam lobe positions to TDC and, therefore, crank position. Freely providing seat-to-seat timing or any of the other cam specs used in DynoSim5 poses no threat to any cam grinder. It takes a lot more than valve-event timing to manufacture a quality cam; full profiles of the lobes are needed to ensure mechanically and dynamically stable operation. Cam companies that refuse to provide potential customers with simple valve-event information for evaluation in programs like DynoSim5 are simply living in the "dark ages." Our suggestion is to contact another cam manufacturer and/or check out the ProRacing Sim Software's ***CamDisk7™*** that contains 6000+ cam files you can instantly load and test in DynoSim5. Every CamFile on *CamDisk7™* has BOTH seat-to-seat and 0.050-inch timing specs, allowing DynoSim5 to automatically calculate valve acceleration rates.

QUESTIONS ABOUT RUNNING A SIMULATION

Question: DynoSim5 displayed an error message "DynoSim5 was unable to complete the simulation. A more balanced combination of components..." What went wrong?

Answer: The combination of components you have selected produced a calculation error in the simulation process. This is often caused by using restrictive induction flow on large-displacement engines or by using radical cam timing on otherwise mild engines. Try reducing the EVO timing specs, increasing the induction flow, selecting a cam with less duration, or reducing the compression ratio. A balanced group of components should not produce this error.

Question: DynoSim5 ***Quick Iterator™*** takes several seconds to complete one cycle of a several-thousand run test. A full series takes way too long. Is there a problem with my computer or the software?

Answer: DynoSim5 is a highly optimized Windows program, however, it uses a full-cycle simulation that performs millions of calculations for each point on the power curves, and this takes some time.

Question: When I run a simulation, part of the horsepower and torque graph doesn't appear on my screen. What can I do to correct the display?

Answer: Open the **Graph Options** menu (right-click on the graph) and select ***Auto Range*** for the **Y1** or **Y2** variable. See page 128 for more information about graph scaling and plotting variables.

MINI GLOSSARY

0.050-Inch Cam Timing Method—See **Cam Timing**, @ 0.050-inch.

ABDC or After Bottom Dead Center—Any position of the piston in the cylinder bore after its lowest point in the stroke (BDC). ABDC is measured in degrees of crankshaft rotation after BDC. For example, the point at which the intake valve closes (IVC) may be indicated as 60-degrees ABDC. In other words, the intake valve would close 60 degrees after the beginning of the compression stroke (the compression stroke begins at BDC).

Air-Fuel Ratio—The proportion of air to fuel: by weight: that is produced by the carburetor or injector.

ATDC or After Top Dead Center—Any position of the piston in the cylinder bore after its highest point in the stroke (TDC). ATDC is measured in degrees of crankshaft rotation after TDC. For example, the point at which the exhaust valve closes (EVC) may be indicated as 30-degrees ATDC. In other words, the exhaust valve would close 30 degrees after the beginning of the intake stroke (the intake stroke begins at TDC).

Atmospheric Pressure—The pressure created by the weight of the gases in the atmosphere. Measured at sea level this pressure is about 14.69psi.
Back Pressure: A pressure developed when a moving liquid or gaseous mass passes through a restriction. "Backpressure" often refers to the pressure generated within the exhaust system from internal restrictions from tubing and tubing bends, mufflers, catalytic converters, tailpipes, or even turbochargers.

BBDC or Before Bottom Dead Center—Any position of the piston in the cylinder bore before its lowest point in the stroke (BDC). BBDC is measured in degrees of crankshaft rotation before BDC. For example, the point at which the exhaust valve opens (EVO) may be indicated as 60-degrees BBDC. In other words, the exhaust valve would open 60 degrees before the exhaust stroke begins (the exhaust stroke begins at BDC).

Big-Block—A generic term that usually refers to a V8 engine with a displacement that is large enough to require a physically "bigger" engine block. Typical bigblock engines displace over 400 cubic inches.

Blowdown or Cylinder Blowdown—Blowdown occurs during the period between exhaust valve opening and BDC. It is the period (measured in crank degrees) during which residual exhaust gases are expelled from the engine before the exhaust stroke begins. Residual gasses not discharged during blowdown must be physically "pumped" out of the cylinder during the exhaust stroke, lowering power output from consumed "pumping work."

Bore or Cylinder Bore—The internal surface of a cylindrical volume used to retain and seal a moving piston and ring assembly. "Bore" is commonly used to refer to the cylinder bore diameter, unusually measured in inches or millimeters. Bore surfaces are machined or ground precisely to afford an optimum ring seal and minimum friction with the moving piston and rings.

Brake Horsepower (bhp)—Brake horsepower (sometimes referred to as shaft horsepower) is always measured at the flywheel or crankshaft by a "brake" or absorbing unit. Gross brake horsepower describes the power output of an engine in stripped-down, "race-ready" trim. Net brake horsepower measures the power at the flywheel when the engine is tested with all standard accessories attached and functioning. Also see Horsepower, Indicated Horsepower, Friction Horsepower, and Torque.

Brake Mean Effective Pressure (bmep)—A theoretical average pressure that would have to be present in each cylinder during the power stroke to reproduce the force on the crankshaft measured by the absorber (brake) on a dynamometer. The bmep present during the power stroke would produce the same power generated by the varying pressures in the cylinder throughout the entire four-cycle process.

BTDC or Before Top Dead Center—Any position of the piston in the cylinder bore before its highest point in the stroke (TDC). BTDC is measured in degrees of crankshaft rotation before TDC. For example, the point at which the intake valve opens (IVO) may be indicated as 30-degrees BTDC. In other words, the intake valve would open 30 degrees before the intake stroke begins (the intake stroke begins at TDC).

Cam Timing @ 0.050-Lift—This method of determining camshaft valve timing is based on 0.050 inches of tappet rise to pinpoint timing events. The 0.050-inch method was developed to help engine builders accurately install camshafts. Lifter rise is quite rapid at 0.050-inch lift, allowing the cam to be precisely indexed to the crankshaft. Camshaft timing events are always measured in crankshaft degrees, relative to TDC or BDC.

Cam Timing @ Seat-To-Seat—This method of determining camshaft timing uses a specific valve lift (determined by the cam manufacturer) to define the beginning or ending of valve events. There is no universally accepted valve lift used to define seat-to-seat cam timing, however, the Society of Automotive Engineers (SAE) has accepted 0.006-inch valve lift as its standard definition. Camshaft timing events are always measured in crankshaft degrees, relative to TDC or BDC.

Camshaft Advance/Retard—This refers to the amount of advance or retard from the manufacturers recommended timing that the cam is installed in the engine. Focusing on intake timing, advancing the cam closes the intake valve earlier. This setting typically increases low-end performance. Retarded cam timing closes the intake valve later which tends to help top end performance.

Camshaft Lift—The maximum height of the cam lobe above the base-circle diameter. A higher lobe opens the valves further, often improving engine performance. Lobe lift must be multiplied by the rocker ratio (for engines using rocker arms) to obtain total valve lift. Lifting the valve more than 1/3 the head diameter generally yields little additional performance. Faster valve opening rates add stress and increase valvetrain wear but can improve performance. High lift rates usually require specially designed, high-strength components.

Centerline—An imaginary line running through the center of a part along its axis, e.g., the centerline of a crankshaft running from front-to-back directly through the center of the main-bearing journals.

Duration or **Valve Duration**—The number of crankshaft degrees (or much more rarely, camshaft degrees) of rotation through which the valve lifter or cam follower is raised above a specified height; either seat-to-seat valve duration measured at 0.006-, 0.010-inch or other valve lifts (even 0.020-inch lifter rise), or duration measured at 0.050-inch lifter rise, called 0.050-inch duration. Intake duration is a measure of all intake lobes, and exhaust duration indicates the exhaust timing for all exhaust lobes. Longer cam durations hold the valves open longer, often allowing increased cylinder filling or scavenging at higher engine speeds.

Exhaust Center-Angle/Centerline or **ECA—**The distance in crank degrees from the point of maximum exhaust valve lift (on symmetric cam profiles) to TDC during the valve overlap period.

Exhaust Valve Closing or **EVC**—The point at which the exhaust valve returns to its seat, or closes. This valve timing point usually occurs early in the intake stroke. Although EVC does not have substantial effects on engine performance, it contributes to valve overlap (the termination point of overlap) that can have a significant effect on engine output.

Exhaust Valve Opening or **EVO**—The point at which the exhaust valve lifts off of its seat, or opens. This valve timing point usually occurs late in the power stroke. EVO usually precedes BDC on the power stroke to assist exhaust-gas *blowdown*. The

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EVO timing point can be considered the second most important cam timing event from a performance standpoint.

Filling & Emptying Simulation—This engine simulation technique includes multiple models (e.g., thermodynamic, kinetic, etc.), and by dividing the intake and exhaust passages into a finite series of sections it describes mass flow into and out of each section at each degree of crank rotation. The Filling And Emptying method can accurately predict average pressures within sections of the intake and exhaust system and dynamically determine VE and engine power. However, the basic Filling And Emptying model can not account for variations in pressure *within* individual sections due to gas dynamic effects.

Four-Cycle Engine—Originally devised by Nikolaus Otto in 1876, the four-cycle engine consists of a piston moving in a closed cylinder with two valves (one for inlet and one for outlet) timed to produce four separate strokes, or functional cycles: Intake, Compression, Power, and Exhaust. Sometimes called the ”suck, squeeze, bang, and blow” process, this technique—combined with a properly atomized air/fuel mixture and a precisely timed spark ignition—produced an engine with high efficiency and power potential. DynoSim5 is designed to simulate the functional processes of a four-cycle engine.

Horsepower—Torque measures how much work (an engine) *can* do; and power is the rate-based measurement of *how fast* the work is being done. Starting with the static force applied at the end of a torque arm (torque), then multiplying this force by the swept distance through which the same force would rotate the torque arm one full revolution determines the power per revolution: Power Per Revolution = Force or Weight x Swept Distance. James Watt (1736-1819) established the current value for one horsepower: 33,000 pound-feet per minute or 550 pound-feet per second. So horsepower is currently calculated as: Horsepower = Power Per Revolution/33,000, which is the same as Horsepower = (Torque x 2 x Pi x RPM)/33,000, or simply: Horsepower = (Torque x RPM)/5,252. The horsepower being calculated by these equations is just one of several ways to rate engine power output. Various additional methods for calculating or measuring engine horsepower are commonly used (to derive friction horsepower, indicated horsepower, etc.), and each technique provides additional information about the engine under consideration.

Induction Airflow—The airflow rating (a measurement of restriction) of a carburetor or fuel injection system. Standard automotive four-barrel carburetors are rated by the measured airflow when the device is subjected to a pressure drop equal to 1.5-inches of mercury. Two-barrel carburetors are tested at 3.0-inches of mercury.

Intake Centerline Angle—The distance in crank degrees from the point of maximum intake valve lift (on symmetric cam profiles) to TDC during the valve overlap period.

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Intake Stroke—One of the four 180-degree full "sweeps" of the piston moving in the cylinder of a four-stroke, internal-combustion engine (originally devised by Nikolaus Otto in 1876). During the intake stroke, the piston moves from *TDC* to *BDC* and inducts (draws in by lowering the pressure in the cylinder) air/fuel mixture through the induction system. Note: The 180-degree duration of the intake stroke is commonly shorter than the period during which the intake valve is open, sometimes referred to as the true "Intake Cycle." The intake stroke is followed by the compression stroke.

Intake Valve Closing or **IVC**—Considered the most important cam timing event from a performance standpoint. The point at which the intake valve returns to its seat, or closes. This valve timing point usually occurs early in the compression stroke. Early IVC helps low-end power by retaining air/fuel mixture in the cylinder and reducing charge reversion at lower engine speeds. Late IVC increases high-speed performance (at the expense of low speed power) by allow additional charge to fill the cylinder from the ram-tuning effects of the induction system at higher engine speeds.

Intake Valve Opening or **IVO**—The point at which the intake valve lifts off of its seat, or opens. This valve timing point usually occurs late in the exhaust stroke. Although IVO does not have a substantial effect on engine performance, it contributes to valve overlap (the beginning point of overlap) that can have a significant effect on engine output.

Lobe-Center Angle or **LCA**—The angle in cam degrees from maximum intake lift to maximum exhaust lift. Typical LCAs range from 100 to 116 camshaft degrees (or 200 to 232 crank degrees).

Normally Aspirated—When the air-fuel mix is inducted into the engine solely by the lower pressure produced in the cylinder during the intake stroke; aspiration not aided by a supercharger.

Otto-Cycle Engine—See Four-Cycle Engine

Overlap or **Valve Overlap**—The period, measured in crank degrees, when both the exhaust valve and the intake valve are open. Valve overlap allows the negative pressure scavenge wave to return from the exhaust system and begin the inflow of air/fuel mixture into the cylinder even before the intake stroke begins. The effectiveness of the overlap period is dependent on engine speed and exhaust "tuning."

RPM—Revolutions Per Minute. A unit of measure for angular speed. As applied to the IC engine, rpm indicates the instantaneous rotational speed of the crankshaft described as the number of crank revolutions that would occur every minute if that instantaneous speed was held constant throughout the measurement period. Typical idle speeds are 300 to 800rpm, while peak engine speeds can reach as high as

10,000rpm or higher in some racing engines.

Simulation and **Engine Simulation**—A engine simulation process or program attempts to predict real-world responses from specific component assemblies by applying fundamental physical laws to “duplicate” or simulate the processes taking place within the components.

Smallblock—A generic term that usually refers to a V8 engine with a displacement small enough to be contained within a “small” size engine block. Typical smallblock engines displace under 400 cubic inches.

Stroke—The maximum distance the piston travels from the top of the cylinder (at TDC) to the bottom of the cylinder (at BDC), measured in inches or millimeters. The stroke is determined by the design of the crankshaft (the length of the stroke arm).

Top Dead Center or **TDC**—The position of the piston in the cylinder bore at its uppermost point in the stroke. Occurs twice within the full cycle of a four-stroke engine; at the start of the intake stroke and 360 degrees later at the end of the compression stroke.

Torque—The static twisting force produced by an engine. Torque varies with the length of the “arm” over which the twisting force is measured. Torque is a force *times* the length of the measurement arm: *Torque = Force x Torque Arm*, where *Force* is the applied or the generated force and *Torque Arm* is the length through which that force is applied. Typical torque values are ounce-inches, pound-feet, etc.

Valve Head and **Valve Diameter**—The large end of an intake or exhaust valve that determines the working diameter. Valve head temperature can exceed 1200 degrees(F) during engine operation and a great deal of that heat is transferred to the cylinderhead through the contact surface between the valve face and valve seat.

Valve Lift—The distance the valve head raises off of the valve seat as it is actuated through the valvetrain by the camshaft. Maximum valve lift is the greatest height the valve head moves off of the valve seat; it is the lift of the cam (lobe height minus base-circle diameter) multiplied by the rockerarm ratio (in engines equipped with rockerarms).

Valve Motion Curve or **Valve Displacement Curve**—The movement (or lift) of the valve relative to the position of the crankshaft. Different cam styles (i.e., flat, mushroom, or roller) typically have different displacement curve acceleration rates. Engine simulation programs calculate a valve motion curve from valve event timing, maximum valve lift, and other cam timing specifications.

Volumetric Efficiency—An engine measurement calculated by dividing the mass of air inducted into the cylinder between IVO and IVC by the mass of air that would fill the cylinder at atmospheric pressure (with the piston at BDC). Typical values range from 0.6 to 1.2, or 60% to 120%. Peak torque always occurs at the engine speed that produced the highest volumetric efficiency.

Dyno Testing Notes

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