USER MANUAL FOR ALL MOTA PROGRAMS

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1 INTRODUCTION

This latest development of the original **MOTA** simulator has forked into 2 different products, **MOTA-8** and **MOTA-7.** Collectively, the two products will be referred to as **MOTA,** still distributed by Ian Williams Tuning. This manual describes how to use each of these packages.

Where **"MOTA Software"** is referred to in this manual is implied the entire suite **MOTA-8** and **MOTA-7**. Where necessary the packages **MOTA-8** and **MOTA-7** will be referred to individually in this manual.

MOTA-8 contains all that was in the previous **MOTA** with the addition of an **Expansion Chamber Optimiser and Piston Ports Optimiser**. It can also be run as a simulator only. In this case its results are identical to those of the original **MOTA** simulator. For this reason, it is unnecessary to include the latter in this distribution.

MOTA-8 designs optimal exhaust systems and piston ports that give maximum power or torque over specified speed ranges of 2-stroke engines. Unlike many software products, which use empirical equations to size exhaust systems, **MOTA-8** uses the same 2-stroke engine simulation package as in the previous versions of **MOTA** to evaluate each exhaust system configuration. It searches systematically through a large number of configurations and chooses that set of dimensions that best matches the user's criteria. For example, a user can ask for the design that maximises power at a particular speed or speed range for a given engine. **MOTA-8** varies the pipe and port dimensions systematically until it comes up with a set of dimensions that appear to give the most power at the nominated speed or speed range. These dimensions will be referred to as optimal. Various combinations of port and pipe dimensions can be selected for the optimisations.

In general, the optimal dimensions will always lead to a better power output than the engine had originally, but there may be a number of such sets of dimensions and the first one output may not be the "best". At the expense of increased computing time, various strategies for obtaining a pipe and ports very close to the "best" are given in this manual. This problem can be thought of as trying to find the highest peak in a set of mountains, each with a different height. The lowest mountain peak will be higher than the valley floor but not as high as the highest peak. Strategies to guarantee finding the highest peak (best port and pipe design) are expensive computationally and not worth pursuing in a product such as this (run times may be many hours compared with half an hour for **MOTA-8**). The philosophy here is to guarantee a better than starting design and suggest ways to improve this.

MOTA-8 will only design optimal exhaust systems of the type:

- Integrated box muffler (A "can" at the end is treated as a box volume, for example the Yamaha KT100S.)
- Integrated duct muffler (A "can" at the end is treated as a duct, for example the Yamaha KT100S.)
- Single piece expansion chamber (for example see the Rotax rot256 Engine Data File.)

MOTA-7 provides a 2-dimensional graphics illustration of the scavenge process. It is a 2-stroke engine simulator only, based on the previous version of the **MOTA** simulator, but with a 2-dimensional scavenging model. The original scavenging model in the simulator is controlled by only 4 variables which values the user enters. These variables are based on practical knowledge, not rigourous engineering. In spite of this, simulation results are quite accurate but do not allow the user to study the detailed 3-dimensional flow in the cylinder during scavenging. By contrast, **MOTA-7** contains a 2-dimensional model of cylinder flow. This is achieved by "squashing" the cylinder about a plane running through the centre of the exhaust port and the axis of the cylinder, and assuming scavenge port symmetry each side of this plane. The resulting cylinder section is then divided into a large number of cells (limits are 99 points diametrically and 99 points axially from BDC to TDC), and the thermodynamic conservation equations are applied at each point for each time step. Clearly, this represents several orders of magnitude increase in computational effort over the original "pipe only" equations in the **MOTA** simulator and **MOTA-8** and the **MOTA-7** run times can be an hour or more compared with several seconds for the original simulator. A 3-dimensional model is not offered because its run times would be several orders of magnitude higher than those of the present 2-dimensional model, making it impractical for commercialisation at this time. For the same reason it is impractical to couple the **MOTA-8** optimiser to **MOTA-7** because current execution times would be unacceptable. Although the output power curves from **MOTA-7** will be a little different from those of **MOTA-8** the animations of scavenge flow within the cylinder provided by **MOTA-7** can be used to determine appropriate modifications to the the cylinder. These animations are available through a "CYLPLOT" option button on the graphics menu of **MOTA-7**.

Section 4.5.6 describes the extra input needed in the Engine Data File for **MOTA-7** and section 6.9 describes how to view the cylinder state animations **MOTA-7** provides.

MOTA is the result of on-going collaboration between University research engineers and mathematicians, and Ian Williams Tuning. As further research and validation is completed, updated versions of the **MOTA** suite of programs are made available.

The term **MOTA** is used to cover the complete suite of programs which build, modify, run and optimise expansion chamber based *Engine Data Files*, and process *Graphics Output Files* and *Engine Performance Files*.

MOTA allows the simulation of 2-stroke engines with reed valve, rotary valve or conventional piston port timed induction systems and expansion chamber exhaust systems (with either an integrated go-kart type muffler or a separate muffler).

Because **MOTA** solves the equations describing the conservation of fluid and thermodynamic properties throughout an engine, it requires the specification of the full engine geometry. This is accomplished through a menu driven environment which prompts you for the required dimensions. This manual describes each of these inputs in detail.

The simulator in **MOTA** uses data supplied from an *Engine Data File*. Such a file is constructed by completing a set of screens which prompt you for information about your engine. The simulator outputs information to a text based *Engine Performance File* which summarises the engine's geometry and performance, and to a *Graphics Output File* which is used to depict various aspects of the engine's performance graphically. Facilities within **MOTA** allow you to view this information.

The strength in **MOTA** lies not so much in its ability to predict accurately the performance of an engine, but in its ability to compare the performances of different engine configurations. For example, if you have the **MOTA** generated power curve for an engine, and you want to see if modifying one of the exhaust pipe dimensions will increase or decrease power, then you can change that particular dimension and re-run the **MOTA** simulator. Comparison of the new power curve with the old will allow you to determine whether or not the change will be beneficial. You can also optimise expansion chamber dimensions to produce the best possible power curve over a specified engine speed.

Each of the **MOTA** products contained herein will simulate one of the cylinders of a multi-cylinder 2-stroke engine provided that the cylinders are identical in layout and dimensions and each cylinder has a separate exhaust system and a separate induction system.

1.1 MOTA HELP

For information and assistance go to our website www.iwt.com.au
The **MOTA** FAQ's provide answers to some common problems.

1.2 IMPORTANT: PLEASE READ BEFORE INSTALLING THE MOTA SUITE OF PROGRAMS

MOTA-8 allows you to design expansion chambers and piston ports automatically, using standard **MOTA** files plus some additional screens as input. You will only be able to run **MOTA-8** and **MOTA-7** if your computer is of a particular type.

1.3 HARDWARE and SOFTWARE REQUIREMENTS

MOTA will not run on Macintosh computers, Tablets, Smartphones or Unix (Linux) based computers or single core Pentium or celeron processor computers.   It will run only on versions of Windows later or equal to Windows 7. You will need to install Adobe Acrobat in order to access the manual. The recommended computers for running it are based on Intel core i7 or Core i9 processors, though it will run slowly on most core i3 and i5 processor based machines.   It should run on equivalent multi core AMD based machines, but this has not been verified.. The reason for the fairly high spec machine requirement is that the simulator has been built to take advantage of the architecture by carrying out most of its computations in parallel, so running it on a single core machine will produce very slow run times. Before buying **MOTA**, you should have returned to Ian Williams Tuning the results of a questionnaire to determine whether **MOTA** will run on your machine.

MOTA was developed using an 800 x 600 screen resolution colour display and small fonts. All programs in the suite will run satisfactorily at higher resolutions but, because they are not resizable, some forms will always appear as small on higher resolution screens.

Once **MOTA** is installed on your computer, if **MOTA-8** or **MOTA-7** fails to run the engine simulator because your computer is not built to handle multi core parallel processing you will get a runtime error and the program will close. The error message may be something like "runtime error, incompatible version of windows" or words to that effect

1.4 INSTALLING MOTA

MOTA-8 and **MOTA-7** are distributed on a USB stick. Unlike a CD, the files on the stick can be deleted accidentally, so it is important that you backup the files to some media where they are at minimal risk of deletion. A CD or DVD is the best option, followed by a back up hard disk.

The USB stick contains a number of folders:

- Documents - pdf version of the **MOTA** manual.
- SAMPLES-8 and SAMPLES-7 – **MOTA-8 and MOTA-7** input engine data files for a number of existing engines.
- README - Contains installation instructions (this document).
- FAQ - A list of frequently asked questions relating mainly to installation and running problems.
- Redistribute - The runtime library essential for **MOTA-8** and **MOTA-7** to run.

To Install the **MOTA** suite of programs, double click the SETUP icon on your USB stick and follow the prompts. After all of the files have been installed, the **MOTA** setup screen will be replaced with a screen telling you that **MOTA** has been installed successfully and directing you to follow the ensuing prompts to install the intel redistributable runtime libraries. You **MUST**

allow this to be carried out, so follow the simple prompts and OK the install. Although not mandatory, it is a good idea to restart your computer after this step. If you have trouble with the installation, read the document in the FAQ folder of the USB stick.

*During the installation, 2 sub-folders of the **MOTA** installation folder called SAMPLES-8 and SAMPLES-7 will be created and loaded with a number of **MOTA-8** and **MOTA-7 Engine Data Files** which you can use to familiarise yourself with the software. Please note that the **MOTA-8** input **Engine Data Files** are different from the **MOTA-7 Engine Data Files**.*

The default structure of the **MOTA** installation is:

c:\users\public\MOTA80

where the **MOTA** folder contains:

- The sub-folders **SAMPLES-8** and **SAMPLES-7**.
- The executable files for running **MOTA-8** and **MOTA-7**.
- **MOTAMAN.pdf** which is a manual accessed via the HELP command on the main screen of each of the **MOTA** packages. It can also be accessed by navigating to the **c:\users\public\MOTA80** folder and double clicking it**.**

1.5 SUGGESTED ORGANISATION OF INPUT/OUTPUT FILES

It is strongly recommended that you create a "back-up" folder in c:\users and copy into it the two "samples" folders which were placed in **c:\users\public\MOTA80** during the **MOTA** installation. You will access the installed "samples" folders when browsing with the **MOTA** packages and again when creating engine data files for your own engines. When creating such a file it is best to do so by editing a file in one of the "samples" directories which closely resembles your own engine. The selected file should be saved to a new name of your choice, such as "Rtx01", this perhaps immediately it has been selected for editing. The necessary changes to "Rtx01" can then be completed as time permits.

When saving the "new" data file you can accept the folder from which the file originated or navigate to a different folder. In this respect it might be a good ploy to create a new folder, such as "fr125max", and save "Rtx01.dat" to this folder. When you perform a simulation using this new data file the output performance and graphics files are saved to the same folder as that of your **Engine Data File** and with the same name.

Later, you may choose to perform an expansion chamber optimisation by running **MOTA-8** with your **Engine Data File** selected. In this case you will be asked to nominate a name for the output **Engine Data File** which will contain the dimensions of the optimal expansion chamber and piston ports. This could be such as Rtx01-a1. The output performance and graphics files will be given the same name.

The procedure described for creating a new **Engine Data File** is easier than creating a new engine data file from scratch. The big advantage of updating an existing engine data file is that this does not have to be completed in a single session, you can save a partly updated version and finish the task later. Compare this with the creation of a new engine data file which has to be complete before it can be saved.

Summarising, suppose you want to prepare a new engine data file, complete an engine simulation using this file and then obtain an optimal expansion chamber design for the engine. It will be best to run with **MOTA-8** throughout and use the following procedure:

- Use the "Edit an Engine Data File" facility in **MOTA-8** to examine various files in the folder SAMPLES-8 and in this way locate the **Engine Data File** which best matches your engine.
- Before you save the selected file under a new name decide whether to add the file to the folder SAMPLES-8 or create a new folder in c:\users and save it there. This last choice is generally best, particularly if you expect to complete a good many optimisation runs on this engine.
- Perform all simulations and optimisations of this engine within the chosen sub-folder. If a sequence of several optimisations is performed you might use several sub-folders but this will be unnecessary if you appropriately name the files to be generated; for example Rtx01-a1, Rtx01-a2, Rtx01-a3, Rtx01-b1. The date might be included in a file name quite usefully, for example Rtx20161105, Rtx20170103. Here the year/month/day sequence ensures that the files will list in chronological order in a directory tree.

2 RUNNING THE MOTA SUITE OF PROGRAMS

In order to run any of the **MOTA** suite of programs, you need to plug the supplied *USB* dongle into a USB port of your computer. The dongle must remain plugged into your computer whilst you are running any of the programs and it may remain plugged into your computer at all times with no undesirable effect.

To start **MOTA-8 or MOTA-7**, double click its icon. These icons were placed on your desktop during the program installation.

If you receive any messages relating to the dongle being missing, check that it is correctly plugged into a USB port. If, with the dongle properly connected in an active USB port, you still receive a message to the effect that the dongle is missing, please

contact your distributor.

The **Engine Simulator** is the most important component of **MOTA**.

The principal function of each program of the **MOTA** suite is the use of an *Engine Data File* by the chosen program. The engine simulation process produces two files by which the user can examine the engine performance. The ***Engine Performance File*** is a text file whilst the *Graphics Output File* contains numerical values for use in the graphical display of the engine's performance. The entire suite of programs which constitute **MOTA** enable:

- The construction and editing of an *Engine Data File* and a number of computational tools to assist in the production of this file.
- The processing of an *Engine Data File* by the **Engine Simulator** in each program of the **MOTA** suite.
- The examination of an engine's performance by viewing the *Engine Performance File* and by the display of graphics through accessing the *Graphics Output File*.
- The ability to compare directly the performance of different engines by the overlay display of their power and torque characteristics.
- The display of this *User Manual* which can be accessed at the same time as most other screens within the **MOTA** environment.
- Tools to assist in the construction of expansion chambers.
- Printer access from most screens within the **MOTA** environment.

3 THE MAIN MENU COMMON TO ALL PROGRAMS IN THE MOTA SUITE

In the following, the term **MOTA** is used to denote the suite of the two programs **MOTA-8 and MOTA-7**.

When one of the two programs which constitute **MOTA** is started the *Main MOTA Menu* screen is displayed. The **Menu Bar** situated at the top of this screen contains seven titles: *File, Run the Simulator, Tools, Expansion Chamber Construction, Powaplot, Help* and *Exit from MOTA*. Each is described briefly in the current section and comprehensively in later sections of this manual.

3.1 FILE

Remember that the format of a **MOTA-7** *Engine Data File* differs to that for a **MOTA-8** *Engine Data File*. If you try to load a data file using the wrong **MOTA** program for that file, an error message box will appear. When creating or editing a data file, make sure that you select a file or option compatible with the particular **MOTA** program you wish to use.

Clicking on File provides a menu comprising six selections:

1. **New Engine Data File.** This allows you to specify the characteristics and dimensions of the engine you wish to simulate. Various screens can be selected from a main Engine Data File construction screen within this option, allowing you to enter your engine's characteristics in a logical manner. When you select the *Save the File* option from this main screen, you must then enter a name for your engine file. The file is then saved to the folder of your choice, with a "*.dat*" extension. All files with this extension are recognised by **MOTA** as Engine Data Files. Such files created by the current version contain internal identifiers which designates them as either **MOTA600** (used with **MOTA-8**) or **MOTA700** (used with **MOTA-7**). This allows **MOTA** to distinguish between valid data files and other files with the same extension which are not suitable data files. Should you later try to load such an invalid file for editing (see 2 below) or for use by the simulator, you will receive a message to the effect that the file is unsuitable. For comprehensive details refer to section 4 of this manual.

2. **Edit Existing Data File.** This allows you to select an existing file of the type constructed under *New Engine Data File*, edit it and then save it under its original name or under a new name. For comprehensive details refer to section 4 of this manual.

3. **View an Engine Performance File.** Selecting this option after a simulation run allows you to look at the "*.per"* file written during an engine simulation. We recommend strongly that you do this. The *Engine Performance File* contains all of your input data and other values such as port areas as well as various measures of your engine's performance. Also, because it is very easy to make typographical mistakes when entering data, the *Engine Performance File* provides a useful check of the correctness of the Engine Data File values. For comprehensive details, refer to section 5 of this manual.

4. **Display Engine Graphical Information.** When an engine simulation is completed a file is created having the same name as the Engine Data File, but with the extension "*.gph*". This option allows you to examine your engine's performance via both static and animated graphics. For comprehensive details, refer to section 6 of this manual. **MOTA-7** graphics files are very different from graphics files generated by **MOTA-8** and can be viewed only with **MOTA-7**.

5. **Engine Data File Conversion (v5 to MOTA-8).** This utility is provided to convert the format of engine data files from **MOTA v5** to that for the simulator of **MOTA-8** contained in **MOTA v8**.

6. **Engine Data File Conversion (MOTA-8 to MOTA-7).** This utility is provided to assist those **MOTA v8** users who want to create data files for the simulator of **MOTA-7** contained in **MOTA v8**.

7. **Exit from MOTA.** Shuts down the **MOTA** environment. This is an alternative to the exit facility provided as a separate option of the *Main MOTA Menu*.

Selecting any of the choices 2-6 will result in a dialogue box inviting you to select the drive, folder and file for the appropriate action. Only files with the relevant extension are displayed in the file dialogue window: Files with the extension "*.dat*" are *Engine Data Files*, those with "*.gph*" are *Graphics Output Files*, and the "*.per*" extension is used for *Engine Performance Files*. You may select any file by double clicking it or by clicking it once and then clicking the "Open" button in the dialogue box.

3.2 RUN THE SIMULATOR

MOTA-7: This selection runs the engine simulator in the **MOTA-7** package. The **MOTA-7** simulator accesses a data file with a "*.dat*" extension, performs an engine simulation run and writes three files with the same name as the engine data file but with the extensions: "*.per*", "*.gph*" and *".cyl"*. The first of these is the *Engine Performance File* which provides text information about the engine's performance. The second file is the *Graphics Output File*. This provides information for a graphics post-processor which can be used to display both stationary and animated views of the engine's performance. The *".cyl"* file is used for the graphical output as described in section 7. These three files are always written to the same drive and folder as that containing the Engine Data File used for the simulation. Comprehensive details of an engine simulation run are given in section 7 of this manual.

MOTA-8: A menu comprising two selections is displayed:

- Normal Engine Simulation.
- Engine Optimisation.

3.2.1 Normal Engine Simulation

This selection runs the engine simulator in the **MOTA-8** package. This accesses a data file with a "*.dat*" extension, performs an engine simulation run and writes two files with the same name as the engine data file but with the extensions: "*.per*" and "*.gph*". The first of these is the *Engine Performance File* which provides text information about the engine's performance. The second file is the *Graphics Output File*. This provides information for a graphics post-processor which can be used to display both stationary and animated views of the engine's performance. These two files are always written to the same drive and folder as that containing the Engine Data File used for the simulation. Comprehensive details of an engine simulation run are given in section 7 of this manual.

3.2.2 Engine and Expansion Chamber Optimisation

This selection runs the optimiser and engine simulator in the **MOTA-8** package. You are asked to select an *Engine Data File* and then provide a number of parameters for the optimisation and a name for the output files. Finally the expansion chamber and port dimensions to be varied during the optimisation are selected. These are detailed in section 7.2. The *".per"* and *".gph"* output files written by the optimiser are similar to those written during a normal engine simulation run. Additionally written are an *Engine Data File* which contains the optimal values and a *Monitor File* with the extension *".mon"* . These files are referred to in section 7.2.3 of this manual. The *Performance File* also contains details of the optimisation.

3.3 TOOLS

Clicking on Tools provides a menu of utilities for calculating and converting engine related parameters. These utilities are described fully in section 8 of this manual.

3.4 EXPANSION CHAMBER CONSTRUCTION

This utility is intended to assist the construction of an expansion chamber comprising a sequence of cones.
At its simplest the expansion chamber will comprise a sequence of **straight cones.**
Should one or more bends occur in the expansion chamber, one or both ends of some cones will be **oblique**.
If the **axis** of the expansion chamber does not lie in a plane the **3-dimensional shape** can be obtained by effectively "rotating" one end of some cones for which both ends are oblique.
Cone Development Patterns can be printed for cone sections of maximum length 400mm and maximum diameter 200mm.
An *Engine Data File* can be selected and patterns printed for any selection of the sections of the expansion chamber described in the file. **Explanatory Diagrams** with text can be selected for display. Full details of this utility are provided in Section 9 of this manual.

3.5 POWAPLOT

This utility is provided to enable the easy comparison of the performance of an engine as measured by a dynamometer with that predicted by the **MOTA** engine simulator. It involves the construction and use of files having a "*.pow*" extension which

contain a set of values of engine speed and power.

The selection of **Powaplot** provides a menu of three selections:

1. **Construct a Power File from a Graphics Output File.** This selection allows you to extract the power curve information from a nominated *Graphics Output File* produced by a **MOTA** engine simulation and write it to a separate *Power File* with the extension "*.pow*".
2. **Construct a Power File Manually.** You enter values of engine speed and the corresponding power or torque through the keyboard and then save this information to a file with a "*.pow*" extension. You are asked to nominate the input units and also whether the speeds will be in equal increments in which case only the initial speed and the increment are entered.
3. **Display a Power File.** Under this selection you are asked to select a *Power File*. The power/torque curves representing the values in this file are then displayed. Many display options are provided such as the change of display units, the change of scales and the selection of other *Power Files* and/or *Graphics Output Files* to provide overlay curves to the display. The overlay facility allows the easy comparison of engine performance.

Comprehensive details of the **Powaplot** utility are provided in section 10 of this manual.

3.6 HELP

Clicking on Help provides a menu of two selections.

1. **User Manual.** This selection provides an on line display of this manual using your computer's Adobe Acrobat Reader. The entire content or any selection of pages of the manual may be output to your printer.
2. **About.** This screen provides fax and email contact details for any enquiries you might have concerning **MOTA** together with an associated website address. The website provides details of **Ian Williams Tuning** which has played a major role in the development of the **MOTA** software. As necessary, technical explanations, upgrade information and any other matters of concern to **MOTA** users will be posted on this site.

3.7 EXIT FROM MOTA

This shuts down the **MOTA** environment. It is an alternative to the exit facility provided in the *File Menu*.

4 FILE MENU: NEW ENGINE DATA FILE/EDIT EXISTING ENGINE DATA FILE

If you select *Edit Existing Engine Data File* a Windows dialogue box will open. Using the prompts on this menu, select the drive and folder in which the data file you wish to edit resides. Once selected, all valid data files will be listed. You may choose the file you wish to view or edit by double clicking it or by clicking it once and then clicking the "Open" button on the dialogue box. You will then be presented with a screen entitled *Data File Construction Utility*, hereafter referred to as the *DFCU* screen. This same screen appears when you select *New Engine Data File* from the *File Menu*.

The *DFCU* screen contains a number of buttons, which, when clicked will display screens on which you enter or change details of your engine. A red button indicates that the screen to which it refers has not been completely filled with data. A green button indicates that the screen to which it refers has been completed with valid data. The *DFCU* screen buttons may be clicked in any order at any time and the displayed screen then completed or modified. However, **MOTA** will not allow you to exit from any screen unless you have properly entered all of the required information. For many of the values to be entered the Data File Construction Utility has a built in validator which, when you try to move to the next screen, will advise you of the valid range of any variable whose value is unacceptable and then asks you to enter a valid value. You may open other Windows applications you may need to assist you in establishing data values, without having to close your **MOTA** screen. For example, you can make selections under the *Tools Menu* to assist in calculating information required by your current data file screen. If a required value cannot yet be decided, you may enter any reasonable value which satisfies the screen validator, and then return to update that screen later. This is a particularly important ploy as you cannot save a partially completed file. Once you start to build a new data file or to edit an old one, all of the buttons on the *DFCU* screen **must** be green, before you can save the file. This simply means that to save a file every screen to which a *DFCU* screen selection button refers **must** be completed with valid data even if this does not yet represent the final values of some of the data.

A Helpful Hint Rather than using the *New Engine Data File* selection it is generally easier to create a new Engine Data File by choosing to edit an existing file which describes the same style of engine. Your new values are inserted as required and when you save the file with these replaced values you can assign a new file name of your choice. This enables you to work through the *Engine Data File* without the need of inserting 'dummy' values and the entire construction of your new file can be completed over several edit sessions if desired.

Be aware that changing some numbers on one screen can make previously green buttons on the *DFCU* screen display red. That is, you will need to enter new data on the corresponding screens. For example, if you are editing a *box muffler* Engine Data File, and you change the muffler type option on the *Engine Configuration* screen from *Box Muffler* to a *Single Piece Expansion Chamber*, you will find that the relevant *Exp'n Chamber* duct button on the *DFCU* screen will display red. You will then have to click this button during your editing session and then enter the information required on the newly displayed screen.

When you have completed filling in an engine data file screen, you can exit this screen by clicking on the *Next Screen* button at the top of the screen. This returns you to the *DFCU* screen where you can now select another screen to construct or edit, or you can save the file if editing has been completed and no buttons display as red. If you click on the *Exit to Main Menu* button before you have saved your file you will be warned that to continue with the exit will result in the loss of the information you have entered from the keyboard and you are given the choice to first save the file.

When you first enter the *DFCU* screen in *New Engine Data File* mode, you have only one column of red buttons available to you. This is because the *Engine Configuration* screen has not yet been filled in and so there is no information about the number of engine ducts and ports etc. Buttons pertaining to these appear only after you have filled in the engine configuration screen. Although you may fill in the screens corresponding to the initial set of red buttons in any order, the *DFCU* screen will not display the entire suite of buttons until the *Engine Configuration* screen has been filled in.

*You can print the contents of any screen that you enter from the DFCU screen once you have filled it in. On each such screen there is a button with the caption **Write to Print File**. Clicking this button writes the content of the screen to a print file. When you select **Next Screen** and are returned to the DFCU screen you will notice that the button **Output Print File** is no longer dull and is now active. Clicking this button will send the contents of the print file to the printer. If you want to print out the contents of a number of screens, do not click the **Output Print File** button after exiting from each screen. Instead, simply enter each screen for which you wish to print the content and click the **Save to Print File** button. The contents of each screen is added to the print file. Only when you have added all of the desired screen contents to the print file should you click the **Output Print File** button on the DFCU screen. The entire contents of the print file will then be sent to your printer. An additional button with the caption **Print Entire Data File** is active on the DFCU screen whenever all the data file screen selection buttons are displayed green. Clicking on this button will send the content of all data file screens to the printer in the order in which the screens are listed on the DFCU screen.*

Clicking the *Save the File* button on the *DFCU* screen will display the normal Windows **Save** dialogue box. If you are editing a file, the name of your file will appear in the dialogue box, ready for you to OK the action. If you wish you may save to a different file name. It does not matter whether you enter the file name with or without the "*.dat*" extension, the extension is allocated correctly in either case. If you have just created a new file, you will need to enter a name for the file in the appropriate place on the dialogue box.

The characters used for a new *Engine Data File Name* can be alpha/numeric only and without spaces. The name of the optimisation output files is limited to twelve characters.

The remainder of this section (Section 4) describes each of the Engine Data File screens in detail.

The screens described in sections 4.1 – 4.6 are completely independent of each other, whereas the remaining screens depend upon the content of the engine configuration screen.

Before proceeding it may be useful to define a number of abbreviations which are used within the discussion of some of the screens. These relate to the piston position and so also to the crank angle. Some of these abbreviations are also used on a number of the graphics output screens.

> **TDC**: Top Dead Centre.

> **BDC**: Bottom Dead Centre.

> **BTDC, ATDC**: Before Top Dead Centre and After Top Dead Centre.

> **BBDC, ABDC**: Before Bottom Dead Centre and After Bottom Dead Centre.

> **EPO**: The crank angle (ATDC) at which the Exhaust Port starts to Open.

> **EPC**: The crank angle (ATDC) at which the Exhaust Port becomes fully Closed.

4.1 ENGINE CONFIGURATION

4.1.1 Induction Type

The choice options are: Piston Port, Rotary Valve and Reed Valve induction types.

4.1.2 Exhaust System Type

The choice options are: Box Muffler, Integrated Muffler (Box Model), Single Piece Expansion Chamber and Integrated Muffler (Duct Model). A box muffler is a cavity, usually circular or rectangular in cross section, with an entry pipe from the engine and an exit pipe to the atmosphere.
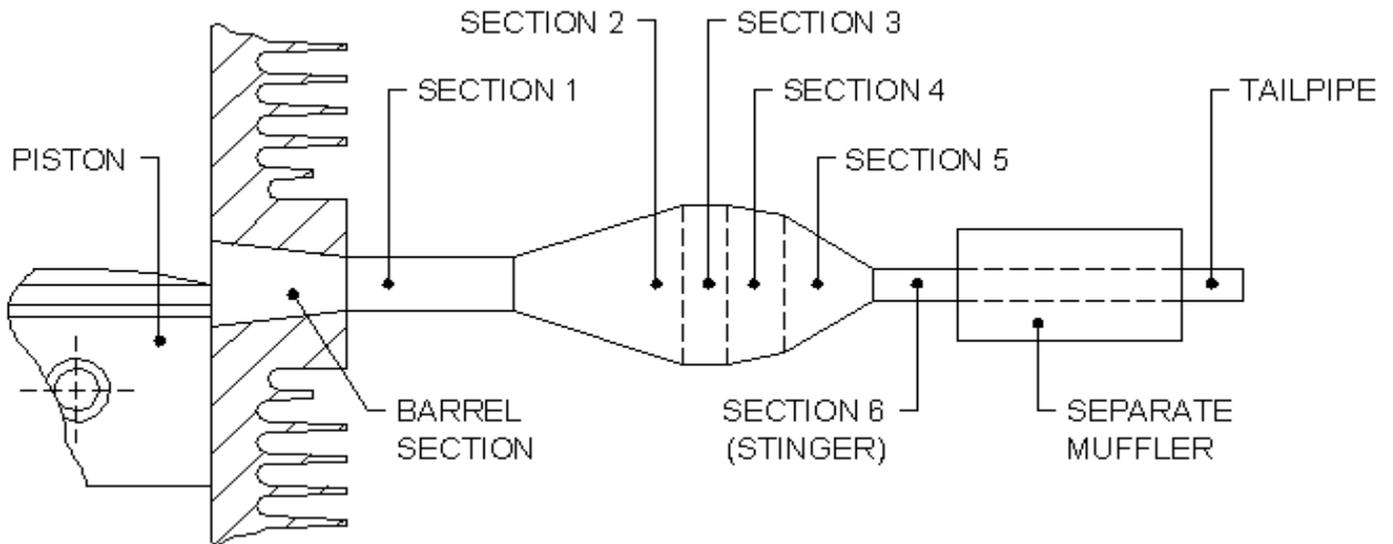
Figure 1

Road Going Motorcycle Exhaust System comprising a Single Piece Expansion Chamber with Separate Muffler
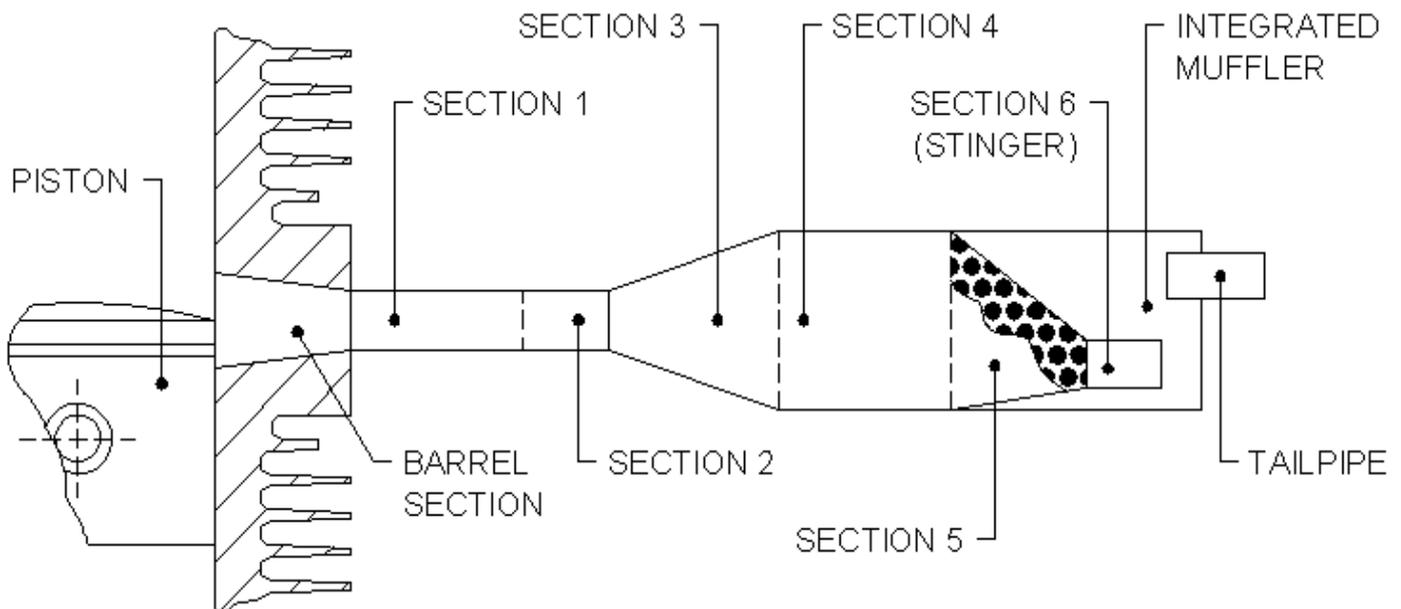
Figure 2

Typical Go-kart Engine Expansion Chamber with Integrated Muffler

A *Single Piece Expansion Chamber* is shown in Figure 1. An *Integrated Muffler* is illustrated in Figure 2. If an exhaust system like that in Figure 1 is used without any type of muffler, you should choose the *Single Piece Expansion Chamber* muffler type. The *Integrated Muffler (Box Model)* and *Integrated Muffler (Duct Model)* refer to the same construction but a different mathematical approach is used to model the muffler in the **MOTA** engine simulator. In most cases the engine performance using either model is almost the same but there is evidence to suggest that the *Duct Model* will at times produce more realistic results.

The *Integrated Muffler (Box Model)* choice refers to the same model used in earlier versions of **MOTA**. If you use this option, the expansion chamber duct screen will ask you to enter only the muffler volume. No account is taken of the relative positions of the muffler, expansion chamber, and tail pipe.

If you make the *Integrated Muffler (Duct Model)* choice, you will need to fill in a screen for the muffler in addition to a screen for the expansion chamber. In the muffler screen, you will be asked to provide geometrical information for each of the sections which make up the duct as well as the dimensions *L1* and *L2* illustrated in Figures 3a & 3b. An *Integrated Muffler* often comprises only one section whose diameter is the same as that of the largest diameter section of the expansion chamber. However, as shown in Figures 3a & 3b, if you are using the *Duct Model* for the muffler **MOTA** allows you to simulate a wide variety of constructions. If there is only a hole in the end of the muffler, you may specify this as a tail pipe of zero length and the appropriate diameter. This option is not available if you select the *Box Model* for the muffler.
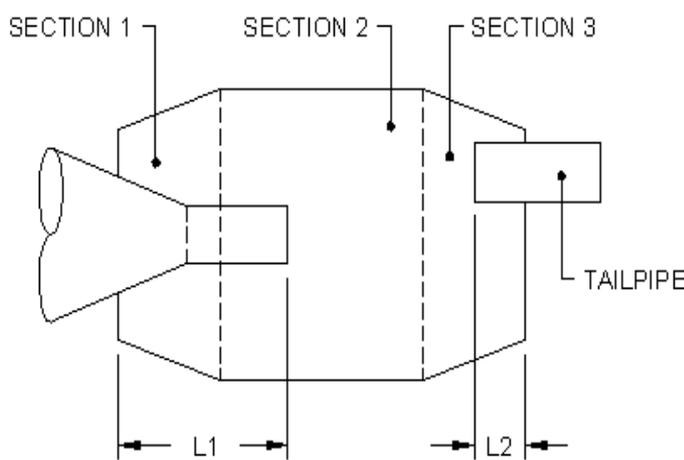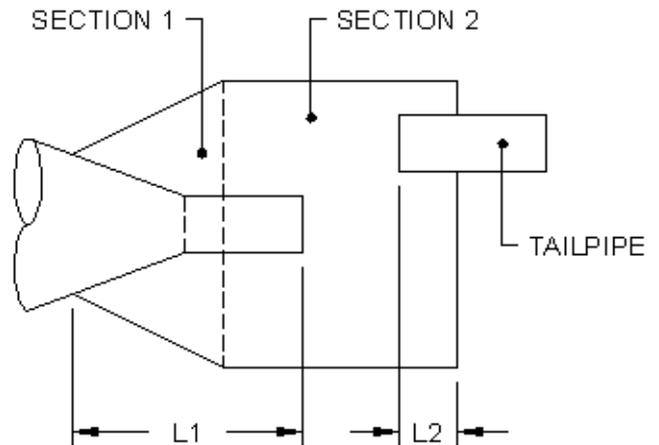
| Figure 3a | Figure 3b |

Typical Integrated Muffler constructions, showing some of the dimensions required for the Duct Model option

4.1.3 Number of Transfer Port Types

This is the number of different transfer port types. Those transfer ports and their associated ducts which repeat with the same dimensions and design, account for just one transfer port type.

4.1.4 Induction Box

You should indicate whether or not your engine has a still air induction box.

4.2 BASIC ENGINE DIMENSIONS

<u>*Remember*</u>…. All dimensions of length are in millimetres and volumes are in cc.

4.2.1 Bore, Stroke, Connecting Rod Length

Self explanatory.

4.2.2 Cylinder Clearance Volume

The volume above the piston crown (with the spark plug installed) when the piston is at top dead centre (TDC).

4.2.3 Crankcase Clearance Volume

The crankcase volume below the piston crown when the piston is at bottom dead centre (BDC). **Transfer duct volumes are excluded**.

4.2.4 Gudgeon Pin Offset

If your engine's gudgeon pin centre line coincides with that of the piston, enter "0.0". If the gudgeon pin centre line is displaced from the piston's centre line in the direction of the crankpin motion at TOP DEAD CENTRE, enter the amount of displacement (termed the offset) in millimetres. Enter an appropriate negative value for the offset otherwise.

4.3 IGNITION AND COMBUSTION DETAILS

4.3.1 The Combustion Efficiency

The efficiency with which an engine burns fuel. The combustion model used in **MOTA** is necessarily simple but quite effective. Experimental tests have shown this type of model to be widely applicable to a number of different engines when only the gross behaviour of the engine (i.e. its power output) is required. The value to use in **MOTA-8** ranges from 0.80 for high performance engines with long exhaust port timings to about 0.85 for more conservatively timed engines. Generally, **MOTA-7** requires efficiencies of 0.85 to 0.95 as its combustion model is slightly different from that of the **MOTA-8** simulator.

4.3.2 The Burn Period

The total number of crankshaft degrees over which actual combustion takes place. Implicit in the use of the simple combustion model is a number of assumptions regarding the onset and cessation of burning in the cylinder. The burning period varies between about 60 degrees for a conservatively ported engine to about 50 degrees for a very high performance engine. For glo-plug ignition model aeroplane engines, the burn period is closer to 40 degrees.

4.3.3 Defining the Ignition Timing Advance Characteristic

MOTA allows different ignition timing (degrees advance) at different engine speeds. If you know these details, you can enter them at the known speeds and **MOTA** will assume a "straight-line" relationship for the ignition timing between these speeds. You should enter the number of engine speeds at which you know your engine's ignition advance. If your engine's ignition advance is a fixed value, enter the value "1" (i.e. 1 point only).

4.3.4 Ignition Advance

A table will be displayed with the number of columns equal to the number you entered in section 4.3.3 above. The first row of this table is completed by entering the engine speeds and the second row is then completed by entering the corresponding values of ignition advance. For the case where "1" was entered in section 4.3.3 above, only a single value of ignition advance will be required and this same value will be used at all engine speeds.

4.4 AMBIENT CONDITIONS

4.4.1 Ambient Pressure and Temperature

The units used to describe the prevailing air conditions are Pascals for pressure and degrees centigrade (C) for temperature. Conversion factors are displayed in case you work in imperial units of pounds per square inch (psi) and degrees Fahrenheit (F).

4.4.2 Water Cooled Exhaust

Selecting this option invokes a model which assumes that the entire exhaust duct is surrounded by a jacket to allow the flow of cooling water. You are asked to enter the temperature (C) of this water.

4.5 FUEL AND SCAVENGE DETAILS

This screen collects details about the characteristics of your fuel and the scavenging characteristics of your engine.

4.5.1 Fuel Calorific Value (i.e. Fuel Heating Value)

A default value for 98 octane petrol is given. If you are using another fuel its calorific value in kcal/kg should be entered. Conversion factors you might need for this purpose are provided.

4.5.2 Throttle Setting (i.e. Throttle Area Ratio)

This is the fraction of the carburettor passage **area** open to flow. It varies from nearly zero when the throttle is closed to the value "1" when it is fully open. Note that the position of the throttle lever is not directly proportional to the flow area, i.e. if the throttle has a butterfly valve and the throttle lever can be rotated between 0 degrees (closed) and 90 degrees (fully open), the relationship between the throttle position and the flow area is:

Fraction of Carburettor Area Open to Flow = 1 - cosine(throttle lever rotation)

4.5.3 Number of Points Defining the Air/Fuel Ratio Characteristic

MOTA allows the use of different Air/Fuel Ratios at different engine speeds. If you know these values you can enter them with their engine speeds. To estimate the Air/Fuel Ratio at intermediate speeds **MOTA** assumes a "straight-line" relationship between adjacent tabulated values. You should enter the number of engine speeds at which you know your engine's Air/Fuel Ratio. If you have only a single value for your engine's Air/Fuel Ratio, enter the value "1" (i.e. 1 point only).

4.5.4 Air/Fuel Ratio(s)

A table will be displayed with the number of columns equal to the number you provided at section 4.5.3 above. The first row of this table is completed by entering the engine speeds and the second row is then completed by entering the corresponding

Air/Fuel Ratios. However, for the case where a "1" was entered at section 4.5.3, only a single value is required and this same value will be used at all engine speeds. If you are unsure of the value(s) to use, the following is a very rough guide:

- High performance engines (e.g. Rotax R128) : 12.5 - 13.0
- Low-Medium performance expansion chamber engines (e.g. Yamaha KT100S): 12.5 - 13.0
- Box Muffler engines (e.g. Comer80) : 13.0 - 14.0

4.5.5 Scavenge Parameters - MOTA-8 only

The scavenge model in **MOTA-8** requires four scavenge parameters to be input. The following is a very broad set of guidelines to their values. You are encouraged to experiment with these values to obtain sensible results for your engine.

The first value represents the maximum fraction of incoming flow from the transfer port(s) to the cylinder which short circuits directly to the exhaust duct, without taking part in any mixing or displacement processes in the cylinder. It is assumed that maximum short circuiting occurs just after gas from the transfer port(s) starts to fill the cylinder and this decreases to zero as the cylinder fills. This **maximum short circuit fraction** usually lies between 0.0 and 0.2. It is never negative and rarely exceeds 0.4. For most high performance engines it is zero. For older engines and those of lower specific power output, a value of 0.2 and above is more appropriate.

The second value is the **inflow displacement fraction** which represents the maximum fraction of incoming flow which promotes displacement scavenging. Displacement scavenging is the bulk movement of exhaust gas out of the cylinder and into the exhaust port as a result of incoming gas from the transfer port(s). It is distinguished from perfect mixing scavenging by the fact that there is a definite interface between the fresh incoming gas and the exhaust gas and no mixing of the two gases occurs across this interface. It is usually a maximum at the beginning of the scavenging process. This parameter is never larger than 1.0 and rarely takes a value below 0.8.

The third scavenge value is the **short circuit cutoff** which is a measure of how far into the scavenge cycle the short circuiting flow described above falls to zero. This value must always be greater than zero. It is usually less than but close to 1.0 and generally should be set to 1.0. If short circuiting is to be constant throughout the scavenge process, as opposed to a uniform decrease, set this parameter to a large value like 10.0. If there is no short circuiting, set the first scavenge value to zero, and this parameter to any number greater than zero. **The value zero must not be used.**

The fourth scavenge value is the **scavenge cutoff** which is a measure of how far into the scavenge cycle displacement scavenging stops and perfect mixing controls the whole process. For high performance engines it generally lies between 0.7 and 1.0. For low performance engines, it is close to zero**, but should never be set to zero.** If there is to be no displacement scavenging, set the second scavenge value to zero and this parameter to any value greater than zero, this situation generally applying to low performing engines. For a constant fraction of displacement scavenging throughout the process, set this parameter to a large number like 10.0. Generally, however, this scavenge value should rarely be made greater than 1.0.

A summary of the recommendations for the values of these four parameters follows:

1. Maximum Short Circuit Fraction (0.0 to 0.4): high performance 0.0; low performance 0.1 to 0.4.
2. Inflow Displacement Fraction: 0.8 to 1.0
3. Short Circuit Cutoff (must exceed 0.0): 1.0 recommended.
4. Scavenge Cutoff: (must exceed 0.0): high performance 0.7 to 1.0; low performance 0.4 to 0.7.

4.5.6 Scavenge Parameters - MOTA-7 only

As detailed above, the scavenge model in **MOTA-8** requires four scavenge parameters which are based on experience, rather than physical modelling. Incorporating a full 3-dimensional physical model of the scavenging process in the cylinder would require hours of high end computer run time per engine simulation. In **MOTA-7**, a compromise has been made by including a 2-dimensional model of the cylinder scavenging process. This increases run time by a factor of up to 200, but it eliminates the use of the scavenging parameters required in **MOTA-8**. Generally, the accuracy of the simulation increases slightly but the main benefit is that a user is able to visualise the fluid flow in the cylinder. Changing the various cylinder parameters is akin to modifying real engine dimensions, hence **MOTA-7** can be used to understand and improve the engine scavenging process.

Figure 4 shows the plan of a typical cylinder with lines cutting the circumference on half of the cylinder representing the exhaust and transfer ports. It is assumed that the port layout is symmetric so the other half of the cylinder will have the same port layout. The 2-dimensionl representation is obtained by flattening the cylinder about the line A-A, this a diametral line passing through the centre of the exhaust port.

The bottom part of figure 4 shows the projection of the engine ports onto the axial plane which is the 2-dimensional representation of the cylinder. The ports will have the same heights as they do in reality, but their widths will be the projected values from the cylinder, that is the widths of the shaded areas. These widths must be calculated before you can enter any information into the boxes on the Scavenge Screen.
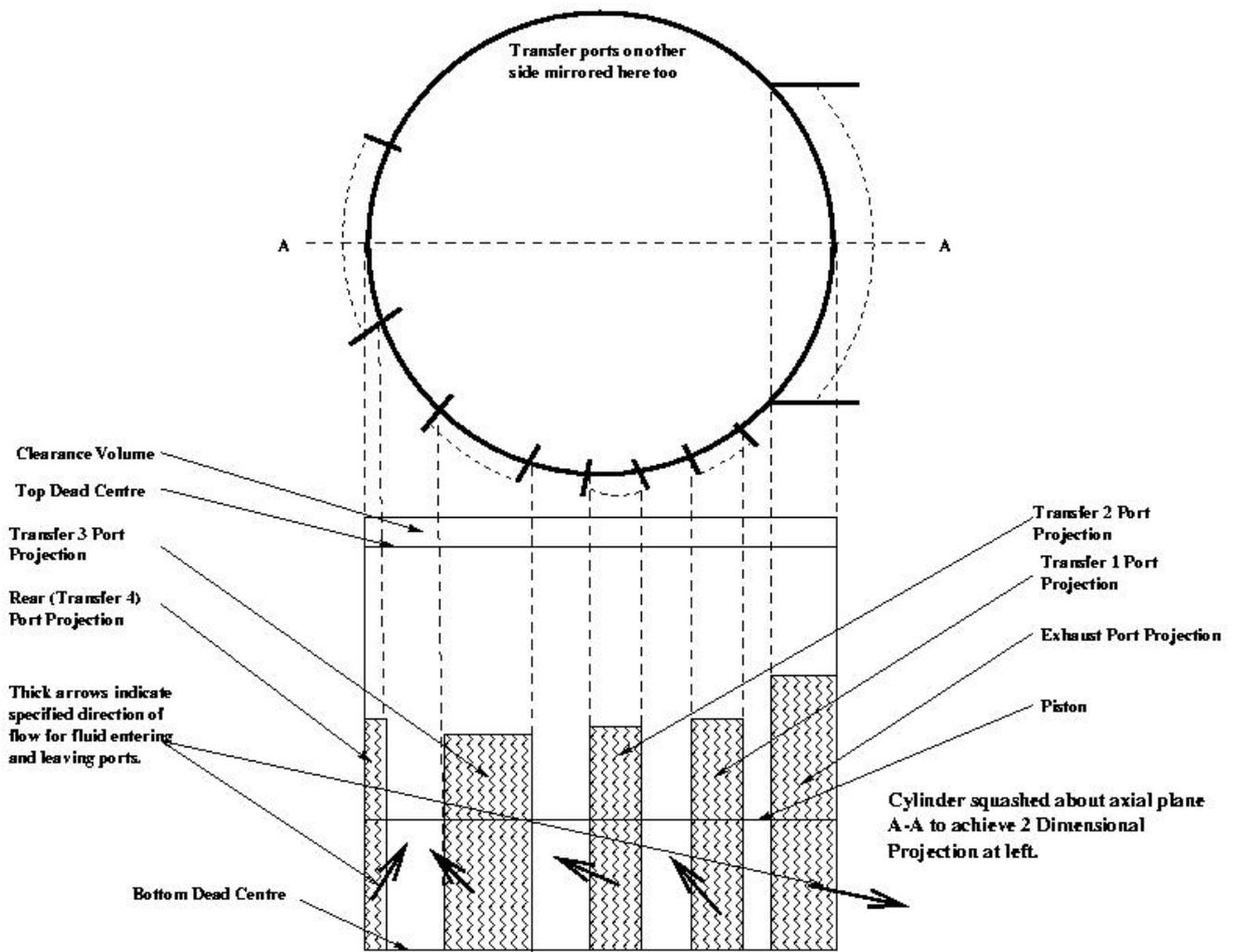
Figure 4

Details of Converting the Cylinder to a 2-Dimensional Model

Inputs to the Scavenge Screen are:

The number of cylinder scavenge ports.

This can be the same as the number of transfer ports or less because you can combine a number of transfer ports into 1 cylinder port. In the demonstration files, contained in the folder **SAMPLES-7** on the distribution media, which is also in your **MOTA-7** installation folder, all of the scavenge ports have been lumped into 1 cylinder port. The individual scavenge ports still operate independently, but all of their flow goes into 1 cylinder port, which might extend from the beginning of transfer 1 to the end of transfer 3. The flow enters the 2D model in an area bounded by the relevant cylinder port, the piston, and the top of the cylinder port. In Figure 4, if there is one cylinder port for each transfer port, the shaded areas above the piston represent the areas in the 2D representation over which the air/fuel inflow is spread. It is prudent to combine adjacent transfer ports if the distance between the end of one port and the start of the adjacent one on the 2-dimensional projection is less than 2.5 times the diametric mesh length. The latter is the cylinder diameter divided by the number of rectangular meshes in the diametric direction. The shaded area above the piston in the exhaust port projection represents that area over which flow is exhausted.

The number of rectangular meshes in the diametric and axial directions for the 2D cylinder.

These are equivalent to the pipe step factor in **MOTA**. In the demonstration files, the numbers are mostly 50 and 50. The numbers do not have to be equal. The mesh size actually changes as the piston moves up and down, so the number of vertical meshes is the same, no matter what the piston position. The larger the number of meshes, the better the resolution. Experiments show that (15,15) is barely adequate, (20,20) is adequate, but (30,30) is preferred. The same engine simulated using (30,30) can take 3 times the processing time as when (20,20) is used. (50,50) is probably overkill but does allow fine resolution of the flow.

The position of the start and end of each cylinder port.

The position of the start and end of each cylinder port, on line A-A, measured from its intersection with the RHS of the cylinder.

The angle of fluid entry and exit, in the 2D plane, for each cylinder port.

These are marked as thick arrows on the attached diagram. They are very important parameters and are not taken into account in **MOTA-8** because the scavenge model is far too simplistic in these programs.

It is necessary to enter the angles at which fluid enters the cylinder via the transfer ducts and leaves via the exhaust duct. Transfer and exhaust ducts attach to their corresponding ports at measurable radial and axial angles. Unfortunately, there is experimental evidence suggesting that fluid does not enter and leave the cylinder parallel to the relevant duct walls. Further, the angles that fluid enters/leaves the cylinder vary with piston position. It is therefore not necessarily correct to project the exhaust and transfer ducts onto the 2-dimensional cylinder and assume that the resulting projected duct angles, are the angles at which the fluid enters or leaves the cylinder. Modelling the varying angle of fluid entry/exit is beyond the scope of **MOTA-7**. A constant entry/exit angle is entered for each port. It is appropriate to start with angles resulting from projecting duct angles onto the 2-dimensional cylinder representation of Figure 4, but these may need to be modified to obtain realistic simulation results. In general, the exhaust port angle should vary from horizontal to pointing 10 degrees down. Side transfer ports (like transfer ports 1-3 in Figure 4) should transfer fluid into the cylinder in a jet pointing away from the exhaust port, such as 45 degrees to the horizontal. By their very positioning, rear transfer ports must direct the fluid partly towards the exhaust port, but should direct the fluid into the cylinder as vertically as possible. Figure 4 gives qualitative information regarding flow directions. A certain amount of experimentation with flow entry/exit angles will be necessary until some familiarisation with the way **MOTA-7** behaves with various angles is acquired.

4.6 SIMULATION RUN DETAILS

4.6.1 Output Units

All geometrical dimensions (lengths, areas and volumes) are output in metric units. However you may select whether you want the output of values such as those representing pressure, temperature, power and torque to be in metric or imperial units (i.e. kW kg C or hp lb F). In the graphical display of power and torque curves, your choice of units will be used as the default but it is then possible to toggle the display between the use of either choice of units. In the *Engine Performance File* the values of power and torque are provided in both metric and imperial units.

4.6.2 Comment for Performance File Header

This allows you to assign a unique identifier to your simulation, e.g. "KT100S low ports, GRZ test pipe, 65 mm step up". It is recommended that you use a different identifier for different simulations of the same engine.

4.6.3 Pipe Step Factor

The flow of air, air/fuel mix and exhaust gases through an engine is modelled mathematically by the two engine simulators in **MOTA**. This "fluid flow" model requires a user supplied value, known as the Pipe Step Factor, for its operation. Throughout an engine simulation the Pipe Step Factor remains constant. It may be useful to provide some insight into the choice of value of this parameter.

To model the gas flow through an engine, **MOTA** divides each duct into a number of longitudinal elements. The length of these elements is controlled by the Pipe Step Factor. **MOTA** requires a minimum of four equispaced points along the shortest "passage section" in an engine to model the gas flow adequately. For example, suppose that this shortest length is a transfer duct whose length is 48 mm. For this engine a good choice of Pipe Step Factor is 48 divided by 4, that is 12. Generally this value will provide a good compromise between run time and accuracy.

Once values have been provided for all duct lengths the prompt for the Pipe Step Factor will include recommended upper and lower limits for its value. Generally, the upper limit will provide a suitable value but because the calculated values of the engine output will vary with this parameter, it may sometimes be necessary to use a value towards the minimum of the recommended range (see section 7, Running the Engine Simulator).

As an example, for the Yamaha KT100S engine, the limits for the Pipe Step Factor suggested by **MOTA** are 15 and 3.7. In making your choice of value, bear in mind that halving the value of the Pipe Step Factor will increase the time for the simulator to complete its run on your computer by a factor of four.

4.6.4 Number of Engine Speeds

This is the number of engine speeds (i.e. number of different rpm's) at which you wish to simulate the engine. The maximum number you can enter is 40. When selecting the number of engine speeds note that the *Graphics Output File* will provide values for the display of power and torque curves only where the simulation is performed over four or more engine speeds.

4.6.5 Engine Speed or Initial (lowest) Engine Speed

If you require an engine simulation at only a single speed, this is the relevant engine speed in rpm. For a multiple speed simulation, this is the initial and lowest engine speed in rpm.

4.6.6 Engine Speed Increment

If the engine simulation is to be performed at more than one engine speed this is the engine speed interval in rpm at which the simulation will proceed.

4.6.7 Engine Speed for Graphics Output

If the engine simulation is to be performed at more than one engine speed this is your choice of the engine speed at which output will be written to the *Graphics Output File*.

4.6.8 Maximum Number of Revolutions at Each Speed

MOTA simulates each engine revolution by modelling the engine's behaviour mathematically at a large number of points throughout each revolution. As the number of completed revolutions increases, the output power should approach a steady value. Experiments show that for most engines an acceptably steady value is reached after about 30 revolutions. **MOTA** has an inbuilt mechanism for determining if it has converged successfully, so if you would like this mechanism to operate, you can input a large number of revolutions, for example 100, and let **MOTA** decide when it has converged at each speed. Where the engine simulation is for a single speed only, the value that you enter should not be less than 40. For a multi-speed simulation, the lower limit for the value you enter is 30 and, if the value you enter is less than 40, it will be ignored by **MOTA** on the first engine speed only and the value 40 substituted.

4.7 PISTON CONTROLLED PORTS DETAILS

The second column of the Data File Construction Utility (*DFCU*) screen contains buttons linked to screens where the information describing your engine's ports will be entered. In this section, the information to be provided for all piston ports is discussed.

Nearly every 2-stroke engine contains at least one piston controlled port. Entry of data for this type of port is therefore common to all engine types. The accurate specification of these ports is crucial for the accurate prediction of an engine's performance.

Port dimensions are provided in either one of two formats, that is as rectangular ports or as profiled ports (see Figures 5 & 6).
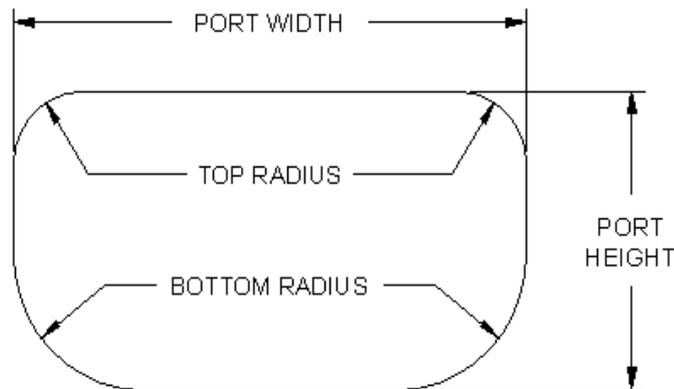
Figure 5

Rectangular Piston Port Configuration

A rectangular port is assumed to have parallel vertical sides and generally has radiused corners. Its specification is therefore quite straight forward, requiring the arc width, corner radii and the crankshaft angles after Top Dead Centre at which the port starts to open and at which it is fully open.

A port should be specified as **profiled** only when the port shape is **not** rectangular, whether with or without radiused corners. In such case, instead of supplying a single port arc width and the corner radii, more information is required. This is the arc width of the port at various positions between the port starting to open, and becoming fully open. Such specification gives **MOTA** very accurate information about the relationship between the area of the port uncovered and the distance of the piston from top dead centre. You should use this option to describe any of your port shapes which deviate significantly from a rectangular shape with or without radiused corners. A construction for dividing the area of an irregular shaped port into a number of equispaced intervals is illustrated in Figure 6 and is described in section 4.7.3
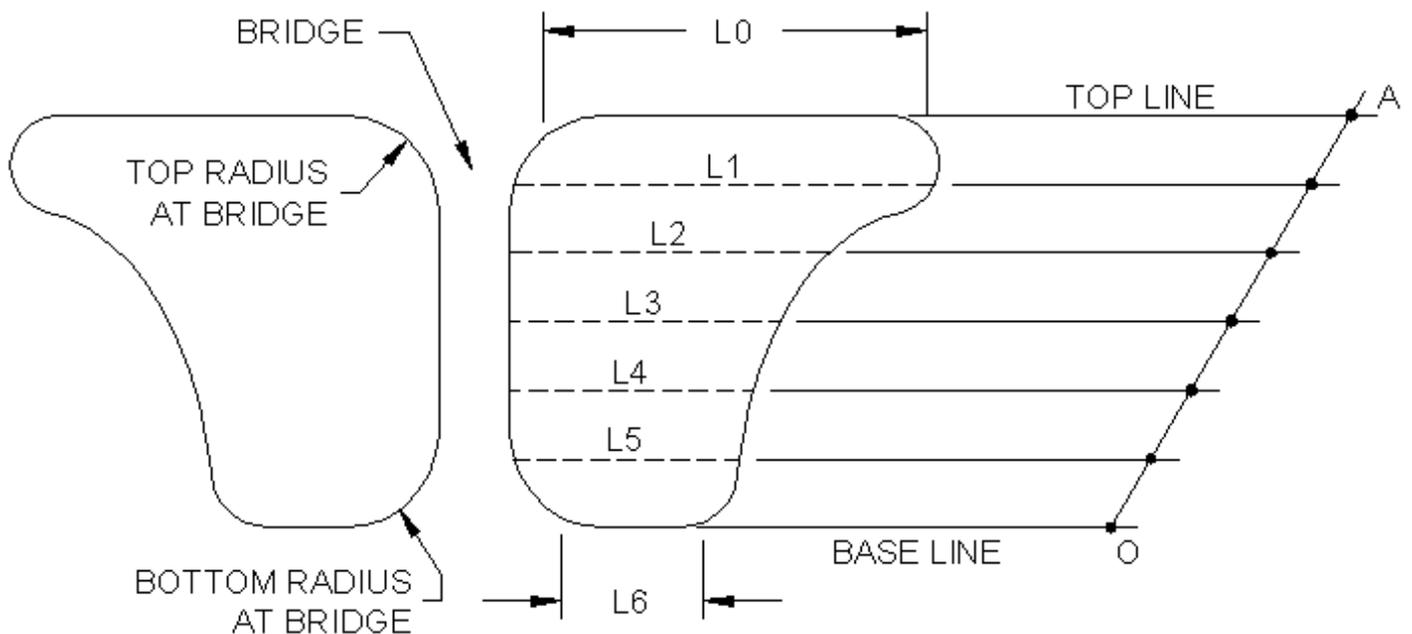
Figure 6

Measuring the Profile of an Irregular Port

The **DFCU** screen lists the number of different types of port. It is always assumed that there is only one type of inlet port duct and one type of exhaust port duct. You will have specified the number of different types of transfer port ducts on the engine configuration screen and, if this is more than one, they will be referred to as Transfer 1, Transfer 2, … on this screen. For each port type you are asked to enter the number of individual ports and say whether you will be providing profiled port data or not. If you answer yes to the profiled data question you are asked for the number of ordinates you wish to use to describe the changing width of the port. You can specify up to a maximum of 11 ordinates which corresponds to a maximum of 10 equispaced intervals.

If you have two identical ports, you are asked whether they constitute a **bridged pair** as distinct from two separate ports. A bridged pair consists of two individual ports of identical geometries, separated by a relatively narrow "bridge" and being fed by, or feeding into a single duct. **MOTA** needs this information so that it can calculate the total effective port area accurately. If you specify two or more unbridged ports, **MOTA** will assume that each port is fed by or feeds into a separate duct and that each of these ducts will be identical in geometry.

For engines with separate exhaust boost ports the area of these ports needs to be included with that of the main exhaust port(s). In the case of a port which is not profiled, this can be approximated by increasing the effective arc width of the relevant main port so that the total area of that port includes that of the boost ports. More accurately, the port may be considered as a profiled port so that the boost port areas can be included as part of the port profiling process (see section 4.7.3).

The exhaust port screen has a prompt for **variable opening angle**. This is provided for engines with variable exhaust port timing and for its selection you must know the relationship between the port opening angle and the engine speed. If you select this option, you are asked for the number of engine speeds at which the exhaust port opening angle will be specified. You are then required to enter the appropriate number of **engine speed/exhaust start open angle** data pairs. A "straight-line" relationship is assumed between adjacent speeds.

In the following sections, the data which needs to be entered on the piston controlled port screens is discussed.

4.7.1 Data Common to Both Rectangular and Profiled Ports

For each piston controlled port, the crankshaft angle at which the piston starts to open the port, the crankshaft angle at which the port is fully open and the port attitude angles are requested. The message VARIABLE OPENING ANGLE will appear in place of the port opening angle for an exhaust port with variable timing. The port attitude angles, namely the radial attitude angle and the axial attitude angle are defined in Figures 7 & 8 and in Figures 9a & 9b. If a port pair is defined as "bridged", the bridge width together with the top and bottom radii at the bridge must be provided for a rectangular port, but, for a profiled port, only the bridge width is required. By definition a bridged pair shares a common duct and the projection of the bridge into this duct is relatively small.

Figure 9a illustrates a section of a conventional rectangular bridged exhaust port . **OM** represents a radius of the cylinder drawn to the mid-point **M** of the right hand port arc width. The radial attitude angle **Ar** is the angle made by **OM** and a line through **M** which is parallel to the port side wall close to the cylinder.

An option provided on the **Tools Menu** can be used to calculate the value of the radial attitude angle of a bridged port pair. You will have to provide the values of the port arc width **XY** and the bridge arc width **YZ**.

An alternative construction is illustrated in Figure 9b. In this case the radius **OM** is parallel to the port wall close to the cylinder and experience suggests that a zero radial attitude angle should be used for such a port configuration.

For exhaust ports with variable opening timing, a table will be displayed for you to input the opening angle of the exhaust port at each of the engine speeds at which you have this information.
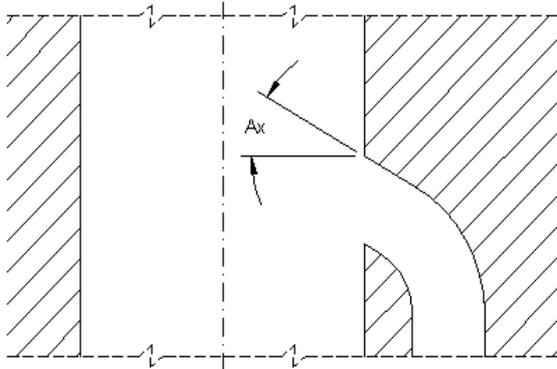
Figure 7

"Ax" is the Axial Attitude Angle
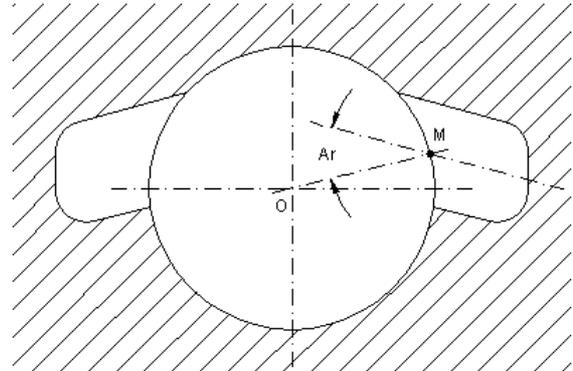
Figure 8

"Ar"is the Radial Attitude Angle
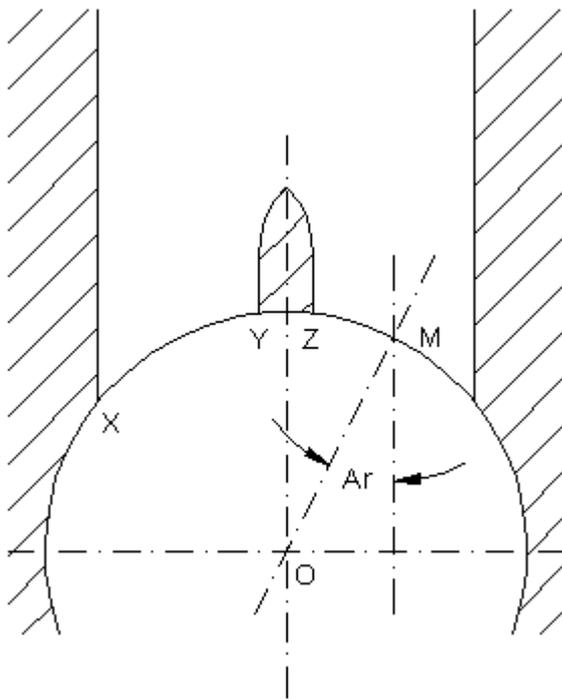
Figure 9a
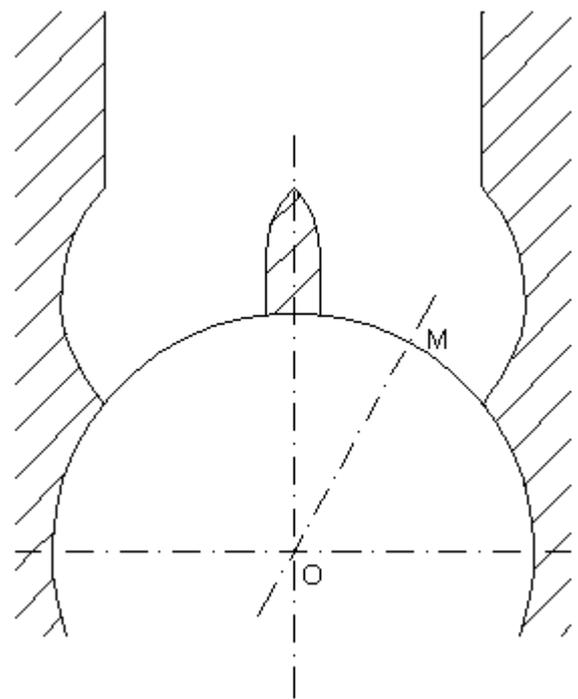
Figure 9b

Radial Attitude Angle for Alternative Bridged Exhaust Port Geometries

4.7.2 Rectangular Ports

This information is required when the port shape is rectangular with radiused corners (see Figure 5). In addition to the values described above, the port arc width and the top and bottom corner radii must also be provided. Note that the value to be used for the port width is the arc width. A facility to convert between chord width and arc width values is provided by clicking *Tools* on the *Main MOTA Menu* and then making the appropriate selection from the *Tools Menu*.

4.7.3 Profiled Ports

If you have chosen the profiled port option and have entered the number of ordinates in the profile data, you will need to fill in a table of ordinate port arc widths.

Irregularly shaped ports should always be described by such a sequence of arc widths (ordinates) measured over a set of equispaced intervals spanning the full height of the port. These ordinates should be submitted to the Engine Data File in the same order as that described by the port opening sequence. *In the case of a profiled inlet port, particular care should be taken to submit the ordinates in the correct sequence of opening order, that is from the bottom of the cylinder upwards.*

A construction which divides one of the ports of an irregular shaped bridged port pair into 6 equispaced intervals, providing 7 ordinates, is shown in Figure 6. To make the construction accurate and easy, the length in millimetres of the chosen line AB should be an integer multiple of 6. A pair of compasses, a pair of dividers, a rule, a set square and a fine pen or sharp pencil are minimum requirements for completing the construction. Generally a suitable port outline can be obtained from a "rubbing" of the cylinder wall.

The construction illustrated in Figure 6 is completed as follows:

First draw parallel base and top lines at either extreme of the port height. Next, using a point O on the base line as centre, draw an arc which intersects the top line at point A. The radius of this arc will exceed the port height and in particular, **it should be easily divided into the required number of equal interval**, in this case six. Now mark the equispaced divisions of OA and finally draw the ordinates $L1$ to $L5$ as a sequence of lines parallel to the base and top lines. The lengths $L0$ to $L6$ are best measured using a pair of dividers.

MOTA treats each division between adjacent pairs of ordinates as a trapezium and with this in mind it will in some cases be appropriate to adjust the lengths of the first and/or last ordinates in order to provide a realistic port area. In Figure 6 notice that the values of $L0$ and $L6$ have been adjusted in an attempt to provide realistic representations of the areas of the two extreme sections of the construction.

Again note that ordinates representing arc width values are required and these will be provided by working off a rubbing from the cylinder.

4.8 INLET ROTARY VALVE DETAILS

This screen is provided only if you selected the rotary valve inlet option on the *Engine Configuration* screen. Prompts ask you to enter the rotary valve data, a schematic of which is shown in Figure 10.
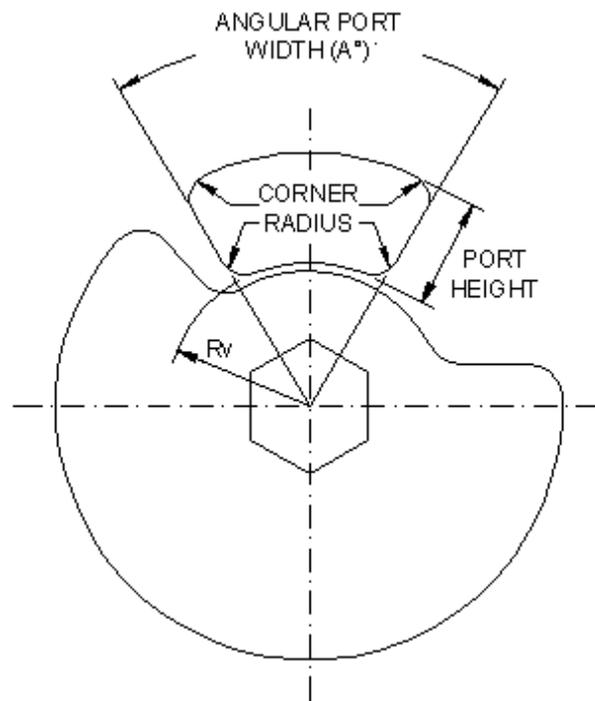

Figure 10

Rotary Valve Configuration

4.8.1 Number of Rotary Valves

You may have one duct or two identical ducts feeding one cylinder. The latter configuration is assumed to require two identical rotary valves. Enter the number of rotary valves here.

4.8.2 Opening Angle

This is the crankshaft angle before top dead centre at which the port starts to open.

4.8.3 Closing Angle

This is the crankshaft angle after top dead centre at which the port becomes completely closed.

4.8.4 Radius to Bottom of Port

The port is assumed to be radially symmetric with respect to the crankshaft centre as in Figure 10. Any other geometry will have to be approximated within these bounds. The radius to the bottom of the port is shown as *Rv* in Figure 10.

4.8.5 Port Height

This is shown in Figure 10.

4.8.6 Angular Port Width

This is the angle *A* in Figure 10. It is assumed that the port sides will lie along radial lines from the crankshaft centre, possibly with small radius corners. Any other geometry will have to be modified to fit this specification.

4.8.7 Corner Radii

This is shown in Figure 10. All corner radii are assumed equal.

4.9 INLET REED VALVE DETAILS

This screen is provided only if you select the reed valve engine option on the ***Engine Configuration*** screen. Prompts ask you to enter data for the reed valve. A typical reed valve is illustrated in Figure 11. Each reed valve comprises a valve block containing a number of rectangular apertures referred to as ports and at least one pair of petals. When closed the reed petals cover the ports.

4.9.1 Number of Reed Valves

You may have one duct or two identical ducts feeding one cylinder. It is assumed that identical ducts require identical reed valves. Enter the number of reed valves here.

4.9.2 Valve Block

- Number of ports
- Block Angle. **Note VERY carefully how this angle is defined in Figure 11.**
- Width of each port
- Corner Radii, assumed the same for all corners of all ports
- Length of each port
- Stop Plate radius (see the note below)

4.9.3 Uniform/Stepped Petal Thickness (Single and Compound Petals)

Generally a reed block port is controlled by a single petal. However, in some cases two petals are clamped together with the length of the outer petal less than that of the inner petal. Such a configuration is referred to as a compound petal. **MOTA** requires you to specify the type of petal, single or compound, contained in your reed valve.

4.9.4 Petals

- Stop Plate Radius. Some reed valves limit petal movement by a guide called a stop plate. This plate usually has the shape of an arc. You need to judge whether the stop plate will have any real effect on the movement of the petal. If not, such as when no stop plate is fitted at all, a small value of radius such as 3 mm can be entered.
- Restricted Maximum Tip Deflection.
- Petal tips may also be restricted as to their maximum outward movements by the port walls. If this is not the case, a large number like 50 mm can be entered, and the program will operate with unrestricted petal deflection
- Width of each petal
- Unclamped Petal Length
- Thickness of each petal
- Density of the petal material
- Young's Modulus of the petal material

Values of Young's modulus and the density for a few common reed petal materials are provided in a table on this screen.

For compound petals, where one petal overlaps the other over part of the unclamped length, prompts appear for the combined thickness of both petals, and the unclamped length of the shorter petal.
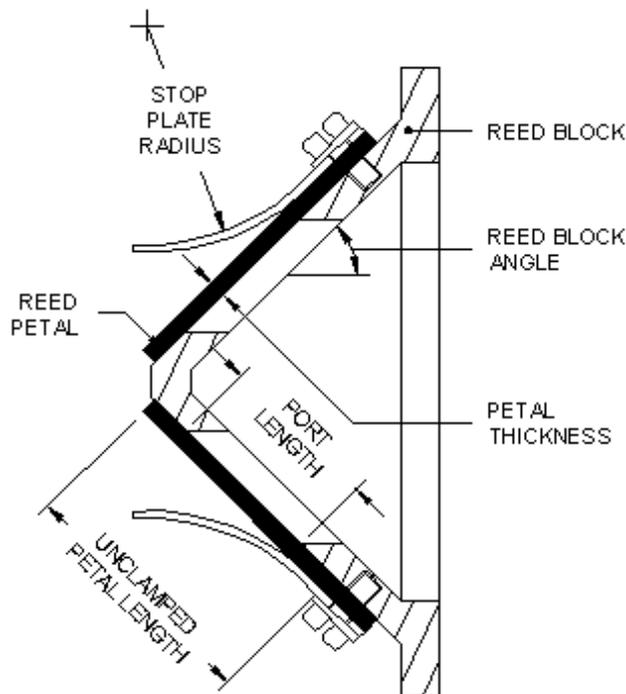
Figure 11

Reed Valve Details

4.10 DUCT SCREENS

The third column of the *DFCU* screen contains buttons which are linked to screens which, when completed, will contain all necessary information about your engine's ducts. Throughout this manual, "Duct" is the general term used to refer to any passage down which gas flows, for example, the carburettor, inlet manifold, exhaust pipe and the passages leading from the crankcase to the transfer port(s). **MOTA** assumes that each duct comprises a sequence of linearly tapered sections. Figures 1 & 2 show typical duct sections for two different exhaust systems. Discontinuities in cross-section area at section junctions are allowed. Typically this may occur in an exhaust duct if the cross sections of the barrel section and the engine pipe are not perfectly matched at the barrel flange. Inlet and transfer ducts can also have more than one section. The information required for all ducts is discussed in the following sections.

4.10.1 Data Common to All Ducts

The **number of section** in each duct. The inlet duct must have a minimum of two sections (even if each has the same cross-section area), the transfer duct and muffler duct must each have a minimum of one section and the expansion chamber duct must have a minimum of four sections.

In counting the number of inlet duct sections, do not include:

- The passage in the barrel between the inlet duct connecting flange and the inlet piston port for a piston port engine.
- The passage in the crankcase between the inlet duct connecting flange and the valve disc for a rotary valve engine.
- The passage in the crankcase between the inlet duct connecting flange and the end of the reed valve block in a reed valve engine.

MOTA adds an extra section automatically for each of these last sections and prompts you for the relevant dimensions.

Because they are so short, most transfer ducts are modelled as single section ducts.

Figures 1 & 2 show how sections are determined and numbered for expansion chambers. Notice that neither the part of the exhaust port duct which is contained in the cylinder barrel nor the tail pipe (if one is present) is considered to be an expansion chamber section for the purpose of data entry. The details of these duct sections are entered separately.

Section numbering for each duct begins at the "inflow" end of the duct, that is, at the end of the duct into which fluid (air, air fuel mix or the engine exhaust) normally flows. **MOTA** assumes that for the inlet duct, the first section starts immediately after any bellmouth present, so your first section measurements should not refer to any bellmouth.

Once the number of duct sections is entered, a table is displayed with spaces set for the entry of the **inlet diameter**, the **outlet diameter** and the **length** of each section. The table is scrollable if the duct comprises more than four sections. For some transfer ducts you may not be asked to enter the outlet diameter of the final section. This will be the case if you selected the option "Smooth Exit" for the transfer duct. This option forces **MOTA** to set the area of the last transfer duct section outlet to be the same as the corresponding transfer port effective area, thus fixing its equivalent diameter.
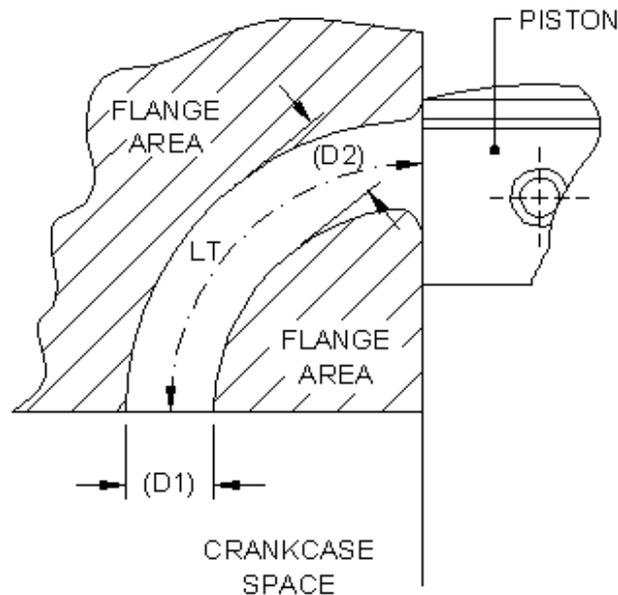
Figure 12

Physical Layout of Transfer Duct Geometry

The correct identification of the property *smooth entry to* or *smooth exit from* the duct is important when completing most of the duct screens. As an illustration, consider Figure 12 which shows a schematic of a single section transfer duct. The inlet diameter (*D1*, crankcase end) is usually very close in value to the outlet diameter (*D2*, transfer port end), so in many cases, an equivalent parallel duct of constant circular cross section can be assumed. The dimensions *D1* and *D2* are the diameters of a circle of the same area as the port openings. For *D1* this may be most easily determined by using a rubbing of the inlet to the duct onto 1 mm square graph paper. Counting the squares gives an area which can be converted to a circle whose diameter is *D1* using the formula:

$$D1 = Square\ Root(1.2732\ x\ Area)$$

Notice that if the port is close to rectangular in shape with radiused corners the *Tools Menu* provides an option for evaluating the diameter of the circular section having the same area.

If the end of a duct at the join with a piston port flares out markedly before it mates with the port, the duct should be marked as having a *non smooth* entry or exit, as appropriate, on the relevant duct screen. Figure 12 depicts such a situation for a single section transfer duct. In addition to the dimensions *D1* and *LT*, you will be asked for the equivalent diameter (*D2*) immediately before the flaring occurs. For a single section transfer duct the corresponding length is the length of the transfer duct along its centreline from its beginning in the crankcase to its end at the piston face. The extension of this procedure to deal with inlet and exhaust ducts and with multiple section ducts follows naturally. The need to divide a transfer duct into more than one section should rarely arise.

4.10.2 Inlet and Induction Ducts

The carburettor, any reed valve or rotary valve present, and associated ducting into the cylinder head or crankcase forms the inlet duct. It is assumed that the inlet duct consists of:

- At least two sections which commence at the entrance to the carburettor and ends at the mounting flange of any reed or rotary valve present (see Figure 13) or at the inlet barrel flange in the case of a piston ported engine. Section numbering starts at the intake to the carburettor and after any bellmouth which may be present.
- One section from the mounting flange on the crankcase (see Figure 13) for a reed or rotary valve to the end of the reed block or to the rotary disk face or, in the case of a piston ported engine, from the inlet mounting flange on the barrel to the piston face.

On the **Engine Configuratio** screen, you indicate whether or not your engine contains an induction duct (in addition to the normal inlet duct). Such a duct leads from the atmosphere to a still air box from which the normal inlet duct feeds. If your engine has an induction duct, you need to indicate on the **Induction Duct** screen whether or not this duct contains an **entry bellmouth.** You will also be asked to enter the volume of the induction (still air) box on this same screen.

For all types of induction, you must specify whether or not there is an **entry bellmouth**. For piston port induction, there is an additional option box labelled *smooth exit*. A smooth exit prevails when the outlet area of the section of inlet duct in the cylinder barrel is the same as the inlet port area, that is, when the duct section is not flared into the port. For reed valve and rotary valve induction, it is assumed that a smooth exit occurs and so the option box for this property is not displayed.

There is also a frame which is titled as **Cylinder Barrel Duct Section** for piston ported induction, as **Inlet Disk Valve Cover Duct Section** for rotary valve engines, and as **Inlet Reed Valve Block Duct Section** for reed valve induction. Information regarding this last inlet duct section which is referred to under the second bullet point above, must be entered here. For each type of induction this comprises the duct diameter at the mounting flange and the length of the duct from its entry to the piston face (piston port) or to the reed valve petal tips (reed valve) or to the rotary valve disk face (rotary valve). In addition, for a piston port controlled engine, if you have specified a non-smooth exit into the inlet port the **diameter at port** input box will be active. This means that due to flaring, the duct area adjacent to the inlet port is different from that of the inlet port itself, and so you need to specify the equivalent diameter of the duct close to the port but immediately before the flaring.
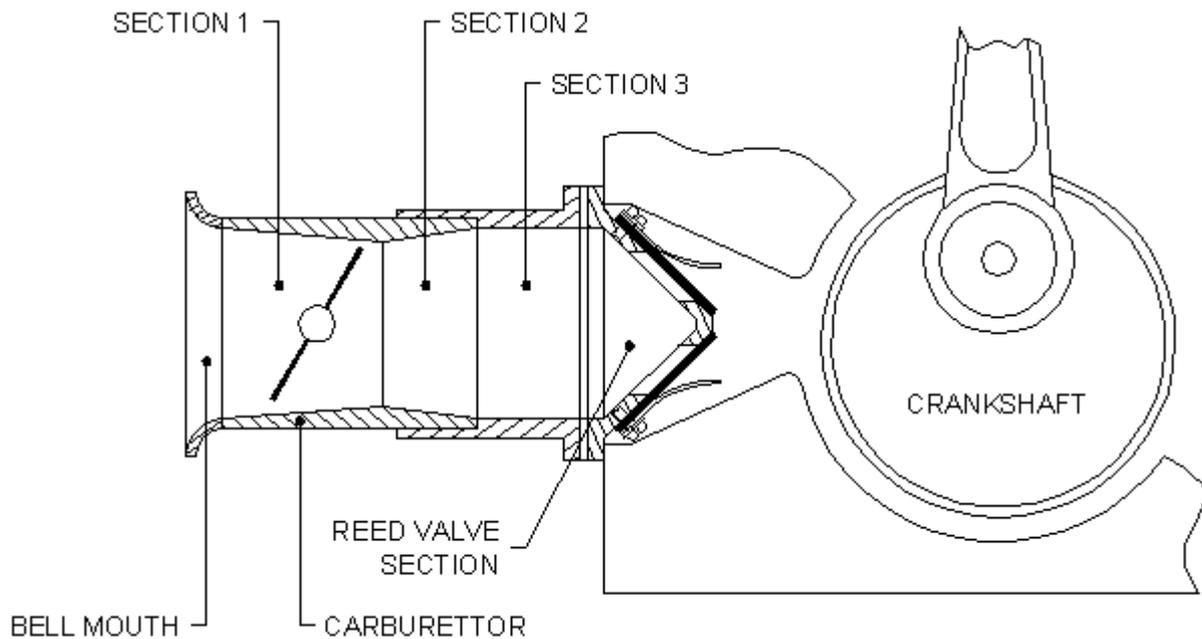
Figure 13

A Typical Inlet Duct with Reed Valve

Notes relating to Figure 13:

For a rotary valve inlet port, the final section is the section between the mounting flange and the rotary valve disc face.

For a piston ported engine, the final section is the section between the mounting flange on the cylinder barrel and the piston face.

The assembly to the left of the mounting flange contains the Carburettor which may be fitted with a bellmouth at its intake end. Another duct section may exist between the carburettor and the barrel (piston port induction) or the crankcase flange (reed valve or rotary valve induction).

For the configuration illustrated, the number of sections to be entered on the Inlet Duct screen is "3" and not "4" because details of the section adjacent to the reed (or rotary or piston) port are entered separately on this screen as previously described.

4.10.3 Exhaust Duct

The *smooth entry* option required for this screen has the same meaning as for the *smooth exit* option on the piston port induction **Inlet Duct** screen and on the **Transfer Duct** screen(s). Your choice will determine whether or not the **Diameter at Port** input box within the **Exhaust Section in Cylinder Barrel** frame needs to be entered (see Figure 14). If the box is not dulled, you will need to enter the equivalent diameter of the exhaust duct at its entry from the cylinder but beyond the flaring in the cylinder barrel at the port. You will always need to enter the diameter of this section at the cylinder barrel flange and the length of the section between this flange and the piston face.

Although the **MOTA** engine simulator treats this section as an exhaust duct section, it must not be included in the **Number of Duct Sections** entered lower down the screen.

If your engine is of the *Box Muffler* type, there will be only one section (by default) in the exhaust duct and you will not be asked for the number of sections in the exhaust system. There will also be a tail pipe diameter and length to be provided, as well as the muffler volume.

If you have chosen to model your engine with either an *Integrated Muffler (Box or Duct Model)* or with a *Single Piece Expansion Chamber*, you will be asked for the tail pipe length and diameter in addition to the details common to all exhaust systems. The muffler volume will also be required for the *Integrated Muffler (Box Model)*.

If you have chosen to model your engine with an *Integrated Muffler (Duct Model)* (as distinct from an *Integrated Muffler (Box Model)* – see section 4.1.2), the exhaust duct description will be entered over two screens. The corresponding buttons on the *DFCU* screen are labelled **Expansion Chamber** and **Duct Muffler**.

The **Expansion Chamber** screen will require the same details as for a *Single Piece Expansion Chamber* engine, less tail pipe details and the muffler volume.

The **Duct Muffler** screen requires dimensional details of the muffler assembly and the exhaust outlet.
The muffler may comprise several conical sections, just like the expansion chamber, so the relevant prompts are identical.
Then follows the prompt **Protrusion of Expansion Chamber into the Muffler** which relates to dimension L1 in Figures 3a & 3b which is the protrusion of the expansion chamber, plus any stinger length, into the first section of the muffler.
Next a frame named **Exhaust Outlet** provides three options, **Tailpipe**, **Hole in Muffler End Cap** and **Hole in Curved Side of Muffler**. Whichever option is selected a final frame is displayed for data entry.
For the **Tailpipe** option the entry of its diameter, length and that part of the length protruding inside the muffler is to be entered. This relates to dimension *L2* in Figures 3a & 3b.
For the **Hole in Muffler End Cap** option only the hole diameter is required.
Where **Hole in Curved Side of Muffler** is selected both the hole diameter and the distance from its centre to the end cap is required.
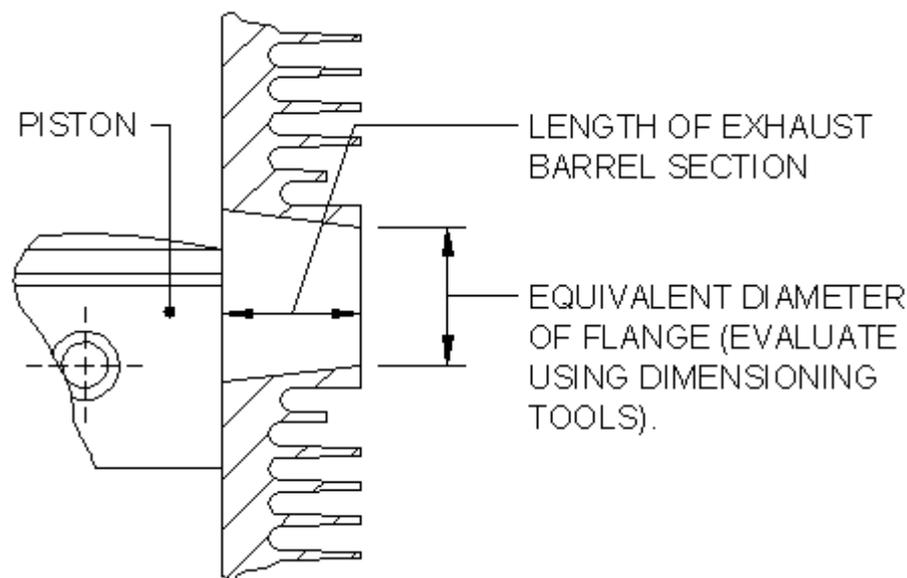
Figure 14

An Exhaust Barrel Section

When an **Expansion Chamber** screen is displayed, the additional button **Display Profile** appears on the screen. Clicking this button displays a schematic of the expansion chamber and a table of dimensions which includes the cone angle and volume of each section. The outline of an Integated Muffler is included for both box model and duct model cases.
The content of this screen can be sent to the printer.

5 FILE MENU: VIEW AN ENGINE PERFORMANCE FILE

The *Engine Performance File* lists your engine's characteristics, as entered in the Engine Data File construction screens, as well as a number of performance measures for your engine. If this menu item is selected, you are asked to select a valid file (such files will have the extension "*.per* "and are generated by the **MOTA** engine simulator). The file selection procedure is identical to that for selecting a data file to edit (section 4), except that only *Engine Performance Files* will be listed.

Following an expansion chamber optimisation ONLY the Performance File commences with the name of the Source Engine Data File, a list of the Optimisation Variables, a table which contains the Initial and the Optimal Values of the variables and a table which lists the Power or Torque provided by the engine at the optimisation speeds both before and after the optimisation. The content of the Performance File then continues as for ordinary simulation runs, that is it contains a header which provides:

- The name of the file
- The date and time when the file was constructed
- The reference title you provided when constructing the Engine Data File

Engine specification and performance details provided by the file are described below.

5.1 SIMULATION PARAMETERS

- Induction type
- Muffler type
- Pipe step factor (section 4.6.3)
- Scavenge parameters (section 4.5.5)

5.2 ENGINE GEOMETRY

- Bore, stroke, connecting rod length, gudgeon pin offset, bore/stroke ratio and connecting rod length/stroke ratio
- Clearance and swept volumes in the crankcase and the cylinder
- Compression ratio in the crankcase and trapped compression ratio in the cylinder
- Volume of the box muffler if applicable

5.3 FUEL PARAMETERS

- Fuel calorific value (section 4.5.1)
- Air/Fuel Ratio(s) (sections 4.5.3 and 4.5.4)
- Throttle setting (section 4.5.2)

5.4 COMBUSTION PARAMETERS

- Burn period (section 4.3.2)
- Combustion efficiency (section 4.3.1)

5.5 AMBIENT CONDITIONS

- Air pressure and temperature (section 4.4.1)
- Temperature of the circulating water coolant in the expansion chamber jacket - if applicable (section 4.4.2)

5.6 PISTON PORT DIMENSIONS

The relevant data for each piston port type is displayed under this heading. First the port name, the number of ports, the port angle, arc and chord widths, the port height and for non-profiled ports the top and bottom corner radii are displayed. Also, for a port pair, the bridge status is displayed. Next, for any bridged port pair, the bridge width, the radii at the top and bottom of the bridge and the effective maximum chord width are displayed. Finally, for each port type, the total area and the two attitude angles are displayed.

5.7 PISTON PORT PROFILE DETAILS

Output under this heading is provided only where at least one port type is defined by means of a sequence of equispaced arc width ordinates. For each such port the sequence of arc width ordinates are tabulated together with the corresponding chord widths and values of total cumulative port area.

5.8 PISTON PORT TIMING DETAILS

The crank angle and the corresponding piston displacement from top dead centre at which each port starts to open and is fully open. If your engine contains a variably timed exhaust port, the timing details are listed.

5.9 ROTARY VALVE PORT DATA (if applicable)

- Angle at which the port begins to open (degrees BTDC)
- Angle at which the port becomes completely closed (degrees ATDC)
- Radius from crankshaft centre line to bottom of port opening
- Port height, angular width, corner radii, maximum port area

5.10 REED VALVE PORT DATA (if applicable)

5.10.1 Block Dimensions

- Port name
- Number of ports in the block
- Port width, length, and corner radii
- Stop plate radius
- Block angle

5.10.2 Petal Dimensions

- Port name
- Petal thickness, width, length, density, Young's modulus
- The four lowest natural frequencies of the petals

5.10.3 Port Dimensions

- Port name
- Maximum port area
- Restricted maximum petal deflection at tip

5.11 DUCT DIMENSIONS

The number, length, inlet and outlet diameters, inlet and outlet cross section areas of each duct section in the engine. Note that each duct section is assumed to be uniformly tapered between its inlet and outlet diameters. The cone angles and volumes are also listed for each expansion chamber section if your engine is of this type. When applicable the dimensions relating to the **Duct Model** of an Integrated Muffler will also be displayed.

5.12 ENGINE PERFORMANCE INDICATORS

The performance indicators which are listed below are provided at each simulation speed.

- Power and Torque in both Metric and Imperial units
- Ignition Timing and Air/Fuel Ratio and the Exhaust Port Timing where this is a variable
- Brake Mean Effective Pressure (BMEP), Pumping Mean Effective Pressure (PMEP), Friction Mean Effective Pressure (FMEP) and Indicated Mean Effective Pressure (IMEP)
- Brake Specific Fuel Consumption
- Flow Ratios: the Delivery and Exhaust Flow Ratios. These are the ratios of gas mass delivered and exhausted per cycle to a "standard" mass of gas that would occupy the entire cylinder at atmospheric conditions. The Delivery and Exhaust Flow Ratios should agree to within 0.1% of each other, indicating that the total gas flow into the engine over one revolution is equal to the total gas flow out of the engine in the same period.
- The Mass based Scavenge Ratio (which should be equal to the Exhaust Flow Ratio referred to above)
- The Volume based Scavenge Ratio (which is the scavenge parameter on which engines are mostly rated)
- Scavenging Efficiency, Trapping Efficiency and Charging Efficiency
- Percentage of gas energy lost through heat transfer from the exhaust system
- Peak Cylinder Temperature and Pressure. If there is an expansion chamber, the lowest, highest and mean temperature at the centre of the expansion chamber "belly". The mean temperature is averaged over one engine revolution.
- The Specific Port Time Area of each piston port and for the induction reed valve or rotary valve if applicable

6 FILE MENU: DISPLAY ENGINE GRAPHICAL INFORMATION

When you select this option you will be asked to choose the name of a *Graphics Output File* (these have the extension "*.gph*") in exactly the same way that you chose a file in the *Edit Existing Engine Data File* and *View an Engine Performance File* options. The graphical information will then be read into **MOTA** from the selected file. **MOTA-7** graphics files are different from **MOTA-8** graphics files so make sure that the program of **MOTA** used to create the graphics file is used to open it. Down the left hand side of your **MOTA** screen a number of buttons will be displayed. Clicking these buttons will display graphically different aspects of your engine's performance. A displayed graph can be sent to your printer by clicking either the **Clr Prt** button if you have a colour printer or the **B/W Prt** button otherwise. However, in the case of animated waves, you have to stop the animation by clicking the **Wave Stop** button before the two print buttons are made operative. If you have a colour printer the colour print option is particularly useful when printing power and torque curves where one or more overlays (see section 6.1) have been selected. This is because the colour coding of the different curves is preserved.

If the simulation run which produced the *Graphics Output File* involved four or more engine speeds the engine power and torque achieved at these speeds can be exhibited graphically and in such case these power curves are immediately displayed as the default screen.

The graphics display button functions are as follows:

6.1 POWER/TORQUE (if applicable)

If you run your engine simulations at four or more engine speeds, this option button is made operative. It allows you to display graphs of engine power and torque plotted against engine speed. The solid lines on the graph represent engine power and the dotted lines represent engine torque. When you select this option and also, when it is initially shown as the default display (see above), four frames are added beneath the buttons at the left hand side of the **MOTA** environment.

The first **Units** frame allows you to change the units in which the graphs are displayed, that is either **kW** for the power and **Nm**

for the torque or **hp** for the power and **ft lbf** for the torque. The default display will correspond with the ***Output Units*** selection made on the **Run Parameters** screen when the corresponding ***Engine Data File*** was prepared.

The second **Display** frame allows you to choose whether to display both power and torque, or either one singly. The single display of torque curve(s) uses solid and not dotted lines.

The third **Overlay** frame allows you to add and remove overlays from the graph. **Adding** an overlay displays a Windows dialogue box asking you to select a file for overlaying. Although only ***Graphics Output Files*** (***.gph***) are displayed initially, clicking the **file type** display on the dialogue box allows you to select ***Power Files*** (***.pow***) as well (the construction and use of ***Power Files*** is described in section 10).

The fourth **Scales** frame allows you to change the scales which were chosen by **MOTA** and, once such a change has been made you can make further changes or choose to restore the default scales to the display.

You may select up to 5 overlay files. You may remove an overlay at any time by clicking the ***Remove*** button. On doing this, a list of overlaid files is displayed and clicking a member of the list removes it from the display.

Note: When you add an overlay file the current scales choice **is not changed**, even if this means that the newly displayed curve is clipped. It has been found that this property is most useful to the engine tuner/designer when comparing the performance of various engine designs. Of course you can change the scales at any time by clicking on ***Change*** in the **Scales** frame and then entering replacement scale limits of your choice. Alternatively you may elect to use the scales provided as the default by **MOTA** by clicking on ***Restore Default*** in the **Scales** frame, the scales so provided will display each of the selected curves in full.

6.2 WAVES

Selecting this option allows you to view the propagation of Pressure, Velocity, Temperature, Density and Purity waves in each engine duct. The display is animated in the sense that it displays the change in the relationship between the chosen variable and the distance down the selected duct several hundreds of times throughout an engine revolution. It repeats this display continuously for as long you wish. You may alter the animation speed by changing the frame speed setting of the horizontal scroll bar displayed towards the bottom of the screen.

When the waves button is clicked, a frame listing of all of the engine ducts appears. Selecting a duct displays another frame listing the various types of wave (pressure, velocity, etc). Selecting a wave type results in the animation described above. You can change the wave type simply by selecting another one. If you change the duct, the wave type frame initialises itself and you must again select a wave type to display the animation.

To print an animation at any one time, click on ***Wave Stop*** to freeze the animation and then click on ***Clr Prt*** if you have a colour printer or click on ***B/W Prt*** otherwise. After the still frame has been printed, you can click on ***Wave Start*** and the animation will continue.

Should images flicker and jump, adjusting the **frame speed control** on the display screen should rectify the problem.

6.3 CYLINDER-EXHAUST PRESSURE DIFFERENCE

The difference between the pressure in the cylinder and the pressure at the cylinder end of the exhaust duct determines whether gas flows from the cylinder into the exhaust duct or into the cylinder from the exhaust duct. In designing a 2-stroke engine, you want to extract the combustion gases as quickly as possible and then **plug the exhaust port** with high pressure exhaust gas to prevent the in-coming fresh charge from the transfer port flowing out through the exhaust port before it is ignited. This option allows you to examine the relationship between the cylinder-exhaust pressure difference and crankshaft angle, to determine how well the exhaust extraction/fresh charge plugging process is working.

6.4 INDUCTION REED VALVE PETAL LIFT (if applicable)

If your engine is fitted with an induction reed valve, this will display the variation of the reed petal tip lift with crankshaft angle.

6.5 SCAVENGE RATIO

At any crankshaft angle, this is the sum of the delivery ratios (see section 6.6) at the outlet end of each transfer duct.

6.6 DELIVERY RATIOS

Over one complete engine revolution, the amount of gas flowing into each engine duct should be identical to that flowing out of the duct at its other end. However, within an engine cycle, the variation with crankshaft angle of the gas flow into one end of a duct will be different from the variation of gas flow out of the duct at the other end. The delivery ratio at any point in time is

just the mass of gas which has flowed through a particular duct end from the start of the engine revolution, divided by the mass of gas in the cylinder at ambient conditions with the piston at bottom dead centre.

Selecting this item provides a sub-menu list of the engine ducts. By clicking on a duct name you obtain the display of both the inflow and outflow delivery ratio curves for the selected duct.

Note that for an engine with multiple transfer duct types, each duct will contribute to the total flow into the engine cylinder, so the **Scavenge Ratio** (see section 6.5) at any crankshaft angle will be the sum of the delivery ratios at the outflow end of each transfer duct.

6.7 BOX CHARACTERISTICS

Selecting this item allows you to display, on the same screen, the variation of Pressure, Temperature, Purity and Density with crankshaft angle for the box you select from the sub-menu list. This sub-menu will always contain the choices *Cylinder* and *Crankcase*. In addition, the choice *Box Muffler* is provided if the engine has a *Box Muffler* or the choice *Int. Muffler* for an engine with an *Integrated Muffler* and where the *Box Model* has been selected. The choice *Induction* is also provided for an engine with an *Induction Box*.

6.8 DUCT CHARACTERISTICS

This selection provides a sub-menu which lists the engine ducts. Clicking on a duct name provides, on the same screen, plots of the variation in duct Pressure, Temperature, Velocity and Purity with crankshaft angle, at either end of the selected duct. "INFLOW" refers to the end of the duct into which fluid would normally flow, whilst "OUTFLOW" refers to the end of the duct through which fluid would normally exit.

6.9 CYLINDER FLOW ANIMATIONS - MOTA-7 ONLY

The CYLPLOT option button starts the cylinder flow animation feature. Its selection leads to the display of option buttons for PURITY, PRESSURE, TEMPERATURE and RETURN. Selecting a property yields an animation of this property as the piston moves from EPO to EPC. The animation repeats until another selection is made. Colours are used to denote qualitative values of the property selected. For example, deep red denotes a gas purity of zero (pure exhaust gas) whilst bright green denotes a gas purity of one (fresh mixture with no exhaust gas). Colours in between denote purities between 0.0 and 1.0. For the temperatures and pressures, the values and colours corresponding to the maximum and minimum of these values are shown. Arrows on all diagrams represent the magnitude and direction of particle velocities at each point. The maximum velocity in the entire animation is given beside an arrow which length corresponds to this maximum velocity. In this way, the velocities at various points in the display can be estimated. The cycle time of the animation can be varied by moving a scroll bar immediately below the display.

There are many assumptions that had to be made in the construction of the model. One was that the cylinder states bounded by the port outlines have to be uniform during cylinder outflow. The consequence of this is seen mainly within the exhaust port boundary, where the states (colours) are uniform in each frame during the gas exit period. Although there can be a partial vacuum in the bottom part of the cylinder during the phase where a fresh charge is drawn in, and the corresponding temperature is therefore quite low, the model sometimes displays minimum temperatures that seem too low. This is a consequence of the heat transfer model between the engine and its environment not being as detailed as it should be. Such a problem is difficult to fix without requiring more information than is currently available in the engine data file. Because the animations are close to reality, the extra benefit obtained by chasing infrequent errors was deemed not worth pursuing.

7 RUNNING THE ENGINE SIMULATOR

When **Run the Simulator** is selected from the *Main MOTA Menu* of **MOTA-7** a sub-menu drops down which provides two options. The first allows you to perform one or several normal simulation runs whilst the second allows you to perform an engine optimisation.
In **MOTA-8** you are simply required to select one or more *Engine Data Files* with which to perform normal simulation runs. In **MOTA-7** you are invited to select one or more "Mota-7 type" *Engine Data Files* and simulations using the 2-dimensional cylinder model will then commence. These may be up to 200 times slower than the simulations in **MOTA-8**.

7.1 NORMAL SIMULATION RUN

For both **MOTA-8 and MOTA-7** this option presents you with a dialogue box which allows you to choose up to twelve Engine Data Files to run in one batch. By holding down the control key, you can select up to twelve *Engine Data Files* in the chosen folder by clicking the mouse over them. When you click the *OK* button, all the *Engine Data Files* you have selected will be processed consecutively by the engine simulator.
Whilst the engine simulations are in progress the red **MOTA** screen is replaced by a blue screen on which the selected *Engine Data Files* are listed and the current file being run is highlighted. Once all simulations have been completed the blue screen needs to be closed and the red **MOTA** screen will again be displayed.

For each *Engine Data File* processed the simulator writes three output files to the same folder from which the data file was

obtained. Each of these output files has the same generic name as the **Engine Data File** except with the extensions "*.per*", "*.gph*" and "*.cyl*". The "*.per*" file is the **Engine Performance File**. It contains text based information about the engine's performance. The "*.gph*" and "*.cyl*" files is the **Graphics Output File** which contains graphical representations of the engine's performance. These files are discussed in detail in sections 5 and 6.

It is a good idea to check if convergence of the engine simulation process is acceptable by viewing the Delivery and Exhaust Flow Ratios written to the **Engine Performance File** by the simulator. For each speed these should differ by less than one 1% although there may be 1 speed in 10 where this tolerance is exceeded. If more than 3 out of 10 speeds indicate a greater than 1% difference between the Delivery and Exhaust Flow ratios the value of the maximum number of revolutions should be increased and/or the value of the pipe step factor should be reduced by editing and saving the Engine Data File and the simulation then re-run.

7.1.1 Demonstration Engine Data Files and Simulation Output Files

A number of sets of engine files are included with **MOTA** to enable users to become familiar with the capabilities of the program. These reside in folders "SAMPLES-8" (**MOTA-8**) and "SAMPLES-7" (**MOTA-7**). These include:

- KT100J: A 100cc go-kart engine having a piston controlled inlet port.
- YZ80: An 80cc reed valve inlet port moto-cross engine, having been highly modified for road racing.
- R128: A 125cc rotary valve inlet port Grand Prix engine.
- KT100S: The world's most popular 100cc go-kart engine.
- YZ250: A 250cc moto-cross engine.
- T75reed: A 100cc reed valve induction go-kart engine.
- KIBCONE: A KT100S engine with an induction box and duct muffler without a tailpipe.
- KIBTAIL: A KT100S engine with an induction box and duct muffler with a tailpipe.
- Tiny1: A 3.4cc model aeroplane engine running on methanol fuel.

The Engine Data Files represent actual engines at various stages of their development .

Assorted additional **Engine Data Files** are included on the CD distribution disk of **MOTA**, these in the SAMPLES-8 folder for **MOTA-8**. These files are identified by their name which generally corresponds to their commonly recognised model, and are supplied without any related **MOTA-8** output files.

7.2 ENGINE AND EXPANSION CHAMBER OPTIMISATION - MOTA-8 ONLY

Selecting this option leads you to being asked to select an **Engine Data File** which is suitable for running with **MOTA-8**. The expansion chamber design tool on the IWT website can be used to provide initial dimensions for an expansion chamber if none is known. The **MOTA-8** software is fairly robust so any reasonable initial dimensions for an exhaust system can be used in the **Engine Data File**. Once an **Engine Data File** is selected you will be presented with a screen containing the choices:

- Exit to Main Menu (this button is active)
- Commence Optimisation (this button is not active)
- Optimisation Parameters (this button is active)

If you want to proceed with the optimisation you must select the last option. On the screen provided you are given the option of optimising either Power or Torque. You need to decide which is appropriate and select it.

Once Torque or Power is selected you are asked for the number of speeds over which the optimisation is to be performed. Optimising at one speed may result in a very high output at that speed with a sharp drop off to either side of that speed. Generally it is best to select a range of speeds over which the optimisation will proceed and you can select up to six speeds. For example, if you have an engine which produces its peak power at 12000rpm, you might seek a pipe which maximises the power curve between 10000rpm and 12500rpm. To do so you could decide to perform the optimisation over six speeds and, when prompted for their rpm values, provide 10000, 10500, 11000, 11500, 12000 and 12500. The more speeds you select, the less chance of "dips" in the power between the selected speeds. Generally it is recommended to select 6 (the maximum number) speeds. You are then prompted to provide weightings for these speeds. These allow you to flag a measure of "importance" to each speed. The weights you provide must be whole numbers from 1 to 9. For the six speeds you might simply maximise the sum of the output at each speed by using the equal weights 1,1,1,1,1,1. When the optimisation is completed and you examine the Power and Torque curves you may feel that the higher speeds were given insufficient weight and decide to run the optimiser with another set of these values, such as 2,2,3,4,4,3. To some extent the selection of the optimisation speeds and their weights is a dynamic exercise to design an expansion chamber which, in your opinion, provides the best shaped optimal output curve (power or torque). Generally the weights 1,2,2,2,2,1 would be recommended for a six speeds optimisation with a similar set of weights for a lower number of optimisation speeds.

The next field to fill in is a name for the new "**Engine Data File**" which, in addition to the associated **Performance** and **Graphics** files, will be created when the optimisation is completed. This data file will contain the dimensions of the optimised expansion chamber. The name you provide must NOT include an extension, for example **ktopt01** and not **ktopt01.dat**. At any time after the optimisation you can access this data file via the "Edit an Existing Engine Data File" facility and elect to print

details of the expansion chamber. Patterns for the construction of the cones can be produced by selecting **"Expansion Chamber Construction"** from the menu bar of **MOTA-8**. Good practice, to avoid confusion, is to keep optimisations for separate engines in separate folders.

The final field is a **"Comment"** for inserting in the Engine Data File and the Engine Performance File. This is for some brief but useful informaion such as to identify the source, content and purpose of the Engine Data File and/or the optimisation. After entering this information, click on the "Next Screen" button and, if all fields have been completed correctly, you will find that the "Select Optimisation Parameters" button will now be green. If it is still red go back into that screen and remedy any errors.

7.2.1 Main Optimisation Variables

Once back at the main optimisation screen, several additional active and inactive red buttons will now appear depending on your engine configuration:

- Expansion chamber section lengths
- Expansion chamber section out diameters
- Muffler dimensions (this button is activeonly for a duct model of an integrated muffler)
- Rotary Valve Start Open and Fully Closed Angles, Port geometry values.(this button is active only when the engine has a rotary valve)
- Piston Port Widths, Start Open and Fully Open angles

It is on these screens that you select those dimensions associated with the chosen group that you would like to vary. On each screen you can select all or any subset of offered dimensions to be varied during the optimisation. The inputs for each screen are self explanatory. When you have completed your selections, click the"Next" button and you will be taken back to the main optimisation screen, where you can select another variable set to be optimised. The button just selected should change colour to green, indicating that optimisation variables in the associated group have been set successfully. If at least two values have been selected for optimisation the "Commence Optimisation" button will be active.

7.2.1.1 The Expansion Chamber Section Lengths Screen

Enter the details of which expansion chamber section lengths are to be optimised.

7.2.1.2 The Expansion Chamber Section Outlet Diameters Screen

Enter the details of which section outlet diameters are to be optimised. You can also choose to constrain some sections to remain parallel.

7.2.1.3 The Integrated Muffler (Duct Model) Dimensions Screen

Enter the details of the integrated muffler dimensions that are to be optimised.

7.2.1.4 The Rotary Valve Screen

Enter the details of rotary valve variables to be optimised.

7.2.1.5 The Piston Ports Screen

This screen provides the selection of Piston Port Start Open (SO) and Full Open (FO) Angles and Piston Port Widths as optimisation variables. Where a new engine design is being considered there is "No Constraint" and this should be selected along with the desired selection of port angles and widths. However, for an existing engine where the addition of metal to the liner and barrel at the ports is impractical, the default "Constraint" option should be retained. Of course it may be interesting to see just what could be achieved without the constraint! As an example, if the EPO is 90 degrees ATDC, under the constraint condition this can only be reduced since increasing the EPO value involves the addition of metal to the liner and, no doubt, to the barrel also. Another example is where the exhaust full open angle is at BDC for which the default "Constraint" option will prevent the selection of this angle for optimisation.

The Port Width Optimisation has 2 inbuilt constraints:

- In general, no individual piston port can extend over more than 78 degrees of arc width. However, if this value is exceeded in the engine file selected for the optimisation it is assumed that this engine runs successfully without trapping the ring(s) and the maximum port arc width contained in this file is now substituted as the maximum permissible value. At each optimisation iteration, each newly computed port width is checked and set equal to the maximum permissible value if this value has been exceeded.
- Throughout an optimisation, steps are taken to ensure that the sum of the port arc widths is not increased excessively. The minimum port start open angle (the EPO) and the maximum of the transfer and exhaust port fully open angles are averaged and the position of the piston is calculated at this "averaged crank angle". The port geometry of the barrel is then interrogated around the bore where the edge of the piston crown would sit and the sum of the angular port widths is not allowed to exceed 85% of the circumference of the bore.

In the initial engine, where a port to pipe transition is "smooth", the port to pipe area ratio is equal to 1.0. During an optimisation involving the arc width and/or port angles the port area will change and the pipe area at the interface with the port is then also changed such that the port to pipe area ratio of 1 is retained.

In the initial engine, where a port to pipe transition is not smooth, the port to pipe area ratio will not equal 1. Whilst the pipe area at the port will not change throughout the optimisation the port to pipe area ratio will vary if associated port angles and/or the angular port width are optimisation variables. In this case the port to pipe area ratio will not be allowed to exceed 1.2 times its original value or become less than 0.8 times its original value. This constitutes another constraint on the values of the angular port width and the two port angles. Newly computed port values are checked against these limits, and modified as necessary, before proceeding with the next optimisation iteration.

If the exhaust port is a power port and this is selected for optimisation, the power port angle at each of the chosen optimisation speeds becomes an optimisation variable. For example, if you have a 6-speed optimisation, there will be 6 power port exhaust optimisation variables. At the end of the optimisation the optimum power port angles will be "spliced" to provide values for the new engine data file. That is, in the new engine data file, power port angles are provided for the same speeds as those defining the "power port angle vs engine speed" relationship in the original engine data file.

For many high performance engines with power ports, the optimiser may give a power port opening angle which decreases to a minimum and then increases at the upper end of the engine speed range. Such a relationship can only be set in an engine with an electronically controlled power valve. For all other control mechanisms, the power valve opening angle decreases with increased engine speed.

Once you have completed filling a screen, click the "Next" button to return to the "Optimisation Set Up" screen. If at least two dimensions have been selected for optimisation the "Commence Optimisation" button will be active. At this stage you may have made selections from one screen only, Expansion Chamber Section Lengths for example, and whilst an optimisation involving only Section Lengths can be performed, most likely you will now click Expansion Chamber Section Diameters to select some or all of the section out diameters as optimisation variables. Notice that the in diameter at the engine flange is offered for selection too. Once you have selected as many dimensions and angles as you wish from the screens provided, and have returned to the "Optimisation Set Up" screen, start the optimisation by clicking the "Commence Optimisation" button.

7.2.2 The Optimisation Screen and Windows

When the "Commence Optimisation" button is pressed there will be short delay before the red **MOTA-8** screen disappears and is replaced by a totally different optimisation screen notifying you that the initial simulation of your engine is in progress. Once this is complete either one or two large blue windows are displayed and continuously updated as the optimisation progresses.

If only expansion chamber dimensions or only port and/or rotary valve related dimensions have been selected as optimisation variables only one blue window is displayed, otherwise two windows are required to display the progress of the optimisation.

For the case of an expansion chamber related optimisation the related blue window is broken up into numerical information about the optimisation and drawings of two expansion chambers. The lower drawing shows the initial expansion chamber whilst the top drawing will gradually converge to the profile of the optimised expansion chamber. Both drawings are made to the same scale. They are redrawn after each optimisation iteration and rescaled as necessary to fit in the fixed size windows. It is the relative difference between the two drawings which is noteworthy. Within limits the screen can be resized as **MOTA-8** is running.

Where some piston port and/or rotary valve dimensions have been selected the related blue window displays the current performance details at the top and below the original and current values of these dimensions are displayed in tabulated form.

Where there are two blue windows a "**Cascade**" menu item at the top of the screen is used to show the Expansion Chamber blue window on top of, but offset from the Piston Ports blue window. The mouse can be used to bring either window to the front. It will be necessary to use the mouse to heighten the expansion chamber blue window and perhaps the other blue window too.

The Menu buttons at the top of the optimisation screen provide usual Windows functionality, including the **Print** option that allows a hard copy of the blue window at the front of the display to be colour printed at any time. Using this button will consume a large amount of blue toner from your printer, it is better to use the **bwprint** button which converts the image to black on white, lessoning toner consumption. Once the print dialogue box has been "OK"d, move the mouse to restore the dynamic blue output window(s).

At the top of the optimisation screen, each of the optimisation speeds is listed with the chosen weights beneath. The original power, current power and power gain (which can be negative) are then listed for each speed. This will show how effective the current dimensions are at any time during the optimisation.

On the next line are two fields showing the target tolerance and the current tolerance. The optimisation method consists of keeping in memory a number of different engine states and replacing the point representing the state with the lowest derived power/torque with a newly derived state which has a power/torque greater than it, according to the mathematics involved. "Tolerance" refers to a measure of how close these states are to each other. It is a complicated mathematical function of the current engine states. If there are n dimensions to be optimised then there are always $(n+1)$; engine states in memory at any

one time during the optimisation. Target tolerance is always 0.001 and preset there. That is, experiments by the developers have shown that when the tolerance gets down to 0.001, to all intents and purposes all the engine states have converged to one state, the optimum, and the optimisation terminates. The difference between current tolerance and target tolerance is a measure of how close the optimisation is to convergence. The optimisation can start off and run with current tolerance exceeding 0.2 and such values suggest the optimisation to be well away from convergence. Current tolerance can decrease and increase during the optimisation until final reduction towards 0.001. Only after the current precision reaches 0.005 does the "**Premature End of Run**" button in the top menu become active. This is because, in the experience of the developers, optimisation dimensions associated with tolerance values above this are considered to be too far from the optimum.

You can restart the optimisation from any "optimal solution" to see if an even better expansion chamber can be found. Generally this will use a different set of engine speeds and/or weights but it is possible that the use of the original combination of these values will provide a different and improved optimum. This could be marked by an initial increase in value of the current tolerance before its reduction and convergence. Be patient, optimisations will take variable amounts of time to convergence and typically could exceed 30 minutes.

After the optimisation criteria have been met, the process stops and the red MOTA-8 screen re-appears, the one or two blue windows described above remain and a white window is added, this with a self explanatory summary of the optimisation results. These show initial and final values of the selected variables, power outputs and other parameters. The content of the added white background window can be printed with the "Print" button in the top menu. The "Cascade" menu item offsets the windows slightly to enable easy selection. All windows remain so that you can print them as required. It is strongly suggested to use the "bwprint" menu button when printing the content of a blue window. The actual optimisation run is finished when the red screen reappears but a blue window will show *Running* in the bottom left hand corner until the "Exit" button is pressed. The blue and white windows can be removed by clicking the "Exit" button on the menu of a blue window. The red MOTA-8 screen will go behind the blue window when this is given the focus such as by clicking on it, but is recovered when the windows are exited or minimised to the system tray.

7.2.3 Example Optimisation Procedure

Suppose you want to optimise the expansion chamber of a KT100S engine. You would prepare a **MOTA-8** Engine Data File, KT100S.dat, as described above and perform a simulation run to produce the output files KT100S.per and KT100S.gph. You would then select *Expansion Chamber Optimisation* under the *Run the Simulator* menu item of **MOTA-8** and then select the KT100S *Engine Data File.* Next, in filling out screens as described above, give a name such as KT100S-opt1 for the engine data, performance and graphics files to be created upon completion of the optimisation. Upon completion of the optimisation the Engine Data File KT100S-opt1.dat will contain the dimensions of the optimised expansion chamber. You can graphically compare the *Power/Torque curves* provided by the original and the optimal expansion chambers, this such as by selecting KT100S.gph as the primary graphics file for display and KT100S-opt1.gph as an overlay file.

Also written throughout the optimisation will be a monitor file, KT100S.mon. This contains cryptic information about the optimisation which is of no use to you as a user but needs to be returned to the developers along with the initial *Engine Data File* should an optimisation fail.

Having examined the *Power/Torque curves* provided by KT100S-opt1.gph you might decide to perform a second optimisation with a different selection of Speeds and Weights. If this is performed by running with the original *Engine Data File*, KT100S.dat, you could provide KT100S-opt2 as the name for the new set of output files. However, you could select KT100S-opt1.dat as the *Engine Data File* for this second optimisation and in this case the output files might be named KT100S-opt1a. In practice several optimisations might be performed before you are satisfied that you have the expansion chamber dimensions which will provide the best possible *Power/Torque curves* for your particular needs. It is wise to name successive sets of output files so that their source is easily traced. Also, for each optimisation, you could include the name of the source *Engine Data file* and the Speeds and the Weights in the "**Comment**" to be written to the output *Engine Data file*.

The *Performance File* created upon conclusion of an optimisation includes details such as the engine speeds and weights, a list of the selected variables with their initial and final values, and more. This information is well worth inspection as is use of the **MOTA-8** Graphics facility to compare engine performance provided before and after the optimisation.

7.2.4 An Example of a Complete Expansion Chamber Optimisation

In each folder of SAMPLES-8 there is a Engine Data File.

In addition, in the folder rot256, there are the files relating to an expansion chamber optimisation of the rot256 engine. The following example describes the files present:

The folder rot256. It contains the following files:

- rot256.dat: The Engine Data File used for the expansion chamber optimisation.
- rot256.mon: The monitor file written during the expansion chamber optimisation of rot256.dat.
- rot256opt.dat: The Engine Data File written upon completion of the optimisation and containing the optimal expansion chamber dimensions.
- rot256opt.per and rot256opt.gph: The corresponding performance and graphics files written at the end of the optimisation.

- rot256_1.dat: A copy of rot256opt.dat. (Access rot256opt.dat via *Edit an Engine Data File* and save it as rot256_1.dat.
- rot256_1.per and rot256_1.gph: The **MOTA-8** output files from a normal simulation run using rot256_1.dat.

8 ENGINE DATA FILE CONSTRUCTION TOOLS

Selecting *Tools* from the *Main MOTA Menu* provides access to a number of utility routines:

1. **Piston Position to Crank Angle.** Converts a piston distance from top dead centre (TDC) to a crank angle.
2. **Crank Angle to Piston Position.** The inverse of (1).
3. **Chord Length to Arc Length.** Converts a "straight-line" distance between two points on a circle to the length of the arc joining the same two points.
4. **Arc Length to Chord Length.** The inverse of (3)
5. **Bridged Port Radial Attitude Angle.** Calculates the effective radial attitude angle of a bridged port.
6. **Rectangular Duct Equivalent Diameter.** Calculates the diameter of a circular duct with the same cross-section area as that of a given rectangular duct.
7. **Integrated Muffler Length.** Calculates the length of an integrated muffler of defined muffler volume space.
8. **Integrated Muffler Volume.** Calculates the muffler volume space of an integrated muffler. This value is required for the Engine Data File if the "box model" for the muffler is selected.

The suite of data file construction tools are provided in recognition of the fact that engine specifications are given in many different ways. You can enter as many combinations of input values to your selected tool as you wish. That is, for each of the various tools selections, the **Calculate** button can be used as many times as you require. The screens provided by the various tool selections are largely self explanatory.

9 EXPANSION CHAMBER CONSTRUCTION

9.1 CONE PATTERNS FOR STRAIGHT EXPANSION CHAMBERS

This first section deals with the construction of straight cone sections and provides the dimensions necessary for you to construct the development patterns.
Please remember that instead of consructing these straight cone section development patterns yourself they can be prepared and printed for you by accessing the screens under Cone Patterns for 2D Expansion Chambers. For each straight cone section you will simply enter zero for each of the two oblique angles.

9.1.1 Development Diagrams Screen

The diagram on this screen shows the dimensions R1, R2, C1 and C2 which enable the construction of the development of a cone frustrum having end diameters D1 and D2 and axial length L. The thickness (T) of the sheet metal used for the construction is also required to ensure that the values D1 and D2 are the internal diameters of the constructed cone. The radii R1 and R2 and the arc lengths C1 and C2 are clearly illustrated in the figure on this screen.
It is generally assumed that D1 will be the smaller of the two diameters.
A pair of compasses and a metric rule will be required to construct a cone development using values provided on this screen.

9.1.2 Enter Cone Dimensions Manually

This screen invites you to enter the diameters (D1 and D2) and the axial length (L) of a straight cone section and the thickness (T) of the sheet metal to be used in its construction. By clicking the "Calculate" button a table with these values and those of the development construction (R1, R2, C1 and C2) is displayed. A "Print" button will now be active; click it to output the content of the table to your printer.

9.1.3 Cone Dimensions from an Engine Data File

This selection will display a list of the Engine Data Files in the appropriate "samples" folder. You can navigate to any other folder if you wish. By selecting an engine having an expansion chamber, a screen is displayed which requires entry of only the thickness (T) of the metal sheet to be used to construct the cones. Once this value is provided a table is displayed which contains the cone dimensions (D1, D2, L) and the development pattern dimensions (R1, R2, C1, C2) for each cone section of the expansion chamber. The content of the table can be output to your printer.

9.2 CONE PATTERNS FOR 2D CURVED EXPANSION CHAMBERS

9.2.1 Explanatory Diagrams

Three diagrams with text support can be selected for display:

- Cone Section having Oblique Ends
  This first figure illustrates the general case of a cone segment where both ends are oblique. Because both angles are "assisting" the bend the oblique angles must be of different sign, one positive and the other negative. It is then usual to set the oblique angle at the small end negative and that at the large end positive.

- The Cut and Bend Angles
  To build an expansion chamber such as one whose dimensions have been provided by the optimiser in **MOTA-8**, all sections are shown as straight sections. It may be necessary to divide some sections into one or more parts to achieve a bend of known total angle.
  This second figure deals with the case where a single section is divided into two parts to achieve a bend of known angle and shows that the bend angle will be twice that of the cut angle.

  Now suppose that instead of making a long cone segment and then cutting it into two parts at the appropriate angle, you intend to make the two parts separately. You will make each piece with the same oblique angle at their join, this angle will be the cut angle which is half of the bend angle to be achieved upon assembly. One problem, the diameter at the join is required, this being the small diameter (D1) on the "large" piece and the large diameter (D2) on the small piece.
  It is time to display the third figure .....

- Diameter at an Intermediate Length
  The expression provided with this third figure allows you to calculate the diameter at the mid section of an angled cut made at any suitable position along a cone segment. This value allows you to produce the two development patterns as an alternative to the "Cut and Join" exercise illustrated by the second figure.
  You do not need to make this calculation yourself; it can be performed for you on the 2D - Enter Cone Dimensions Manually screen to be discussed in the next section.

9.2.2 Enter Cone Dimensions Manually

Command buttons on this screen include "DISPLAY DEVELOPMENT", "PRINT THE DEVELOPMENT" and "EVALUATE DIAMETER AT AN INTERMEDIATE SECTION". Clicking this last button allows you to enter the dimensions of a straight cone and the distance from its small end where its diameter is required. Clicking a "CALCULATE" button will display the result.
The principal use of the screen is to allow a cone development pattern to be printed. Values of the two end diameters, the length and the two oblique angles of the cone are entered and also the thickness of the metal sheet for its construction. Clicking "DISPLAY DEVELOPMENT" provides a scaled display of the development and shows the number of pages (generally A4) that printing will require. Finally you can click the "PRINT THE DEVELOPMENT" button to produce the entire number of pages of the development pattern.

Working through this screen and entering zero for the two oblique angles will provide the development pattern of a straight cone section; this an alternative to the "hands on" construction described in previous sections.

9.2.3 Multi Section Angled Cone

This screen enables a single cone to be represented as several joining pieces which provide a total bend angle and may also have oblique extreme ends.
Command buttons on this screen include "DISPLAY THE PIECE DIMENSIONS", "PRINT PATTERN OF SELECTED PIECE", "PRINT PATTERN OF ALL PIECES" and "PRINT SCREEN CONTENT".
A frame labelled "Enter Straight Cone Dimensions" requires entry of the two diameters and the length of a cone. The thickness of the metal sheet to be used in constructing its multi-piece representation must also be entered.
A second frame labelled "Multi Piece Construction Details" requires entry of the "Number of Separate Pieces", the "Total INTERNAL Bend Angle", the "Additional Oblique Angle at End 1" and the "Additional Oblique Angle at End 2".
Once all values have been satisfactorally entered in these two frames, various command buttons become active.
Clicking "DISPLAY THE PIECE DIMENSIONS" will provide a table containing the dimensions, oblique angles and axial length of each piece. Various criteria could have been applied to the process of representing a single cone by several joining pieces, this with a total internal bend and the option of oblique ends. That adopted is to have the short length equal for all pieces. The value of this short length is displayed. The total of the axial lengths of all pieces will equal that of the single cone represented.
Clicking the "PRINT SCREEN CONTENT" button can be used to print all values displayed on the screen.
Clicking the "PRINT PATTERN OF SELECTED PIECE" button will cause an option button to be positioned against each of the separate pieces listed in the table. Clicking any one of these option buttons will cause the developmemt pattern of that piece to be written to the printer.
Use of the "PRINT PATTERN OF ALL PIECES" button is self explanatory.

9.2.4 Cone Dimensions from an Engine Data File

This selection will display a list of the Engine Data Files in the appropriate "samples" folder. If you wish you can navigate to any other folder before selecting an Engine Data File for an engine with an expansion chamber. A screen is then displayed which contains a table of the dimensions of the expansion chamber sections and a prompt for the thickness of the metal sheet to be used in cone construction. Once this value has been entered two command buttons become active: "PRINT PATTERNS OF SELECTED SECTIONS" and "SELECT SECTION FOR CUT AND BEND PATTERNS".
By clicking "PRINT PATTERNS OF SELECTED SECTIONS" a selection button is provided against each expansion chamber section listed in the table and an "OK" button displayed on the screen. Make your selection(s), click on "OK" and development patterns of the selected cone sections will be sent to the printer.

By clicking "SELECT SECTION FOR CUT AND BEND PATTERNS" an option button is provided against each expansion chamber section listed in the table. Once you click on an option button you are prompted to enter the Number of Separate Pieces and the Bend Angle. An "OK" button is displayed for use once these two values have been entered. Generally the patterns for the requested Number of Separate Pieces is then sent to the printer. However if a message is displayed to inform you that the short side length of the sections is less than 10mm, this with the value displayed, you have the option to abort printing. Printing is not permitted when a message informs that the short side length is less than 5mm with this value also displayed.

9.3 CONE PATTERNS FOR 3D CURVED EXPANSION CHAMBERS

This selection is used to produce the development pattern of a cone section with oblique ends PLUS **a rotation of the one end relative to the other end**. This enables the construction of an expansion chamber whose axis does not lie in a plane and is then said to be 3-dimensional.
Care must be taken when commencing work to construct the cone from a flat sheet metal copy of the development pattern. **This is because the combination of two non-zero oblique angles and a rotation of one end of the cone results in a non symetric cone development. It follows that the development pattern has a top side and a bottom side.** It is the **TOP SIDE** whose outline is displayed on the screen which **represents the OUTER SURFACE of the finished cone.**
Values to be entered in order on this screen are the small end and large end diameters, the axial length and the thickness of the sheet metal to be used in the construction. Next are the small end and large end oblique angles with the non zero small end oblique angle generally negative and the large end oblique angle always positive. Finally the **ROTATION ANGLE** is entered. Looking at either face, a positive angle provides a clockwise rotation and a negative angle provides an anti-clockwise rotation.

It may be helpful to read, remember and perhaps print the following note:

> **The Small End Diameter is D1.**
> **The Large End Diameter is D2.**
> **The Small End Obligue Angle is non-zero and generally Negative.**
> **The Large End Oblique Angle is non-zero and always Positive.**
> **When viewing an end face, a Positive Rotation Angle will rotate this face Clockwise with respect to the other end face.**
> **When viewing an end face, a Negative Rotation Angle will rotate this face Anti-Clockwise with respect to the other end face.**
>
> **Both the scaled development displayed on the screen and the full size development pattern provided by a printer show the outside surface of the cone to be constructed. To avoid mistakes, the Top Face should be clearly marked on the sheet metal copy of the development pattern when this is prepared for constructing the cone. It is the Top Face which represents the outer surface of the finished cone.**

10 POWAPLOT

This allows you to construct and manipulate *Power Files*. These have the extension "*.pow*". In particular, **Powaplot** can be used to generate viewable graphs from dynamometer output. Such graphs can then be compared with other predicted and experimental power/torque curves using the overlay facility provided in **Powaplot**.

10.1 CONSTRUCT A POWER FILE FROM A GRAPHICS OUTPUT FILE

An engine simulation performed by **MOTA** which involves at least four engine speeds allows the display of power/torque curves when the associated *Graphics Output File* is accessed. This feature of **Powaplot** allows you to select a *Graphics Output File* and to nominate the number of cylinders in the complete engine. The power/torque curve information is then extracted from the "*.gph*" file, the power values multiplied by the number of cylinders and the values then written to a separate file having the same name as the source *Graphics Output File* but with the extension "*.pow*". The content of the new *Power File* is also displayed graphically in an environment identical to that of the power/torque option described in section 6.1, having precisely the same functionality as that option. The file can also be accessed as an overlay file both within the use of **Powaplot** and when displaying graphical information though a *File Menu* selection.

10.2 CONSTRUCT A POWER FILE MANUALLY

This enables you to construct a *Power File* by entering information on the screen which is displayed when you select this option.

The main data comprises an engine speed and a corresponding power or torque for as many speeds as you have selected in the first box on the screen. The minimum and maximum number of speeds are 4 and 40 respectively. The initial screen assumes the default options of *imperial units*, *unequal speed intervals* and *power*, but you may change these to suit the data you wish to input. If you select the *equal speed interval* option, you are presented with two boxes for you to enter the *lowest speed* and the *speed interval*; the boxes relating to your engine speed are then completed automatically so that you need only enter the corresponding power or torque values. If the *unequal speed increments* option is chosen, you are required to enter values of both the engine speed and the corresponding power or torque.

When you are satisfied with your input, click the *Save as a File* button and then select a drive and folder and provide a name for your file. The data you entered is then displayed graphically on the screen, together with the file construction screen. You may change the data on this screen and save to a new file or simply overwrite an existing file as often as you wish. Each time, the appropriate file is created and the corresponding graph is displayed. The display has the same functionality as the power/torque option described in section 6.1.

10.3 DISPLAY A POWER FILE

This enables you to select an existing *Power File* and display it in the same environment and with the same functionality as the power/torque option described in section 6.1. File selection is through the common dialogue box described previously.

CONVERSION FACTORS

LENGTH: 1 in = 25.4 mm
AREA: 1 sq.in = 6.4516 sq.cm
VOLUME: 1 cu.in = 16.387 cc
MASS: 1 lb = 0.45359 kg
POWER: 1 hp = 0.74570 kW
TORQUE: 1 ft lbf = 1.3558 Nm
VELOCITY: 1 ft/s = 0.30480 m/s
TEMPERATURE: degrees C = (degrees F - 32)/1.8
CALORIFIC VALUE: 1 BTU/lb = 0.55556 kcal/kg
FUEL CONSUMPTION: 1 lb/hph = 0.60828 kg/kwh
DENSITY: 1 lb/cu.ft = 16.0185 kg/m3
PRESSURE and YOUNG'S MODULUS: 1 psi = 6894.76 N/m2

EQUIVALENTS: 1 000 000 000 N = 1 GN
                     1 calorie = 4.1868 joules
                     1 N/m2 = 1 Pascal
                     1 atm = 101325 Pascals or 14.696 psi

CUSTOMER SUPPORT

All enquiries and requests for assistance should be directed to Ian Williams:
from Overseas: +61 8 8340 9277
by email: iwt@iwt.com.au

Our main distributor's website contains some more information concerning **MOTA**. Included are further technical explanations of some of the terms used in **MOTA** and links to related sites. Additional engine data files will be placed on the site as they become available to us, as will any other news we have concerning **MOTA**.

You can visit this website at: http://www.iwt.com.au

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TRADEMARKS

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DEDICATION

My contribution to **MOTA-8** is dedicated to my late wife Joyce.
Her encouragement and support were my extreme pleasure.
Malcolm.

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