

MANUAL FOR WINRT60, VERSION 1.0

BY

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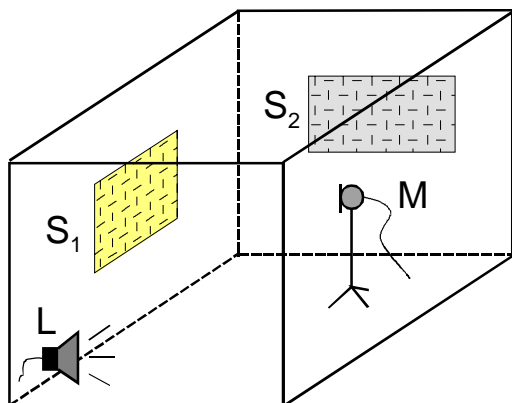
CONTENTS

1	INTRODUCTION.....	3
2	OVERVIEW.....	3
3	MAIN FEATURES	3
4	BRIEF DESCRIPTION OF THE PROGRAM.....	4
4.1	Calculation options.....	7
4.2	Program execution. examples using different methods	7
5	MENUS.....	9
5.1	The file menu	10
5.1.1	The database of absorbent structures	11
5.1.2	Making a report	12
5.2	The calculation method menu	13
5.2.1	Sabine's reverberation time formula.....	13
5.2.2	Eyring's reverberation time formula.....	14
5.2.3	Arau-Puchades' reverberation time formula.....	14
5.2.4	The sound absorption of air.....	15
5.3	The absorbent menu	15
5.4	The diagram menu.....	16
5.5	The help menu.....	16
5.6	The Toolbar	16
5.7	The set-up information window	17
6	WinRT60 LICENSE TRANSFER.....	18

1 INTRODUCTION

The program WinRT60 calculates reverberation time in rooms based on knowledge of all absorbing structures in the room including air absorption. A verification of these calculations are normally performed by the use of a measurement system comprising a loudspeaker and microphone and a suitable software such as WinMLS™ to evaluate the decay of sound in the room, see the sketch in *Figure 1-1*.

For the calculation of the reverberation time the user chooses between three different methods or formulae's, i.e. using the classical formula of either W.C. Sabine or C.F. Eyring besides a



newer one by H. Arau-Puchades. For the method by Sabine only the total absorbing area and the room volume need to be known, whereas the Arau-Puchades formula demands specifications of the locations of all absorbers. A short overview of the basic theory with formulas is given in Section 5.2.

Figure 1-1. Sketch of a room with absorbers of areas S_1 and S_2 . Loudspeaker L and microphone M for measurements.

The calculations are based on input of data from two different sources, which may be combined. The first is a database in Microsoft Excel format, containing the name, a description and data for the absorption coefficient for each absorbing surface intended to be placed in the room. Secondly, the program can be used simultaneously with the program WinFlag (from version 2.1), from where calculated data for the absorption coefficient of various structures may be pasted into WinRT60. Some simple examples on a database are supplied with the program. However, it is presupposed that the user extends these databases with own data, either from measurements, from product specifications or from other sources. However, certain rules must be followed to make the database work seamlessly with the program

2 OVERVIEW

The program main files are the following:

- WINRT60_1.0.EXE This is the main program
- WINRT60_HELP.PDF Help file (this document)

To get help during program execution it is assumed that the help file may be read, the computer must have the program Adobe Acrobat installed, version 4.0 or higher. Please note that there are several cross-references in the document, i.e. when sections and figures are referred to, clicking on the Section or Figure number will bring you to the item.

3 MAIN FEATURES

- Calculates the reverberation time, usually denoted T_{60} , in rooms using the formulae's due to W.C. Sabine, C.F. Eyring or H. Arau-Puchades. The latter applies strictly only to rooms of rectangular shape.
- The calculations are based on data for the absorption coefficient for each absorbing structure in the room. These data are based on frequency band calculations or

measurements, basically in one-third-octave bands but octave band data may be used as well.

- The necessary data for the absorption coefficients is either taken from a database in Microsoft Excel-format and/or from calculated results using the program WinFLAG™. The program is supplied with some examples for a database.
- The absorption capability of the air in a room is often neglected but may give an important contribution to the total absorption especially when the moisture content is low, i.e. in certain times of the year when the relative humidity is low, maybe below 20 – 30 %. The effect is accounted for by a calculation of the power attenuation coefficient of air according to ISO 9613 Part 1. From this coefficient the equivalent absorption area due to the air is calculated and added to the absorption of the other structures in the room.
- A report window in Rich Text Format (.rtf file) is implemented where specifications of the room and the absorbents used, tables of results and diagrams may easily be imported.
- Calculated results for the reverberation time, together with specifications of the room and the absorbents used, may also be exported to a Microsoft Excel file.
- The set-up for a calculation, based on a certain selection of absorbents and specified data for the room may be saved in file and later recalled for further calculations.
- On errors in the input data the set-up will be displayed in a separate window, see section 5.7.

4 BRIEF DESCRIPTION OF THE PROGRAM

The program is started either from your program menu or by clicking on the file WinRT60_1.0.exe or by making a shortcut to this file and start from the desktop. The following window should then appear, see *Figure 4-1*.

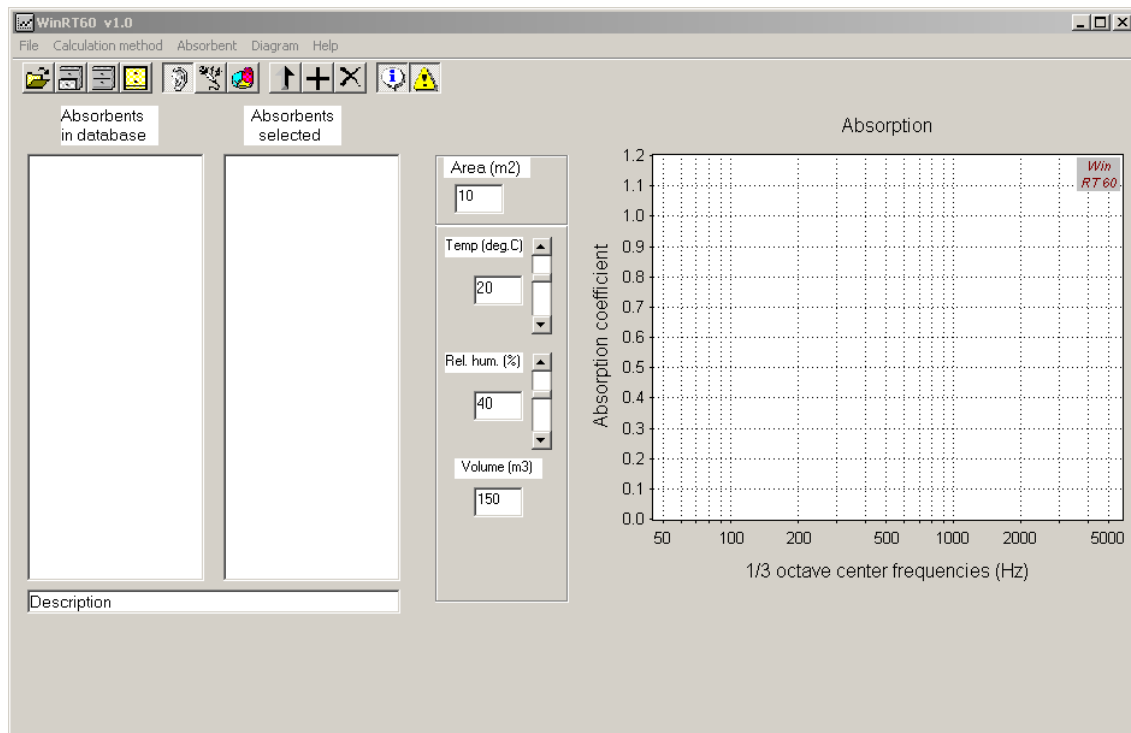


Figure 4-1. The calculation window at start-up time

In the list box to the left (labelled “Absorbents in database”) the names of the various absorbing structures will appear when loaded from a database file or pasted from the program WinFLAG (version 2.1 or later). First loading from the database and thereafter filling in by data from WinFLAG may combine these two sources of data. The data from the latter will be added to the bottom of the list.

In the list box labelled “Absorbents selected” the user will assemble all the absorbing structures to be used in the calculation of the reverberation time. There are three possible ways to transfer an absorbent from the database list to the absorbents list being: 1) by double-clicking on the absorbent in the database list, 2) by marking an absorbent in the database list and then click on the button marked with “+” in the toolbar and 3) using the submenu “Add from database” under the main menu “Absorbent”.

Below these two list boxes there is a narrow list box containing the word “Description”. Here the short user description of the absorbent structure will appear when clicking on the absorbents name either in the database box or in the selection box. At the same time the absorption characteristic for the structure will show up in the diagram, see *Figure 4-2*.

The default option for calculating reverberation time is using the method of Sabine. The pressed button in the toolbar having an ear as an icon indicates this (Sabine used his ear and a stopwatch to register the decay of sound when he established his famous formula).

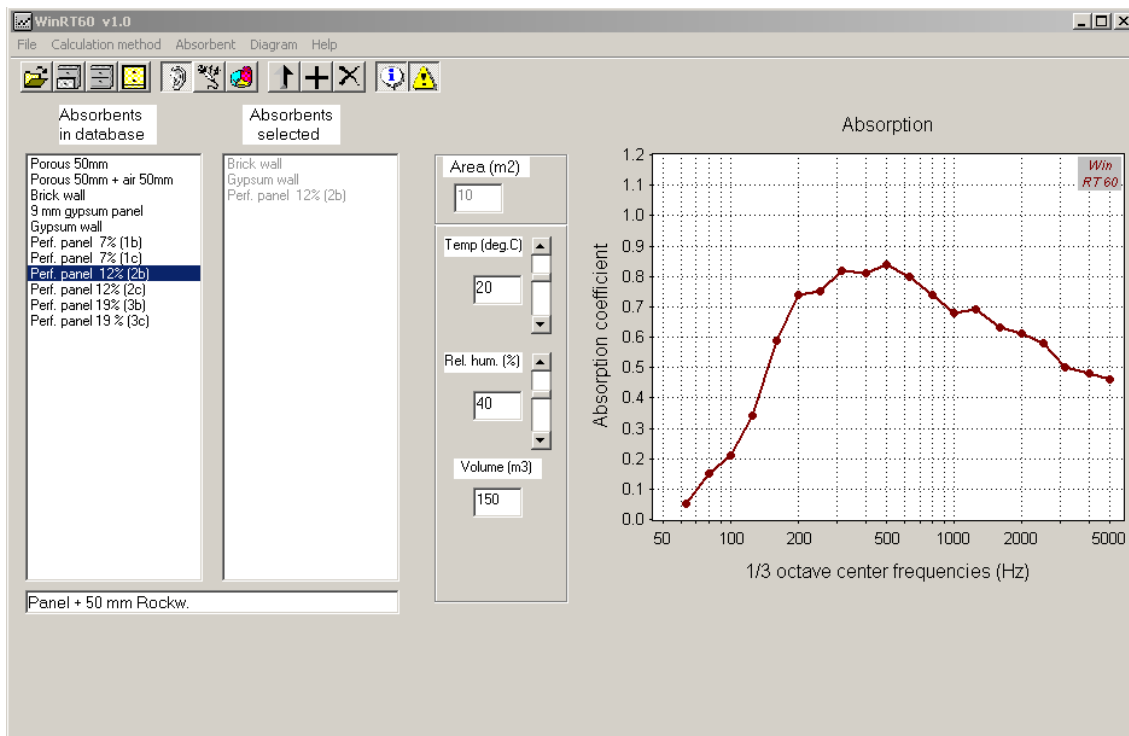


Figure 4-2. The calculation window after a database is loaded and three different absorbing structures is placed in the selection box. The absorption characteristics for the selected panel absorbent intended for the ceiling are shown.

As a first example, using the formula of Sabine, we will state that our room has dimensions 10 by 6 by 2.5 meters, i.e. a total volume of 150 m³. There are brick walls of total area 50 m²

and the remaining walls, 30 m², are gypsum stud walls. Covering half the ceiling area is an absorbent, a perforated panel backed by 50 mm Rockwool. The floor absorption is for simplicity neglected. *Figure 4-2* shows the situation when a database is loaded and furthermore, the absorbent structures mentioned above are all loaded into the list box named “Absorbents selected”. In the latter the names are shown in grey colour indicating that the curve showing the absorption coefficient in the diagram and the description below the list boxes is taken from the database.

The next step is to assign the proper area to the selected absorbents by clicking on each of them as shown in *Figure 4-3*. The database text is then shown in grey indicating that the information is now taken from the selection box. Here the brick wall is clicked on and both the curve and the description are shown. At the same time the input box named “Area (m²)” is open for input of the area of the selected absorbent. As seen we have already input the chosen 50 m² for this wall.

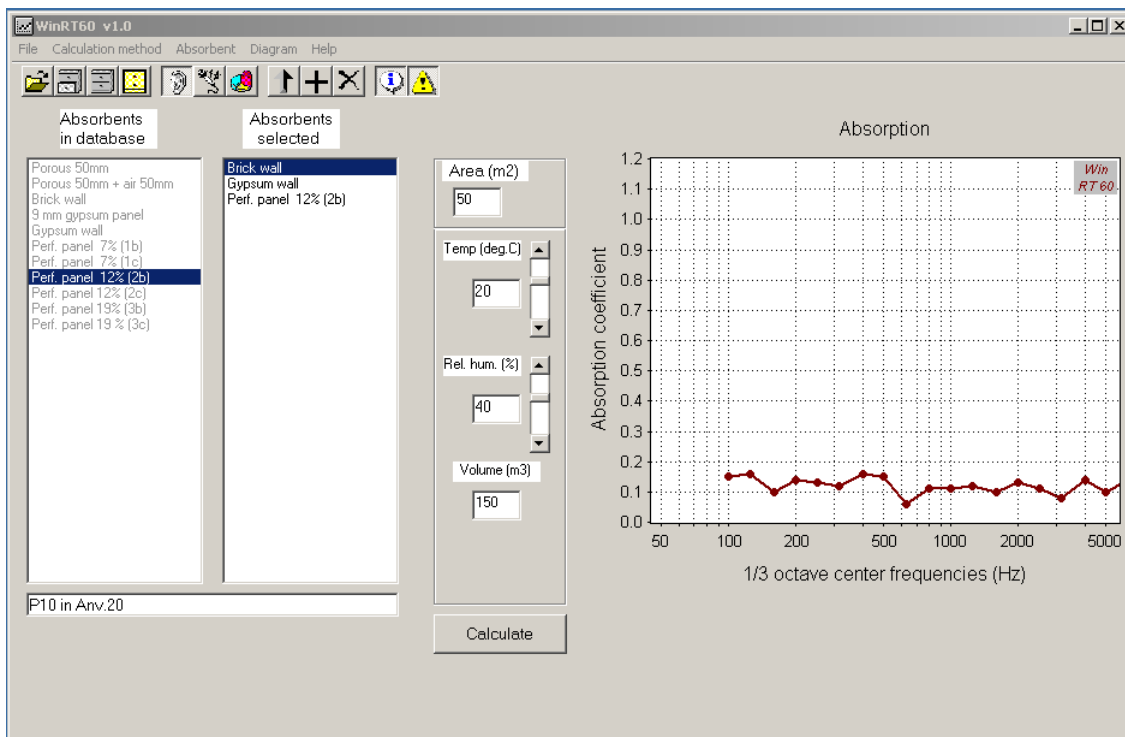


Figure 4-3. The calculation window at the stage of assigning areas to the selected absorbents and input of data for the room.

At this stage all the remaining input boxes for a Sabine calculation is of course open for adjustments. Please note that button named “Calculate” have appeared under the input boxes. Clicking on this button a calculation is performed and the calculated reverberation time will be shown in the diagram, see *Figure 4-4*. One may note that there are no calculated results below 100 Hz even if data for the ceiling absorbent is present down to 63 Hz. The reason is that there are no data below 100 Hz for the other absorbents in the selection, the brick walls and the gypsum walls. The data for the gypsum wall is limited upwards to 3150 Hz thereby also limiting the reverberation time in this end also.

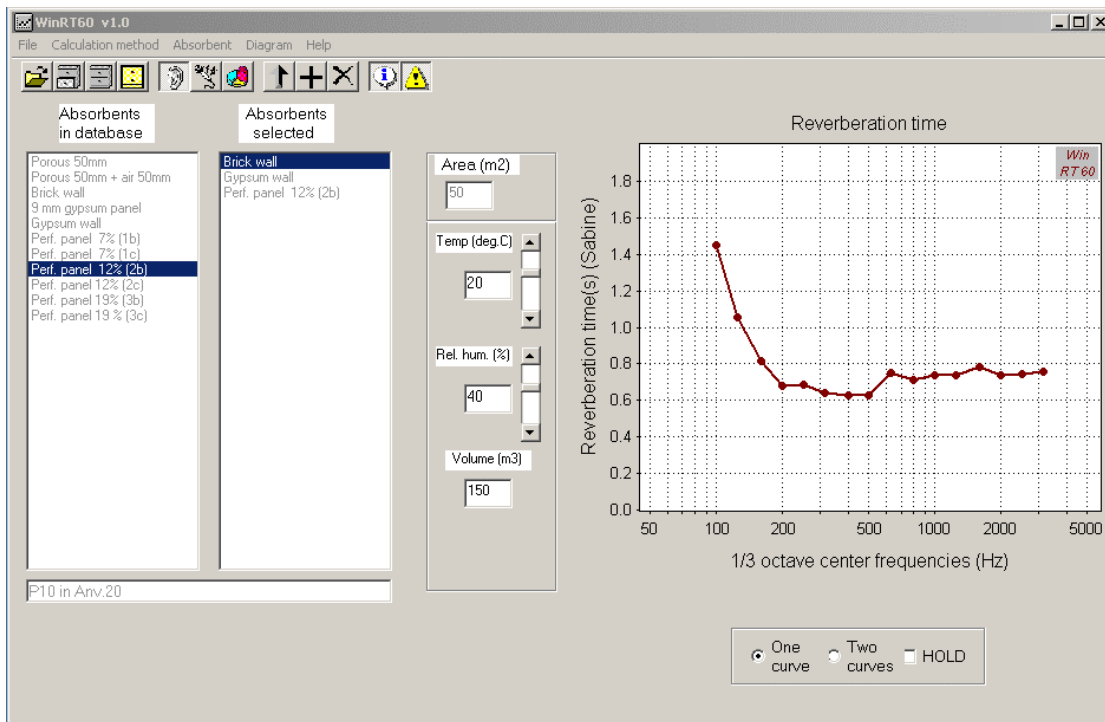


Figure 4-4 The calculation window showing the result using the Sabine formula.

4.1 CALCULATION OPTIONS

One important option in the program is the possibility to calculate the reverberation time by using different methods or formulas. This option is better explained and illustrated by examples given in the following section.

After a calculation is performed a frame will appear below the diagram. Here one is offered the choice of having one or two curves displayed, a previous result together with the last calculated one. This also offers the possibility to compare results using different calculation methods. Marking the box “HOLD” after a calculation will keep this result for a comparison with a later result. Unmarking the box will continually update the second curve.

Two other options should also be mentioned in this context. On the right end of the toolbar there are two buttons, one with an information icon and one with a warning icon. The first one, when depressed, will give information concerning input when using the method by Arau-Puchades. The second one will give a warning when the selected absorbent covers less than the proper room surface area (Arau-Puchades), furthermore, when the total absorbent area is less than the rooms total surface area (Eyring).

4.2 PROGRAM EXECUTION. EXAMPLES USING DIFFERENT METHODS

As mentioned above the default calculation method is by using the simple Sabine formula, an example is shown in *Figure 4-4*. Choosing the method by Eyring, which also requires input of the total surface area of the room an input box for this variable, will appear below the volume

input box. The Eyring method is chosen either by using the menu “Calculation method” or clicking on the button with an icon depicting a microphone.

Using the same data for the room as before, see section 4 above, *Figure 4-5* gives the result applying the Eyring formula. The broken curve shows the results from the former calculation using the Sabine formula. As seen, the differences are not large in this case but are wholly dependent on the actual situation.

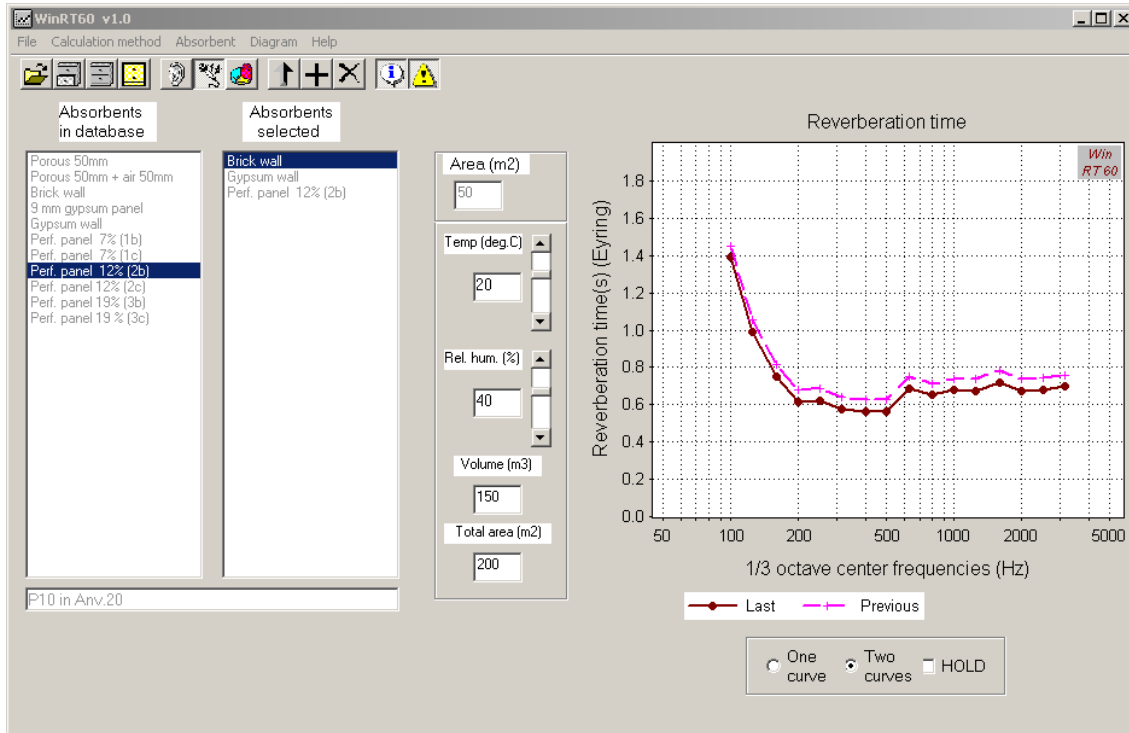


Figure 4-5. The calculation window showing the result using the Eyring formula, solid curve denoted “Last”, as compared with result using the Sabine formula, broken curve denoted “Previous”.

The third calculation method implemented is due to Arau-Puchades, see the reference below, a method that may be seen as a modified Eyring method. It strictly applies only to enclosures of rectangular shape and the intension is to take into account a non-uniformly distribution of absorbents, which is quite the normal situation in practical cases. The formula is a product sum of Eyring’s formula defined for the room surfaces in the three main axis directions, X, Y and Z, each term weighted by the relative area in these directions. For further details, see Section 5.2.3.

Using this method implies that one must first input the room surface area in these three directions. Secondly, the selected absorbent structures must be assigned to the proper surfaces. The former is implemented clicking on each of the radio buttons inside the frame appearing below the list boxes when choosing the Arau-Puchades method, see *Figure 4-6*. The surface area in each direction X, Y and Z is subsequently written into the input box at the right end of this frame. In this example the last surface input was the Y-surface having an area of 50 m². The total surface area of the room is now calculated from these data and will appear in the box with the label “Total area (m²)”.

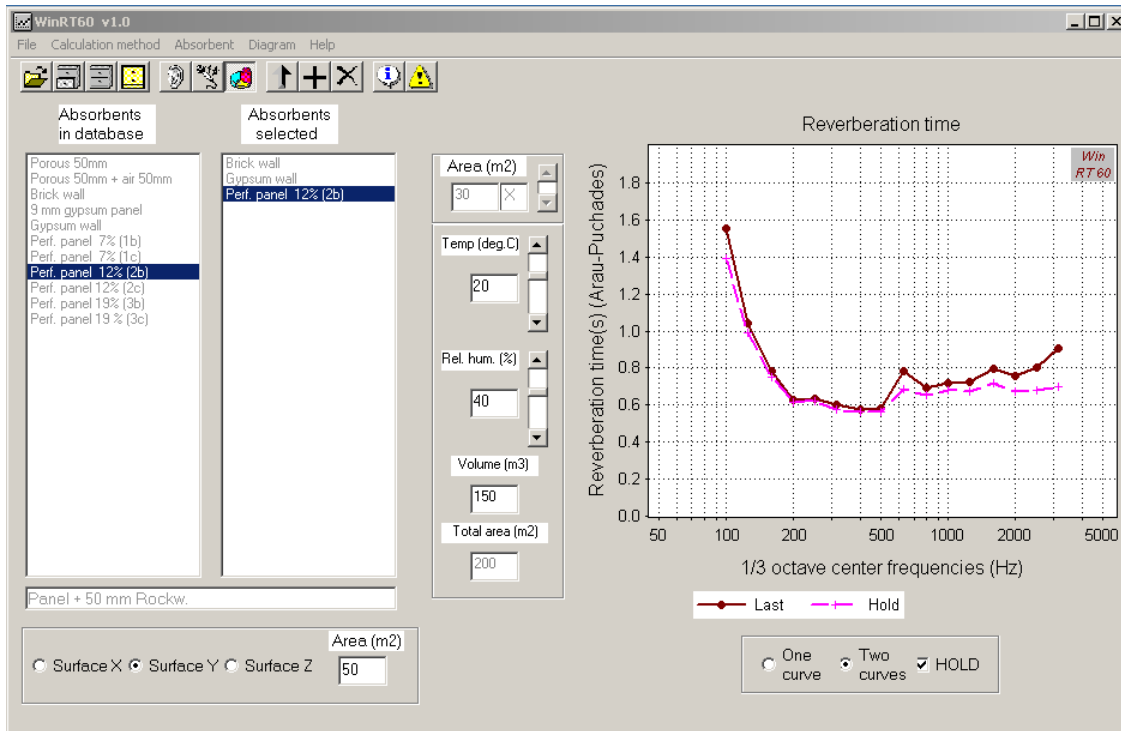


Figure 4-6. The calculation window showing the result using the Arau-Puchades formula, solid curve denoted “Last”, as compared with result using the Eyring formula, broken curve denoted “Previous”.

The second step is as before to input the area of the absorbents by clicking in the selection box. However, one must at the same time assign each selected absorbent structures to its proper room surface. The latter is accomplished by using the small scroll bar inside the absorbent area frame to mark the absorbent with an X, Y or Z according to which surface it belongs to.

The complete procedure, defining the surface areas of the room and assigning absorbents to them, is however given as information (the info button in the toolbar must be pressed) when selecting the Arau-Puchades method. This method is again chosen from the menu “Calculation method” or clicking on the toolbar button having an icon depicting a pie chart with three colours.

In the example shown in Figure 4-6 the differences is again not very large between the calculation methods. However, it should be pointed out that the differences are wholly dependent on the actual situation. If the larger surfaces of a room have a very low mean absorption coefficient the method of Arau-Puchades will give significantly longer reverberation time than the other methods.





5 MENUS

Most of the menus have been pointed to and used in the examples given in the preceding section. Below, we will explain these menus in detail and give further reference to the various calculation methods and the necessary input data. Most of the submenus are reflected in a corresponding toolbar button.

5.1 THE FILE MENU

The menu contains the following submenus:

- Open database
- Find in database
- Open selection
- Save selection
- Export results
- Make report
- Report window
- EXIT

Menu	Shortcut	Toolbar button	Description
Open database	Ctrl O		Opens a formerly prepared database of different absorbing structures and input their given names in the list box labelled "Absorbents in database". The database must be in the Microsoft Excel format with extension .xls. The structure of the database must adhere to certain rules that are explained in section 5.1.1.
Find in database	Ctrl F	None	A simple search routine for an absorbent name in the database containing the input text. If found, the absorbent will be marked and the curve will be displayed.
Open selection	Ctrl T		Opens a file with a formerly saved selection of absorbents, the specifications of the room and the calculation method used. Calculations according to the given selection are performed and results displayed.
Save selection	Ctrl S		Saves all the data for a given selection of absorbents, the room data and the present calculation method to an ordinary text file (ASCII). The file name is given by the user with the extension ".sla"
Export results	Ctrl E		The last calculated reverberation time data, together with all data for the room, are exported to a Microsoft standard Excel-file with the extension ".xls".
Make report	None	None	Hides the calculation window and opens up a report window with a text box (.rtf – format) in which the user may import set-up specifications, results tables and the graphical picture. A description is given below; see section 5.1.2.
Report window	None	None	Shows the current report window. Hides the calculation window.
EXIT	None	None	Terminates the program on confirmation

5.1.1 The database of absorbent structures

As mentioned above is the necessary data for the absorption coefficients either taken from a database in Microsoft Excel-format and/or from calculated results using the program WinFLAG™. Some simple examples on databases are supplied with the program, containing data which the user may use preparing a proper database. The basic shape of a database is shown in *Table 1* below. Here the various cells are marked with colours according to rules that must be followed, see explanation below the table. The absorbents must be numbered consecutively and given a name and a short description.

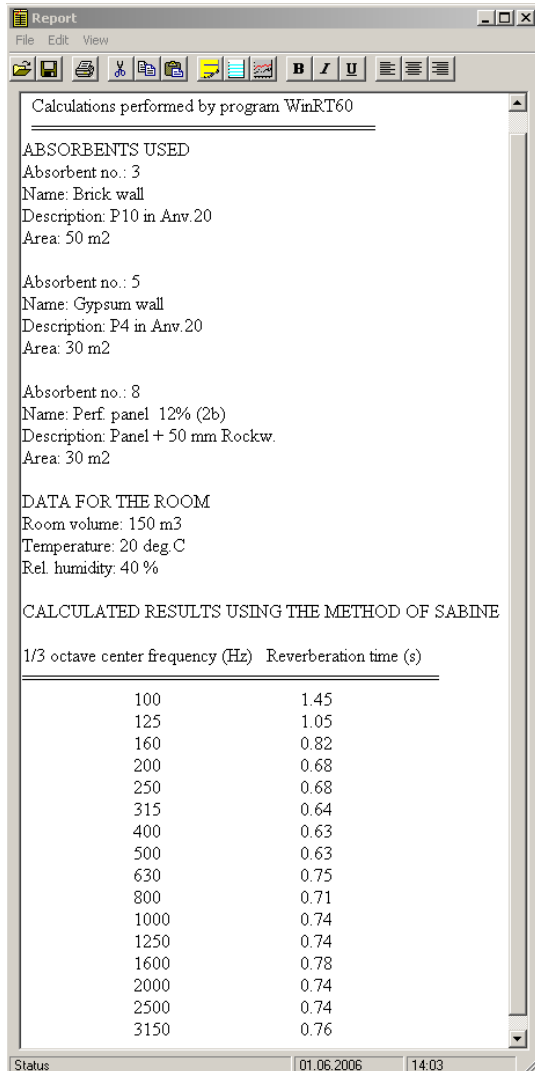
WinRT60	Number	1	2	3
Database testsheet	Name	Porous_50mm	Porous50_Air50	Lm_porous50_Air50
Alpha for absorbents	Description	Glax 50 mm	Glax + Air	Foil +Glax + Air
	Frequency (Hz)	Alpha	Alpha	Alpha
	40			
	50		0.013	0.013
	63	0.008	0.029	0.030
	80	0.027	0.059	0.061
	100	0.057	0.103	0.108
	125	0.095	0.159	0.169
	160	0.155	0.247	0.270
	200	0.227	0.347	0.394
	250	0.313	0.461	0.542
	315	0.409	0.579	0.695
	400	0.510	0.688	0.818
	500	0.609	0.778	0.873
	630	0.699	0.844	0.849
	800	0.777	0.884	0.771
	1000	0.838	0.902	0.680
	1250	0.882	0.904	0.614
	1600	0.911	0.902	0.586
	2000	0.926	0.914	0.504
	2500	0.935	0.942	0.355
	3150	0.943	0.947	0.267
	4000	0.953	0.951	0.196
	5000	0.959	0.955	0.137
	6300	0.958	0.957	0.107
	8000			
	10000			

	Do not modify!
	Keep this form
	Fill partly or wholly
	May be left blank
	For free use

Table 1. Example showing the database structure for absorbents

5.1.2 Making a report

The menu **Make report** opens up a new window, see *Figure 5-1* below, allowing the user to make a report specifying the absorbents used and the data for the room, a table of the calculated reverberation times and a copy of the graphical picture. In the example shown the Sabine calculation method is used and no graphical picture is pasted.



There are three menus in the report, **File**, **Edit** and **View** and a toolbar. Most of the submenus are reflected in this toolbar. The **File** menu has the following items

- Open...
- Save as...
- Print
- Calculation window
- Close

The first two submenus will open up the Microsoft standard window for opening/saving files. The first option is included if need be to use a formerly saved report file (or a text file) as the basis for a new report. The save option saves the report as an rtf-file.

The print option opens up a standard print window allowing the user to directly print the report on an attached printer. The user can process the report file in a text-processing program. As a consequence, the toolbar offer only a limited number of processing options; i.e. font type and aligning in addition to the standard cut, copy and paste. The latter items are also found under the **Edit** menu.




Figure 5-1 The report window where the layer properties and one-third-octave results are imported

Furthermore, the submenu Calculation window will hide the report window and revert to the main calculation window for further calculations, the results of which may be added to the report. The Close option will, after confirmation, close the report window (without saving).

The **Edit** menu has the common options of editing (undo, cut, copy and paste) of which the last three is reflected in the toolbar with the Microsoft common icons. In addition one will find three special paste commands:

- Paste set-up data
- Paste T60 results
- Paste diagram

These commands is summarized as follows:




Menu	Shortcut	Toolbar button	Description
Paste set-up data	None		Pastes the name, description and area for all absorbents used together with room data specific for the applied calculation method.
Paste T60 results	None		Pastes a table of the calculated reverberation time T_{60} according to the applied calculation method.
Paste diagram	None		Pastes the diagram currently shown in the calculation window.

Finally, the **View** menu controls the toolbar and the status line.

5.2 THE CALCULATION METHOD MENU

The menu contains the following submenus:

- Sabine
- Eyring
- Arau-Puchades

Menu	Shortcut	Toolbar button	Description
Sabine	F1		Calculates the reverberation time according to the classical formula by Sabine based on the total absorption area in a room with a given volume V . For further details, see section 5.2.1 below.
Eyring	F2		Calculates the reverberation time according to the formula by Eyring based on the mean absorption coefficient in a room with a given total surface area S and a volume V . For further details, see section 5.2.2 below.
Arau-Puchades	F3		Calculates the reverberation time according to the formula by Arau-Puchades based on the mean absorption coefficient on room surfaces S_X , S_Y and S_Z , total surface area $S (=S_X+S_Y+S_Z)$ and volume V . For further details, see section 5.2.3 below.

5.2.1 Sabine's reverberation time formula

This model for the reverberation time in rooms is due to W.C. Sabine (1868 – 1919) who in the year 1900 published his famous article “Reverberation” presenting his formula relating the reverberation time to the total absorbing area in a room. It is based on the assumption that the sound field in the room is perfectly diffuse, i.e. sound energy density is everywhere the same

and the sound propagates with equal probability in all directions. The formula may be expressed as

$$T_{Sa} = \ln(10^6) \cdot \frac{4V}{c_0 A} \approx \frac{55.26}{c_0} \cdot \frac{V}{A}, \quad (1)$$

where V and c_0 is the volume of the room and the speed of sound, respectively. The total absorption area A of the room is given by

$$A = \sum_i \alpha_i S_i, \quad (2)$$

where α_i is the absorption coefficient of the surface having the area S_i . The sum is taken over all absorbing areas in the room. Despite its simplicity and the assumptions behind its derivation it is probably the most commonly used formula in practice. It should be noted that it is not usable for highly damped rooms. Even when the absorption coefficient is equal to one on all surfaces the reverberation time is still finite. Obviously, in such a situation the reverberation time must be zero.

5.2.2 Eyring's reverberation time formula

There are a number of reverberation time formulas in the literature taking account of the fact that reverberation is not a continuous process but involves a stepwise reduction of the sound energy impacting on the various room surfaces. C. F. Eyring, see reference below, developed in 1930 one such formula. This may be expressed as

$$T_{Ey} = \frac{55.26}{c_0} \cdot \frac{V}{-S \cdot \ln(1 - \bar{\alpha})}, \quad (3)$$

where S is the total surface area of the room and $\bar{\alpha}$ is the average absorption coefficient, i.e. given by

$$\bar{\alpha} = \frac{1}{S} \sum_i \alpha_i S_i. \quad (4)$$

The expression is obviously correct for totally absorbing surfaces in the room in which case T_{Ey} will become zero. Furthermore, for $\bar{\alpha} \ll 1$ the formula (3) will be equal to the Sabine formula, equation (1).

Reference:

Eyring, C. F. (1930) Reverberation Time in "Dead" Rooms. *J. Acoust. Soc. Am.* **1**, 217 – 241.

5.2.3 Arau-Puchades' reverberation time formula

There have been several suggestions on how to take account of non-uniformly distributed absorption in a room, which in fact is the normal situation in practice. The formula implemented in this program is due to H. Arau-Puchades, see the reference below. It applies strictly to rectangular rooms only and may be considered as a product sum of Eyring's formula defined for the room surfaces in the three main axis directions, X, Y and Z, each term weighted by the relative area in these directions. It may be expressed as

$$T_{AP} = \left[\frac{55.26}{c_0} \cdot \frac{V}{-S \ln(1 - \bar{\alpha}_x)} \right]^{\frac{S_x}{S}} \cdot \left[\frac{55.26}{c_0} \cdot \frac{V}{-S \ln(1 - \bar{\alpha}_y)} \right]^{\frac{S_y}{S}} \cdot \left[\frac{55.26}{c_0} \cdot \frac{V}{-S \ln(1 - \bar{\alpha}_z)} \right]^{\frac{S_z}{S}}. \quad (5)$$

Using this formula one may e.g. assign the ceiling and the floor to the area S_X having the average absorption coefficient $\bar{\alpha}_X$, the two sets of sidewalls to the corresponding surface areas and absorption coefficients with indices Y and Z .

Reference:

Arau-Puchades, H. (1988) An Improved Reverberation Formula. *Acustica* **65**, 163 – 180.

5.2.4 The sound absorption of air

The absorption of air should not be neglected when calculating the reverberation time in a room. This is a factor that normally will affect the results in the high frequency range, i.e. in the kHz range, and being heavily dependent on the air moisture content. The absorption, or what we may denote excess attenuation, is characterized by a power attenuation coefficient m with dimension metre^{-1} . General data for a related coefficient $\alpha = 4.343 \cdot m$ (dB/km), given as a formula and also in tabular form as a function of frequency, air temperature, air pressure and relative humidity, is found in ISO Standard 9613 Part 1. In WinRT60 the air pressure is set equal to one standard atmosphere, i.e. 101325 Pa.




The excess attenuation will, when included into the reverberation time calculation, result in an added total absorption area of $4mV$ (m^2), where V is the volume of the room. The added absorption area is easily included into the formula of Sabine and Eyring. Using the formula of Arau-Puchades a choice has been made to divide the added absorption area in proportion to the size of the areas S_X , S_Y and S_Z .

5.3 THE ABSORBENT MENU

The menu contains the following submenus:

- Database
 - Add from WinFLAG
- Selection
 - Add from database
 - Delete absorbent

These submenus modify either the content of the database list box or the content of the list box containing the selected absorbents. Modifying the database list box is possible only by pasting data from the program WinFLAG™.

Menu		Shortcut	Toolbar button	Description
Database	Add from WinFLAG	Ctrl W		An absorbent calculated using the program WinFLAG is pasted from the Clipboard into the database list box. It is added to the bottom of the list.
Selection	Add from database	Ctrl D		A marked absorbent in the database list box is copied into the list box containing the selected absorbents. Double-clicking in the database list box may alternatively perform this.
	Delete absorbent	Del		A marked absorbent in the selection list box is deleted.

5.4 THE DIAGRAM MENU

The menu offers the choice of changing the values on the axes of the diagram. No new calculations are performed. The choices are the following:

- First frequency
- Last frequency
- Y minimum
- Y maximum

Submenu	Shortcut	Description
First frequency	None	Opens up a window to specify the first frequency marking on the abscissa. The default value is 45 Hz.
Last frequency	None	Opens up a window to specify the last frequency marking on the abscissa. The default value is 5700 Hz.
Y minimum	None	Opens up a window to specify the minimum value for the ordinate. The default value is zero.
Y maximum	None	Opens up a window to specify the maximum value for the ordinate. The default values are 1.2 for the absorption coefficient and 5.0 (s) for the reverberation time.


5.5 THE HELP MENU


The choices are:

- Opening the full manual (pdf-file)
- Information on WinFLAG

Submenu	Shortcut	Description
Manual (pdf-file)	Ctrl H	Opens up this help file in pdf-format. The program to read this file, Adobe Acrobat, must be installed.
About WinRT60	None	Displays an information window on WinRT60

5.6 THE TOOLBAR

As seen from the descriptions of the menus above, most submenus are reflected in the buttons of the toolbar. The two buttons on the right end of the toolbar are exceptions here. When the button with the information sign, , is depressed, information on the necessary steps in the Arau-Puchades method is given.

When the button with the warning sign, , is depressed, warnings are generally issued (before any calculation is performed) when the selected absorbents cover less than the defined surface areas of the room. In this case, answering “No” when asked to proceed with the calculations, the set-up information window will be displayed, see section 5.7.

6 WINRT60 LICENSE TRANSFER

Once you have registered the software, you may transfer the license from one computer to another. For this to work, the software has to be registered on the user's computer. Once the transfer is complete, the original program will become unregistered and expire immediately (so it is not possible to run the software on two computer simultaneously).

To transfer the license, the user will need the registration number from the new computer. You must install and run the software on this computer to obtain the registration number. Then click the **Start** button on the source computer and open the command line prompt (select **All programs**→**Accesories**→**Command Prompt**).

Then use the command line to transfer the license. The first part is the full path of the executable (your path may not be the same as shown below). XXXX-XXXX is the registration number from the other machine.

```
"c:\Program Files\WinRT60_v1\WinRT60_1.0.exe" /TRANSFER XXXX-XXXX-RT
```