MANUAL FOR PROGRAM WINFLAG, VERSION 1.0

INTRODUCTION

The program calculates absorption coefficient, impedance and sound reduction index for constructions combined of material layers of different types (porous materials, perforated plates etc.). Calculations may be performed at single frequencies or as mean values in 1/3-octave bands, in both cases for a free field sound incidence as well as in a diffuse field. The program is modelling the acoustic properties of a combination of such layered materials using the transfer matrix method. Basically, each layer in the combination, assumed to be of infinite extent, is represented by a matrix giving the relationship between a set of physical variables on the input and output side of the layer. These matrices may then be combined to give the relationship between the relevant physical variables for the whole combination. Characteristic data as absorption coefficient, input impedance and transmission loss (sound reduction index) might then be calculated assuming plane wave incidence. The size and complexity of these matrices is totally dependant of the specific material in the actual layer, i.e. how many physical variables one have to use describing the wave motion in the material and then how many material parameters that are necessary to specify the material. In many cases, only two physical variables are sufficient being the sound pressure and the particle velocity, a procedure utilised in the program WinFLAG.

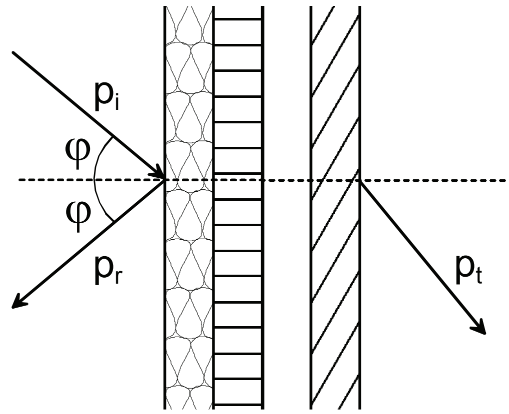


Figure 1-1 Combination of several layers (each of infinite extent)

For the description of layers being thin plates (panels), either perforated or non-perforated, two physical variables are always sufficient. Porous materials may also be included if they are modelled as an equivalent fluid, a model that is applicable to many porous materials, e.g. mineral wool type absorbents. The basic assumptions are that the material is homogeneous and isotropic, having pores filled with air embedded in an infinitely stiff matrix or skeleton. If the elastic properties of this skeleton have to be taken into account a description using two physical variables only is not feasible. It is therefore not to be expected that the program WinFLAG give correct results in the latter case.

1 OVERVIEW

The program main files are the following:

- WINFLAG_1.0.EXE — This is the main program
- FLAG.DLL — "Dynamic Link Library" - calculation routines
- BE250.PRN — Data file for complex Bessel functions
- WINFLAG_HELP.PDF — Help file (the present file)

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. In this help file there is also information on licence transfer to another computer, see heading no. 0.

2 BRIEF DESCRIPTION OF THE PROGRAM

The program starts by clicking on the file WINFLAG_1.0.EXE (or by making a shortcut to this file and start from the desktop). The following window should then appear, see *Figure 2-1*.

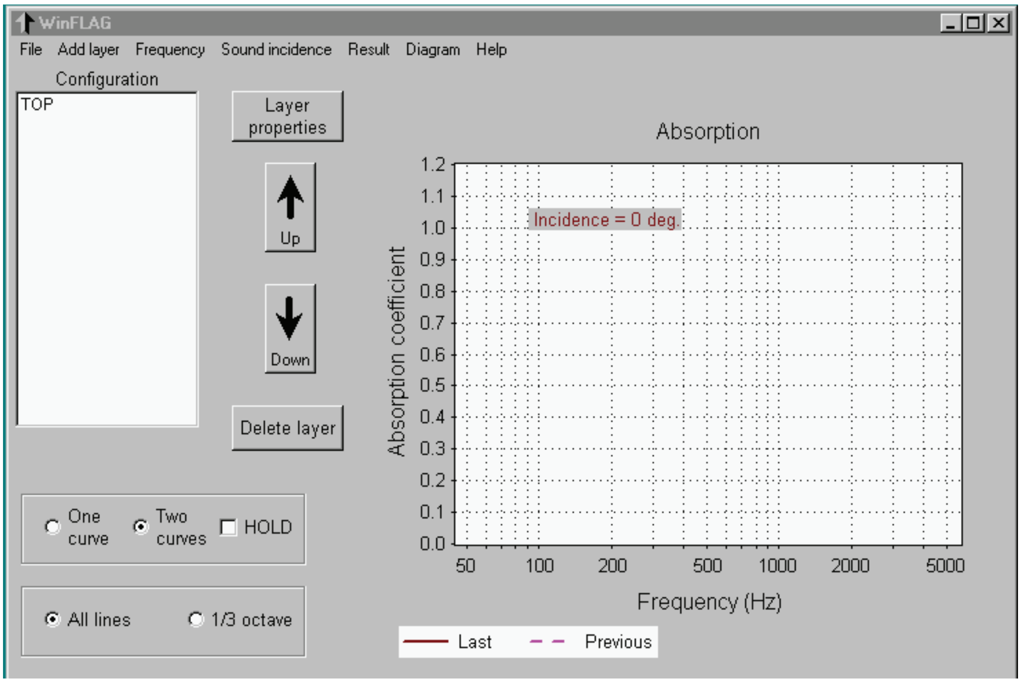


Figure 2-1 The main window at start-up time

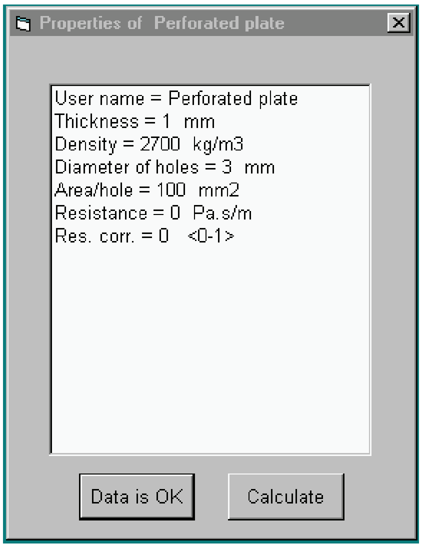
In the list box to the left (labelled Configuration and having the word TOP on the first line) one composes the actual combination of layers for which calculations are desired. The word TOP indicates the side of the incident plane wave. As mentioned in the introduction, the layers may be of the type porous materials, perforated panels etc. For a detailed description of the different types of layers, see under the heading no. 3.2 below.

The graphical picture to the right always shows the results of the calculations. In addition, a previous result may be displayed in the same diagram. At start up time a default diagram for the absorption coefficient is shown.

The program has a total of seven menus, which is explained in more detail under the heading no. 3. From the last one of these menus: **Help**, this help file may be called.

- **File** handles the configuration and result files. Exits the program.
- **Add layer** adding a chosen type of layer (NB! no calculations are performed)
- **Frequency** frequency range of calculations, type of scale (linear, log)
- **Sound incidence** choice of angle of incidence or diffuse incidence.
- **Result** choice of calculated result (absorption, impedance, transmission)
- **Diagram** choice of axis scale values in the diagram
- **Help** calling the help file containing the manual

To the right of the list box specifying the actual configuration one will find four command buttons. Clicking on the button **Layer properties** (or double clicking in the list box) will bring up a new window giving the material properties for a layer marked in the list box. An example is shown in *Figure 2-2* where the layer is a perforated plate. All parameter values listed may be changed by clicking on them. In addition, one may exchange the default name of the layer into a chosen user name. As shown, this specification session may be terminated by a calculation. Alternatively, the calculations may be started with the command button **Calculate** that will appear under the configuration list box. This button will appear when changes necessitate a recalculation, see the example given in *Figure 2-3*. A number of changes, however, will automatically start the calculations.



Concerning the command buttons **Up** and **Down**, shown in *Figure 2-1* or *Figure 2-3*, these will move a marked layer up or down in the configuration list box. The button **Delete** will delete a marked layer.

Figure 2-2 The window listing the properties of a given layer (example Perforated plate)

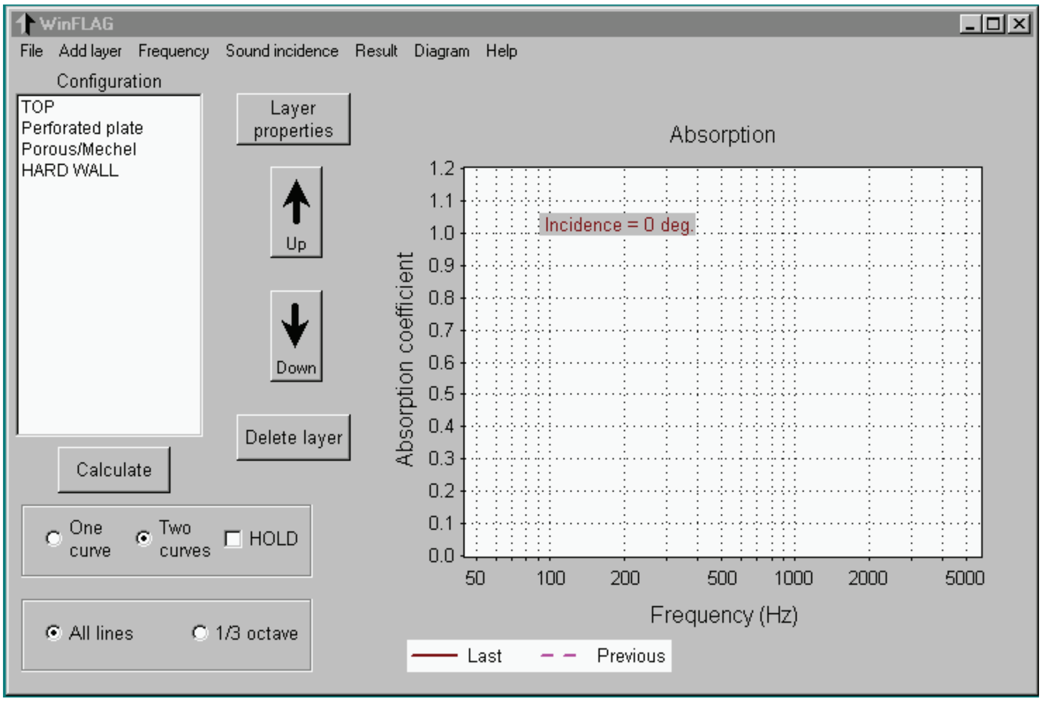


Figure 2-3 The main window where layers have been entered into the configuration list box (before parameters are updated and any calculations performed)

2.1 CALCULATION OPTIONS

Below the configuration list box one will find two frames containing options. The first offers the possibility of having two curves displayed, a previous result together with the last calculated result. This is the default option. Marking of 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. The exception to this action is when displaying the input impedance. In this case the two curves represent the real and imaginary part of the impedance respectively, and no former results are available.

The last set of options offers the choice between calculating results for all frequency lines or mean values in 1/3 octave bands, frequency range 40 Hz to 10 kHz (centre frequencies of bands). In the latter case mean values are based on a minimum of 10 frequency lines inside each 1/3 octave band.

2.2 PROGRAM EXECUTION. SOME EXAMPLES

Starting the program the main window will appear as shown in *Figure 2-1*. The first task for the user is to "compose" the configuration by pulling down the various layers in the configuration list box by clicking on the submenus under the menu **Add Layer**. Having done this, one may change the default parameters for each layer to the actual ones by clicking on the button **Layer properties** or double clicking on the item in the list box. This opens up the property window, an example of which is shown in *Figure 2-2*. When the last layer is updated one may start the calculations from this window, alternatively by the command button **Calculate** under the configuration list box, see *Figure 2-3*. A calculation will otherwise start automatically when using the menu **Frequency** or **Sound incidence**. Below are shown examples of results from calculations of absorption coefficients, input impedance and sound reduction index.

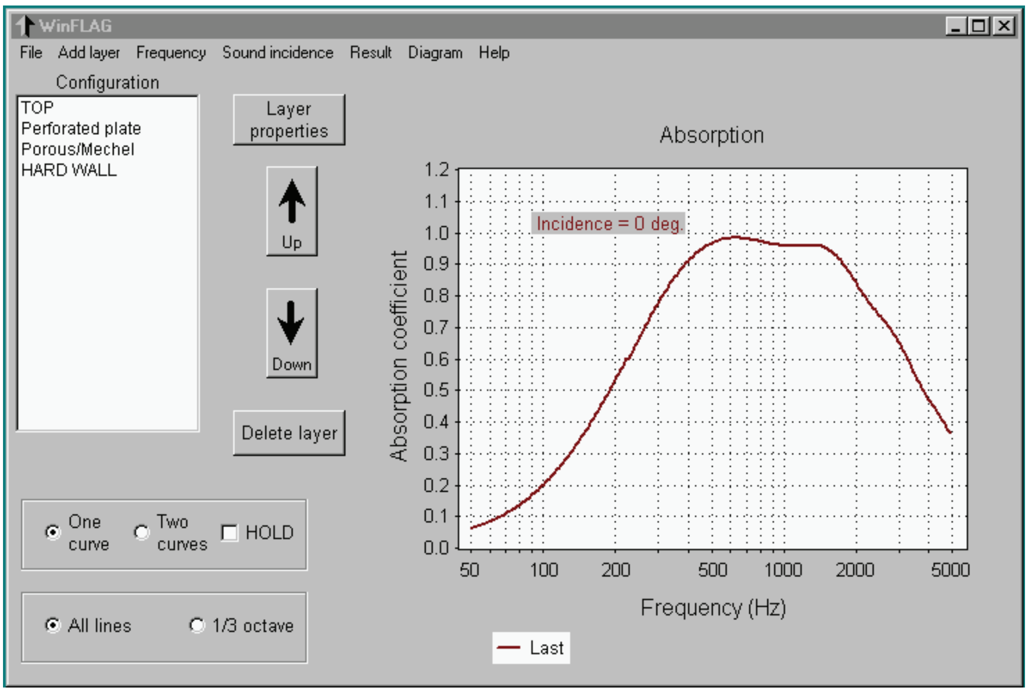


Figure 2-4 Example showing the absorption coefficient of resonant absorber for normal incidence. The parameters for the chosen layers are the default ones except for the thickness of the porous layer (100 mm)

An example from a calculation of the absorption coefficient is shown in *Figure 2-4*. The resonant absorber is a perforated plate combined with an air space filled with a porous material described using the model after Mechel. A more detailed description of the various models is given below under the heading number 3.2.

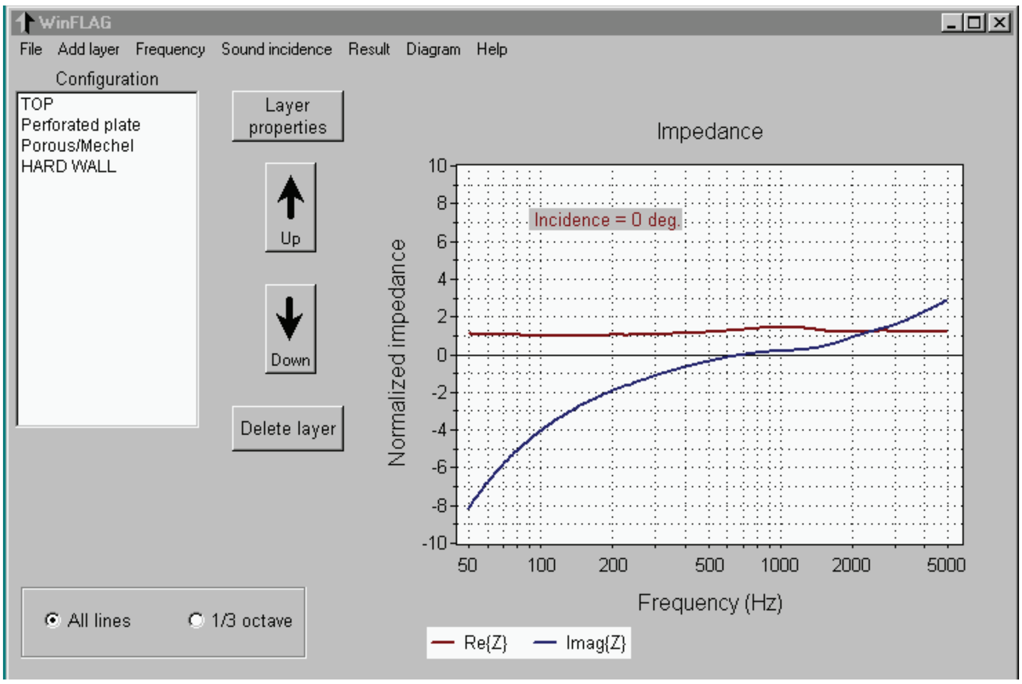


Figure 2-5 The normalised impedance corresponding to the data in Figure 2-4.

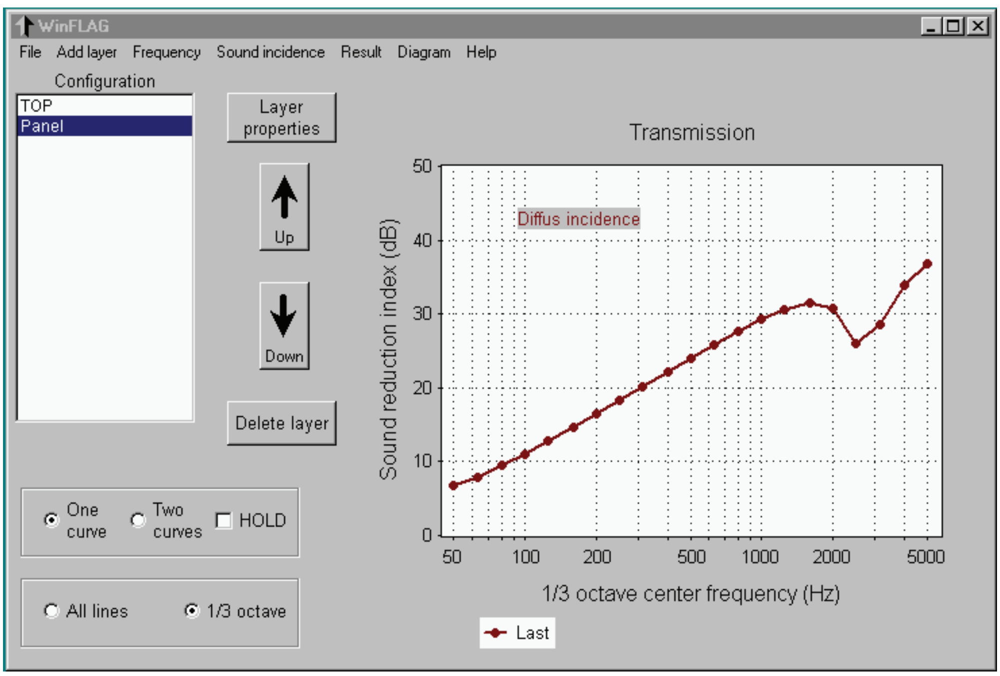


Figure 2-6 Example on the sound reduction index for a thin panel (chipboard or similar). Diffuse sound incidence. Calculation of mean values in 1/3 octave bands.

The *Figure 2-5* shows the normalised input impedance for the same configuration as above, and finally *Figure 2-6* shows an example of calculation of the sound reduction index of a thin panel in a diffuse sound field. The panel is a 10-mm thick chipboard or equivalent material. In contrast to the examples above, mean values in 1/3 octave band are calculated.

3 MENUS

A short description of the main menus is given above. Below we shall describe the menus in more detail in addition to giving some tips and explanations concerning the input data, which the user must supply to the program. Specifically, this applies to the input parameters for the different layers.

3.1 THE FILE MENU

The menu contains the following submenus:

- Save configuration
- Open configuration
- Export results
- EXIT

The first three submenus will open up the Microsoft standard window for saving/opening files.

Menu	Shortcut	Description
Save configuration	None	Saves the configuration and all parameters for the layers to a file. The file name is given by the user but the file gets the extension ".lag"
Open configuration	None	Opens a file with a formerly saved configuration. Calculations according to the given configuration are performed and results are displayed.
Export results	Ctrl E	The last calculated results are exported to a text file (ASCII) with the extension ".txt". The file is suitable for input to a spreadsheet or equivalent. Data that are not relevant in a given configuration, e.g. the sound transmission index when a HARD WALL is included, are set equal to an arbitrary high (negative) number.
EXIT	None	Terminates the program on confirmation.

Please note that proper saving of the configuration presuppose that a calculation has been performed, i.e. the configuration saved is the last one calculated on.

3.2 THE ADD LAYER MENU

The submenus offer the choice of adding the following type of layer:

- Air
- Porous/Delany-Bazley
- Porous/Mechel
- Porous/Attenborough
- Porous/Allard-Johnson
- Slotted plate
- Perforated plate
- Microperforated plate
- Limp mass
- Panel
- HARD WALL

Clicking on one of these submenus brings a layer of the specified type into the configuration list box. A short description of each of these layers is given in the table below together with a reference to a heading under which to find a more detailed explanation of the various models used.

Submenu	Shortcut	Description
Air	None	This layer has its thickness as the only parameter. The default value is 100 mm. See details under the heading number 3.2.1
Porous/Delany-Bazley	None	Porous material described by the empirical model after Delany and Bazley. The model has two parameters, the thickness and the flow resistivity and presuppose a porosity near to 100 %. On details, see under the heading number 3.2.2
Porous/Mechel	None	Porous material described by a model after Mechel. Compared to the model after Delany and Bazley it has the porosity as an additional parameter. The model is a combination of a theoretical model for the behaviour at low frequencies and an empirical model for the higher frequencies. See details under the heading number 3.2.3
Porous/Attenborough	None	Theoretical model after Attenborough using a total of five parameters. Two of these parameters, a factor s_f describing the form of the pores and the flow resistivity r, are input as one parameter $s_f^2 \cdot r$. Details are given under the heading number 3.2.4.

Porous/Allard-Johnson	None	Theoretical model with a total of six parameters. The shape of the pores and their interconnections are characterised by parameters denoted viscous and thermal length. Details are given under the heading number 3.2.5.
Slotted plate	None	Conventional slotted plate constructed from beams of rectangular cross section and having sharp edges, e.g. a wooden slotted panel. See details under the heading number 3.2.6
Perforated plate	None	Plate or panel perforated with holes of circular shape; typically metal, gypsum or chipboard panels. See details under the heading number 3.2.7.
Microperforated plate	None	Plate or panel perforated with holes of circular shape but the diameter of the holes are less than 0.5 mm. Details are given under the heading number 3.2.8
Limp mass	None	A mass layer characterised by its thickness and density only. Represent typically a thin layer of plastics or metal. See details under the heading number 3.2.9.
Panel	None	A thin panel characterised by its bending stiffness, mass and loss factor. See details under the heading number 3.2.10
HARD WALL	None	An infinitely stiff wall. It is typically used to represent a termination for an absorbent placed against the ceiling or wall in a room. This layer has no parameters.

3.2.1 The air layer

The layer is specified by its thickness in mm and characterised by the specific impedance (characteristic impedance) $\rho_0 \cdot c_0$ of air, where ρ_0 is the density and c_0 is the speed of sound. These quantities are given the values applicable for a temperature of 20 °C, i.e. ρ_0 and c_0 take on the values 1.21 kg/m^3 and 343 m/s. The characteristic impedance is then approximately 415 Pa·s/m.

3.2.2 Porous layer, model Delany-Bazley

The model presented by Delany and Bazley, see reference below, is an empirical one based on a large number of measurement on materials having a porosity approximately equal to one (or 100% as used in this program). Using the frequency and the flow resistivity of the material as the only variables they arrived at empirical equations for the complex propagation coefficient Γ and the complex characteristic impedance Z_k of the material which may be written:

$$Z_k = \rho_0 c_0 \left[1 + 0.0571 \cdot E^{-0.754} - \mathrm{j} \cdot 0.087 \cdot E^{-0.732}\right]$$

and $$\Gamma = \mathrm{j}\frac{\omega}{c_0}\left[1 + 0.0978 \cdot E^{-0.700} - \mathrm{j} \cdot 0.189 \cdot E^{-0.595}\right] \qquad \text{where } E = \frac{\rho_0 f}{r}.$$

The quantity r is the flow resistivity in Pa·s/m^2, f is the frequency in Hz and ω is the angular frequency in radians/s. The window specifying the material parameters for a layer using this model may be seen from the *Figure 3-1*.

Reference: M.E. Delany and E.N. Bazley (1970) Acoustical properties of fibrous materials. *Applied Acoustics* **3**, 105.

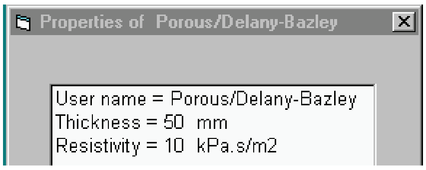


Figure 3-1 The property window for a porous layer using the Delany-Bazley model

3.2.3 Porous layer, model Mechel

Mechel presents an extension of the Delany-Bazley model where he gives different equations depending on frequency. The model uses a theoretical expression for the behaviour at low frequencies combined with curve fitting procedure to experimental data to predict the behaviour in the middle and the high frequency ranges. The model has the porosity as an additional parameter as compared with the Delany-Bazley model. We omit the presentation of the equations here, which can be found from the references below. The window specifying the material parameters for a layer using this model may be seen from the *Figure 3-2*.

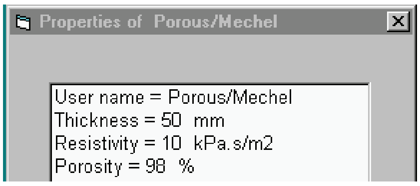


Figure 3-2 The property window for a porous layer using the Mechel model

References:
1. F.P. Mechel (1976) Ausweitung der Absorberformel von Delany und Bazley zu tiefen Frequenzen. *Acustica* **35**, 210 - 213.
2. F.P. Mechel (1988) Design charts for sound absorber layers. *J. Acoust. Soc. Am.* **83**, 1002 - 1013.

3.2.4 Porous layer, model Attenborough

The work of Attenborough is primarily directed towards modelling ground impedance for the purpose of predicting outdoors sound propagation. He introduces a parameter s_f, the pore shape factor, to account for the shape of the pores in the material. One is not, however, able to measure this parameter separately and it must then be estimated by other means. In the program it is input in combination with the flow resistivity as a product $s_f^2 \cdot r$. An additional parameter to describe the pore orientation in the material, the *sinuosity* or more commonly termed the *tortuosity*, is also introduced. The window specifying the material parameters for this model may be seen from *Figure 3-3*. More details concerning this model may be found in the reference below. Please note that Attenborough uses the symbol q^2 for tortuosity.

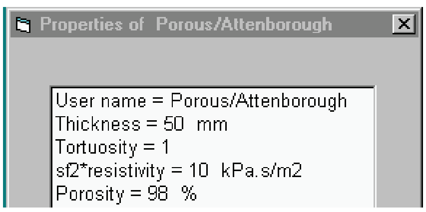


Figure 3-3 The property window for a porous layer using the Attenborough model

Reference:
Attenborough, K. (1985) Acoustical impedance models for outdoor ground surfaces, *J. Sound Vib.* **99**(4), 521 - 544.

3.2.5 Porous layer, model Allard-Johnson

This model, which is thoroughly explained in the book by Allard, see the reference below, introduces two parameters to characterise the shape of the pores in the material. These parameters are termed characteristic *viscous length* Λ and characteristic *thermal length* Λ'. The advantage of this description is that, using high frequency sound (some hundred kHz), one may by measurements determine each of these parameters separately. As an indication of the magnitude of Λ and Λ' will, for foam materials, be in the range of some tenths of μm to some hundred μm. The relationship between these two parameters also gives an indication of the pore shape. For a material with pores resembling straight tubes the two parameters will be of the same magnitude. In contrast, if the pores are interconnected by narrow tubes giving high resistance for flow, we will have $\Lambda << \Lambda'$.

The window for specification of the parameters for this model is shown in *Figure 3-4*. Please note, as stated in the introduction, that in most cases materials of the type of plastic foam need additional parameters for a complete description of the acoustical behaviour. The program will only give correct results when the elastic properties of the frame material may be neglected. As a rule of thumb, for foam layers 25 - 100 mm thickness, the elastic properties may strongly influence the acoustic data below 500 - 1000 Hz.

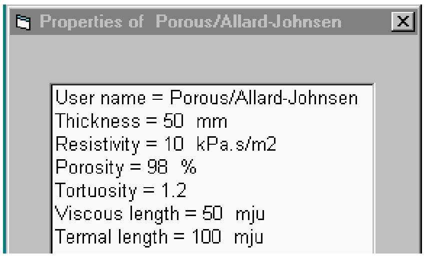


Figure 3-4 The property window for a porous layer using the Allard-Johnson model

References:
J.F. Allard (1993) *Propagation of sound in porous media*. Modelling sound absorbing materials. Elsevier Applied Science, London and New York.

Ph. Leclaire, L. Kelders, W. Lauriks, M. Melon, N. Brown, B. Castanede (1996) Determination of the viscous and thermal characteristic length of plastic foams by ultrasonic measurements in helium and air. *J. Appl. Physics* **80**, 2009 - 2012.

3.2.6 Slotted plate

The layer is intended to be included in a resonance absorber composed of a slotted plate placed at a distance from a ceiling or a wall, i.e. the absorber system is the plate, an airspace and a hard backing wall. The slotted plate will typically be an assemblage of parallel sharp edged beams of rectangular cross section with a specified thickness and width. The distance between the beams is characterised by the *slot width*, see the window for the specification of parameters shown in *Figure 3-5*, and the width of the beams goes into the parameter *centre-to-centre distance* between slots. The density of the material is also part of the specification going into the calculation of the equivalent mass impedance of the plate. Normally, the influence of the latter impedance will be very small.

To obtain a high absorption coefficient for a resonance absorber the panel must be combined with a porous layer or a fabric placed close to the slots, this to give the necessary resistance component. (An exception to this rule is by using the so-called microperforated plate or panel, se below). If a fabric is used, the total resistance (in Pa·s/m) must be specified.

In case one is using a porous layer in the air space directly behind the slotted plate there is also the possibility to add an extra *resistance correction* to the data. This is a parameter which should take on values between zero and one. This indicates that one is adding a resistance component equal to the total resistance of the porous layer having a maximum thickness of one *end correction* for the slots. The default value of this parameter is zero and it should only be changed if warranted by user experience.

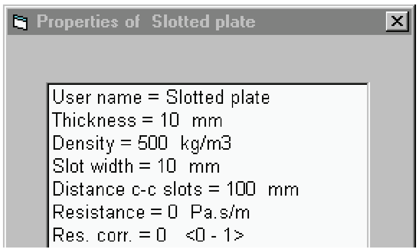


Figure 3-5 The property window for a slotted plate

Reference:
U.R. Kristiansen, T.E. Vigran (1994) On the design of resonant absorbers using a slotted plate. *Appl. Acoustics* **43**, 39 - 48.

3.2.7 Perforated plate

As for the slotted plate, the perforated plate is intended for use in a resonance absorber. However, the plate in this case is typically a thin metal plate perforated by holes. The program assumes that the shape of the holes is circular. The model may also be used for thicker plates of other materials, e.g. gypsum, chipboard or similar. The window for specifying the parameters has already been presented, see *Figure 2-2*. Obviously, the parameters resemble the ones for the slotted plate.

It is assumed that the perforation is regular so a certain area can be attributed to each hole. For holes placed in a rectangular pattern the parameter *area/hole* will be the centre-to-centre distance squared. Alternatively, one may use the percentage perforation of the plate to calculate an equivalent value for this parameter.

3.2.8 Microperforated plate

This plate is in principle equal to the perforated plate described above but with an important exception: the diameter of the holes should typically be less than 0.5 mm. A porous layer or a fabric is then superfluous to get a necessary resistance component for such a plate used in a resonance absorber. As shown in *Figure 3-6*, the window for specifying the parameters has never the less the option for adding a fabric with a given flow resistance. The option for calculating the mass impedance of the plate, however, is *not* presently in use.

An analytical expression to calculate the impedance of the holes in such a plate has been known for nearly hundred years but the idea to exploit the principle to make a practical acoustical absorber was put forward by Maa in 1987. The reference given below is a later article by the same author, which also have a number of references to other papers on the subject.

It should be pointed out that the present program does not use the approximate formulas for the impedance given by Maa but the calculations are based on the full analytical solution which include Bessel functions with complex argument. This does not imply, however, that the accuracy is very much better than when using the approximate formulas.

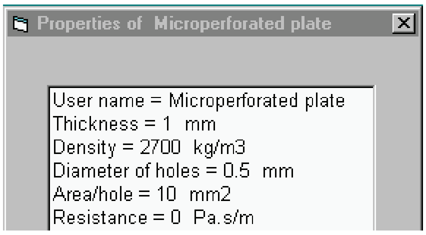


Figure 3-6 The property window for a microperforated plate.

Reference:
Maa, D. Y. (1998) Potential of microperforated panel absorber. *J. Acoust. Soc. Am,* **104**(5), 2861 - 2866.

3.2.9 Limp mass

The layer is primarily intended to represent a thin, impermeable sheet (plastic, metal etc.) or a very thin plate or panel where the bending stiffness is negligible. It may then be used to calculate the absorption of membrane absorbers, i.e. when this layer is combined with an air space in front of a hard backing wall. However, the normal use will be to see the effect of covering a porous material with an impermeable thin layer. In the specification of the input parameters, see *Figure 3-7*, there is also the opportunity to specify a resistance component added to the mass. The size of this component must wholly depend on user experience.

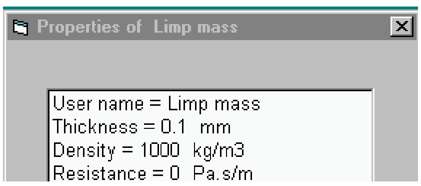


Figure 3-7 The property window for a mass layer (limp mass)

3.2.10 Panel (solid plate)

The model used for the layer panel is based on thin plate theory which implies that the wavelength for bending waves in the plate is larger than approximately six times the thickness of the plate. The so-called wall impedance Z_v of a plate, i.e. the difference in sound pressure across the plate divided by the velocity of the plate, may then be written

$$Z_v = j\omega m \left[1 - \left(\frac{f}{f_g} \right)^2 \cdot (1 + j\eta) \sin^4 \varphi \right],$$

where m, η and f_g are the mass pr unit area, the loss factor and the coincidence frequency respectively. φ is the angle of the incident plane wave and f and ω symbolise the frequency in Hz and the angular frequency in radians pr second. The coincidence frequency is given by

$$f_g = \frac{c_0^2}{2\pi} \sqrt{\frac{m}{B}}$$

where the mass pr unit area m and the bending stiffness B may be calculated from the density of the material ρ and the plate thickness h, respectively from the elastic modulus (Young's modulus) E, Poisson's ratio υ and the thickness using the equations

$$m = \rho \cdot h \qquad \text{and} \qquad B = \frac{E}{1-\upsilon^2} \cdot I = \frac{E}{1-\upsilon^2} \cdot \frac{h^3}{12}.$$

Here the I is symbolising the area moment of inertia pr unit width. The window for specification of the necessary input parameters is shown in *Figure 3-8*.

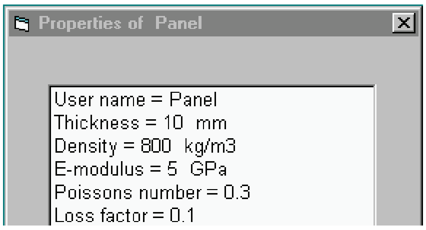


Figure 3-8 The property window for a thin solid plate (panel).

3.3 THE FREQUENCY MENU

The submenus have the following items:

- Frequency range
- Linear scale
- Logarithmic scale

Clicking on any of these items starts a new calculation.

Submenu	Shortcut	Description
Frequency range	Ctrl F	Opens up a new window to specify the frequency range of the calculations including the number (max. 500) of frequency lines used, see *Figure 3-9*.
Linear scale	None	The frequency is incremented linearly
Logarithmic scale	Ctrl L	The frequency is incremented logarithmically. This option is automatically chosen when calculating mean values in 1/3-octave bands, see calculation options under heading no. 2.1.

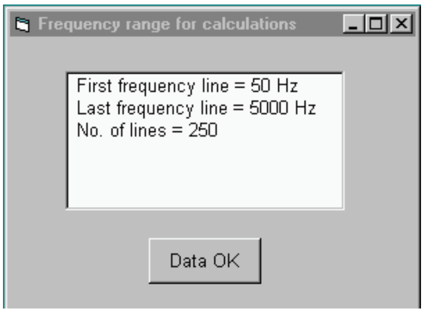


Figure 3-9 Window for setting the frequency range and number of lines used in the calculations

The frequency range being used in the calculations are always specified by the first and the last frequency line in addition to the total number of lines inside this range. When calculating mean values in 1/3 octave bands one should preferably set the first frequency line equal to or lower than the lower cut-off frequency of the first frequency band of interest. Conversely, the last frequency line should be equal to or higher than the upper cut-off frequency of the last band of interest.

3.4 THE SOUND INCIDENCE MENU

The submenus have the following items:

- Angle
- Diffuse
- Reverberation room

Clicking on any of these items starts a new calculation.

Submenu	Shortcut	Description
Angle	Ctrl V	Opens up a window for specification of the plane wave angle of incidence (between 0 and 90 degrees). Zero degrees signify normal incidence.
Diffuse	Ctrl D	Calculates a mean value for all angles of incidence. More details concerning this calculation is given below.
Reverberation room	Ctrl K	Calculates an estimate of the absorption coefficient measured for the actual absorbent configuration in a standardised reverberation room test. The specimen is assumed to have a square shape and choosing this option bring up a window for input of the length of the side of the square. The default value is 3.2 meter giving approximately an area of 10 m^2.

When choosing "Diffuse", mean values for the absorption coefficient and the sound reduction index are calculated, the latter one only if relevant. Mean values are not calculated for the impedance. Furthermore, the reverberation room option only applies to the case of absorption coefficients. Some details concerning the calculation of these mean values are given under the heading no. 3.4.1.

3.4.1 Statistical absorption and transmission coefficients

Choosing the item "Diffuse" a statistical absorption coefficient α_{stat} is calculated using the expression

$$\alpha_{\text{stat}} = 2\int_0^{\pi/2} \alpha(\varphi)\sin\varphi\cos\varphi\,\mathrm{d}\varphi\,,$$

where $\alpha\ (\varphi)$ is the absorption coefficient with the incident angle φ. If relevant for the actual configuration, i.e. the layer HARD WALL is not included, a mean transmission coefficient τ_{stat} is calculated in the same way and the mean sound reduction index R in dB is displayed. In this case, however, the upper limit in the integration is set to approximately 80 degrees which is the usual simple way to get a better fit between measured and calculated results. In each case the integral is solved using a 16 point Gaussian routine.

With the option "Reverberation room" integration over the angle of incidence is also performed. In this case, however, the limited size of the absorbent is taken into account. Due to diffraction effects the effective "acoustical size" may become larger than the actual geometrical size of the absorber. As a result of this so-called edge effect the absorption coefficient may become larger than 1.0.

Thomasson, see the reference below, have shown that we may write

$$\alpha_{\mathrm{stat}} = \frac{4\,\mathrm{Re}\{Z_{\mathrm{n}}\}}{\pi} \int_0^{\pi/2} \int_0^{2\pi} \frac{\sin\varphi}{\left|Z_{\mathrm{n}} + Z_{\mathrm{f}}\right|^2} \mathrm{d}\varphi \, \mathrm{d}\theta \ ,$$

where Z_{n} is the normalised input impedance of the absorber (normalised to $\rho_0 \cdot c_0$). The impedance Z_{f} is by Thomasson denoted "field impedance" which is dependent on the shape and dimensions of the absorber and also on frequency and the angle of incidence. In general the sound incidence must be specified by the angle of incidence φ referred to the normal and to the azimuth angle θ as well.

The calculations in the program presuppose a square specimen. Please note that the formula above applies to *locally reacting* materials. In the case of mineral wool porous materials the calculations have shown to be fairly accurate. Applied to bulk reacting absorbers as resonance absorbers where the airspace is not subdivided (into cassettes) the accuracy is not asserted. Probably the edge effect is a little overestimated.

Reference:
S.-I. Thomasson (1980), On the absorption coefficient, *Acustica* **44**, 265 - 273.

3.5 THE RESULT MENU

The menu gives the choice on which calculated result should be displayed, i.e.

- Absorption coefficient
- Input impedance
- Sound reduction index

None of these choices calls up the calculation procedure because all relevant data are calculated simultaneously.

Submenu	Shortcut	Description
Absorption coefficient	Ctrl A	Display the chosen values for the absorption coefficient, i.e. the coefficient for a given angle of incidence, a mean value in a diffuse field or an estimate from a reverberation room.
Impedance	Ctrl I	Display the real and imaginary part of the normalised input impedance for a given angle of incidence.
Sound reduction index	Ctrl R	Display the chosen values for the sound reduction index, either for a given angle of incidence or a mean value in a diffuse field. In the latter case the upper limit of integration is 80 degrees.

3.6 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 except when displaying the impedance where the value is -10.
Y maximum	None	Opens up a window to specify the maximum value for the ordinate. The default values are 1.2, 10.0 and 50.0 for the absorption coefficient, the impedance and the sound reduction index, respectively.

3.7 THE HELP MENU

The choices are:

- pdf-file
- About WinFLAG

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

4 WINFLAG LICENCE 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\WinFlag\WINFLAG_1.0.EXE” /TRANSFER XXXX-XXXX-FL

NTNU, 17 Feb. 2003
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T.E. Vigran