DOCUMENTATION

FILOS

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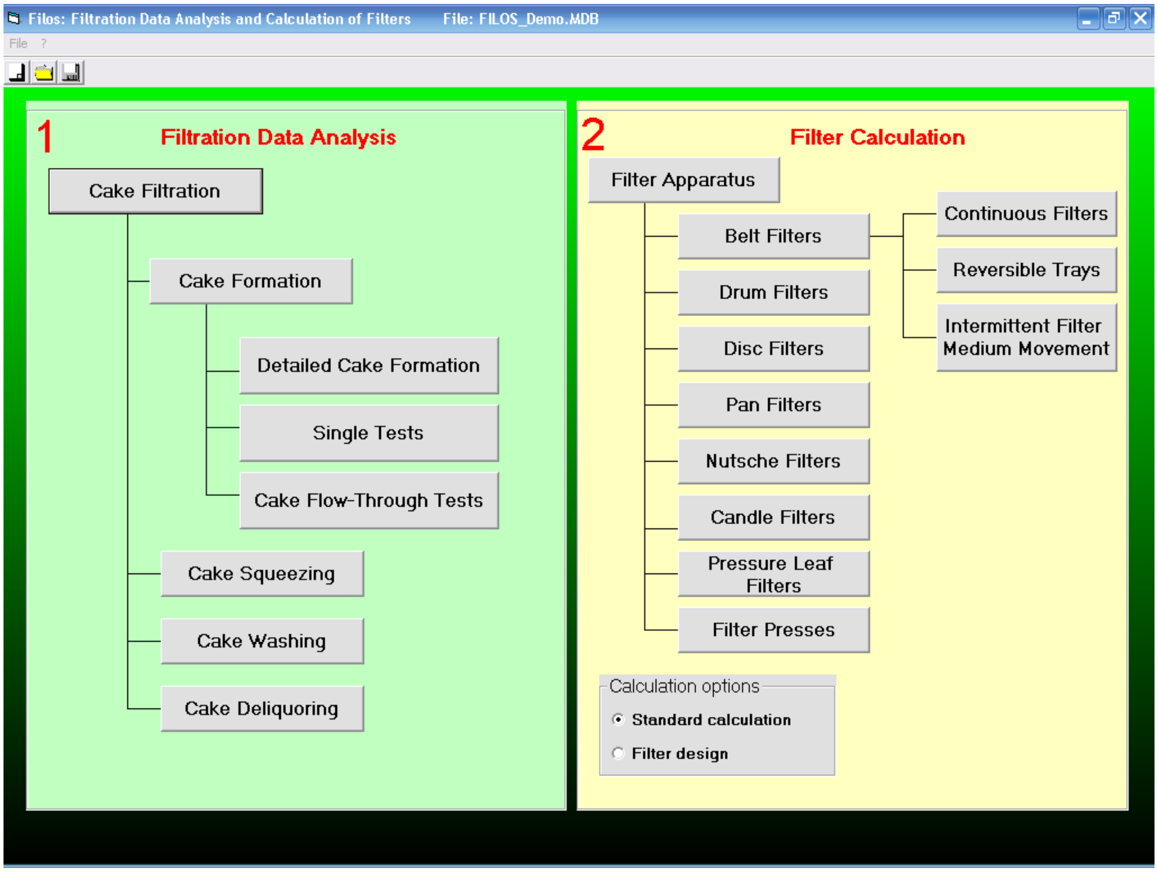
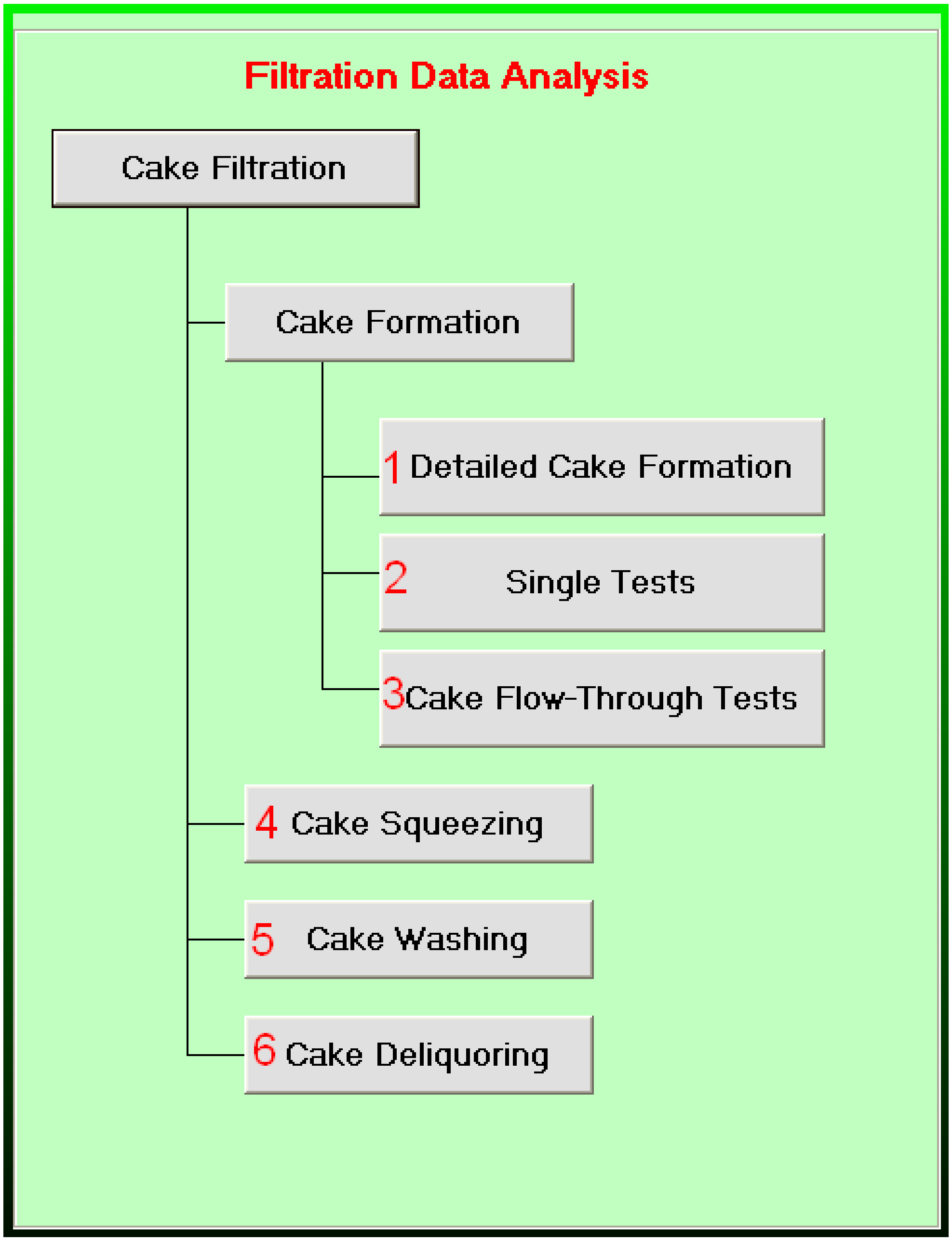
CONTENTS

1. The Start Window



The Start window enables the Selection of any program module for the Analysis of Filtration data for the cake forming filtration of suspensions with a pressure difference as driving potential with consideration of the optional steps: cake squeezing, cake washing, cake deliquoring (see first part of the program: Filtration Data Analysis (1)) and the calculation of the performance of all important and widely used Filter Apparatuses including their Design and Optimization (see second part of the program: Filter Calculation (2)).

1.1 The Filtration Data Analysis Modules



The above left part of the *Start* Window enables the selection of one of the 6 *Filtration Data Analysis* modules. We can come always directly to this start window by clicking the command button *Start Window* which is placed in every program window.

We use this part of the program when we want to analyse filtration data from Batch Filters in laboratory, pilot or industrial scale (cake forming filtration of suspensions with a pressure difference Dp as driving potential including the optional steps of cake squeezing, cake washing and cake deliquoring) with the aim to get the necessary theory based parameters for the practise reliable calculation of diverse Filter Apparatuses.

The Filtration Data Analysis modules enable:

A) The reliable and user friendly determination of the necessary filtration parameters for the calculation of the performance and the design of various filter apparatuses (see *Filter Calculation* module) via the analysis of filtration data from batch filter experiments in a laboratory, pilot or industrial scale (pressure or vacuum nutsche filters, candle filters, pressure leaf filters filter presses).

B) The judgment of the quality of the experiments via plotting the test data on the basis of theoretically based diagrams

C) The systematic saving of all experimental data (input data) as well as the analysed data (output data) in a database. In one file the data of all test series for all materials and all apparatuses can be saved enabling among others the comparison of the behaviour of different suspensions.

To A)
Which parameters are determined in the Filtration Data Analysis modules?

I) From the Analysis of *Cake Formation* experiments (module Detailed Cake Formation, or Single Tests or Cake Flow-Through Tests) we determine:

1) the cake permeability Pc0 for a definite pressure difference Dp0
2) the cake compressibility nc
3) the filter medium resistance Rm and hce

Pc0, nc, hce are necessary parameters for the calculation of the cake formation step (cake height as a function of filtration time) but are also needed for the calculation of the cake washing and cake deliquoring step.

II) From the Analysis of *Cake Washing* experiments (module Cake Washing) we calculate:

1) Adaptation parameter Aw
2) Adaptation parameter Bw

Aw, Bw are necessary adaptation parameters for the calculation of the wash out content in the discharged filter cake

III) From the Analysis of the *Cake Deliquoring* experiments (module Cake Deliquoring):

1) Adaptation parameter Ad
2) Adaptation parameter Bd

3) Adaptation parameter alpha
4) Adaptation parameter betta
5) Adaptation parameter gamma

Ad and Bd are necessary adaptation parameters for the calculation of the moisture content of the discharged filter cake RF (or cake solids content TS or cake Saturation S).

The parameters alpha, betta, gamma are necessary adaptation parameters for the calculation of the gas volume flow rate (momentary gas flow rate for batch filters and integral gas flow rate for continuous filters) that flows through the filter cake during the cake deliquoring step.

IV) From the Analysis of Cake Squeezing data (module Cake Squeezing) we determine:

1) Adaptation parameter Alpha_hc
2) Adaptation parameter Alpha_RF
3) Adaptation parameter Alpha_Eps
4) Adaptation parameter Alpha_Pc

The parameters Alpha_hc, Alpha_RF, Alpha_Eps, Alpha_Pc are necessary for the calculation of the squeezing behaviour of the filter cake (cake height hc, moisture content RF, cake porosity ε, cake Permeability Pc) as a function of the squeezing pressure Ps at equilibrium. Alpha_RF and Alpha_Pc are necessary input parameters for the calculation of the performance of Filter Presses with cake squeezing.

1 Detailed Cake Formation

It is the most powerful of all Data Analysis modules. We use it when we have cake formation experiments with the registration of the filtrate mass or filtrate volume as a function of the filtration time. Typical testing filter apparatuses are pressure nutsches but also all other filter devices with an easy registration of the filtrate mass during the cake formation step.

Main task of this module is for a given test series the reliable and user friendly determination of the cake permeability function (cake permeability Pc0 for a definite pressure difference Dp0 and cake compressibility nc) as well as the determination of the filter medium resistance Rm and hce. The above mentioned parameters are the key parameters for the proper selection, design and optimization of filters because they do not only determine the cake formation behaviour but they influence considerably the washing and deliquoring of the filter cake.

In *Detailed Cake Formation* module we have as an additional tool a *Simulation* module integrated that enables the calculation of the cake formation step including Tables & Graphs when having a systematic variation of filtration time or cake height or suspension amount. For opening the Simulation window click the *Simulation* command button on the task bar.

2 Single Tests

Typical application of this module is when during one filtration experiment we do not have the registration of the filtrate amount (mass or volume) as a function of the filtration time but only one measurement. Such a measurement is typically the end filtration time tf and the corresponding cake height hc. Instead of the cake height hc we can have as input the filtrate mass or volume. Typical test apparatus which delivers us filtration data for this module is the vacuum nutsche. With this apparatus the registration of the filtrate mass as a function of time is difficult but the measurement of the final filtration time and the corresponding cake height is easier than in the pressure nutsche. For this module we have only one input table for all experiments of a given test series and each row has the data of a different experiment. The main task of this module is the same as that of the *Detailed Cake Formation*: The determination of the cake permeability Pc0 for a definite pressure difference dp0, of the cake compressibility nc and of the filter medium resistance Rm and hce.

3 Cake Flow-Through Tests

We use this module especially when we have fast filtering suspensions. In this case we have a relatively short filtration time and the use of the *Detailed Cake Formation* or the *Single Tests* module give us normally not accurate values of the cake permeability and especially of the filter medium resistance. Of course this module can be used for every suspension. What experimental data are needed? One experiment can be described as follows: With a pressure difference dpf we form a filter cake of a height hc and then we give on the cake surface a liquid amount of the mass Mf or the volume Vf. With a pressure difference dpfl ("fl" means flow through) the liquid flows through the cake and we measure the flow through time, that is the time until the liquid reaches the cake surface. One experiment is one row in the input table. For the correct determination of the filter medium resistance hce more than 3 experiments with different cake heights are necessary. The correct determination of the cake compressibility demands the variation of the pressure difference used for cake formation. If the compressibility is not needed (that is for example the case when it is known that the material is incompressible) then only the cake height needs to be varied. It is also recommended to use the mother liquid as flow through liquid in order to get reliable and accurate filtration parameters.

4 Cake Squeezing

This module is needed when we squeeze the cake after cake formation or after cake washing to homogenize the cake and reduce its moisture content via cake volume reduction using a membrane or a piston. Membrane filter presses for example or filter press automats are typical filters which enable the squeezing of the filter cake. This module can analyse data from experiments with industrial filters like membrane filter presses / filter press automats but also laboratory experiments using nutsche filters with the use of a piston or other methods for cake squeezing.

The main aim of this module is the determination of the adaptation parameters necessary to calculate the cake height, the cake porosity, the moisture content and also the cake permeability as a function of the squeezing pressure. These parameters are needed for the calculation of the pre squeezing and squeezing step in filter presses (see Filter Presses module in the Filter Calculation program part.

At least 3 experiments are needed. How one experiment has to be carried out? After formation of a filter cake we squeeze this cake with the pressure Ps and we measure in equilibrium state (after practically no more liquid comes out of the cake) the height of the squeezed cake and the cake moisture content. Because the squeezed cake is saturated with liquid the cake porosity depends on the value of the cake moisture content and is calculated after entering the measured cake moisture content. When we want to know also the dependence of the squeezing pressure on the cake permeability (and this is needed when we have in filter presses after the squeezing step a cake washing or cake deliquoring) then during the experiment and after we have squeezing equilibrium we give on the squeezed cake a definite amount of liquid and with a pressure difference dp this liquid flows through the cake. We measure the time needed until this liquid flows through the cake (washing time or cake flow through time) and from this measured time, from the liquid amount, from the height of the squeezed cake and from the flow through pressure difference dp the cake permeability of the squeezed filter cake is calculated.

5 Cake Washing

When we have to calculate a filter apparatus with a cake washing step then in this case for the calculation of the wash out content in the discharged cake X as a function of the specific washing liquid amount W (washing ratio) we need adaptation parameters which have to be determined by analysing washing experimental data (preferably laboratory experiments). The analysis of such data and the determination of the needed parameters is the main job of the Cake Washing module.

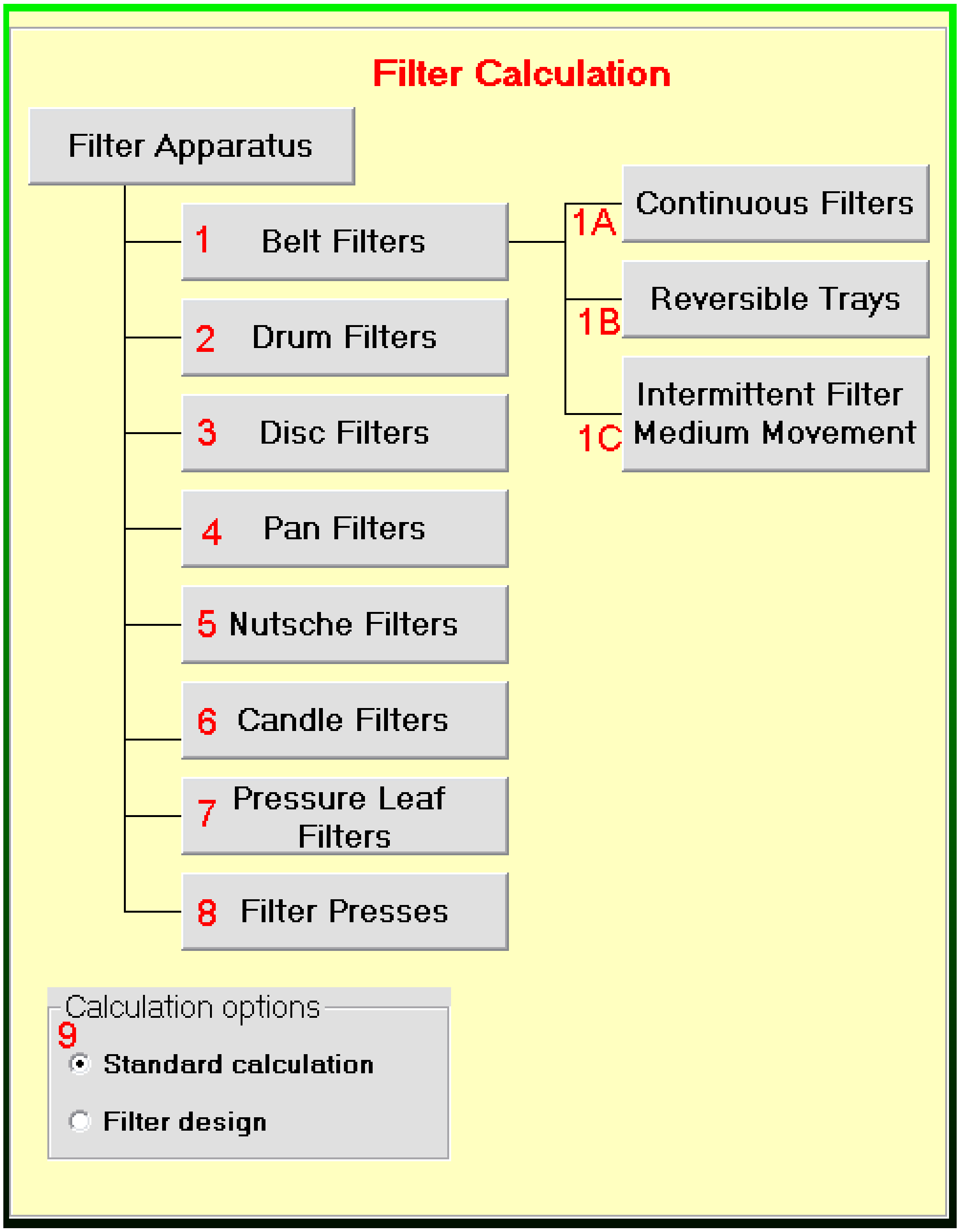
At least 2 washing experiments are needed but 3 or more are recommended. How one washing experiment should be carried out? After finishing the cake formation we give on the saturated filter cake a definite amount of washing liquid and with a washing pressure difference dpw the liquid flows through the cake. It is not necessary that the washing time is measured (if the washing time is measured this module also enables the determination of the cake permeability during the cake washing). It is also not necessary that we stop the experiment after the washing liquid reached the cake surface (end of the washing step). In many cases we can not measure the washing and deliquoring time but we only know the total washing and deliquoring time (that is the time from beginning of the washing until the end of the experiment). After stopping the experiment we measure the cake moisture content Rf and the wash out content in the filter cake X. What we need as input data for the washing module from one experiment? That is the washing pressure difference dpw, the cake height hc, the wash liquid amount Mw or Vw, the cake moisture content Rf and the wash out content of the cake at the end of the experiment X.

6 Cake Deliquoring

If we want to calculate the cake moisture content after cake deliquoring or / and the gas flow rate (the gas flow rate is needed for the design of the compressor) in an industrial filter as a function of the cake height, the pressure difference and the deliquoring time two adaptation parameters for the cake moisture content (Ad, Bd) and three adaptation parameters for the gas flow rate (alpha, betta, gamma) are needed. The determination of these parameters is the main job of this module.

At least two deliquoring experiments are needed but three or even more are recommended. How one deliquoring experiment should be carried out? After the cake formation or the cake washing is finished and without interrupting the experiment due to the pressure difference dpd (in most of the cases the deliquoring pressure difference is equal the cake formation pressure difference but this is not obligatory) gas penetrates in the cake and displaces the liquid in the cake voids. After a definite deliquoring time td we stop the experiment and we determine the moisture content of the cake Rf. In case we can measure the gas flow rate then we should measure the value of this parameter to the deliquoring time td. In the data input table each row is for the data of one experiment. We enter there the pressure difference dpd, the cake height hc, the deliquoring time td and the measured cake moisture content RF. The input of the gas volume flow rate Vg is optional.

1.2 The Filter Calculation Modules



The Program part *Filter Calculation* with its 8 modules enables the calculation of the performance of all important and widely used Filter Apparatuses including their design and optimization. All simulations can be saved in one file together with the input and results of the *Filtration Data Analysis* program part enabling the comparison of the filter performance not only for different machine constructive and setting parameters but also for different materials (=suspensions). Via the command button _*Take Data*_ the two program parts communicate together. *Take Data*, as the interface of the two program parts, enables the automatic and easy transfer of all material data from the *Filtration Data Analysis* part (input and calculated parameters) to the *Filter Calculation* modules.

The considered Filter Apparatuses are divided in 3 groups and all filters (program modules) belonging to the same group have a similar program concept:

- Continuous Filters (Belt Filters, Drum Filters, Disc Filters and Pan Filters)
- Batch Filters without Cake Squeezing (Nutsche Filters, Candle Filters, Pressure Leaf Filters)
- Filter Presses

For the calculation of each filter two options can be selected:

- Standard Calculation: Enables the calculation of the filter performance for a given material and a given machine and machine setting parameters including the systematic variation of various influencing parameters with the tabular and graphical display of their influence on the result parameters (see command button *Tables & Charts*)

- Filter Design: Enables the Calculation of the needed Filter Area when the Filter performance is given. The filter performance is in this sense synonym with Result parameters. In the general case (with Cake Washing and Deliquoring) we have as main result parameters the Solids Throughput (dry solids mass over time) Ms, the cake moisture content Rf and the wash out content X in the discharged cake.

1A Belt Filters-Continuous Filters
1B Belt filters – Reversible Trays
1C Belt Filters – Intermittent Filter Medium Movement
2 Drum Filters
3 Disc Filters
4 Pan Filters

Option: Standard Calculation

Calculates the performance of the filter including cake formation, cake washing (for belt filters also counter current washing is considered) and cake deliquoring step. The cake washing step is optional. Only for disc filters the cake washing is not considered because these filters are normally not used for cake washing due to their geometry.

For the Continuous Belt Filters both options regarding the filter construction are considered: Standard filter segments or no standard segments. The result parameters in the general case are the following: Cake height hc, solids throughput Ms (cake formation step), cake moisture content Rf and cake Saturation S, integral gas flow rate Vg (important for the dimensioning of the compressor) (cake deliquoring step), washing liquid flow rate Vw, specific washing liquid consumption W and Wm and the wash out content of the discharged filter cake X. Additionally the times for cake formation, washing and deliquoring are displayed. More result parameters can be displayed by selecting them from the configuration window and by opening the *Show more results* window.

Tables and curves showing the influence of the machine and machine setting parameters on the result parameters are displayed in the *Tables & Charts* window after clicking the *Tables & Charts* command button in the main window.

Input parameters are the material parameters (listed on the left column of the window and for each step separately: cake formation, washing and deliquoring material parameters), the machine parameters (geometry of the filter area and zone division for cake formation, washing and deliquoring) and the machine setting parameters (pressure difference and belt speed or rotational speed).

In the same file many simulations can be saved and displayed. One simulation is displayed in the table of the main window after clicking the *Accept* command button. To insert a new simulation just click an empty row in the overview table of the main window. All data of the previous current simulation are taken automatically. Then change the data you want to change and click the *Accept* command button. After *Accept* the new simulation is listed in the overview table. With *Accept* the data are not yet saved in the database. The saving can be done immediately after *Accept* by selecting *File* → *Save* or before exiting the module the program asks for saving. <u>You have first to Accept the data which you want to Save!</u> To delete a simulation select first the simulation you want to delete in the overview table and then click the menu *Table*→ *Delete Simulation* and finally *Accept* and *Save*.

<u>Option Filter Design</u>

The Filter Design main window for continuous Filters (Belt, Drum, Disc and Pan Filters) looks different that the *Standard Calculation* Window. Design means to calculate the filter Area and other unknown machine constructive and machine setting parameters for a definite pressure difference and a definite cake height. Besides the pressure difference and the cake height depending on the selected option we can have the following options with regard to further input parameters:

- Input of the Solids Throughput Ms
- Input of Solids Throughput Ms and moisture content Rf
- Input of Solids Throughput Ms, moisture content Rf and specific wash liquid amount W (washing ratio)

The first step of filter design calculates the theoretical filter area and other machine and setting parameters and the second design step (second design window that opens after clicking *To the next step*) enables the selection of the proper filter from the saved filter series database and the calculation of the performance of this filter under the given design conditions.

5 Nutsche Filters
6 Candle Filters
7 Pressure Leaf Filters

Option Standard Calculation

It calculates the performance of the filter including cake formation, cake washing and cake deliquoring step. The cake washing and cake deliquoring steps are optional. The filter setting input parameters and the step specific result parameters are displayed separately. For the cake formation step the filtration time tf or the cake height hc or the suspension amount for one cycle (Msus or Vsus) can be entered. Once one of the above parameters is entered the others are calculated and displayed. For the cake washing step the washing time tw or the specific washing liquid amount W (=washing ratio) or the wash liquid volume Vw can be entered. For the cake deliquoring the program offers the flexibility to enter not only the cake deliquoring time but instead of it the cake moisture content Rf (result parameter). Entering the Rf-value the deliquoring time is then calculated.

The final result parameters in the general case are the following: Cycle time tc, average solids throughput Ms, cake moisture content RF, gas flow rate Vg at the end of the deliquoring step, washing liquid flow rate Vw, specific washing liquid consumption Wm (wash liquid volume related to the solids mass) and the wash out content of the discharged filter cake X. More result parameters can be displayed by selecting them from the configuration window and by opening the *Show more results* window.

Tables and curves showing the influence of the machine and machine setting parameters on the result parameters are displayed in the *Tables & Charts* window after clicking the *Tables & Charts* command button in the main window. Especially the calculation of the influence of the cake height on the solids throughput enables the optimization of the filter because the cake height which gives maximal production rate can be determined.

Input parameters are the material parameters (listed on the left column of the window and for each step separately: cake formation, washing and deliquoring material parameters), the machine constructive parameters (filter area) and the filter setting parameters (specific for each step: Cake formation (pressure difference for cake formation Dpf and filtration time tf or cake height hc or suspension amount for one cycle Msus or Vsus), Cake Washing (pressure difference for cake washing Dpw, washing time tw or washing ratio W or wash liquid volume Vw), Cake Deliquoring (pressure difference for cake deliquoring Dpd, deliquoring time td or cake moisture content RF)

In the same file many simulations can be saved and displayed. One simulation is displayed in the table of the main window after clicking the *Accept* command button. To insert a new simulation just click an empty row in the overview table of the main window. All data of the previous current simulation are taken automatically. Then change the data you want to change and click the *Accept* command button. After *Accept* the new simulation is listed in the overview table. With *Accept* the data are not yet saved in the database. The saving can be done immediately after *Accept* by selecting *File →Save* or before exiting the module the program asks for saving. You have first to Accept the data which you want to Save! To delete a simulation select the simulation in the overview table you want to delete and then click the menu *Table→Delete Simulation* and finally *Accept* and *Save*.

Option Filter Design

The Filter-Design window for these filters is similar to the Standard Calculation window. The only difference to the *Standard Calculation* option (see description above) is that in *Filter Design* option the filter area is not an input but a calculated parameter. As input instead of the filter area is the average solids throughput Ms. By clicking *Calculate Ms* a window opens and instead of the solids throughput the suspension throughput or the suspension amount or solids mass which have to be treated in a definite time can be entered. In the *Tables & Charts* window we have the influence of the cake height on the result parameters. Important is the diagram Filter area as a function of cake height (optimization diagram) that enables to determine the minimal (= optimal) filter area for a given filter performance.

8 Filter Presses

Option Standard Calculation

It calculates the performance of the Filter Presses (Filter Press Automats included). In the general case besides the cake formation step the following optional steps are calculated: Presqueezing, washing, Squeezing and deliquoring (the word deliquoring is used when the cake moisture reduction is caused due to the liquid displacement via penetration of gas in the cake as a result of the applied gas pressure difference) of the filter cake. Which steps are considered for each simulation can be selected in the configuration window. That means it is possible to calculate only the cake formation step (simplest option). The filter setting input parameters and the step specific result parameters are displayed separately.

For the cake formation step the depth of the filter plate hp is given and the filtration time tf is calculated. For the calculation of the cake formation time different options for the filtration pressure profile are considered. Also the case of using the membrane pressure to filter the residual suspension in the filter press by having the suspension pipe closed is considered (rest filtration with membrane pressure). For the cake washing step the washing time tw or the specific washing liquid amount W (=washing ratio) or the wash liquid volume Vw can be entered. For the cake deliquoring the program offers the flexibility to enter instead of the cake deliquoring time the cake moisture content Rf (result parameter). Regarding the presqueezing and squeezing steps the squeezing pressure and the squeezing time are entered and the filtrate mass removed from the filter cake, the height, the porosity, the moisture content and the permeability of the squeezed filter cake are calculated. It is assumed that the squeezing time is enough to reach practically the equilibrium state.

The final result parameters in the general case are the following: Cycle time tc, average solids throughput Ms (cake formation step), cake moisture content Rf, gas flow rate Vg at the end of the deliquoring step, washing liquid flow rate Vw, specific washing liquid consumption Wm and the wash out content of the discharged filter cake X. More result parameters can be displayed by selecting them from the configuration window and by opening the *Show more results* window.

Tables and curves showing the influence of the filter constructive and filter setting parameters on the result parameters are displayed in the *Tables & Charts* window after clicking the *Tables & Charts* command button in the main window. Especially the calculation of the influence of the cake height on the solids throughput enables the optimization of the filter presses because the cake height which gives maximal production rate can be determined.

Input parameters are the material parameters (listed for each step separately: cake formation, squeezing, washing and deliquoring material parameters), the constructive parameters (filter area and the depth of the filter plates hp) and the filter setting parameters specific for each step. For the cake formation we have the pressure difference profile for the cake squeezing the squeezing Pressure and squeezing time, for the cake washing the pressure difference for cake washing Dpw and one of the following parameters:washing time tw or washing ratio W or wash liquid volume Vw and finally for the cake deliquoring the pressure difference for cake deliquoring Dpd and one of the following parameters: deliquoring time td or cake moisture content RF.

In the same file many simulations can be saved and displayed. One simulation is displayed in the table of the main window after clicking the *Accept* command button. To insert a new simulation just click an empty row in the overview table of the main window. All data of the previous current simulation are taken automatically. Then change the data you want to change and click the *Accept* command button. After *Accept* the new simulation is listed in the overview table. With *Accept* the data are not yet saved in the database. The saving can be done immediately after *Accept* by selecting *File* → *Save* or before exiting the module the program asks for saving. <u>You have first to Accept the data which you want to Save!</u> To delete a simulation select the simulation in the overview table you want to delete and then click the menu *Table*→*Delete Simulation* and finally *Accept* and *Save*.

Option Filter Design

The Filter Press-Design window is similar to the Standard Calculation window. The only difference to the *Standard Calculation* option (see description above) is that in *Filter Design* option the filter area is not an input but a calculated parameter. Input instead of the filter area is the average solids throughput Ms. By clicking *Calculate Ms* a window opens and instead of the solids throughput the suspension throughput or the suspension amount or solids mass which have to be treated in a definite time can be entered. Each Filter Design simulation is done for a given average solids throughput and a given plate depth hp. In the *Tables & Charts* window we have the influence of the plate depth hp on the result parameters. Important is the diagram filter area as a function of the plate depth hp. We have an optimal Design of the Filter Press for a plate depth that gives the minimal filter area.

9 Calculation Options

Standard Calculation

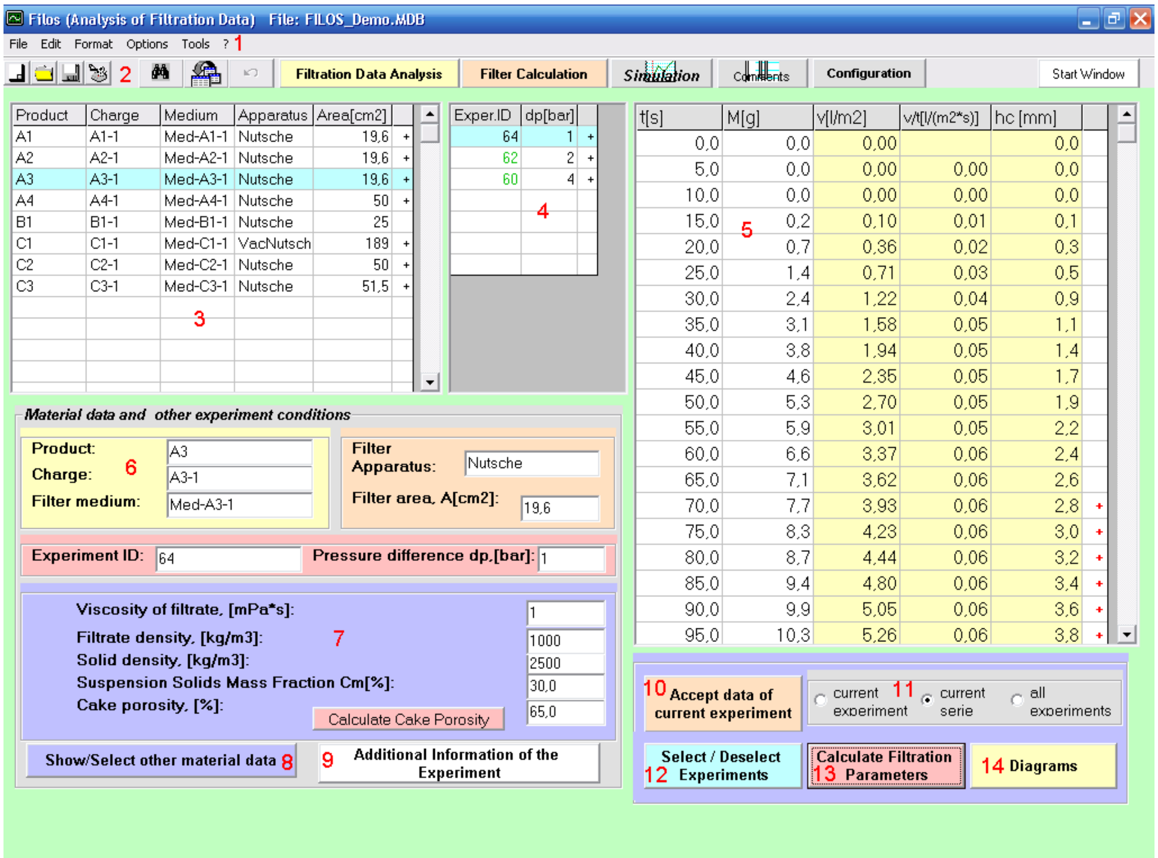
We select this option if the filter area of the filter we want to calculate is known or if we want to have the filter area as input parameter

Filter Design

We select this option if we want to calculate the needed filter area for a given filter performance.

2 The Detailed Cake Formation Module

2.1 The Main window of the Detailed Cake Formation Module



Main window of the *Detailed Cake Formation* module. Enables the input of the registered data by the balance during a cake formation experiment (time / filtrate mass see first and second column in table (5)) for any cake formation experiment. These data can be copied from an Excel file and pasted to the input table (5). The experiments of the selected test series in (3) are displayed in the table (4). In table (5) we have the data of the selected experiment in table (4). The 5 parameters, which are displayed in the overview table for the test series are like the family name of the experiment. Only the experiments which have the same family name belong to the same test series. The same family name means identical names for the parameters: Product, Charge, Filter Medium, Filter Apparatus and identical filter area. These data ("family name" of the experiment) are entered in (6) together with the Experiment ID ("first name" of the experiment) and the pressure difference for this experiment. If the cake compressibility has also to be determined then at least data of 3 experiments with different pressure differences should be entered (see (4)). Theoretically even with 2 experiments with different dp the compressibility can be determined. Concluding: One experiment is identified with its family name (the values of the parameters: Product, Charge, Medium, Apparatus, Area) and its name (Experiment ID). After entering these data in (6) you have to click *Accept* *data of current experiment* (10) to display them in the overview table (3). Before saving the entered data you must first click *Accept data of current experiment* (10) In only one file you can save theoretically all your test series.

1. Menu for the main window of the Detailed cake Formation Window

2.

Task bar with symbols and command buttons for the main window of the *Detailed cake Formation* module.

1. Opens a new empty file (a new file is identified because on the top task bar has the name NONAME.MDB
2. Opens the window to select and open an existing program file
3. Copies the accepted data. In every program window there is an *Accept*-command button. Data which you want to save you have first to accept them by clicking the *Accept* command button
4. Prints the current program window
5. Opens the *Search* – window
6. Opens the *Data View* Window
7. No function
8. This command button is in any program window and enables directly the opening of any Filtration Data Analysis module from any program window.
9. This command button is in any program window and enables directly the opening of any Filter Calculation module from any program window.
10. Opens the main window of the Simulation-Tool for the simulation of the cake filtration step of batch filters.
11. Opens the window that enables the input and display of comments separately for the file, the module and the test series. Comments to the experiment are entered after clicking the *Additional Information of the Experiment* command button.
12. Opens the Configuration window
13. This command button is in any program window and enables the user to come directly to the *Start* Window from any place of the program.

3, 4

Product	Charge	Medium	Apparatus	Area[cm2]	
A1	A1-1	Med-A1-1	Nutsche	19,6	+
A2	A2-1	Med-A2-1	Nutsche	19,6	+
A3	A3-1	Med-A3-1	Nutsche	19,6	+
A4	A4-1	Med-A4-1	Nutsche	50	+
B1	B1-1	Med-B1-1	Nutsche	25	
C1	C1-1	Med-C1-1	VacNutsch	189	+
C2	C2-1	Med-C2-1	Nutsche	50	+
C3	C3-1	Med-C3-1	Nutsche	51,5	+
D1	D1-1	Med-D1-1	Nutsche	19,6	+

Exper.ID	dp[bar]	
64	1	+
62	2	+
60	4	+

Overview tables for the test series (3) and the experiments of the selected test series (4)

How a test series is characterized?

A test series includes all experiments which carried out with a given suspension, a given filter medium and a given test apparatus. The experiments of the selected test series (see blue colour) are listed in the small table. The test series is like the family and the experiments are the children of the family. Each test series is identified by the names/values of 5 parameters: Names for Product and Charge, name of the filter medium, name of the filter test apparatus and the value of the filter area. In the test series overview table it is not possible to have two rows with exactly the same data. The same is with the small table: It is not possible to have 2 entries with the same Exp. ID. It is like the fact that you can not have in one family (=test series) two children (=experiments) with the same name!

How to add a new test series?

To add a new test series click first an empty row of the test series overview table. The parameters of the previous active experiment are displayed in the input field (6) of the main window. Change at least one of the 5 names/values which together identify the family name (=test series name).These are the names for the product, the charge name, the names for the filter medium and the filter apparatus and the value of the filter area. Then change the name of the experiment (Exp ID) and enter the pressure difference for the first experiment of the new test series you want to enter. Then change the material input parameters in the input field (7) of the main window and then manually or via copy-paste from an excel file enter the time-filtrate mass values in the first 2 columns in the table (5) of the main window.

If it is the first test series you enter then of course all input fields are empty at the beginning. It is not important the order of entering/changing the data. You can for example first enter the time-filtrate mass data in the table and enter as last the names/values of the test series parameters in (6). To display the data for the new test series and the new experiment in the overview tables (3) and (4) you have to click the command button *Accept Data of current experiment*. Accept doesn't mean *saving* in the database program file. For saving the data in the file you have to click the save-icon in the task bar or select from the File-menu *File→Save* or *File→Save As*. BUT you shouldn't try to save any data without clicking first the *Accept* command button.

<u>What is the meaning of the "+" in the last column of the test series and experiments table?</u>
The + in the test series table means that if we have in the main window the option *All experiments* (see (11)) then the experiments of this series which have the + are considered in the regression analysis (see first results window of detailed cake formation module). Double clicking one row in the test series table the + is removed. Double clicking again the + appears. The same concept is for all tables which have the last column as +-column. Regarding the experiments table removing the + by double clicking and having in (11) the option *Current Series* selected the experiment without + is not considered for the regression analysis.

<u>How to delete one experiment, a test series or all test series?</u>
Select the menu entry *Options→Operations with Experiment list table* and then selecting:
- *Clear all experiments* you delete all test series with all experiments
- *Delete current series* you delete the selected test series
- *Delete current experiment* you delete only the selected experiment

After deleting for saving the changes you don't need to click first *Accept* and then *Save* but only *Save.*

5

t[s] 1	M[g] 2	v[l/m2] 3	v/t[l/(m2*s)] 4	hc [mm] 5	6
0,0	0,0	0,00		0,0	
5,0	0,0	0,00	0,00	0,0	
10,0	0,0	0,00	0,00	0,0	
15,0	0,2	0,10	0,01	0,1	
20,0	0,7	0,36	0,02	0,3	
25,0	1,4	0,71	0,03	0,5	
30,0	2,4	1,22	0,04	0,9	
35,0	3,1	1,58	0,05	1,1	
40,0	3,8	1,94	0,05	1,4	
45,0	4,6	2,35	0,05	1,7	
50,0	5,3	2,70	0,05	1,9	
55,0	5,9	3,01	0,05	2,2	
60,0	6,6	3,37	0,06	2,4	
65,0	7,1	3,62	0,06	2,6	
70,0	7,7	3,93	0,06	2,8	+
75,0	8,3	4,23	0,06	3,0	+
80,0	8,7	4,44	0,06	3,2	+
85,0	9,4	4,80	0,06	3,4	+
90,0	9,9	5,05	0,06	3,6	+
95,0	10,3	5,26	0,06	3,8	+

Input table for the measured data (time-filtrate mass) for the selected cake formation experiment.

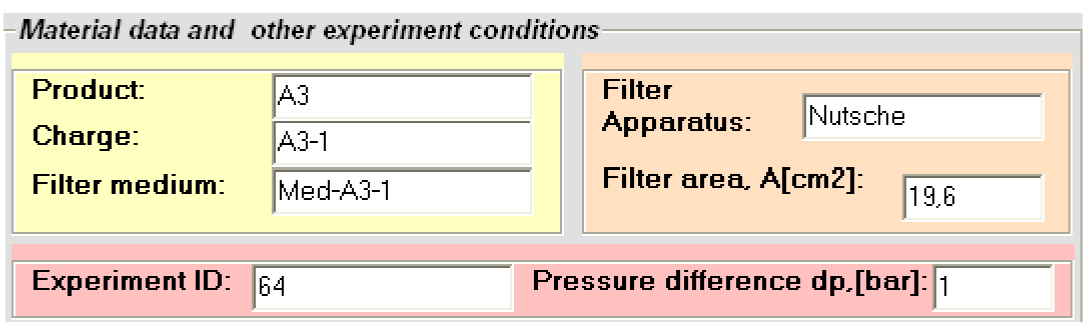
These data are needed for the calculation of the cake permeability Pc and the filter medium resistance Rm and hce. If the option in (11) *Current Experiment* is selected by clicking *Calculate Filtration Parameters* only this experiment is analysed. If in (11) the option *Current Series* is selected and if in the experiments list the current experiment has the + in the last column then this experiment is analysed together with the other experiments of the current test series, which have also the +. It is recommended first to do the Analysis of the current experiment separately and do the necessary corrections and after that you do together the analysis for all experiments of the current test series in order to be able to determine also the cake compressibility.

1. t(s): Filtration time. Can be entered in s or min (time unit can be selected from the configuration window)
2. M(g): Filtrate mass to the time t. Instead of mass the filtrate volume can be entered (the input parameter mass or volume can be selected from the configuration window).

3. v(l/m2): area specific filtrate volume. A calculated parameter needed for the regression analysis (see cake formation equation)
4. v/t (l/(m2 s): average or integral specific filtrate flow rate to the time t (calculated). Optional the differential flow rate dv/dt can be displayed by selecting the menu *Format → Show dv/dt*
5. hc(mm): Calculated (expected) cake height to the filtration time t.
6. One row (=measurement) with + it is considered for the regression analysis. Removing/ reinserting the + via double clicking the corresponding row. If the values of one row are not meaningful (for example M=0) these rows have automatically no + and no + can be inserted via double click.

<u>Comments</u>
- Data can be copied from an excel document as time and filtrate mass columns and pasted in the input table.
- Only rows with + are considered for the analysis
- The + in one row can be removed/reinserted by double clicking this row
- Inserting or deleting a row and other operations with the table can be done with the *Edit*-menu.
- Even with only one measurement (=one row in the table) the cake permeability can be determined. In this case the filter medium resistance is set to zero!
- Time can be entered / displayed in sec or min (see configuration –window)
- Instead of filtrate mass the filtrate volume can be entered /displayed. (See Options: Input of filtrate measuring units in the configuration window)
- the parameters in the columns with yellow colour are calculated parameters
- Decimal places of the calculated parameters are set after clicking the label *Decimal Places* in the *Configuration* window.
- Instead of the integral specific filtrate volume flow rate v/t the differential value can be displayed. For that select in the menu Format → dv/dt

6

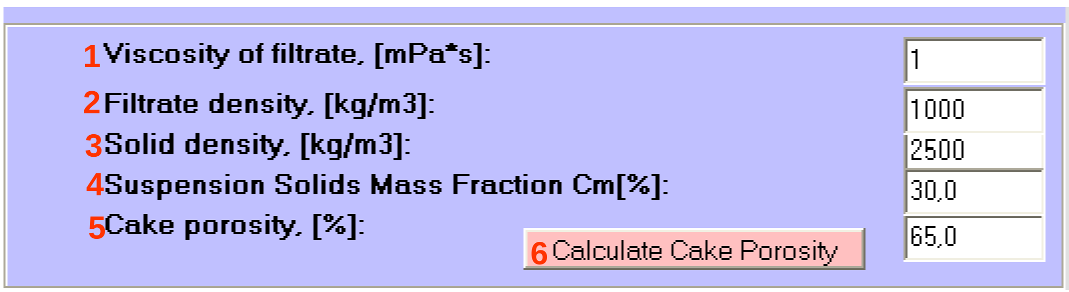


Input field for the name of the test series, the name of the experiment and the cake formation- pressure difference

Comments

- the name of the test series consist of the values of 5 parameters: product name, charge name, filter medium name, test apparatus name and filter area of the test apparatus. These 5 names/values identify the family (=test series) of the experiment. The Experiment ID is like the first name of the experiment. The experiment is like the child of the family (=test series).
- The values of these parameters are all displayed in the overview tables for test series and experiments only after clicking the *Accept* command button
- When we change at least one of the above five values which identify the test series and if we have more than 1 experiment for this test series after clicking *Accept* we are asked if we want just to change the name of the test series. If we answer with *No* then a new series is created and the current experiment before changing the test series name is taken to the new created test series.

7



Material Input parameters necessary for the analysis of cake formation experiments

Comments

1. Please notice that the viscosity of the mother liquor (=filtrate) has to be entered in mili Pa s. The viscosity depends on the temperature of the filtrate that's why the value for the suspension temperature has to be entered. Wrong viscosity means wrong calculated cake permeability. If the viscosity is not known, then please enter the value $1 = 10^{-3}$ Pa s (that is the viscosity of water for 20°C). The determined cake Permeability is in this case related to water as mother liquid.
2 The filtrate density is needed to transform the filtrate mass in filtrate volume. For the data analysis the specific filtrate volume (= filtrate volume divided by the filter area) as a function of time is needed. The specific filtrate volume is displayed as calculated column in the data input table (5).
3 Instead of the solids density the suspension density can be entered. Which parameter should be the input parameter this can be selected in the configuration - window. When the suspension density is selected as input then this value can be selected as specific for only the current experiment or the same for all experiments of the test series. It happens that the suspension samples for the experiments of a given test series have different solids concentrations and that's why we can have a variation of the suspension density from experiment to experiment.

4 Instead of the suspension solids mass fraction Cm the solids volume fraction Cv or the suspension concentration C in g/l may be entered. Which parameter should be entered can be selected from the configuration window. Similar to the suspension density, it can be selected if this parameter will be specific for the experiment or the same for all test series experiments. Cm and Cv values can be entered in % or without %.
5 Instead of the cake porosity (entered in % or without %) the concentration parameter kappa can be entered (see configuration). For the calculation of the cake permeability the kappa-value is needed, which is calculated from the cake porosity and the suspension solids concentration Cv.
6 Enables the calculation of the cake porosity from one cake formation experiment.

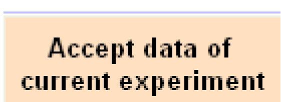
8

This command button opens a window that shows on the left the values of the input material parameters and on the right the values of the calculated parameters. In the above example we have as calculated parameters the suspension density, the suspension solids volume fraction Cv, the suspension solids concentration C in g/l and the concentration parameter kappa.

9

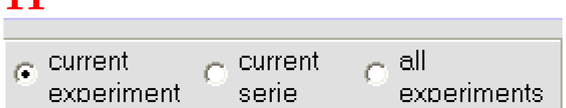
This command button enables the input of comments to the current experiment and any other information that is helpful but is not needed for the data analysis.

10



We always have to click first the *Accept* command button if we want to save any inputs or any changes for the current experiment. That means before saving first we have to click the *Accept* – command button.

11



1) Option <u>current experiment</u> selected
After clicking *Calculate Filtration Parameters* only the data of the current experiment are analysed. For the analysis only the rows with + are considered. In the results window we display a theory based curve for the current experiment and the cake permeability Pc

and the filter medium resistance Rm / hce for this experiment. This option enables a user friendly correction of the data and the accurate determination of the filtration parameters.

2) Option <u>current series</u> selected

After clicking *Calculate Filtration Parameters* all experiments of the current test series with + are analysed together. This enables the comparison of different experiments especially with regard to the result parameters (=cake permeability and filter medium resistance) but especially the determination of the cake compressibility in the second result window. In this second result window the cake permeability and the filter medium resistance for different pressure differences are analysed and the results are the cake compressibility nc and filter medium compressibility mc. If the cake compressibility has to be determined, it is necessary to have at least 3 experiments with different pressure difference (theoretically 2 experiments, but the accuracy is then the problem).

It is recommended to use first the option current experiment. In this option you correct the measured data, so that you have a straight line. Any deviation from the straight line is usually found for short times and / or for very long times (sedimentation effects). Use in these cases the option in the results window “first point with +” and delete in the diagram the points which have a big deviation from the straight line. Then click in the results window *Accept* and go back to the main window. After analysing all experiments of the test series separately then select the option *current series* to analyse all together and be able to determine the cake and filter medium compressibility.

3) Option <u>all experiments</u> selected

Select this option if you want to compare the filtration behaviour of experiments from different test series. Just place the + to those test series which have the experiments you want to compare and then for each of these series with + place the + only to these experiments you want to analyse. That means this option analyses together all experiments with + of all test series with +.

12

Select / Deselect Experiments

Opens a window, which enables the fast selection / de selection (insert the + or remove the +) of experiments. This is only necessary if we have in one file a lot of test series / experiments.

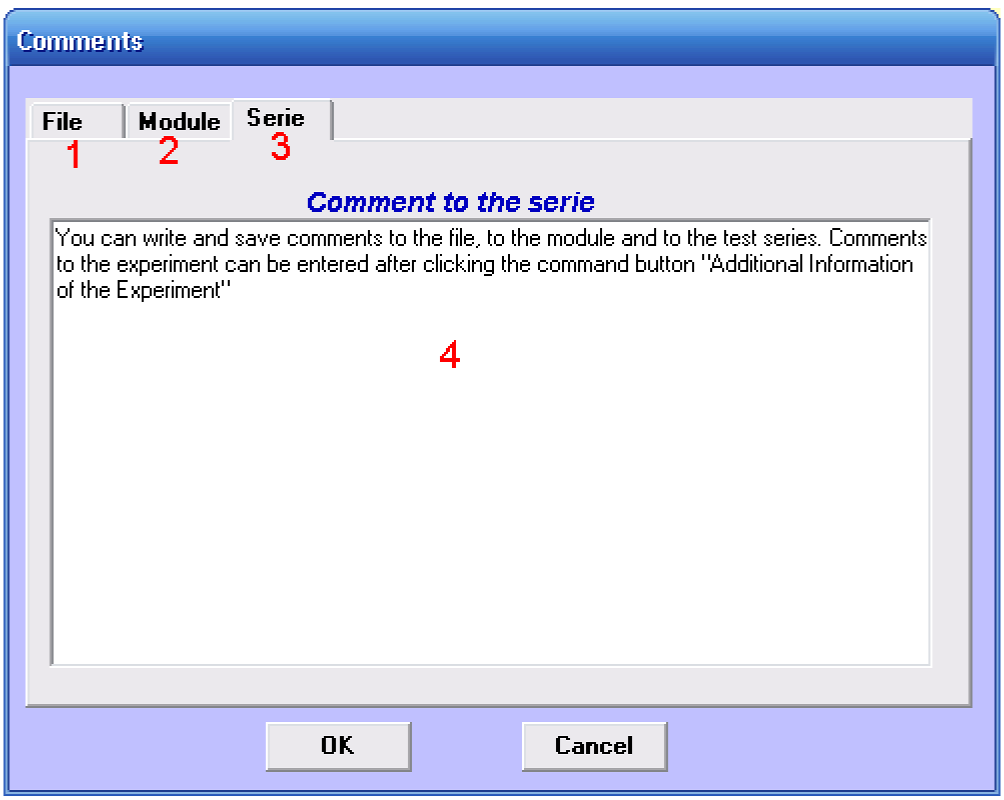
13

Opens the first analysis results window with the theory based graph and the display of the calculated cake permeability Pc, filter medium resistance Rm and hce (separately for each experiment).

14

Opens the Diagrams – window that calculates and displays as tables and graphs all important parameters related to the filtration (=cake formation) step and based on the input parameters of the main window and mass balances.

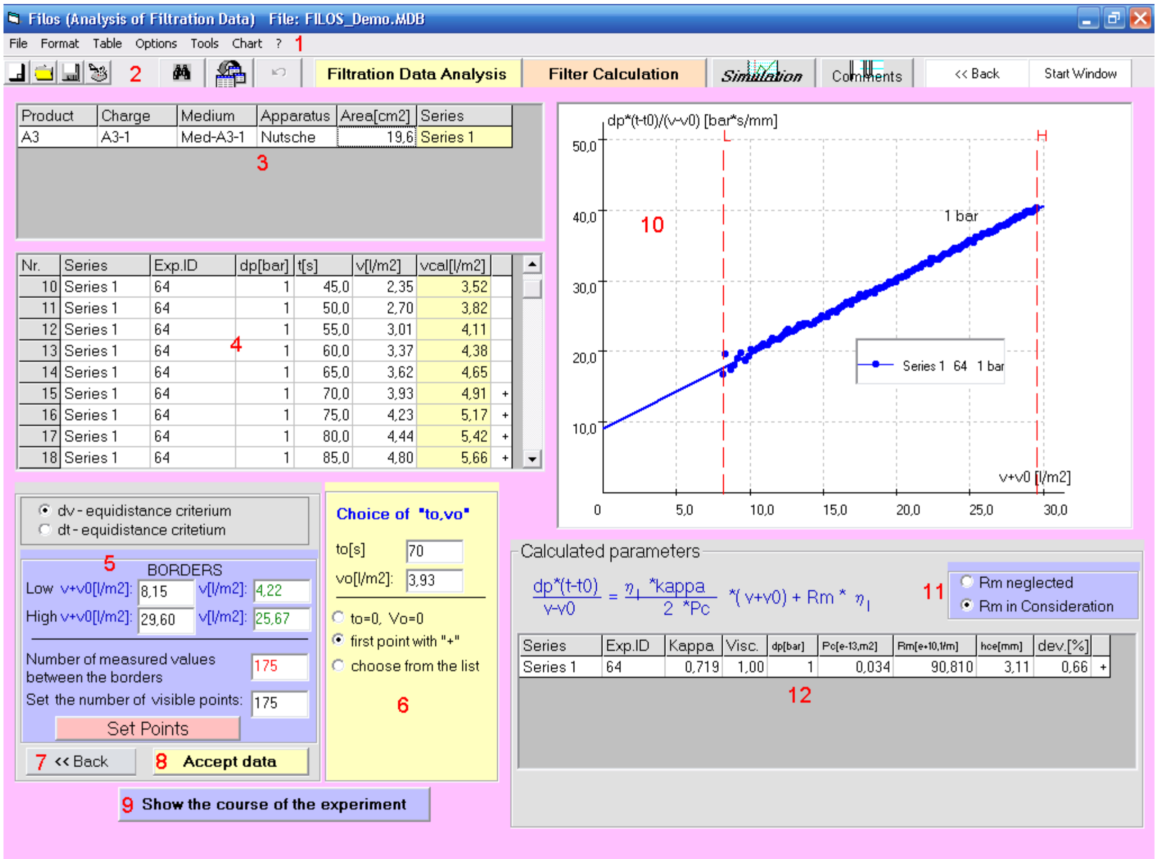
The Comments window



Comments – window. It opens after clicking the command button *Comments* on the top task bar, which is placed in every window of the Filtration Data Analysis modules. For the Filter Calculation modules you have other comment windows. You can write and save separately comments for the current File (select the label *File*), for the current module (select the label *Module*) and for the current test series (select the label *Series*). For comments to one experiment the command button Additional Information of the Experiment has to be clicked.

2.2 Detailed Cake Formation - The First Results Window

2.2.1 Option: Current Experiment



First results window of the module *Detailed Cake Formation* when in the main window the option *Current Experiment* is selected. That means we analyse for this selection option only the selected experiment of the main window.

1

Menu of the main results window

2

Task bar of the main results window

3

Display of the name of the current test series (the name is characterized by the values of the 5 parameters and it's the "family name" of the experiment. The name *Series 1* is a default help name. It makes sense to use this help name when we compare experiments from different test series to identify the series. In such a case we don't have to use the names/values of the 5 parameters for the identification.

4

Table with the input data for the regression analysis.

- Rows without + are not considered for the regression analysis.
- Inserting/removing the + via double click the corresponding row.
- Each row has the name (help name) of the test series, the Exp. ID, the pressure difference dp, the filtration time t, the area specific filtrate volume v and the calculated specific filtrate volume vcal. We calculate vcal by using the cake formation equation for the given time and the calculated filtration parameters which are displayed in (12).
- By clicking *Show the course of the experiment* (9) we get the diagram with the comparison between measured and calculated values.
- You can change the number of measured points which have to be considered for regression analysis by entering the wished number of measured points in the input field *Set the number of visible points* in (5) and then click *Set Points*. This number should be of course less than the number displayed in red in the display field *Number of measured values between the borders*.

5

Input and display fields for the x-axis (= v+v0 - axis) position of the red bars of the diagram. *Low v+v0* show the left red bar and *High v+v0* the right red bar. On the right of these two input fields we have as display parameters the corresponding specific filtrate volume v.

<u>*Number of measured values between the borders*: </u>Display field for the maximal number of measurement points between the borders (this number is the sum of the displayed measurements with + and all other measurements which are excluded from the regression by removing the + between the red bars).

<u>*Set the number of visible points:*</u> Input and display field for the measurement points between the borders, which are shown in the diagram (that means are considered for the regression analysis). This input field is important for the reduction of the measurement points when we have too high number of points. Just enter the number of the points you want to have and click *Set Points*. Automatically the number of points with + is reduced (points with + means the points we see on the diagram, what is the same with the points we consider for regression analysis to determine the filtration parameters) and the diagram is refreshed and new regression analysis is done with the display of the new calculated parameters in (12). After changing the number of visible points by entering a new value in the field *Set the number of visible* points and clicking<u> *Set Points* </u>also the table (4) is refreshed and the number of rows with + is equal to the set number of visible points. You can hide or delete all rows of the table, which have no + from the Menu *Table*. Select for that *Table→ Data without "+" → HIDE DATA* or for deleting the measurements without +: *Table→Data without "+" →DELETE DATA.*

<u>Please notice that before exiting the result window you have to click *Accept Data* (8) if you want to have the same window with the made changes after coming back to this window or/and if you want to save these changes!</u>

6

Defines which (t0, v0) we should use in the cake formation equation (see equation displayed in this window) for the regression analysis to determine the cake permeability Pc and the filter medium resistance Rm and hce for the current experiment. In many cases we may get accurate values for these parameters if we don't use the first option (t0=0, V0=0) but the option *first point with "+"*. Even with this option it is sometimes necessary to remove the first measurement points (remove the +) to get a straight line. The third option: *choose from the list* enables the selection of any t0, V0. It is recommended for this option to use relatively small values of t0 otherwise you will have not accurate results. Important for accurate values for permeability and filter medium resistance is that the considered measurements (these are the rows with + = the displayed points in the diagram) give us a straight line. In many cases the first points are not on a straight line. It is recommended to use the option first point with "+". If still we don't have a straight line remove the points which are not in the straight line and then the filtration parameters will be accurate.

7

Goes back to the main window

8

Click always the command button *Accept data* if you want that the changes are kept after you exit this window or/and if you want to save these changes.

9

By clicking *Show the course of the experiment* instead of the theory based diagram (default diagram) the diagram v=f(t) is displayed with a comparison between measured values (points) and calculated values. The calculated values are listed in the last column of table (4). We get these values from the cake formation equation which is displayed in this window by using the calculated filtration parameters Pc and Rm. Because for this diagram we have another x-axis parameter (we have now the time) also the borders field (5) is different showing now the position of the left and right bar as *low* time and *High* time.

10

Theory based plotting of the measured data and the regression line. The slope gives the cake permeability and the intersection with the y-axis the filter medium resistance Rm.

Comments

- The diagram can be copied and pasted for example to a word document. This is valid for all diagrams of the program. Select for that the menu *Chart* → *Copy Chart*.
- Clicking the Menu *Chart* → *Diagram Outlook* you have many possibilities for formatting the diagram.
- Double clicking in the diagram area you can write text giving explanations to the curves.
- Clicking the x- and y-axis description you can change or /and move this description

- You can remove any measured points from the diagram by drawing a rectangular which includes these point(s). On the right top side of the diagram appear the command buttons *Cut Points* and *Cancel*. Clicking *Cut Points* you remove the measured points from the diagram and you have automatically a refreshing of the window including a recalculation of the parameters.
- You can hide the borders (red lines) by clicking the menu *Chart → hide borders*
- Clicking *Show the course of the Experiment* instead of the above default diagram the v=f(t) diagram is plotted with the comparison of measured and calculated values (v is the area specific filtrate volume).
- The diagram dp* dt/dv =f(v) is displayed instead of the default by clicking the menu *Options → dp * dt/dv =f(v)*

11

By selecting the option *Rm neglected* the permeability of the system cake-filter medium is calculated and Rm and hce are set to zero. In this case the regression line starts from (0,0). This option is automatically selected when we have only one measurement point.

12

Table with the results of the regression analysis (for each experiment one row): cake permeability Pc, medium resistance Rm, medium resistance hce and relative deviation in % quantifying the deviation between the measured and calculated values (values on the regression line). Besides the above result parameters we have as first column the display of the Series name (default name), the Exp. ID, the concentration parameter kappa, the filtrate viscosity and the pressure difference dp. The kappa- and viscosity columns are also input columns. Changing these values we can see the influence on the result parameters Pc, Rm and hce.

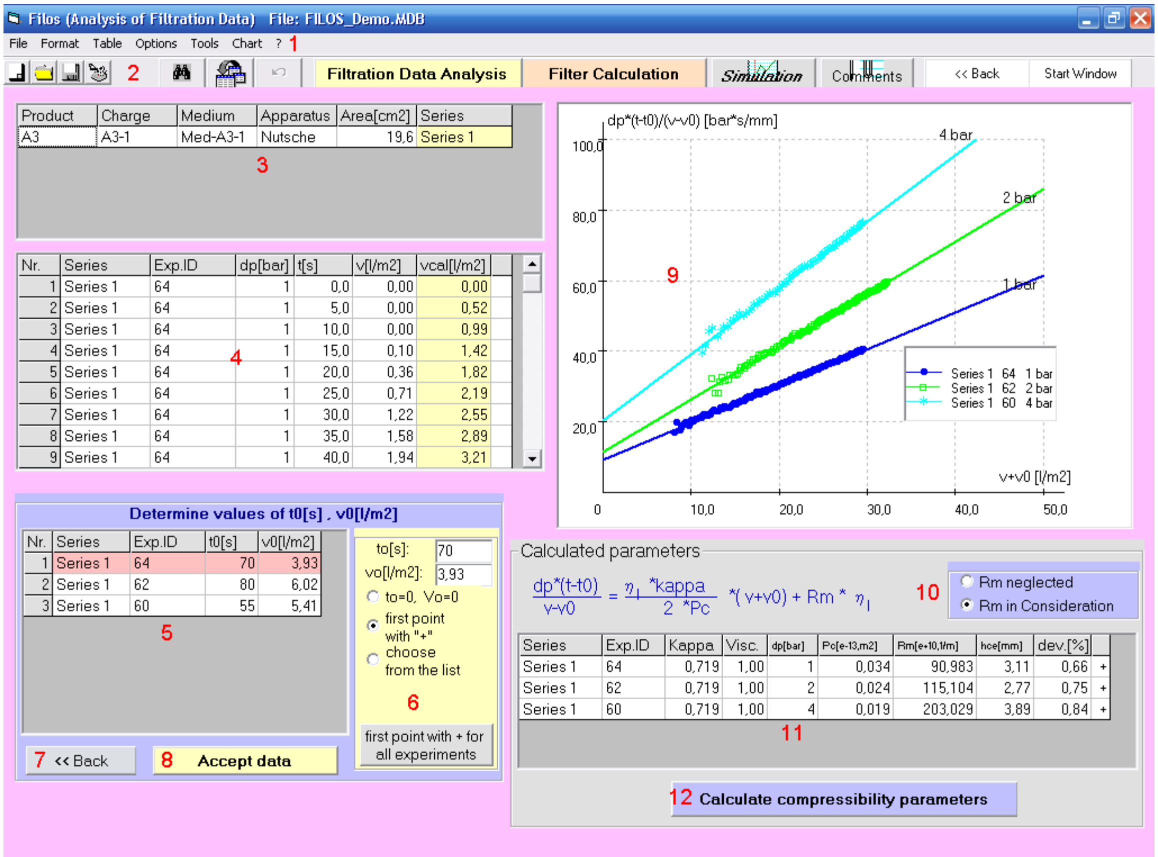
Comments to the first result window

As already mentioned, the program gives the possibility to analyse all experiments of one test series together or even all experiments of all test series together. It is highly recommended that you first analyse each experiment separately because for this option you have all possibilities to correct the experimental errors and exclude them from the regression analysis. This module is an excellent and unique tool for reliable determination of the cake permeability Pc and the filter medium resistance Rm and hce (results are displayed in (12)). For the program is not disturbing if for some time periods due to problems with the testing apparatus or with the maintenance of constant pressure difference or with the filtration behaviour of the suspension we have deviations from the cake formation theory. The *Detailed Cake Formation* module enables the easy excluding of not good measurements, so that correct values of the filtration parameters can be determined.

Besides the advantage of the accurate calculation of the cake permeability and the filter medium resistance this module makes the experimental procedure easier because many errors during the experiments can be detected and eliminated. An example what is meant with that: It is known that very often at the beginning of the filtration experiment due to accumulation of the filtrate in the lower part of the nutsche filter the measurements are not correct and the theory based plotting of the results (10) give us for short times not the expected straight line. To avoid this people tried to fill this part of the apparatus with filtrate before starting the experiment, so that an immediate (correct) registration of the filtrate mass by the balance can be recorded. And this as experimental measurement to be able to have a correct determination of the cake permeability and the filter medium resistance. Such experiments are of course very complicated. Using FILOS such complicated experiments are not necessary because the program enables the easy and reliable "filtering" of the wrong measured data.

FILOS enables the reliable determination of the cake permeability and the filter medium resistance because it uses the general cake formation equation (see eq. in the right bottom side of the results window above) and it gives the possibility to start the regression analysis not from time zero but from any time t0. This time t0 should be greater than zero but still small enough. High t0-values mean also problems with accuracy. In most of the cases the selection of the option *first point with* + gives reliable values for cake permeability and filter medium resistance.

2. 2.2: Detailed Cake Formation - The First Results Window- Option *Current Series*



Results window of the module *Detailed Cake Formation* when in the main window the option *Current series* is selected. That means we analyse together all experiments with + of the selected test series. Each experiment is analysed separately and for each experiment we have as results the cake permeability Pc and the filter medium resistance Rm and hce (see result table (11))

1

Menu of the main results window

2

Task bar of the main results window

3

Display of the name of the current test series (the name is characterized by the values of the 5 parameters and it is the “family name” of the experiment. The name *Series 1* is a default help name. It makes sense to use this help name when we compare experiments from different test series to identify the series. In such a case we don’t have to use the names/values of all five parameters for the identification.

4
Table with the input data for the regression analysis for all experiments with + of the selected test series.
- Rows without + are not considered for the regression analysis. Inserting / removing the + via double click the corresponding row.
- Each row has the name (help name) of the test series, the Exp. ID, the pressure difference dp, the filtration time t, the area specific filtrate volume v and the calculated specific filtrate volume vcal. We calculate vcal by using the cake formation equation for the given time and the calculated filtration parameters which are displayed in (11).

5
Overview table for the selected t0, v0 values for each experiment used by the program for the regression analysis. By selecting one experiment (one row of this table) the corresponding t0,v0-option is displayed in the field (6). In (6) we can change the option for each experiment separately or for all experiments together by clicking the command button in (6).

6
Defines which (t0, v0) we should use in the cake formation equation (see equation displayed in this window) for the regression analysis to determine the cake permeability Pc and the filter medium resistance Rm and hce for every experiment separately. In many cases we can get accurate values for these parameters if we don't use the first option (t0=0, V0=0) but the option *first point with "+"*. Even with this option it is sometimes necessary to remove the first measurement points (remove the +) to get a straight line. The third option: *choose from the list* enables the selection of any t0, V0. It is recommended for this option to use relatively small values of t0 otherwise you will have not accurate results. Important for accurate values for permeability and filter medium resistance is that the considered measurements (these are the rows with + or the displayed points in the diagram) give us a straight line. In many cases the first points are not on a straight line. It is recommended to use the option first point with "+". If still we don't have a straight line remove the points which are not in the straight line and then the filtration parameters will be accurate.

7 Goes back to the main window

8
Click always the command button *Accept data* if you want that the changes are kept after you exit this window or/and if you want to save these changes.

9
Theory based plotting of the measured data and the regression line. For each experiment a separate analysis and a separate line. The slope indicates the cake permeability and the intersection with the y-axis indicates the filter medium resistance. For example parallel lines of all experiments means the same permeability (incompressible filter cake).

- The diagram can be copied and pasted for example to a word document. This is valid for all diagrams of the program. Select for that the menu *Chart* → *Copy Chart*.
- Clicking the Menu *Chart* → *Diagram Outlook* you have many possibilities for formatting the diagram.
- Double clicking in the diagram area you can write text giving explanations to the curves.
- Clicking the x- and y-axis description you can change or /and move this description
- You can remove any measured points from the diagram by drawing a rectangular which includes these point(s). On the right top side of the diagram appear the command buttons *Cut Points* and *Cancel*. Clicking *Cut Points* you remove the measured points from the diagram and you have automatically a refreshing of the window including a recalculation of the parameters.
- The diagram dp* dt/dv =f(v) is displayed instead of the default by clicking the menu *Options* → *dp * dt/dv =f(v)*
-

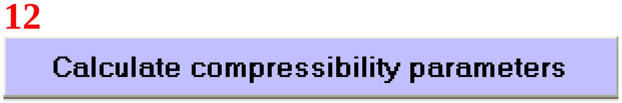
10

By selecting the option *Rm neglected* the permeability of the system cake-filter medium is calculated and Rm and hce is set to zero for all experiments. In this case the regression lines start from (0,0). This option is automatically selected when we have for a given experiment only one measurement point.

11

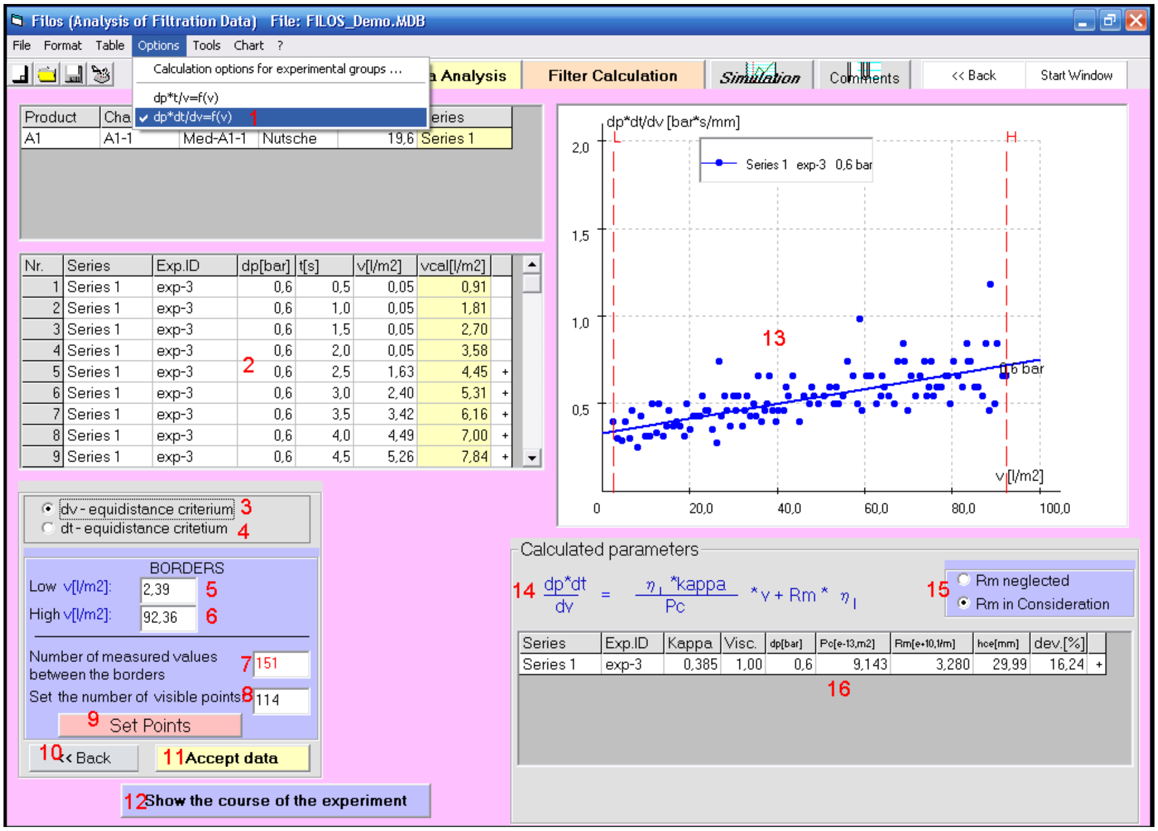
Table with the results of the regression analysis (for each experiment one row): These results are the cake permeability Pc, filter medium resistance Rm, cake related filter medium resistance hce and relative deviation in % indicating the degree of the deviation between the measured and calculated values (values on the regression line). Besides the above result parameters we have as first column the display of the Series name (default name), the Exp. ID, the concentration parameter kappa, the filtrate viscosity and the pressure difference dp. The kappa- and viscosity columns are also input columns. Changing these values we can see the influence on the result parameters Pc, Rm and hce.

12



Clicking *Calculate Compressibility Parameters* opens the window for the analysis of the cake permeability Pc and the filter medium resistance Rm as a function of the pressure difference and the determination of the cake compressibility nc and the filter medium compressibility mc. The compressibility calculation window opens if at least 2 experiments with different pressure difference are analysed in the first results window.

2. 2.3: Detailed Cake Formation - The First Results Window- Analysis Using the Differential Cake Formation Equation Option: *Current Experiment*



Results window of the module *Detailed Cake Formation* when in the main window the option *Current Experiment* is selected (that means we analyse only the selected experiment of the main window) and the regression analysis is based on the differential cake formation equation (14). This window is not the default window and has to be selected by clicking the Menu *Options → dp* dt/dv = f(v)*. Default is the results window with the regression analysis based on the integral cake formation equation.

1

Selection of the results window for analysis of the selected experiment based on the differential cake formation equation by clicking the menu *Options → dp*dt/dv = f(v).*

2

Listing of the input data for the regression analysis.

- Rows without + are not considered for the regression analysis.
- Inserting / removing the + via double clicking the corresponding row.
- Each row has the name (help name) of the test series, the Exp. ID, the pressure difference dp, the filtration time t, the area specific filtrate volume v and the calculated specific filtrate volume vcal. We calculate vcal by using the cake formation equation for

the given time and the calculated filtration parameters which are displayed in (16). By clicking *Show the course of the experiment* (12) we get the diagram with the comparison between measured and calculated values.
- You can change the measured points which have to be considered for regression analysis by entering the wished number of measured points in the input field *Set the number of visible points* in (8) and then click *Set Points*. This number should be of course less than the number displayed in red in (7).

3

When reducing the number of measurements (points in the diagram) by entering the wished number of points in the input field *Set the number of visible points* (8) when we select the option *dv-equidistance criterium* the program reduces the points in such a way that the filtrate volume difference dv of the reduced points is almost constant. This guarantees a minimal error regarding the filtration parameters and compared to the use of all measured points.

4

When reducing the number of measurements (points in the diagram) by entering the wished number of points in the input field *Set the number of visible points* (8) when we select the option *dt-equidistance criterium* the program shows the diagram v=f(t) and reduces the points in such a way that the filtration time difference dt of the reduced points is almost constant.

5

Input and display field for the x-axis (= v-axis) position of the left red bar in the diagram. Moving the left red bar by keeping the mouse pressed the corresponding v-value is displayed in this field. Or entering another value in this field the left red bar in the diagram takes the new entered x-axis position.

6

Input and display field for the x-axis (= v-axis) position of the right red bar of the diagram. Moving the right red bar by keeping the mouse pressed the corresponding v-value is displayed in this field. Or entering another value in this field the right red bar in the diagram takes the new entered x-axis position.

7

Display of the number of measured points between the left and the right red bar. This number includes the visible points in the diagram (these are the points with +) as well as the not visible points (these are the points without +).

8

Input and display field for the wished number of measurement points between the borders (red bars) we want to consider for the regression analysis, that means we want to have visible on the diagram (these will be the rows in table (2) with the +. All other rows will not have the +.

9
The command button *Set Points* refreshes the window (displays a new diagram and the recalculated filtration parameters in (16)) in case we change the measured points we want to consider for the regression analysis. This change can be done by moving the red bars or by entering a new number in the input field *Set the number of visible points* and at the end clicking *Set Points*.

10 Goes back to the main window

11
Click always the command button *Accept data* if you want that the changes are kept after you exit this window or/and if you want to save these changes.

12
By clicking *Show the course of the experiment* instead of the theory based diagram (default diagram) the diagram v=f(t) is displayed with a comparison between measured values (points) and calculated values. The calculated values are listed in the last column of table (2). We get these values from the cake formation equation which is displayed in this window by using the calculated filtration parameters Pc and Rm.

13
Theory based plotting of the measured data and the regression line. The linear regression is based on the differential cake formation equation (14). The slope of the line indicates the cake permeability and the intersection with the y-axis indicates the filter medium resistance.
- The diagram can be copied and pasted for example to a word document. This is valid for all diagrams of the program. Select for that the menu *Chart → Copy Chart*.
- Clicking the Menu *Chart → Diagram Outlook* you have many possibilities for formatting the diagram.
- Double clicking in the diagram area you can write text giving explanations to the curves.
- Clicking the x- and y-axis description you can change or /and move this description
- You can remove any measured points from the diagram by drawing a rectangular which includes these point(s). On the right top side of the diagram appear the command buttons *Cut Points* and *Cancel*. Clicking *Cut Points* you remove the measured points from the diagram and you have automatically a refreshing of the window including a recalculation of the parameters.
- You can hide the borders (red lines) by clicking the menu *Chart → hide borders*
- Clicking *Show the course of the Experiment* instead of the above default diagram the v=f(t) diagram is plotted with the comparison of measured and calculated values (v is the area specific filtrate volume).
- The diagram dp* t/v =f(v) (default diagram) is displayed by clicking the menu *Options → dp * t/v =f(v)*

14

Differential cake formation equation used for the linear regression analysis.

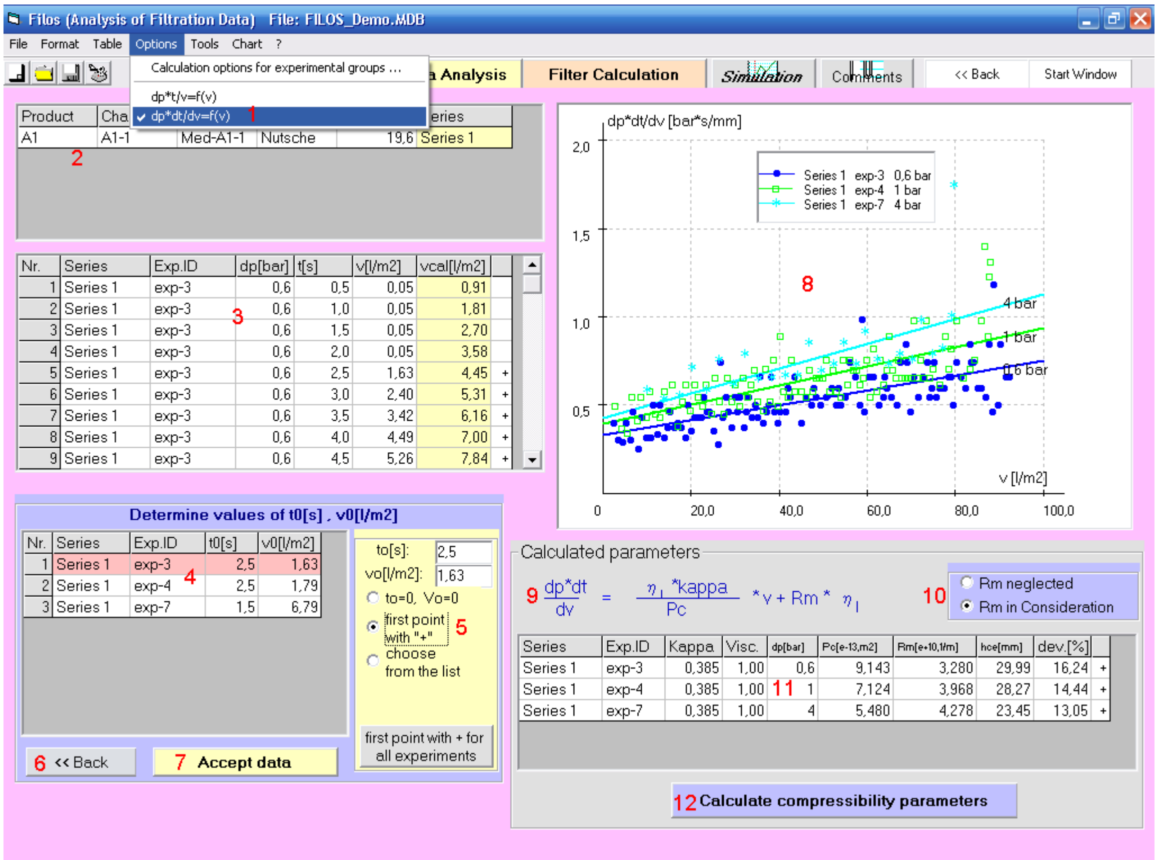
15

By selecting the option *Rm neglected* the permeability of the system cake-filter medium is calculated and Rm and hce is set to zero. In this case the regression line starts from (0,0).

16

Table with the results of the regression analysis: cake permeability Pc, medium resistance Rm, medium resistance hce and relative deviation in % quantifying the deviation between the measured and calculated values (values on the regression line). Besides the above result parameters we have as first column the display of the Series name (default name), the Exp. ID, the concentration parameter kappa, the filtrate viscosity and the pressure difference dp. The kappa- and viscosity columns are also input columns. Changing these values we can see the influence on the result parameters Pc, Rm and hce.

2. 2.4: Detailed Cake Formation - The First Results Window- Analysis Using the Differential Cake Formation Equation Option: *Current Series*



Results window of the module *Detailed Cake Formation* when in the main window the option *current series* is selected (that means we analyse all experiments with + of the selected series) and the regression analysis is based on the differential cake formation equation (9). This window is not the default window and has to be selected by clicking the Menu *Options* → *dp* dt/dv = f(v).* Default is the results window with the regression analysis based on the integral cake formation equation.

1

Selection of the results window for analysis of the experiments of the selected test series based on the differential cake formation equation by clicking the menu *Options* → *dp*dt/dv = f(v).*

2

Display of the name of the current test series (the name is characterized by the values of the 5 parameters and it's the "family name" of the experiment. The name *Series 1* is a default help name. It makes sense to use this help name when we compare experiments from different test series to identify the series. In such a case we don't have to use the names/values of all 5 parameters for the identification.

3

Listing of the input data for the regression analysis.
- Rows without + are not considered for the regression analysis.
- Inserting/removing the + via double click the corresponding row.
- Each row has the name (help name) of the test series, the Exp. ID, the pressure difference dp, the filtration time t, the area specific filtrate volume v and the calculated specific filtrate volume vcal. We calculate vcal by using the cake formation equation for the given time and the calculated filtration parameters which are displayed in (11).

4

!!! Not relevant for this option but only for the regression analysis based on the integral cake formation equation, which is selected by clicking the menu *Options*→ *dp* t/v=f(v)*

Overview table for the selected t0, v0 values for each experiment used by the program for the regression analysis. By selecting one experiment (one row of this table) the corresponding t0,v0-option is displayed in the field (5). In (5) we can change the option for each experiment separately or for all experiments together by clicking the command button in (5).

5

!!! Not relevant for this option but only for the regression analysis based on the integral cake formation equation, which is selected by clicking the menu *Options*→ *dp* t/v=f(v)*

6 Goes back to the main window

7

Click always the command button *Accept data* if you want that the changes are kept after you exit this window or/and if you want to save these changes.

8

Theory based plotting of the measured data and the regression line. Separate analysis for each experiment. The linear regression is based on the differential cake formation equation (9). The slope of each line indicates the cake permeability and the intersection with the y-axis indicates the filter medium resistance.
- The diagram can be copied and pasted for example to a word document. This is valid for all diagrams of the program. Select for that the menu *Chart* → *Copy Chart*.
- Clicking the Menu *Chart* → *Diagram Outlook* you have many possibilities for formatting the diagram.
- Double clicking in the diagram area you can write text giving explanations to the curves.
- Clicking the x- and y-axis description you can change or /and move this description

- You can remove any measured points from the diagram by drawing a rectangular which includes these point(s). On the right top side of the diagram appear the command buttons *Cut Points* and *Cancel*. Clicking *Cut Points* you remove the measured points from the diagram and you have automatically a refreshing of the window including a recalculation of the parameters.
- The diagram dp* t/v =f(v) (default diagram) is displayed by clicking the menu *Options* → *dp * t/v =f(v)*

9

Differential cake formation equation used for the linear regression analysis.

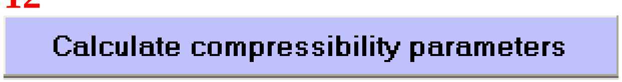
10

By selecting the option *Rm neglected* the permeability of the system cake-filter medium is calculated separately for each experiment and Rm and hce is set to zero. In this case the regression line starts from (0,0).

11

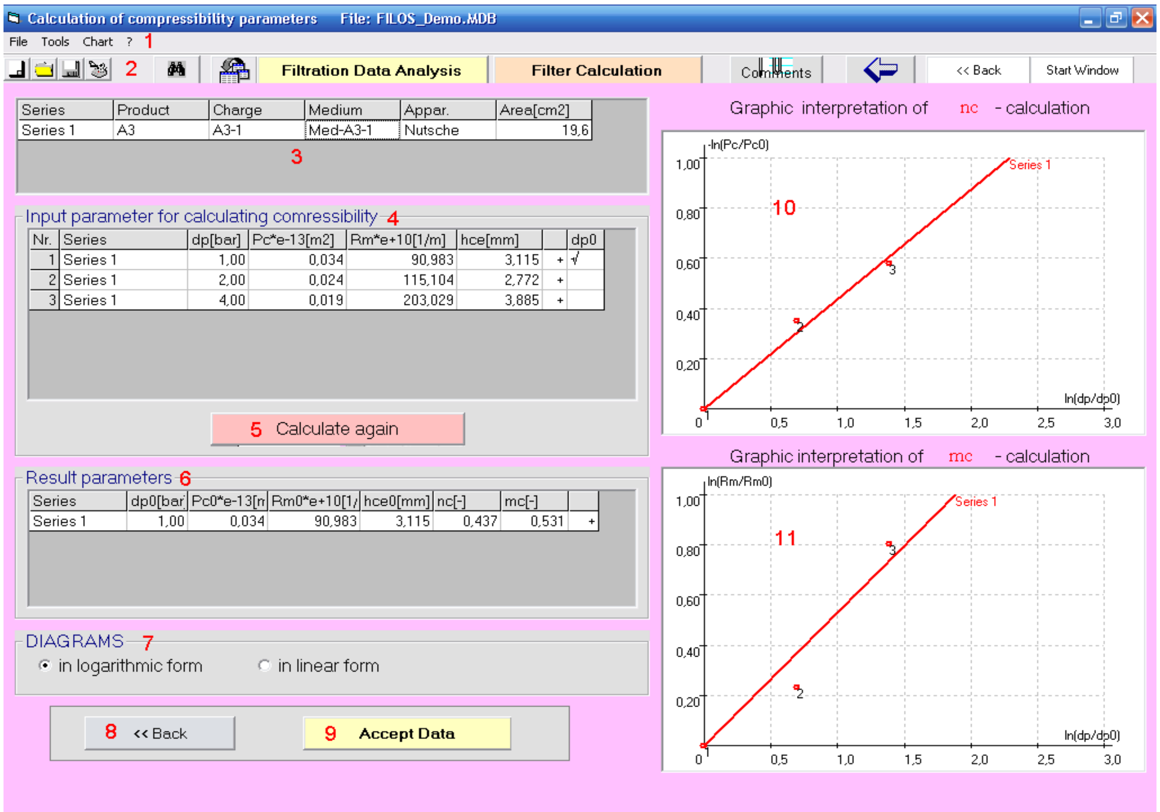
Table with the results of the regression analysis (for each experiment one row): cake permeability Pc, medium resistance Rm, medium resistance hce and relative deviation in % quantifying the deviation between the measured and calculated values (values on the regression line). Besides the above result parameters we have as first column the display of the Series name (default name), the Exp. ID, the concentration parameter kappa, the filtrate viscosity and the pressure difference dp. The kappa- and viscosity columns are also input columns. Changing these values we can see the influence on the result parameters Pc, Rm and hce.

12



The command button *Calculate Compressibility Parameters* opens the window for the analysis of the cake permeability Pc and the filter medium resistance Rm as a function of the pressure difference and the determination of the cake compressibility nc and the filter medium compressibility mc. The compressibility calculation window opens if at least 2 experiments with different pressure difference are analysed in the main results window.

2.3 Detailed Cake Formation – The Second Results Window (Calculation of Cake Compressibility and Filter Medium Compressibility)



Results window for the cake and filter medium compressibility. The results of this window are displayed in table (6): For a definite pressure difference dp0 we get the cake permeability Pc0, the filter medium resistance Rm0 and hce0, the cake compressibility nc and the filter medium compressibility mc. Having the cake compressibility nc and the filter medium compressibility mc the cake permeability and filter medium resistance for any pressure difference can be calculated. Due to the problem regarding the accuracy of the filter medium resistance, for the calculation of filters in the *Filter Calculation*-part the filter medium compressibility is not considered, that means only the medium resistance hce0 is used. Regarding the filter cake, besides the cake Permeability Pc0 for the pressure difference dp0 the use of the cake compressibility nc is essential.

Input parameters for this window are the results of the first results window (that is the window that calculates the cake permeability and the filter medium resistance for each experiment separately). These results are listed in table (4).

1
Menu bar of the cake compressibility window

2
Task bar of the cake compressibility window

3
Display of the name of the current test series (the name is characterized by the values of the 5 parameters and it's the "family name" of the experiment. The name *Series 1* is a default help name. It makes sense to use this help name when we have experiments from different test series to identify the series. This is the case when we select in the main window the analysis option *all experiments*. In such a case we don't have to use the names/values of all 5 parameters for the identification of the experiment.

4
Results of the first results window. These are the input data for the regression analysis in this window for the determination of the cake and filter medium compressibility factors nc and mc. The dp0 and Pc0 are defined by double clicking the last column (dp0-column). Default dp0 is taken the minimal value. Each row of the table with + is one point in the diagrams (10) and (11). The (0,0) point is always the row with the dp0.
- When we have more than one test series then the rows for each row are distinguished by a zebra colour. For each test series we have an own dp0, Pc0 and an own regression line and also an own results row in (6).
- The dp, Pc and Rm columns are input columns, that means the values can be changed (not recommended) and by clicking *Calculate again* new values for the result parameters are calculated.

5.
Clicking *Calculate again* we recalculate the result parameters (cake compressibility and filter medium compressibility) in case we change the values in the input table (4). The values in table (4) are taken as default from the first results window and are the results of the regression analysis there.

6
Display of the result parameters. These are the selected dp0 and the corresponding Pc0, Rm0 and hce0 and the results of the regression analysis: cake compressibility nc and filter medium compressibility mc. Each test series has its own results (its own results row). Please notice that the results in this table, for each test series separately, can be considered as the final analysis results for the test series. The values dp0, Pc0, nc and hce0 are the parameters which are needed for the Filter calculation modules to calculate the filter performance.

7
When we have the option *in logarithmic form* (that is the default option) the diagrams (10) and (11) are double logarithmic with the line of the regression analysis. If the option

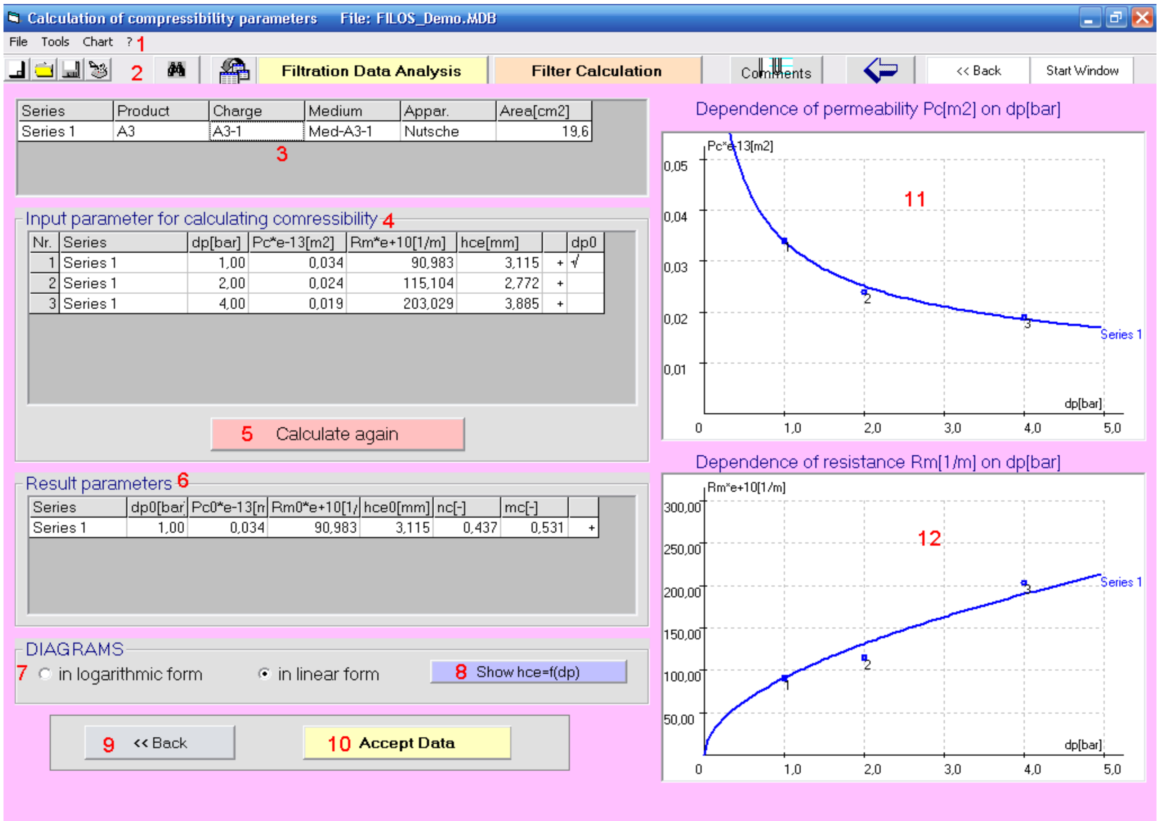
in linear form is selected then we have as graphs the cake permeability Pc as a function of the pressure difference Pc=f(Dp) and as second graph the filter medium resistance Rm as a function of the pressure difference Rm=f(Dp).

8 Goes back to the main results window.

9
Click always *Accept Data* if you want to keep these results also after exiting the window. You can then click *Save* from any other window and these accepted data will be saved in the database file.

10
Diagram showing the cake permeability as a function of the pressure difference in a double logarithmic way. The line is the regression line. The slope of the line is the cake compressibility. The points are the cake permeability –values determined in the main results window with the corresponding pressure differences. This is the default graph. If the option in linear form is selected then we have not a double logarithmic curve but a linear. If more than one test series are analysed (that is the case when we select the option all experiments in the main window) then we have for each test series an own regression line.

11
Diagram showing the filter medium resistance Rm as a function of the pressure difference in a double logarithmic way. The line is the regression line. The slope of the line is the filter medium compressibility mc. The points are the medium resistance –values determined in the first results window with the corresponding pressure differences. This is the default graph. If the option *in linear form* is selected then we have not a double logarithmic curve but a linear. Don't worry if sometimes the points in this case do not fit well to the regression line. This is due to the difficulty to get an accurate filter medium resistance when the measurement points are not enough (for example for filtration experiments with fast filtering suspensions). For the filter calculation is not necessary to have the filter medium compressibility but just the hce0 –value.



-Results window for the cake and filter medium compressibility when the option in (7) *in linear form* is selected. The default option is *in logarithmic form*. The results of this window are displayed in table (6). For a definite pressure difference dp0 we get the cake permeability Pc0 and the filter medium resistance Rm0 and hce0. Having the cake compressibility nc and the filter medium compressibility mc the cake permeability and filter medium resistance for any pressure difference can be calculated. Due to the problem regarding the accuracy of the filter medium resistance for the calculation of filters in the Filter Calculation-part the filter medium compressibility is not considered, that means only the medium resistance hce0 is used. Regarding the filter cake besides the cake Permeability Pc0 for the pressure difference dp0 the use of the cake compressibility nc is essential. Input parameters for this window are the results of the main results window (that is the window that calculates the cake permeability and the filter medium resistance for each experiment separately). These results are listed in table (4).

1

Menu bar of the second results window (cake compressibility window)

2

Task bar of the second results window (cake compressibility window)

3

Display of the name of the current test series (the name is characterized by the values of the 5 parameters and it is the "family name" of the experiment. The name *Series 1* is a default help name. It makes sense to use this help name when we have experiments from different test series to identify the series. This is the case when we select in the main window the analysis option *all experiments*. In such a case we don't have to use the names/values of all 5 parameters for the identification of the experiment.

4

Results of the main results window. These are the input data for the regression analysis in this window for the determination of the cake and filter medium compressibility factor. The dp0 and Pc0 are defined by double clicking the last column (dp0-column). Default dp0 is taken the minimal value. Each row of the table with + is one point in the diagrams (10) and (11). The (0,0) point is always the row with the dp0.
- When we have more than one test series then the rows for each row are distinguished by a zebra colour. For each test series we have an own dp0, Pc0 and an own regression line and also an own results row in (6).
- The dp, Pc and Rm columns are input columns, that means the values can be changed and by clicking *Calculate again* new values for the result parameters are calculated.

5

Clicking *Calculate again* we recalculate of the result parameters (cake compressibility and filter medium compressibility) in case we change the values in the input table (4). The values in table (4) are taken as default from the main results window and are the results of the regression analysis there.

6

Display of the result parameters. These are the selected dp0 and the corresponding Pc0, Rm0 and hce0 and the results of the regression analysis: cake compressibility nc and filter medium compressibility mc. Each test series has its own results (its own results row). Please notice that the results in this table separately for each test series can be considered as the final analysis results for the test series. The values dp0, Pc0, nc and hce0 are the parameters which are needed for the *Filter Calculation* modules to calculate the filter performance.

7

When we have the option is *in logarithmic form* (that is the default option) the diagrams (10) and (11) are displayed double logarithmic with the line of the regression analysis. If the option *in linear form* is selected then we have as graphs the cake permeability Pc as a function of the pressure difference Pc=f(Dp) and as second graph the filter medium resistance Rm as a function of the pressure difference Rm=f(Dp).

8

Opens the window that shows in a linear form a graph with the filter medium resistance hce as a function of the pressure difference Dp.

9

Goes back to the main results window.

10

Click always Accept Data if you want to keep these results also after exiting the window. You can then click Save from any other window and these accepted data will be saved in the database file.

11

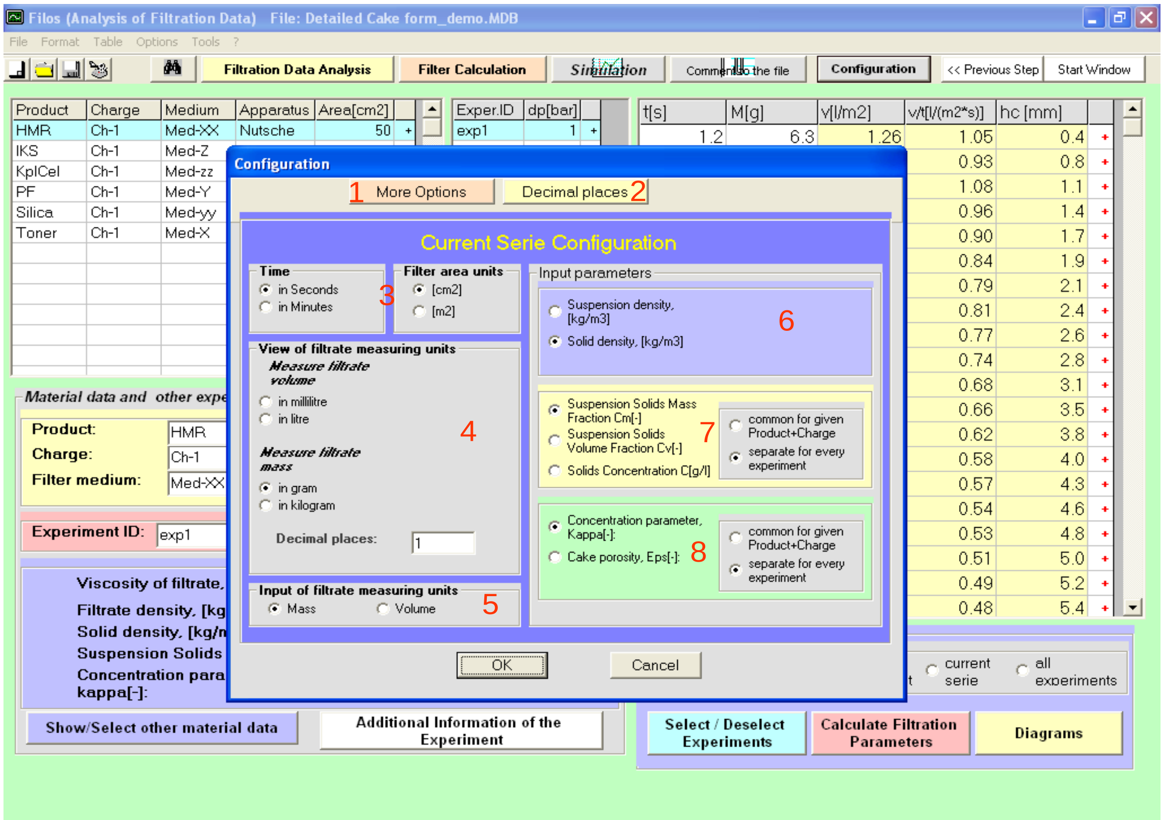
Diagram showing the cake permeability as a function of the pressure difference. It compares the calculated values with the “measured” values (points). The points are the cake permeability –values determined in the first results window with the corresponding pressure differences. If more than one test series are analysed (that is the case when we select the option *all experiments* in the main window) then we have for each test series an own curve.

12

Diagram showing the filter medium resistance Rm as a function of the pressure difference. It compares the calculated values with the “measured” values (points). The points are the filter medium resistance –values determined in the first results window with the corresponding pressure differences. If more than one test series are analysed (that is the case when we select the option *all experiments* in the main window) then we have for each test series an own curve.

2.4 Configuration Window, Calculation of Cake Porosity, Calculation of the kappa Parameter

Configuration window for Detailed Cake Formation and Single Tests Modules



Configuration window for the *Detailed Cake Formation* module (the same window is for the module *Cake formation - Single Tests*). Can be opened after clicking the Configuration, which is placed in the upper task bar of the main window.

1

Enables the display of the suspension solids concentration and cake porosity in % and without %

2

Defines the decimal places for the output parameters. If opening the decimal places-window all values are zero then, this means that the program wasn't properly installed. The reason can be that the program folder (subfolder of program files) was write-protected when the program was first started after the installation.

3

Time in sec or min and filter area in cm2 or m2.

4

Unit for the filtrate amount. The parameter of the filtrate amount that has to be entered in the input table of the main window can be the filtrate mass or the filtrate volume. This is defined in the field (5). Default is the filtrate mass

5

Definition of the filtrate amount parameter (mass or volume) for the input table in the main window.

6

Instead of the solids density the suspension density can be entered in the material input field of the main window (default is the solids density)

7

Selection of the suspension solids concentration parameter as input (default is mass solids fraction Cm). If the option button separate for every experiment is selected this means that for each experiment we can use different values.

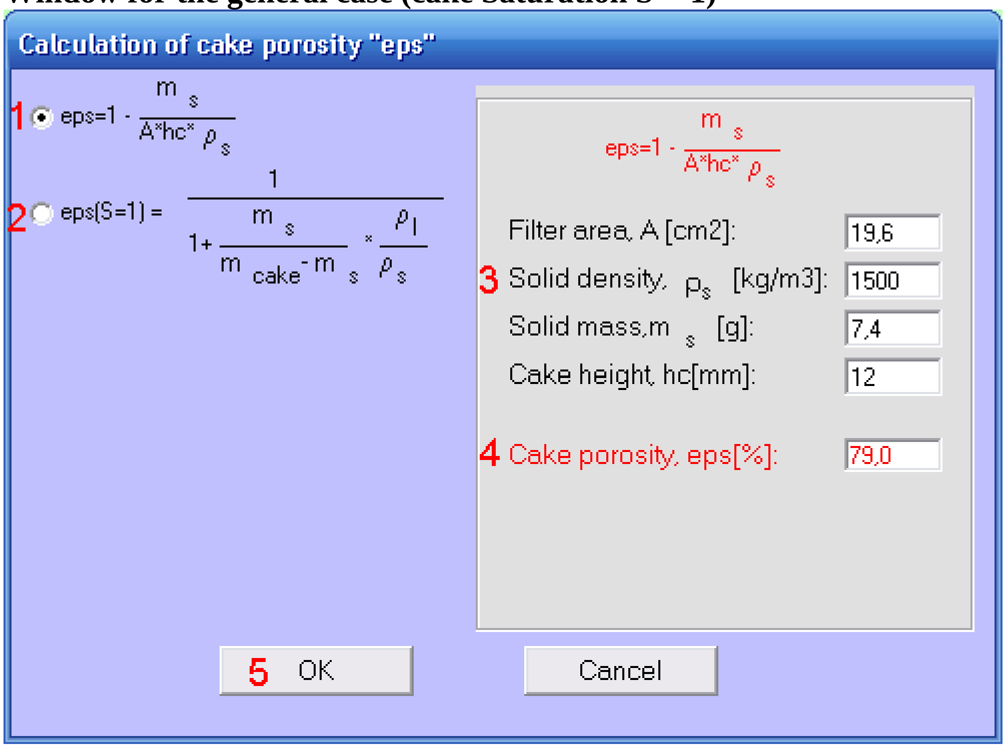
8

Instead of the parameter kappa the cake porosity can be entered. This porosity considers only the voids between particles (that's important to know in case that the particles have an inner porosity). The option separate for each experiment means that we can use for each experiment individual kappa or porosity values.

Calculation of the Cake Porosity

The cake porosity is for the analysis of filtration data and for the calculation of filters a very important input parameter, which first has to be determined from a cake formation experiment. We have two cases for the porosity calculation:
- If the cake has not a 100% saturation (gas in the cake voids) then we need to form a cake and measure the cake height and the dry solids mass of the whole cake. Additional input parameters are the solids density and the filter area. (see option (1)).
- If a cake has 100% saturation then we don't need the cake height of the formed cake but only a representative part of the cake and the wet and dry mass of this sample. Additionally the liquid and solids densities are needed (see option (2))

Window for the general case (cake Saturation S<=1)



Window for the calculation of the cake porosity for the general case (cake Saturation S<=1). This window opens after clicking the command button *Calculate Cake Porosity* in the left lower part of the main window. This command button appears only if the cake porosity and not the parameter kappa is an input parameter. If kappa is the input parameter the cake porosity can be calculated from the *Calculator* window which may be opened from the menu *Tools* → *Calculator* (Label *Calculate Eps*)

1

Selects the option for not saturated cake and displays on the right the necessary input parameters for the porosity calculation

2

Selects the option for a saturated cake (S=1) and displays on the right the necessary input parameters for the porosity calculation

3

Input parameters for the cake porosity calculation when the cake is not saturated (S<1):

- filter area of the test apparatus
- density of the solids (material parameter)
- solid mass ms is the cake mass without any liquid in it (after compete drying). Please notice that in case that the liquid in the cake before drying has relatively a high salt concentration then after drying this salt stay as solids in the cake and is an error source.
- the cake height should be measured as accurate as possible. It is recommended to use thick cakes in order to avoid big errors.

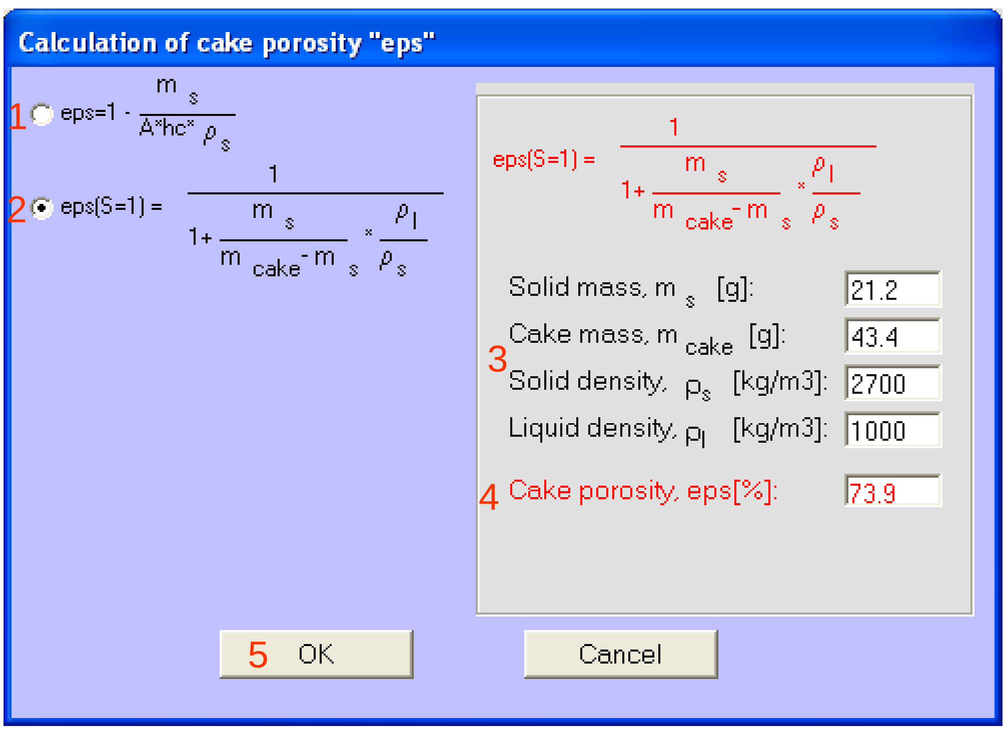
4

displays the calculated cake porosity which can be taken to the main program window by clicking OK

5

Takes the calculated cake porosity to the porosity input field in the main window

Window for the saturated cake (S=1)



Window for the calculation of the cake porosity for the saturated cake (cake Saturation S=1). In this case the measurement of the cake height is not necessary. This window opens after clicking the command button *Calculate Cake Porosity* in the left lower part of the main window. This command button appears only if the cake porosity and not the parameter kappa is an input parameter. If kappa is the input parameter the cake porosity can be calculated from the *Calculator* window which may be opened from the menu *Tools* → *Calculator* (Label *Calculate Eps*)

1
Selects the option for not saturated cake and displays on the right the necessary input parameters for the porosity calculation

2
Selects the option for a saturated cake (S=1) and displays on the right the necessary input parameters for the porosity calculation

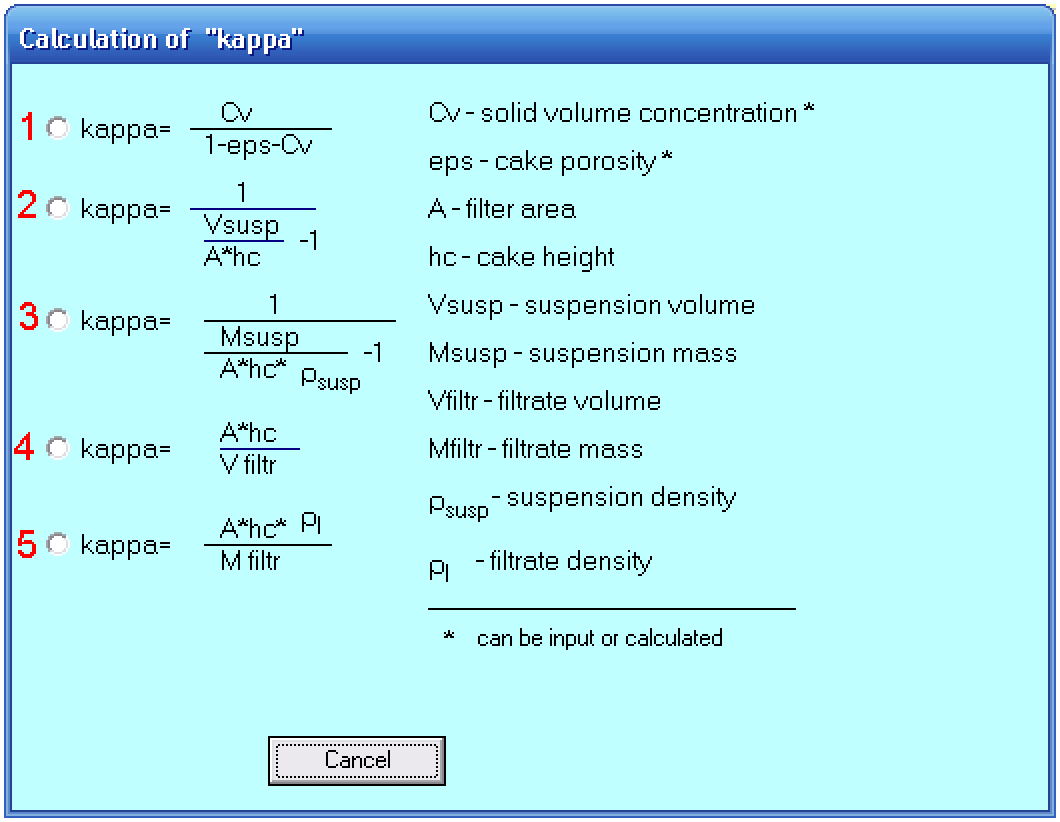
3
Input parameters for the cake porosity calculation when the cake is saturated (S=1):
- solid mass ms is the mass of the cake sample after compete drying. Please notice that in case that the liquid in the cake before drying has relatively a high salt concentration then after drying this salt stay as solids in the cake and is an error source.
- mcake mass of the wet cake sample (before drying)
- density of the solids
- density of the liquid in the cake before drying

4
Displays the calculated cake porosity which can be taken to the main program window by clicking *OK*

5
Takes the calculated cake porosity to the porosity input field in the main window

Calculation of the kappa - parameter

The accuracy of the parameter kappa (defined as cake volume over the corresponding filtrate volume) influences the accuracy of the cake permeability value because this parameter is in the cake formation equation. The program enables all options (5 options) for the calculation of the kappa-value.



This window opens after clicking the command button *Calculate "kappa"* in the left lower part of the main window. This command button appears only if the parameter *kappa* and not the cake porosity is the input parameter. If cake porosity is the input parameter the kappa - value can be calculated from the *Calculator* window which may be opened from the menu *Tools* → *Calculator* (Label *Concentration parameter*). Please notice that in the calculator window the kappa – parameter is called concentration parameter.

1

kappa calculation from the suspension solids volume fraction Cv and the cake porosity. Selecting this option the program enables also the calculation of Cv and cake porosity in the case that these values have to be first determined.

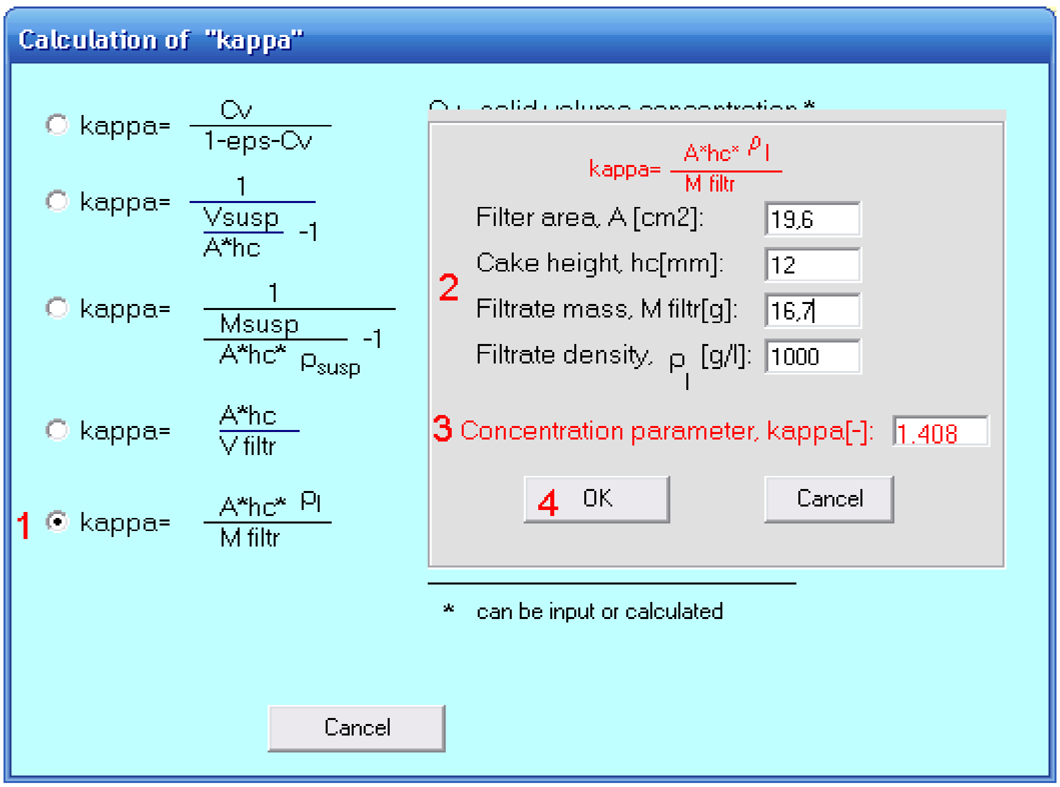
2

kappa calculation from one cake formation experiment if the Suspension volume Vsusp, the filter area A and the cake height hc after finishing the cake formation are known.

3
kappa calculation from one cake formation experiment if the Suspension mass Msusp, the suspension density ρsusp, the filter area A and the cake height hc after finishing the cake formation are known.

4
kappa calculation from one cake formation experiment if the filtrate volume Vfiltr, the filter area A and the cake height hc after finishing the cake formation are known.

5
kappa calculation from one cake formation experiment if the filtrate mass Mfiltr, the filtrate density, the filter area A and the cake height hc after finishing the cake formation are known.



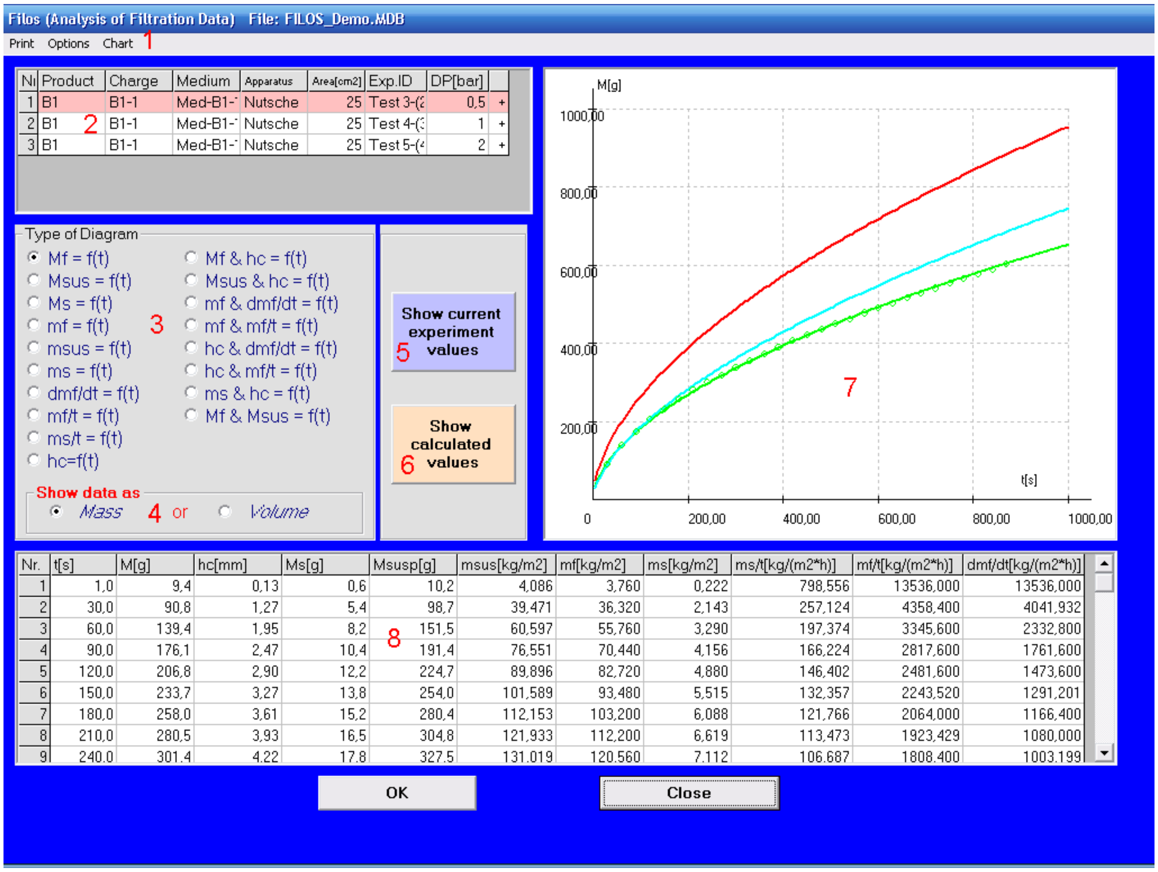
1 Typical option for the determination of the kappa-parameter when the test apparatus allows the measurement of the filtrate mass to the time the cake formation step finished and before starting washing or deliquoring.

2.Input of the filter area A, the cake height hc, the filtrate mass Mfiltr at the end of the cake formation and the filtrate density.

3 Display of the calculated kappa-value

4 With OK the calculated kappa-value is taken to the input field in the main window.

2.5 Diagrams Tool of the Detailed Cake Formation Module



The *Diagrams* window displayed after clicking the command button *Diagrams* in the main window. In the first two columns of table (8) we have the measured values which are also displayed in the first two columns of the input table in the main window. In the other columns we have the display of other calculated parameters by using mass balances. Depending on the option we select in the main window: *Current experiment*, *current series* or *all experiments* we have a display in the graph (7) only of the current experiment or of all experiments of the current series with + or all experiments in the main window with +. The data in table (8) are for the selected experiment in table (2). This selected experiment is identified in the graph because of the measured points, which are displayed only for the selected experiment. The curves are fitting the measured data via regression analysis (just an empirical fitting without using any physically based model). In (3) we have the possibility to display in the graph different parameters even double diagrams.

1

Menus of the *Diagrams* window. In the menu *Options* → *Set Filter Area* you have the possibility to enter any filter area and have with this new filter area a recalculation of all parameters and refreshing of the diagrams. For that click the menu *Options* → *Set Filter Area* and then select the option *common value for filter area* and enter the wished filter area in the filter area input field and click OK.

- In the menu *Chart* you can copy the diagram and paste it for example in a word document and you have formatting possibilities for the graph.

2
Table with listing of all experiments selected from the main window. The data of the selected experiment are displayed in table (8). In the Graph only those experiments with + in the last column are displayed. Remove /reinsert the + by double clicking the corresponding row.

3
A listing of all possible diagrams. By selecting the wished diagram from the list the diagram is automatically refreshed. By clicking the command button *show current experiment values* (5) the data of the diagram are displayed as table.

4
Selecting the option *Volume* then in the whole window instead of Mass the Volume is displayed. Default is the Option *Mass*.

5
Show current Experiment values: It shows as table the data of the current experiment in the current graph. These data are also displayed in table (8) but together with other parameters.

6
Show calculated values: Opens a window with a table showing the calculated time dependence of the current y-axis parameter(s) and for all experiments displayed in the diagram. The time interval may be defined in this window.

7
The displayed diagram has as x-axis always the filtration time. The y-axis parameter is determined from the selected curve in (3). The number of experiments depends on the selected option in the main window. If for example current series is selected then the curves for all experiments with + belonging to this test series are displayed (see table with the experiments in table (2)). Removing the + from one experiment in table (2) via double clicking automatically the corresponding curve is removed. Selecting the menu entry *Chart → Diagram Configuration*, option button: *current experiment* only the curve of the selected experiment in table (2) is displayed.

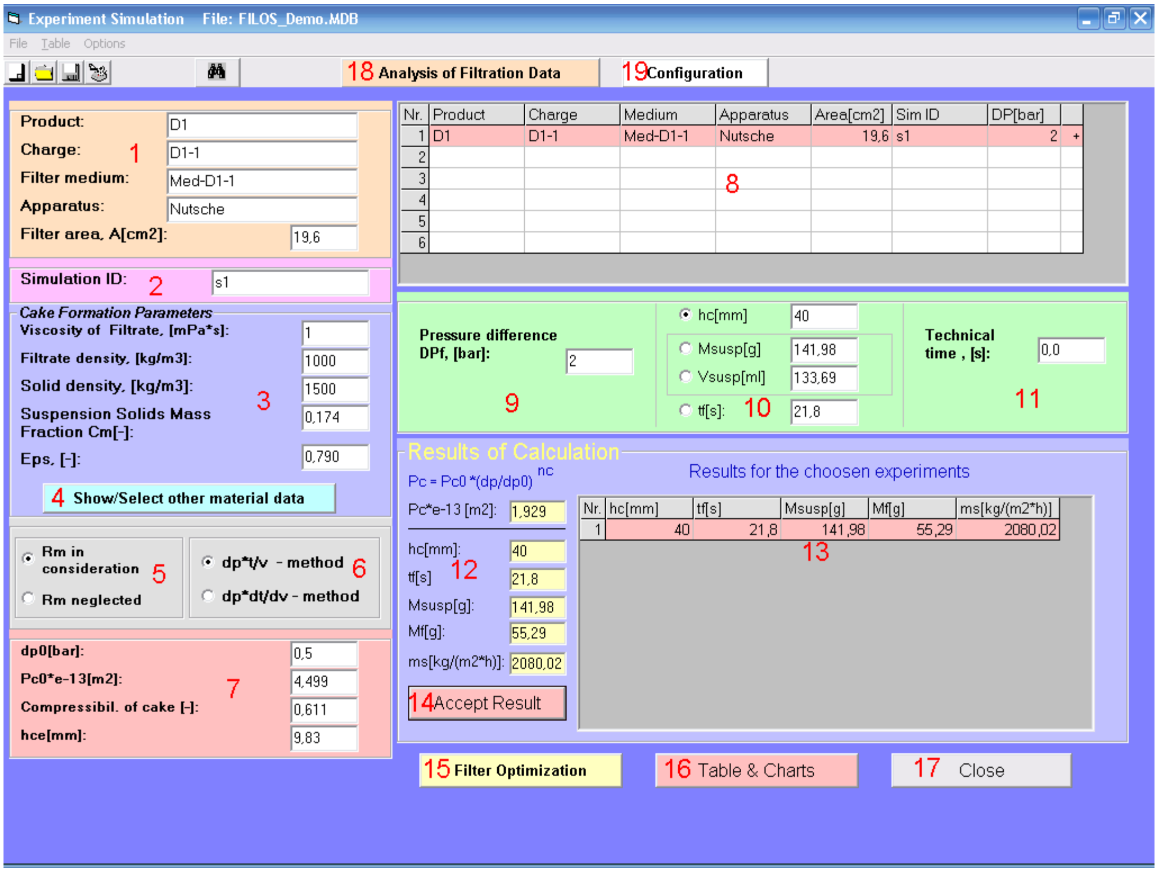
8
In the first and second column of the diagrams table we have for the current experiment the display of the time dependency of the filtrate mass M. The values of these two columns are our input data and are taken from the main window. Then using mass balances the following parameters for the measured time are calculated and displayed: Cake height hc, solids mass in the test apparatus Ms, filtered suspension mass up to the time t Msus, area specific masses for suspension msus, for filtrate mf and for solids ms,

then area and time specific solid mass ms/t and filtrate mass mf/t and as last column the differential area and time specific filtrate mass dmf/dt.

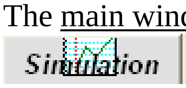
The units of the displayed parameters in the table can be changed from the Units – window. To open the units-window click the menu entry *Options* → *Set measuring units*.

The values of the not area specific parameters: filtrate mass M, solids mass Ms and suspension mass Msusp can be calculated and displayed in table (8) for any values of the filter area. The default filter area is the filter area of the used testing apparatus entered in the main window. For the input of any filter area value click the menu entry *Options* → *Set Filter area* and in the small window that opens select the option *Common value for filter area*. Then you can enter any filter area value in the Filter area input field and select the unit (cm2 or m2).

2.6 The SIMULATION – Tool of the Detailed Cake Formation module



The main window of the simulation module opens after clicking the command button



on the task bar of the main and results window of the *Detailed Cake formation* module. This module is needed if you have a suspension and a given batch filter apparatus with known filter area A (filter nutsches, candle filters, pressure leaf filters, filter presses etc) and you want for a given pressure difference Dpf (9) to calculate the filtration time tf necessary to form a definite cake height hc (10) or you have the filtration time tf and you want to calculate the cake height hc. Other options are the input of suspension mass Msusp or suspension volume Vsusp and the calculation of cake height hc and filtration time tf.

Also tables and diagrams can be obtained with illustration of the influence of the filtration time (or of the cake height or of the suspension amount) on various result parameters. More than one simulation can be done and saved. This enables the comparison of the filtration behaviour for different suspensions and/or different apparatuses and filter settings. The simulations are listed in table (8) and the main results in table (13). For the listing of a new simulation or for overwriting an existing simulation after doing some changes always the *Accept Result* command button has to be clicked. The needed material data for the simulation in (3) and (7) are taken automatically, if for the given suspension in (1) data existing. Of course the material data can be changed or entered in this window. This module is ideal for simulating a cake formation experiment but it doesn't calculates the cake washing or/and the cake deliquoring step. If also these steps have to be calculated then the Filter Calculation modules *Nutsche Filters*, *Candle Filters*, *Pressure Leaf Filters*, *Filter Presses* have to be used.

1

Input fields for the names of the material (Product), charge, filter medium and apparatus and for the value of the filter area. All these data are taken automatically from the entered values in the main window of the detailed cake formation module (values for the current experiment). These taken data can be changed and saved independently (specific for the Simulation module). If such data are not existing then they can be entered manually. For saving of a new simulation first the *Accept Result* command button has to be clicked and then the Save (via clicking the save –symbol in the task bar or via clicking the menu entry *File→Save*.

2

Input field for the name of the simulation. It is not allowed that 2 simulations have the same name. If we don't give an individual name for the current simulation then a default name is automatically created.

3

Input fields for the material parameters. These parameters together with the parameters in (7) are necessary for the calculation of the cake formation step. These data are loaded automatically from the main window of the *Detailed Cake Formation* module and are the entered data for the current experiment. These data can be changed or entered manually and saved as specific data for the simulation that means any changes are not taken to the main window of the *Detailed Cake Formation* module. In the configuration window (19) instead of the Solids density the suspension density can be entered. Instead of the suspension solids mass fraction the volume fraction Cv or the solids concentration C in g/l can be selected as input parameter. Instead of the cake porosity Eps the parameter kappa can be selected. These configuration options are the same as for the *Detailed Cake Formation* main window.

4

It opens a window that displays on the left (blue colour) the values of the entered parameters in (3) (except the viscosity) and on the right (green colour) the calculated parameters. For the above example we have as calculated parameters the suspension density, the parameter kappa, the suspension solids volume fraction Cv and the suspension solids concentration C. Clicking the label *Set New Configuration* other input parameters can be selected.

Furthermore this window enables the calculation of the cake porosity (if the cake porosity is an input parameter, for that click command button *calculate "Eps"*) or the parameter kappa (if kappa is an input parameter, for that click the command button *calculate "kappa"*).

5
If *Rm neglected* is selected then the influence of the filter medium resistance is not considered in the calculations. In this case the hce-value (expressing the medium resistance) is not displayed in (7). The default option is *Rm in consideration*.

6
If the dp*dt/dv option is selected and in case that the analysis of data is done with the differential method then in (7) the data determined from the data analysis using this differential method are taken. Default option is dp*t/v (data taken in (7) are the analysis results using the integral cake formation equation).

7
The cake Permeability Pc0 for the pressure difference dp0, the cake compressibility and the filter medium resistance hce are needed for the calculation of the cake formation step. These data are the results in the second results window of the *Detailed Cake Formation* module. If data analysis results for this suspension are existing then the values of these parameters are taken automatically otherwise they have to be entered manually.

8
Overview table for all accepted simulations. The results of the selected simulation and if this simulation has the + in the last column are displayed in (12) and (13) (removing/inserting the + via double click in this row).

9
Input fields for the pressure difference Dpf for the current simulation

10
Input/display fields for the cake height hc, the suspension mass Msusp, the suspension volume Vsusp and the filtration time tf. If one of these parameters is selected means that it is an input parameter and all others are calculated.

11
Input field for the technical time. That is in this case the cycle time of the batch filter minus the cake formation time.

12
Display of the cake permeability Pc for the entered pressure difference Dpf under consideration of the cake compressibility then the cake height hc, the filtration time tf and the suspension mass Msus as well as the filtrate mass Mf and the average specific solids throughput ms. The displayed values in this field are valid for the current simulation (see selected row in the simulation overview table in (8))

13
Listing of the main result parameters for all simulations with +, which are displayed in the simulations overview table in (8). When one simulation in (8) is selected then the corresponding values in table (13) are also selected (highlighted with rose colour).

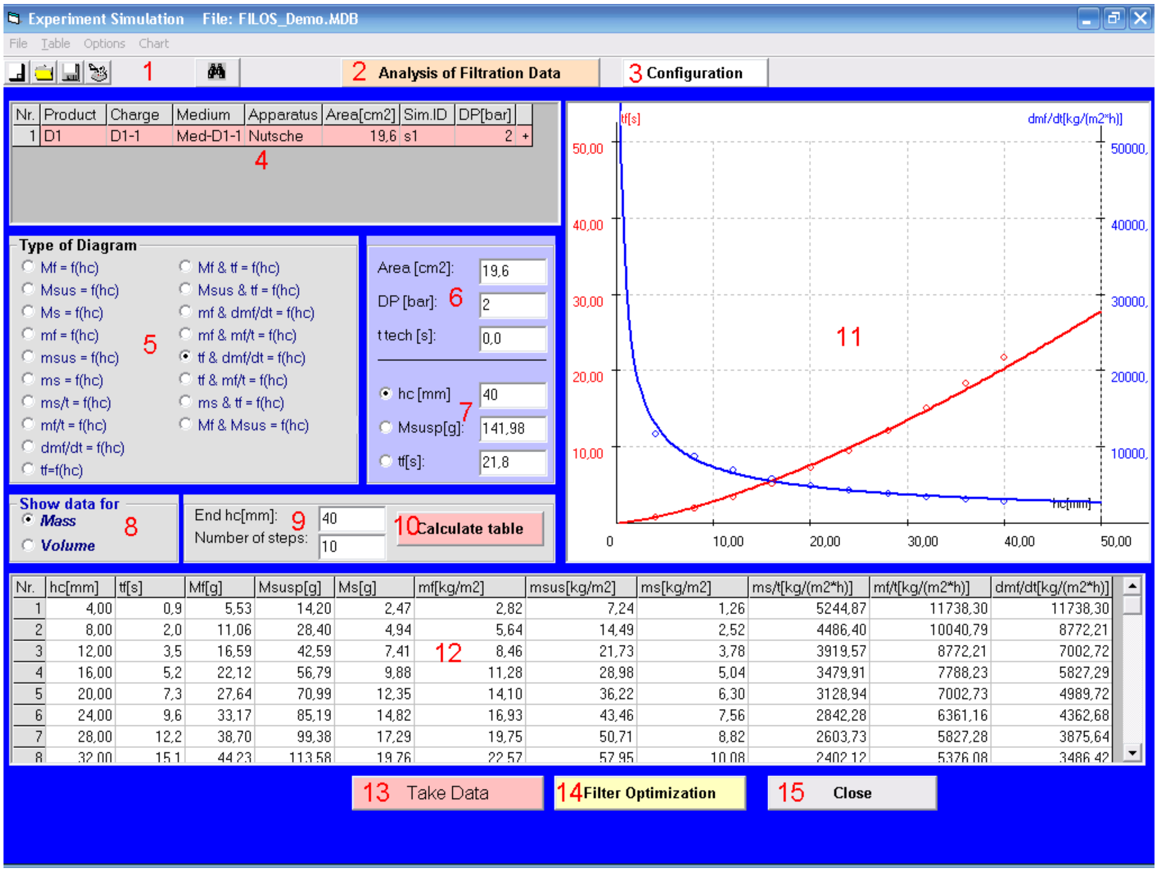
14
One simulation can be displayed in the overview table only after clicking the *Accept Result* command button and if all necessary data are entered. Otherwise after clicking *Accept Result* the program gives us a message for entering the missing parameter values. Please notice that *Accept* doesn't mean Save. For saving any changes in the file the *Save* icon has to be clicked or the **Save** command from *the File* –menu has to be clicked.

15
Opens a window that enables for each simulation besides Tables & Graphs the determination of the optimal operation conditions of the filter apparatus (optimal cake height hc and the corresponding filtration time and suspension mass Msusp for one cycle)

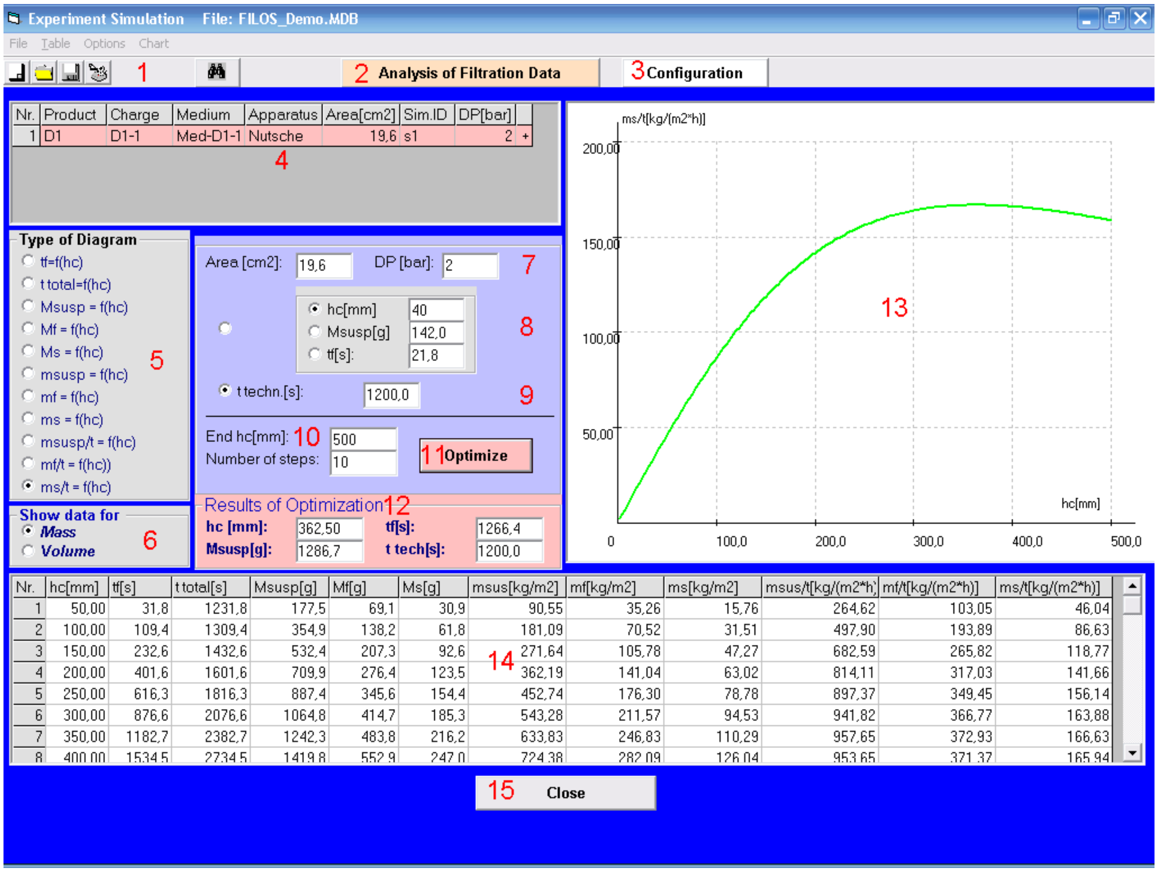
16

Opens the Tables & Charts window (see figure below) that enables for each simulation the calculation of all important result parameters as a function of the filtration time tf or the cake height hc or the suspension mass Msus. The results are displayed as Table and as curves.

17
Closes the Simulation window and comes back to the main window of the Detailed Cake Formation module.



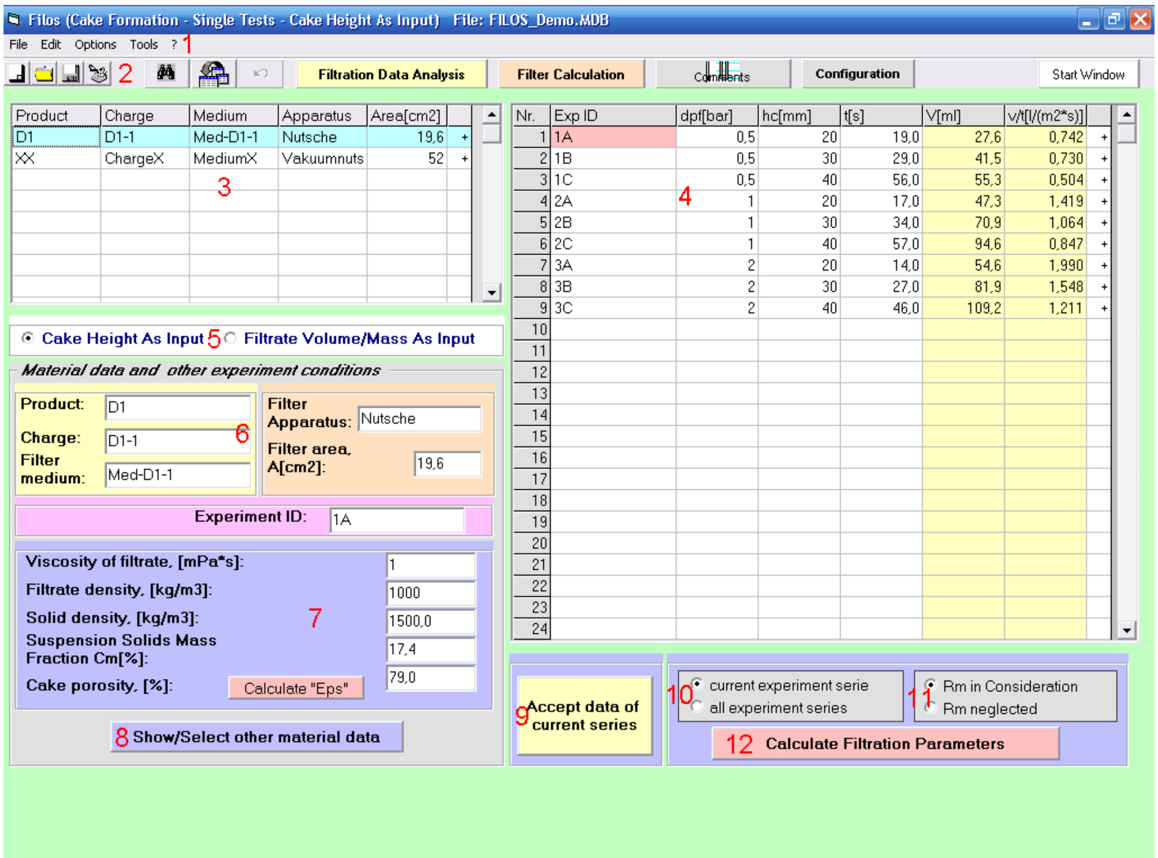
<u>Tables & Charts window</u> of the Simulation-module. It opens after clicking the command button *Tables & Charts* in the main simulation-window. The table (12) with the calculated values is displayed for the selected simulation in the overview table. The simulations overview table with the selected simulation in colour is displayed in (4).The diagram (11) is displayed for the selected option in (5) and can be copied and pasted to a word document. In case we have more than one simulation in (4) then we display the curves for all simulations with + (default option) or only the curve for the selected simulation. This can be done by clicking the menu *Chart* → *Diagram Configuration* and select the option *Draw diagram for Current Experiment*. The x-axis parameter is the same with the parameter in the first column of the results table (12. It can be the cake height hc, the filtration time tf or the suspensions Mass Msusp. If we want for example to have the filtration time tf as x-axis parameter (that means a systematic variation of tf) then we have just to click the option tf in (7). The same is with Msusp and hc. The filter area, the pressure difference and the technical time in (6) are taken from the previous window but they can be changed. After changing one of these values the calculated values in (7) are automatically refreshed and the table (12) and the diagram (11) are refreshed after clicking the command button *Calculate table* in (10).



This window opens after clicking in the simulation-main window the command button *Filter Optimization*. This window is similar with the Tables & Charts window descried above (explanations for the Tables & Charts window are valid also for this window). Additional "speciality" of the optimization window is that it finds for each selected simulation in the overview table (4) the optimal cake height hc and the corresponding suspension mass and filtration time (see (12)). This is the cake height for which the solids throughput ms/t is maximal (see corresponding optimization diagram ms/t =f(hc)).

3. The Single Tests Module

3.1 The main window of the Single Tests Module



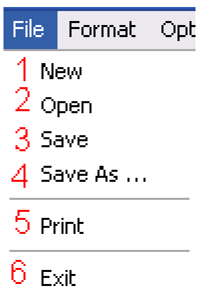
Main input window for the module *Single Tests*. This module is needed when we have one measurement from each experiment as we have for example in case of the vacuum nutsche experiments when we measure the filtration time t at the end of the cake formation time and the corresponding cake height. Each row in the input table is one experiment. We enter the pressure difference for cake formation dp, the measured cake height hc and the measured cake formation time t. Instead of the cake height the filtrate mass or filtrate volume and the corresponding time can be entered depending on the selected option button in (5). Default is the cake height as input and the corresponding filtrate volume or mass is calculated and displayed in the input table together with the specific filtrate volume or mass flow rate (see columns of the input table in yellow colour).

The main task of this module is the calculation of the cake permeability Pc and the filter medium resistance Rm and hce for each pressure difference (see results window) and in case we have experiments with more than one pressure difference the determination also of the cake compressibility nc. This task is the same as for the module *Detailed Cake Formation* with the difference that for this module we have only one table for all experiments of the test series instead of one table for experiment.

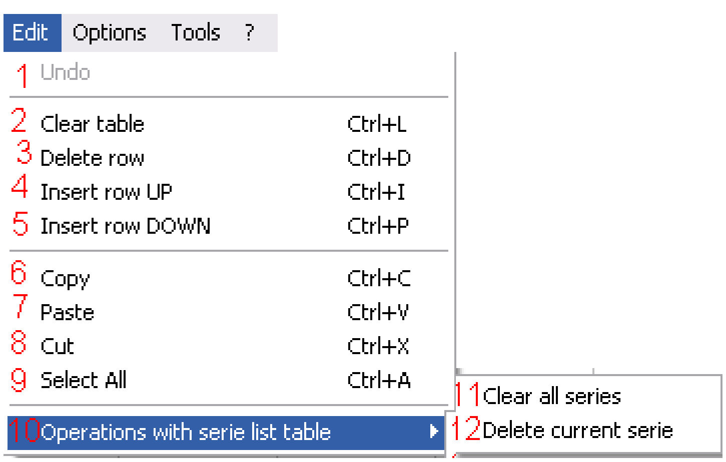
All test series are listed in (3). The data of the selected test series (experiments and their results) are entered/listed in the input table (4). All data which identify the test series are entered in (6). A new entered test series in (6) is displayed in the test series overview table (3) only after clicking *Accept data of current series* (9). Please notice that you have first to click *Accept data of current series* before saving your data.

For the analysis of the entered data in the input table (4) the material parameters in (7) are needed. These are the same with the module *Detailed cake Formation*.

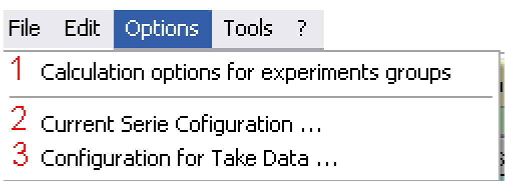
1. Menu bar of the *Single Tests* input data window.



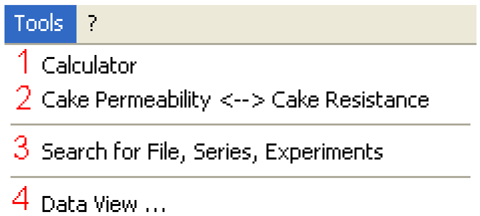
1. Opens a new database file and displays the program window of the previous file.
2. Enables the opening of an existing program file. An existing file can also be opened by clicking the *Open File* command button from the *Search* – window. The Search window opens after clicking the Search symbol in the task bar or from the Menu *Tools* → *Search for File, Series, Experiments*.
3. Saves the changes in the database file. Before saving we should accept the changes by clicking the *Accept* button which is placed in every program window.
4. Saves all data of the current file in a file with a different name.
5. Printing of the current program window.
6. Exiting of the program.



1. Undo is possible after *Clear Table, Delete row, Insert row UP, Insert row DOWN, Clear all series* and *Delete current serie*.
2. Deletes the data of the current input table but not the test series.
3. Deletes the current row of the data input table.
4. Inserts a row in the data input table above the selected row.
5. Inserts a row in the data input table below the selected row.
6. You can select one or more rows in the data input table (the selected rows are highlighted with a dark blue colour). With copy you have the possibility to paste them for example in Word or in Excel or even in the same program table.
7. You can paste copied data in the data input table.
8. Cuts the selected rows in the data input table. With paste you can load them in Word or in Excel or even in the same program table.9.
9. Selects all data in the data input window (highlighted with a dark blue colour). With copy you have the possibility to paste them for example in Word or in Excel or even in the same program table.
10. Click this menu entry if you want to delete all test series or the current series.
11. Deletes the data of all test series.
12. Deletes the data of the current test series.



1. Opens a small window enabling some selections regarding the analysis of the data. When *average Dp* is selected all data of the test series are analysed together and not for each pressure difference separately. Default option is *Separate Dp*. The options *Rm neglected* and *Rm in consideration* can be also selected from the main window. The other options are actually not important.
2. Opens the *Configurations* window. The same window opens after clicking the *Configuration* button in the task bar.
3. When going from one Analysis module to the other, test series-data and some other common data of the current module are automatically transferred to the next Analysis module and the next empty row in the test series list is selected if we click the option *Yes* (Default Option). If we select the option *No* then no transfer of data from the one module to the other occurs.



1. Opens the Calculator
2. Enables the calculation of two of the following parameters if one of them is entered: cake permeability Pc(m2), cake resistance rc (m-2) and cake resistance alpha (m/kg).
3. Opens the *Search* window.
4. Opens the *Data view* window.

2

Task bar of the Single –tests input data window.

3

Overview table for the test series with single tests experiments. The 5 columns display the names for product, charge, filter medium, test apparatus and the filter area. These data are entered in (6) and are displayed in the overview table (3) after clicking the command button *Accept data of current series*. The inputs in (6) identify the test series and we can not have two test series with the same values of these 5 parameters. Selecting one test series this is highlighted with a blue colour and all data of this series are displayed in the input table (4). You can start the analysis of the data after clicking *Calculate filtration Parameters* (12).

4

Input table for the measured *Single Tests* experiments of one test series. One measurement is one row of the table. We have as input the name of the experiment (Exp ID), the pressure difference for cake formation dp, the cake height hc, the cake formation time t. As calculated columns (yellow colour) we have the filtrate mass or volume M /V that corresponds to the measured cake height and the specific filtrate volume flow rate v/t in l/(m2 s). Instead of the cake height hc the filtrate volume V or filtrate mass M can be entered and the cake height is then calculated (see option buttons in (5)). The selection of mass M or volume V is enabled in the *Configuration* window (see fields *Measure filtrate volume* and *Measure filtrate mass*). The + in the last column means that we consider the experiment for the regression analysis which can be started after clicking the command button *Calculate Filtration Parameters*. Via double clicking one row the + is removed and we exclude this measurement from the analysis. This makes sense if we know that this was a wrong measurement. Using the *Edit* menu you can delete the table or the current row, you can insert new rows, you can copy the table and paste it for example in a word or an excel document.

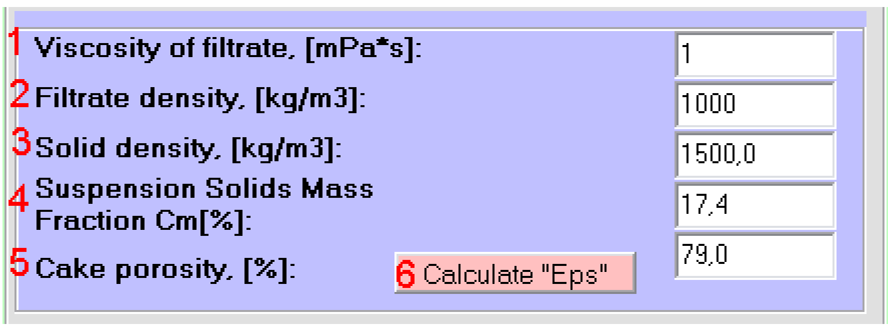
5

If option button *Cake height as Input* is selected then we have in table (4) the cake height as input (default option). If the option *Filtrate Volume / Mass as Input* then we have the filtrate volume or the filtrate mass as input instead of the cake height. The cake height is then calculated. The selection of mass M or volume V is enabled in the *Configuration* window (see fields *Measure filtrate volume* and *Measure filtrate mass*).

6

Input field for the 5 parameters which identify the test series (names for Product, Charge, Filter medium, Filter Apparatus and the value of the filter area) and for the name of the experiment (Experiment ID). The exp ID can also be entered in the first column of the input table (4). In this case it is also displayed in the input field in (6).

7



Input field for the material parameters needed for the analysis of the cake formation experiments (are the same as for the module *Detailed cake Formation*).

<u>Comments</u>

1. Please notice that the viscosity of the mother liquor (=filtrate) has to be entered in mili Pa s. The viscosity depends on the temperature of the filtrate thats why the value for the given temperature has to be entered. Wrong viscosity means wrong calculated cake permeability. If the viscosity is not known, then please enter the value $1 = 10^{-3}$ Pa s (that is the viscosity of water for 20°C). The determined cake Permeability is in this case related to water as mother liquid.

2 The filtrate density is needed to transform the filtrate mass in filtrate volume. For the data analysis the specific filtrate volume (filtrate volume divided by the filter area) as a function of time is needed.

3 Instead of the solids density the suspension density can be entered. Which parameter should be the input parameter can be selected in the configuration window. When the suspension density is selected as input then this value can be selected as specific for only the current experiment or the same for all experiments of the test series. It happens that the suspension samples for the experiments of a given test series have different solids concentrations and that's why we can have a variation of the suspension density from experiment to experiment.

4 Instead of the suspension solids mass fraction Cm the solids volume fraction Cv or parameter C in g/l. Which parameter should be entered can be selected from the configuration window. Similar to the suspension density it can be selected if this parameter will be specific for the experiment or the same for all test series experiments. Cm and Cv values can be entered in % or without %.
5 Instead of the cake porosity (entered in % or without %) the concentration parameter kappa can be entered (see configuration). For the calculation of the cake permeability the kappa-value is needed, which is calculated from the cake porosity and the suspension solids concentration Cv.
6 Enables the calculation of the cake porosity from one cake formation experiment.

8

Show / Select other material data: Opens a window that shows on the left the values of the input material parameters and on the right the values of the calculated parameters. In the above example we have as calculated parameters the suspension density, the suspension solids volume fraction Cv, the suspension solids concentration C in g/l and the concentration parameter kappa.

9

Accept data of current series: We always have to click first the *Accept data of current series* command button if we want to save any inputs or changes for the current test series. That means before saving first click the *Accept data of current series* – command button.

10

- current experiment series: If this option is selected only the data of the selected test series in the test series overview table (see blue colour in (3)) are analysed. These are the data displayed in the current input table (4).
- all experiment series: If this option is selected then the data of all test series which have the + in the last column in the series overview table are analysed together. This enables the comparison of the filtration behaviour of different test series.

11

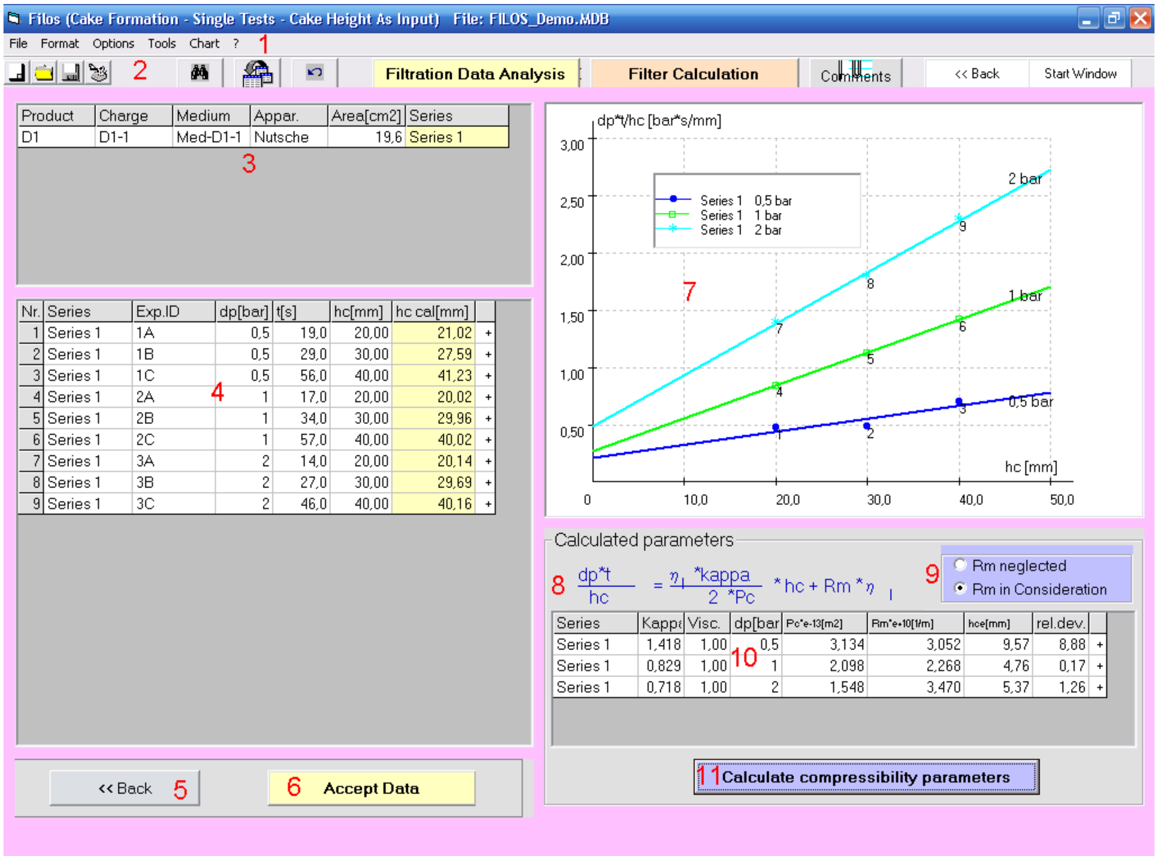
-Rm in Consideration: If this option is selected the regression analysis results for the group of experiments with the same cake formation pressure difference dpf are the cake permeability Pc and the filter medium resistance Rm and hce (default option). This option is only possible if at least 2 measurements with different cake heights and of the same pressure difference are existing.
- Rm neglected: If this option is selected the regression analysis results for the group of experiments with the same cake formation pressure difference dpf are only the permeability Pc. This is the permeability of the system cake-filter medium. This option is automatically selected if only one measurement for a given pressure difference is existing. Even if we have more than one measurements and different cake heights it makes sometimes sense to use this option due to the problems regarding the reliability of

the correct determination of the filter medium resistance. This is especially the case for fast filtering suspensions with relatively high suspension solids content.

12

Starts the regression analysis for the determination of the filtration parameters and opens the main results window. We have one regression analysis for every group of experiments. One group of experiments includes the experiments which belong to the same test series and have the same pressure difference. Which data are analysed and which parameters are determined depends on the selections in (10) and (11) and on the rows with + in the tables (3) and (4).

3.2 The results window of the Single Tests Module



Results window of the module *SingleTests* when in the main window the option *Current experiment serie* is selected. That means we analyse together all experiments with + of the selected test series. The experiments (rows in the data input table) with the same pressure difference belong to the same group and are analysed together. For each group we have one linear regression analysis and we have as results the cake permeability Pc and the filter medium resistance Rm and hce (see result table (10)).

1

Menu of the main results window

2 Task Bar of the main results window

3

Display of the name of the current test series (the name is characterized by the values of the 5 parameters and it's the "family name" of the experiment. The name *Series 1* is a default help name. It makes sense to use this help name when we compare experiments from different test series to identify the series. In such a case we don't have to use the names/values of all 5 parameters for the identification.

4

Listing of the input data for the regression analysis. Rows without + are not considered for the regression analysis. We can remove/add the + via double clicking the corresponding row. The diagram with the linear regression and the regression results (see (7) and (10)) are automatically updated. Each row has the name (help name) of the test series, the Exp. ID, the pressure difference dp, the filtration time t, the measured cake height and the calculated cake height from the determined filtration parameters.

5 Back: Goes back to the data input window

6

Accept Data: Click always the command button *Accept Data* if you want that the changes are kept after you exit this window or/and if you want to save these changes.

7

Theory based plotting of the measured data with the regression line(s). For each experiment group (to one experiment group belong all experiments with the same pressure difference) we have a separate analysis and a separate line. The slope indicates the cake permeability and the intersection with the y-axis indicates the filter medium resistance. Parallel lines for example mean the same permeability (incompressible filter cake).

- The diagram can be copied and pasted for example to a word document. This is valid for all diagrams of the program. Select for that the menu *Chart → Copy Chart*.
- Clicking the Menu *Chart → Diagram Configuration* you have possibilities for formatting the diagram.
- Double clicking in the diagram area you can write text giving explanations to the curves.
- Clicking the x- and y-axis description you can change or /and move this description
- You can remove any measured points from the diagram by drawing a rectangular which includes these point(s). On the right top side of the diagram appear the command buttons *Cut Points* and *Cancel*. Clicking *Cut Points* you remove the measured points from the diagram and you have automatically a refreshing of the window including a recalculation of the parameters.

8

It shows the cake formation equation that is used by the program for the linear regression analysis of the cake formation experimental results.

9

By selecting the option *Rm neglected* the permeability of the system cake-filter medium is calculated and Rm and hce is set to zero for all experiment groups (to one experiment group belong all experiments with the same pressure difference). In this case the regression lines start from (0,0). This option is automatically selected when we have for a given experiment group only one experiment or the same cake height for all experiments of this group.

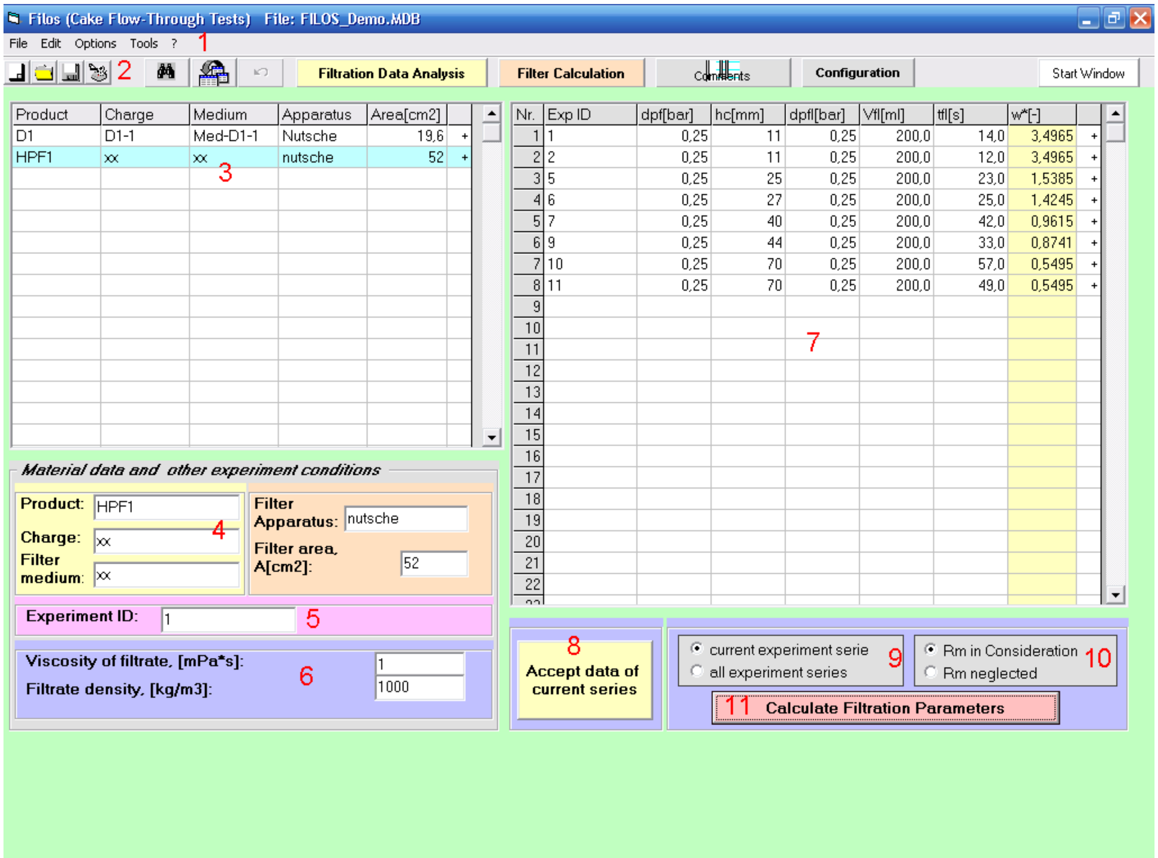
10
Table with the results of the regression analysis (one row for each experiment group, that means for each pressure difference): Cake permeability Pc, medium resistance Rm, medium resistance hce and relative deviation in % indicating the degree of the deviation between the measured and calculated values (values on the regression line). Besides the above result parameters we have as first column the display of the Series name, the concentration parameter kappa, the filtrate viscosity and the pressure difference dp. The kappa- and viscosity columns are also input columns. Changing these values we can see the influence on the result parameters Pc, Rm and hce.

11
Command button *Calculate Compressibility Parameters*. Opens the window for the analysis of the cake permeability Pc and the filter medium resistance Rm as a function of the pressure difference and the determination of the cake compressibility nc and the filter medium compressibility mc. The compressibility calculation window opens if at least 2 experiment groups (=experiments with 2 different pressure differences) are analysed in the main results window.

This window for the calculation of the cake compressibility is called the second results window and is exactly the same as for the module Detailed Cake Formation. For description of this window see Chapter 2.3.

4. The Cake Flow – Through Tests - Module

4.1 The main window of the Cake Flow-Through Tests Module



We use the *Cake Flow-Through Tests* module especially when we have fast filtering suspensions. In this case we have a relatively short filtration time and the use of the *Detailed Cake Formation* or the *Single Tests* module give us normally not accurate values of the cake permeability and especially of the filter medium resistance. Of course this module can be used for every suspension. What experimental results are needed? One experiment can be described as follows: With a pressure difference dpf we form a filter cake with the height hc and then we give on the cake surface a liquid amount of the mass Mf or the volume Vf. With a pressure difference dpfl (not necessarily the same as the cake formation pressure difference dpf) the liquid flows through the cake and we measure the flow through time, that is the time until the liquid reaches the cake surface. One experiment is one row in the input table (7). For the correct determination of the filter medium resistance hce more than 3 experiments with different cake heights are necessary. The correct determination of the cake compressibility demands the variation of the pressure difference for cake formation. If the compressibility is not needed (that is for example the case when it is known that the material is incompressible) then only the cake height needs to be varied. It is also recommended to use the mother liquid as flow through liquid in order to get reliable and accurate filtration parameters.

1

Menu bar of the *Cake Flow-Through Tests* input data window.

2

Task bar of the *Cake Flow-Through Tests* input data window

3

Overview table for the test series with cake flow through experiments. The 5 columns display the names for product, charge, filter medium, test apparatus and the value of the filter area. These data are entered in (4) and are displayed in the overview table (3) after clicking the command button *Accept data of current series*. The inputs in (4) identify the test series and we can not have two test series with the same values of these five parameters. Selecting one test series this test series is highlighted with a blue colour and all its data are displayed in the input table (7). You can start the analysis of the data after clicking *Calculate filtration Parameters* (11).

4

Input field for the five parameters which identify the test series (names for Product, Charge, Filter medium, Filter Apparatus and the filter area - value).

5

Input field for the name of the experiment (Experiment ID). The Exp ID can also be entered in the first column of the input table (7). In this case it is also displayed in the input field in (5).

6

The viscosity of filtrate and the filtrate density are the only material parameters needed for the analysis of the cake flow through input data in table (7). It is recommended to use the suspension mother liquid (=filtrate) as liquid given above the cake for the flow through experiments. That’s why we write filtrate viscosity and filtrate density. If the liquid is not the same we will have problems regarding the reliable calculation of the filtration parameters.

7

Nr 1	Exp ID 2	dpf[bar] 3	hc[mm] 4	dpfl[bar] 5	Vfl[ml] 6	tfl[s] 7	w*[-] 8	9
1	1	0,25	11	0,25	200,0	14,0	3,4965	+
2	2	0,25	11	0,25	200,0	12,0	3,4965	+
3	5	0,25	25	0,25	200,0	23,0	1,5385	+
4	6	0,25	27	0,25	200,0	25,0	1,4245	+
5	7	0,25	40	0,25	200,0	42,0	0,9615	+
6	9	0,25	44	0,25	200,0	33,0	0,8741	+
7	10	0,25	70	0,25	200,0	57,0	0,5495	+
8	11	0,25	70	0,25	200,0	49,0	0,5495	+
9								
10								
11								

Input table for the cake flow through measurement data. Each row represents the results of one experiment.

1. Nr.: Number of rows (=experiments)
2.: Exp ID: Name of the experiment
3. dpf(bar): Pressure difference for cake formation
4. hc(mm): Cake height
5. dpfl (bar): Cake flow through pressure difference.
6. Vfl (ml): Volume of the liquid given above the cake for the cake flow through experiment. In *Configuration*-window can be selected if we want to have the liquid volume Vfl or the liquid mass Mfl as input.
7. tfl (s): Measured cake flow through time. That is the time needed for the given liquid amount Vfl to flow through the cake of a height hc and with a flow through pressure difference Dpfl.
8. w*(-): Liquid over the cake at the beginning of the experiment related to the cake volume.
9. If we have a + in this column means that this measurement is considered for the regression analysis. Double clicking the current row removes the + and excludes this experiment from the regression analysis.

8

<u>Accept data of current series</u>: We always have to click first the *Accept data of current series* command button if we want to save any inputs or changes for the current test series. That means before saving first click the *Accept data of current series* – command button.

9

- current experiment series: If this option is selected only the data of the selected test series in the test series overview table (see blue colour in (3)) are analysed. These are the data displayed in the current input table (4).
- all experiment series: If this option is selected then the data of all test series which have the + in the last column in the series overview table (3) are analysed together. This enables the comparison of the filtration behaviour of different test series.

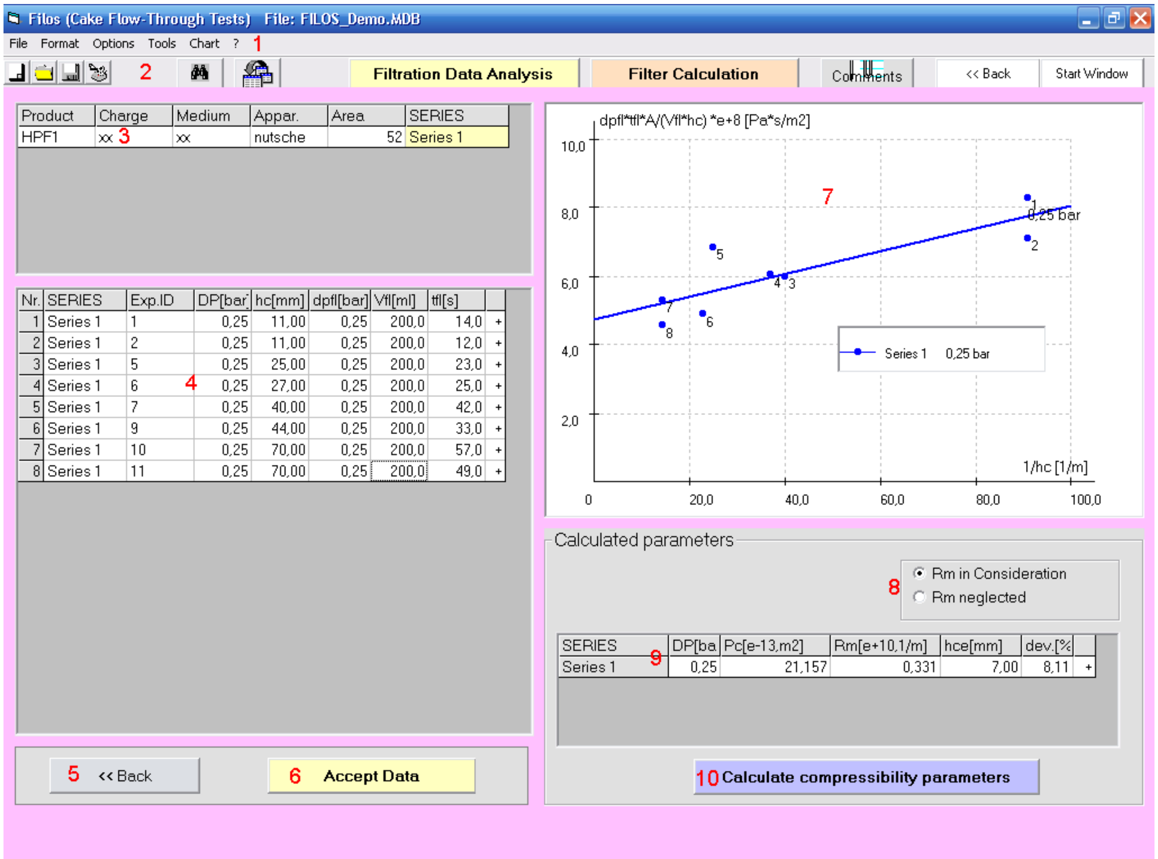
10

-Rm in Consideration: If this option is selected the regression analysis results for the group of experiments with the same cake formation pressure difference dpf are the cake permeability Pc and the filter medium resistance Rm and hce (default option). This option is only possible if at least 2 measurements with different cake heights and of the same pressure difference exist.
- Rm neglected: If this option is selected the regression analysis results for the group of experiments with the same cake formation pressure difference dpf are only the permeability Pc. This is the permeability of the system cake-filter medium. This option is automatically selected if only one measurement for a given pressure difference is existing. Even if we have more than one measurements and different cake heights it makes sometimes sense to use this option due to the problems regarding the reliability of the correct determination of the filter medium resistance. This is especially the case of fast filtering suspensions with relatively high suspension solids content.

11

Calculate Filtration Parameters: Starts the regression analysis for the determination of the filtration parameters and opens the main results window. We have one regression analysis for every group of experiments. One group of experiments are those which belong to the same test series and have the same pressure difference. Which data are analysed and which parameters are determined depends on the selections in (9) and (10) and on the rows with + in the tables (3) and (7).

4.2 The Results Window of the Cake Flow-Through Tests Module



Results window of the module *Cake Flow Through Tests* when in the main window the option *Current experiment series* is selected. That means we analyse all experiments with + of the selected test series together. The experiments (rows in the data input table) with the same pressure difference belong to the same group and are analysed together. For each group we have one linear regression analysis and we have as results the cake permeability Pc and the filter medium resistance Rm and hce (see result table (9))). In the above example we have experiments with only one pressure difference (=only one experiment group) and that's why we have only one regression line. In this case it is not possible to calculate the cake compressibility because at least 2 experiment groups with different pressure difference are needed. The calculation of the cake compressibility is started after clicking the *Calculate compressibility parameters* button.

1

Menu of the main results window

2

Task Bar of the main results window

3

Display of the name of the current test series (the name is characterized by the values of the five parameters and it's the "family name" of the experiment. The name *Series 1* is a default help name. It makes sense to use this help name when we compare experiments from different test series to identify the series. In such a case we don't have to use the names/values of all five parameters for the identification.

4

Listing of the input data for the regression analysis. Rows without + are not considered for the regression analysis. We can remove/add the + via double clicking the corresponding row. The diagram with the linear regression results (7) and the display of these results as table (9) are automatically updated. Each row has the name (help name) of the test series, the Exp. ID, the pressure difference for cake formation dpf, the cake height hc, the pressure difference for the cake flow through test dpfl, the liquid amount over the cake at the beginning of the experiment Vfl and the flow through time tfl.

5

<u>Back</u>: Goes back to the data input window

6

<u>Accept Data</u>: Click always the command button *Accept Data* if you want that the changes are kept after you exit this window or/and if you want to save these changes.

7

Theory based plotting of the measured data and the regression line. For each experiment group (to one experiment group belong all experiments with the same pressure difference) we have a separate analysis and a separate line.

- The diagram can be copied and pasted for example to a word document. This is valid for all diagrams of the program. Select for that the menu *Chart* → *Copy Chart*.
- Clicking the Menu *Chart* → *Diagram Configuration* you have some possibilities for the diagram formatting.
- Double clicking in the diagram area you can write text giving explanations to the curves.
- Clicking the x- and y-axis description you can change or /and move this description
- You can remove any measured points from the diagram by drawing a rectangular which includes these point(s). On the right top side of the diagram appear the command buttons *Cut Points* and *Cancel*. Clicking *Cut Points* you remove the measured points from the diagram and you have automatically a refreshing of the window including a recalculation of the parameters.

8

By selecting the option *Rm neglected* the permeability of the system cake-filter medium is calculated and Rm and hce is set to zero for all experiment groups (to one experiment group belong all experiments with the same pressure difference). This option is automatically selected when we have for a given experiment group only one experiment or the same cake height for all experiments of this group.

9

Table with the results of the regression analysis (one row for each experiment group, that means for each pressure difference): Cake permeability Pc, medium resistance Rm, medium resistance hce and relative deviation in % quantifying the deviation between the measured and calculated values (values on the regression line). Besides the above result parameters we have as first column the display of the Series name and the pressure difference dp.

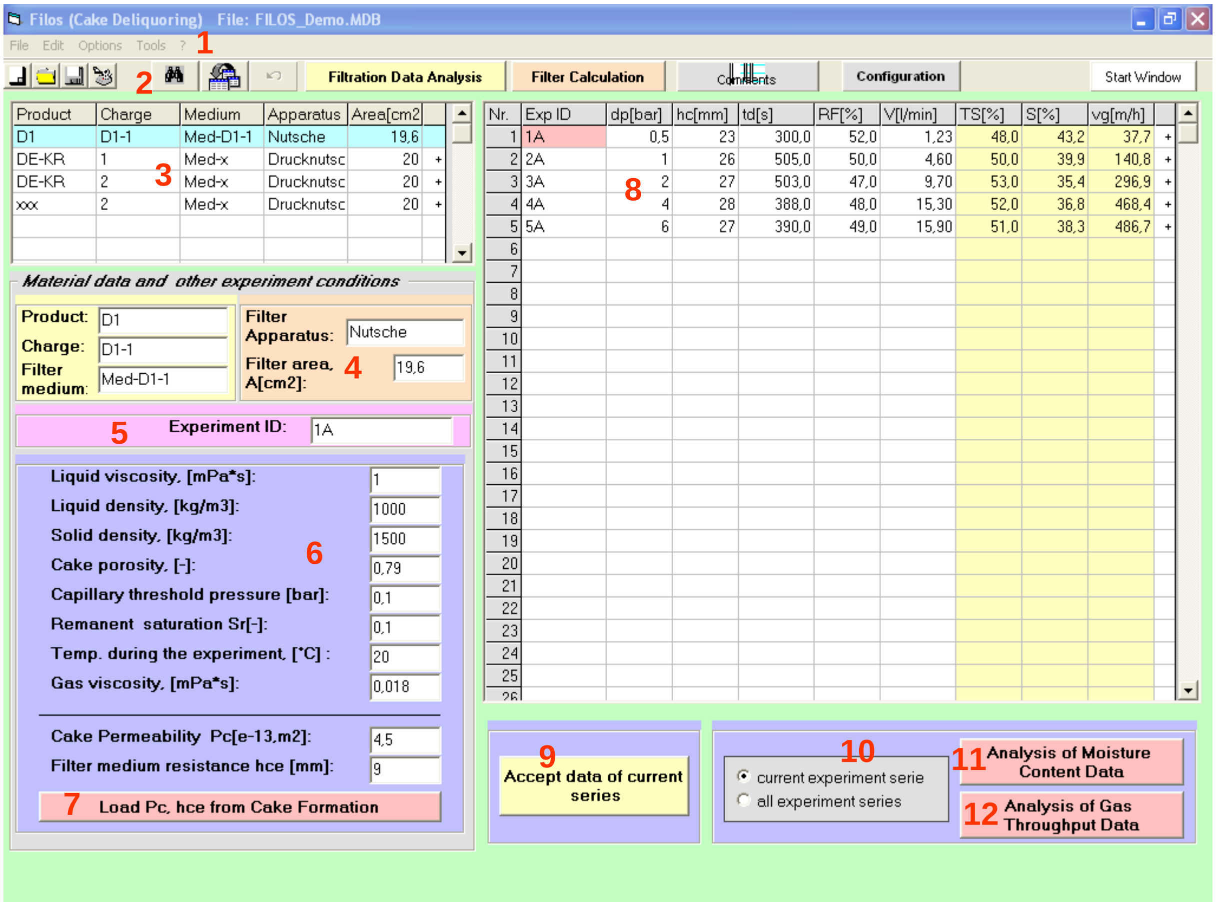
10

Calculate Compressibility Parameters - Command button. Opens the window for the analysis of the cake permeability Pc and the filter medium resistance Rm as a function of the pressure difference and the determination of the cake compressibility nc and the filter medium compressibility mc. The compressibility calculation window opens if at least 2 experiment groups (=experiments with 2 different pressure differences) are analysed in the main results window.

This window for the calculation of the cake compressibility is called the second results window and is exactly the same as for the module *Detailed Cake Formation*. For description of this window see Chapter 2.3.

5. The Cake Deliquoring Module

5.1 The main window of the Cake Deliquoring Module



Data Input window for the Cake Deliquoring module: If we want to calculate the cake moisture content after cake deliquoring or / and the gas flow rate (the gas flow rate is needed for the design of the compressor) in an industrial filter as a function of the cake height, the pressure difference and the deliquoring time two adaptation parameters for the calculation of the cake moisture content Rf (Ad, Bd) and three adaptation parameters for the gas flow rate Vg (alpha, betta, gamma) are needed. The determination of these parameters is the main job of this module.

At least 2 deliquoring experiments are needed but 3 or even more are recommended. How one deliquoring experiment should be carried out? After cake formation or cake washing is finished and without interrupting the experiment due to the pressure difference dpd (in most of the cases the deliquoring pressure difference is equal the cake formation pressure difference but this is not obligatory) gas penetrates in the cake and displaces the liquid entrapped in the cake voids. After a definite deliquoring time td we stop the experiment and we determine the moisture content Rf of the cake. In case we can measure the gas flow rate then we should measure the value of this parameter to the deliquoring time td. In the data input table (8) each row is for the data of one experiment. We enter there the pressure difference dp, the cake height hc, the deliquoring time td and the measured cake moisture content RF. The input of the gas volume flow rate is optional. Selecting in the configuration window the option *Gas Troughput not measured* we have a simpler window because all data regarding the gas throughput are not displayed.

1

Menu bar of the Cake Deliquoring input data window.
For explanations regarding the menu entries see Chapter 3.1.

2

Task bar of the Cake Deliquoring input data window.

3

Overview table for the test series with cake deliquoring experiments. The 5 columns display the names for product, charge, filter medium, test apparatus and the value of the filter area. These data are entered in (4) and are displayed in the overview table (3) after clicking the command button *Accept data of current series* (9). The inputs in (4) identify the test series and we can not have two test series with the same values of these five parameters. Selecting one test series this is highlighted with a blue colour and all data of this series are displayed in the input table (8). You can start the analysis of the data after clicking the command buttons *Analysis of Moisture Content Data*. If we have the general case with Gas throughput measurement as in the above figure then we can also analyse the gas throughput via clicking *Analysis of Gas Throughput Data*.

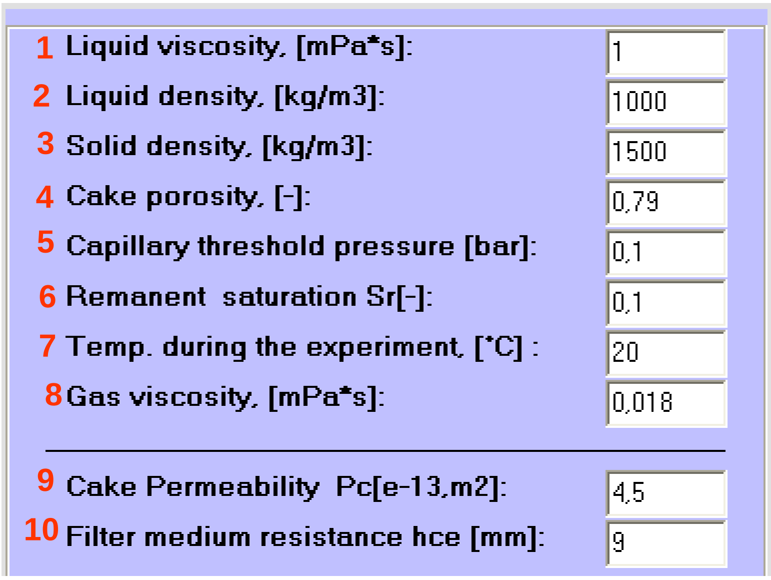
4

Input field for the five parameters which identify the test series (names for Product, Charge, Filter medium, Filter Apparatus and the value of the filter area)

5

Input field for the name of the experiment (Experiment ID). The exp ID can also be entered in the first column of the input table (8). In this case it is also displayed in the input field in (5).

6



Necessary material input data for the analysis of the cake deliquoring measured data to determine the adaptation parameters Ad and Bd. If the option in *Configurations Gas Throughput not measured* is selected the parameters *Temp. during the experiment* and *Gas viscosity* are not displayed.

1. Liquid Viscosity. Is the viscosity of the washing liquid if the cake is washed before deliquoring. If no cake washing then the filtrate viscosity is taken. It is entered in (mili Pa s) (default unit). For example for water at 20°C the value of 1 (=1 mili Pas) has to be entered.
2. Liquid density Is the density of the washing liquid if the cake is washed before deliquoring. If no cake washing then the filtrate density is taken. Default input unit is kg/m3
3. Solids density. The density of the solids. Entered in kg/m3 (default unit)
4. Cake Porosity Defined as volume of the cake-voids over the volume of the cake (dimensionless parameter). It can be determined from a nutsche experiment by using the *Calculator* window (select the menu *Tools* → *Calculator* (Label: *Calculate Eps*). In this module entered as absolute value and not in %.
5. Capillary pressure pke (bar): Capillary threshold pressure. To have a cake deliquoring the applied pressure difference should be higher than pke. The higher pke the more difficult is the deliquoring step. Actually it is not necessary to have the exact value of pke. The error by not entering the exact pke-value is compensated by the adapting parameters Ad and Bd. The pke-value depends on the cake permeability Pc and is the higher the smaller the cake permeability. For permeability values between 0,1 to 1 * 10^{-13} m^2 we may enter pke between 0,2 and 0,4 bar. For cake permeability greater than 1 *10^{-13} m^2 values between 0 and 0,1 bar may be entered. For permeability between 0,1 and 0,01* 10^{-13} m^2 pke values between 0,4 and 1 bar can be used.
6. Sr: Remanent cake saturation. This saturation corresponds to the minimal possible cake saturation that can be achieved in the cake deliquoring step. It is a dimensionless

parameter entered as absolute value. Often this parameter can not be measured accurately but it is not necessary to have an accurate Sr-value. Entering a value between Sr=0,1 and Sr=0,15 for almost all the cases we have a good approximation. Exception are the cases with porous particles. The error by not entering the exact Sr-value is compensated by the adapting parameters Ad and Bd via linear regression analysis.

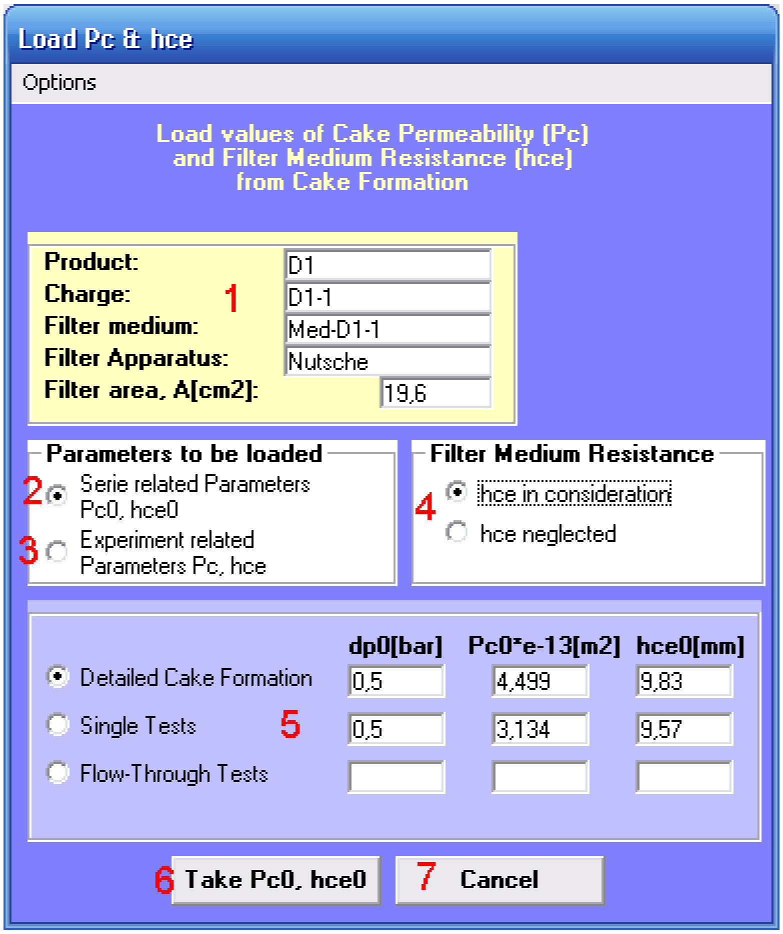
7. Temp. during the experiment (°C): Needed only for the analysis of the gas throughput data. The entered parameter is taken as the gas temperature that flows through the cake during deliquoring.

8. Gas viscosity (mPa*s): Needed only for the analysis of the gas throughput data. For air for example for 20°C the value of 0,018 mili Pa*s can be entered.

9. Cake Permeability Pc: This parameter is needed for the calculation of the deliquoring index K and has influence on the adaptation parameter Ad. This value together with the filter medium resistance hce are determined in the cake formation modules (*Detailed cake formation* or *Single Tests* or *Cake Flow Through tests*) and can be loaded after clicking the command button *Load Pc, hce from Cake Formation*. Important is that the Pc-value used in this module and the Pc0-value used in the *Filter Calculation* module for the same suspension should be the same.

10. Filter medium resistnce hce: This parameter is also needed for the calculation of the deliquoring index K and has influence on the adaptation parameter Ad. This value together with the cake permeability Pc are determined in the cake formation modules (*Detailed cake formation* or *Single Tests* or *Cake Flow Through tests*) and can be loaded after clicking the command button *Load Pc, hce from Cake Formation*. Important is that the hce-value used in this module and the hce-value used in the Filter Calculation module for the same suspension should be the same.

7 Load Pc, hce from Cake Formation



Load Pc, hce from Cake Formation: After clicking this command button the above window opens for selecting and loading the cake permeability Pc and the filter medium resistance hce from the cake formation modules *Detailed Cake Formation*, *Single Tests* and *Flow Through Tests*.

1. Display of the characterization data of the current test series.
2. Series related Parameters Pc0, hce0: If this option is selected the dp0, Pc0 and hce0 for the three cake formation modules are displayed in (5). We have Dp0, Pc0 and hce0 – values for the modules in (5) only if we did the second regression step (that is the calculation of the cake compressibility). In case we have data in (5) we can select from which of the 3 modules we want to take the Pc and hce –values and then we click *Take Pc0,hce0* to load them in the Deliquoring Window.
3. Experiment related Parameters Pc, hce: If we select this option a list of all experiments is displayed and for each selected experiment the values of Pc and hce (if existing) are displayed in (5) with the possibility to select one of the 3 modules in (5) in which we have data and load them in the deliquoring module. .

4. The display of the values of the filtration parameters in (5) depends on the option selected in (4). If we have the option hce neglected then the hce-value in (5) is always zero.
5. Depending on the selected option (2) or (3) and the option in (4) we have a display of Pc and hce values for the modules we have data. Select one of these 3 modules in which we have data and click *Take Pc0, hce0* to load these data in the deliquoring window.
6. Take Pc0, hce0: Takes the selected Pc and hce- values in (5) and loads them in the deliqoring window.
7. Closes the window without taking any data to the deliqiuoring window.

8. Input table for the measured cake deliquoring experiments of one test series. One measurement is one row of the table. We have as input the name of the experiment (Exp ID), the pressure difference for cake deliquoring dp, the cake height hc, the deliquoring time td, the cake moisture content Rf and as optional the gas throughput V. The units of the gas throughput can be selected in the configuration window. As calculated columns (yellow colour) we have the solids content in the cake TS (TS=1-RF), the cake Saturation S and in case we have gas throughput the specific gas throughput vg in m3/(m2 h). The + in the last column means that we consider this experiment for the regression analysis. The regression analysis can be started after clicking the command button *Analysis of Moisture Content Data* or in case of gas throughput data the command button *Analysis of Gas Throughput Data*.. Via double clicking one row the + is removed and we exclude this measurement from the analysis. This makes sense if we know that this was a wrong measurement. Using the *Edit* menu you can delete the table or the current row, you can insert new rows, you can copy the table and paste it for example in a word or an excel document.

9

Accept data of current series: We always have to click first the *Accept data of current series* command button if we want to Save any inputs or changes for the current test series. That means before saving first click the *Accept data of current series* – command button.

10

- current experiment series: If this option is selected only the data of the selected test series in the test series overview table (see blue colour in (3)) are analysed. These are the data displayed in the current input table (8).
- all experiment series: If this option is selected then the data of all test series which have the + in the last column in the series overview table are analysed together. This enables the comparison of the cake deliquoring behaviour of different test series.

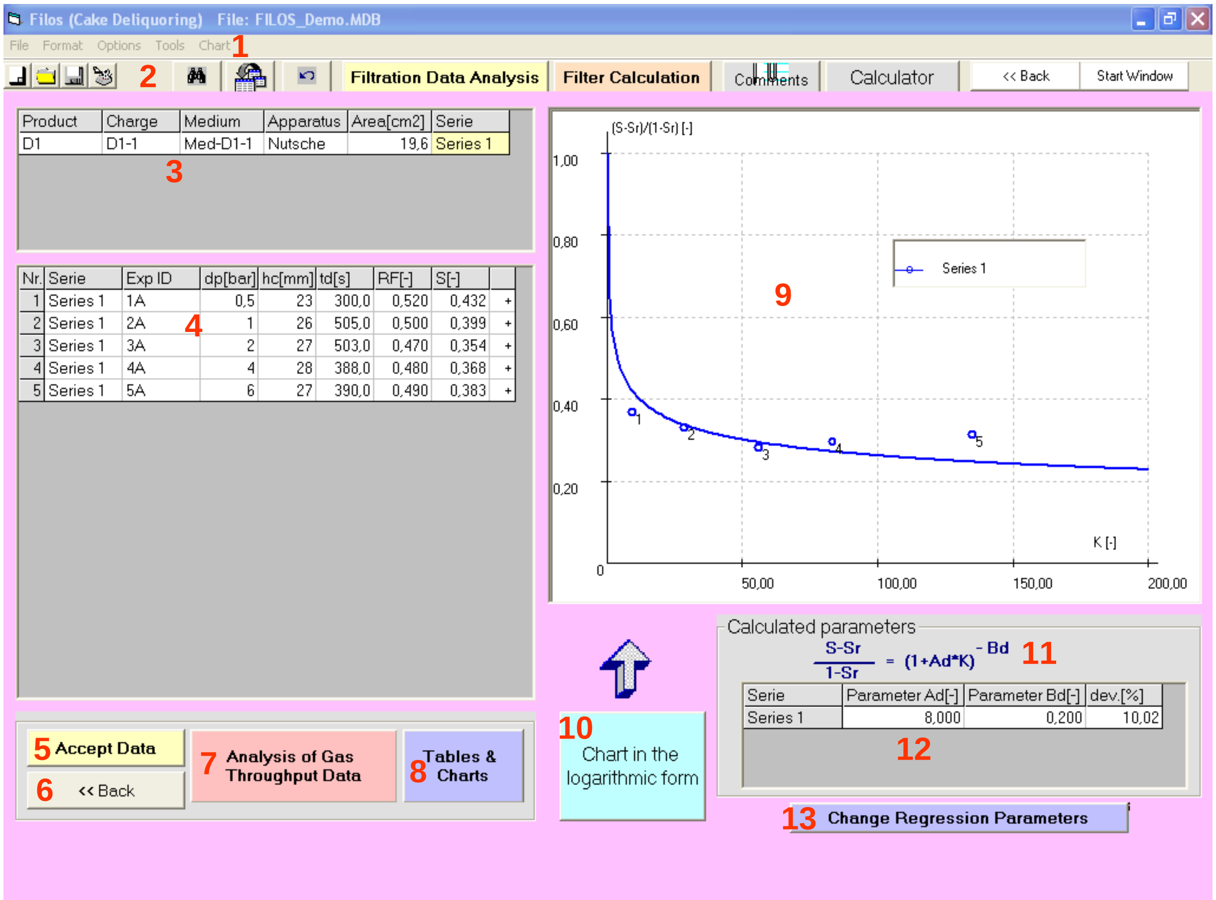
11

Analysis of Moisture Content Data: Starts the regression analysis of the input data in (8) for the determination of the adaptation parameters Ad and Bd. These parameters are needed for the calculation of the cake moisture content Rf in the *Filter Calculation* module.

12

Analysis of Gas Throughput Data Starts the regression analysis of the input data in (8) for the determination of the adaptation parameters alpha, betta, gamma. These parameters are needed for the calculation of the Gas throughput in the *Filter Calculation* module.

5.2 The Results Window of the Cake Deliquoring Module for the Analysis of Cake Moisture Data



Results window of the cake deliquoring module: Opens after clicking the command button *Analysis of Moisture Content Data* in the main window. It displays the regression analysis diagram for the current test series (9) and the calculated adaptation parameters Ad and Bd (12). If in the main window the option *all experiment series* is selected then we have regression analysis for each test series with + displayed in the overview table in the main window. Each tests series has then its own curve in the diagram and in the results list we have the adaptation parameters Ad and Bd for every analysed test series. To be able to save the results first the *Accept data* button has to be clicked. Clicking the *Tables & Charts* command button (8) we can have as table and diagram the calculated time dependence of the moisture content RF, the cake solids content TS and the cake Saturation S for any pressure difference and any cake height. For these calculations the eq. displayed in (11) is used with the determined adaptation parameters Ad and Bd. When we have in the main window gas throughput data then we have in the results window the display of the command button *Analysis of Gas Throughput Data*. Clicking in (7) the results window with the analysis of Gas throughput data opens.

1

Menu bar of the Cake Deliquoring results window.

2

Task bar of the Cake Deliquoring Results window

3

Display of the name of the current test series (the name is characterized by the values of the five parameters and it's the "family name" of the experiment. The name *Series 1* is a default help name. It makes sense to use this help name when we have experiments from different test series to identify the series. This is the case when we select in the main window the analysis option *all experiment series*. In such a case we don't have to use the names/values of all five parameters for the identification of the experiment.

4

Listing of the input data for the regression analysis. Rows without + are not considered for the regression analysis. We can remove/add the + via double clicking the corresponding row. The diagram and the regression results are then automatically updated. Each row has the name (help name) of the test series, the Exp. ID, the pressure difference dp, the cake height hc, the deliquoring time td, the cake moisture content RF and the cake Saturation S.

5

<u>Accept Data</u>: Click always the command button *Accept Data* if you want that the changes are kept after you exit this window or/and if you want to save these changes.

6

<u>Back:</u> Goes back to the main window. Click first *Accept Data* before going back to the main window if you want to keep in memory the last data of the results window.

7

<u>Analysis of Gas Throughput Data</u>: Opens the window with the analysis results of the gas throughput data. This command button is displayed if we have in the main window gas throughput data.

8

<u>Tables & Charts:</u> Clicking this command button we can have as table and diagram the calculated time dependence of the moisture content RF, the cake solids content TS and the cake Saturation S for any pressure difference and any cake height. For the calculation the eq. displayed in (11) is used with the determined adaptation parameters Ad and Bd in (12).

9

Theory based plotting of the measured deliquoring data and the regression curve.
- The diagram can be copied and pasted for example to a word document. This is valid for all diagrams of the program. Select for that the menu *Chart* → *Copy Chart*.
- Clicking the Menu *Chart* → *Diagram Outlook* you have some possibilities regarding the formatting of the diagram.
- You can remove any measured points from the diagram by drawing a rectangular which includes these point(s). On the right top side of the diagram appear the command buttons *Cut Points* and *Cancel*. Clicking *Cut Points* you remove the measured points from the diagram and you have automatically a refreshing of the window including a recalculation of the parameters.

10

Chart in the logarithmic form: Displays instead of the linear diagram (default) the measured points and the regression curve as double logarithmic diagram:
ln((S-Sr)/(1-Sr)) =f (lnK)

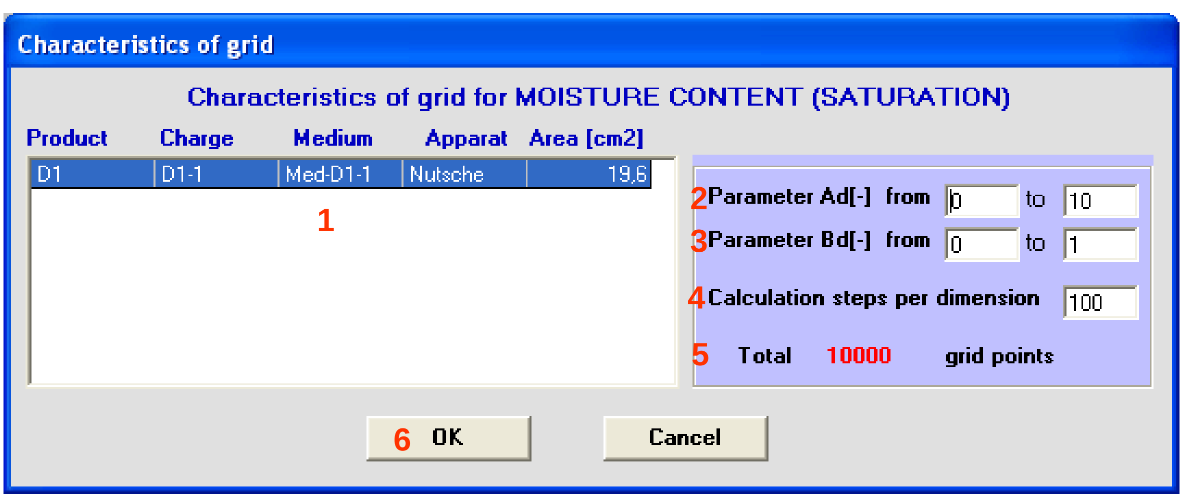
11

Cake deliquoring equation used for the regression analysis of the deliquoring experimental results.

12

Listing of the regression analysis results: These are the adaptation parameters Ad and Bd. If these parameters are accepted then click *Accept Data*. In such a case the data are kept in memory and can be saved. Without clicking *Accept Data* when leaving this module any data / changes in the results window are lost. This is valid for all results windows of the Data Analysis modules.

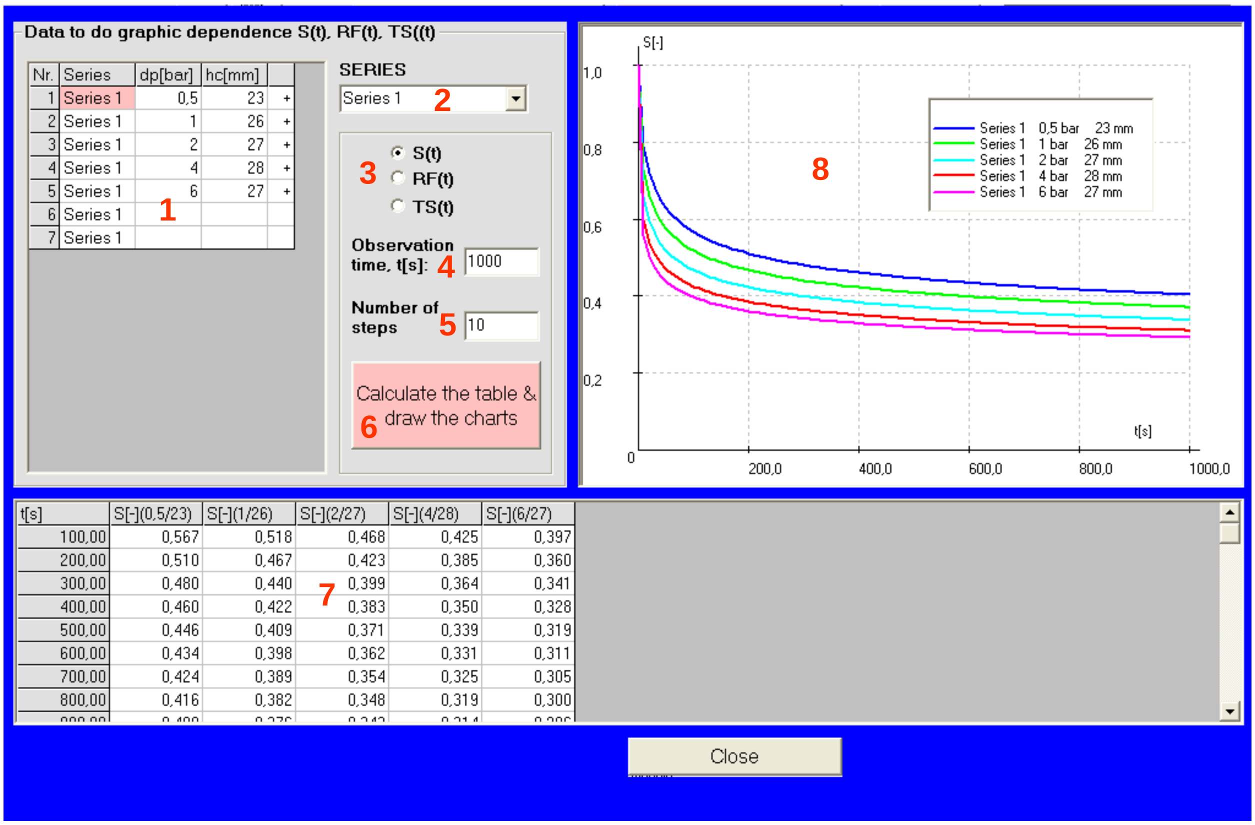
13



Change Regression Parameters.Clicking this button opens the above window which enables the input of Admin, Admax (2) and Bdmin, Bdmax (3) as well as the number of variations of each parameter (4) (= calculation steps per dimension). The total grid points

(5) are the number of calculations. Each of this calculation is done with a definite Ad and Bd which are within the set boarders Admin-Admax and Bdmin-Bdmax. As regression analysis results are taken those Ad and Bd which give the best fitting of the measured points.

Tables & Charts window of the Cake Deliquoring module



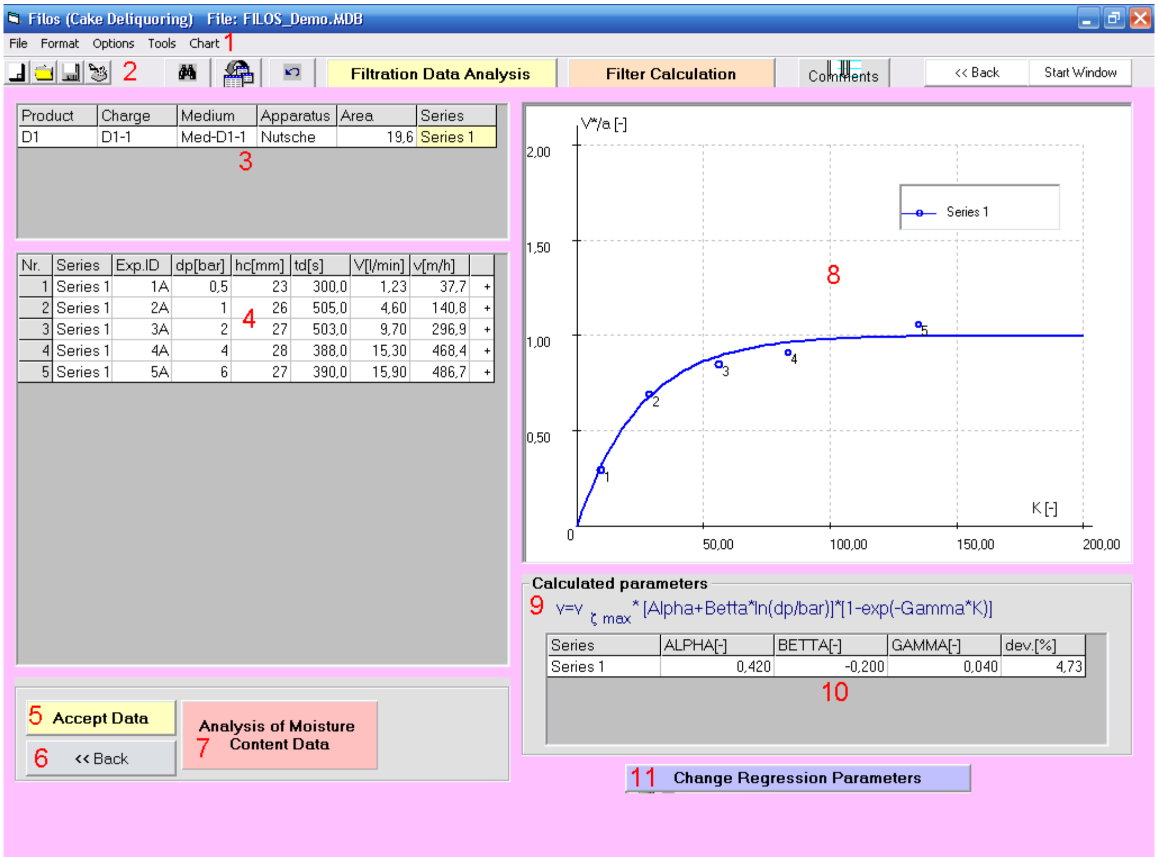
Tables & Charts window for the cake Deliquoring module: This window opens after clicking the *Tables & Charts* command button in the results window of the cake Deliquoring module. We have as table (7) and diagram (8) the calculated time dependence of the moisture content RF, the cake solids content TS and the cake Saturation S for any pressure difference and any cake height.

1. Listing of the test series name (default name), the pressure difference dp and the cake height hc. One row in table (1) with + is one curve in diagram (8). Default are listed those dp-hc combinations for which we have experimental data. In an empty row of the table any dp-hc values can be entered and after clicking *Calculate the table & draw the charts* the diagram (8) and the table (7) are updated. The number of curves in the diagram is equal the number of rows with dp-hc which have the +.

2. When more than one test series are analysed (option: all experiment series in the main window) we can click in any row in table (1) and then select in (2) one Series name. With *Calculate the table & draw the charts* a calculation is done.

3. We have the options to draw in the diagram the time dependence of cake Saturation S, cake moisture content RF or the solids content TS. The diagram results are also displayed as table in (7).
4. Input of the maximal deliquoring time for the diagram and the table.
5. Number of steps: Means the number of displayed rows in table (7).
6. Calculate the table & draw the charts: Any changes in any of the fields (1), (2), (3), (4) and (5) need the clicking of this command button to update the table and the diagram.
7. Table with the data of the diagram. As first column is the deliquoring time with so many rows as entered in (5). Each of the other columns represents the data of one curve. Regarding the column description the first number in brackets is the pressure difference and the second the cake height. If for example we have as description of one column S(1/26) this means that we display the values of the cake saturation S for the pressure difference dp=1 bar and cake height hc=26 mm.
8. Diagram illustrating the time dependence of cake Saturation S or cake moisture content RF or solids content TS (see selected option in (3)). The number of curves corresponds to the number of rows with + in (1).

5.3 The Results Window of the Cake Deliquoring Module for the Analysis of Gas Throughput Data



Gas Throughput Results window: If in the main window we have in the input table Gas throughput data (in the configuration window the option *Gas Throughput measured* has to be selected) then the Gas Throughput Results window opens after clicking in the main window the command button *Analysis of Gas Throughput Data*. The regression analysis results are displayed as a diagram (8) and as a list with the values of the calculated adaptation parameters *alpha*, *betta*, *gamma* (10). These parameters are needed for the calculation of the Gas throughput in the *Filter Calculation* module.

1

Menu bar of the Cake Deliquoring Results window.

2

Task bar of the Cake Deliquoring Results window

3

Display of the name of the current test series (the name is characterized by the values of the 5 parameters and it's the "family name" of the experiment. The name *Series 1* is a default help name. It makes sense to use this help name when we have experiments from different test series to identify the series. This is the case when we select in the main window the analysis option *all experiment series*. In such a case we don't have to use the names/values of all 5 parameters for the identification of the experiment.

4

Listing of the input data for the regression analysis. Rows without + are not considered for the regression analysis. We can remove/add the + via double clicking the corresponding row. The diagram (8) and the list with the regression results (10) are then automatically updated. Each row has the name (help name) of the test series, the Exp. ID, the pressure difference dp, the cake height hc, the deliquoring time td, the gas throughput V and the specific gas throughput (calculated from the measured gas throughput V).

5

<u>Accept Data</u>: Click always the command button *Accept Data* if you want that the changes are kept after you exit this window or/and if you want to save these changes.

6

<u>Back:</u> Goes back to the main window. Click first *Accept Data* before going back to the main window if you want to keep in memory the last data of the results window.

7

<u>Analysis of Moisture Content Data</u>: Opens the Results window displaying the analysis results of the cake moisture content (calculation of the adaptation parameters Ad and Bd).

8

Theory based plotting of the measured gas throughput data during cake deliquoring and the regression curve.
- The diagram can be copied and pasted for example to a word document. This is valid for all diagrams of the program. Select for that the menu *Chart → Copy Chart*.
- Clicking the Menu *Chart → Diagram Outlook* you have some possibilities regarding the formatting of the diagram.
- You can remove any measured points from the diagram by drawing a rectangular which includes these point(s). On the right top side of the diagram appear the command buttons *Cut Points* and *Cancel*. Clicking *Cut Points* you remove the measured points from the diagram and you have automatically a refreshing of the window including a recalculation of the parameters.

9

Semi empirical Gas throughput equation used for the regression analysis.

10

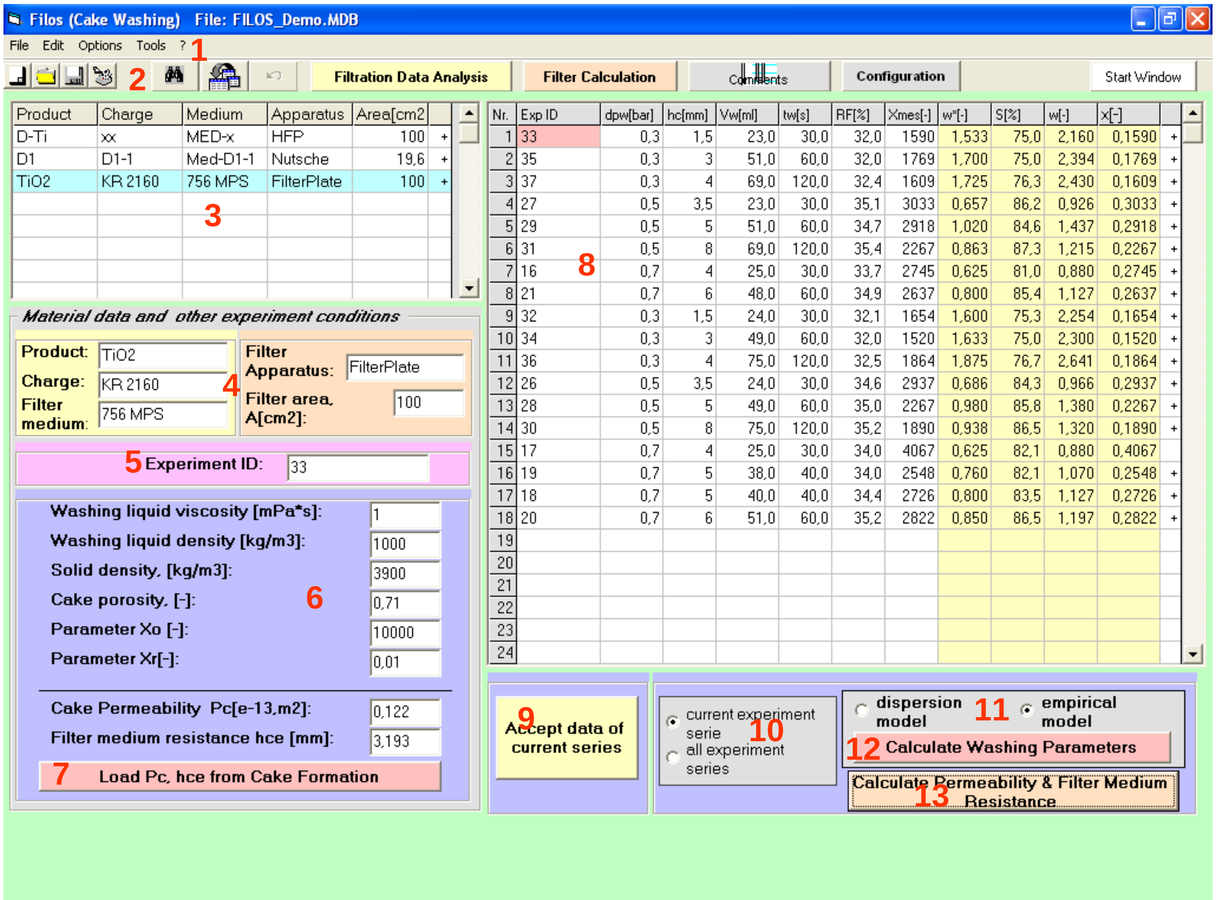
List with the regression analysis results: Adaptation parameters *alpha, betta, gamma*. These parameters are necessary for the calculation of the gas throughput in the *Filter Calculation* module. If you want to save these data first you have to click *Accept Data* before exiting this window. In the last column of the results list the deviation between measured and calculated values is displayed as indicator of the quality of the regression analysis.

11

<u>Change regression parameters</u>: Opens a window with the input fields for min and max values for the adaptation parameters *alpha*, *betta*, *gamma* and an input field for the number of variations for each parameter during the regression analysis (see input field *calculation steps per dimension*). If we have for example as input for *calculation steps* 50 that means that each parameter is varied from min to max 50 times and for all combinations we do regression analysis. As result we display in the results list (10) the parameter combination with the minimal deviation (the deviation is displayed in the last column of the results list in (10)).

6. The Cake Washing Module

6.1 The main window of the Cake Washing Module



When we have to calculate a filter apparatus with a cake washing step then in this case for the calculation of the wash out content in the discharged cake X as a function of the specific washing liquid amount W (washing ratio) we need adaptation parameters which have to be determined by analysing washing experimental data (preferably laboratory experiments). The analysis of such data and the determination of the needed parameters is the main job of the Cake Washing module.

At least 2 washing experiments are needed but 3 or more are recommended. How one washing experiment should be carried out? After the cake formation we give on the saturated filter cake a definite amount of washing liquid and with a washing pressure difference dpw the liquid flows through the cake. It is not necessary that the washing time is measured (if the washing time is measured this module also enables the determination of the cake permeability during the cake washing). It is also not necessary that we stop the experiment after the washing liquid reached the cake surface (end of the washing step). In many cases we can not measure the washing and deliquoring time but we only know the total washing and deliquoring time (that is the time from beginning of the washing until the end of the experiment). After stopping the experiment we measure the cake moisture content Rf and the wash out content in the filter cake X.

The Cake Washing main window (see figure above) enables the input of cake washing measured data (8) for the current test series. Data of many test series can be saved in the same program file. The test series list is in (3). The analysis of the data in the input table (8) starts after clicking the command button *Calculate Washing Parameters*. It is recommended to use the option *empirical model*.(11). For this option the analysis results which are displayed in the washing results window are the adaptation parameters Aw and Bw. These parameters are necessary for the calculation of the wash out content in the cake X in the *Filter Calculation* modules. When we select the option all experiment series (10) clicking the *Calculate Washing parameters* command button we have the analysis of the data of all listed test series with + in the test series overview list (3). In the results window we have then in the diagram one curve for each test series and in the result list the adaptation parameters Aw and Bw for all analysed test series. This enables the comparison of the washing behaviour of different test series.

For a given test series each row in the input table represents one experiment. Needed input parameters (see columns of the input table from left to the right) are the name of the experiment (Exp ID), the pressure difference for the cake washing step dpw, the cake height hc, the wash liquid volume Vw, the washing time tw (optional and not necessary for the determination of the adaptation parameters Aw and Bw), the moisture content of the discharged cake RF and the measured wash out content X. Calculated parameters (columns in yellow colour) are the washing ratio w* (=wash liquid volume related to cake volume), the cake Saturation S, the washing ratio W (=wash liquid volume related to the cake voids volume) and the specific wash out content x (x=X/X0 with X0 the wash out content of the cake directly after cake formation that means saturated with mother liquid). If the washing time tw is not entered (not measured) then it is displayed as a calculated parameter.

The parameters displayed in the data input table depend on the configuration settings in the configuration window (opens after clicking the configuration command button). For example the moisture content is not an input parameter if *NO Deliquoring after washing* is selected. If the configuration option Vw and tw measured is selected we have the washing time tw also as input parameter (and not calculated). In such a case it is possible to calculate the cake permeability and the filter medium resistance using the measured washing time via clicing *Calculate Permeability and Filter Medium Resistance*.

1
Menu bar of the Cake Washing input data window. For explanations regarding the menu entries see Chapter 3.1.

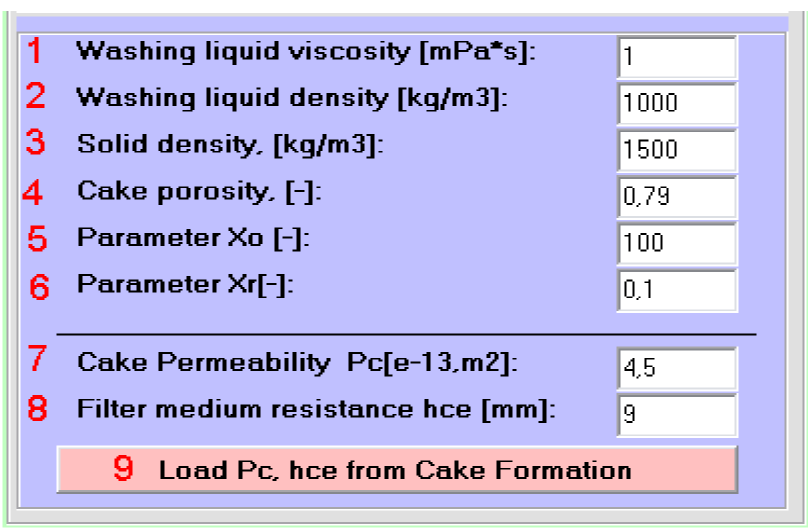
2
Task bar of the Cake Washing input data window.

3
Overview table for the test series with cake washing experiments. The 5 columns display the names for product, charge, filter medium, test apparatus and the filter area. These data are entered in (4) and are displayed in the overview table (3) after clicking the command button *Accept data of current series*. The inputs in (4) identify the test series and we can not have 2 test series with the same values of these 5 parameters. Selecting one test series this is highlighted with a blue colour and all data of this series are displayed in the input table (8). You can start the analysis of the data after clicking the command buttons *Calculate Washing Parameters*.

4
Input field for the 5 parameters which identify the test series (names for Product, Charge, Filter medium, Filter Apparatus and the value of the filter area)

5
Input field for the name of the experiment (Experiment ID). The exp ID can also be entered in the first column of the input table (8). In this case it is also displayed in the input field in (5).

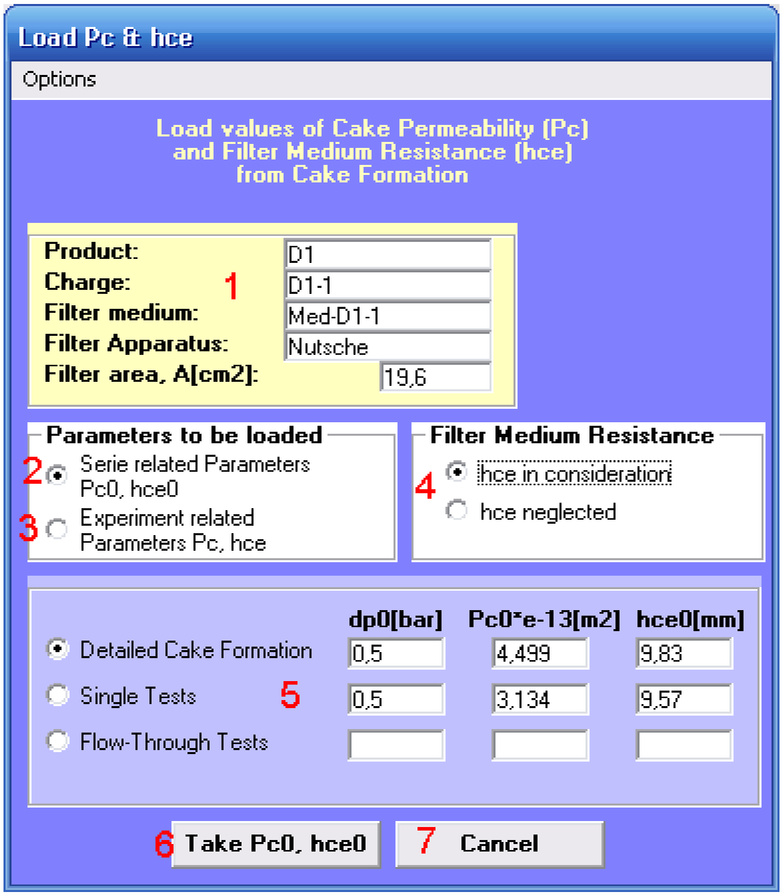
6



Necessary material input data for the analysis of the cake washing measured data to determine the adaptation parameters Aw and Bw.

1. Liquid Viscosity. Is the viscosity of the washing liquid. It is entered in (mili Pa s) (default unit). For example for water at 20°C the value of 1 (=1 mili Pas) has to be entered.
2. Liquid density Is the density of the washing liquid. Default input unit is kg/m3
3. Solids density Density of the solids. Entered in kg/m3 (default unit)
4. Cake Porosity (-) Defined as volume of the cake-voids over the volume of the cake (dimensionless parameter). It can be determined from a nutsche experiment by using the *Calculator* window (select the menu *Tools* → *Calculator* (Label: *Calculate Eps*). It is entered in this module as absolute value and not in %.
5. X0-Max wash out (-): Maximal wash out content in the cake. That is the cake content of the wash out substance after finishing the cake formation step when all pores of the cake are filled with the mother liquid. It can take any unit. It is recommended to use the specific cake wash out content by relating the wash out content to a kg dry solids. For example X0=5 g/kg dry solids means that after finishing the cake formation step a cake with 1 kg dry solids will have 5 g of the wash out substance. This amount has to be wash out during the cake washing and deliquoring steps.
6. Xr-Min wash-out(-): Absolute wash out content in the cake that can not be removed even with very high washing liquid amount. It is recommended, like X0, to use the specific cake wash out content by relating the wash out content to a kg dry solids. For example Xr=0,1 g/kg dry solids means that in the best case we can have in the discharged cake a wash out content of 0,1 g/kg dry solids.
7. Cake Permeability Pc (e-13 m2): This parameter is needed for the calculation of the washing time but not for the calculation of the wash out content X (for the calculation of X the washing ratio W and the adaptation parameters Aw and Bw are needed. The determination of Aw and Bw is the main task of this module). This value together with the filter medium resistance hce are determined in the cake formation modules (*Detailed cake formation* or *Single Tests* or *Cake Flow Through tests*) and can be loaded after clicking the command button *Load Pc, hce from Cake Formation*. Important is that the Pc-value used in this module and the Pc0-value used in the *Filter Calculation* module for the same suspension should be the same.
8. Filter medium resistnce hce: This parameter is also needed for the calculation of the washing time but not for the calculation of the wash out content X. This value together with the cake permeability Pc are determined in the cake formation modules (*Detailed cake formation* or *Single Tests* or *Cake Flow Through tests*) and can be loaded after clicking the command button *Load Pc, hce from Cake Formation*. Important is that the hce-value used in this module and the hce-value used in the Filter Calculation module for the same suspension should be the same.

7 Load Pc, hce from Cake Formation



Load Pc, hce from Cake Formation: Like in the deliquoring main window after clicking this command button the above window opens for selecting and loading the cake permeability Pc and the filter medium resistance hce from the cake formation modules *Detailed Cake Formation*, *Single Tests* and *Flow Through Tests*.

1. Display of the characterization data of the current test series.
2. Serie related Parameters Pc0, hce0: If this option is selected the dp0, Pc0 and hce0 for the 3 cake formation modules are displayed in (5). We have Dp0, Pc0 and hce0 –values for the modules in (5) only if we did the second regression step (that is the calculation of the cake compressibility). In case we have data in (5) we can select from which of the 3 modules we want to take the Pc and hce –values and then we click Take Pc0, hce0 to load them in the Washing Window.
3. Experiment related Parameters Pc, hce: If we select this option a list of all experiments is displayed and for each selected experiment the values of Pc and hce (if existing) are displayed in (5) with the possibility to select one of the 3 modules in (5) in which we have data and load them in the washing module. .
4. The display of the values of the filtration parameters in (5) depends on the option selected in (4). If we have the option hce neglected then the hce-value in (5) is always zero.

5. Depending on the selected option (2) or (3) and the option in (4) we have a display of Pc and hce values for the modules we have data. Select one of these 3 modules in which we have data and click *Take Pc0, hce0* to load these data in the washing window.
6. Take Pc0, hce0: Takes the selected Pc and hce- values in (5) and loads them in the washing window.
7. Closes the window without taking any data to the washing window.

8

1	2	3	4	5	6	7	8	9	10	11	12	13
Nr.	Exp ID	dpw[bar]	hc[mm]	Vw[ml]	tw[s]	RF[%]	Xmes[-]	w*[-]	S[%]	w[-]	x[-]	
1	33	0,3	1,5	23,0	30,0	32,0	1590	1,533	75,0	2,160	0,1590	+
2	35	0,3	3	51,0	60,0	32,0	1769	1,700	75,0	2,394	0,1769	+
3	37	0,3	4	69,0	120,0	32,4	1609	1,725	76,3	2,430	0,1609	+
4	27	0,5	3,5	23,0	30,0	35,1	3033	0,657	86,2	0,926	0,3033	+
5	29	0,5	5	51,0	60,0	34,7	2918	1,020	84,6	1,437	0,2918	+
6	31	0,5	8	69,0	120,0	35,4	2267	0,863	87,3	1,215	0,2267	+
7	16	0,7	4	25,0	30,0	33,7	2745	0,625	81,0	0,880	0,2745	+
8	21	0,7	6	48,0	60,0	34,9	2637	0,800	85,4	1,127	0,2637	+
9	32	0,3	1,5	24,0	30,0	32,1	1654	1,600	75,3	2,254	0,1654	+
10	34	0,3	3	49,0	60,0	32,0	1520	1,633	75,0	2,300	0,1520	+
11	36	0,3	4	75,0	120,0	32,5	1864	1,875	76,7	2,641	0,1864	+
12	26	0,5	3,5	24,0	30,0	34,6	2937	0,686	84,3	0,966	0,2937	+
13	28	0,5	5	49,0	60,0	35,0	2267	0,980	85,8	1,380	0,2267	+
14	30	0,5	8	75,0	120,0	35,2	1890	0,938	86,5	1,320	0,1890	+
15	17	0,7	4	25,0	30,0	34,0	4067	0,625	82,1	0,880	0,4067	
16	19	0,7	5	38,0	40,0	34,0	2548	0,760	82,1	1,070	0,2548	+
17	18	0,7	5	40,0	40,0	34,4	2726	0,800	83,5	1,127	0,2726	+
18	20	0,7	6	51,0	60,0	35,2	2822	0,850	86,5	1,197	0,2822	+

Input table for the measured cake washing experiments of one test series. Using the *Edit* menu you can delete the table or the current row, you can insert new rows, you can copy the table and paste it for example in a word or an excel document.

1. Displays the number of entered measurements.
2. Input field for the experiment name (=Exp ID). The experiment name can also be entered in the field (5).
3. dpw (bar): Pressure difference for cake washing.
4.hc(mm): Cake height. That is the cake height measured after finishing the experiment.
5. Vw(ml): Washing liquid volume given above the cake before starting the cake washing. It can be entered also as mass if in configuration window the option *Mass* in the field *Input of washing liquid measuring units* is selected. If in the configuration window the option *tw measured* is selected then the washing liquid amount is a calculated and the washing time is input parameter.

6. tw(s): Washing time. That is the time from begin of the washing until the liquid level given above the cake reaches the cake surface. If the option in configuration window *Vw(Mw) measured* is selected the washing time is then a calculated parameter.
7. RF(%): Cake moisture content after finishing the cake washing and deliquoring step. Entered in % or as absolute value (see configuration window). This input column is only displayed if we select in the configuration window the option *Yes* in the *Deliquoring after Washing* field. If we know that the cake has a saturation of 100% (zero displacement of the liquid in the cake after washing) we should select the configuration option *No* in the *Deliquoring after Washing* field.
8. Xmes (-): Wash out content of the discharged cake. Has the same unit as the maximal wash out content X0. It is recommended to use as unit for X0, Xr and Xmes the amount of wash out content related to 1 kg dry solids. For the determination of Xmes the cake has to be re suspended with a definite amount of pure washing liquid and then the wash out concentration of the re suspended washed cake has to be measured. From the measured concentration value the wash out content Xmes related to 1 kg dry solids can be determined. That means the input parameter Xmes has to be first calculated from the measured concentration of the re suspended washed cake and this calculated value has to be entered in the input table of the main window of the cake washing module. This Xmes calculation is enabled by the new developed *Calculator*. This new calculator has not yet been integrated in FILOS (only in the new CentriStar) and will be given for free to the companies which use only the FILOS program.
9. w*(-): washing ratio defined as wash liquid volume divided by the cake volume (calculated)
10. S(%): cake Saturation defined as liquid volume in the cake divided by the cake voids volume. It is calculated from the entered cake moisture content Rf. It is displayed only if the cake moisture content is an input parameter.
11. w(-): Washing ratio defined as washing liquid volume divided by the cake voids volume. A calculated parameter.
12. x(-): specific wash out content in the cake (x=Xmes/X0). Calculated parameter with maximal possible value xmax=1 (cake not washed at all) and minimal possible xmin=Xr/X0.
13. The + in the last column means that we consider this experiment for the regression analysis which can be started after clicking the command button *Calculate Washing Parameters.* Via double clicking one row the + is removed and we exclude this measurement from the analysis. This makes sense if we know that this was a wrong measurement.

9

<u>Accept data of current series</u>: We always have to click first the *Accept data of current series* command button if we want to save any inputs or changes for the current test series. That means before saving first click the *Accept data of current series* – command button.

10

- current experiment series: If this option is selected only the data of the selected test series in the test series overview table (see blue colour in (3)) are analysed. These are the data displayed in the current input table (8).
- all experiment series: If this option is selected then the data of all test series which have the + in the last column in the series overview table are analysed together. This enables the comparison of the cake washing behaviour of different test series.

11

– Dispersion model: If this option is selected and after clicking the *Calculate washing Parameters* command button the entered washing data are analysed on the basis of the modified dispersion model. It is not recommended to use this option because for the *Filter calculation* modules the empirical model is used, which is simpler and can give similar accuracy as the dispersion model.
- Empirical model: Default option (recommended because the empirical model is used for the calculation of the wash out content in all *Filter Calculation* modules). If this option is selected and after clicking the *Calculate washing Parameters* command button the entered washing data are analysed on the basis of the relative simple empirical model and the adaptation parameters Aw and Bw are determined (this model is displayed in the cake washing results window).

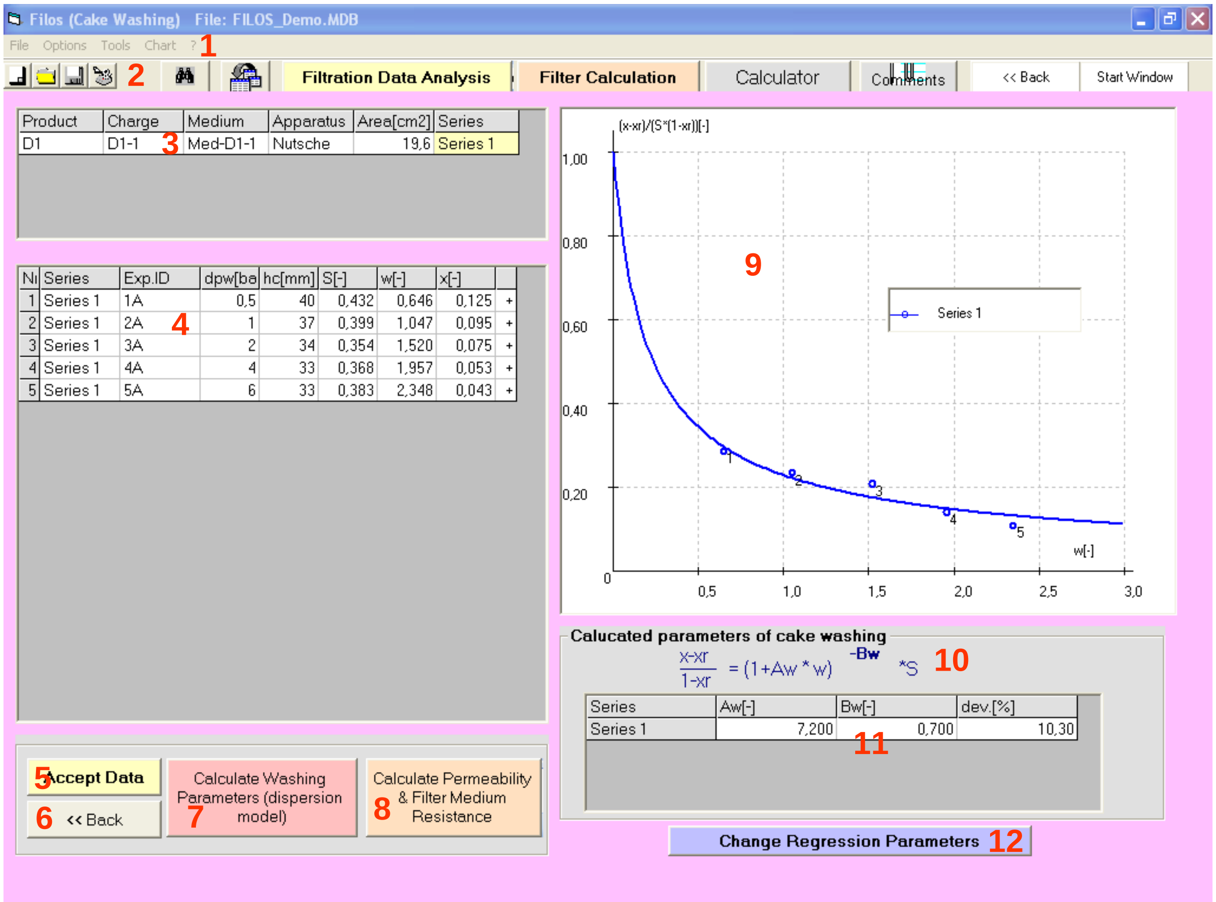
12

Calculate Washing parameters. Starts the regression analysis based on the empirical model (if the option *empirical model* is selected) and displays the results window with the regression diagram and the listing of the calculated adaptation parameters for cake washing Aw and Bw. The parameters Aw and Bw are necessary for the calculation of the wash out content X as a function of the washing ratio W (W= wash liquid volume divided by the cake voids volume).

13

Calculate Permeability & Filter Medium Resistance Only possible if we have as input in the data input table not only the washing liquid amount but also the washing time tw (for that the option in the configuration window *Vw(Mw) and tw measured* should be selected).

6.2 The Cake Washing Results window (Option: Empirical Model)



<u>Cake Washing Results window (Option: Empirical Model):</u> This window opens after clicking in the main window of the *Cake Washing* module the command button *Calculate Washing Parameters* and if the option *empirical model* is selected. It displays the regression analysis results of the data entered in the main window for the selected test series as a diagram (9) and as listing of the calculated adaptation parameters Aw and Bw (11). If in the main window the option *all experiment series* is selected then for each test series with + in the series overview table in the main window we have a separate regression and the calculated parameters for every test series are listed in (11) enabling the comparison of different test series.

1

Menu - bar of the Cake Washing Results window.

2

Task bar of the Cake Washing Results window (option: *empirical model*)

3

Display of the name of the current test series (the name is characterized by the values of the 5 parameters and it's the "family name" of the experiment. The name *Series 1* is a default help name. It makes sense to use this help name when we have experiments from different test series to identify the series. This is the case when we select in the main window the analysis option *all experiment series*. In such a case we don't have to use the names/values of all 5 parameters for the identification of the experiment.

4

Listing of the input and calculated data necessary for the regression analysis. Rows without + are not considered for the regression analysis. We can remove/add the + via double clicking the corresponding row. The diagram with the regression results (9) and the list with the calculated adaptation parameters (11) it is then automatically updated. Each row has the name (help name) of the test series, the Exp. ID, the pressure difference during cake washing dpw, the cake height hc, the cake saturation S (calculated from the entered cake moisture content), the washing ratio w and the specific wash out content x (x=X/X0).

5

Accept Data: Click always the command button *Accept Data* if you want that the changes are kept after you exit this window or/and if you want to save these changes.

6

Back: Goes back to the main window. Click first *Accept Data* before going back to the main window if you want to keep in memory the last data of the results window.

7

Calculate Washing parameters (dispersion model): Opens the results window with the results of the regression analysis of the washing data, which are based on the dispersion washing model.

8

Calculate Permeability & Filter Medium Resistance: Opens the window with the regression diagram and the regression result parameters: cake permeability Pc and filter medium resistance hce. This command button is displayed if in the data input table of the main window also the washing time is an input parameter. That means both parameters are measured: washing liquid amount (as mass or volume) and washing time (when having this case you have to select the option *Vw(Mw) and tw measured* in the configuration window). The determined parameters cake permeability Pc and filter medium resistance hce are average values because for each pressure difference no separate regression analysis is done as we have it in the cake formation modules. If we want to consider the influence of the pressure difference on the cake permeability and the determination of the cake compressibility then it is recommended to use the *Cake Flow - Through Tests* module.

9

Theory based plotting of the measured cake washing data and the regression curve.

- The diagram can be copied and pasted for example to a word document. This is valid for all diagrams of the program. Select for that the menu *Chart* → *Copy Chart*.
- Clicking the Menu *Chart* → *Diagram Outlook* you have some possibilities regarding the formatting of the diagram.
- You can remove any measured points from the diagram by drawing a rectangular which includes these point(s). On the right top side of the diagram appear the command buttons *Cut Points* and *Cancel*. Clicking *Cut Points* you remove the measured points from the diagram and you have automatically a refreshing of the window including a recalculation of the parameters.

10

Cake washing equation used for the regression analysis of the experimental results for the option *empirical model*.

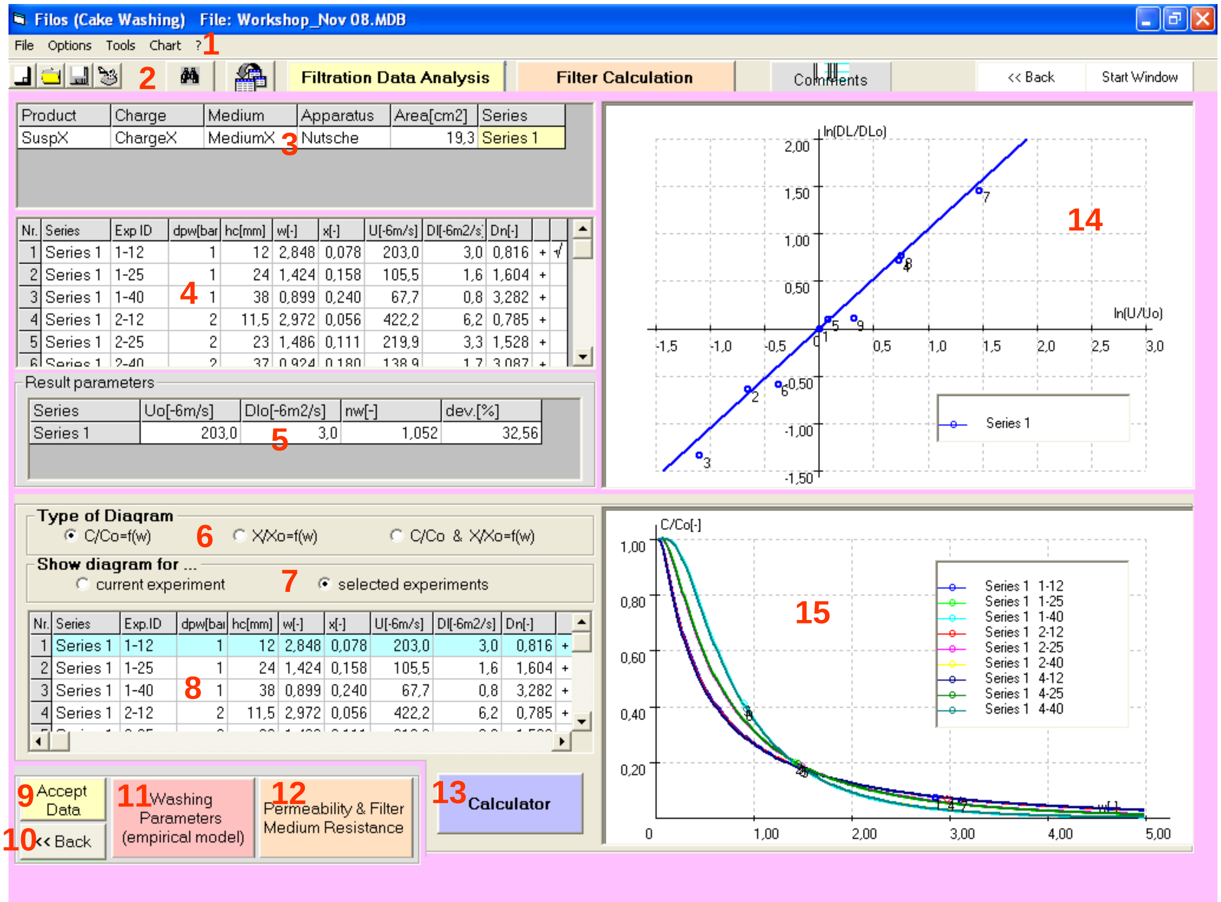
11

Listing of the regression analysis results for the option *empirical model*: These are the adaptation parameters Aw and Bw. If these parameters have to be saved then you have to click first *Accept Data*. In such a case the data are kept in memory and can be saved. Without clicking *Accept Data* when leaving this module any changes in the results window are lost. This is valid for all results windows of the Data Analysis modules.

12

<u>Change Regression Parameters</u>. Clicking this button opens a small window which enables the input of Awmin, Awmax and Bwmin, Bwmax as well as the number of variations of each parameter (= calculation steps per dimension). The total grid points are the number of calculations. Each of this calculation is done with a definite Aw and Bw which are within the set boarders Awmin-Awmax and Bwmin-Bwmax. As regression analysis results are taken those Aw and Bw which give the best fitting of the measured points.

6.3 The Cake Washing Results window (Option: Dispersion Model)



Cake Washing Results window (Option: Dispersion Model): This window opens after clicking in the main window of the *Cake Washing* module the command button *Calculate Washing Parameters* and if the option *dispersion model* is selected. It displays the regression analysis results of the entered data in the main window for the selected test series as diagrams (14) and (15) and lists the calculated parameters U0, Dl0, nw in (5). Dl0 is the dispersion coefficient (has the same unit as the diffusion coefficient) for the wash liquid velocity U0. The dimensionless parameter nw enables the calculation of the dispersion coefficient for each hc/dpw-combination. Having Dl the dimensionless washing index Dn is calculated. Having Dn and the washing ratio w the wash out content in the cake can be calculated.

If in the main window the option *all experiment series* is selected then for each test series with + in the series overview table of the main window we have a separate regression and the calculated parameters for each test series are listed in (5) enabling the comparison of different test series.

How the regression analysis for the option *dispersion model* is done?

For each measurement we have as input the pressure difference dpw and the cake height hc. Further inputs are the wash liquid amount Vw or Mw, the cake moisture content Rf and the wash out content of the discharged cake X. The program calculates from the input data for each experiment the washing ratio W, the wash liquid velocity U and the expected specific wash out content x directly after finishing cake washing (before starting cake deliquoring). Having this specific wash out content x and the washing ratio w the program determines for each experiment such a washing index Dn which gives a calculated x-value equal the measured value x. From this Dn-value the Dl value is then calculated. Having determined the dispersion coefficient Dl for each experiment a linear regression analysis (see diagram 14) is done. The slope of the line gives the parameter nw, which enable the calculation of Dl (and Dn) for each cake washing velocity U.

1

Menu bar of the Cake Washing Results window.

2

Task bar of the Cake Washing Results window (Option: *dispersion model*)

3

Display of the name of the current test series (the name is characterized by the values of the 5 parameters and it's the "family name" of the experiment. The name *Series 1* is a default help name. It makes sense to use this help name when we have experiments from different test series to identify the series. This is the case when we select in the main window the analysis option *all experiment series*. In such a case we don't have to use the names/values of all 5 parameters for the identification of the experiment.

4

Display for each experiment the test series name (help name), the name of the experiment (Exp ID), the pressure difference during cake washing dpw, the cake height hc, the washing ratio w (=wash liquid volume divided by the cake voids volume), the calculated specific (related to X0) wash out content in the cake directly after completing the washing step x (is calculated from the wash out content of the discharged cake Xmes, the cake moisture content Rf and the maximal wash out content in the cake X0). The parameter U in the next column is the wash liquid velocity and Dl and Dn are the dispersion coefficient (Dl) and the washing index (Dn). Both parameters are determined from the specific wash out content x and the washing ratio w.

Double clicking one row of this table the + disappears (except the last column = the column on the right of the +-column). That means that this measurement is not considered for the regression analysis.

5

Listing of the results of the linear regression analysis (see diagram (14)). The dispersion coefficient Dl0 is related to the wash liquid velocity U0. The U0-value can be changed if we select another washing experiment as reference experiment. For that double click the last column of table (4)(empty column on the right of the +-column) of another experiment and see how the regression diagram is updated and also the results data U0, Dl0 and nw in the results list (5). The dimensionless parameter nw is the slope of the regression line and is needed for the calculation of Dl and Dn for any wash liquid speed.

6

Type of Diagram: In table (8) any experiment can be selected (see blue colour) and depending on the selected option in (6) different curves with the comparison of measured and calculated values are displayed in (15). For all curves we have as x-axis the washing ratio w which can be interpreted as dimensionless washing time. C/C0 is the specific wash out concentration of the wash filtrate and X/X0 is the specific wash out content in the cake.

7

If option selected experiments is clicked that means in diagram (15) depending on the selection in (6) we have a display of the curves for each experiment with + in table (8). If the option current experiment is selected then only the curve(s) of the selected experiment in table (8) are displayed.

8

Table with the listing of the washing experiments and important parameters (entered and calculated). This table is the same as in (4) (for the description of the table parameters see (4)). It enables the selection of any experiment for plotting of the diagram in (15) which enables the comparison of measured and calculated parameters. Depending on the option in (7) we can have a diagram only for the selected experiment or for all experiments with +.

9

Accept Data: Click always the command button *Accept Data* if you want that the changes are kept after you exit this window or/and if you want to save these changes.

10

Back: Goes back to the main window. Click first *Accept Data* before going back to the main window if you want to keep in memory the last data of the results window.

11

Washing parameters (empirical model): Opens the results window with the results of the regression analysis of the washing data, which are based on the empirical mathematical model.

12

<u>Calculate Permeability & Filter Medium Resistance</u>: Opens the window with the regression diagram and the regression result parameters: cake permeability Pc and filter medium resistance hce. This command button is displayed if in the data input table of the main window also the washing time is an input parameter. That means both parameters are measured: washing liquid amount (as mass or volume) and washing time (when having this case you have to select the option *Vw(Mw) and tw measured* in the configuration window). The determined parameters cake permeability Pc and filter medium resistance hce are average values because no separate regression analysis for each pressure difference is done as we have it in the cake formation modules. If we want to consider the influence of the pressure difference on the cake permeability and the determination of the cake compressibility then it is recommended to use the *Cake Flow - Through Tests* module.

13

<u>Calculator</u>: Clicking Calculator instead of the table (8) with the listing of the experiments we display an empty table for entering any combination of cake height hc, pressure difference dpw and washing ratio w. For these entered values the program calculates and displays based on the regression analysis results (see U0, Dl0, nw –values displayed in (5)) the corresponding values for cake velocity U, dispersion coefficient Dl, washing index Dn, specific wash out concentration of the wash filtrate C/C0 and finally specific wash out concentration in the filter cake. After clicking *Plot Diagram* we have a display of the curves on the right bottom side of the window. Which curves we display depend on the selection in the *Type of Diagram*-field.

14

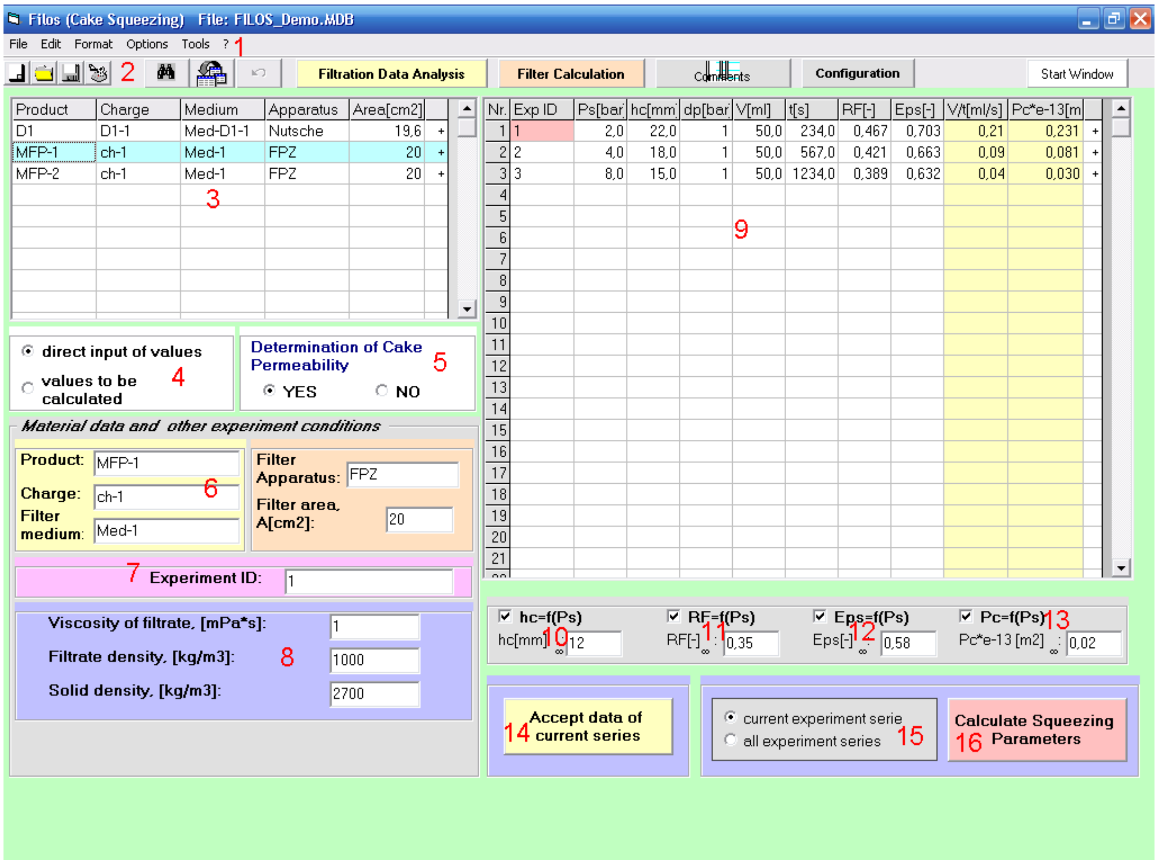
Diagram with the regression line and the measured cake washing data as listed in table (4). This diagram is a graphical illustration of the determination of the parameter nw (=slope of the regression line). The parameter nw is necessary for the calculation of Dl and Dn for any combination of cake height and pressure difference (hc-dpw). Only the rows with + in table (4) are considered for the regression analysis. Double clicking in the last column of one row in table (4) the diagram and the regression results are updated because another U0 is selected.

15

This diagram displays the specific wash out content of the wash filtrate C/C0 or the specific wash out content in the cake X/X0 or both parameters (see selection in (6)) as a function of the washing ratio w for the selected experiment in table (8). Depending on the option in (7) we can have a plot for the selected experiment only or for all experiments in table (8) which have the + in the last column. If we open the *Calculator* window (for that click the *Calculator* – command button) we can display such curves for any combination of cake height and pressure difference.

7. The Cake Squeezing Module

7.1 The main window of the Cake Squeezing Module



This module is needed when we squeeze the cake after cake formation or after cake washing to reduce the moisture content via cake volume reduction using a membrane or a piston. Membrane filter presses for example or filter press automats are typical filters which enables the squeezing of the filter cake. This module can analyse data from experiments with industrial filters like membrane filter presses / filter press automats but also laboratory experiments with pressure nutsche filters with the use for example of a piston for cake squeezing. The main job of this module is the determination of the adaptation parameters necessary to calculate the cake height, the cake porosity, the moisture content and also the cake permeability of the squeezed cake (equilibrium state) as a function of the squeezing pressure. These parameters are needed for the calculation of the pre squeezing and squeezing step in filter presses (see *Filter Presses* module in the Filter Calculation program part.

At least 3 experiments are needed. How one experiment has to be carried out to get the necessary experimental input data for the module *Cake Squeezing*? After formation of a filter cake we squeeze this cake with the pressure Ps and we measure in equilibrium state (after practically no more liquid comes out of the cake) the height of the squeezed cake and the cake moisture content. Because the squeezed cake is saturated with liquid the cake porosity depends on the value of the cake moisture content and is calculated from it. When we want to know also the dependence of the squeezing pressure on the cake permeability (and this is needed when we have a cake washing or cake deliquoring in filter presses after the squeezing step) then after we have squeezed the cake we give on the cake a definite amount of liquid and with a pressure difference dp this liquid flows through the cake. We measure the time needed until this liquid flows through the cake (=until the liquid level reaches the cake surface) and from this measured time, from the liquid amount, the height of the squeezed cake and the flow through pressure difference dp the cake permeability of the squeezed filter cake is calculated.

1

Menu bar of the Cake Squeezing main window.

2

Task bar of the Cake Squeezing main window

3

Listing of the test series with the selected test series highlighted (blue colour). One test series is characterized by the values of the 5 parameters and it's the "family name" of the experiment: Names for product, charge, filter medium and name and filter area of the filter test apparatus.

4

- <u>direct input of values</u>: If selected then the values of the moisture content RF or of the cake porosity Eps have to be entered in the data input table (9). Entering for example the cake moisture content then the cake porosity is calculated and vice versa.
- <u>values to be calculated</u>: If this option is selected then the cake moisture content and the cake porosity are calculated parameters and are listed in the data input table (the RF and Eps – columns appear then in yellow colour as an indication that they are calculated parameters). Input parameters in this case for a given experiment are the Cake mass (=mass of the wet cake after finishing the squeezing experiment) and the solid mass (=mass of the dry cake).

5

<u>Determination of Cake Permeability</u>

- <u>YES</u>: If this option is selected means that for the given test series we have flow through experiments and the data input table has 5 additional columns (compared to the option NO): These are the flow through pressure difference dp, the liquid volume V given above the squeezed cake for the flow through experiment, the flow through time t (time needed until the liquid reaches the cake surface) and the calculated parameters: volume flow rate during the flow through experiment and cake permeability of the squeezed cake.

- <u>NO</u>: If this option is selected means that for the given test series we do not have flow through experiments. In this case the above mentioned 5 columns (see option YES) are not displayed in the data input table. This option is selected if for example we want to design a filter press with no washing and no deliquoring of the squeezed cake.

6
Input field for the 5 parameters which identify the test series (names for Product, Charge, Filter medium, Filter Apparatus and the value of the filter area)

7
Experiment ID: Input field for the name of the experiment. The name of the experiment can also be entered in the Exp ID column of the data input table. In this case entering the experiment name in the table this name is also displayed in (7).

8. Material parameters necessary for the analysis of the squeezing data:
- Viscosity of filtrate: Necessary only if we have flow through tests of the squeezed cake (Option YES in (5) selected). It is recommended that we should use as flow liquid the mother liquid (=filtrate) in order to get correct value of the cake permeability.
- Filtrate density and solid density are needed for the calculation of the cake porosity from the cake moisture content and vice versa.

9

1	2	3	4	5	6	7	8	9	10	11	12
Nr.	Exp ID	Ps[bar	hc[mm	dp[bar	V[ml]	t[s]	RF[-]	Eps[-]	V/t[ml/s]	Pc*e-13[m	
1	1	2,0	22,0	1	50,0	234,0	0,467	0,703	0,21	0,231	+
2	2	4,0	18,0	1	50,0	567,0	0,421	0,663	0,09	0,081	+
3	3	8,0	15,0	1	50,0	1234,0	0,389	0,632	0,04	0,030	+
4											
5											

Data input table for the case that for the given test series we have cake squeezing and flow through experiments of the squeezed cake. In case that we do not have flow through experiments the following columns are not displayed: dp, V, t, V/t, Pc

1. Nr.: Counting the number of experiments of the given (selected) test series.
2. Exp ID: Name of the experiment. This name can also be entered in (7) and displayed here.
3. Ps (bar): Squeezing pressure in bar.
4. hc(mm): Cake height of the squeezed cake in the squeezing equilibrium state (that means when practically no more liquid comes out of the cake).
5. dp(bar): Pressure difference for the cake flow through test of the squeezed cake.
6. V(ml): Liquid volume given above the cake after the squeezing step for the flow through test. Instead of the volume the liquid mass can be entered (the selection of volume or mass as input parameter is done in the Configuration window).
7. t(s): Flow through time. That is the time from the beginning of the flow through experiment up to the time the liquid reached the cake surface.

8. RF(-): Absolute value of the cake moisture content (not in %) of the squeezed cake. If the option *values to be calculated* is selected, then RF is a calculated parameter from the mass of the wet squeezed cake and the mass of the dry cake and displayed in yellow colour as an indication of a calculated parameter.
9. Eps(-): Cake Porosity as absolute value (not in %). It can be an input or a calculated parameter from the entered cake moisture content RF. If the option *values to be calculated* is selected, then the cake porosity Eps and the cake moisture content RF are both calculated from the mass of the wet squeezed cake and the mass of the dry cake and displayed in yellow colour as an indication of a calculated parameter.
10. V/t (ml/s): Calculated volume flow rate during the cake flow through experiment.
11. Pc(e-13 m2): Calculated cake permeability of the squeezed cake.
12. If one row (one experiment) has a "+" in the last columns means that this experiment is considered for the regression analysis. If we don't want to consider one measurement for the regression analysis (because for example this measurement was wrong) we just double click this row and remove the +.

10

– If the Check box hc=f(Ps) is checked means that we want/can analyse the influence of the squeezing pressure on the cake height and determine the adaptation parameter Alpha_hc. When clicking *Calculate Squeezing Parameters* the window with the regression analysis results for the cake height as a function of squeezing pressure is displayed.

- hc(mm)∞: input field for the minimal possible cake height of the squeezed cake (that is the cake height for Ps→ ∞). This value should be always smaller than the entered hc-values in the data input table. It is recommended to do one squeezing experiment with relatively very high squeezing pressure and get all required minimal parameters: hc∞, RF∞, Eps∞ and Pc∞.

11

If the Check box RF=f(Ps) is checked means that we want/can analyse the influence of the squeezing pressure on the cake moisture content and determine the adaptation parameter Alpha_RF. When clicking *Calculate Squeezing Parameters* the window with the regression analysis results appears and the command button in this results window RF=f(Ps) is enabled.

- RF(-)∞: input field for the minimal possible cake moisture content of the squeezed cake (that is the cake moisture content for Ps→ ∞). This value should be always smaller than the entered (or calculated) RF-values in the data input table. It is recommended to do one squeezing experiment with relatively very high squeezing pressure and get all required minimal parameters: hc∞, RF∞, Eps∞ and Pc∞.

12.

If the Check box Eps=f(Ps) is checked means that we want/can analyse the influence of the squeezing pressure on the cake porosity and determine the adaptation parameter Alpha_Eps. When clicking *Calculate Squeezing Parameters* the window with the regression analysis results appears and the command button in this results window Eps=f(Ps) is enabled.

- Eps(-)∞: input field for the minimal possible porosity of the squeezed cake (that is the cake porosity for Ps→ ∞). This value should be always smaller than the entered (or calculated) cake porosity-values in the data input table. It is recommended to do one squeezing experiment with relatively very high squeezing pressure and get all required minimal parameters: hc∞, RF∞, Eps∞ and Pc∞.

13. If the Check box Pc=f(Ps) is checked means that we want/can analyse the influence of the squeezing pressure on the permeability of the squeezed cake and determine the adaptation parameter Alpha_Pc. When clicking *Calculate Squeezing Parameters* the window with the regression analysis results appear and the command button in this results window Pc=f(Ps) is enabled.

- Pc*e-13(m2))∞: input field for the minimal possible permeability of the squeezed cake (that is the cake permeability for Ps→ ∞). This value should be always smaller than the calculated Pc-values in the data input table. It is recommended to do one squeezing experiment with relatively very high squeezing pressure and then with this squeezed cake do a flow through test. The so determined cake permeability can be entered in this field as the minimal possible cake permeability.

14

<u>Accept data of current series</u>: We always have to click first the *Accept data of current series* command button if we want to save any inputs or changes for the current test series. That means before saving first click the *Accept data of current series* – command button.

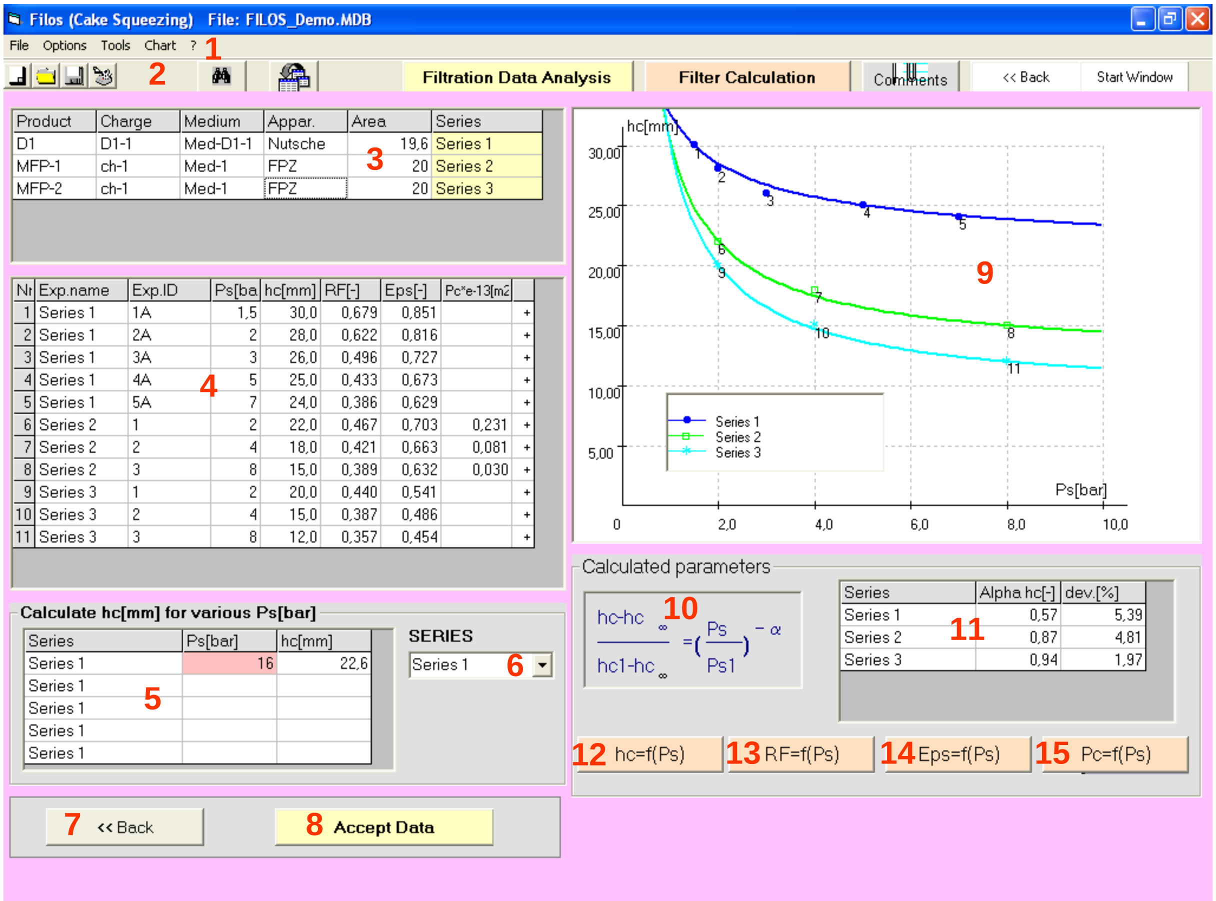
15

- <u>current experiment series</u>: If this option is selected only the data of the selected test series in the test series overview table (see blue colour in (3)) are analysed. These are the data displayed in the current data input table (9).
- <u>all experiment series</u>: If this option is selected then the data of all test series which have the + in the last column in the series overview table (3) are analysed together. This enables the comparison of the cake squeezing behaviour of different test series.

16

<u>Calculate Squeezing Parameters</u>: Clicking this command button opens the window with the regression analysis results enabling the determination of the adaptation parameters Alpha_hc, Alpha_RF, Alpha_Eps and Alpha_Pc.

7.2 The Results Window of the Cake Squeezing Module



Cake Squeezing results window: Opens after clicking the command button *Calculate Squeezing Parameters* in the main window and when we select in the main window the option *all experiment series* and at least for one test series we have the option *Determination of Cake Permeability YES* (that means at least for one test series we measured also the flow through behaviour of the squeezed cake). In case we have for all test series with + in the main window the option *Determination of Cake Permeability NO* then the command button Pc=f(Ps) (see (15)) is not displayed because no flow through experiments are existing for analysis. If the option in the main window *current experiment series* is selected then we have in the results window the analysis of the data of only the selected test series. That means that we have in the results window only one regression curve and in the results table (11) only one adaptation parameter.

Normally as default (=first) result window is the window with the analysis results of the height of the squeezed cake as a function of the squeezing pressure (hc=f(Ps)). The analysis results for the other parameters (cake moisture content RF, cake porosity Eps and cake permeability Pc) can be displayed after clicking the corresponding command button (13, 14, 15). For each result window we have the corresponding diagram with the regression curve(s) (see (9)) for the test series displayed in (3) and the regression results (adaptation parameter(s)) in a table below the diagram). The values of all measurement points in the diagram are displayed as table in (4). Double clicking one row of this table the + is removed and automatically a new regression is done without considering this measurement. Please notice that only after clicking *Accept Data* these results are kept in memory and can be saved. Based on the determined adaptation parameters and using the displayed equation (see (10)) the calculator in (5) enables the calculation of the corresponding result parameter (hc or RF or Eps or Pc) for any squeezing pressure Ps.

1

Menu bar of the Cake Squeezing results window.

2

Task bar of the Cake Squeezing results window

3

Display of the name of the test series which are selected for the data analysis. If in the main window the option *current experiment series* is selected then in this field only the current simulation is displayed. When we have in the main window the option *all experiment series* then we have in this field all test series of the main window displayed, which have a + in the last column. The name of one test series is characterized by the values of the 5 parameters and it's the "family name" of the experiment. The name in the last column (for example *Series 1*) is a default help name. It makes sense to use this help name when we have experiments from different test series to identify the series. This is the case when we select in the main window the analysis option *all experiment series*. In such a case we don't have to use the names/values of all 5 parameters for the identification of the experiment.

4

Listing of the input/calculated data necessary for the regression analysis for all test series listed in (3). Rows without + are not considered for the regression analysis. We can remove/add the + via double clicking the corresponding row. The diagram with the regression results (9) and the list with the calculated adaptation parameters (11) it is automatically updated. Each row has the name (help name) of the test series, the Exp. ID, the squeezing pressure Ps, the height hc, the moisture content RF, the cake porosity Eps and the cake permeability Pc of the squeezed cake. The cake permeability is only for the test series displayed for which cake flow through data were entered.

5

Calculator: Depending on the result window we have (hc=f(Ps) or RF=f(Ps) or Eps=f(Ps) or Pc=f(Ps)) calculates the corresponding result parameter (height hc or moisture content RF or porosity Eps or Permeability of the cake) for any squeezing pressure Ps. For the calculation the equation in (10) is used. The value of the adaptation parameter used in this equation is the regression analysis result and is displayed in (11). For the case we have more than one test series analysed together (as it is the case above) in (6) we select for which series the calculation has to be done.

6

Selection of the test series for which we want to calculate the height hc or the cake moisture content RF or the cake porosity Eps or the cake permeability Pc for any squeezing pressure Ps. The calculated parameter depends on our current results window.

7

<u>Back</u>: Goes back to the main window. Please click *Accept Data* before clicking *Back* if you want to keep the regression analysis results of the current results window in memory after exiting this window and as precondition for saving these results. After *Accept Data* you can leave the results window but coming back you see the same results as you last had before exiting this window.

8

<u>Accept Data:</u> Click always the command button *Accept Data* if you want that the changes are kept after you exit this window or/and if you want to save these changes.

9

Diagram with the regression curve(s). Depending on which command button we have active (clicked) (see 12, 13, 14, 15) we have the plotting of hc=f(Ps) or RF=f(Ps) or Eps=f(Ps) or Pc=f(Ps). In case we have in the main window the option *all experiment series* we display for each test series with + one regression curve. Each measurement point has a number, so that this point can be identified in the table (4). In the Menu *Chart → Diagram Configuration* you can remove the numbers and you can format the diagram (different symbols for the points, Black-White diagram etc.). The diagram can be copied and pasted for example to a Word document (this *copy – paste* function is valid for all diagrams of the program). If one or more measurements are not good and we don't want to consider them for the regression analysis, just find the row of this measurement in table (4) from its number and double click this row in the table to remove the +. Automatically a new regression analysis is done without this point. Another way to remove points from the diagram: A mouse click next to this point and then draw a rectangular which includes this point. On the right top side of the diagram appears a *Cut* – button. After clicking *Cut* this measured point disappears from the diagram and a new regression analysis without this point is done.

10

Equation used for the regression analysis. The regression analysis determines the parameter α. The determined value of this parameter is displayed in (11). Please notice that the exponent α in the equation is identical with the parameter Alpha_hc or Alpha_RF or Alpha_Eps or Alpha_Pc depending on the current results window.

11

Listing of the values of the regression analysis result parameter and the corresponding deviation between measured and calculated values in %.

12
hc=f(Ps): Opens the results window for the regression analysis of measured cake height as a function of the squeezing pressure Ps.

13
RF=f(Ps): Opens the results window for the regression analysis of measured or calculated cake moisture content as a function of the squeezing pressure Ps.

14
Eps=f(Ps): Opens the results window for the regression analysis of calculated or measured cake porosity as a function of the squeezing pressure Ps.

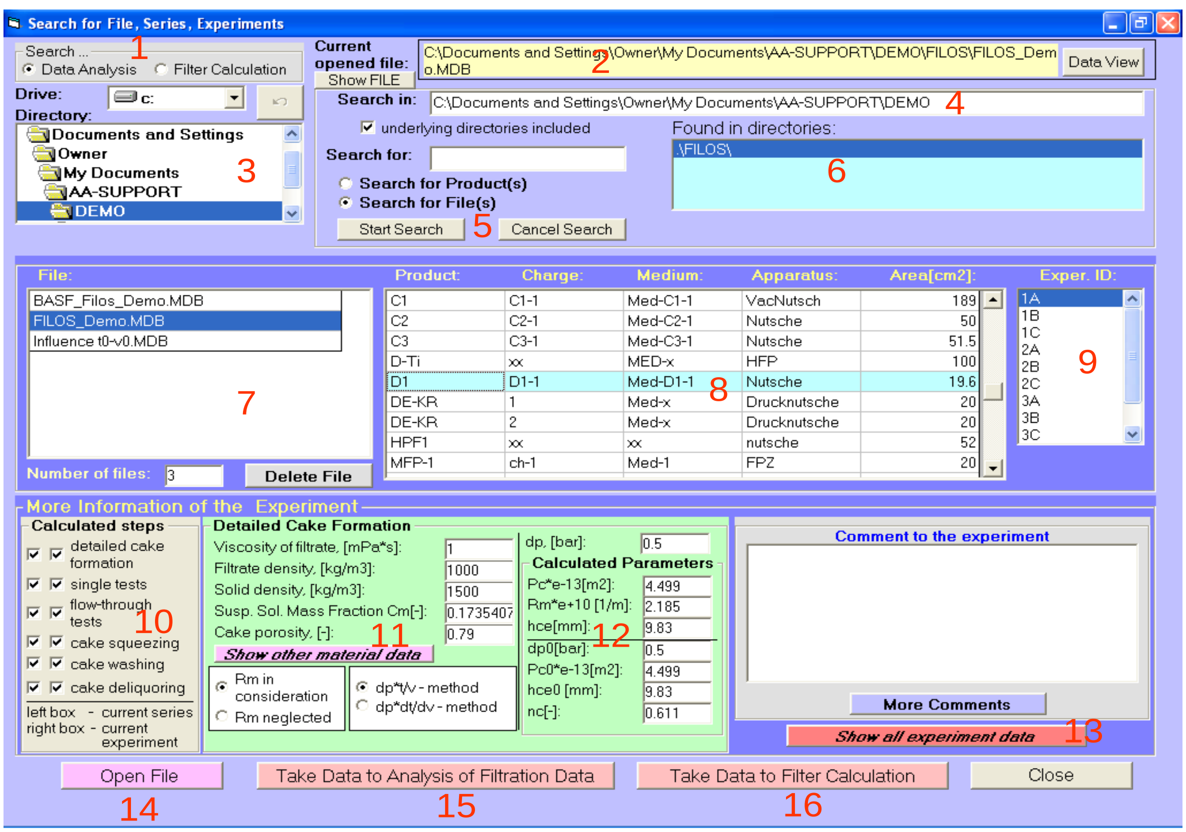
15
Pc=f(Ps): Opens the results window for the regression analysis of calculated cake permeability as a function of the squeezing pressure Ps.

8. The Search Module

We have two different windows for the Search-module: If we click the symbol from the *Data Analysis* part we get the window as displayed below. Clicking the above Search-symbol from the *Filter Calculation* program part we get the window in Chapter 8.2.

The *Search* – module enables the search for any program file or tested material, the display of the data (entered and calculated) of any experiment (*Filtration Data Analysis*) or simulation (*Filter Calculation*) without having to open the file in which the experiments or simulations are saved. The *Search* – module enables also not only the display of the data of any experiment / simulation but the opening of the file, where this experiment or simulation is saved. Furthermore any experiment or experiment- series of any program file can be added to the experiments of the opened file enabling the comparison of data, which originally were saved in different files. Finally the transfer of material data to the *Filter Calculation* modules is enabled.

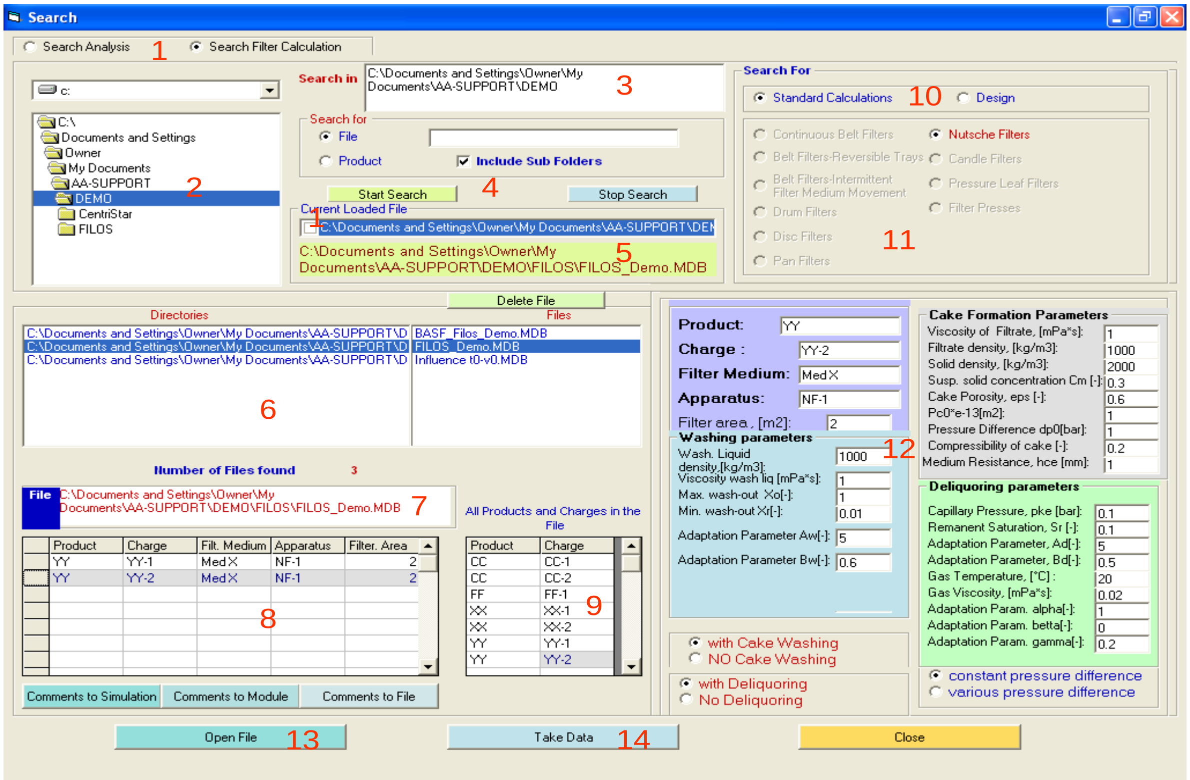
8.1 The Search window for the Filtration Data Analysis modules

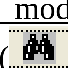


Search-window for the *Filtration Data Analysis* modules: The Search window opens by clicking the Search-symbol in the task bar ( ) or by selecting in the *Tools*-menu the entry *Search for File, Series, Experiment*.

1. Possibility to switch from the Search-window for *Analysis of Filtration Data* to the Search window for *Filter Calculation*.
2. Displays which program file is the current opened file (that is the file we are working at the moment).
3. Possibility to select any folder in which we want that the program searches, finds and displays all program files that are saved in this folder (included subfolders if the checkbox *underlying directories included* is checked). The selection is done by double click.
4. Display of the selected folder in which we want to search for program files.
5. The Search is started after we click *Start Search* and is stopped after we click *Cancel Search*.
6. The display of the results of the Searching. These are all subfolders of the selected directory in (3). That means in (6) we display all subfolders of the displayed directory in (4) which have program files.
7. The display of all program files of the selected folder in the directories list (6)
8. A listing of all test series of the selected program file in (7)
9. A listing of all experiments of the selected test series in (8)
10. Shows for the selected test series in (8) which modules have data (left) and for the selected experiment in (9) which modules have data (check boxes on the right).
11. Input data for the module *Detailed Cake Formation* necessary for the analysis of cake formation data to determine the cake permeability, cake compressibility and filter medium resistance.
12. Permeability and filter medium resistance for the selected experiment as well as standard permeability Pc0 (for pressure difference Dp0), medium resistance hce0 and cake compressibility nc for the selected test series.
13. Possibility to display the data of all modules, which have data. In (11) and (12) as default only the data of *Detailed Cake Formation* module are displayed.
14. The selected file in (7) can be opened.
15. Enables the transfer of the data of the selected test series or the selected experiment to the current opened file (the open file is displayed in (2)).
16. Enables the selection of a filter calculation module and the transfer of the material data of the selected test series for the Filter Calculation.

8.2 The Search window for the Filter Calculation Modules



Search-window for the Filter Calculation modules. This *Search* window opens by clicking the Search-symbol in the task bar () or by selecting in the *File*-menu the entry *Search*.

1. Possibility to switch from the Search-window for *Filter Calculation* to the Search window for *Filtration Data Analysis*
2. Possibility to select any folder in which we want that the program searches, finds and displays all program files that are saved in this folder (included subfolders if the checkbox *include sub folders* is checked. The selection is done by double click.
3. Display of the selected folder in which we want to search for program files (for the folder selection see (2))
4. The Search is started after we click *Start Search* and is stopped after we click *Stop Search.*
5. Displays which program file is the current opened file (that is the file we are working at the moment).
6. The display of the Searching results. All program files of the selected directory (subdirectories included).
7. The display of the selected program file in (6)
8. The display of all simulation series in the selected program file.

9. A listing of all suspensions (product-charge names) used in all simulations of the selected file

10 For the selecting simulation series (see (8)) we can choose if we want to see the simulation data for the option *Standard Calculation* or *Filter Design*.

11 Displays the Filter Calculation modules we did simulations for the selected simulation series.

12 Displays the material input data for the selected filter apparatus and the selected simulation series.

13 Opens the selected program file in (6)

14 Enables the transfer of the selected simulation series data to any filter calculation module of the current (opened) file.

9. Take Data

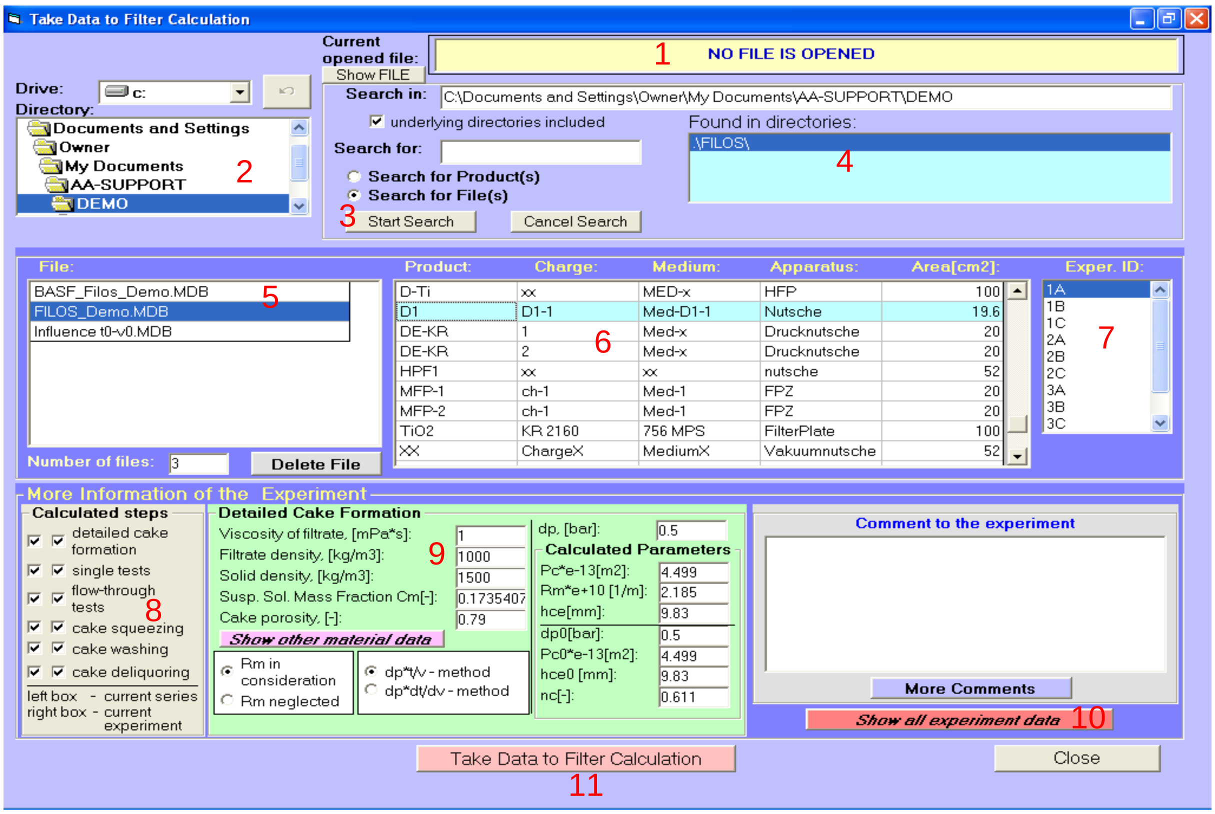
The Interface between the Filtration Data Analysis Part and the Filter Calculation Part.

The *Take Data* command button which is placed in the task bar (below the menus) of every window of the *Filter Calculation* modules is the interface between the two program parts *Analysis of Filtration Data* and *Filter Calculation*. By clicking the command button *Take Data* the first *Take-Data* window opens (see fig. below), which enables first the selection of the program file in which the material data of a wished test series are saved. Then in this first Take Data window we select the wished test series and finally we click the command button *Take Data to Filter Calculation* to open the second and last *Take Data* window.

Please notice that when a program module of the *Filtration Data Analysis* part is our current module and not a *Filter calculation* module by clicking the *Search* symbol in the task bar () the *Search* window for the *Filtration Data Analysis* module opens. By clicking the command button *Take Data to Filter Calculation* in this *Search*-window (description of the *Search* window see Chapter 8.1) the same window opens as when clicking *Take Data* command button from a *Filter Calculation*. This window also enables the searching, the selection and the transfer of the suspension and the necessary material data as well as the selection of the filter apparatus we want to calculate the performance or we want to design.

Imagine that you want to calculate the performance of a Nutsche Filter (or any other continuous or batch working filter apparatus). How we open the Standard calculation window for the Nutsche Filter Calculation? Please notice that for each Filter apparatus we have 2 calculation options: *Standard Calculation* and *Filter Design*. The *Standard Calculation* option calculates the filter performance for a given apparatus (that means a filter area is given). For the *Filter Design* option the filter performance is given and the Filter area is calculated. For our example (calculation of the performance of a Nutsche filter) we click the command button *Nutsche Filters* in the Start Window (Calculation Options: *Standard Calculation*) or we can click from any program window of the Analysis modules the command button *Filter Calculation* and select the Filter apparatus we want to calculate (in our example Nutsche Filters). If we have a Filter calculation module already open, then we have to click the command button *Standard Calculations modules* and then select the filter we want to calculate.

Actually as already mentioned above, it is not necessary that we first have to open for example the Nutsche-standard Calculations window to be able to load the necessary material data for the calculation of the Nutsche performance. From any window of the program part *Filter Calculations* just click the command button *Take Data* and the first Take Data -window appears (see figure below). In this window you can first search and select the database file in which the material data are saved and you want to load in the current opened file. In the above example we know that our data we want to load are in the folder *My Documents\AA-Support\DEMO* (see figure below). We first have to select this folder and then click the command button *Start Search*. The program displays also all subfolders of the selected directory which have database files of the program *FILOS.* In the files list we have a display of all database files of the selected folder/subfolder. For the selected folder and database file we have a listing of all test series and for each selected test series a listing of all experiments of this test series. For the selected test series we have on the left bottom side of the window the info which modules of the Filtration Data Analysis part have data. On the right of this field we have the display of the results for the module *Detailed Cake Formation* (the most important module of the Data Analysis – part). By clicking the command button *Show all experiment data* we have a display of all input and result material data for all modules, which have data.

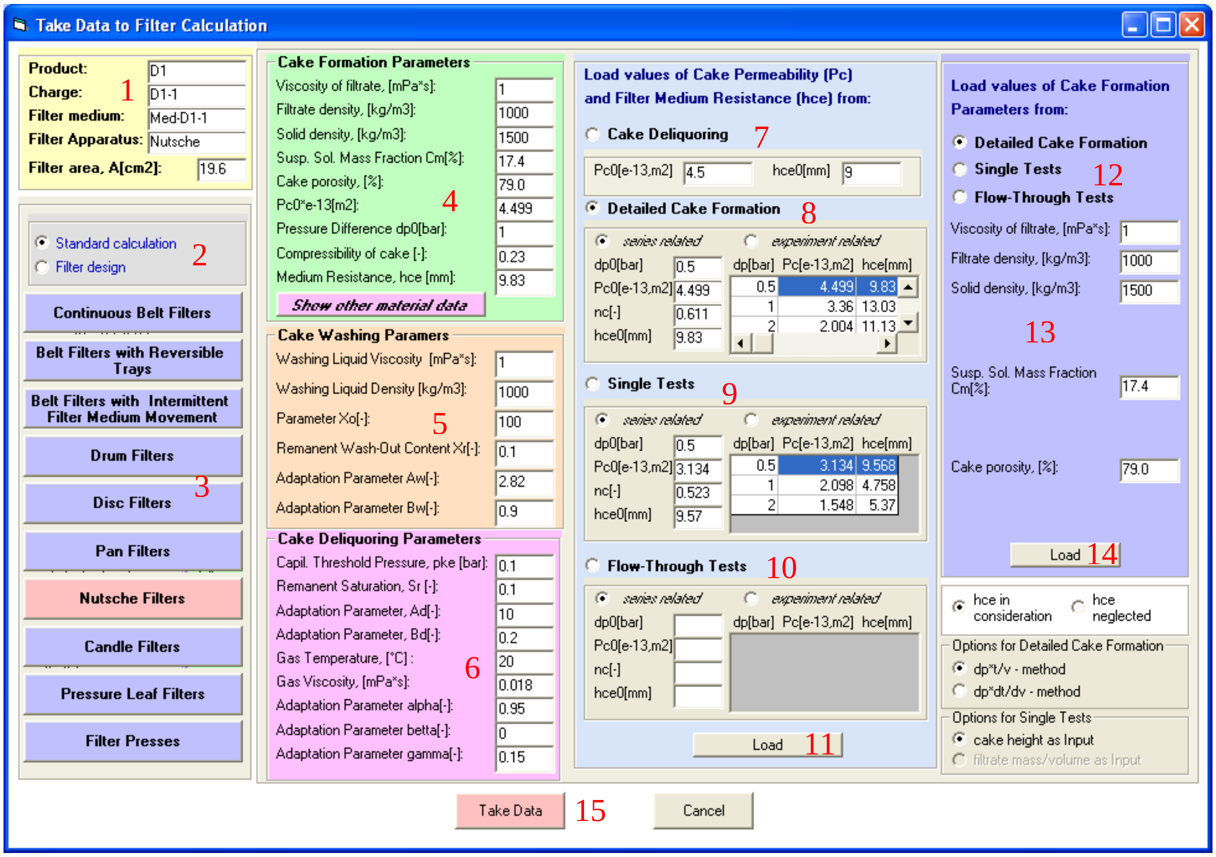


First *Take Data* – Window. This window opens after clicking the command button *Take Data* which is displayed in the task bar of every *Filter Calculation* module. The *Take Data* - windows (see also second *Take Data* window below) enable the search and selection of any test series which are saved in any program file and the transfer of the material data (these material data are input and result parameters of the *Filtration Data Analysis* modules) for the calculation of any filter apparatus.

1. Displays the name of the current file (that is the file we are working at the moment). If we haven't yet opened a file then NO FILE IS OPENED is displayed.
2. Selection of the folder in which we want to do the *Search* for program files (default: subfolders of the selected folder are included)
3. By clicking *Start Search* we start the Searching process for program files in the selected folders.

4. The display of all subfolders in which program files were found.
5. Program files in the selected subfolder in (4)
6. Test Series list of the selected program file in (5)
7. Listing of all experiments of the selected test series in (6)
8. Shows for the selected test series in (8) which modules have data (left) and for the selected experiment in (9) which modules have data.
9. Permeability and filter medium resistance for the selected experiment as well as standard permeability Pc0 (for the pressure difference Dp0), medium resistance hce0 and cake compressibility nc for the selected test series (input and output data of the analysis module *Detailed Cake Formation).*
10. Opens the window with the display of the most important input and output data of all Analysis modules, which have data
11. Opens the *second Take Data* window which enables the selection of the filter apparatus and the display/modification of the material data of the selected test series and finally the transfer of these data to the selected *Filter Calculation* module.

For the transfer of the material data to any filter calculation module just click in the first *Take Data* window (see figure above) the command button *Take Data to Filter Calculation* and the second *Take Data* window opens that enables first the display and even the change of the material data of the selected test series and then the selection of the filter apparatus which we want to calculate and finally the transfer of these data to the selected filter calculation module (in the above example to the Nutsche Filters – module)



<u>The second *Take Data* – window</u>, which appears after we click in the first *Take Data* - window the *Take Data to Filter Calculation* – command button. In this window (second *Take Data* – window) we have a display of all filter apparatuses (3) and we can select which one we want to calculate. We can even select which calculation option we want to have: *Standard Calculation* (=calculation of the performance of a given filter) or *Filter Design*. The material data are also displayed (see 4,5,6). If some data are not existing (because for example no experiments were carried out and analyzed), then we can enter the missing values in this window and/or modify them manually. Clicking the command button *Take Data* the program opens the window for the calculation of the selected apparatus and displays all material data in this filter calculation window.

1. Identity data of the selected test series (the selection was done in the first *Take Data* window)
2. Selection of the *Filter Calculation* option. If for example *Standard Calculation* is selected then the window for the *Standard Calculation* of the selected Filter apparatus in (3) will open after clicking *Take Data* command button (15).
3. Selection of the filter apparatus we want to calculate.
4. Cake formation material parameters necessary for the filter calculation.
5. Cake Washing material parameters
6. Cake Deliquoring material parameters

7 If this option is selected then we use for the filter calculation the Pc0 and hce –values we used in the *Cake Deliquoring* module. This is the default option if deliquoring data exist.
8 If this option is selected then we use for the filter calculation the Pc0, dp0, nc and hce –values determined in the *Detailed Cake Formation* module.
9 If this option is selected then we use for the filter calculation the Pc0, dp0, nc and hce –values determined in the *Single Tests* module.
10 If this option is selected then we use for the filter calculation the Pc0, dp0, nc and hce –values determined in the *Cake Flow Through Tests* module.
11 Loads the values of the selected option
12 Possibility to load material input parameters from any of the three *Cake formation* modules.
13 Display of the material input parameters of the module selected in (12)
14 Loading of the material input data which are displayed in (13)
15 Opens the main window of the selected *Filter Calculation* module and loads all selected/entered material data.