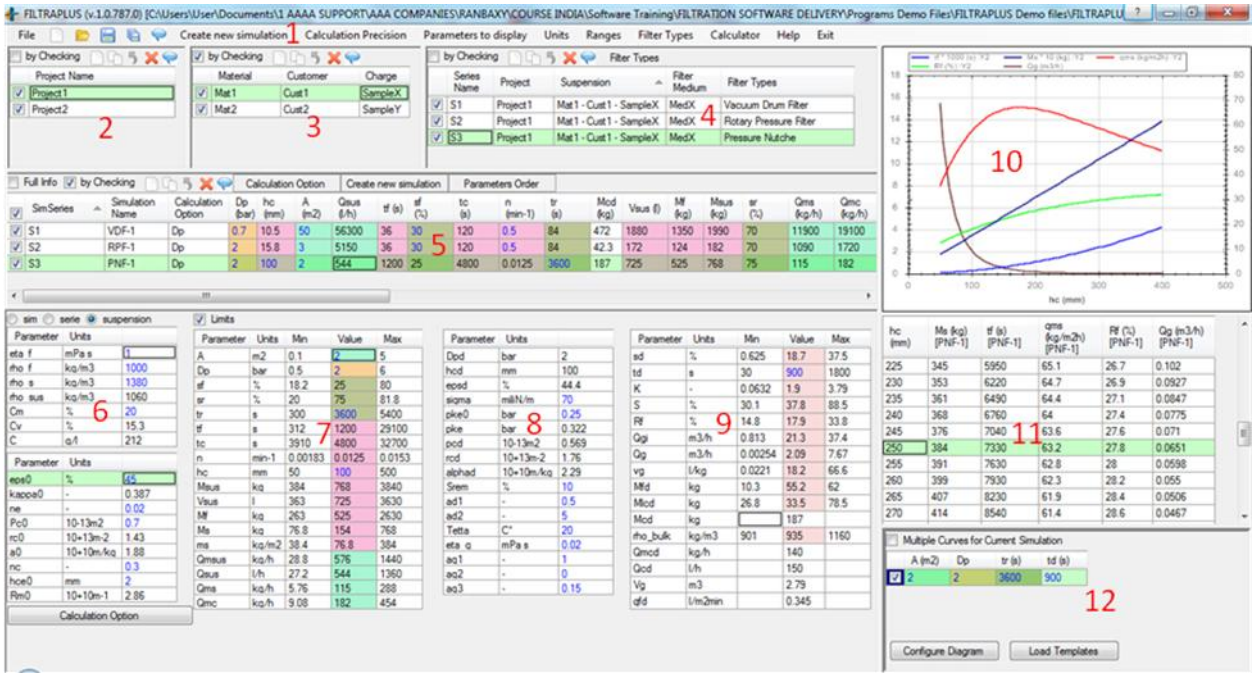
DOCUMENTATION

FILTRAPLUS 2014

OCTOBER 2014

CONTENTS

A The Main Window of FILTRAPLUS



1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

Main window of FILTRAPLUS for creating a Filter simulation (cake formation and the optional step of cake deliquoring) for any filter type (Batch and Continuous working filters) and for displaying the simulation results (**5**, **7**, **9**) as filter performance of a given filter or as filter design for a given performance. Additionally the influence of any material or setting parameter on the filter performance can be displayed as diagram (**10**) and table (**11**). Every simulation (see list of simulations in **5**) belongs to a definite Simulation series (**4**) and every Series belongs to a definite project (**2**). Simulations belonging to the same series have the same suspension, the same filter type and the same filter medium. Even simulations of different series (that means of different projects, different suspensions or/and different filter types) can be displayed together in the horizontal table (**5**) and their results can be directly compared to each other even in a diagram and table form (**10**,**11**).

For each simulation, we have a high flexibility regarding the input parameters by using the parameters grouping concept. All parameters belonging to the same group have the same color and are listed together (exception is the group of the filter area A). Any one parameter of the filter group can be input and all others are calculated. The input parameters are always displayed in blue and the calculated in black color. This concept gives a very high flexibility to the program. For example in the column of cake formation with settings & result parameters (**7**) all the following parameters: tf, tc, n, hc, Msus, Vsus, Mf, Ms, Mc, ms belong to the same group and any one of them can be entered and the others are then calculated. Even more parameters belong to this group but they are not displayed in the above screenshot (how to display parameters see command *Parameters to display*). *FILTRAPLUS* has highest flexibility regarding the parameters, which are displayed. By clicking the *Parameters to display* command in the menu task bar the user can define in *the Parameters to display* window which parameters have to

be shown. Each series has specific parameters, which are displayed. All others are then hidden.

Very useful program feature is the Limits concept: By checking the checkbox *Limits* we have on the left and right of all possible input parameters their minimal and maximal values. This helps the user to always enter meaningful values. Every time one parameter it is entered we have automatically refreshing of the min-max values (but also of the diagram and the table). For the limits calculation the program uses the min-max values of the "Ranges" window. This window can open by selecting the *Ranges*-menu. For each filter type, different values for the min-max parameters can be entered and saved.

For each simulation, different calculation options can be used. The calculation options can be selected in the *Calculation Options* window (opens by clicking the command button *Calculation Options*). We can have a simulation with constant pressure difference (Dp=const) but also with constant suspension flow rate (Qp=const, as we have in case when using a volumetric pump) or with constant suspension flow rate followed by constant pressure difference (Qp+Dp=const, as we have approximately when using a centrifugal pump). Besides the calculations for plane area we have all 3 options (Dp=const, Qp=const, Qp+Dp=const) also for convex cylindrical area, as it is the case when using candle filters. Every simulation can be done only for the cake formation step or for both steps: cake formation and cake deliquoring. For the cake deliquoring step the calculation of the evaporation of the liquid in the cake can be considered. For Filter Press applications different cake height, pressure difference and cake permeability for the cake deliquoring step can be considered taking into account the change of the cake structure when membrane squeezing is applied. Also different values for the density and viscosity of the liquid in the cake (compared to the mother liquid) can be entered to consider the case that the cake was washed prior to deliquoring.

The Units of almost all parameters can be changed by clicking the *Units*-command in the menu task bar. Also US-Units can be selected. To enable the easy selection of the units 3 default sets of units can be saved and selected: units for a laboratory filter device, units for a pilot filter and units for industrial filter. By clicking OK in the *Units* window all selected units are applied for all simulations of the file.

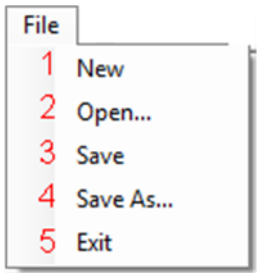
Projects, Suspensions, Series and Simulations can easily be created, deleted but also duplicated and comments can be entered. The duplication is a powerful tool that enables for example the easy creation of new simulations by just changing some parameters of the previous (mother) simulation.

A1 The Menu Task Bar

1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15

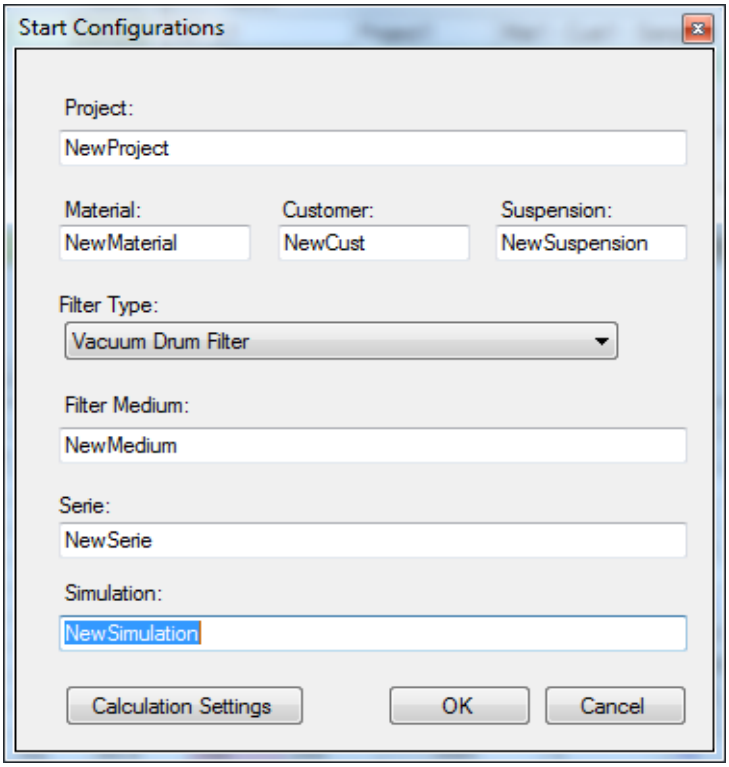
Except of the File-menu, all other entries (2-13) are command buttons. That means by selecting one of them we have not any sub menus. The *File* menu has the following entries: *New, Open, Save, Save As, Exit.* All these entries of the *file* –menu appear also as commands because of their importance in order to have an easy access to them. The *Create New Simulation* button enables the user-friendly creation of a new simulation, which can belong to different series or even to different projects. The *Calculation Precision* window enables the adjustment of the decimal digits, which are displayed for the calculated numbers. Default precision number is 3. The *Parameters to display* button opens the window that enables the checking of the parameters, which have to be displayed for the current Simulation Series. The *Units* button opens the *Units* window to define the units, which the user wants to have. The selected units are valid for all simulations in the file. By clicking the *Ranges* command opens the *Ranges*-window enabling the assignment of minimal and maximal values for material and setting parameters specific for each filter type. The clicking of the *Filter Types* button opens a window for the selection of the wished Filter type for the current simulation series. The user can select one of 14 filter types. Clicking the *Calculator* button the main window of the powerful and user friendly program opens, which enables different useful calculations related to the suspension characterization, cake formation, cake washing and cake deliquoring. Finally, the *Help* button opens the Help window that explains all parameters of the program and gives important information to the proper use of the program.

A1.1 The File-Menu



1, 2, 3, 4, 5

1. New



Opens a window that enables the user-friendly creation of the first simulation in the new file. The user enters first the name of the Project (first project in this file), then enters the name of the suspension for the first simulation (Material name, Customer name, charge name), then selects the filter type and the filter medium of the first simulation. Furthermore, we enter the name of the simulation series, in which the simulation will belong. Finally, we enter the name of this first simulation. Last 2 entries are like the first and family name (first name=simulation name and family name-series name).

For the creation of a new simulation for an existing (not new) file, there are two ways. The user friendlier way is by clicking the command button *Create New Simulation* in the menu task bar or by clicking the *New* –symbol at the top of the simulations table (only if the new simulation has to belong to the current series, otherwise new series have to be first created).

2. Open

Enables the loading of an existing program file

3. Save

Saves the last changes in the current file. When we do any change in one simulation the series of this simulation, the suspension that belongs to this series and the corresponding project are

displayed in Bold indicating that we have unsaved data for this simulation.

4. Save As

Saves the current data of the file under another name

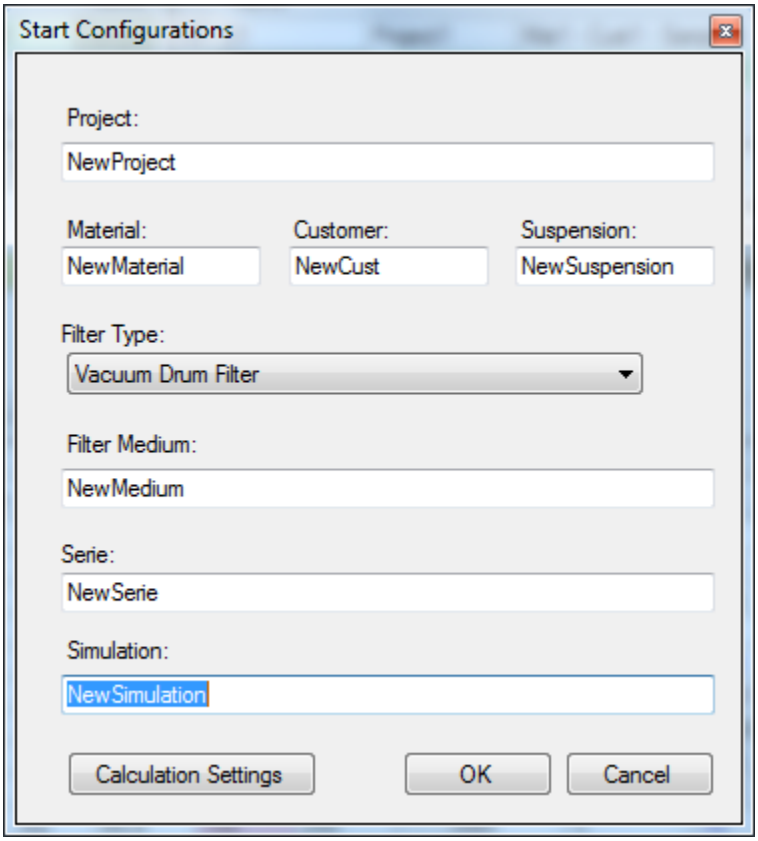
5. Exit

After clicking *Exit* we display a window which asks if we want to Save any changes or we want to Exit without saving of the changes.

A1.2 Open-icon

Enables the loading of an existing program file

A1.3 New-icon



Opens a window enabling the user-friendly creation of the first simulation in the new file. The user enters first the name of the Project (first project in this file), then enters the name of the suspension for the first simulation (Material name, Customer name, charge name), then selects the filter type and the filter medium of the first simulation. Furthermore, we enter the name of the simulation series in which the simulation will belong and finally we enter the name of this

first simulation. Last 2 entries are like the first and family name (first name=simulation name and family name-series name).

A1.4 Save-icon

Saves the last changes in the current file. When we do any change in one simulation the series of this simulation, the suspension that belongs to this series and the corresponding project are displayed in Bold indicating that we have unsaved data for this simulation.

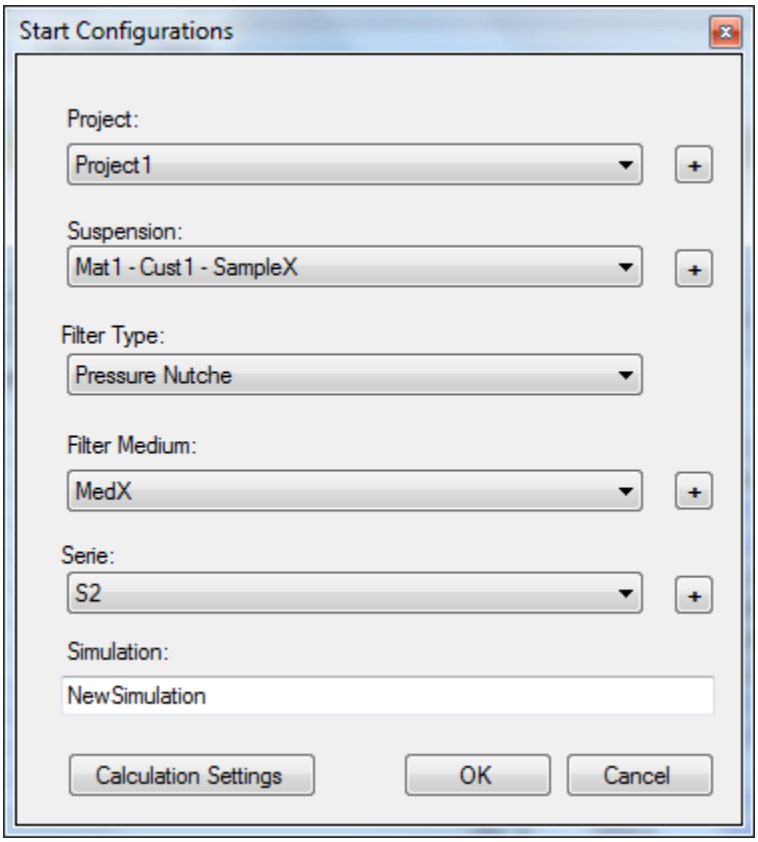
A1.5 Save As-icon

Saves the current data of the file under another name

A1.6 Comments-icon

Opens a window enabling the input of comments for the current file (=the current session)

A1.7 Create New Simulation



Create New Simulation window

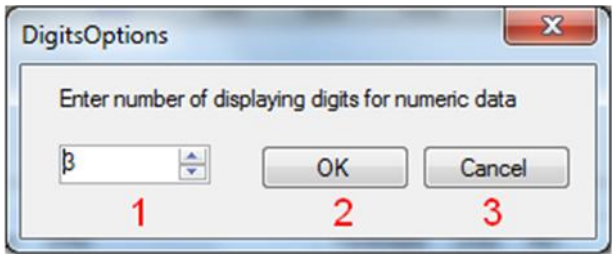
To create a new simulation we have first to decide to which project this simulation will belong, then which suspension, which filter type and which filter medium and which name the simulation series will have in which the new simulation will belong. Finally, the name of the new simulation is needed. The easiest case is when the new simulation will belong to the current series. The above window displays after clicking Create New Simulation the data of the current series (Project, Suspension, Filter type, filter medium, Series name) and the user needs just to enter the new simulation name and click OK.

If the new simulation will not belong to the current series then we have to create a new or select an existing series in which the new simulation will belong. We create new series by clicking the "+" symbol at the right of the series field and then enter a name for the series. If this new series will have another filter medium we can select it from the existing filter medium list or with "+" we can enter the name of the new filter medium. If the filter type will be different then we can select another one using the filter type combo box. If the new series of the new simulation will have another suspension then we can select an existing one using the suspensions combo box or creating a new suspension by clicking the "+" at the right of the suspension field. Finally, in case that the new simulation will be for another project than the current one we can select the project of the new simulation by using the projects combo box or if the simulation will be for a new project we can create the new project by clicking the "+" in the projects field.

Clicking the Calculation Settings button a window opens which enable the selection of the calculation options for the new simulation. Also possible is to change the parameters which have to be displayed and the ranges. Please notice that any changes in the Parameters to display window and in the Ranges window will be taken for all simulations of the current series.

The creation of a new simulation is also possible without clicking the button Create New Simulation. Selection/Creation of the project, the suspension, the filter type, the filter medium and the series of the new simulation can be done by selecting them from the main window or in case of creating new project or suspension or series, by clicking the New-symbol in the corresponding table (if for example a new series has to be created we click the new-symbol above the series table etc.).

A1.8 Calculation Precision



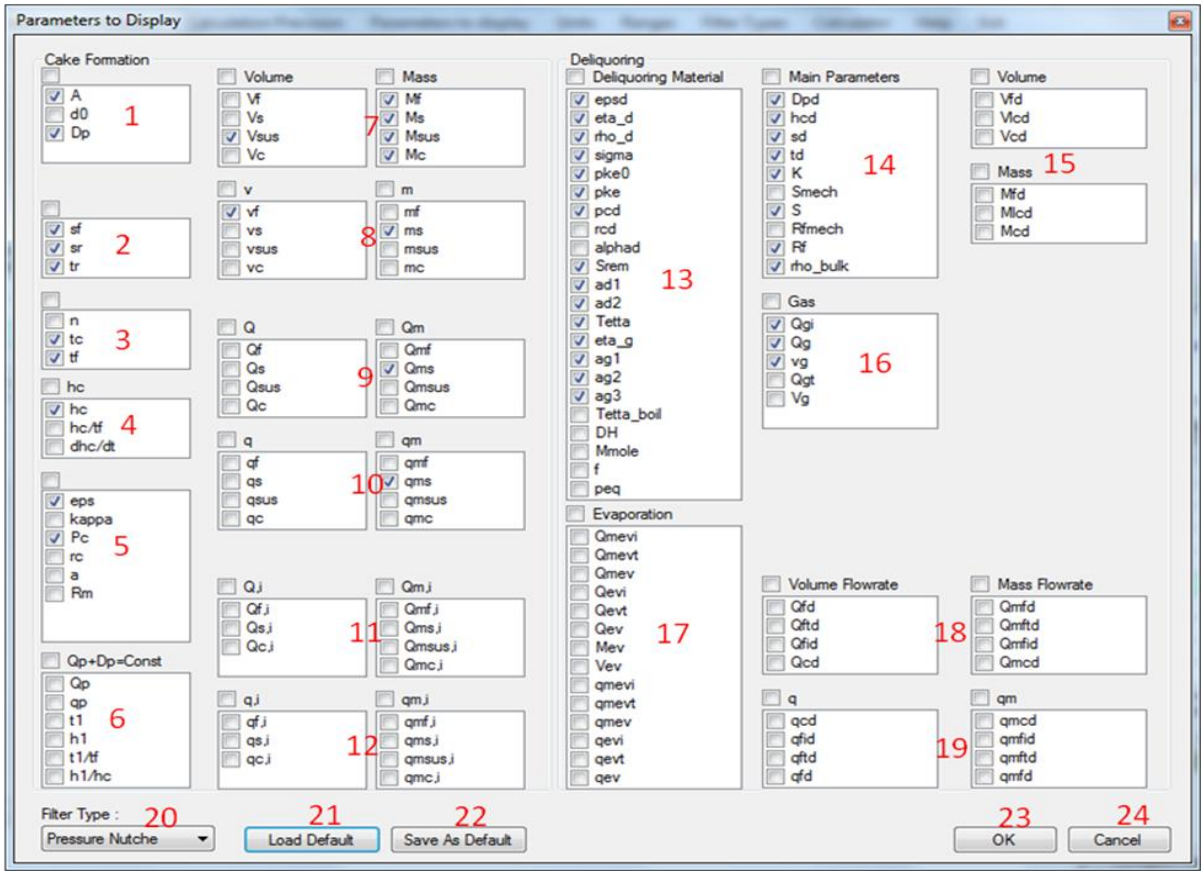
Calculation Precision window
Opens after clicking the button *Calculation Precision* on the menu task bar. Default precision number is 3 (see 1). Maximal possible precision that can be selected is 10. If for example we

have 3 as selected precision (default value) we will have the following number of digits after the decimal point depending on the number in front of the decimal digit:

0 digits if n>100
1 digits if 100>n>10
2 digits if 10>n>1
3 digits if 1>n>0.1
etc.
For example we will display such values: 123/ 45.7/ 9.23/ 0.238/ 0,0124/ etc.
If we select instead of 3 the digit 4 then the above numbers would be displayed for example as follows:
123.3/ 45.74/ 9.231/ 0.2382/ 0.01244/ ec.

By clicking *OK* the selected precision is applied to all simulations of the file and not only to the current simulation (similar is with the units). With *Cancel* we return back to our main window without any changes.

A1. 9 Parameters to display



1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24

Parameters to display window

This window opens after clicking the button Parameters to display on the menu task bar. As can be seen in the above listing of the parameters the program calculates many parameters and for a given simulation and depending on the needs of the user only some of them would be important and have to be displayed. After clicking OK (23), the program shows in the horizontal table of the main window the checked parameters. These parameters are valid for the current series. Each series can have individual displayed parameters. This makes sense because imagine you have one series with a vacuum drum filter and one series with a pressure nutsche: For the vacuum filter is the rotational speed n important but not for the pressure nutsche. For the pressure nutsche could be for example the suspension amount for one charge. That's why the program allows by using this window the saving of default values individual for each filter type. You just select for example Vacuum Drum Filter as filter type (20) then you check which parameters you want to have as default for this filter type and then click Save as Default (22). Any time you want to use the default values, you have to choose the corresponding Filter type (20) then click Load Default (21) and then press OK (23). The displayed parameters for the current series are then updated. Of course, you can check and display any parameters you like for the current series and you are not restricted to use only the default parameters.

1. A, d0, Dp

We recommend that A and Dp should be always checked because these are of the most important parameters in the program. The d0 parameter is necessary to be checked when we have cylindrical area as calculation option (if candle filter is selected as filter type). If we have plain area as calculation option then in this case the d0 should not be checked. Even if d0 is checked, it is not displayed by the program, if we have as calculation option "plain area" selected.

2. sf, sr, tr (at least one of these parameters should be checked)

sf=tf/tc, cake formation time related to cycle time
sr=tr/tc with sr=1-sf: remanent time related to cycle time
tr=remanent time, that is the time component of one cycle that does not belong to cake formation

For continuous filters sf is the most important parameter but for batch filters is the remanent time tr more important.

3. n,tc,tf

n=rotational speed or cycle frequency with n=1/tc
tc=cycle time with tc=tf+tr
tf=cake formation time

The parameter n is important for the rotary filters but not for batch filters.

4. hc, hc/tf, dhc/dt

hc=cake height

hc/tf=average cake height increase at the filtration time tf
dhc/dt=differential cake height increase at the filtration time tf

The cake height hc is one of the most important parameters together with Dp and tf and is recommended to be always selected.

5. Eps, kappa, pc, rc, a, Rm

Eps=cake porosity for the cake formation step at the cake formation pressure Dp.
kappa=ratio of cake volume to filtrate volume at the cake formation pressure Dp
Pc=cake permeability at the cake formation pressure Dp
rc=1/pc=cake resistance
a=cake resistance (unit: m/kg)
Rm= absolute filter medium resistance

The program considers a cake volume reduction of the cake depending on the pressure difference Dp and the volume reduction coefficient ne (see cake formation material input parameters). That means the cake porosity eps is only constant and equal eps0 (eps0=cake porosity for Dp=1 bar) if ne=0. Also the program considers a cake compressibility in the sense of the decrease of the cake permeability with increasing pressure difference and depending on the cake compressibility nc. Only if nc=0 we will have constant cake permeability pc (pc=pc0).

6. Qp, qp, t1, h1, t1/tf, h1/hc

Qp=pump volume flow rate for the suspension feeding in the filter (valid only for the calculation options Qp=const and Qp+Dp=const)
qp=Qp/A specific pump volume flow rate (related to the filter area)
t1=time at which during cake formation the maximal pressure difference Dp is reached (parameter only valid for the option Qp+Dp=const)
h1= cake height at which during cake formation the maximal pressure difference Dp is reached (parameter only valid for the option Qp+Dp=const)
t1/tf=portion of the filtration time at which the filtration takes place at constant suspension flow rate (parameter only valid for the option Qp+Dp=const)
h1/hc= portion of the cake height at which the filtration takes place at constant suspension flow rate (parameter only valid for the option Qp+Dp=const)

The above parameters (Qp, qp, t1, h1, t1/tf, h1/hc) are specific for the calculation option Qp+Dp=const (centrifugal pump) and if for the current simulation this option is selected then we should have at least one of these parameters checked because one of these parameters should be input. We recommend as default input parameters h1/hc or t1/tf.

7. Vf, Vs, Vsus, Vc / Mf, Ms, Msus, Mc

Vf=filtrate volume collected at the filtration time tf
Vs=solids volume of the cake at filtration time tf
Vsus=Suspension volume needed for one filter cycle

Vc= Cake volume at the end of cake formation
Mf=filtrate Mass collected at the filtration time tf
Ms= solids mass of the cake at filtration time tf
Msus= Suspension mass needed for one filter cycle
Mc=Mass of the filter cake at the end of cake formation (saturated cake)

All the above parameters belong to the same group together with tf, hc, n, tc and the specific mass and volume parameters (8). That means entering one of the above parameters all others including tf, hc, n, tc and the specific mass and volume parameters (8) are calculated.

8. vf, vs, vsus, vc / mf, ms, msus, mc

vf=specific filtrate volume collected at the filtration time tf (vf=Vf/A)
vs=specific solids volume of the cake at filtration time tf (vs=Vs/A)
vsus=specific suspension volume needed for one filter cycle (vsus=Vsus/A)
vc= specific cake volume at the end of cake formation (vc=Vc/A)
mf=filtrate Mass collected at the filtration time tf (mf=Mf/A)
ms= solids mass of the cake at filtration time tf (ms=Ms/A)
msus= Suspension mass needed for one filter cycle (msus=Msus/A)
mc=Mass of the filter cake at the end of cake formation (saturated cake) (mc=Mc/A)

All the above parameters belong to the same group together with tf, hc, n, tc and the absolute mass and volume parameters (7). That means entering one of the above parameters all others including tf, hc, n, tc and the absolute mass and volume parameters (7) are calculated.

9. Qf, Qs, Qsus, Qc/ Qmf, Qms, Qmsus, Qmc

Qf= filtrate volume flow rate (average) related to the filtration time Qf = Vf/tf
Qs=cake solids volume flow rate (average) related to the cycle time Qs = Vs/tc
Qsus= Suspension volume flow rate (average) related to the cycle time Qsus = Vsus/tc
Qc= Cake volume flow rate (average) related to the cycle time Qc = Vc/tc
Qmf= filtrate mass flow rate (average) related to the filtration time Qmf = Mf/tf
Qms=cake solids mass flow rate (average) related to the cycle time Qs = Ms/tc
Qmsus= Suspension mass flow rate (average) related to the cycle time Qsus = Msus/tc
Qmc= Cake mass flow rate (average) related to the cycle time Qc = Mc/tc

All above parameters belong with the filter area in the same group and although they are not placed together with the filter area A. That means entering one of the above parameters all others and the filter area A are calculated. We call this the design option as an alternative to the input of filter area and calculation of all above parameters.

10. qf, qs, qsus, qc/ qmf, qms, qmsus, qmc

qf=specific filtrate volume flow rate (average) qf = Qf/A
qs=specific cake solids volume flow rate (average) qs = Qs/A
qsus= specific suspension volume flow rate (average) qsus = Qsus/A

qc= specific cake volume flow rate (average) qc = Qc/A
qmf= specific filtrate mass flow rate (average) qmf = Qmf/A
qms=specific cake solids mass flow rate (average) qms = Qms/A
qmsus= specific suspension mass flow rate (average) qmsus = Qmsus/A
qmc= specific cake mass flow rate (average) qmc = Qmc/A

11. Qfi, Qsi, Qci / Qmfi, Qmsi, Qmsusi, Qmci

Qfi= filtrate volume flow rate (instantaneous)
Qsi=cake solids volume flow rate (instantaneous)
Qsusi= Suspension volume flow rate (instantaneous)
Qci= Cake volume flow rate (instantaneous)
Qmfi= filtrate mass flow rate (instantaneous)
Qmsi=cake solids mass flow rate (instantaneous)
Qmsusi= Suspension mass flow rate (instantaneous)
Qmci= Cake mass flow rate (instantaneous)

12. qfi, qsi, qci / qmfi, qmsi, qmsusi, qmci

qfi= specific filtrate volume flow rate (instantaneous) qfi=Qfi/A
qsi=specific solids volume flow rate (instantaneous) qsi=Qsi/A
qsusi= specific suspension volume flow rate (instantaneous) qsusi=Qsusi/A
qci= specific cake volume flow rate (instantaneous) qci=Qci/A
qmfi=specific filtrate mass flow rate (instantaneous) qmfi=Qmfi/A
qmsi=specific solids mass flow rate (instantaneous) qmsi=Qmsi/A
qmsusi= specific suspension mass flow rate (instantaneous) qmsusi=Qmsusi/A
qmci= specific cake mass flow rate (instantaneous) qmci=Qmci/A

13. epsd, eta_d, rho_d, sigma, pke0, pke, pcd, rcd, alphad, Srem, ad1, ad2, Tetta, eta_g, ag1, ag2, ag3, Tetta_boil, DH, Mmole, f, peq

epsd= cake porosity for the deliquoring step. Calculated considering the deliquoring pressure difference but it can be entered as a value not depending on the porosity of the cake formation step. This is the case for example in Membrane Filter Presses when the cake is deliquored after a squeezing step.
eta_d= viscosity of the liquid in the cake when deliquoring begins. It is only displayed if it is checked in the Calculation Option window. Makes sense to display and enter when we have cake washing before deliquoring. Otherwise, the viscosity of the mother liquid is used for cake deliquoring and eta_d is not displayed.
rho_d= density of the liquid in the cake when deliquoring begins. It is only displayed if it is checked in the Calculation Option window. Makes sense to display and enter when we have cake washing before deliquoring. Otherwise, the density of the mother liquid is used for cake deliquoring and rho_d is not displayed.
sigma=surface tension of the cake liquid when deliquoring begins. Together with the pke0 (standard capillary pressure) and the cake permeability pcd the capillary pressure pke is calculated.

pke0=standard capillary pressure (=capillary pressure for water as liquid (20°C) and a cake permeability of pc=10-13 m2)
pke=capillary pressure. As default is a calculated parameter from sigma, pke0 and the pcd
pcd=cake permeability during cake deliquoring. As default is a calculated parameter from pc0 and the max (Dpf, Dpd). This parameter can also be entered as independent by selecting in Calculation Option window Cake permeability/resistance input.
rcd=cake resistance for the deliquoring step with rcd=1/pcd
alphad=cake resistance for the deliquoring step in m/kg
Srem=remanent cake saturation (usual default value Srem=10%)
ad1= adaptation parameter for the calculation of cake moisture content. The ad1 –value is an indication of the deliquoring efficiency when ad2=5 (default: ad1=0.5)
ad2= adaptation parameter for the calculation of cake moisture content (default: ad2=5)
Tetta=gas temperature during deliquoring (equal normally to the suspension temperature)
eta_g=gas viscosity at the entered gas temperature (default air 20°C : 0.02 mili Pa s)
ag1, ag2, ag3= adaptation parameters for the calculation of the gas flow rate during cake deliquoring (default: ag1=1, ag2=0, ag3=0.2)
Tetta_boil= Boil temperature of the liquid in the cake during deliquoring (needed for the calculation of the evaporated liquid)
DH= molar boil Enthalpy of the liquid in the cake during deliquoring (needed for the calculation of the evaporated liquid)
Mmole= molar mass of the liquid in the cake during cake deliquoring (needed for the calculation of the evaporated liquid)
f=adaptation parameter for the calculation of the evaporated liquid mass.
peq= boiling pressure for the liquid in the cake (calculated from pke, Tetta_boil and DH)

14. Dpd, hcd, sd, td, K, Smech, S, Rfmech, Rf, rho_bulk

Dpd=pressure difference for cake deliquoring. Default is taken equal to the cake formation pressure difference Dpd=Dp. In the Calculation Option window by checking Pressure difference Input the Dpd can be entered and not depending on the cake formation pressure
hcd= cake height during cake deliquoring. Default is a calculated parameter from the cake height in the cake formation step but can be also an input parameter by checking the checkbox Cake height input in the Calculation Option – window. In such a case from the entered hcd the epsd (cake porosity) is calculated based on the solids mass in the cake which is of course the same for both steps: formation and deliquoring of the cake.
sd=specific deliquoring time (related to the cycle time) sd=td/tc
td=cake deliquoring time
K=deliquoring index (most important dimensionless parameter indicating how far we are from the deliquoring equilibrium (default K-values between 3 and 5)
Smech=cake saturation due to only mechanical deliquoring (excluding the saturation reduction due to evaporation)
S= real cake saturation including mechanical deliquoring and evaporation of the cake liquid.
Rfmech= cake moisture content due to only mechanical deliquoring (excluding the moisture reduction due to evaporation)
Rf= real cake moisture content including mechanical deliquoring and evaporation of the cake liquid.

rho_bulk=density of the wet filter cake: rho_bulk=Mc/Vc

15. Vfd, Vlcd, Vcd / Mfd, Mlcd, Mcd

Vfd= filtrate volume due to cake deliquoring at the deliquoring time td
Vlcd=liquid volume remained in the cake at the deliquoring time td
Vcd= cake volume at the deliquoring time td
Mfd= filtrate mass due to cake deliquoring at the deliquoring time td
Mlcd= liquid mass remained in the cake at the deliquoring time td
Mcd= cake mass at the deliquoring time td

16. Qgi, Qg, vg, Qgt, Vg

Qgi=instantaneous gas volume flow rate at the deliquoring time td
Qg=integral gas volume flow rate (from beginning of deliquoring up to time td) related to the cycle time tc: Qg=Vg/tc
vg=specific gas consumption vg=Vg/Ms (for example x liter gas/kg dry solids)
Qgt= average gas flow rate (from beginning of deliquoring up to time td) related to the deliquoring time td: Qgt=Vg/td
Vg=Gas volume from beginning of deliquoring up to the time td

The Gas volume for the above parameters is related to norm conditions (Tn=0 °C=273 K and pn=1 bar)

17. Qmevi, Qmevt, Qmev, Qevi, Qevt, Qev, Mev, Vev, qmevi, qmevt, qmev, qevi, qevt, qev

Qmevi=instantaneous mass flow rate of the evaporated liquid during at the time td (Qmevi=dMev/dt)
Qmevt=average mass flow rate of the evaporated liquid at the time td (related to deliquoring time td: Qmevt=Mev/td)
Qmev=Mass flow rate of the evaporated liquid at the time td (related to cycle time tc: Qmev=Mev/tc)
Qevi=instantaneous volume flow rate of the evaporated liquid at the time td (Qevi=dVev/dt)
Qevt=average volume flow rate of the evaporated liquid at the time td (related to deliquoring time td: Qevt=Vev/td)
Qev=Volume flow rate of the evaporated liquid at the time td (related to cycle time tc: Qev=Vev/tc)
Mev=mass of the evaporated cake liquid during deliquoring at the time td
Vev= volume of the evaporated cake liquid during deliquoring at the time td
qmevi= specific instantaneous mass flow rate of the evaporated liquid at the time td (qmevi=Qmevi/A)
qmevt= specific average mass flow rate of the evaporated liquid at the time td (qmevt=Qmevt/A)
qmev= specific mass flow rate of the evaporated liquid at the time td (qmev=Qmev/A)
qevi= specific instantaneous volume flow rate of the evaporated liquid at the time td (qevi=Qevi/A)
qevt= specific average volume flow rate of the evaporated liquid at the time td (qevt=Qevt/A)

qev= specific volume flow rate of the evaporated liquid at the time td (qev=Qev/A)

18. Qfd, Qftd, Qfid, Qcd/ Qmfd, Qmftd, Qmfid, Qmcd

Qfd=filtrate volume flow rate at the time td (average value related to the cycle time Qfd=Vfd/tc)
Qftd= filtrate volume flow rate at the time td (average value related to the deliquoring time Qftd=Vfd/td)
Qfid=instantaneous filtrate volume flow rate at the time td (Qfid=dVf/dt)
Qcd=cake volume flow rate at the time td (Qcd=Vc/tc)
Qmfd=filtrate mass flow rate at the time td (average value related to the cycle time Qmfd=Mfd/tc)
Qmftd= filtrate mass flow rate at the time td (average value related to the deliquoring time Qmftd=Mfd/td)
Qmfid=instantaneous filtrate mass flow rate at the time td (Qmfid=dMf/dt)
Qmcd=cake mass flow rate at the time td (Qmcd=Mc/tc)

19. qcd, qfid, qftd, qfd / qmcd, qmfid, qmftd, qmfd

qcd= specific cake volume flow rate at the deliquoring time td (=Qcd/A)
qfid= specific instantaneous filtrate volume flow rate at the deliquoring time td (=Qfid/A)
qftd= specific filtrate volume flow rate at the deliquoring time td (average value related to the deliquoring time td (=Qftd/A)
qfd= specific filtrate volume flow rate at the deliquoring time td (average value related to the cycle time) (=Qfd/A)
qmcd= specific cake mass flow rate at the deliquoring time td (=Qmcd/A)
qmfid= specific instantaneous filtrate mass flow rate at the deliquoring time td (=Qmfid/A)
qmftd= specific filtrate mass flow rate at the deliquoring time td (average value related to the deliquoring time td (=Qmftd/A)
qmfd= specific filtrate mass flow rate at the deliquoring time td (average value related to the cycle time) (=Qmfd/A)

20. Filter Type Selection

The current simulation series has a definite filter type. When creating a new series the program automatically recognizes the selected filter type and displays its name in (20) and its corresponding display parameters, which were assigned as default display parameters to this type. If the user wants other parameters than the defaults to be displayed then the Parameters to Display window has to be opened, the wished parameters have to be checked and then click OK (23). If now we want these new parameters not only to be taken for the current series but also to be saved as the default settings for this filter type then the button *Save As* Default has to be clicked.

21. Load Default

Loads the default parameters, which are saved for the filter type group, which is selected in (20). It is a useful command when we have done some changes in the Parameters to display-window and we want to come back to the default values in order to display them in the main window.

22. Save As Default

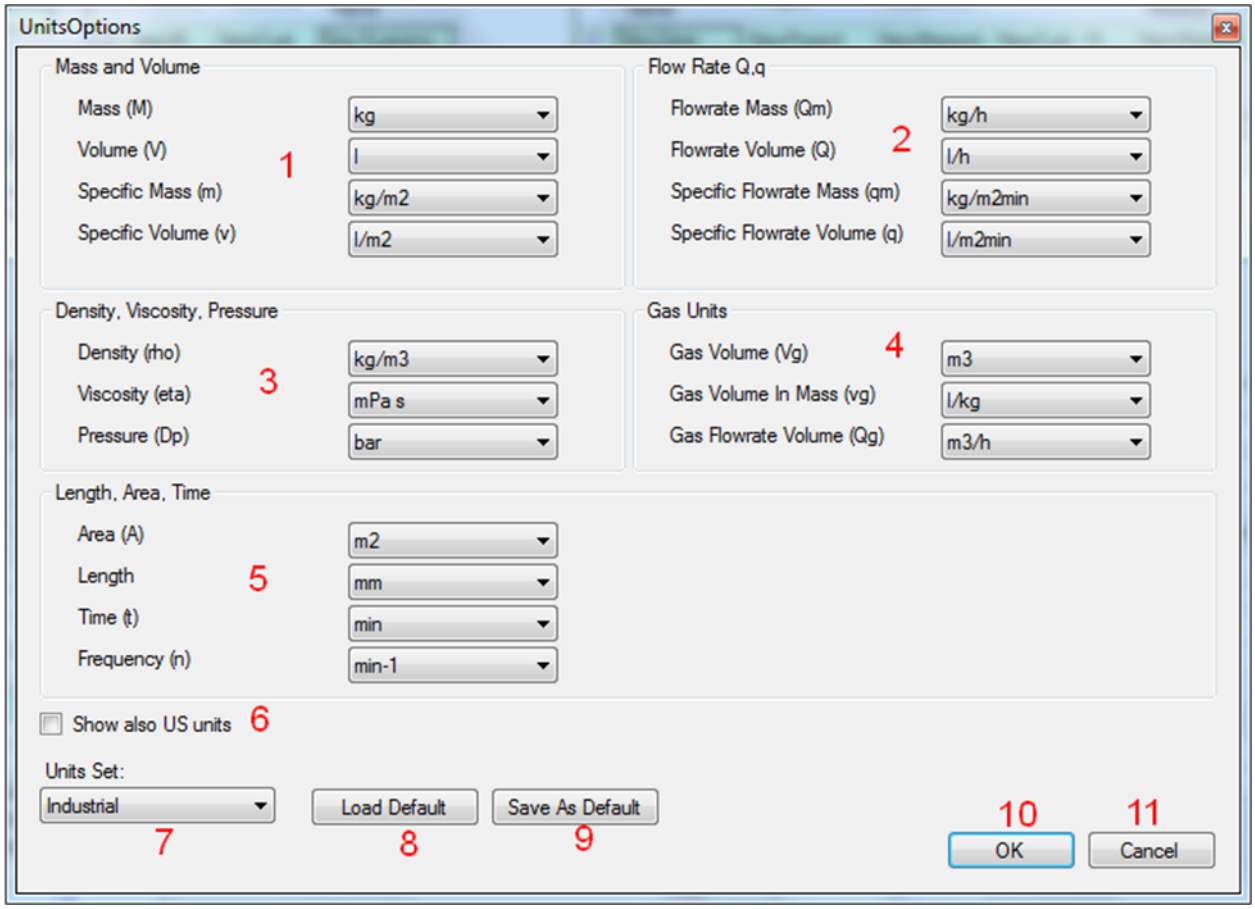
Any changes in this window can be saved as default settings for the selected filter type by clicking the Save As Default button. The saving of default parameters specific for each filter type takes into account that some or many of the parameters in this window have different importance for each filter type.

23. OK
Takes the checked parameters and display them for all simulations of the current series.

24. Cancel

Return to the main window without any changes in the display parameters for the current simulation series. Even if some changes are saved as new default values when you click *Cancel* also the saving of new default data is cancelled.

A1.10 Units



1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11

Units-window

The program provides a high flexibility regarding the units of the parameters used in the program. To enable an easy and reasonable selection of the units 3 set of units can be saved as default and can be taken to the main window. We can save default set of units for Industrial Filters, for Pilot Filters and for Laboratory filters. For example if we want to simulate a laboratory scale test we want to have always grams as mass and cm2 as filter area and l/h as gas flow rate without having always to select these units. By saving them as default we just have to choose in (7) *laboratory* and then click *Load Default*. The default units for the *laboratory scale* are then loaded and with *OK* are taken as the new units in the main window. The same is with the *Pilot scale* and the *Industrial* scale filters. Please notice that with OK the selected units are taken for all simulations of the current file and not just for the current simulation series. The

program enables also the use of US units by checking in (7) *Show also US units.*

1. M, V, m, v

Here we set the units for all Mass and Volume parameters as well as for all specific mass and volume parameters (specific means related to the filter area: m=M/A and v=V/A). These units are valid for all liquids and solids but not for the gas. For the gas units see (4).

2. Qm, Q, qm, q

Here we set the units for all Mass flow rate (Qm) and volume flow rate (Q) parameters as well as the area related (specific) mass flow rate (qm) and volume flow rate (q) parameters (qm=Qm/A and q=Q/A). In this units group the gas rate values are not included (see for the gas units in 4).

3. rho, eta, Dp

Here we set the units for densities (rho) for viscosities (eta) and for the pressure difference Dp. Default units are for these parameters: rho: kg/m3, eta: mili Pa*s and Dp: bar

4. Vg, vg, Qg

Here we set the units for the gas that flows through the cake during the cake deliquoring step. Vg is the absolute gas volume (in norm conditions), vg=Vg/Ms with Ms the dry solids mass of one cycle and Qg the gas flow rate (norm conditions).

5. Area A, Length, time (t) frequency (n)

Here we set the units for the filter area A, the length (for example for the cake height hc and the diameter d0 of a candle filter), the time (t) and the frequency (n). The parameter n is very important for the rotary filters and we have there a default unit min^{-1}.

6. Show Also US-units

Having this checkbox checked the list of units for each parameter group is extended because the most important US-units are added. Only for the time, frequency, density and viscosity we have not any additional units.

7. Units Set

Here we can select 3 options: *Industrial*, *Pilot*, *Laboratory*. If for example we select *Industrial* and we click *Load Default* (8) the saved units for this selection are loaded and with *OK* can be taken for all simulations in the file. We can also change the default values by doing some changes and then press *Save as Default*. In such a case new default units are saved for the selected group (industrial or pilot or laboratory).

8. Load Default

Loads the default saved units for the selected filter type size in (7). By loading the units, we can take them for all simulations or we can change them and save the changed units (9) as the new default values for the selected group.

9. Save as Default

Saves the current units as the default values for the selected filter type scale (*industrial, pilot, laboratory*).

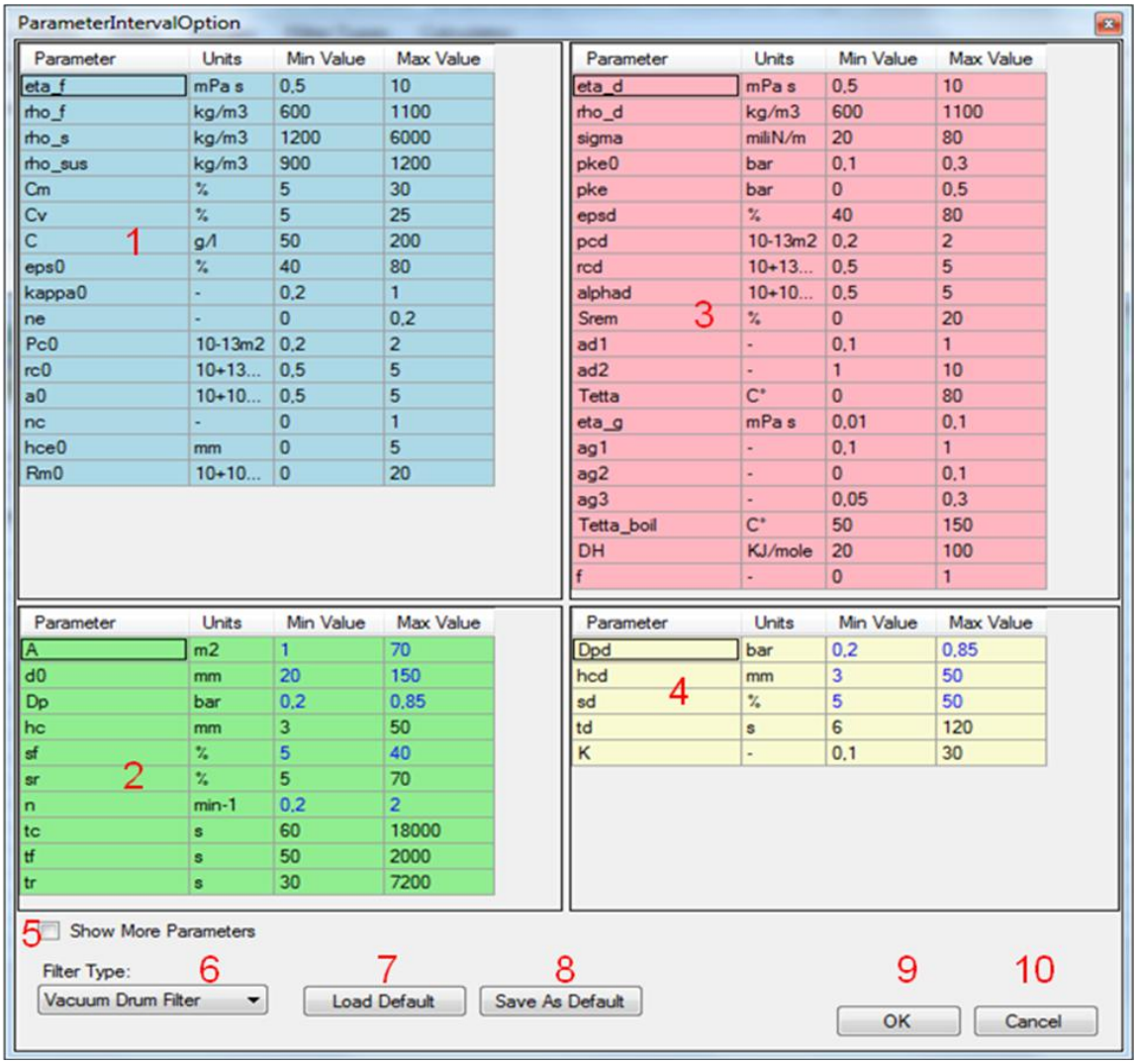
10. OK

Takes the selected units and apply them in all simulations of the program

11. Cancel

Any changes we did after opening the *Units* window are not valid and we exit the window.

A1.11 Ranges



1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Ranges window:

In this window the user can save for each filter type minimal and maximal possible values for all material (=suspension and cake) parameters and also for all filter constructive, setting and result parameters. These parameters are specific for the simulation series. That means changing in this window the values of any parameters and clicking *OK* these parameters are taken as new range-parameters for the current series but not for all series, which have the same filter type! This makes sense because the ranges depend not only on the filter type but also on the given suspension, which is filtered with the selected filter type. To understand the meaning of saving different default min-max material parameters for each filter type an example: For a Pan Filter we should have normally high suspension solids mass content, high cake permeability values and relatively low cake porosities. For a Candle Filter we have relatively low values of suspension solids content, high porosity, low permeability etc. The parameters in blue color are very

important for the “dynamic” calculation of the min-max parameters in the main window. The *Limits* concept is a very powerful tool because it shows always the possible meaningful values interval for each parameter and enables especially the input of only meaningful parameters. How for example could the user know what is the possible (that means the min-max values) productivity (solids throughput) and cake moisture content of a filter for a given suspension, given filter area range and definite setting parameters without the limits concept? There are some parameters (mostly result parameters), for which the knowledge of the ranges is not important for the limits calculation. To show or change the min-max values of these parameters you have to check the *Show More Parameters* checkbox.

1. General Material parameters

These parameters are necessary for the calculation of the cake formation step and most of them are needed also for the calculation of the cake deliquoring step. Since the dynamic limits calculation takes place after we enter definite values of the material parameters, the input of min-max values individual for each machine type serves just as orientation for the user.

2. Geometrical and setting parameters necessary for the calculation of the cake formation step.

The diameter d0 of the cylindrical area has importance only for the candle filters. The parameters (sf, sr, tr) belong to the same group. The same is with (hc, n, tc, tf). For each group only one parameter has a blue color. The others are in black color. The blue color shows, which parameter is taken as input for the dynamic limits calculation. If for example instead of n we want to have the cake height hc as input, we just enter the wished min and max hc values. Automatically the hc-values appear in blue color and the n (which was the input) appears now in black. The filter area A and the pressure difference Dp are always in blue, that means they are always used for the dynamic limits calculation.

3. Minimal and maximal Material parameters for the cake deliquoring step.

As with all other parameters, for each filter type we can save individual min-max values taking into account the types of suspensions, which can be optimally treated with each filter type. The ranges in this window are very valuable for the user because he can have an orientation regarding the possible input values. Since the material parameters have to be entered before any dynamic limits calculation, also these parameters are serving as orientation for the input of meaningful values.

4. Minimal and maximal values for the setting parameters of the cake deliquoring step.

The pressure difference for the deliquoring step Dpd and the cake height hcd are always in blue color, that means they are always inputs. It is recommended, for the cake height hcd to enter the same min-max values as we have for the cake formation step (2). The parameters (sd, td, K) belong to the same group and only one is input (blue color).

5. Show More Parameters-Checkbox

When this checkbox is checked appears a list with min-max values of result parameters of the cake formation and deliquoring step. These values are needed for the dynamic limits calculation but it is not important to have their exact values since the limits calculation is based on the min-max values of the blue colored parameters in (2) and (4)

6. Filter type-selection

Here we select one of the 14 filter types for which we want to load and view the default values or change them or use them for the current simulation series. When we create a new simulation series, the program recognizes the filter type of this series and automatically updates the ranges window. If for example we have for our current series a vacuum drum filter then when we open the Ranges-windw this filter type appears in (6).

7. Load Default

When we select in (6) one filter type we have not automatically the loading of its default ranges. To display the default ranges (min-max values) of the new selected filter type we have to click *Load Default*.

8. Save As Default

Having the ranges of the selected filter type displayed (please notice that when selecting a new filter type we have to click *Load Default* to display its default ranges) we can do any changes we like and then by clicking *Save As Default* these changed data are taken as the new default min-max values for the selected filter type.

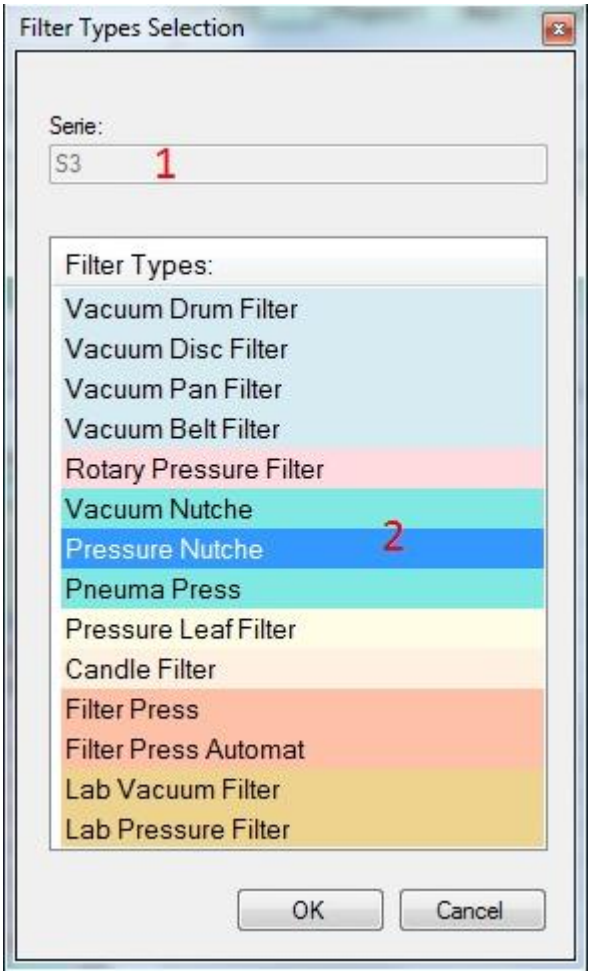
9. OK

With *OK* we take the displayed ranges for the current simulation series.

10. Cancel

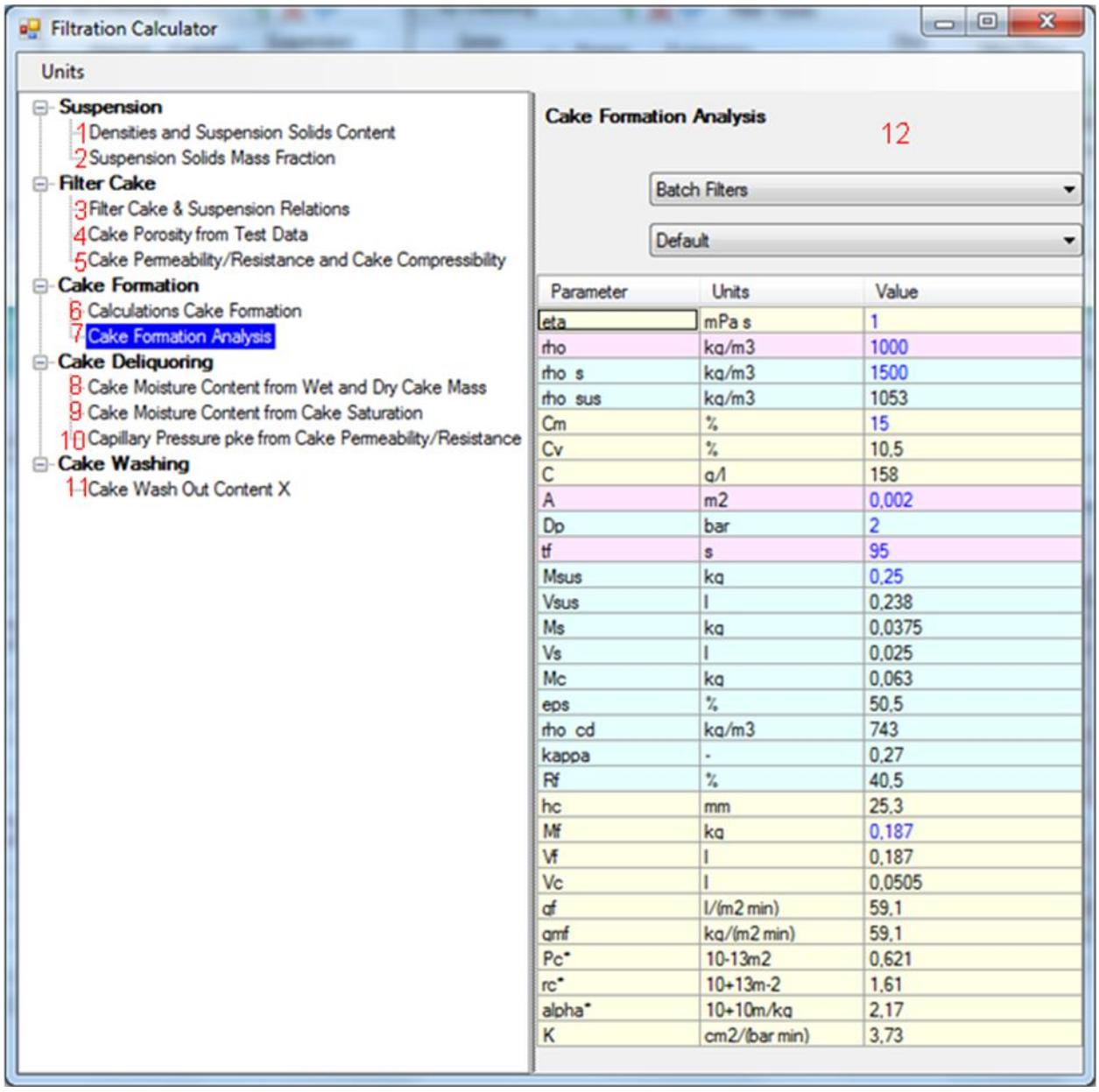
We return to the main window and any changes we do in the *Ranges* window are not valid.

A1.12 Filter Types



Clicking the Filter Types button in the Menu –bar the above window opens which enables the user to assign a definite filter type to the current simulation series. The name of the current simulation series is displayed in (1). In (2) we display the list of all filter types and the filter type of the current series is highlighted. This can be for example the default filter type of a new created series and we want to change this type or it can be the filter type of a duplicated series for which we want to change the filter type. After selecting the new filter type with *OK* we take this new selected filter as the new filter type of the current series.

A1.13 Calculator



1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

Screenshot of the Filtration Calculator (deliverable also as an independent program) with the 11 listed modules in a tree-structure. On the left, we have the listing of all modules and here we can select the wished module. After the selection, this module is highlighted with a blue background color and its corresponding window is displayed on the right. This user-friendly program has high flexibility regarding the input and calculated parameters by building group of parameters. This concept we have it also in FILTRAPLUS. The parameters, which belong to the same group are placed next to each other and have the same background color. For every group only one parameter is input and all others are calculated. Input parameters, are indicated by blue color and calculated by black. We have some groups with only one parameter; that means

this parameter has to be entered always.

1. Densities and Suspension Solids Content

Calculates solids or suspension or mother liquid density if two densities and the suspension solids content as mass or volume fraction or concentration are given. Calculates the solids content if the 3 densities (for liquid, solids and suspension) are given.

2. Suspension Solids Mass Fraction

Calculates the solids mass fraction of the suspension Cm (%) if the suspension mass and the solids mass (after drying) are given. Non volatile solutes in the liquid are also considered in order to get exact results even for cases when non volatile substances solved in the mother liquid are not negligible.

3. Filter Cake & Suspension Relations

Calculation of the Suspension amount (Msus/Vsus) for a given area A and a given cake height hc for plane filter area or convex area (candle filters) or concave area (centrifuges) if the solids density or suspension density and the cake porosity or the kappa-parameter are given. High flexibility of the calculations: Instead of Msus/Vsus the cake height or the geometry of the machine or the cake porosity or the suspension solids content or the densities can be calculated.

4. Cake Porosity from Test Data

Calculation of the cake porosity from tests with filters with plane or convex or concave filter area under consideration of nonvolatile solutes in the cake liquid. Two options: Saturated cake (all voids filled with liquid) and non saturated cake are considered. The second option can be always used.

5. Cake Permeability/ Resistance and Cake Compressibility

Calculation of the cake permeability/cake resistance for any pressure difference and any cake compressibility if the standard cake permeability/cake resistance (values for Dp=1 bar) are given. The module is so flexible that the cake compressibility or the pressure difference or the standard cake permeability/cake resistance can be calculated when the other parameters are entered.

6. Calculations Cake Formation

Calculation of the filtration time for given suspension- and cake parameters (viscosity and density of mother liquid, density of solids or suspension, suspension solids content as mass or volume fraction or concentration, standard cake permeability/cake resistance, cake compressibility and filter medium resistance), for a given pressure difference and a given cake height. Alternatively, the cake height or the amount of suspension Msus/Vsus is calculated. The

calculations are based on constant pressure difference during the cake formation (Dp=const)

7. Cake Formation Analysis

A powerful tool for the analysis of a filtration test (cake formation) with constant pressure difference (Dp=const) for the determination of the cake porosity and the cake permeability. Material input parameters are the viscosity and density of the mother liquid, the solids or suspension density and the suspension solids content. Furthermore the filter area A, the pressure difference Dp and the filtration time tf are entered. To get the cake porosity and cake permeability another 2 input parameters are needed as for example the dry solids mass of the cake and the cake height. There is a high flexibility regarding the two last input parameters. The user has the flexibility to enter from each of the following two groups of parameters anyone parameter:

1 Group:
Msus, Vsus, Ms, Vs, Mc, eps, rho_cd, kappa, Rf
2 Group:
hc, Mf, Vf, Vc, qf, qmf, pc, rc*, alpha*, K*

This module is not only a test analysis module but also a filtration simulation module if in the above 2 groups the cake porosity (eps) and the cake permeability (pc) are entered instead calculated. Please notice that the symbol for the permeability (pc* instead of pc) is to indicate that the determined permeability is the permeability of the system cake –filter medium and pc*=pc only if the filter medium resistance is neglected. The module enables the determination of both parameters: pc* and pc if the filter medium resistance is entered (for this select in the second combo box the entry: Medium Resistance considered). This module enables the analysis & simulation not only of batch filter tests but also of continuous filter tests. For this, the entry Continuous Filters in the first combo box has to be selected. The parameters of the above two groups are for the option Continuous Filters modified and adjusted to the conditions of these filters (for example instead of Ms we enable the input of Qms).*

8. Cake Moisture Content from Wet and Dry Cake Mass

Calculates the cake moisture content from the wet and dry cake mass. The case of not volatile solutes in the cake liquid is also considered. This enables to get exact results even for cases when non- volatile substances solved in the mother liquid are not negligible.

9. Cake Moisture Content from Cake Saturation

Calculates the cake moisture content from the cake porosity and the cake saturation. Alternatively, the cake saturation can be calculated if the cake moisture content and the cake porosity are entered or the cake porosity can be determined if the cake saturation and the cake moisture content are given.

10. Capillary Pressure pke from Cake Permeability/ Resistance

Calculation of the capillary threshold pressure if the cake permeability/cake resistance is given. Additional input parameters are the surface tension of the liquid in the cake and the standard capillary threshold pressure pke_st: That is the value for the standard cake permeability $pc,st=10^{-13}$ m^2 *and water 20 °C as cake liquid.*

11. Cake Wash Out Content X

Determination of the wash out content in the cake X as g/kg_dry solids by re suspending the wet cake with a definite amount of wash liquid, re filtering and measuring the wash out concentration in the filtrate. Besides the wash out content X also the cake moisture content is calculated.

12. Window of the selected module

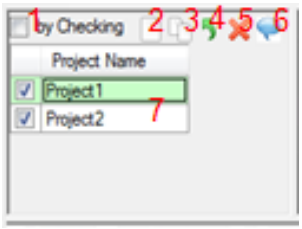
A 1.14 Help

Opens the *Help* window, which allows explanations to all parameters used by the program as well as information to each field and each command of the main window.

A 1.15 Exit

After clicking *Exit* we display a window which asks if we want to Save any changes or we want to Exit without saving of the changes.

A 2 Projects Table



1, 2, 3, 4, 5, 6, 7

A table with the display of all projects (7) in the current file. Every simulation belongs to a definite series and every series belongs to a definite project. Every project can have one or more suspensions (see the table for suspensions next to the projects table) and one or more series. Finally, one series can have one or more simulations. Simulations of the same series have always the same suspension and the same filter type. The projects concept enables an excellent sorting of all simulations and makes it possible to save all simulations in only one file with still user friendly access to each simulation. This gives the possibility to compare simulations of different projects (with different suspensions and eventually different filter types).

If the checkbox *by checking* is checked, we display in the next table only the suspensions, which belong to the selected project. By clicking the *New*-symbol (2) a new project can be created. A new project automatically creates a new simulation, which belongs to a new created series and this series has as suspension a new created suspension. The filter type of this new created series is selected in the small window that appears after clicking the *New*-symbol (2) for creating a new project. The *duplication* –symbol (3) enables the duplication of all data of the selected project (suspensions, series and all simulations belonging to these series). The *Undo*-symbol (4) cancels any changes, which are related to the current project and displays the last saved data belonging to this project. The *delete*-symbol (5) deletes the current project. The *comments* –symbol (6) enables the writing of comments to the selected project.

1. If the checkbox *by checking* is checked we display in the next table only the suspensions, which belong to the selected project. If the checkbox is unchecked then we display all suspensions of the projects, which have their checkbox checked.

2. By clicking the *New*-symbol, a new project can be created. A new project automatically creates a new simulation, which belongs to a new created series and this series has as suspension a new created suspension. The filter type of this new created series is selected in the small window that appears after clicking the *New*-symbol for creating a new project.

3. The *duplication* –symbol enables the duplication of all data of the selected project (suspensions, series and all simulations belonging to these series).

4. The *Undo*-symbol cancels any changes, which are related to the current project and displays the last saved data belonging to this project.

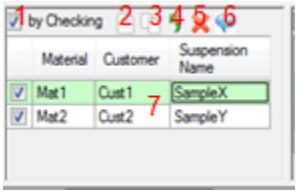
5. The *delete*-symbol deletes the selected project and all related data to this project (suspensions and series with all simulations related to these series)

6. By clicking the *Comment*-symbol a small window opens for entering comments to the selected project or for viewing already existing comments.

7. List of the Projects.

The selected project is highlighted with green background color. If the checkbox *by checking* (1) is checked then we display the suspensions and series of only the selected project. If *by checking* is unchecked we display all suspensions and series of those projects which have their checkbox in front of their name checked.

A3 Suspensions Table



1, 2, 3, 4, 5, 6, 7

Listing of the suspensions, which are used by the simulation series. One simulation series includes one or more simulations with a definite suspension. The current simulation is always highlighted by a light green background color. Also highlighted is the series of the current simulation (current series=”mother” of the simulation) and the suspension, which is used by the current (see highlighted suspension in 7). Every suspension is characterized by 3 names: *material* name – *customer* name – *charge* name (equivalent to the family name- father name – first name of a person). The suspension with its 3 names characterizes the definite sample taking into account that the same suspension of a definite process (same material and customer name) depending on many factors has changing filtration behavior (different charge name). The listed suspensions depend on the checkboxes of the projects table. If *by checking* in the projects table is checked, then we display only the suspensions of the selected project. *If by checking* in the project table is unchecked then all suspensions of the checked projects are displayed.

If *by checking* (1) is checked, then only the simulation series, which use the current suspension are displayed. If *by checking* (1) is unchecked then we display all series which use the checked suspensions. By clicking the *New*-symbol (2) a new suspension can be created. By clicking the *duplicate*-symbol (3) a new suspension is created with the same material and customer name and an addition of “d” at the end of the charge name (“d” as indication of duplication) and for this new suspension all series of the “mother” suspension are copied to this new suspension. Clicking the *Undo*-symbol (4) all changes to the simulation series which use the current suspension are cancelled and we return to the last saved data. The *delete* –symbol (5) deletes the current

suspension and all simulation series, which use this suspension. The *comment* –checkbox (6) allows the saving and viewing of comments to the selected suspension.

1. If the checkbox *by checking* is checked, we display only the simulation series, which belong to the selected suspension. If the checkbox is unchecked then we display all simulation series, which use the checked suspensions.

2. By clicking the *New*-symbol, a new suspension is created. A new suspension automatically creates a new simulation, which belongs to a new created series. The filter type of this new created series can be selected in the small window that appears after clicking the new-symbol for creating a new suspension.

3. By clicking the *duplicate*-symbol a new suspension is created with the same material and customer name and an addition of "d" at the end of the charge name ("d" as indication of duplication) and for this new suspension all series of the "mother" suspension are copied to this new suspension.

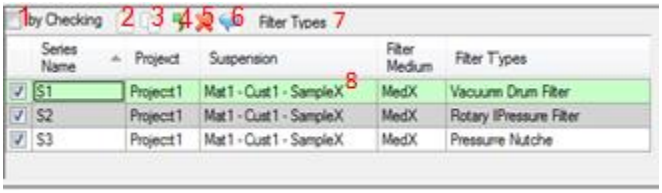
4. The *Undo*-symbol cancels any changes, which are related to the current suspension and displays the last saved data belonging to this suspension.

5. The *delete*-symbol deletes the selected suspension and all series, which use this suspension.

6. By clicking the *comment*-symbol a small window opens for entering comments to the selected suspension or for viewing already existing comments.

7. List of the Suspensions The selected suspension is highlighted with green background color. If the checkbox *by checking* in the projects table is checked then we display the suspensions of only the selected project. If *by checking* is unchecked we display all suspensions of the checked projects.

A4 Series Table



1, 2, 3, 4, 5, 6, 7, 8

In this table, we have a listing of the simulation series with the current series highlighted with green color. Every series has a name (see series name), belongs to a definite project and has a definite combination of Suspension, Filter Medium and Filter Type. Two simulation series can have the same project, the same suspension, the same filter medium and filter type but NOT the same series name. Which series are displayed in the table depends on the settings of the projects and suspensions tables. If for example we have the *by checking* checkbox in projects and

suspensions checked then we display only the series of the highlighted project and the highlighted suspension.

The filter series is like a family for a group of simulations. All simulations which belong to the same series have the same settings regarding *Parameters to display* and *Ranges* (min-max) - values but each simulation of the current series can have of course individual (=simulation specific) calculation option. The name of the selected series can be changed in the cell, where the name is displayed. The same is with the filter medium.

A new series can be created by clicking the *New* –symbol (2). In the small window that appears, we select the filter type of this new series. The new created series has automatically as project and suspension the highlighted project and highlighted suspension. The filter medium for the new series has to be entered in the corresponding cell. The new created series creates automatically a new simulation in the simulation table. The duplication of a series (by clicking the duplicate-symbol (3)) creates a new series with identical data as the "mother" series. The only difference is the addition of the letter "d" at the end of the series name of the original series as indication that the series is duplicated. Of course, the name of the series can be changed by entering another name in the corresponding cell. Any changes with simulations belonging to the current series (if these changes are not already saved) display the entries of this series in the series table in bold font. When clicking the *Undo*-symbol these changes are undone and we return to the saved data regarding the current series. Deleting a series (by clicking the *delete*-symbol (5)) deletes the selected series and all simulations belonging to this series. As with the other tables, comments can be entered, saved and viewed for the selected series by clicking the *comments*-symbol (6).

When the checkbox *by checking* is checked, we display in the simulations table only those simulations, which belong to the current series. Otherwise, all simulations of the checked series are displayed.

1. If the checkbox *by checking* is checked we display in the simulations table only the simulations, which belong to the selected series. If this checkbox is unchecked then we display all simulations, which belong to the checked series.

2. By clicking the *New*-symbol, a new series is created. A new series automatically creates a new simulation, which belongs to the new created series. The filter type of this new created series is selected in the small window that appears after clicking the *New*-symbol for creating a new series.

3. By clicking the *duplicate*-symbol, a new series is created with identical data as the "mother" series. The only difference is the addition of the letter "d" at the end of the series name of the original series as indication that this new series is a duplication of the previous current series.

4. The *Undo*-symbol cancels any changes, which are related to the current series and displays the last saved data belonging to this series.

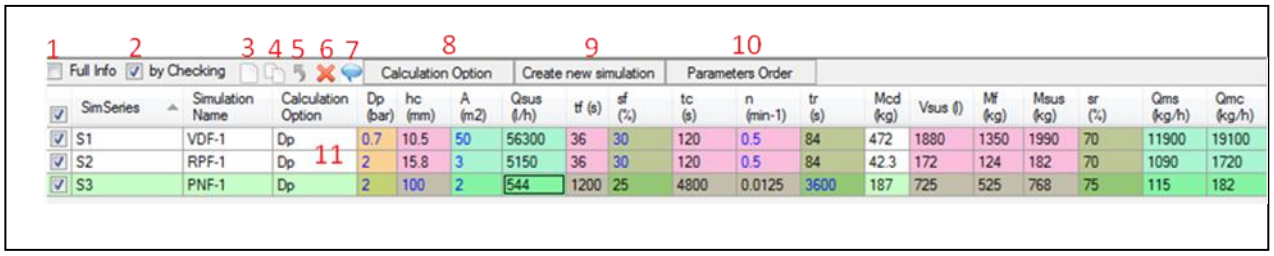
5. The *delete*-symbol deletes the selected series and all simulations belonging to this series.

6. By clicking the *comment*-symbol a small window opens for entering comments to the selected series or for viewing already existing comments.

7. By clicking the *Filter Types*- button a small window opens that enables the selection of the wished filter type for the current series. Alternatively the *Filter Types* button in the menu bar can be clicked, which displays the same filter type selection window.

8. List of the Series. The selected series is highlighted with green color. If the checkbox *by checking* in the suspensions table is checked then we display only the series, which use the selected suspension. If *by checking* in the suspensions table is unchecked we display all series of the checked suspensions.

A5 Simulations Table



SimSeries	Simulation Name	Calculation Option	Dp (bar)	hc (mm)	A (m2)	Qsus (l/h)	tf (s)	sf (%)	tc (s)	n (min-1)	tr (s)	Mcd (kg)	Vsus (l)	Mf (kg)	Msus (kg)	sr (%)	Qms (kg/h)	Qmc (kg/h)
S1	VDF-1	Dp	0.7	10.5	50	56300	36	30	120	0.5	84	472	1880	1350	1990	70	11900	19100
S2	RPF-1	Dp	2	15.8	3	5150	36	30	120	0.5	84	42.3	172	124	182	70	1090	1720
S3	PNF-1	Dp	2	100	2	544	1200	25	4800	0.0125	3600	187	725	525	768	75	115	182

1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11

In this table, we have a listing of the simulations with the current simulation higlighted with green color. Every simulation has a name (see column before the calculation option column) and belongs to a definite series. Two simulations belonging to the same series can not have the same name. Which simulations are displayed in the table, depends on the settings of the series table. If for example we have the *by checking* checkbox in series table checked then we display only the simulations which belong to the highlighted (current) series. After the series and simulation name (which identifies the simulation like family name and first name) we display the calculation option. The program considers 3 calculation options with regard to the pressure profile during the cake formation step:

-Dp=const

-Qp=const (Volumetric Pump)

-Qp+Dp=const (Centrifugal Pump)

The calculation option is specific for each simulation, that means different simulations in the same series can have different calculation options. The selection of one of the above 3 options depends on the filter type. Normally all continuous filters are working with a constant pressure difference (Dp=const). But considering Batch Filters as for example Filter Presses or Candle filters we have in most of the cases for the cake formation step the use of a Centrifugal Pump (Qp+Dp=const) or a volumetric pump (Qp=const) . That means for filter series with such filter types simulations with different calculation options make sense.

Which parameters we have displayed in the simulations table depends on the selection we do in the *Parameters to Display* –window.. Of course, any parameters can be checked in the *Parameters to Display* –window and appear in the main window for all simulations of the current series. If we have simulations in the simulations table from different series and each of these series has different display-parameters then we do not display the common display-parameters but all parameters, which are selected to be displayed at least for one series. For example we have two simulations in the table and the one is a rotary vacuum filter simulation and the other one is a pressure nutsche simulation: Of course these 2 simulations belong to different series because we can not have 2 simulations in one series with different filter types.

For the rotary vacuum filter we have a set of default display parameters and one important parameter is the rotational speed n. For the pressure nutsche we have another set of default parameters and one important display parameter is the suspension volume for one filter cycle Vsus. For the rotary filter the suspension volume is not important and for the nutsche filter the rotational speed or cycle frequency n is also not important. But displaying both simulations in the table (the *by checking* –checkbox in the series table should be unchecked) both parameters: n and Vsus are displayed with their values and although Vsus for the vacuum drum filter and n for the pressure nutsche are not checked as display parameters.

In the table, we have in the general case a display of cake formation and deliquoring parameters. The deliquoring step is optional for one simulation and can be selected in the *Calculation Options*-window by checking/unchecking the Checkbox *Use Deliquoring*. If the deliquoring is unchecked and in the simulation table we have only simulations with consideration only of the cake formation then we do not display any deliquoring parameters. Otherwise, for the simulations with no deliquoring no values for the deliquoring parameters are displayed.

A special and very useful feature of the simulations table is that this table is not only display- but also input table.That means, for all parameters, which are displayed in the simulations table and can be input parameters (for example filter area A, pressure difference Dp, cake height hc, filtration time tf, cycle time tc, solids throughput Qms, deliquoring time td, moisture content Rf etc.) we can enter values in the table and not only in the vertical columns. The possibility to enter parameters in the simulations table is of high practical importance because when more than one simulation is displayed we can change the values of the parameters for more than one simulation and compare the results of different simulations. The input parameters are displayed in blue color and the calculated in black. FILTRAPLUS has a very user-friendly concept with the grouping of parameters. All parameters, which belong to the same group, can be easily recognized because they have the same background color. Any one of the parameters, which belong to the same group, can be entered (blue color) and all others are calculated (black color). For example the filter area A and the solids throughput Qms, suspension volume flow rate Qsus etc belong to the same group. Entering the area A, we calculate the productivity (Qms) and entering the productivity (Qms) we calculate the filter area A (Filter Design). With this example, we see that in *FILTRAPLUS* the FILOS concepts of *Standard Calculation* and *Filter Design* are integrated in one module.

The parameters of the current simulation which are displayed in blue color (input parameters) are also displayed in blue color in the vertical columns. We have 2 options for entering the parameters: In the vertical columns or in the simulations table. Exceptions are the material parameters, which are displayed only in the vertical columns.

With the drag and drop method the order of the columns in the simulations table can be changed. That means the user can have his own order regarding the display parameters The ordering of the parameters can be also done in a user friendly way after clicking the button *Parameters Order* above the simulations table.

When the checkbox *by checking* is checked we display only the curves and tables for the current selected simulation. Otherwise (checkbox *by checking* is unchecked) we display curves for all

checked simulations. Exception is, when the checkbox *Multiple Curves for the current Simulation* in the right bottom side of the main window is checked. In this case, all curves are related to the current simulation and each curve is created by changing one or more of the constant parameters of the current simulation.

1. *Full info*-checkbox

If this checkbox is checked, we have at the beginning of the table 4 additional columns displaying: the project name, the suspension name (material-customer-charge), the Filter medium and the filter type for each simulation. By un checking this checkbox these 4 columns are hidden.

2. *By checking* checkbox

When the checkbox *by checking* is checked, we display only the curves and table for the current selected simulation. Otherwise (checkbox *by checking* is unchecked) we display curves for all checked simulations. Exception is, when the checkbox *Multiple Curves for the current Simulation* in the right bottom side of the main window is checked. In this case, all curves are related to the current simulation with the possibility of systematic variation of one or more parameters.

3. By clicking the *New*-symbol a new simulation is created, that means we have a new row in the table with empty cells for the input and calculated parameters. The values of the material parameters for the cake formation step and the deliquoring step are taken automatically from the previous simulation.

4. By clicking the *duplicate*-symbol a new simulation is created with identical data as the "mother" simulation. The only difference is the addition of the letter "c" at the end of the simulation name of the original simulation as indication that this simulation is copied.

5. The *Undo*-symbol cancels any changes, which are related to the current simulation and displays the last saved data belonging to this simulation.

6. The *delete*-symbol deletes the selected simulation

7. By clicking the *comment*-symbol a small window opens for entering comments to the selected simulation or for viewing already existing comments.

8. By clicking the *Calculation Option* button the window opens which allows the selection of the pressure difference profile for the cake formation step (Dp=const, volumetric pump (Qp=const) or Centrifugal Pump (Qp+Dp=const)). We can also decide if we have plane or cylindrical filter area. Furthermore we can choose if we want to display also the deliquoring step and if yes, if we want to have calculation and display of the gas flow rate. Possible is also the selection for of the liquid evaporation. In order to consider squeezing of the cake prior to cake deliquoring individual cake height, pressure difference and cake permeability for the deliquoring step can be selected. Finally, different viscosity and density than the mother liquid can be selected for the

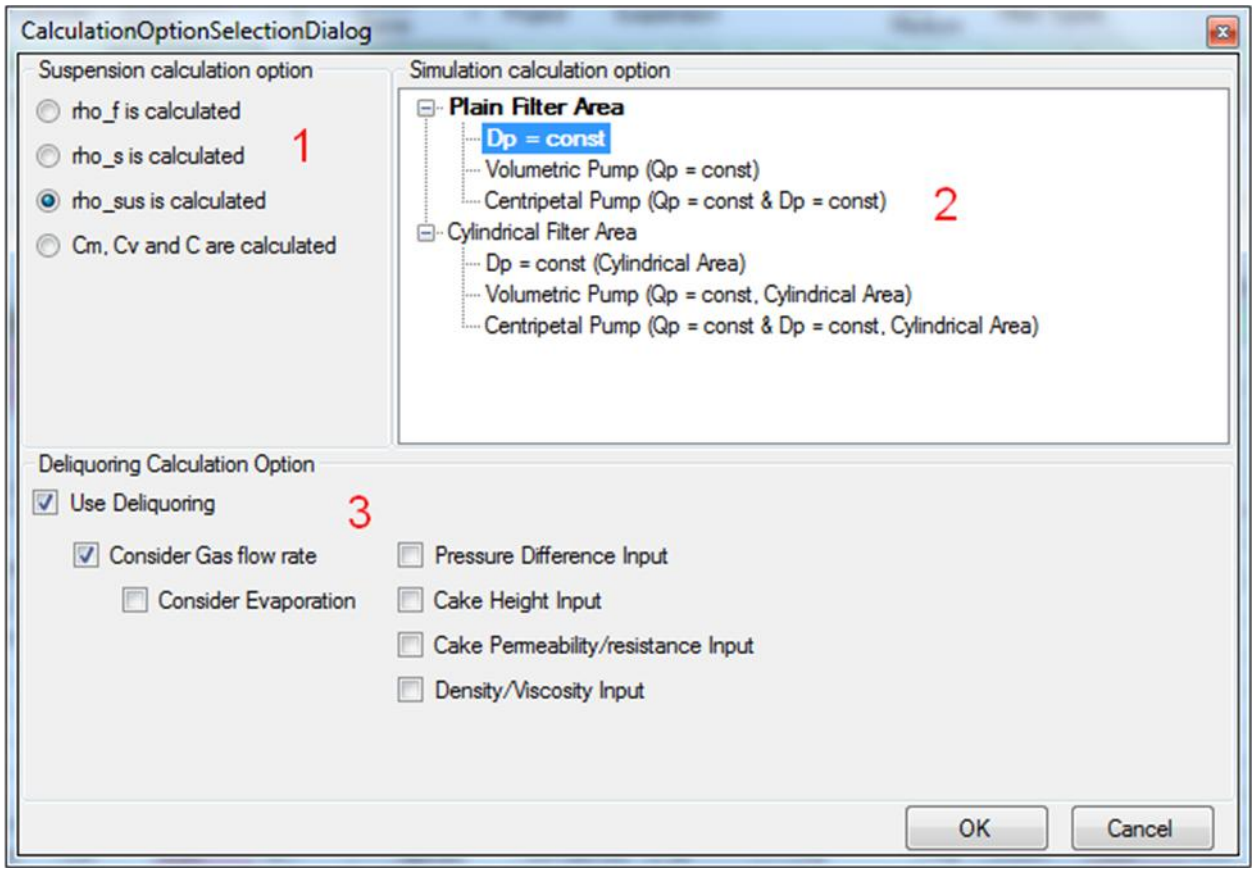
deliquoring step taking into account a possible washing step prior to cake deliquoring.

9. Opens the window for the creation of a new simulation.

10. Opens the window for ordering the parameters displayed in the simulations table.

11. List of the Simulations. The selected simulation is highlighted with green background color. If the checkbox *by checking* in the series table is checked then we display only the simulations, which belong to the selected series. If *by checking* in the series table is un checked we display all simulations of the checked series.

A5.1 The Calculation Option Window



1, 2, 3

The Calculation Option window opens after clicking the Calculation Option command button in the main window. This window enables to selection of important options specific for the current simulation like geometry of the filter area (plain or convex cylindrical), the pressure profile during the cake formation step, the consideration of cake deliquoring or not, etc.

1. Regarding the filtrate density, the solids density, the suspension density and the solids content in the suspension the user has the highest flexibility regarding the inputs. We need always 3 inputs in the suspension material parameters field in the main window: As input can even be for example all 3 densities and the suspension solids content parameters (Cm, Cv, C) are calculated (for this the option button “Cm, Cv and C are calculated” has to be selected). Or, any 2 of the 3 densities and one of the 3 solids content parameters are input. For example the filtrate density and the suspension density are inputs and the solids density is calculated (for this the option button “rho_s is calculated” has to be selected). Default option is “rho_sus is calculated”.

2. Selection first of the geometrical shape of the filter area: Plain or cylindrical (that is convex cylindrical shape as we have it for example in candle filter type). For each of these filter area

types we have 3 options which determine the profile of the pressure difference during cake formation:

-Dp=const

-Volumetric Pump (Qp=const)

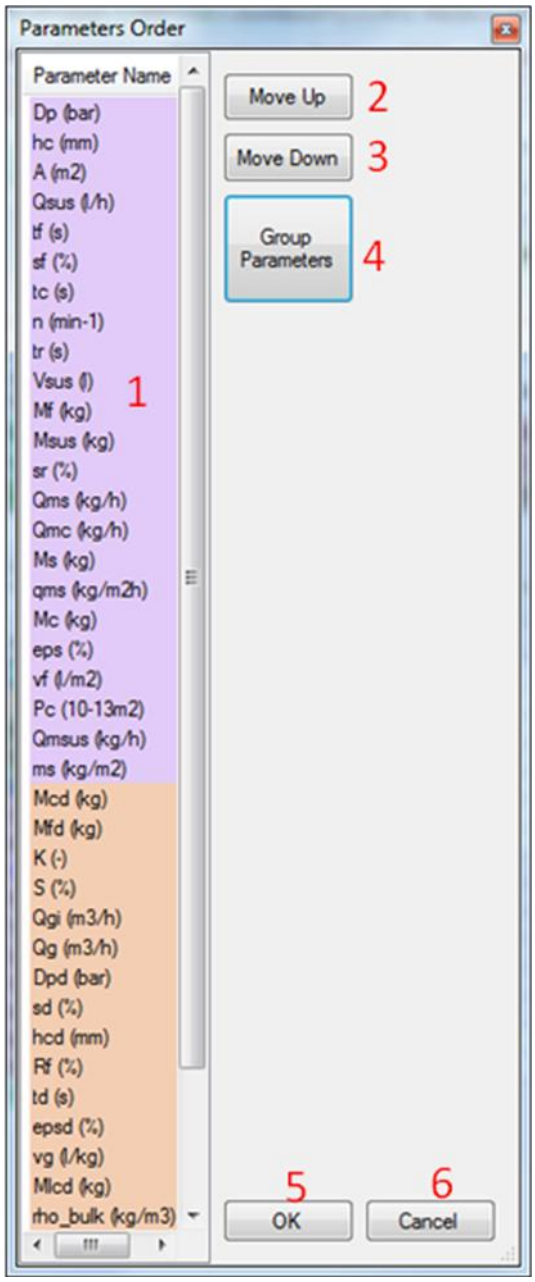
-Centrifugal Pump (Qp=const & Dp=const)

The option Dp=const is for all continuous working filters and for nutsche filters. The volumetric pump by pumping a constant suspension flow rate due to the increasing cake resistance causes a continuously increasing pressure difference Dp. Normally the filtration ends after reaching a maximal pressure difference. The centrifugal pump has both parameters variable: The suspension flow rate and the pressure difference. The program approximates the pump operation by using an interval of constant suspension flow rate Qp with increasing pressure and a second interval of constant pressure difference Dp with decreasing suspension flow rate.

3. Deliquoring Calculation Option

In this field we can choose if we want to display in the main window also the deliquoring step and if yes if we want to have calculation and display of the gas flow rate. Possible is also the selection for considering the liquid evaporation. The program considers also the squeezing of the cake prior to cake deliquoring. For such cases the input of individual cake height, pressure difference and cakepermeability for the deliquoring step is enabled by checking the corresponding checkboxes. Finally different viscosity and density than the mother liquid for the deliquoring step can be entered taking into account a possible washing step prior to cake deliquoring. For this the checkbox “Density/Viscosity Input” has to be checked.

A5.2 The Parameters Order Window



1, 2, 3, 4, 5, 6

1. List of the parameters as they appear in the horizontal simulations table. To change the order of these parameters we can click on one parameter and drag-and-drop it up to the position we want to have it. Another option is to select the parameter we want to change its position and move it by using the Move Up (2) or Move Down buttons (3).

2. Moves selected parameter upwards.

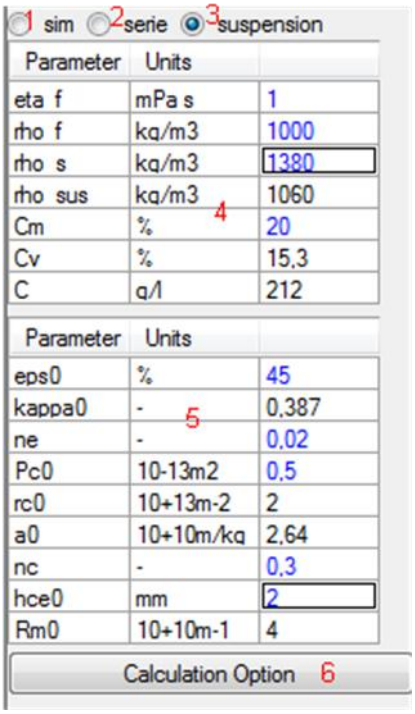
3. Moves selected parameter downwards.

4. Orders the parameters in two groups: The cake formation and the cake deliquoring group. These two groups are distinguished by different color.

5. Click OK to save selected parameters order in Simulations table.

6. Click Cancel to close window without saving of any changes in the Parameters Order-window.

A6 Material Parameters of General Importance



1, 2, 3, 4, 5, 6

Material parameters of general importance means, that they are needed for the calculation of both steps: cake formation and cake deliquoring. These are suspension parameters (4) and cake & filter medium parameters (5). The values in blue color indicate input parameters. The following parameters belong to the same group (that means the value of only one parameter has to be entered and all others are calculated):

-rho_s, rho_sus

-Cm, Cv, C

-eps0, kappa0

-pc0, rc0, a0

-hce0, Rm0

Any changes of the parameter values automatically update all calculations and the diagram (no need to press any Refresh-button). Depending on the selected option button (see 1, 2, 3) the changes for these material parameters can be taken only for the current simulation (1) or for all simulations of the current series (2) or for all simulations with the same suspension (3). If, for example, we want to change the solids density and these changes have to be considered for all simulations with the same suspension, then first select the option button *Suspension* (3) and then change the density value. These option buttons are very useful because many times it makes

sense to change definite values only for the current simulation and see the influence of this change by comparing with other simulations with the old value. That means 2 simulations with the same suspension (same material, customer and charge name) do not need necessarily to have the same values of the material parameters.

1. *Sim*-option button

When this option button is selected any change of the material parameters (4, 5) are considered only for the current simulation.

2. *Serie*-option button

When this option button is selected any change of the material parameters (4, 5) is considered for all simulations of the current Series.

3. *Suspension*-option button

When this option button is selected, any change of the material parameters (4, 5) is considered for all simulations, which have the same suspension (can be simulations of different series and even of different projects). Same suspension means to have the same ID (=same material, customer and charge name).

4. Material parameters characterizing the suspension.

eta_f	viscosity of mother liquid
rho_f	density of mother liquid
rho_s/ rho_sus	solids density /suspension density
Cm/Cv/C	suspension solids mass fraction/ suspension solids volume fraction/ suspension solids concentration

The viscosity and density of the mother liquid are always input parameters. The solids density and the suspension solids mass fraction are default inputs.

5. Material parameters for the filter cake and the filter medium

eps0, kappa0	cake porosity (Dp=1bar), specific cake volume (related to filtrate volume) (Dp=1 bar)
ne	cake volume reduction factor
Pc0/ rc0/ a0	cake permeability / cake resistances in m^{-2} and in m/kg
nc	cake compressibility (cake permeability reduction factor with increasing pressure difference Dp)
hec0/ Rm0	average specific filter medium resistance/ average absolute filter medium resistance

Default inputs are: eps0, ne, Pc0, nc, hce

The above material parameters for the filter cake and the filter medium can be best determined by analysis of laboratory filtration tests and by using *FILOS* and the *Filtration Calculator*.

6. Calculation Option (see description p. 39)

A7 Cake Formation Settings & Result Parameters

Limits

Parameter	Units	Min	Value	Max
A	m2	1	50	70
Dp	bar	0,2	0,7	0,85
sf	%	5	30	40
sr	%	60	70	95
tr	s	72	84	114
tf	s	9	36	90
tc	s	30	120	300
n	min-1	0,2	0,5	2
hc	mm	3,598	8,646	14,65
Msus	kg	678,7	1631	2764
Vsus	l	641,3	1541	2612
Mf	kg	461,4	1109	1879
Ms	kg	135,7	326,2	552,9
Mc	kg	217,3	522,1	884,9
ms	kg/m2	2,715	6,524	11,06
Qmsus	t/h	0,9786	48,93	68,5
Qsus	m3/h	0,9247	46,24	64,73
Qms	t/h	0,1957	9,786	13,7
Qmc	t/h	0,3133	15,66	21,93

You see here a typical case for the calculation of the performance of a rotary vacuum filter. Given is the filter area A, the pressure difference Dp (calculation option Dp=const), the specific area for cake formation sf and the rotational speed n (see parameters in blue color as an indication of the input parameters). All other parameters are then calculated (see parameters in black) like the cake height hc, the solids throughput Qms etc. Depending on the filter type of the current simulation and the calculation option as well as the settings in the "Parameters to display window" the appearance of this field can vary with respect to the listed parameters and which parameters are input.

Parameters with the same background color belong to the same group, and anyone of the parameters of one group can be input (blue color) and the others are calculated. For example, filter area A and the solids throughput Qms (productivity) belong to the same group. That means entering the filter area A the solids throughput Qms is calculated and entering the solids throughput Qms the needed filter area A is calculated (filter design). Similar is with the hc-group: Entering the filtration time tf the cycle time tc and cake height hc are calculated and entering the cake height hc we have calculation of the filtration time tf and the cycle time tc.

For plane area and the calculation options Dp=const and Qp=const we have 4 groups and for the third option (Centrifugal Pump) we have 5 groups of parameters. For the cylindrical area, the input of the diameter of the cylindrical area d0 has additionally to be entered. The pressure difference for the option Dp=const and for the option centrifugal pump is the only parameter in its group and this means that Dp is always entered. For the volumetric pump, alternatively instead of the maximal reached pressure Dp, the pump suspension flow rate Qp can be entered and the maximal reached pressure Dp is then calculated.

All parameters displayed in this field are input/calculated parameters. That means if in the "Parameters to Display" window we select a cake formation settings & result parameter, which can not be input (only calculated), then this parameter is displayed in the simulation table but not in this vertical column. The reason is not to have too much parameters in this input/calculate field (please notice that for the cake deliquoring Setting & Results field we display also only calculated parameters).

A very powerful program option is the limits calculation. The limits calculation concept is activated by checking the *Limits*-checkbox. In such a case, we have 2 additional columns on the left and on the right of the values of the parameters. These additional two columns display the min-max possible values for every potential input parameter. These min-max values are always updated as soon as the value of any input parameter has changed. This allows among other benefits the input of only meaningful values. When an entered parameter is outside of the ranges, the corresponding limit is displayed in red color as a help to correct this value. The limits calculations can be disabled by unchecking the *Limits* checkbox. When we disable the limits calculations, the speed of the calculations is higher. Important for the limits are the ranges, which we enter in the *Range*s-window. For every filter type, a default set of ranges can be entered/changed and saved and these values are used for the limits calculations.

A8 Material parameters for the Cake Deliquoring step

Parameter	Units	
Dpd	bar	0,7
hcd	mm	8,646
epsd	%	45,32
sigma	miliN/m	70
pke0	bar	0,25
pke	bar	0,3258
pcd	10-13m2	0,5565
rcd	10+13m-2	1,797
alphad	10+10m/kg	2,382
Srem	%	10
ad1	-	0,5
ad2	-	5
Tetta	C°	20
eta_g	mPa s	0,02
ag1	-	1
ag2	-	0
ag3	-	0,15

In this column we find in the first 2 cells the pressure difference Dpd and the cake height hcd for the cake deliquoring step. These are actually not material parameters but influence the material parameters of the cake deliquoring step and that is the reason why they are placed above the material parameters. Dpd can be taken as equal to the cake formation pressure Dp (default case) or can be entered as independent value by checking the checkbox "Pressure difference input" in the *Calculation Options* window. The same is with the cake height hcd: It is normally (default) calculated from the cake height of the cake formation step hc and the porosities for cake formation eps and cake deliquoring epsd. But, any value of the cake height can be entered (by checking the checkbox "cake height input" in *the Calculation options* – window) and in such a case the cake porosity epsd is calculated from the etered hcd.

The pressure difference Dpd (if higher than the cake formation pressure Dp) influences the cake permeability pcd (if the pcd is not entered but calculated). The pcd together with the surface tension of the cake liquid *sigma* and the standard capillary pressure pke0 gives the capillary pressure pke. Cake permeability pcd, capillary pressure pke, pressure difference Dpd, cake porosity epsd, cake liquid viscosity, cake height hcd and filter medium resistance hce0 together with the deliquoring time td determine the deliquoring index K. The K-value together with the 2 adaptation parameters ad1 and ad2 as well as the remanent cake Saturation Sr are needed for the calculation of the cake Saturation S. The cake Saturation S with the cake porosity epsd and the ratio of solids density to liquid density gives the cake moisture content Rf. The parameters: (Tetta, ag1, ag2, ag3) are needed for the calculation of the gas flow rate through the cake. These 4 parameters do not appear, if in calculation option- window the checkbox *Consider Gas flow rate* is not checked. In this case, all gas flow related parameters are not calculated.

If in the calculation option – window the checkboxes Consider Gas flow rate and *Consider*

Evaporation are checked we display additionally the following 5 parameters:

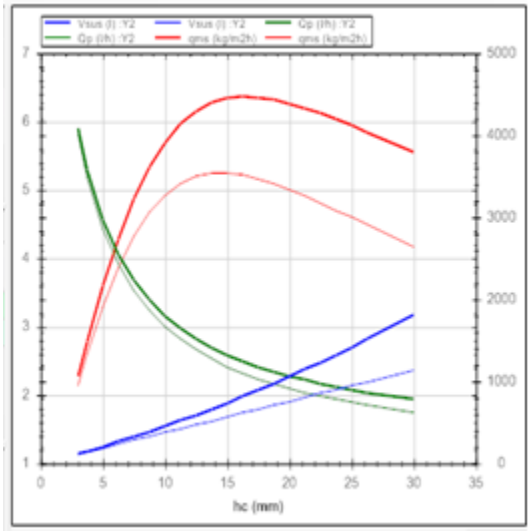
(Tetta_boil, DH, Mmole, f, peq). These inputs are necessary for the calculation of all parameters related to the liquid evaporation during cake deliquoring. In case that these parameters are not displayed although the checkbox *Consider Evaporation* is checked, please open the window *Parameters to display* and check these parameters.

A9 Settings & Result Parameters for the Cake Deliquoring step

Parameter	Units	Min	Value	Max
sd	%	5	50	50
td	s	6	60	60
K	-	0,2995	2,995	2,995
S	%	30,77	30,77	66,93
Rf	%	15,6	15,6	28,67
Qgi	m3/h	87,6	721,7	721,7
Qg	m3/h	2,206	193,9	193,9
vg	l/kg	0,2255	19,81	19,81
Mfd	kg	64,75	132,2	132,2
Mlcd	kg	60,28	60,28	131,1
Mcd	kg		386,5	
rho_bulk	kg/...	894	894	1058
Qmcd	t/h		11,59	
qfid	l/m2h	24,82	24,82	401,4
Vg	m3		6,462	
qfd	l/m2h		79,33	

The important setting parameters for the cake deliquoring step are the pressure difference Dpd, the cake height hcd and the deliquoring time td. The first 2 parameters are listed in the previous column (column for deliquoring material parameters) because both influence the values of some material parameters due to the cake compressibility. The deliquoring time is one of many parameters, which belong to the input/calculated parameters in this column. All these parameters belong to the same group. That means only one parameter is entered and all others are calculated. All parameters in this column, which belong to the only one input group are distinguished by those which are only calculated parameters by the background color of their values. That means contrary to the column with the cake formation Setting & Result parameters we have in this column not only input/calculated but also only calculated parameters displayed. Which parameters are displayed we select in the *Parameters to display* window by checking the corresponding checkboxes. When the *Limits* checkbox is checked, we display on the left and right of the input/calculated parameters the min-max values, which are automatically refreshed with any change of the simulation parameters. For the only calculated parameters, no limits are displayed.

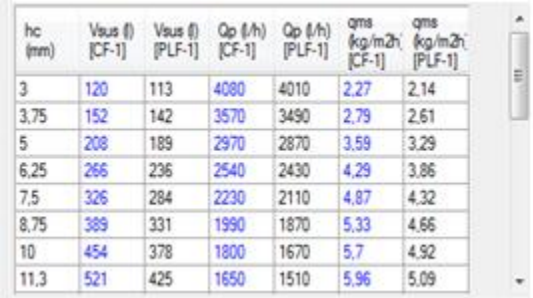
A10 Diagram



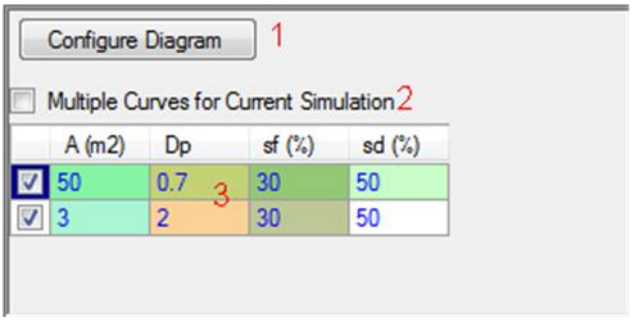
The displayed curves in the diagram are updated automatically as soon as we change any input parameter. There are 2 diagram options depending on the checkbox *Multiple Curves for Current Simulation* in (12) (see field below the table for the diagram). The default diagram option is when this checkbox is unchecked. In this case we display curves for the current simulation (if the *by checking* checkbox of the simulations table is checked) or for all checked simulations (if the *by checking* checkbox of the simulations table is unchecked). The second diagram option is when the *Multiple Curves for Current Simulation* checkbox is checked. In this case we consider always the current simulation (no matter if the by checking checkbox in the simulations table is checked or not) and we can create for each y-axis parameter more than one curve by changing of one or more input parameters (=multiple curves for the current simulation). For example we are interested to have for a given simulation curves with Qms=f(hc) for 3 different pressure differences Dp and all other parameters constant. These 3 curves are created by checking the checkbox *Multiple Curves for Current Simulation* and adding another 2 rows in the right bottom side of the window by clicking the "+". In the created 2 additional rows, we just enter the other 2 values of the Pressure difference and we get 3 curves (one for the current simulation and the other two for the entered two pressure differences).

All diagram settings: x-, y1-, y2-axes parameters, the interval for the x-axis parameter, the number of iterations, the linear or logarithmic plot for x or/and y1 or/and y2 axis parameters etc. are selected in the *Configure Diagram* window.

A11-12 Table belonging to the Diagram



hc (mm)	Vsus (l) [CF-1]	Vsus (l) [PLF-1]	Qp (l/h) [CF-1]	Qp (l/h) [PLF-1]	qms (kg/m2h) [CF-1]	qms (kg/m2h) [PLF-1]
3	120	113	4080	4010	2,27	2,14
3,75	152	142	3570	3490	2,79	2,61
5	208	189	2970	2870	3,59	3,29
6,25	266	236	2540	2430	4,29	3,86
7,5	326	284	2230	2110	4,87	4,32
8,75	389	331	1990	1870	5,33	4,66
10	454	378	1800	1670	5,7	4,92
11,3	521	425	1650	1510	5,96	5,09



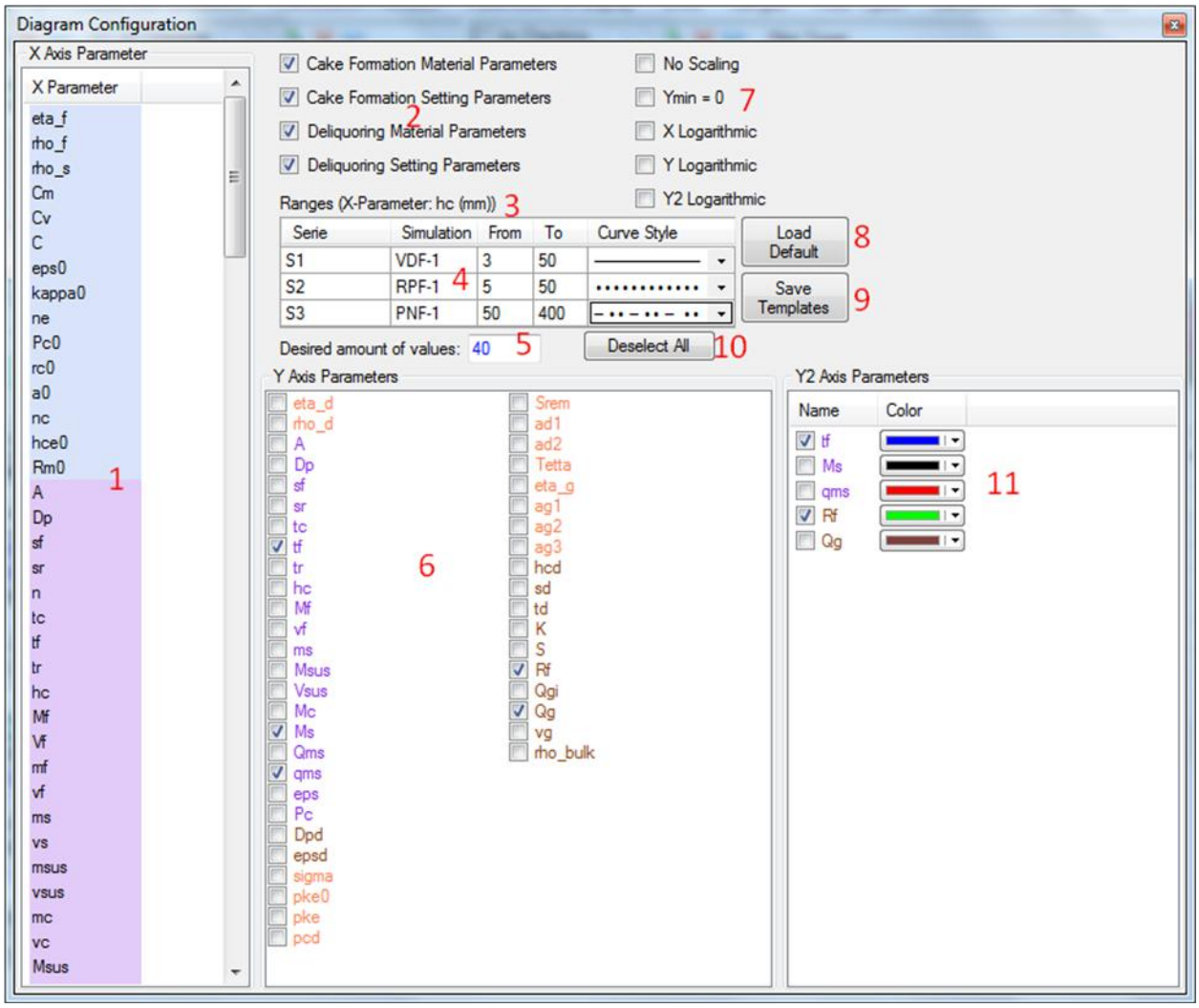
1, 2, 3

The diagram table shows as default the x-axis parameter in the first column. The number of simulations for which we have curves in the diagram can be seen in the small table at the right bottom side of the window (2). The highlighted curve(s) in the diagram are in bold lines and correspond to the selected row in this small table. The selected row has a green background color. The values of the selected simulation in the small table are highlighted in the diagram table with a blue color. The order of the parameters in the table can be changed by the user. Just click the name of the parameter and drag and drop it using the mouse to the place you want to have it.

1. Opens a window for defining the diagram configurations (see detailed explanations (Configure Diagram window)

2., 3. Checkbox *Multiple Curves for Current Simulation*. Default is unchecked: If unchecked we display in the diagram the curves for the current simulation or the curves of all checked simulations in the simulations table. The small table in (3) displays the constant setting parameters for the displayed simulations in the diagram. If this checkbox is checked then we can have for the current simulation more than one curve by varying one or more setting parameters. For this option the small table in (3) displays as first row the constant setting parameters of the current simulation and in the other rows the constant setting parameters for the additional simulations.

A12.1 The Configure Diagram Window



1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11

This window opens after clicking the command button *Configure Diagram* in the main window and enables the definition of all diagram settings: Selection of the x-, y1-, y2-axes parameters, the interval for the x-axis parameter, the number of iterations, the linear or logarithmic plot for x or/and y1 or/and y2 axis parameters, the color and style of the curves as well as the creation of curve profiles (curve templates) etc. are selected in the *Configure Diagram* window.

1. List of the parameters, which can be selected as x-axis parameter for the diagram. Using the checkboxes in (2) we can control which group of parameters we want to display. If for example we are not interested to see any deliquoring parameter in this list we just uncheck the last 2 checkboxes in (2)

2. When we check one of these 4 checkboxes we display the corresponding parameters in the x- and y-axes list (1, 6), so that we can select them for the diagram. An exception is the first checkbox (Cake formation material parameters) because this group of parameters is displayed

only in the x-axis list. This is logical because these parameters are not result parameters but always inputs.

3. Displays which parameter is selected as x-axis parameter. The x-axis parameter is also highlighted in the x-axis list (1) after selecting the parameter.

4. Listing of the min-max values for the x-axis and curve style specific for each simulation. If for example we want to have curves for 2 simulations of 2 different series, as for example one series with a filter press and one series with a pressure nutsche and we have selected the cake height as x-axis parameter then it is obvious that we should use different min-max values for the cake height for the 2 simulations. We can load default min-max values by clicking "Load Default" (8) or enter any values we like.

5. The number we enter there, determines how many iterations (variations) of the x-axis parameter we wish for the plotting of the diagram. With this number, we determine also the number of rows in the table below the diagram. The number of rows in the table is normally not exact the same as the entered value because only round numbers are displayed for the x-axis parameter.

6. List of the parameters, which can be selected as y1/y2 axis parameters. Which parameters we display in this list depends on the checkboxes in (2). The different color of the parameters allows us to identify in which group they belong: Cake Formation Settings or Deliquoring Material or Deliquoring Settings parameters. If in the *Parameters to Display* window one parameter is unchecked then it is not displayed in the main window and not in the Diagram Configuration window. If we wish to have such a parameter for the diagram, we have first to check it in the *Parameters to display* window.

7. These checkboxes allow the formatting of x- and y1/y2 axes of the diagram. We can have anyone of these axes in linear or logarithmic scale (see last 3 checkboxes). If *No Scaling* is checked, we display the y-axis parameters without any multiplication factor. Sometimes it is necessary for a better display to have this checkbox unchecked (default case). The multiplication factor is then displayed in the diagram legend attached to the name of the parameter.

8. Loads the default min-max values for the selected x-axis parameter in the table in (4), so that they can be taken for the diagram (default case). These values are taken from the *Ranges*-window and are individual (specific) for each series.

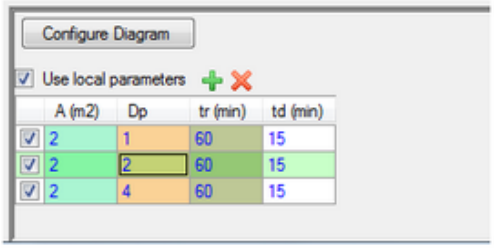
9. The *Save Templates* command button saves all configuration as a template. The saved list of diagrams can be loaded by clicking the command button Load Templates in the main window. In this Curves Templates window we can select any curve of the list with the automatically display of the diagram and the corresponding table in the main window.

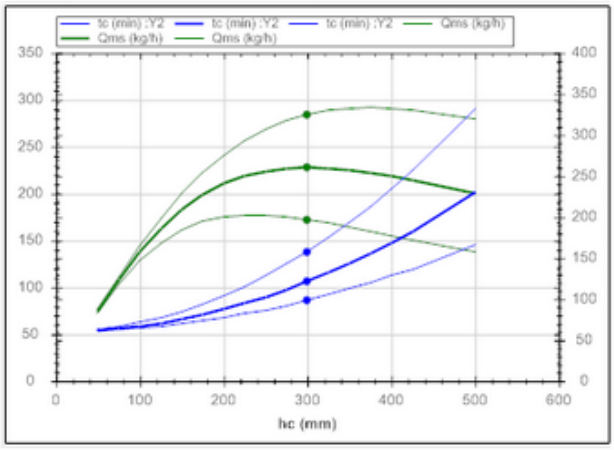
10. The *Deselect All* command button deletes all selections in the y-axis field (6) enabling the easy selection of other new parameters for the y1/y2 axes.

11. In this field we have a list of all selected y-axis. Checking the checkbox of one of these

parameters means the display of this parameter as y2-axis (right-axis) parameter. Unchecking a parameter in this field means that we want to have this parameter as y1-axis parameter. Deleting of a parameter from the diagram can be done by unchecking the parameter in the y-axis parameter field in (6). For each parameter the user can define individual color by choosing a color on the right of this parameter. The new color is then automatically displayed in the diagram.

A12.2 Multiple Curves for Current Simulation





There are 2 diagram options depending on the checkbox *Multiple Curves for current Simulation*. The default diagram option is when this checkbox is unchecked. In this case we display single curves for the current simulation (if the *by checking* checkbox of the simulations table is checked) or for all checked simulations (if the *by checking* checkbox of the simulations table is checked). Single curves mean that we have only one curve for a given y-axis parameter for the current simulation. The second diagram option is when the *Multiple Curves for current Simulation* checkbox is checked. In this case we consider always the current simulation (no matter if the *by checking* checkbox in the simulations table is checked or not) and we can create for each y-axis parameter more than one curve by adding additional rows in the small table on the right bottom side of the main window. In this new added row we change the value of one or more parameters and create another curve for the same y axis parameter (=multiple curves for the current simulation). For example we are interested to have for a given simulation, curves with Qms=f(hc) for 3 different pressure differences Dp and all other parameters constant. These 3 curves are created by checking the checkbox *Multiple Curves for current Simulation* and adding another 2 rows in the right bottom side of the window by clicking the "+". In the created 2 additional rows, we just enter the other 2 values of the Pressure difference Dp and we get 3 curves (one for the current simulation and the other 2 for the entered 2 pressure differences).

By clicking the *delete* symbol on the right of the "+" symbol we can delete a curve in the

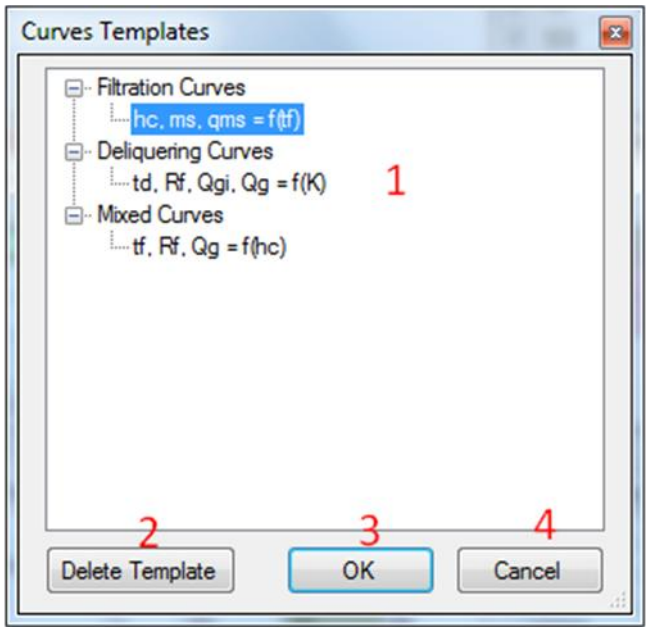
diagram by deleting the corresponding row in this table. Only the first row can not be deleted. This is the curve for the input parameters of the current simulation and this curve is the same with the curve displayed when we have the option *Multiple Curves for current Simulation* unchecked.

A12.3 Table with the listing of the input parameters (which are kept constant for the curves)

If we have the checkbox *Multiple Curves for current Simulation* unchecked then each row of this table corresponds to one simulation in the simulations table. The columns display the values of input parameters, which are constant during variation of the x-axis parameter.

If we have the checkbox *Multiple Curves for current Simulation* checked then the first row represents the current simulation and we can add additional curves to this simulation: By clicking the "+" symbol, we add a new row in this table and by changing the values of one or more parameters in this row we create new curves for the same y-axis parameters as we have for the current simulation.

A12.4 Load Templates



1, 2, 3, 4

In the Diagram Configuration window, which opens after clicking the Configure Diagram button we can save any diagram with all its settings by clicking the button Save Templates. That means that the user can have its library with his defined diagrams and can load them any time. This

library of user-defined diagrams we call them diagram templates. The viewing, loading or deleting of these templates can be done in the Templates – window, which opens after clicking the command button Load Templates in the main window. Depending on the selected x/y-axis parameters we have 3 groups of templates: Filtration Curves (when we have only cake formation parameters), Deliquoring Curves (when we have only deliquoring parameters) and Mixed Curves (when we have cake formation and deliquoring parameters).

1. List of the template curves.Select the curve you want to display as diagram in the main window. Upon selection this curve is automatically displayed in the main window without having to click OK. By clicking OK the window closes and the template curve is displayed in the main window. By clicking Cancel the window closes and the previous curve (before opening the Templates window) is displayed in the main window

2. Click Delete Template button and then OK if you want to remove the selected template curve from your list. Please notice that if you click Cancel after the Delete Template the window closes and the Deleting is cancelled (that means you still have all curves which you had before opening the Templates window).

3. The OK command button takes the selected diagram template and displays it in the main window. If you click OK after deleting a template then the deleting is not valid, that means the templates list is still the same as before opening the templates window.

4. The *Cancel* command button returns to the main window without any changes.

B Listing of all Parameters

B1 Cake Formation (Material parameters)

Nr.	Symbol in the program	Explanation	Default Units
1	eta f	Mother liquid viscosity (default=1)	mili Pa s
2	rho f	Mother liquid density (default=1000)	kg/m^3
3	rho s	Solids density (default=2000)	kg/m^3
4	rho sus	Suspension density	kg/m^3
5	Cm	Suspension solids mass fraction (default=2-30)	%
6	Cv	Suspension solids volume fraction	%
7	C	Suspension solids concentration	g/l
8	eps0	Cake porosity (Dp=1 bar) (default=50)	%
9	kappa0	Cake volume/filtrate volume (Dp=1 bar)	--
10	ne	Cake porosity factor (default=0)	--
11	eps	Cake porosity	%
12	kappa	Cake volume/filtrate volume	--
13	pc0	Cake permeability (Dp=1 bar) (default=0.01-10)	10^{-13} m^2
14	rc0	Cake resistance (Dp=1 bar) (default=0.1-100)	10^{13} m^{-2}
15	a0	Cake resistance (m/kg) (Dp=1 bar) (default=0.1-100)	10^{10} m/kg
16	nc	Cake compressibility (default=0 - 1)	--
17	pc	Cake permeability	10^{-13} m^2
18	rc	Cake resistance	10^{13} m^{-2}
19	a	Cake resistance (m/kg)	10^{10} m/kg
20	hce0	Specific Filter medium resistance (default=0)	mm
21	Rm0	Filter medium resistance	10^{10} m^{-1}

B2 Cake Formation (Settings & Results Parameters)

Nr.	Symbol in the program	Explanation	Default Units
1	A	Filter area	m^2
2	d0	Candle diameter	mm
3	Dp	Pressure Difference	
4	tf	Filtration time	bar
5	sf	Specific filtration time (=tf/tc)	%
6	sr	Specific residual time (=tr/tc)	%
7	tr	Residual time (tr=tc-tf)	s, min
8	tc	Cycle time	s, min
9	n	Cycle frequency (for rotary filters called rotational speed)	min^{-1}
10	hc	Cake height	mm
11	hc/t	Mean height rate	mm/min
12	dhc/dt	Differential height rate	mm/min
13	Msus	Suspension Mass for one cycle	kg
14	Vsus	Suspension volume for one cycle	l
15	msus	Specific suspension mass (=Msus/A)	kg/m^2
16	vsus	Specific suspension volume (=Vsus/A)	l/m^2
17	Qmsus	Suspension mass rate (related to the cycle time tc)	Kg/h
18	Qmsus,i	Instantaneous suspension mass rate	Kg/h

19	Qsus	Suspension volume rate	l/h
20	Qp	Instantaneous Suspension volume rate	l/h
21	qmsus	Specific suspension mass rate (=Qmsus/A)	kg/(m^2 min)
22	qmsus,i	Differential specific suspension mass rate	kg/(m^2 min)
23	qsus	Specific suspension volume rate	l/(m^2 min)
24	qp	Differential specific suspension volume rate	l/(m^2 min)
25	Ms	dry solids mass	kg
26	Vs	Suspension solids volume	l
27	ms	Specific suspension solids mass	kg/m^2
28	vs	Specific suspension solids volume	l/m^2
29	Qms	Suspension solids mass rate related to tc	Kg/h
30	Qms,i	Differential suspension solids mass rate	Kg/h
31	Qs	Suspension solids volume rate	l/h
32	Qs,i	Differential suspension solids volume rate	l/h
33	qms	Specific suspension solids mass rate	kg/(m^2 min)
34	qms,i	Differential specific suspension solids mass rate	kg/(m^2 min)
35	qs	Specific suspension solids volume rate	l/(m^2 min)
36	qs,i	Differential specific suspension solids volume rate	l/(m^2 min)
37	Mf	Filtrate Mass	kg
38	Vf	Filtrate volume	l
39	mf	Specific filtrate mass	kg/m^2
40	vf	Specific filtrate volume	l/m^2
41	Qmf	Filtrate mass rate related to filtration time tf	Kg/h
42	Qmf,i	Differential filtrate mass rate	Kg/h
43	Qf	Filtrate volume rate related to filtration time tf	l/h
44	Qf,i	Differential filtrate volume rate	l/h
45	qmf	Specific filtrate mass rate related to filtration time tf	kg/(m^2 min)
46	qmf,i	Differential specific filtrate mass rate	kg/(m^2 min)
47	qf	Specific filtrate volume rate related to tf	l/(m^2 min)
48	qf,i	Differential specific filtrate volume rate	l/(m^2 min)
49	Mc	Cake Mass	kg
50	Vc	Cake volume	l
51	mc	Specific cake mass	kg/m^2
52	vc	Specific cake volume	l/m^2
53	Qmc	Cake mass rate	Kg/h
54	Qmc,i	Differential cake mass rate	Kg/h
55	Qc	Cake volume rate	l/h
56	Qc,i	Differential cake volume rate	l/h
57	qmc	Specific cake mass rate	kg/(m^2 min)
58	qmc,i	Differential specific cake mass rate	kg/(m^2 min)
59	qc	Specific cake volume rate	l/(m^2 min)
60	qc,i	Differential specific cake volume rate	l/(m^2 min)

M=mass
V=volume
m=M/A specific mass
v=V/A specific volume

Qm=mass flow rate
Q=volume flow rate
qm=Qm/A specific mass rate
q=Q/A specific volume rate

B3 CakeDeliquoring (Material Parameters)

Nr.	Symbol in the program	Explanation	Default Unit
1	epsd	Cake porosity (deliquoring) (default =50)	%
2	eta_d	Viscosity of cake liquid (deliquoring) (default =1)	mili Pa s
3	rho_d	Density of cake liquid (deliquoring) (default =1000)	kg/m^3
4	sigma	Surface tension of cake liquid (deliquoring) (default =70)	mili N/m
5	pke0	Standard capillary pressure (for $p_{c,st}=10^{-13} m^2$) (default =0.25)	bar
6	pke	Capillary pressure	bar
7	pcd	Cake permeability (deliquoring) (default=0.01 - 10)	$10^{-13} m^2$
8	rcd	Cake resistance (deliquoring) (default =0.1-100)	$10^{13} m^{-2}$
9	alphad	Cake resistance (m/kg) (deliquoring) (default = 0.1-100)	10^{10} m/kg
11	Srem	Remanent cake saturation (default =10)	%
12	ad1	Adaptation parameter (deliquoring) =deliquoring efficiency (default=0.5)	--
13	ad2	Adaptation parameter (deliquoring) (default =5)	--
14	Tetta	Cake temperature (default =20)	°C
15	eta_g	Gas viscosity (default =0.02)	mili Pa s
16	ag1	Gas adaptation parameter (default =1)	--
17	ag2	Gas adaptation parameter (default =0)	--
18	ag3	Gas adaptation parameter (default =0.2)	--
19	Tetta_boil	Boil temperature of cake liquid (default =100)	°C
20	DH	Molar enthalpy of evaporation (default=40)	KJ/mole
21	Mmole	Molar mass (default =18)	g/mole
22	f	Evaporation factor (default=1)	--
23	peq	Evaporation pressure (always calculated)	bar

B4 Cake Deliquoring (Settings & Results Parameters)

Nr.	Symbol in the program	Explanation	Default Unit
1	Dpd	Pressure difference (deliquoring)	bar
2	hcd	Cake height (deliquoring)	mm
3	sd	Specific deliquoring time (cycle time related)	%
4	td	Deliquoring time	s, min
5	K	Deliqoring index	--
6	Smech	Saturation due to mechanical deliquoring only	%
7	S	Cake saturation	%
8	Rfmech	Cake moisture content due to mechanical deliquoring only	%
9	Rf	Cake moisture content	%
11	Qgi	Instantaneous volume gas rate	m^3/h
12	Qgt	Integral volume gas rate related to td	m^3/h
13	Qg	Integral volume gas rate related to tc	m^3/h
14	Vg	Gas volume (norm conditions)	m^3
15	vg	Specific gas volume (related to solids mass)	l/kg
16	Mfd	Filtrate mass (deliquoring)	kg
17	Vfd	Filtrate volume (deliquoring)	l
18	Mev	Evaporated liquid mass	kg
19	Vev	Evaporated liquid volume	l

20	Mlcd	Liquid mass in the cake	kg
21	Vlcd	Liquid volume in the cake	l
22	Mcd	Cake mass after deliquoring	kg
23	Vcd	Cake volume	l
24	ρbulk	cake bulk density	Kg/m^3
25	Qmfid	Instantaneous filtrate mass rate (deliquoring)	Kg/h
26	Qmftd	Filtrate mass rate related to td (deliquoring)	Kg/h
27	Qmfd	Filtrate mass rate related to tc (deliquoring)	Kg/h
28	Qfid	Instantaneous filtrate volume rate (deliquoring)	l/h
29	Qftd	Filtrate volume rate related to td (deliquoring)	l/h
30	Qfd	Filtrate volume rate related to tc (deliquoring)	l/h
31	Qmcd	Cake mass rate related to tc (deliquoring)	Kg/h
32	Qcd	Cake volume rate related to tc (deliquoring)	l/h
33	Qmevi	Instantaneous evaporation mass rate	Kg/h
34	Qmevt	Evaporation mass rate related to td	Kg/h
35	Qmev	Evaporation mass rate related to tc	Kg/h
36	Qevi	Instantaneous evaporation volume rate	l/h
37	Qevt	Evaporation volume rate related to td	l/h
38	Qev	Evaporation volume rate related to tc	l/h
39	qmfid	Instantaneous area specific filtrate mass rate (deliquoring)	$kg/(m^2 min)$
40	qmftd	Area specific filtrate mass rate related to td (deliquoring)	$kg/(m^2 min)$
41	qmfd	Area specific filtrate mass rate related to tc (deliquoring)	$kg/(m^2 min)$
42	qfid	Instantaneous area specific filtrate volume rate (deliquoring)	$l/(m^2 min)$
43	qftd	Area specific filtrate volume rate related to td (deliquoring)	$l/(m^2 min)$
44	qfd	Area specific filtrate volume rate related to tc (deliquoring)	$l/(m^2 min)$
45	qmcd	Area specific cake mass rate related to tc (deliquoring)	$kg/(m^2 min)$
46	qcd	Area specific cake volume rate related to tc (deliquoring)	$l/(m^2 min)$
47	qmevi	Instantaneous area specific evaporation mass rate	$kg/(m^2 min)$
48	qmevt	Area specific evaporation mass rate related to td	$kg/(m^2 min)$
49	qmev	Area specific evaporation mass rate related to tc	$kg/(m^2 min)$
50	qevi	Instantaneous area specific evaporation volume rate	$l/(m^2 min)$
51	qevt	Area specific evaporation volume rate related to td	$l/(m^2 min)$
52	qev	Area specific evaporation volume rate related to tc	$l/(m^2 min)$