

FILTER DESIGN SOFTWARE

Solid-Liquid Separation Equipment Selection – Design – Simulation - Education – Training

Filter Design Software (FDS) has been developed from the successful p^C-SELECT software that has been used by numerous filtration equipment and user companies since it was launched in 1991. FDS is a result of a collaboration with companies in the equipment supply, pharmaceutical, fine chemical and mining industry sectors where the software has been tested during its development.

FDS is an aid to equipment specification and is also a training and educational tool for use by both industry and academia – so it contains many explanations, pictures and diagrams of equipment. The simulation procedures have in-built constraints that arise due to equipment design features that affect the operation of the equipment, along with many guides to aid correct input of data.

FDS is industry tested, intelligent and interactive software that is designed to be user friendly for those users who may not be familiar with the bewildering choice that exists amongst solid-liquid separation equipment. FDS is also a valuable tool for the solid-liquid separation equipment expert.

FDS is a sequence of interlinked modules that can be used independently from one another. The full set of FDS modules offers many capabilities, including:

- A catalogue and explanation of the main operational and design features of 70+ equipment types
- Full analysis capabilities of leaf filter, jar sedimentation and expression test results to give the relevant parameters for scale-up and simulation of solid-liquid separation equipment
- Comparison of data sets from a range of tests or trials
- Simulation of 20+ types of vacuum and pressure filters
- The ability to import data files from other software (e.g. Excel[®] spreadsheets)
- Web access to equipment suppliers.

SELECTION MODULE & EQUIPMENT CATALOGUE

The equipment catalogue, which can be called up from the opening screen, is designed for use as a reference manual - it gives technical information and diagrams and photographs about all of the generic types of equipment stored in FDS.

Specifications: Feed rate (m³/h): 5-50; Duty: Operation: batch; Objective: washed solids; Setting: Settling rate (cm/s): 0.1-5; Supernatant clarity: good; Sludge proportion (%): 2-20; Filtration: Cake growth rate (cm/min): 0.02.

Selected equipment list: 13 items

	W/aming	(1)	(2)	(3)	(4)	(5)	Particle size (µm)	Solids conc. (%w/w)
Basket (pendulum) centrifuge	None	9 C	5	6	6	26	10-1000	4-30
Circular basin thickener	None	1 S	5	2	9	17	0.1-500	<20
Diaphragm filter press	None	0 B	0	3	7	0.1	10-20	0.3-30+
Filter press	1B	6 C	8	8	8	30	1-100	<1.30+
High gradient magnetic separator	1h	1 S	4	2	8	15	<400	<10
Low gradient intensity magnetic separator	1h	3 C	4	2	8	17	0.05-4000	5-30
Low shear crossflow microfilter	1h	1 S	9	2	6	18	0.05-20	<20
Multi (horizontal) element leaf pressure filter	None	5 C	8	8	8	29	1-100	<1.20+
Multi (vertical) element leaf pressure filter	None	2 C	6	8	8	29	1-100	<1.20+
Multi element leaf vacuum filter	None	5 C	7	5	8	25	1-100	5-30+
Screen classifier	1SD	9 C	5	4	4	18	45-100000	20-40
Single leaf (Nutsche) pressure filter	None	6 C	8	8	8	30	1-200	<1.20+
Tube press	1hB	8 C	7	4	7	26	1-200	0.3-30+

Equipment descriptions:

Variable volume filters and presses - general
A family of filters devised to handle suspensions of finer solids that are difficult to pump and/or filter. Typical feeds include suspensions of gelatinous and fibrous materials and those particulates containing occluded liquid within an inherent porous structure.

Diaphragm filter press
Typical uses: Batch processing of suspensions forming compressible filter cakes where dry cakes and/or efficient post-treatment are required.
Process settings: Solid product dryness and state: 8 C
Washing performance: 8
Liquid product quality: 8
Crystal breakage: 7
Feed properties: Particle size range: 1-200 µm
Solids concentration range: 0.3-30+ %w/w
These machines are similar in form and general operation to filter presses. However, the plate surfaces are modified by the addition of flexible diaphragms to form 'membrane plates'. Although variants exist, feed pumping operations are generally stopped after 80% of the required volume of filtrate has been produced. The

Equipment schematic 1: DIAPHRAGM FILTER PRESS (filtration/washing/decanting). Schematic shows wash input, feed input, filtrate output, and wash output. Labels include overhead support to allow separation of membrane plates, membrane plates, diaphragm cakes, conveyor, and wash tank.

Example of an equipment selection results screen

The equipment selection procedures enable selection from more than 70 solid-liquid separation equipment types, including thickeners, centrifuges, hydrocyclones, etc – there are many more if the variants within each type are counted. Selection is possible from either limited or from more extensive information – obviously, the more information that is available about the feed and the process the better the selection!

Key features in the Selection Module include:

- User specification of the process and the duty that the equipment will be expected to perform
- Automatic comparison of the specifications with the FDS database
- Ranked listing of solid-liquid separation equipment that match the specifications
- General and detailed information about solid-liquid separation equipment - technical design and operational information about each equipment item in the list is provided in a descriptive format on screen, together with diagrams and photographs
- Facility to prioritise the equipment list according to process criteria (such as cake washability, cake dryness or the damage likely to be caused to the particles)
- Identification of equipment in the list that is marginal for technical reasons
- Customisable list of web addresses of equipment suppliers and facility to paste suppliers addresses to a web browser.

DATA ANALYSIS MODULE

The tests carried out early in the assessment of a solid-liquid separation problem – for either equipment selection or to gather design data – are either a constant pressure leaf filter test (sometimes pilot scale tests may be available) and/or a jar sedimentation test. A piston press test is sometimes carried out to assess compression or consolidation effects on the separation. Whichever test is done, FDS enables rapid analysis of the measured data.

The screenshot shows the FDS Data Analysis Module interface. It is divided into several sections:

- General Information:** Includes fields for 'Description of experiment', 'Solid' (Material X), 'Liquid' (Material Y), 'Data file', 'Unit file', and 'Result file'. There are 'Save results' and 'Display method' buttons.
- Data Sequence / Unit Preferences:** A list of data points with columns for 'Time', 'Liquid volume', 'Press dimensions', 'Pressure', 'Density', 'Liquid viscosity', and 'Slurry concentration'. There are 'Unit preferences' dropdowns for Time, Liquid volume, Press dimensions, Pressure, Density, Liquid viscosity, and Slurry concentration. A 'Filename' field and 'Abandon' button are also present.
- Experimental Data:** Fields for 'Piston diameter' (0.043 m), 'Piston press length' (0.193 m), 'Applied pressure' (2 MPa), 'Solids density' (2600 kg/m³), 'Liquid density' (995 kg/m³), 'Liquid viscosity' (0.001 Pa s), and 'Initial slurry concentration' (0.1 vol frac). An 'Update calculation' button is at the bottom.
- Characteristic Plot:** A graph titled 'Identification of filtration and consolidation regions' showing $dL/dt \times 10^5$ (m/m^{0.5}) on the y-axis (log scale from 1.00E-05 to 0.01) and Time (s) on the x-axis (log scale from 10.0 to 100000). Red data points are plotted, showing a plateau followed by a sharp drop.
- Tabulated Results:** A table with two columns: 'filtration phase (left)' and 'consolidation phase (right)'.

Specific cake resistance	8.73E+12	m/kg	Consolidation coefficient	1.03E-07	m ² /s
Filter medium resistance	1.97E+13	1/m	Consolidation index	5.00E+00	[25]
Effective feed concentration	361.2	kg/m ³	Final cake concentration	0.377	v/v
Mass dry cake/filter area	50.18	kg/m ²	Final cake moisture content	38.71	%
Average cake growth rate	1.97E-02	cm/min	Volume solids/filter area	0.0193	m
Cake solids concentration	0.367	v/v			
Cake moisture content	40.81	%			
Cake wet/dry mass ratio	1.689				

Callouts point to various features:

- User defined experimental data and units:** Points to the 'Description of experiment', 'Solid', and 'Liquid' fields.
- Save results to file:** Points to the 'Save results' button.
- Interactive graphical representation of data:** Points to the 'Characteristic Plot'.
- Calculated data and scale-up/sizing parameters:** Points to the 'Tabulated Results' table.
- Warnings showing calculated data affected, displayed when assumptions have been made due to missing input data:** Points to the 'Consolidation index' value [25] in the table.
- Display meanings of warnings:** Points to the 'Display warnings' button.
- Display more graphs:** Points to the 'Show graphs' button.

Example of a data analysis screen

After the user has entered the experimental measurements in their preferred format then FDS carries out the correct analysis. Even with well conducted tests, sometimes some of the necessary input data is missing yet the best possible analysis must be done with what information is available.

FDS deals with this situation in two ways. Firstly, when the input data are entered they are checked as far as is possible and if FDS suspects that the data may be incorrect it warns the user or does not accept the data. In many cases FDS displays a range of acceptable values for the data as a guide to what is realistic. Secondly, the calculation sequences within FDS are hierarchical. Depending on which data are missing, a sequence of assumptions are made in order to carry out the calculation. After an assumption has been made, a warning may appear against item(s) of output data on the results screen.

Key features of the Data Analysis Module include:

- Analysis of constant pressure filtration test data
- Analysis of jar test sedimentation data
- Analysis of piston press or consolidation data
- Checking of input data to protect against possible incorrect data entry
- Interactive graphical presentation of data to enable the user to input interpretations of the measured data
- Output data in graphical or tabulated format
- All data required for process design, simulation and scale-up (and much more) are output
- Data from several analyses can be compared and correlated.

SIMULATION MODULES

Two simulation modules are available – the *Vacuum Filter Simulation Module* and the *Pressure Filter Simulation Module*. These provide the calculation sequences for 10 types of vacuum filters and 11 types of pressure filters.

The screenshot shows the software interface for filter simulation, divided into several sections:

- General Information:** Includes fields for Notes, Names, Config. file, Pump curve file, Unit file, Wash curve files, and Result file.
- Cycle Configuration, Unit Preferences etc.:** Allows defining the cycle (Phase 1: filtration, Phase 2: wash, Phase 3: gas deliquor, Phase 4: wash) and setting various physical properties like Density, Viscosity, Surface tension, Slurry conc., Solute conc., Solute diffusivity, Particle size, Vacuum, Rotational speed, and Time.
- Simulation Data:** Contains parameters for Filter, Suspension, and Phase 1, such as Drum diameter, Drum width, Drum submergence, Area fraction - washing, Area fraction - gas deliquor, Phase not used, Rotational speed, and Filter medium resistance.
- Schematic mass balance:** A flow diagram showing the separator and its inputs/outputs for Feed, Wash, Cake, Filtrate, and Washings, with associated mass and solute values.
- Graphical Results:** A plot of Cumulative volume of liquid vs Angle, showing a curve that rises and then levels off.

Callouts highlight the following features:

- User defined cycle configuration and units:** Points to the Cycle Configuration and Unit Preferences sections.
- User defined feed suspension and filter cycle data:** Points to the Simulation Data section.
- Save results to file:** Points to the Result file field in the General Information section.
- Graphical representation of all calculated data for the filter cycle:** Points to the Graphical Results plot.
- Mass balance from the simulation for each component in the feed and wash:** Points to the Schematic mass balance diagram.
- Tabulated representation of calculated data:** Points to the 'Show table' button in the Graphical Results section.

Example of filter simulation results screen

The first step in a simulation is to gather and input the necessary data. This requires the filter cycle – the combination of the cake formation, cake washing and cake deliquoring stages – to be defined. FDS allows for more than one washing or deliquoring in a cycle. Each stage requires its own sets of input data – which can be in the units preferred by the user.

Key features of the Simulation Modules include:

- Input of process data for the feed suspension, filter cake and filter type
- Prevention of impractical stages on particular designs of filters – (such as cake washing on a rotary disc filter)
- Simulation of different modes of cake formation (in practice this depends on the type/method of pumping the feed to the filter) – constant pressure, constant flow and variable pressure/variable flow
- Simulation of compression filtration
- Simulation of cake post-treatment processes (cake washing and cake deliquoring)
- Options to over-ride default washing and deliquoring models with experimentally measured data
- Checking of input data for its reasonableness (FDS offers a range of numerical values for the data to guide the user as to what is realistic)
- Where possible the simulation calculation sequences within FDS are hierarchical - depending on which data are missing, a sequence of assumptions are made in order to carry out the calculation
- FDS takes account of practical constraints (for example, the minimum cake thickness that can be discharged from the particular filter design) that affect the operation of the filter type
- Graphical or tabulated output of results
- On screen display of a process mass balance, indicating the input/output amounts of the solid, the liquid, and the dissolved component that is monitored during cake washing
- Results from the simulation can be saved on disk for later recall and viewing in spreadsheets.

COMPUTER REQUIREMENTS and UPDATES

FDS is supplied as a CD and will run on any personal computer operating under Windows. FDS requires 75 MB of hard disk space.

ORDER FORM

**To: Filtration Solutions, 6 McCarthy Close, Whitwick, Leics, LE67 5HN, UK.
(Fax: +44 (0)1530 382038 email: filtsol@virginmedia.com)**

Please supply the following:

	Number of copies	Price per copy	Total
Selection module and equipment catalogue		£450	
Data analysis module		£150	
Vacuum filter simulation module		£350	
Pressure filter simulation module		£350	
TOTAL			

All prices are in Pounds Sterling and include postage and packing.

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