NEW COMPUTER SOFTWARE FOR THE SELECTION OF SOLID/LIQUID SEPARATION EQUIPMENT

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ABSTRACT

The paper details new Windows® based computer software for the selection of solid/liquid separation equipment. The software interprets information obtained from databases through an inference engine to generate numerically ranked equipment selection whilst maintaining a balance between ease of use, level of knowledge conveyed and comprehensibility. The software facilitates the integration of additional information for special process requirements, solid and liquid phase properties as well as access to text and pictorial descriptions of equipment types.

Hyperlinks with databases provide access to equipment manufacturer details. Facility for other user definable hyperlinks is also provided to access information sources on the world wide web via the internet. It is shown how the software for equipment selection will ultimately be integrated with software for equipment scale-up and simulation.

KEYWORDS

Equipment selection, filtration, software, algorithm.

INTRODUCTION

The specification of filters is generally performed through rules-of-thumb (or heuristics) rather than by applying fundamental theoretical relationships. Equipment is rarely specified without recourse to extensive laboratory and pilot scale tests, and the data produced can lead to erroneous specification and scale-up of separators unless care and consistency are observed. The lack of a standard approach can lead to the poor specification and sizing of filters with the result that required production rates may not always be achieved and unforeseen difficulties arise in filter cycle operations.

Progressive developments by the authors have facilitated a combined theoretical and experimental approach to the use of computer software in filter specification and simulation[1-8]. Their philosophy considers that with the present state of knowledge about suspensions, and their behaviour in process separators, it is most appropriate to have interactive computer software that forms an integral part of an experimental program (see Figure 1). Within this context, new Windows® based computer software for solid/liquid separation equipment selection has been developed and the remainder of the paper describes its principal features.

BASIS OF THE SOFTWARE

The general procedure developed by Purchas[1], and the use of ranking indices, provide the basis for functionality of the software. With reference to Figure 2 an initial list of equipment can be drawn up by following up to four steps:

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Step 1: *Specify the separator duty to define three characterising letter codes* (i.e. a→i). The general requirements of the process duty are quite limited and confined to the scale (a→c), mode of operation (d or e), and the overall objective of the separation (f→i). These objectives and unavoidable restrictions can be specified before any experiments are undertaken. Other specifications, such as the need for filter sterility or the possibility of toxic or flammable hazards, can be considered at a later stage.

Steps 2 and 3: *Perform and analyse rudimentary bench scale filtration and sedimentation tests to define four characterising letter codes* (i.e. A→L). The objective of a sedimentation test is to determine the initial rate of settling (A→C), clarity of the supernatant liquid (D or E) and the final proportion of sludge (F→H). In some cases it may be necessary to chemically pretreat the test suspension with, for instance, flocculants or coagulants to achieve a suitable rate of sedimentation and/or filtration. The objective of the filtration test is to determine the average rate at which cake is formed, although a computer aided analysis can yield further information that is useful for subsequent equipment scale-up and simulation[1,3]. A single letter code is used to denote the cake formation rate (i.e. I→L).

If the proposed duty is simply to thicken a slurry then it is not necessary to carry out a filtration test. However, for a total separation of the solid from the liquid (as obtained in a filter, for example) both settling and filtration tests need to be performed.

Step 4: To select and rank equipment from the duty specification, jar sedimentation test and filtration test letter codings it is necessary to provide charts and/or tables that relate equipment performance to these codings. Table 1, which is an extract from a more complete listing, gives examples of how individual types of equipment can be associated with the codings. Within each generic class a wide range of different types of separator exists, for example, more than ten sub-classes of pressure filters can be identified. Whilst each sub-class may contain a variety of types, they tend to differ in detail of design rather than possess major differences related to fields of application. Naturally, designs from different manufacturers will differ but almost all will fit into a sub-class.

Whilst many classes of solid/liquid separation equipment will allow most functions to be performed (e.g. cake formation, cake washing, etc.), not all will execute a function with the same degree of effectiveness. Relative performance indices can be adopted and Table 2 shows the relevant indices for the equipment presented in Table 1. Each class of equipment is allocated an index of performance between 0 and 9, with larger numbers indicating better performance. Indices are given for dryness of the solids product, the effectiveness of solids washing, the quality of the liquid product and the tendency of the equipment to cause crystal breakage. Also shown in Table 2 is an indication as to whether the solids are usually discharged as a cake or as a slurry, and the basic feed properties which the equipment can generally handle.

The procedures defined by Figure 2 and Tables 1 & 2 were combined (with due cognisance of the protocols in Figure 1) to produce interactive computer software capable of the ranked selection of solid/liquid separation equipment. Briefly, information for 70+ equipment types (as outlined in Tables 1 and 2) was transposed into database format. These databases are interrogated by the computer software, compared with user defined entries for the duty, settling and filtration characteristics by an inference engine and the equipment list is subsequently produced.

DESCRIPTION OF SOFTWARE

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An example of the screen display presented to the user during equipment selection is shown in Figure 3. When the software starts only the 'Specifications' box in the top left hand corner of the screen is displayed (i.e. *Region 1*). The available entries allow the user to select up to 7 items from drop down lists. These equate to the letter codings for Duty, Settling characteristics and Filtration characteristics outlined previously in **Steps 1, 2** and **3**. In the example, an item in each drop down list has been chosen, indicating that experimental data are available for the slurry in question; the respective letter codes are bdh, BEG and K[1]. An equipment selection can be performed by specifying only the items for duty, in this case a longer list of equipment is likely to result.

With the items for duty, settling and/or filtration characteristics specified by the user the list of potentially suitable equipment is produced by choosing the 'Select equipment' command button with the mouse, the items in the 'Selected equipment list' box toward the top right of the screen are displayed (i.e. *Region 2*). The process invokes the procedures described previously in **Step 4** and for the example 10 items of equipment are selected by the software. In Figure 3 these are presented in alphabetical order although the list can be re-ranked according to the indices for solid dryness, liquid clarity, washing ability and crystal breakage as well as an overall ranking which represents the sum of the four individual indices for each equipment item. An indication of typical particle size and solids concentration in the feed slurry are also shown in addition to any selection warnings (e.g. 1b, 1BG etc.); a full text description of the warning codes is available by choosing the 'Warning' command button.

Highlighting an item in the 'Selected equipment list' box with the mouse presents the user with further text and pictures in the lower half of the screen display. In *Region 3*, text descriptions are given for the general class into which the selected equipment item falls. In *Region 4*, text more specific to the highlighted item is displayed. In *Region 5,* several pictorial representations of the equipment are available. At least one schematic and one photograph can be displayed for each of the 70+ sub-classes of equipment and each image is viewable at a larger size for closer inspection.

The command buttons labelled 'Additional criteria' and 'List suppliers' can also be chosen within *Region 5* of the screen. The former displays text describing factors that may be important following the initial equipment selection process (Figure 4). Items are categorised under the headings 'Potential further tests', 'Process requirements', 'Solid phase properties' and 'Liquid phase properties' as shown in Table 3 and the user must decide which are important for the equipment and/or process route under consideration. A list of suppliers can also be displayed (Figure 5). The list contains the names and web addresses of companies that are able to supply the highlighted equipment type. The user is able to copy the web address with the mouse, paste the URL directly into a live web browser and hence access relevant company information via the internet. Facility exists for the user to produce their own 'custom database' where preferred suppliers may be included and subsequently accessed by the software.

CONCLUSIONS

This paper has described the principal features of new Windows® based computer software for the selection of solid/liquid separation equipment which facilitates a ranked listing and access to on-line equipment and process information from a knowledge of the required duty and basic experimental data. Ultimately the software will be further developed to integrate facility for:

- The consistent analysis of filtration, expression, jar sedimentation and capillary pressure tests to allow the accurate determination of the parameters required for process simulation and the basic information needed for equipment selection

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- The detailed simulation and sizing of process scale batch and continuous filters involving combinations of cake filtration, consolidation, washing and deliquoring.

By doing so a number of benefits will arise, including:

- The ability to investigate new plant and ask 'what-if' questions about filter installations to facilitate optimum equipment selection(s), filter sizing, cycle configuration(s) and filter operation
- The ability to troubleshoot existing filter installations and identify potential solutions
- Consistent experiment analysis to give characterisation and scale-up parameters
- Facility for educating the user in solid/liquid separation science and knowledge
- Unbiased information on solid/liquid separation equipment so appropriate manufacturers can be approached in the early stages of equipment selection.

ACKNOWLEDGEMENTS

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FIGURES AND TABLES

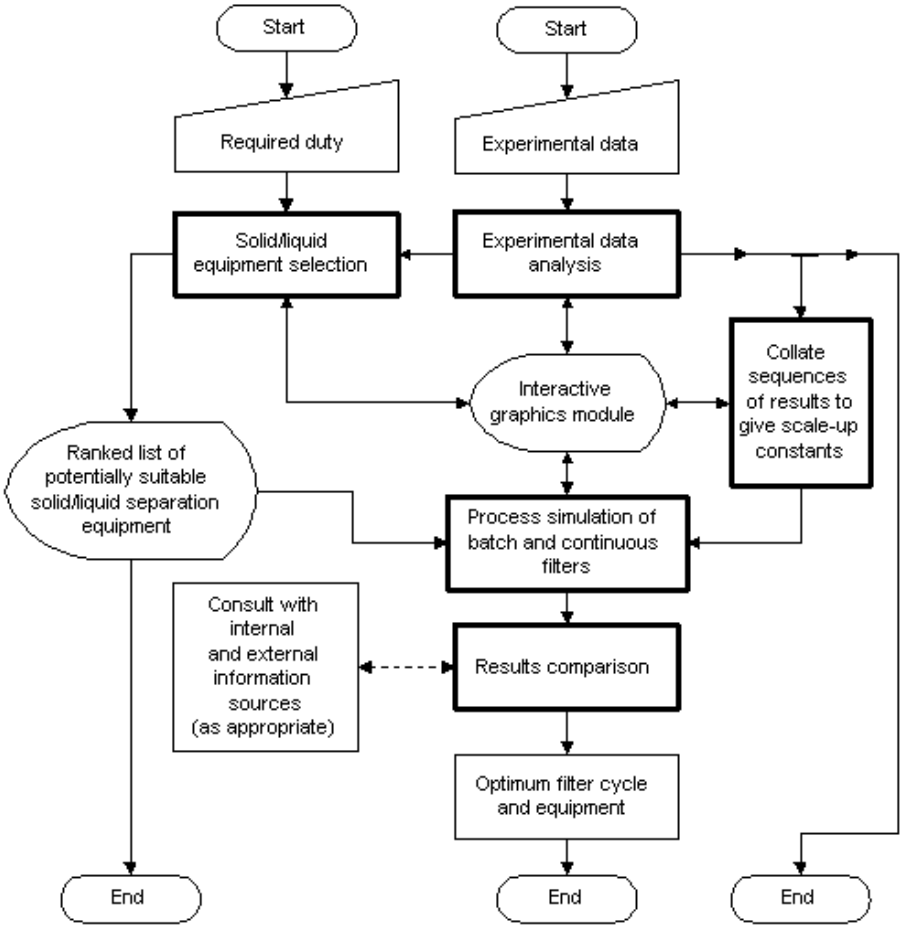

Figure 1: Overall flowsheet showing levels of integration for equipment selection, scale-up and simulation.

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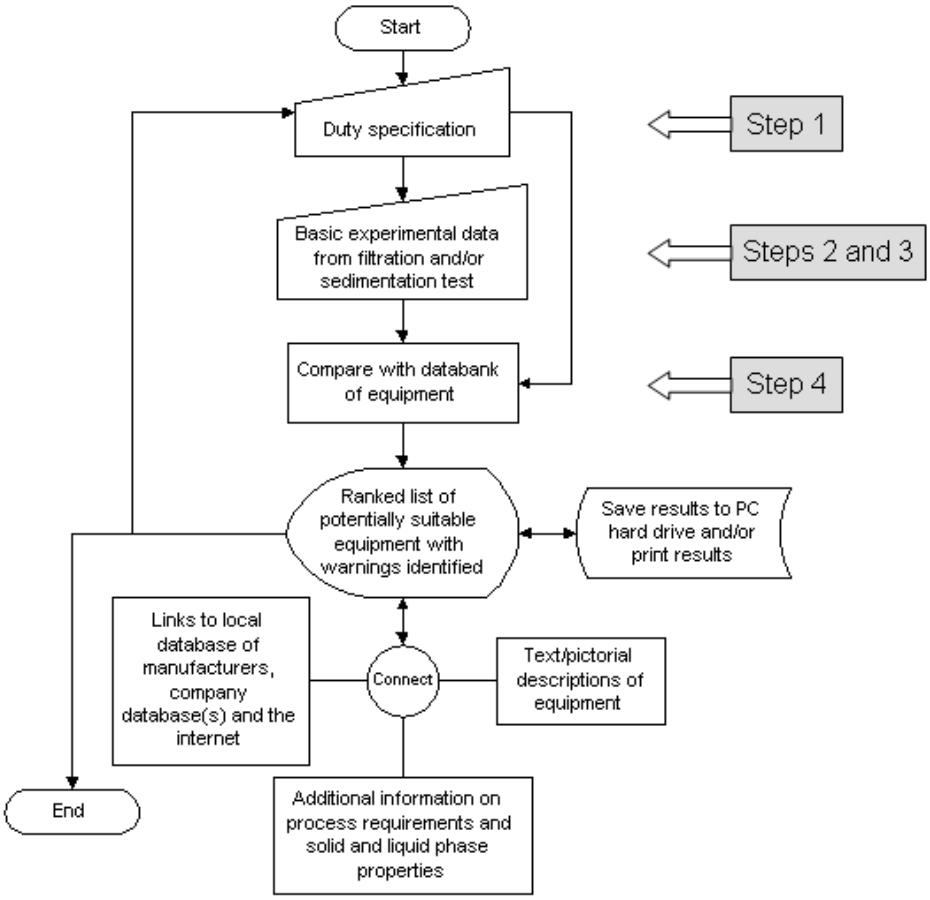

Figure 2: Outline flowsheet for equipment selection, i.e. a more detailed flowsheet developed from a sub-section of Figure 1.

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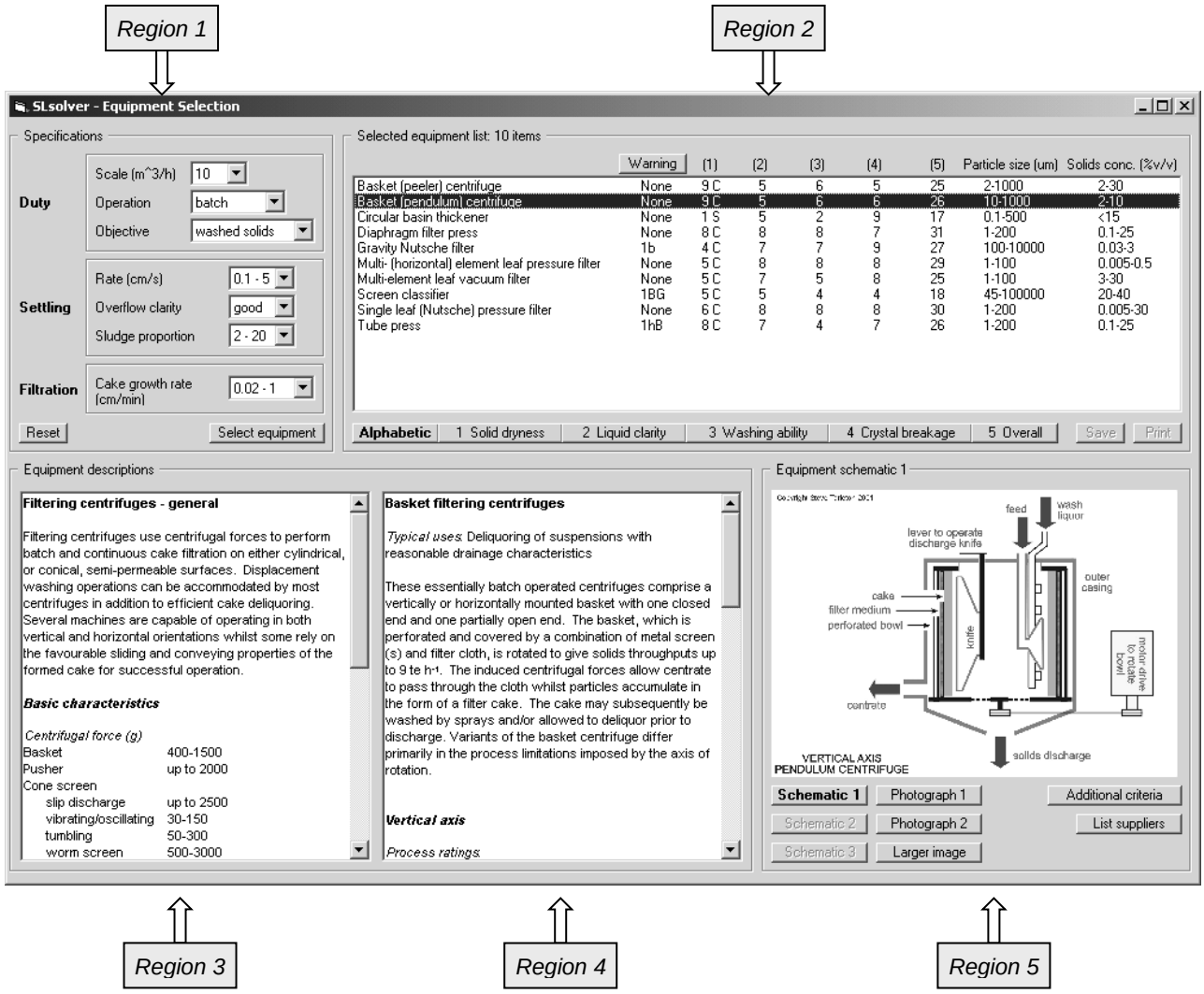

Figure 3: Example screen display from equipment selection by the computer software.

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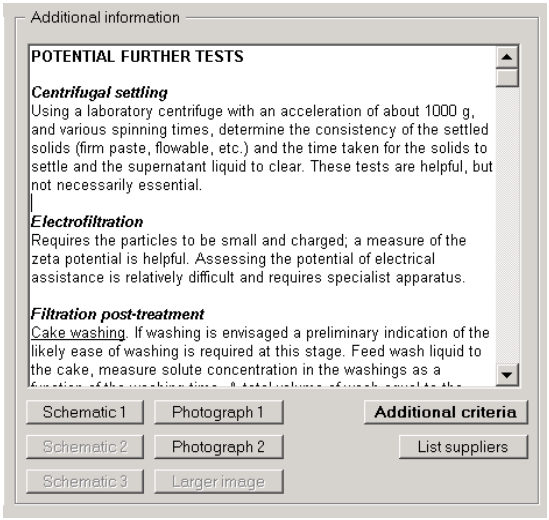

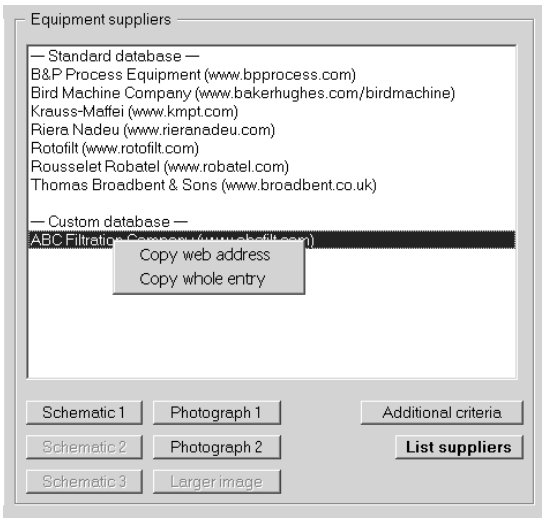

Figures 4 and 5: Parts of *Region 5* of the example screen display from equipment selection showing 'Additional information' (*left*) and 'Equipment suppliers' (*right*).

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Type of equipment	Duty specification	Separation characteristics Settling	Filtering
Gravity thickeners and clarifiers			
circular basin thickener	a, b or c	B or C	
	d or e	E	
	g or h	F or G	
Hydrocyclones			
conical reverse flow	a or b	B or C	
	e	D or E	
	f, g or h	F, G or H	
Sedimenting centrifuges			
tubular bowl	b or c	A or B	
	d	D or E	
	f (or g)	F	
Filtering centrifuges			
pusher	a or b	B or C	K or L
	e	E	
	g, h or i	G or H	
Vacuum filters			
single leaf (vacuum Nutsche)	c	A, B or C	J, K or L
	d	D or E	
	g, h or i	F or G	
Pressure filters and presses			
filter press	a, b or c	A (or B)	I or J
	d	D or E	
	f, g, h or i	F, G or H	

'()' around a letter index indicates a marginal choice

Table 1: A shortened list showing the classification of equipment according to duty and slurry separation characteristics – the full list contains more than 70 equipment types[1].

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	Performance indices				Feed solid properties	
Type of equipment	Solids product dryness & state†	Washing	Liquid product quality	Crystal breakage	Particle size (μm)	% by volume solids in feed
Gravity thickeners and clarifiers						
circular basin thickener	1 S	2	5	9	0.1-500	< 15
Hydrocyclones						
conical reverse flow	1 S	2	4	7	5-200	2-30
Sedimenting centrifuges						
tubular bowl	3 S	-	6	5	0.1-100	0.005-3
Filtering centrifuges						
pusher (single stage)	9 C	7	4	4	40-7,000	4-40
pusher (multi-stage)	9 C	8	4	4	40-7,000	4-40
Vacuum filters						
single leaf (vacuum Nutsche)	6 C	8	7	8	1-500	0.03-1
single leaf (tilting pan)	7 C	9	7	8	20-80,000	3-40
Pressure filters and presses						
filter press	6 C	8	8	8	1-100	0.005-30

A '-' performance index may be taken to mean either zero (that the equipment is not effective) or that the equipment is not suitable for that particular duty. † State of solids product: S ≡ slurry or free flowing, C ≡ cake.

Table 2: A shortened list showing the relative performance characteristics of solid/liquid separation equipment – the full list contains more than 70 equipment types[1].

Parameter	Additional criteria
Potential further tests	Settling, Cake washing/deliquoring, Magnetic, Flotation, Electrofiltration
Process requirements	Integration, Use of additives, Reliability, Space, Product value, Cost
Solid phase properties	Chemical composition, Size distribution, Particle shape/strength, Solubility, Toxicity, Reactivity, Sterility, Abrasivity, Surface properties, Value
Liquid phase properties	Chemical composition, Temperature, pH/ionic strength, Viscosity, Toxicity, Volatility, Flammability, Sterility, Surface tension, Value

Table 3: A summary of additional selection criteria.

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