



This item was submitted to Loughborough's Institutional Repository (<https://dspace.lboro.ac.uk/>) by the author and is made available under the following Creative Commons Licence conditions.


C O M M O N S D E E D

Attribution-NonCommercial-NoDerivs 2.5

You are free:

- to copy, distribute, display, and perform the work

Under the following conditions:



Attribution. You must attribute the work in the manner specified by the author or licensor.



Noncommercial. You may not use this work for commercial purposes.



No Derivative Works. You may not alter, transform, or build upon this work.

- For any reuse or distribution, you must make clear to others the license terms of this work.
- Any of these conditions can be waived if you get permission from the copyright holder.

Your fair use and other rights are in no way affected by the above.

This is a human-readable summary of the [Legal Code \(the full license\)](#).

[Disclaimer](#) 

For the full text of this licence, please go to:
<https://creativecommons.org/licenses/by-nc-nd/2.5/>

COMPUTER BASED SELECTION OF SOLID/LIQUID SEPARATION EQUIPMENT

R.J. Wakeman¹ and E.S. Tarleton² (e.s.tarleton@lboro.ac.uk)

¹School of Engineering, Exeter University, Exeter EX4 4QF, UK.

²Department of Chemical Engineering, Loughborough University, Loughborough LE11 3TU, UK.

INTRODUCTION

Filtration and separation technology contains numerous heuristics, evidenced by consulting industrial reference books such as *Solid/Liquid Separation Equipment Scale-Up*¹. A majority of industrial process engineers need to possess wide ranging knowledge covering many unit operations and rarely have the opportunity to gain in-depth specialist knowledge of filtration and separation technology. Consequently the large number of heuristics that have evolved in the technology are confusing.

Solid/liquid separation technology, whether it be in the areas of selection or design, is best dealt with by software designed to run interactively, so that the engineer can input data and receive a result rapidly. An expert system such as p^C -SELECT² can be used to ensure the correctness of input data as far as this is possible, and it can utilise interactive graphics facilities to show effects of changes in variables or to allow the engineer access to calculations to make value judgements. To be most effective the software must be a well-chosen mix of algorithms, expert system, and input information by the engineer³.

There exist a number of charts which serve as a guide to the approach to equipment selection, the better ones of which consider a variety of possible eventualities and indicate where decisions must be made. These charts generally have been devised by experts to be fairly comprehensive and are of value to the solid/liquid separation expert. They also illustrate the near impossibility of combining comprehensiveness with useability when so much interacting information is presented in written form. Purchas¹ introduced a general guide for the non-specialist, which is a valuable aid to one confronted with this confusing and complex area. This guide is adopted, suitably extended and adapted, for use in the software p^C -SELECT² which incorporates features of the type discussed in this paper.

THE APPROACH TO EQUIPMENT SELECTION

The essential steps in solid/liquid separation are shown in a simplified form in Figure 1. There are three principal sets of data which characterize the problem. The first set describes the requirements of the separation in the process environment, the second set concerns the data obtained from leaf and/or jar tests to characterize the filtration and/or sedimentation behaviour of the slurry, and the third set constitutes a data bank which holds information about available solid/liquid separation equipment.

EQUIPMENT SELECTION BY P^C -SELECT

Information associated with more than fifty categories of equipment is held in the p^C -SELECT data bank. These data are analysed using public knowledge, heuristics and decision making techniques.

Results from the analyses are data sheets which detail both experimental and calculated results from tests, and a list of recommended equipment which satisfies the process requirements and slurry characteristics. The list may be sorted and ranked according to various relative operational

performance criteria or product quality demands. Any other screens displayed during the analysis also may be printed for inclusion in reports.

p^C -SELECT² allows entry into its rule based selection procedures at various levels. The level of entry is determined by the amount and type of information available. There are two important entry points:-

(a) The first is the ability to enter for an initial list of equipment without any form of test data, but with a knowledge of the process. Here, a list can be produced, but against each item in the list will be one or more warning messages indicating the need for additional data of a particular type.

(b) The second entry point is after the analysis of leaf and/or jar test data, the results from which will enable a more reliable and shorter list to be drawn up than was possible at the previous entry level.

Entry into the expert system with a low level of data (excluding any test data) will lead to a long list of equipment which might be capable of achieving the separation. The list is divided into three parts: (i) a summary of the information fed into the selection procedure; (ii) a list of the selected equipment that indicates for each item, through selection warnings, what further action should be taken to check the equipment suitability and what limitations the equipment may possess; and (iii) the relative performance of the selected equipment based on various criteria, including solid product dryness, liquid product clarity, washing effectiveness and the tendency of the equipment to cause crystal breakage.

The suitability of the equipment is related to typical particle size ranges and feed concentrations. Although the latter information has been used in the selection, the values have been implied through the use of other data such as settling rates and it is at this point the engineer can check the equipment information against other measured data. The relative performance criteria for the selected equipment are based on a scale from 0 to 9, with larger numbers indicating better performance and showing whether the solid is generally discharged in cake (C) or slurry (S) form. Selection warnings marked against any item in the list reflect uncertainty about the suitability of the particular equipment or because of a shortage of input data which has led to a 'best approximation' being made at some point in the analysis.

AN EXAMPLE OF EQUIPMENT SELECTION

It is not the purpose of the example to demonstrate all the facilities of p^C -SELECT, but to illustrate the general method of approach to equipment selection using computers. As an example consider the following: identify a preliminary list of equipment to produce dewatered (unwashed) solids from a slurry continuously fed to the separation plant at about $10 \text{ m}^3 \text{ h}^{-1}$. Leaf test data indicate a likely cake growth rate of about 1 cm min^{-1} , and a jar test shows a settling rate of 0.5 cm s^{-1} to give a clear supernatant liquor and a final sludge volume of about 10% of the starting suspension volume. These data lead to the preliminary selection shown on Figure 2.

A full analysis using p^C -SELECT uses algorithm and graphics software with interactive input from the engineer to analyse test data followed by expert system software, again with engineer input. A selection and a report if desired, are completed within minutes and 'what if?' queries are easily investigated.

The sensitivity of the selection to changes in process performance can also be assessed. For example, if the particle size distribution were to change such that the mean size was halved the settling and filtration rates could be expected to reduce by a factor of 4 and a cloudy supernatant may result. If this were to happen a pusher centrifuge would clearly become a non-viable option,

the choice of a decanter centrifuge would be less desirable due to the reduced settling rate, but the suitability of a variable volume filter for the task would increase.

The procedures outlined above enable the non-expert to make rational decisions based on expert knowledge, without the need to consult an expert in the earlier stages of solving his problem. This is important in solid/liquid separation, as the expert is often a representative of an equipment manufacturing company whose job it is to sell a particular type of separator. Taking filters as an example, many types usually will be capable of carrying out a particular filtration, but probably only a few general types will be most suited to the task. It is wise to have an insight into which types these are before consulting an expert.

Software such as p^C -SELECT enables the rapid analysis of data and exploration of alternatives. It puts the engineer in a position to ask more penetrating questions of whichever expert he or she may consult, and reduces expenditure on unwarranted pilot scale testwork. These advantages are gained without the need for extensive computer knowledge or high speed/capacity computers.

CONCLUDING REMARKS

The widespread use of heuristics, the lack of standard approaches to most aspects of design and the limited information available to the design engineer in texts gives rise to several requirements in solid/liquid separation. There is a need to

- standardise small scale tests
- rationalise the analysis of the data which come from the tests
- formalise the approaches to process design and scale-up of equipment.

Manufacturers of different equipment types tend to use different heuristic approaches to equipment sizing, making it very difficult for a user engineer to check that the correct equipment is being specified for the separation and that the size of the equipment is appropriate. Computer software could be of considerable assistance not only in the areas identified above, but also in design and scale-up⁴.

REFERENCES

1. D.B. Purchas and R.J. Wakeman, *Solid/Liquid Separation Equipment Scale-up*, Uplands Press & Filtration Specialists, 1986.
2. E.S. Tarleton and R.J. Wakeman, *Solid/Liquid Separation Equipment Simulation & Design: p^C -SELECT - Personal computer software for the analysis of filtration and sedimentation test data and the selection of solid/liquid separation equipment*, Separations Technology Associates, 1991.
3. R.J. Wakeman and E.S. Tarleton, Solid/liquid separation equipment simulation and design - an expert systems approach, *Filtration and Separation*, **28**(4), 274, 1991.
4. R.J. Wakeman and E.S. Tarleton, Modelling, simulation and process design of the filter cycle, *Filtration and Separation*, **27**(6), 412-419, 1990.

TABLES AND FIGURES

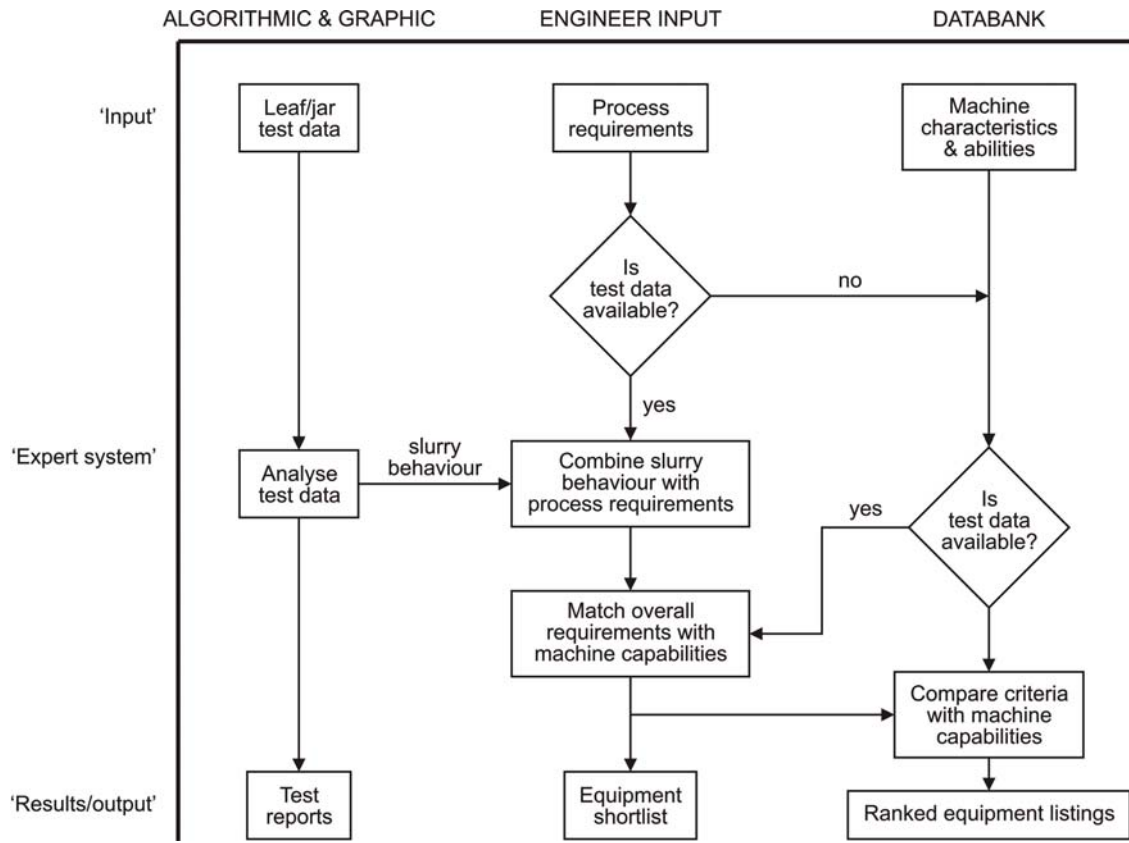


Figure 1: The approach to equipment selection used by p^C-SELECT².

Solid/Liquid Separation Equipment Simulation & Design, PC-SELECT

DATA SHEET FOR EQUIPMENT SELECTION

Specifications

| | |
|------------|---|
| Duty | Scale:- medium (10 m ³ /hr) Operation:- continuous Objective:- dewatered solids recovery |
| Settling | Rate:- medium (0.1-5 cm/s) Overflow clarity:- good Sludge proportion:- medium (2-20% vol) |
| Filtration | Cake growth rate:- medium (0.02-1 cm/min) |

| Selected equipment description | Selection warnings | Particle size (µm) | Feed conc. (% v/v) |
|--------------------------------------|--------------------|--------------------|--------------------|
| Horizontal belt, pan or table filter | None | 20-80,000 | 3-40 |
| Bottom fed drum filter, knife dis. | None | 1-200 | 3-30 |
| Bottom fed drum filter, roll dis. | None | 1-50 | 3-30 |
| Bottom fed drum filter, string dis. | None | 1-70 | 3-30 |
| Continuous pressure filter | None | 1-100 | 0.01-30 |
| Variable volume filter | 1iB | 1-200 | 0.1-25 |
| Pusher centrifuge | None | 40-7,000 | 4-40 |
| Disc filter | None | 1-700 | 3-30 |
| Scroll (decanter) centrifuge | 1i | 1-5,000 | 4-40 |

| Selected equipment description | F3: index | F4: index | F5: index | F6: index | F7: index |
|--------------------------------------|-----------|-----------|-----------|-----------|-----------|
| Horizontal belt, pan or table filter | 7C | 7 | 9 | 6 | 31 |
| Bottom fed drum filter, knife dis. | 6C | 7 | 7 | 8 | 28 |
| Bottom fed drum filter, roll dis. | 6C | 7 | 7 | 8 | 28 |
| Bottom fed drum filter, string dis. | 6C | 7 | 7 | 8 | 28 |
| Continuous pressure filter | 6C | 7 | 6 | 7 | 26 |
| Variable volume filter | 8C | 7 | 4 | 7 | 26 |
| Pusher centrifuge | 9C | 4 | 5 | 4 | 22 |
| Disc filter | 4C | 6 | 0 | 8 | 18 |
| Scroll (decanter) centrifuge | 4C | 4 | 3 | 3 | 14 |

F3 index:- Solid product dryness
 F4 index:- Liquid product clarity
 F5 index:- Washing performance
 F6 index:- Crystal breakage
 F7 index:- Overall performance

Equipment listed in order of overall performance rating

Figure 2: Equipment selection by p^C-SELECT.