ENSURING APPLICATION OF SEPARATION BEST PRACTICE DURING PROJECTS

Cliff Grover, Approtech
(Appropriate Process Technology Ltd)

ABSTRACT

Technical understanding of separation is constantly advancing and new equipment developments occur regularly, yet obstacles remain to applying state-of-the-art techniques within a project setting, particularly on new oil fields. Many historical separator performance shortfalls have been caused not by a lack of advanced separation expertise but more by a failure to implement sometimes quite basic principles of good separation practice. These instances were usually the result of complex project, technical and commercial interactions, rather than being rooted solely in separation theory. Unless such issues are resolved, future opportunities to improve separation performance and reliability will be lost.

This paper summarises the ways in which the range of design techniques and equipment options available may be applied in a project context – including the influences of Oil Companies, Main Engineering Contractors, Process Design Houses, and Specialist Consultancies. The review examines the process of turning field production predictions into a final system and equipment design. It proposes strategies for ensuring that old mistakes are not repeated, and full advantage is taken of new design understandings.

Critical aspects for success are a high degree of involvement by the Oil Company all the way from the earliest conceptual stages through to the operational phase, working effectively with the main engineering contractor, placing executive authority in the hands of the separation system designers, and developing designs and project processes that are capable of handling a key characteristic of separation systems - uncertainty. These techniques are also important where emerging technology and/or subsea pre-processing is being considered.

1 INTRODUCTION

Designing production separation systems in the oil and gas industry, particularly oil-water settling, is a combination of theory and empiricism. Basic separation theory is well defined but real complications emerge when theory is applied to the wide range of crude oils that exist and to the many plant configurations possible. These practical constraints to defining exactly what equipment is necessary for a certain duty, and how big it should be, are not adequately recognised by present methodologies for designing and procuring separators in a project environment. Unlike a pump, a compressor, or a glycol gas-dehydration unit, it is not possible to properly define a design basis that flows from a manageable number of well-defined process parameters. The possible variabilities in crude oils, wellfluid behaviour, phase behaviour, co-produced emulsifiers, demulsifier chemicals, droplet size spectra and suchlike are so wide that the Operator cannot guarantee to the designer what feedstock will be, and even if this was possible, the designer could then not guarantee a product quality with the same certainty that, say, outlet gas dryness from a glycol unit can be defined.

And yet the design and procurement environment in which oil and gas facilities are created has not, after many decades, fundamentally changed in the way it manages building separators. Although there has been one notable refinement in this area, as we will see, this has actually made matters worse. How can a technical and commercial management endeavour that is the modern project - based on detailed specifications, highly integrated multi-disciplinary designs, and binding commercial agreements - handle something which by its nature cannot be accurately defined? Whilst separation theory continues to advance towards the goal of definitive predictive design methods, it is unlikely to ever achieve this to the same degree that other unit operations do, hence the way in which separator designs are managed will always remain important.

If separator designs are not properly managed, all the technical advances such as those discussed in these conferences will not by themselves provide the total solution to the needs of all the involved parties. Furthermore, purchasing and project methodologies that do not recognise the uncertain nature of separation systems will severely restrict the adoption of emerging separation technologies, and have already done so.

This paper deals with the design and project management processes mainly around oil-water settlers, but many of the principles are also applicable to the uncertainties inherent in gas/liquid separations and produced water treatment.

2 SEPARATION DESIGN IS COMPLEX AND UNCERTAIN

Other papers in this conference cover the many technical aspects of separation design, and it is not the intent of this paper to address technical issues themselves, but to address the application of those techniques in a project setting. It is, however, important to touch on technical issues briefly, so as to understand the degree of technical uncertainty involved.

Appendix A lists the results of a brainstorm of factors that affect separation design from the standpoints of technical theory and project application. Whilst Appendix A is not intended to be exhaustive, it is immediately clear that there is a large number of different aspects involved in designing separators. With a typical new oil separation installation, it is impossible to predict with any degree of accuracy its ultimate performance, with the biggest variabilities occurring in characterising well fluids from a limited number of well test samples, in determining the droplet size spectra and phase behaviour likely, and in the performance differentials between various demulsifier chemicals. The fluid testing required to resolve such uncertainties is rarely possible without extensive Early Production testing, and even then, wells will often refuse to cut water on demand and will thereby withhold vital information from the designer in the very tests designed to yield this data.

Contrast this situation with other platform unit operations. For an oil & gas processing system which at first sight is complex, a TEG-based Gas Dehydration unit is almost a model of definable chemical engineering. Variability in gas composition from design-stage predictions has little effect provided condensed or carry-over liquids are adequately separated from the gas stream to the contactor. The residual vapour water content of the incoming stream is definable to within a very small range of uncertainty - usually less than 1% - and the exit water content required to produce an operating water dewpoint is similarly easily defined. To define the glycol concentration necessary to achieve the water dewpoint, some differences of method exist (e.g. Worley vs. Parrish equilibrium data), but these are well understood. Efficiencies of modern structured packings are similarly well defined and different packings can be selected for their appropriate duties. Tail gas treating methods and performance to suit current environmental requirements are also well-defined. Ironically, one of the few areas of any significant uncertainty within a glycol dehydrator are around a dehydrator's separators, but these are usually easily managed if sound and specific glycol unit design experience is adopted.

Other platform unit operations are similarly far more easily defined than separation - pumps, piping, compression, hydrocarbon dewpointing, seawater filtration, fuel gas treatment, control, power generation. Even multi-phase flow, to the extent that it occurs within a topsides design, rarely presents any significant design issue.

When this contrast between poor definability of separation systems and high definability of other platform unit operations is considered, a major reason for the ongoing difficulties with separation systems emerges - the design and procurement methods used simply do not adequately allow for the inherent uncertainty in separation systems.

3 PROJECT DESIGN AND PROCUREMENT PRACTICES FOR SEPARATORS

For UK-engineered projects, and with some differences for other countries, the oil company will generally place a design contract for the facility with an EPC-style engineering contractor. Such a project is a complex affair with well-established engineering and project management structures. The structures are oriented towards managing the facility design and progressing it in a multi-discipline environment towards defined budget and timescale goals, whilst also meeting overall production and performance criteria.

Such structures are predicated on well-defined engineering content, and do not allow easily for changes in design - indeed change control is a major project management element, and often a headache for all. Much less do these structures cope with uncertainty. Whilst, for example, space can be allocated for e.g. 3 x 50% vs. 4 x 33% units, pending knowledge of a supplier's equipment capability, or rack space can be allowed for a possible line size change, these occurrences are not favoured, and are resolved at the earliest opportunity to allow "fixed engineering" to continue apace.

Separation system design is usually left until conceptual design. Concept design generally moves at a fast pace driven by targeted first oil dates and the project schedule required to meet these, and often addresses only the most major aspects of development options (platform vs. subsea wells, floating vs. fixed, etc). Designs are always pressurised towards smaller and less, for cost, space and weight reasons. It is rare to address the separation system design in any depth at this stage, although it does happen. Too often, though, a cursory review of the separation design yields a basic design adequate for the immediate purposes of the concept stage, with perhaps less than the ideal amount of thought given to whether it will work properly. However, once the overall concept is fixed, the separation system design is also fixed by default, and woe betide any Process Engineer who might want to subsequently internally optimise the design, especially if it involves a change in the oil processing system or vessel size. Hence a design which may not have been objectively thought through will progress by default into the final design, driven not by technical design and optimisation, but by project management drivers and timescales.

"Fixed engineering" practices also manifest themselves strongly in the procurement interface with suppliers. Procurement methodologies are oriented towards conformance to defined specifications, competitive (and, it is assumed, therefore cost-effective) bidding, quality conformance, delivery time and ethical purchasing. Mechanical integrity requirements are well defined by national codes and standards and are easily verified through equally well-defined testing methodologies. Delivery predictions are constantly monitored.

The remaining issue for the equipment purchasing process is the ultimate equipment performance. In many cases, this is also easily defined and tested - pump and compressor curves are works-tested, control systems can have full functionality tests before they leave a suppliers works. But where the key performance criterion is a process parameter, such as product quality, things start to get a little muddy, and the issue of the "Process Guarantee" arises.

Again making a comparison with the example of the TEG-based dehydration unit, the process guarantee for a TEG unit is easily defined. For a given gas flow, composition, temperature and pressure, the system is guaranteed to produce a specified gas dryness. Such a guarantee can be confidently given, and a supplier will include specific design margins (such as a margin on packing height or the ability to increase lean TEG concentration or rate) to ensure it is met. TEG guarantees are rarely failed except through peripheral issues such as dirty filters - almost never by basic mis-design.

For a separator process guarantee, the industry has in general remained resolutely unsophisticated. The standard approach has been, and still continues to be, that the contractor will request, and the supplier will usually offer, a process guarantee that the vessel will meet a certain %BS&W water-in-oil, ppm oil-in-water and "USgals/MMscf" liquid in gas. Occasionally this is brought up to date by expressing liquid carry-over in metric units.

In contrast to the easily-defined TEG unit guarantee, and considering the degree of uncertainty inherent in separation train design, it is immediately apparent that although a separator process guarantee may be perfectly valid, (given an objective view of the system and sufficient information on which to base a design), it is equally possible that the process guarantee will be under-specified, inadequate, unverifiable, and possibly untrustworthy. The phrase that the guarantee was "not worth the paper it is written on" was often used, but far from correctly describing a supplier's technical expertise, this phrase in fact revealed a dire lack of understanding of the issues concerned.

The restricted value of process guarantees was one item cited in the early-to-mid 1990's when project separator procurement processes underwent their largest and possibly most detrimental change as far as separator performance was concerned. Oil companies and EPC contractors became frustrated with the apparent poor performance of installed separators and their alleged failure to meet guarantees, whilst at the same time seeing that the equipment supplier's markup on vessels added cost to a project. This coincided with a significant change and broadening of the internals and retrofits market, with the emergence of a large number of new Consultancy and internals specialist companies and the transition of the traditional separator suppliers' business styles to meet the emerging competition.

The formula adopted, and which continues on most UK oil and gas engineering projects today, is to pre-qualify and select on shop capability and price a vessel fabricator with whom all project vessels will be placed. This has valid advantages in cost saving and concentration of procurement and inspection effort. For a separator vessel which needed a process guarantee, the EPC contractor would then approach, either directly or via the selected vessel fabricator, a number of "Process Design Houses", or internals suppliers, to provide the vessel size and internals, and the process guarantee.

This approach did nothing whatsoever to solve the underlying issues that led to separator performance problems, and indeed probably made them worse. Now, the company supplying the process guarantee had a far smaller order value and profit potential. Even if a commercial element to the guarantee was written in (which rarely occurred), that liability would necessarily be capped in relation to the profit on an order for £50,000 - £100,000 in today's value. Any such penalty was no real recompense to the oil companies if the guarantee failed, yet it also added little or no incentive to the supplier, over and above their own desire to maintain a good reputation, to ensure the design worked. The procurement and performance responsibility for separators was now split between the highest possible number of disparate parties (oil company, EPC contractor, vessel supplier, internals supplier, chemicals supplier) with no-one to oversee and ensure ultimate performance.

Whether a separator is procured as an integrated package comprising Vessel, Internals and Process Guarantee, or using the more recent practices described, both methods have the same basic flaw : competitive tender for equipment entailing significant uncertainty.

Competitive tender is a vital part of the procurement process, and is acceptable in most instances. But "most instances" only include those occasions where the item being purchased can be properly defined, with a low degree of uncertainty. However, we have established that there is significant uncertainty inherent in the design of separation systems, so it should be clear that a purchasing methodology based on fixed definitions is not suitable for separators.

Competitive tendering on separators puts the supplier in a difficult position. Suppliers know that only the lowest priced bids will even be initially considered, (obviously ill-qualified contenders excepted). Furthermore, provided competing bids are normalised to be equally acceptable on technical and commercial content, then it will simply be the lowest priced bid that will win the contract. With an integrated vessel and internals supply, the smaller the vessel the lower its cost will be, and the more likely the supplier is to win out on cost. With separate vessel fabrication and internals supply, the equation changes little. Indeed, even if the vessel size is initially fixed, the Process House supplying internals-only is then presented with a wider range of possible scope and price options - from minimal internals through to "the full works", for performance increments that are difficult to define.

The issues surrounding competitive tendering are universal across all equipment items on a platform, but the difference with a separation system is that an option presents itself where it would simply not be supportable elsewhere - that is, to make the vessel smaller or to supply simpler internals, either of which have a direct price-competitive effect. This does not imply that suppliers cut corners to cheapen their supply, rather, it reflects the high degree of uncertainty in a separation design. A range of perfectly valid technical options will usually be available, differing mainly in their degree of design safety margin, but this is at a point in the purchasing cycle where discussion of the issues arising and proper optimisation are prevented by the project history and commercial structure of competitive bidding.

Separator design in this environment therefore becomes a committee process rather than an objective technical process. The supplier may feel that to achieve the requested duty, the vessel ought to be much larger, or that more extensive internals are required, but feels that the extra cost of a larger vessel or better internals would price their bid out. If there is little chance of receiving an order on a design with high safety margins, then an inevitable pressure is placed on the supplier to move away from that design. Hence a dance is set up between the letter of the specifications, the uncertainties involved, and the perceived competitive position, to arrive at what will inevitably be a compromise design. However, all this is concealed from the purchaser and ultimate owner, since the EPC procurement bid assessment tabulation will usually only have a simple one-line entry - "Process Guarantee - Complies / Does not Comply". This purchasing process has no method of handling the more than likely situation where "it would be better if you did something different and whilst this might cost a little more now, it means your platform will operate much better and you won't have to retrofit this vessel in 2 years' time".

This is not what the Oil Company and Operator needs.

This situation principally only occurs with separators, and only occurs due to the degree of uncertainty inherent in their design. Consequently, the conclusion must be that the described project and procurement practices concerning separators are unsuitable and must change.

4 PROBLEMS THAT RESULT

The problems that result from not implementing good separation practice on projects are, unfortunately, familiar to many, and are one reason behind many of the papers in this conference series. Again, it is not the intent of this paper to cover these issues in depth, other than to recognise the wide range of problems that occur.

Problems typically include:

- excessive water export in product oil
- early-life finely dispersed water passing through the equipment almost entirely unseparated and exceeding export specifications, especially where no electrostatic coalescer exists
- ongoing tight dispersions with rising water cut being separated only in the electrostatic coalescer, bottlenecking through the coalescer return pumps or hydrocyclones
- overloading of electrostatic coalescer
- higher water export increasing pipeline corrosion, requiring costly corrosion inhibition, or even backing out valuable oil export capacity
- where exported by tanker, excessive water separation in the ship's hold, and consequent treatment requirements

- bottlenecking of oil production
- increased criticality of chemicals selection, especially where interactions with corrosion and scale inhibitors occur
- excessive demulsifier chemical usage and costs, environmental impact of high-performance but toxic chemicals
- more frequent production trips through attempts to operate at higher than design operating levels
- inability to handle foam generation, carry-over into gas processing and compression, compressor damage and downtime
- costs of antifoam dosage
- excessive sensitivity to production changes such as well testing
- inability to cope with "difficult" wells
- insufficient slug handling capacity
- poor water quality issues, which although a reflection of water handling equipment shortcomings, often originate in separation
- produced water disposal difficulties; may require dispensations and extra effort to resolve
- increased operations effort to maintain production targets, plus associated costs
- increased engineering effort to overcome problems, plus associated costs
- debottlenecking studies and retrofits, shutdown losses whilst changing out internals, costs of these projects
- insufficient platform space and weight capability to make radical changes

5 ECONOMIC CONTEXT

The economic context under which separators are purchased is relevant to understanding how much effort should be applied to separation systems in the design phase, and why present methods are inadequate.

The various building blocks that make up the costs of an offshore facility range from large and costly equipment items such as platform structures, pipelines, power generation, and drilling facilities at the higher cost end, down to low-cost low-tech units such as the Fuel Gas Treatment system. The relevant importance of each of these units, and consequent design effort required, can be assessed using for example their cost, or criticality rating. It might be assumed that a high-cost piece of equipment should always have a high degree of effort expended on its design and purchase. Alternatively, effort might be allocated based on equipment criticality, or it might be assumed that high cost equals high criticality. Finally, of course, no conscious thought may be given at all as to the appropriate design effort necessary.

However, a major criterion - uncertainty - is typically not brought into the equation, and can lead to an inappropriate level of effort being applied to an apparently less important item of equipment. By including uncertainty, we can assess whether or not the present (or historical) degree of effort that goes into platform design is appropriate, as follows.

The cost of an equipment item may be very high, such as an export pipeline. Its criticality is also very high, since failure of the pipeline in service would stop all production and cause an environmental catastrophe. However, the uncertainty involved in pipeline design is actually very small. Provided the normal mechanical and metallurgical considerations are fully applied, the chance of a pipeline failing is extremely small, and this is borne out by the almost complete absence of pipeline failures in service. Similarly, engineering of the jacket structure of a platform is a well-defined process, reducing the risk inherent in a very costly oilfield building block to extremely small proportions. The design, fabrication and testing of each of these building blocks are well-described by codes, standards and established engineering practice. Thus by including performance uncertainty in assessing these units, we can say that pipelines and platform jackets are currently appropriately engineered.

At the other end of the cost spectrum, many items on an offshore facility have a low unit cost, but also a low, or even zero, criticality to oil production and revenue generation, or may be adequately spared. Whilst failure of these items can be a significant nuisance, there is no obvious driver towards applying a high engineering effort.

Along these lines, we have assessed the criticality and uncertainty of the various building blocks of a platform topsides against their unit costs. The variables Criticality and Uncertainty were related as follows:

C	Criticality of that equipment item to oil production	0.0 = not at all critical 1.0 = 100% critical
U	Uncertainty of equipment to perform to specification	0.0 = performance is certain (0% of installations causing difficulties) 1.0 = performance is completely uncertain (100% of installations causing difficulties)
C-U factor	Criticality-Uncertainty factor	= C * U 0.0 = No production risk 1.0 = Production risk inevitable

This is a simplified classification, as factor values will vary between installations, and without a large database of supporting information, allocation of criticality ratings and particularly uncertainty is inevitably subjective to a degree. Further, in order to avoid excessive complication, the value of any loss of production has not been factored in. However, some conclusions can be identified.

By plotting the C-U factor against equipment cost, items which are both critical and uncertain can be identified without undue influence of criticality or cost alone. Example results obtained, based on an offshore oil development from 2002, are as follows:

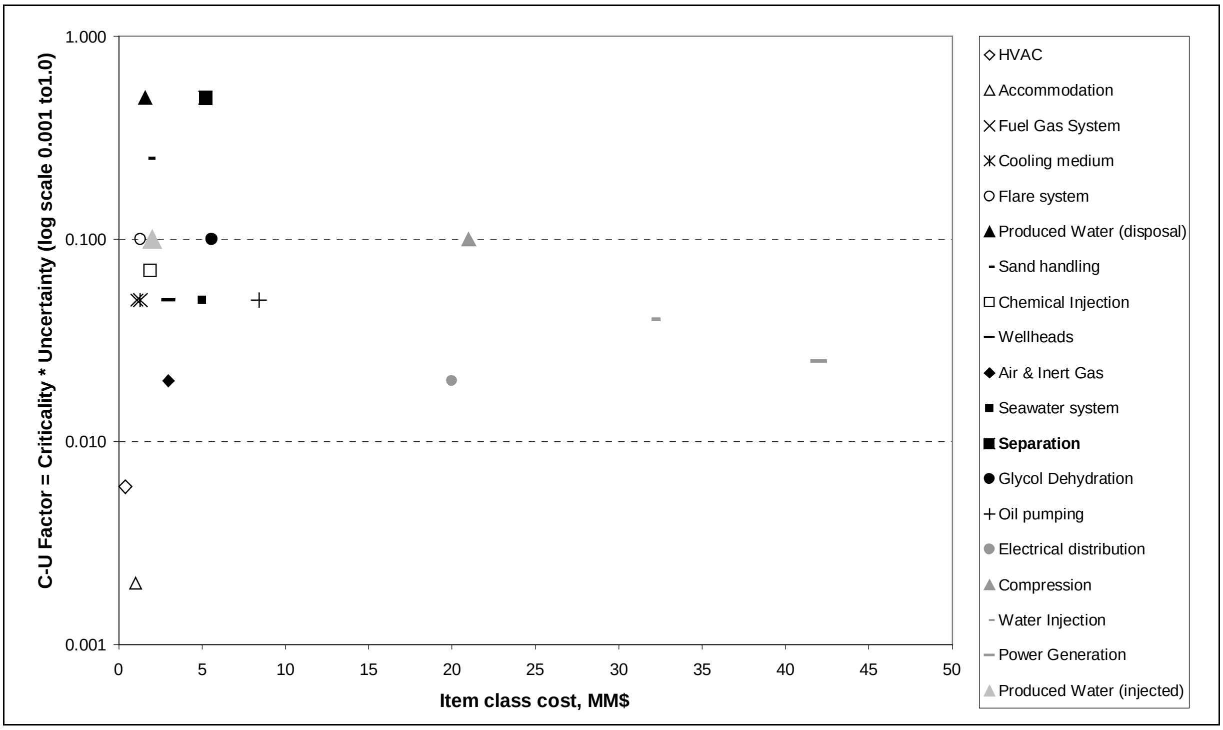

Figure 1 - Criticality-Uncertainty Assessment

This assessment shows that the topsides equipment items most likely to impact overall production over the whole field life, due to the combination of their production criticality and performance uncertainty, are Separation, and Produced Water Treatment for disposal. Produced water disposal appears here due to its propensity to cause problems later in field life as water volumes increase, and the ongoing environmental pressures on disposal water. If reinjected, Produced Water Treatment is less likely to cause production criticality.

The assessment also shows an important feature usually not recognised, *that the equipment most likely to cause production problems is also amongst the least costly major equipment on a platform*. A topsides production separation system can cost typically from rarely more than $5 million down to under $1million, depending on size and complexity.

Why, for such important equipment, are design and procurement techniques which will increase the likelihood of production shortfalls persistently adopted? Why is extra engineering effort not applied to separation systems design? Why are adequate design practices and performance safety margins not ensured, when to do all this will add a great deal to production certainty, but little to the facility cost.

6 A BETTER DESIGN AND PROCUREMENT METHODOLOGY

Many oil companies have recognised that as asset owners and operators they have ultimate responsibility for the satisfactory design and operation of production separation systems. Not all, though, have recognised that delegation of responsibility to Engineering Contractors and Suppliers at the start of the construction phase has historically not produced the best results, for reasons discussed above. The message is emerging, though: one oil company executive remarked to the author some years ago that they basically knew what they had to do but repeatedly, as soon as they passed the project to the Engineering Contractor, they lost control of separation system design.

This is indeed the key to successful production separation systems design. The oil company must be well-versed in this critical area of production technology, and must keep control of the system design, procurement and operation at all stages of a project, from the very earliest stage right through to the end of field life. They would not delegate responsibility for managing another large oilfield uncertainty - the reservoir itself - but many companies have seemed hitherto happy to delegate separation systems design to others.

The principles of successful production separation systems design and implementation are as follows:

1 Recognise the uncertainty in separation systems design

Separators, particularly oil-water settlers, are inherently uncertain in their design. Every activity and practice concerned with the design of separators, the separation systems, and their procurement and operation must recognise that they cannot be defined with the same degree of certainty that applies to e.g. pumps, compressors, and dehydration units.

2 Establish oil company in-house expertise to manage the separation systems

Once principle 1 is recognised, it is clear that the oil company must maintain in-house expertise so that they can control their separation systems designs to their own benefit. Delegation to outside companies who may have different pressures upon them, and at the wrong time, may lead to designs that are not optimal and do not allow for uncertainty.

Many oil companies have downsized engineering staff over the years, and specialist technical groups can suffer. Three principles should be recognised - (a) it is worth retaining a separation specialist, (b) even a single engineer in this role can be quite effective - it does not have to a large department, and (c) it is far more cost-effective to do this and pre-empt problems than to solve them afterwards - that indeed may require a large department.

3 Allocate a project authority responsible for the separation system design

With suitable in-house expertise, the oil company must allocate a responsible authority to each project, with sole responsibility for managing the separation system design throughout its entire life cycle. This authority need not be full-time on the project, but should have full technical and commercial responsibility for the separation systems. A key aspect is that this authority must be able to veto inadequate designs.

Owing to typical project timescales, another important function must be to provide continuity throughout the project, including the very likely scenario that individual personnel are changed out over the years. All design decisions made, including options rejected, should be fully documented.

4 Include separation uncertainty within the project economic model

Separation system uncertainty must be figured into the project economic model just as reservoir uncertainty is. In this way, the risk of "spoiling the ship for a ha'p'orth of tar" is avoided. As demonstrated in section 5, the separation system is a low-cost item with high impact on production if under-designed.

5 Start the separation systems design in parallel with reservoir assessment

To treat the separation system design as something that will simply fall in with requirements at a later date defers this vital process to a point that is far too late in the design sequence. Separation systems design starts at the reservoir, to take account of production techniques (natural depletion, downhole pumps, gas lift, waterflood), of reservoir pressure levels and differing strata, of water breakthrough characteristics, and of basic oil properties.

Thus, at the same time that reservoir productivity assessments are being made, the reservoir engineers can, if asked (which rarely happens), provide vital data that will provide very good early indications of the likely system design - production profiles, wellhead temperatures and pressures, separator operating pressures, number of stages, oil-water shear locations, where best to take water off, whether an electrostatic coalescer is required, what the water cut profile over field life is likely to be, whether to recycle water within the oil train, whether to add heat, how to integrate oil processing with produced water treatment, and chemicals requirements.

This work should be carried out at the earliest phases of field feasibility and concept studies, and by the time the design reaches the EPC Contractor, the separation system configuration should be nearly complete.

6 Involve the Process Houses and Specialist Consultancies early and fully

Whilst the oil company has the ultimate responsibility for design, it is inevitably limited in the breadth of its experience on different fields, in that it only has a finite number of its own facilities operating, plus possibly some feedback from partner fields. In contrast, the "Process Houses" and Specialist Consultancies deal with many diverse installations during the course of a year - far more than the oil company will probably have experience of. Their experience can therefore be useful to feed into a field development.

However, this involvement needs to occur before any competitive bidding stage is reached, or the advice given at that point may be shaped by the commercial situation prevailing, as discussed above. To obtain the best advice, it is also advisable to pay for it and engage them fully in the design process. Suppliers often carry out huge amounts of unpaid work (via "budget enquiries") hoping that the contract ultimately placed will come their way, thus recompensing them. One look at the huge and ongoing turnover of supplier companies in this business over the years will show that this method of doing business is not sustainable. Loss of experienced suppliers ultimately also adversely affects the oil companies.

A supplier can usefully be involved at any stage of engineering development, both before and after the engineering contractor is involved.

Once a supplier is involved, let them see the whole picture - all available data, production profiles, proposed designs. A simple "Process Data Sheet" with a couple of design cases is woefully inadequate, and has been the source of many past errors.

An innovative way of involving Design Houses and Consultants, which also allows them the opportunity to present relevant or emerging technology over and above their basic separation skills, is to put the separation system design out to Design Competition in order to find the best option, in the way that oil companies do with whole platforms. Such a design competition should be carried out early in the project's life, and definitely before the Concept Design contract is let. It should also not be predicated upon the cheapest design, but on achieving the best technical design - the most robust, least uncertain, and most appropriate design for the facility concerned.

7 Plan well test sampling so as to provide oil property and separability data

It is just as important to obtain oil physical property and separability data from a well test as it is the other reservoir parameters usually obtained. Most oilfield production systems are, somehow, just about adequately designed from as few as a single downhole PVT sample. Instead of this, a much larger quantity of oil (at an absolute minimum several barrels) should also be obtained for physical property and separability characterisation. Although the oil will be dead and aged by the time it reaches the lab, techniques exist to reconstitute it in a pressurised system, and for it to be studied at length in, for example, a Dispersion Characterisation Rig. Although sometimes maligned, bottle tests, when performed by a laboratory experienced in separability characterisation, and not just in chemical comparison, can in fact be extremely useful.

8 Write the Oil Company / EPC Contractor production performance contract correctly

Once a project is confirmed as feasible and moves into the engineering stages, the importance of correctly constructing the oil company / EPC Contractor contract is vital to successful separation systems design. It is not appropriate to negotiate a simple production performance guarantee where the platform production rate and export quality guarantees are taken on by the EPC contractor. EPC Contractors rarely carry the relevant specialist expertise in house to assure separation systems performance at a detailed level, hence they will simply obtain these guarantees from the "Process House", and pass them through to the oil company to fulfil their own contractual obligations. This is a key mistake in so many past projects, for the reasons given above.

Instead, the Oil Company, who by this stage should have a very clear idea of the correct design for the separation system due to its early work as recommended above, should instead require the EPC contractor to comply with oil company requirements for the separation system. In effect, even if a supplier's Process Guarantee was obtained by the conventional route, because of the guarantee pass-through from Contractor to

Oil Company, and lack of specialist expertise in the Contractor, the guarantee will not have been properly scrutinised. The oil company are effectively taking on the performance risk themselves anyway, but without realising this is happening. So it is far better for the oil company to pro-actively manage that risk in-house, determine the conditions to minimise that risk, and then impose those conditions on the EPC contractor and its sub-contractors

9 Allow for separation uncertainty in the project schedule

The contractor must be given the separation design principles established beforehand by the oil company's own in-house expertise, and they must be carried out.

If there is further optimisation of the basic separation design to be carried out, the project schedule must allow for this, rather than seeking a freeze earlier than can realistically be achieved from a technical point of view. If a layout and weight freeze is important, as it usually is, then sufficient space and weight allowances must be made for a potential worst-case scenario. Too often, separator sizes are determined or limited simply by the space available on the topsides, with little recognition of whether these sizes were adequate.

10 Properly define the separation system during detailed engineering - "Think Droplet"

Detailed process engineering must take into account the full production profiles predicted, water cut variation over field life, and variability in these predictions (e.g. P_{10} / P_{50} / P_{90} confidence levels). Design cases for separation must not be limited to the typical Max Oil / Max Water / Max Fluids / Max Gas selections. Whilst in some cases these do define relevant design points, they may well not define the "Worst Separability" case and do not adequately identify the separation risk points in the field life.

Hopefully, the issues of oil/water shear and droplet formation locations have been accounted for in the early oil company design work recommended here. However, Process Systems Engineering must constantly look at not only the "Separator" design, but areas where droplets form, such as control valves and pumps - "Think Droplet". Shear locations, droplet formation and re-formation must be minimised wherever possible and mitigated when not. The whole well-to-export processing system works together to help or hinder separation performance, and must be treated as an integrated system.

11 Avoid competitive tender for separator designs and supply

As detailed in section 2, owing to the uncertainty in separator design, they cannot be defined closely enough that the competitive tender process works effectively. Suppliers are put in a very difficult position where to provide an otherwise sensible design safety margin will probably result in losing the contract on cost. Separators must be taken outside the usual multiple bidders competitive procurement model.

Instead, the oil company and contractor should work together to develop a definition of their needs for the particular contract, and then implement these in the relevant way. They may need extra advice on vessel sizing, internals types and capabilities, fluid testing, CFD or physical modelling studies. These needs should be defined and then companies invited to pre-qualify based primarily on experience, capability, or test facilities, according to what service is being sought. Price for these services is almost never relevant - cost savings obtained by selecting a supplier on cost are miniscule compared to the risk of using a company with inappropriate experience. Obtain CVs of the personnel nominated to work on your contract, check they are suitably experienced, and then ensure they actually work on your contract. Reference lists should be obtained, relevant installations identified and followed up. Bear in mind that a supplier's bad experience on a previous installation may actually help with clarifying and expanding their experience, so also find out what they did wrong and hence learnt, not just what they did right.

Recognise that supplier companies may not hold all the answers under one roof, and the project may have to pick and choose, arbitrating between the various options, even within the same separator vessel, using the oil companies own expertise.

Finally, whichever supplier company is used - allow them to make a profit. Open-book contracts are one way to ensure that the profit margin on a contract will not disappear leading to conflict between technical performance and commercial reality. Profitable suppliers are stable companies within the market, which benefits the long-term interests of the oil companies and Contractors, as well as the suppliers themselves.

12 Write Process Guarantees correctly

The old-style process guarantee may indeed be "not worth the paper it is written on". The supplier has not been fully-enough involved in the design process, and is put in a conflicting position by project history and competitive bidding.

Instead, if a process guarantee is felt to be necessary, such as if a specific equipment item is required (inlet device, gas demister), then ensure that the guarantee has a commercial element to it. A "process guarantee" is *not* a technical guarantee. It is a commercial contract that ties technical performance to commercial performance - i.e. a portion of the contract value. It is not a guarantee that performance will be met. It is a contractual condition that focuses the suppliers' attention on achieving the best possible results, so that they achieve the targeted profit. Most separator performance specifications are such that if the performance is not met, then the situation can often not be "put right". Hence an absolute guarantee, especially with no fee retention, is indeed worthless, particularly as the usual get-out is that the oil company cannot guarantee the feed conditions, so how can the supplier guarantee the product? Additionally, the contract value is miniscule compared to the potential revenue losses resulting in production shortfall, so no supplier will ever agree commercial terms that can recompense the oil company for their losses. But this is not a reason for not bothering with a guarantee.

Instead, construct a guarantee agreement that is meaningful to all parties - to benefit the purchaser by focusing the supplier's attention on the design and to apply best efforts, and conversely, to provide incentive to the supplier to minimise their risks by ensuring there is adequate information from the buyer to start with. This process also brings together the design engineers and purchasing management such that they work together towards the common good, rather than allowing technical and commercial pressures working against each other.

It is in the guarantee negotiation that the degree of uncertainty is finally flushed out, since a sum of money is being judged as meaningful and risk-worthy. If a supplier only agrees to a 1% retention, this tells you something compared to a supplier that agrees to a 15% retention.

13 Long-term considerations

Follow up the performance of newly installed, and existing, separation systems. Meaningful feedback from operating units to the designers does not happen nearly as much as it should - surprisingly sometimes not even when performance is poor and is causing the operator difficulties. Feedback is of most use when it can be related back to the design methods used for a particular installation for the benefit of future designs. However, as design methods differ subtly and not so subtly between different suppliers, there is also a need for a commonality of design method to emerge.

No adequate large-scale database of separator installations exists, detailing sizes, throughputs, internals, operating levels, and performance achieved at different life stages - *which is also correlated to standard performance calculations*. Such a database could usefully be created in a JIP project which ultimately could provide a public-domain correlation of separation performance against key fluid and sizing characteristics.

7 CONCLUSIONS

Production separation systems involve a considerable degree of design complexity and performance uncertainty, neither of which have been adequately recognised in project design and procurement processes.

Existing commonly-adopted methods for their design and procurement within a project environment, particularly design freezes before adequate design assessment has been carried out, and competitive tendering, exacerbate the situation and can directly contribute to performance shortfalls.

Economic assessment incorporating performance uncertainty factors shows that production separation systems are amongst the lower-value topsides equipment items yet are highly critical to platform operation, and are the most likely to cause production difficulties. In contrast, other high-criticality or high-value items can usually be depended on to perform reliably.

Economic assessment shows that for a small extra investment in the separation systems design and equipment, considerably greater confidence can be achieved in the ultimate system performance. Doing it right costs very little more, but avoids many operational difficulties in later field life.

A better design and purchasing methodology is for the oil company to take pro-active control of the entire separation system design process in order to manage uncertainty. This paper lists a 13-point plan for achieving this, focusing on integrating the separation design from the earliest stages of field development, and ensuring control is maintained throughout the project process.

APPENDIX A

BRAINSTORM OF FACTORS AFFECTING SEPARATOR DESIGN

Theory, Design Techniques & Equipment Options

- basic fluid properties (density, viscosity, interfacial tension, and variability with temperature)
- separability
  - bottle tests
  - dispersion characterisation rigs
  - pilot plant and field tests
  - controllability of recirculating dispersions in pilot rigs
- chemical injection
- droplet size distribution
  - dynamically changing
  - complex interactions
  - wells have individual signatures
- sedimentation ("Stoke's Law") / cut size method
- dense packed settling
- Q/A method, requiring experimental data
- CFD
  - understand what is and is not possible
  - 2D, 3D
  - separation
  - piping
  - incorporation into purchasing cycle
- Physical modelling
  - understand what is and is not possible
  - incorporation into purchasing cycle
- Hydraulic efficiency (prevention of bypassing, plug flow, etc.)
  - establishing a realistic target dimensionless residence time
  - incorporation of testing into purchasing cycle
- internals
  - inlet devices
    - cyclonic
      - high-intensity vs low intensity
    - non-cyclonic
  - plate packs
    - configurations
    - sand tolerance
    - location within vessel
  - distribution baffles
    - type
    - open area
    - holes vs. square vs. other shapes, orientation of slots
  - demisters
    - mesh
    - vane
    - axial-flow cyclones
    - tangential-inlet cyclones
  - foam packs
    - when do they work?
    - location in vessel
  - weir design
    - spillover
    - submerged, and at what height?

        - § weir differences for sedimentation vs. dense-packed settling predominating
    - Ø sand removal
- v In-line separation
- v Pre-separation and equipment combinations
- v Resolution of requirements that conflict between early and late life

Project-specific considerations

- v Design case assessment
    - Ø profiles assessed for system and equipment design often based on:
        - § total production, not allowing for differing pressure levels, production type (gas lift, ESP, etc), differential water cuts between sources, etc
        - § Cases: "max oil" – "max water" – "max fluids" – "max gas" ...... but almost never "maximum difficulty"
        - § FWHT, FWHP data sometimes not adequately profiled for purposes of separation system design
    - Ø uncertainty not factored into the separation design:
        - § P10 / P50 / P90
        - § change of water cut for same oil rate

- v Separability data available
    - Ø usually almost none
    - Ø well test data is biased toward PVT data
    - Ø chemical testing aimed at selecting between demulsifiers
    - Ø bottle tests poorly constructed
    - Ø fluid characterisation mapping never carried out
    - Ø classical chem eng scale-up methodologies not applied to separation

- v chemical injection
    - Ø location not far enough upstream
    - Ø no options for re-injection downstream (re-shear locations)
    - Ø interference (scale inhibitor, corrosion inhibitor)
    - Ø oil-soluble demulsifier usage continued into water-continuous operational phase

- v System engineering issues
    - Ø recycle water schemes – re-shearing valves introduce a blocked valve case d/s of high potential wellhead pressures – a safety issue
    - Ø Separator pressures set by reservoir capability and gas compression demands

- v Piping/vessel interfaces
    - Ø inlet piping constrained by space
        - § rarely is a correct approach layout adopted
        - § side-bends throw fluid to one side
        - § upstream size changes affect separability
        - § differences in design criteria between pipe sizing and vessel nozzle sizing not adequately addressed
    - Ø outlet piping dictated by piping supports etc, not vessel function
        - § e.g. water outlet half-way down vessel
    - Ø split-flow separator designs should be centre inlet + double outlet, not double inlet + centre outlet

- v System and equipment design – Oil Companies
    - Ø downsizing of in-house engineering
    - Ø outsourcing
    - Ø responsibility passed to Eng Contractor
    - Ø in-house design manuals may not be updated to reflect best practice (due to downsizing)

- System and equipment design – Engineering Contractor
  - ECs are generalist engineers of large complex systems - rarely any separation specialists on board
  - Fail to apply the criticality/uncertainty rating principle
  - Project structures oriented to early freeze of large equipment items and "getting on with the job"
    - Concept Selection / Front-end Engineering / Detailed Design
    - AFD/AFC cycle
  - System design does not assess risk of not making design specifications and mitigating them
    - Electrostatic Coalescer is a great insurance policy !
      - sometimes rescues a poor separation system design – production hit not taken – "no problem"
      - sometimes omitted when it should not be
      - false assumptions made about how large they need to be
  - System design fails to adopt good separation practices
    - separation design not internally optimised at Concept stage
    - no time between in FEED to internally optimise separation design
    - un-optimised design goes forward unexamined
  - Procurement Models
    - lowest price of 3 bids
    - "It's got a Process Guarantee therefore it must be OK"
    - vessel procurement with vessel fabricator sub-contracting process design and internals
  - Adoption of new developments produces dependence on one supplier
    - what if technology is not reliable enough?
    - commercial implications of single-source

- System and equipment design – Process House
  - highly competitive business – profit margins low
    - prone to re-organisation / take-over / re-management / buy-out cycle
    - key staff turnover
    - budget for research can be restricted to project-funded applications
  - have had vessel procurement removed from their scope
    - internals only
    - reduced profit opportunities
  - separation is part science, part black art
    - much less definitive chemical engineering science than e.g. glycol dehydration
    - opportunity for a differences of approach and opinion to arise, resulting in more or less competitive designs
    - time lag between vessel order and arrival of difficult separation period, and lack of definitive design data at project stage, mean it is commercially unsustainable for a supplier to offer a meaningful guarantee, especially on "internals-only" order values
  - commercial pressure to reduce size and cost
    - else will lose the contract
    - "smaller" tallies with project pressures to reduce space, weight and cost
  - best widget