Reducing 'Separation Anxiety' with Powerful 3D Flow and Thermal Simulation

a report by

Stephen Ferguson

Senior Consultant Engineer, CD-adapco

Separating reservoir fluids into streams of oil, water and gas is a major concern to the global oil and gas industry, and has been almost since its inception. Historically, the major driver for effective separation was economics – extracting the maximum amount of usable hydrocarbon from the reservoir fluids. However, environmental concerns now mean that oil and gas producers are also increasingly bound by legislation that strictly controls the levels of pollution in discharged produced water. This combination is referred to as 'separation anxiety'.

Designing separators to meet these demands remains a significant engineering challenge. Critically, separators do not come in a 'one size fits all' specification; instead, they must be carefully chosen to account not only for the unique composition of fluids produced from a given reservoir, but also for the likely changes in composition that will occur over the lifetime of the well.

Separator technology that is effective in early production may become less effective or even fail as the well matures, or because of some temporary and unexpected change in the reservoir fluids. The increasing cost of platform real estate also means that there is constant demand either to reduce the size of offshore separators or to move them off the platform altogether, turning to newly developed subsea separation technologies.

Whatever type of separation technology is employed, or whatever retrofits and adjustments are made, the cost of getting it wrong can be immense. The production capacity of any facility depends, to an extent, on the effectiveness of its separation process.

Although most facilities employ at least two independent separation trains, diverting production while diagnostic analysis is performed on a poorly performing separator inevitably resultsin a reduction of throughput. With oil prices topping US$60/barrel, even a 5% drop in production in a 50,000 barrels/day installation will cost in excess of US$150,000/day. Worse, if significant problems occur in the separation process whose cause cannot easily be diagnosed, the only alternative is to stop production altogether, or ship the reservoir fluids for processing at another facility.

Stephen Ferguson is a Senior Consultant Engineer with CD-adapco in London, specialising in providing engineering solutions for the oil and gas industry. Prior to joining CD-adapco, he worked for a major automotive manufacturer and for Europe's largest engineering consultancy. Mr Ferguson obtained his undergraduate degree in 1993, and received an MSc in computational fluid dynamics from Imperial College London in 1998.

Separator Flow Simulation

Computational fluid dynamics (CFD) has been applied at every stage of the oil, gas and petrochemical production process and can provide insight into any problem involving fluid flow (whether liquid, gas or a mixture of both) or structural components that are influenced by flow, and thus is particularly suitable for separator analysis. CFD simulation can help both in the design of new separator technology and in determining the range of operating conditions under which existing technology might be successfully deployed.

Data from CFD calculations can also be used to assist other types of analysis: for example, the forces acting on the separator internals can be calculated either directly within the CFD code or via an external stress-analysis software package. In extreme cases, where fluid forces cause large deflections of components, the CFD simulation can be coupled directly with the stress-simulation tool and both stress and fluid simulations can be performed simultaneously, each simulation feeding new boundary conditions to the other.

Case Study 1 – Sloshing in a Free Water Knockout Drum

The free water knockout (FWKO) drum is perhaps the crudest form of separator. FWKO drums work on a gravitational principle, relying on the fact that oil has a lower specific gravity than water and, if allowed to settle, will float to the top, forming a layer than can easily be skimmed off and extracted. Water is extracted through a valve at the bottom of the tank, while in the example shown in *Figure 3* the oil trickles over a weir plate at the left-hand side of the drum into the oil-stream outflow.

Under normal operating conditions, this system provides a very effective means of preliminary separation. However, when deployed aboard a floating production, storage and offloading vessel (FPSO), there is a risk of the tank being disturbed by the motion of a passing wave, causing sloshing within the tank and leading to significant amounts of water passing over the weir plate or oil-emulsion 65μm, contaminating the water out-take and, possibly, damaging downstream separation equipment.

Figure 4 shows a large sloshing motion that has developed in the vessel due to the disturbing motion of a passing wave (as predicted by the CFD calculation). The simulation predicts that, under these conditions, a significant amount of water will slosh over the weir plate into the oil outflow.

In order to prevent sloshing, separator manufacturers typically insert a series of permeable vertical baffles into the tank, which act to dampen the motion of the fluid within the vessel, preventing

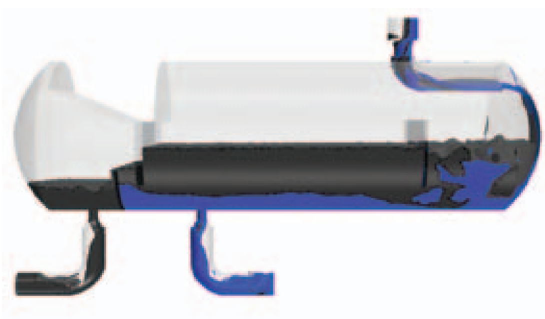
Figure 1: The Largest Single Product of the Global Oil and Gas Industry – Neither Oil nor Gas, but Water

Water is produced at a rate of approximately three barrels to every one barrel of oil. In 1999, the oil and gas industry was responsible for extracting 77 billion barrels of water.

Figure 2: Water Outflow Point

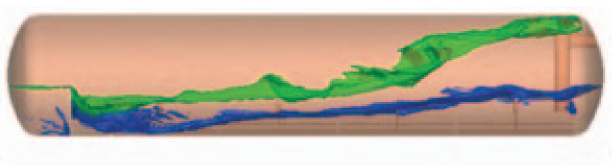
Environmental concerns mean that oil and gas producers are increasingly bound by legislation that strictly controls the level of pollution in discharged or re-injected water.

Figure 3: Three-phase Separator



Courtesy of Saudi Aramco.

Figure 4: Computational Fluid Dynamics Simulation of a Free Water Knockout Drum Disturbed by a Passing Wave While Aboard a Floating Production, Storage and Offloading Vessel



the development of large-scale sloshing motions. CFD simulation allows separator designers to make informed decisions early in the design process, before even the first prototypes are available, allowing them to answer questions such as 'How many baffles do I need?', 'How do the baffles influence separator performance?', 'What sort of forces are acting on the baffles and on the vessel walls?' and 'Under what range of wave conditions can the separator safely operate?'.

Case Study 2 – Redesign of a Gas Phase Separator

The aim of a gas phase separator is to remove small particles of hydrocarbon condensate (and other well fluids) from a stream of natural gas. In order to be effective, the separator needs to be able to remove the wide variety of droplet sizes transported in a typical gas-stream, from large visible droplets of hydrocarbon to individual mist particles measuring just a few microns in diameter.

Exactly which fate each particle eventually meets depends largely on its size, but in order for the separator to work effectively all but the smallest particles should be caught by one of the first three mechanisms.

The vane pack de-mister acts as the final line of defence, removing a fine mist of droplets with diameters of around 10mm or less. For effective operation, it is critical that the de-mister is not blocked by much larger oil particles, which, given enough time, should fall onto the surface of the liquid layer due to the influence of gravity.

> Designing separators to meet these demands remains a significant engineering challenge.

The separator therefore needs to be long enough, upstream of the de-mister, to ensure that the gas flow has sufficient residence time to allow these larger particles to fall into the liquid layer of hydrocarbon at the bottom of the tank.

The simulation results reported in *Figure 5* show that the majority of 65mm and 35mm particles hit either the vessel wall or the liquid surface a short distance after entering the separator. In contrast, many of the small 5mm particles are carried with the gas flow until it passes through the vane pack, at which stage they are removed.

The simulation predicted an overall trapping efficiency of 90%, with almost 100% of particles with a diameter of 40mm or higher removed by the separator. The separator manufacturers were able to significantly reduce the length of the separator after establishing, with the aid of further simulation, that since larger particles were hitting the walls of the liquid surface soon after entering the separator, much of the length upstream of the de-mister was unnecessary. ■