Vessel Design: Why Redistribute

"Where Engineering Meets Ingenuity"

In the study of basic fluid flow we learned that, as a rule of thumb, 80% of the flow travels through 20% of the vessel cross section right in the middle of the vessel. This is referred to as the 80/20 rule. 21st century CFD modelling has proved this over and over. Yet, the reality of this is often overlooked in the design of oilfield process vessels. The results can be serious lack of performance, even when vessels are oversized!

As a buyer you may focus on retention time rather than fluid dynamics. After all, retention time has been a common industry topic for over nine decades, while computational fluid dynamics really only came into its own with the development of dual core CPUs in 2007. CFD is comparatively new to the world, and to us! So, we relate to the subject of retention time.

Retention time is often misconstrued as a direct relationship between the volume of a vessel and the flow rate of the inlet fluids. If a vessel holds 20 barrels, and we produce 20 barrels per hour through it, the retention time may be thought to be one hour. This simplistic approach can be easily conveyed, but it does not represent reality … not even remotely!

Consider the 80/20 rule. It states that 80% of the flow travels through 20% of the vessel cross section. Is the fluid retention 1/5th of what it would be if we could get fluid flow through 100% of the vessel? Again, this is a common, but overly simplified interpretation.

The fact is that we must slow the fluid flow rate down to achieve separation. This means the flow rates must be laminar, not turbulent. In general terms, the slower the fluid flow the greater the efficiency of separation. The threshold of turbulent flow is about 15 feet per second, but efficient separation occurs at or below about three feet per minute! That's 0.05 feet per second … really slow!

Furthermore, fluid flow at these very slow flow rates does not occur in piston displacement. Piston displacement means that the inlet flow is displacing itself through the vessel as if it were pushing a piston, where little or no mixing occurs. Since our oilfield process vessels do not use pistons, the actual flow mixes as it travels through our vessels. And, the more the 80/20 rule applies, the greater the mixing.

Mixing is said to be the opposite of separation. In fact, mixing energies deter separation. The greater the mixing, the poorer the separation. However, the greater the mixing the greater the retention time, since a portion of inlet fluid stays in the vessel much longer than it would if it were being displaced by a piston. And, even though this portion may stay in the separation vessel longer, the fact that it is mixing prevents means that separation is minimized or defeated altogether! This makes the use of retention time calculation only marginally realistic when used to calculate separation efficiency and/or vessel sizes. Beware of this trap!

Physical and CDF modelling have taught us that fluids flowing through a vessel do in fact converge into the center of that vessel, whether it is vertical or horizontal. As the fluid converges into the middle it obviously accelerates. As it accelerates, it carries with it larger and larger droplets of the fluid that would otherwise separate.

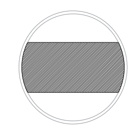
In the oil patch we call this "carryover". We see it all the time! Separators carry over oil with outlet gas; oil that flows to the gas gathering system and gas plant rather than into our lease

tankage as we had hoped. Oil supposedly treated in heater treaters carries over creating tank bottoms of BS&W in the oil tanks. Carryover is all too common, and most of it occurs because of poor vessel designs that result in flow according to the 80/20 rule.

The good news is that we can defeat the 80/20 rule with simple re-distribution baffles. What follows is a basic "how-to" dissertation in how to get it done.

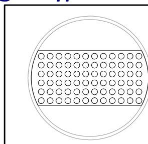
WAVE BREAKING/REDISTRIBUTION BAFFLES

For 100 years vessel designers have realized the value of stopping waves before they propagate throughout the length of horizontal separators. A few of these experts also understood the realities of how converging flow reduces separation capacities. They applied this knowledge by adding wave breaking redistribution baffles. Those baffles were often solid baffles across the horizontal centerline of horizontal process vessels. As the industry grew in its sophistication, some companies built working models so they could optimize their designs. Those firms quickly learned that while solid baffles like the one pictured here do reflect waves, they also inhibit flow on the downstream side of the wave breaking baffles.



SOLID BAFFLE

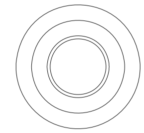
Once they learned this important lesson, they began using perforated wave breaking baffles, like the one pictured here, which both reflect waves caused by surges in flow, and gas slugs or "heads", and help to redistribute flow. Concentric wav breaking and redistribution baffles like the one pictured here at the right can slow down converging flow velocities by redistributing the fluid flow throughout the entire vessel cross section, allowing for more rapid Stokes' Law separation in our typical dynamic flow conditions and ballistic separation flow paths. This is a far better approach than the solid baffle, since the fluids will flow through the entire vessel cross section rather than just above and below the baffle.



PERFORATED BAFFLE

You might think that the issue stops her, but it does not. As most project managers agree, "The devil is in the details", and there is one more significant detail worth communicating. It is that the cross section of a round vessel is not linear! Let me explain by referencing a simple example:

> *If we select a 48" ID vessel as our example, we can evaluate the cross sectional area of various areas inside that circle. In the graphic at the right we see a 48" OD circle with a 36"OD circle inside of it, a 24"OD circle inside of it, and a 10.8" circle inside it. Cleary the next-to-the-largest circle is $3/4^{th}$ the diameter of the larger circle. But, when we compare the cross sectional areas we see that the larger circle has a total area of 12.56 square feet, while the ¾ size circle has an area of 7.07 square feet, or just 56.28% the area of the larger circle. The annular space between these circles contains 5.49 square feet, or 43.72% of the overall area of the larger circle.*



CONCENTRIC AREAS

> *Additionally, the next smaller 24"OD circle has half the diameter of the larger circle, but contains only 25% of the largest circle.*
>
> *The next smaller 21.6" circle has 90% of the diameter of the 2' OD circle, an area of 2.51 square feet, which is 20% of the 48"OD circle. This small 2.51 square foot cross sectional area represents the size circle we would expect 80% of the total flow in a 48"OD vessel to*

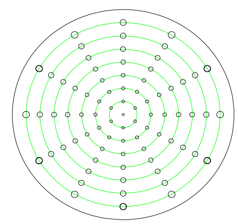
converge into. And, with 80% of the flow moving through 20% of the vessel the flowing velocity is obviously four times greater than it would be if we had uniform fluid distribution

Additionally, since the outer 1' annular space contains 43.72% of the overall cross sectional area, we need to move an equivalent amount of fluid through it. But, how do we make that happen?

Traditionally, we don't! And since we don't, we lose most of the process capacity of the vessel.

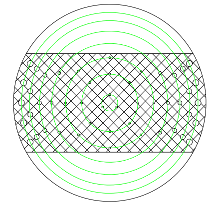
In order to flow in this outermost area we need to take special care to move at least 43.72% of the process fluid through this outermost area, while uniformly distributing the remaining fluid through the remaining inner area. The often overlooked key word here is "uniformly".

The 12.56 square feet of cross sectional area equals 1808.64 square inches. If we said we want 1% of the total fluid to flow in 1% of the total space, we would want 1% of the fluid to flow through each 18.08 square inches, or 100 4.25" x 4.25" spaces. So, we could divide the total cross sectional area into 100 squares measuring 4.25" x 4.25" and drill equal size holes in each square. 43.72% of these squares would reside in the outer 1' of the vessel's ID. But, while this is mathematically correct, it may not be practical.



CONCENTRIC HOLE PATTERN

A more practical approach is to use a concentric hole pattern, starting with a single small hole in the center and radiating outward to ever larger holes. It might look like this, where the center hole is ½" ID and each successive hole radiating outward increases in diameter by 1/8". Using a radial pattern of 12 sets the total open area is 72.46 square inches, equal to a single 9.6"ID hole. This kind approach is almost never seen in our industry!



DIVERGING RADIUS HOLE PATTERN

In reality, while redistribution baffles are almost always full diameter, wave breaking baffles are not. Wave breaking redistribution baffles are normally left open top and bottom to avoid structural issues whenever large surges or heads occur. In proper vessel designs the wave breaking redistribution baffle should be similar to the one shown here at the right, where the diameter of the holes and the hole circle radius increases as the concentric circles extend closer to the vessel ID. When the designer balances these variables the vessel achieves uniform redistribution, and both retention time and separation efficiency are maximized.

In order to convert a solid wave breaker into a wave breaker and redistribution baffle the hole sizes and concentric circle radius' need to be reduced concentrically with the larger holes and centerline circles nearer the vessel walls and the smallest holes and centerline circles near the center of the vessel.

For practical purposes this sort of tapered hole approach is no more costly to produce than the concentric hole approach, since all legitimate vessel fabricators use automatic CNC controlled burn tables to produce component parts and baffles. This automated approach means that custom parts like this baffle can be produced without adding materially to their cost of fabrication.

However, when these decisions are left to the manufacturer competitive pressures often drive manufacturers to reduce costs, particularly in times when the market is shrinking. So properly *designed baffles, trimmed top and bottom and perforated to accomplish desired uniform fluid redistribution throughout the entire cross section of a vessel, are often left unperforated or deleted altogether. The result is a significant reduction in overall separation capacity and efficiency.*

Remembering that "…the devil is in the details", savvy end users and all facility engineers will design and specify perforated wave breakers, or call on experts who can do this for them. Properly designed and strategically located they maximize separation and improve performance by at least a factor of 3-5.

One final note. The vessels you specify will be in service for the next 15-30 years or more. When you weigh the cost the savings of eliminating internals against the income generated by maximizing separation (generating more stock tank barrels of oil over the life of the vessel), it's likely that you'll be able to justify the time to create a vessel RFQ specification that includes properly designed wave breaker redistribution baffles.

To learn more about designing oilfield process vessels please see our article titled "Vessel Sizing" where you'll find more guidelines to help you make certain that the vessels you purchase will actually process your fluids to your satisfaction.

If you need help, call us!

ABOUT BREAKTHROUGH ENGENUITY'S OWNER/INVENTOR

Bill Ball is the founder and owner of Breakthrough Engenuity LLC. He has a distinguished history of oilfield separation system designs, and a comprehensive list of related patents. Bill's hands-on oilfield experience and career portfolio make him one of the industry's leading separation authorities today. After his university studies he launched his career in a 1,000,000 b/d waterflood operation where he was responsible for the evaluation and performance improvement of all surface facilities. He sent most of his work days crawling through the process equipment of the day, making improvements wherever possible.

This hands-on experience was the foundation Bill needed to improve, develop, and advance the technologies necessary to improve process equipment efficiencies across the board. In the early years Bill learned what works, and what doesn't! In the decades since his accumulated separation knowledge and experience led to his many patents, each of which speaks for itself.

The result is a unique approach; one where, "Engineering meets ingenuity!"

Bill's efforts continue to innovate improvements like the patent pending combination free water knockout- heater treater in one vessel. It's called "KOTREAT®". Each new KOTREAT® eliminates the time and expense of installing two separate vessels. And, through the use of highly efficient internals, KOTREAT® is a game changer when it comes to performance.
Another example of ingenious innovation is the MorOil™ system. MorOil™ is a patent pending system designed to condense the valuable C4+ hydrocarbon liquids from produced natural gas streams to generate a new producer stream of cash flow in the form of saleable, highly valued NGLs.

These are just a few of Breakthrough Engenuity's unique contributions.

Today, Breakthrough Engenuity is one of the industry's leading low-cost engineering and design firms. We specialize developing designs for the industry's most efficient high and low pressure, two and three-phase heated and unheated separators, as well as providing general engineering services geared to specialty subjects like:

- *Natural gas handling to optimize income and liquids recovery.*
- *Proper line sizing to avoid turbulence, erosion-corrosion, and mixing energies.*
- *Specialty vessel internals designed to maximize separation performance.*
- *The application optimization of oilfield chemicals geared to reduce cost and improve performance.*
- *3D modelling to avoid costly facility installation delays.*

Now, more than ever, Breakthrough Engenuity can be found in every sector of the oil and gas industry, adding cash flow to operators and efficiency to their operations. We're a full service engineering firm. We pledge to meet and exceed every client expectation.

CONTACT US

If all else fails, or if you just have a question, don't hesitate to call Bill Ball at Breakthrough Engenuity for assistance. You can reach Bill at the office at 918-298-6841, or on his cell phone at 918-231-9698.