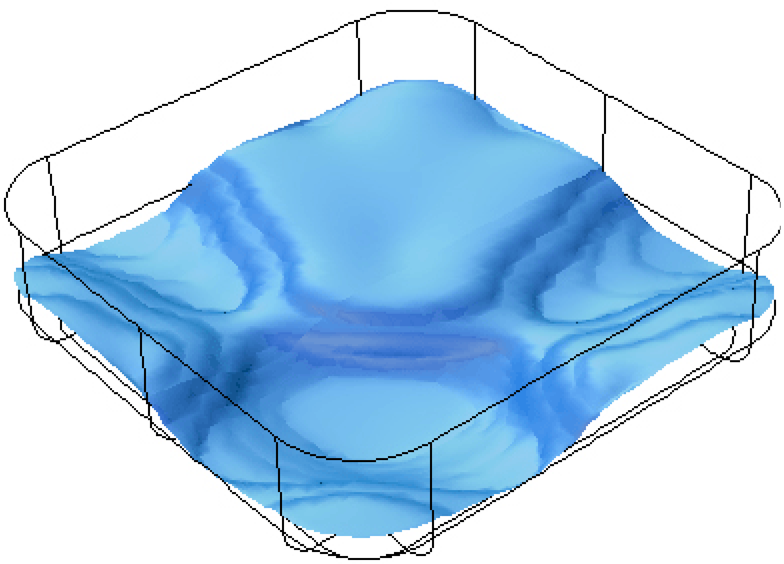
Computer Simulation of Multiphase Separators for Floating Platforms Helps Shrink Size by 50%

Computer simulation helped Natco to design an oil-gas separator that is smaller than previous models by up to 50 percent. The smaller size permits a reduction in the offshore processing platform, potentially saving millions in construction and operating costs. Separating oil, water and gas is particularly difficult on floating platforms since wave motion tends to mix the three phases. Natco previously had to rely on costly physical testing to evaluate separator designs, but this did not let them visualize the liquid phase movement inside the vessel. By using computational fluid dynamics (CFD) software to study the hydrodynamics inside a separator, engineers were able to see what was happening to the oil, water and gas during even the most complicated wave motions. They learned that a horizontal baffle configuration that is often used in separators was ineffective and that conventional porous baffles had too much porosity to dampen the liquid motion. Their new internal baffle design dampens wave motion so well that separation time is sharply reduced. "Because it takes less time for oil and gas to separate, the vessel can be smaller, which is what our customers are demanding," explains Dr. Ted Frankiewicz, vice president, Natco Liquid Process Solutions.



Test of 3D-Box Motion Simulations: Two-Directional Diagonally Movement

For more than 50 years, Natco has been providing process equipment and system expertise to the oil and gas industry. The company designs, builds, and services virtually every type of oil and gas process equipment, from individual wellhead units to large field production systems, onshore and offshore, around the world. Its product line includes gas processing equipment for dehydration and conditioning, oil processing equipment such as oil-gas separators, dehydrators and desalters, oily water treatment systems, and custom-made vessels. Operationally, the Natco Group of companies is headquartered in Houston, Texas, with major operations throughout the United States, Europe and Asia.

Close-Up of Rocking Table Model

Floating separators affected by waves

Much oil production is now done on offshore platforms that float, such as semi-submersibles, tension leg platforms, and floating, production, storage, and offloading (FPSO) systems. Separating the oil and water from gas is done in a stand-alone device called a 3-phase separator that occupies part of the production platform. Oil companies would like to make their floating platforms as small as possible to minimize both the initial construction cost as well as the on-going operating expenses. Reducing the weight of the platform by just one pound, for example, is estimated to save $5 - $8 in construction costs. As oil companies strive to reduce the size of the platforms, manufacturers of oil-gas separators, such as Natco, are forced to shrink the size of their products as well. This has been difficult, however, because of the wave motion experienced by floating platforms. "Weather conditions are normally calm, but sometimes they are stormy," explains Dr. Frankiewicz. "The platform can experience six-degree of wave motion: surge, sway, heave, pitch, roll, and yaw. This has a natural mixing effect on the oil, water and gas." The mixing effect increases the time it takes to separate the oil and gas. Since separation occurs as the liquids and gas flow through the vessel The longer it takes to separate the three phases, the larger the vessel must be.

Oil-gas separators employ an arrangement of internal baffles in an attempt to dampen wave motion. "The design of the baffles is a critical issue because the more effective they can be, the more they can suppress sloshing, which directly affects separation time," says Frankiewicz. Baffles can be placed in different orientations (horizontal or vertical) and at different locations within the separator. They can be made of different materials, and the amount of porosity can vary from low to a high percentage. Finding the optimal combination of all these variables is a critical design goal. In the past, engineers built scale models to determine how well certain baffle designs performed. The testing was very expensive however, due to the cost of building the model and running the test program. Also, the information obtained from testing was limited. One reason was that tests were done on scale models. It wasn't known how accurately the results could be applied to a full

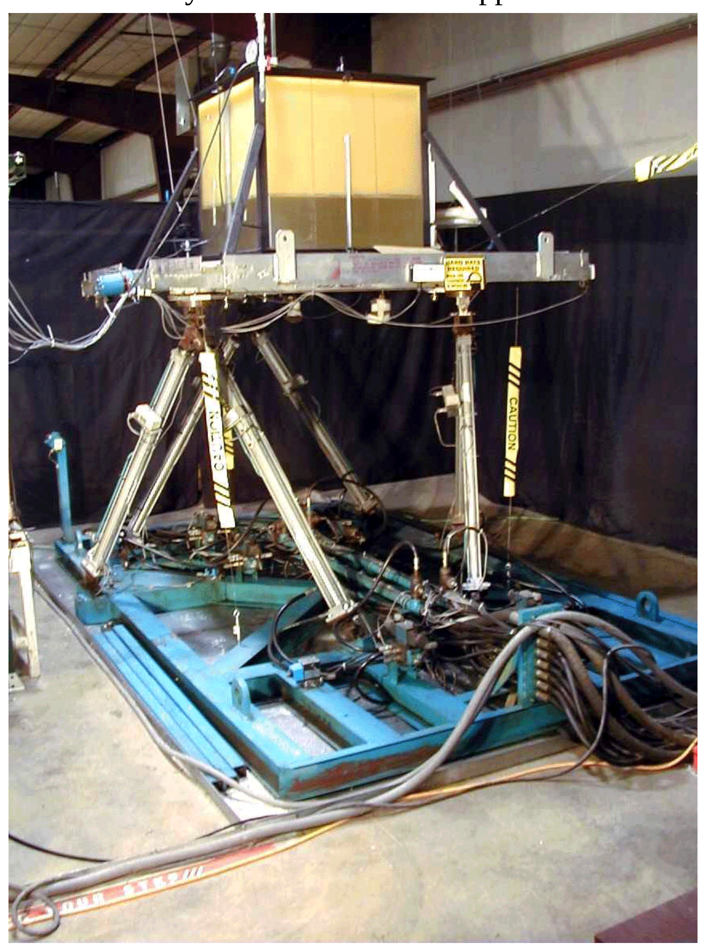
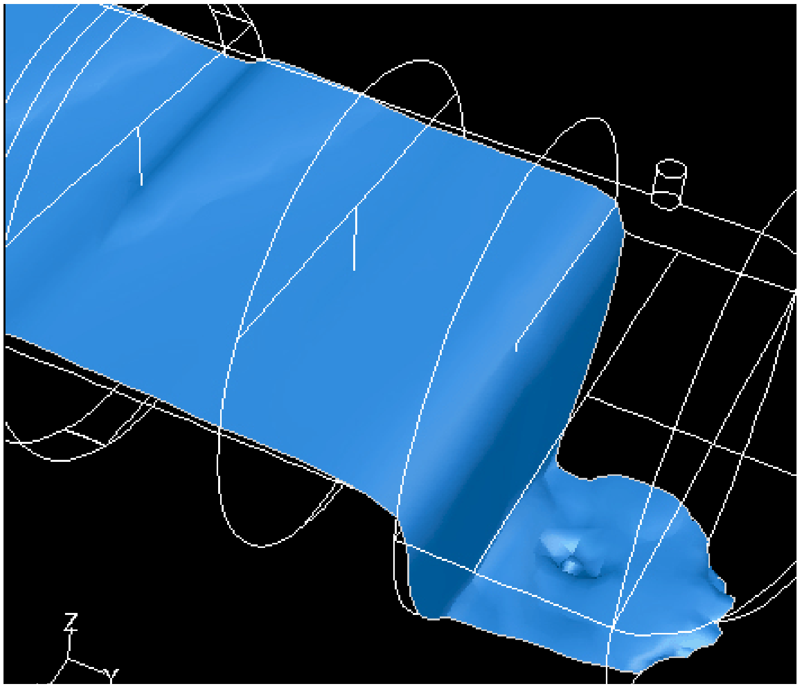


Photo of Wave Motion Simulator

size vessel. In addition, even when the model was made of Plexiglas, it was difficult to visualize and interpret the sloshing or the mixing patterns.

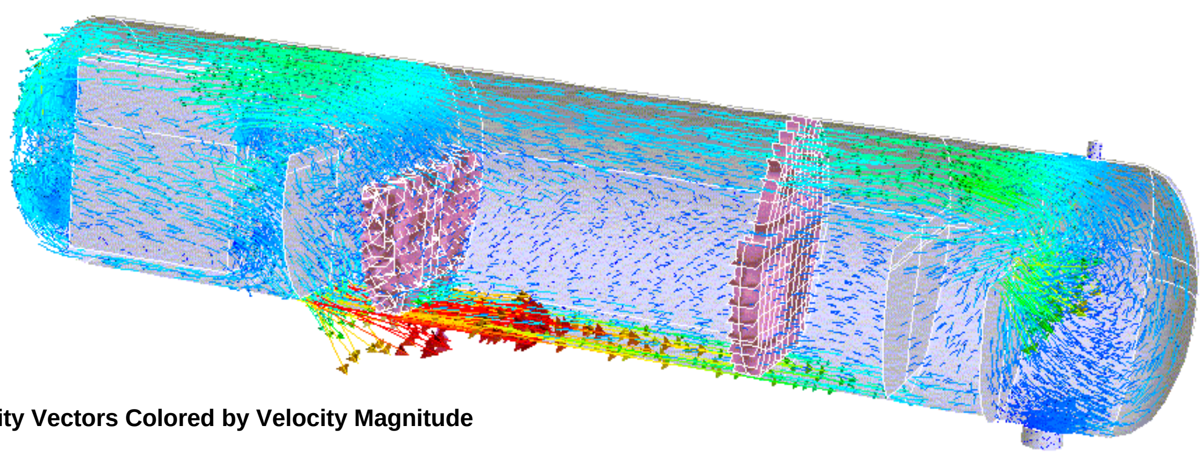
The search for an alternative to scale model testing led Natco engineers to CFD. "With CFD, we can simulate the full size vessel and actually see the details of liquid motion," says Frankiewicz. A CFD simulation provides fluid velocity and pressure values throughout the solution domain for time-dependent problems with complex geometries and boundary conditions. As part of the analysis, a designer may change the geometry of the system or the boundary conditions such as the inlet fluid velocity, and view the effect on fluid flow patterns. CFD is an efficient and effective tool for generating detailed parametric studies, significantly reducing the amount of experimentation necessary to develop a device. Natco chose FLUENT CFD software from Fluent Inc., Lebanon, New Hampshire because it is one of the few solvers capable of solving multiphase flow problems, a requirement for this application since it deals with oil, water and gas flow. The company also prefers this CFD program to others because of the user-friendly nature of its interface and because the vendor provides strong technical support.



3D Vortex Formation at Oil-Gas Interface

Problems with previous baffle designs

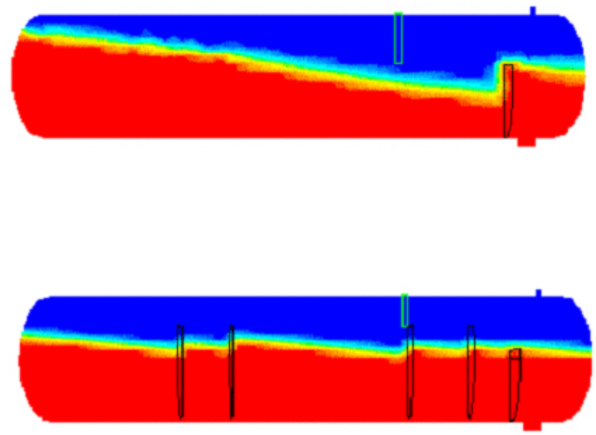
Natco's first experience in applying CFD to separator design was to model an existing separator in the analysis software. The geometry was created directly from Fluent's preprocessor, GAMBIT. This module also automatically produced the geometry meshing. Dr. Chang-Ming Lee, the Natco engineer who performs the CFD analyses, took advantage of the software's ability to produce both unstructured and structured meshes. He placed an unstructured mesh consisting of tetrahedral and hybrid elements at both ends of the separator, scaling the unstructured mesh to account for differences in the size of the components being analyzed. In the central portion of the device, Dr. Lee placed a structured mesh consisting of hexahedral elements. He tried both fine and coarse meshes. The fine mesh had about 126,000 cells while the coarse mesh had


Velocity Vectors Colored by Velocity Magnitude

approximately 40,000. To represent the wave motion of the processing platform, Lee created a user-defined function with assistance from Fluent's technical support based on known environmental data. He used FLUENT's Volume of Fluid (VOF) model to track the free surface interface and liquid-liquid interface in the vessel, and used the k-epsilon model for turbulence.

The first separator that Lee analyzed had no internal baffles. An animated presentation of the results, created with FLUENT's post-processor, made it easy to see the severe sloshing inside the vessel. Next he modeled the separator with baffles, which were specified as porous media, in the vertical orientation, trying different baffle materials, shapes, and degrees of porosity. He ran multiple CFD analyses to find the most effective combination of the design variables. One of the interesting findings in this set of analyses was that conventional porous baffles had too much open area to provide sufficient damping. By using CFD, Lee was able to evaluate varying amounts of open area to obtain more effective damping. To assess the different designs, he compared the amplitude of the fluctuating drag coefficient on the end wall of the unit, derived from the sloshing motion. A preliminary design that used less open area had a drag coefficient that was 56 percent of the original value. With subsequent modifications to the design, Lee was able to reduce that to about 38 percent of the original value.

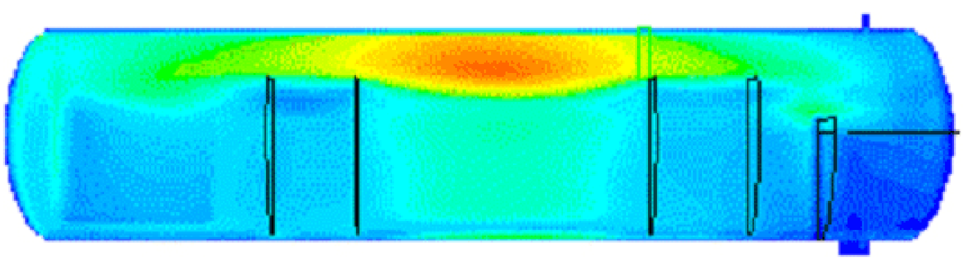
Natco has since used the CFD method to design a three-phase separator that completes oil, water and gas separation in three to four minutes of retention time, which is half the volume of previous devices. The design uses the new, optimized baffle design and placement that Lee developed based upon his earlier analyses. Natco took advantage of CFD



2D contour plots of oil volume fraction are used to compare liquid sloshing (sea state) without (top) and with (bottom) baffles

analysis to find the best location for these baffles within that particular separator. "Since we had the specifications about where that separator would be located on the platform, we are able to plug that information into the simulation model," Lee explains. Those results, combined with using more effective baffles, resulted in a separator that worked more effectively. Because separation time was significantly reduced, the size of separator could be reduced as well. "The analyses we ran to optimize baffle placement were specific to that one separator's location on the platform," Frankiewicz adds. "But now that we have a CFD model, we have the ability to optimize baffle placement in any new offshore separators we supply."

By applying CFD analysis to the problem of oil-water-gas separator design, Natco has been able to minimize wave motion within the device, thus reducing the time needed to separate oil from gas and water. This, in turn, enables the company to build smaller separators and meet the oil companies' demands. "By letting us visualize the effectiveness of baffle designs and their placement in the vessel, CFD lets us get a level of wave suppression we couldn't achieve in the past, "says Frankiewicz. "CFD is key to properly designing our separators."



Contour Plot of Velocity Magnitude