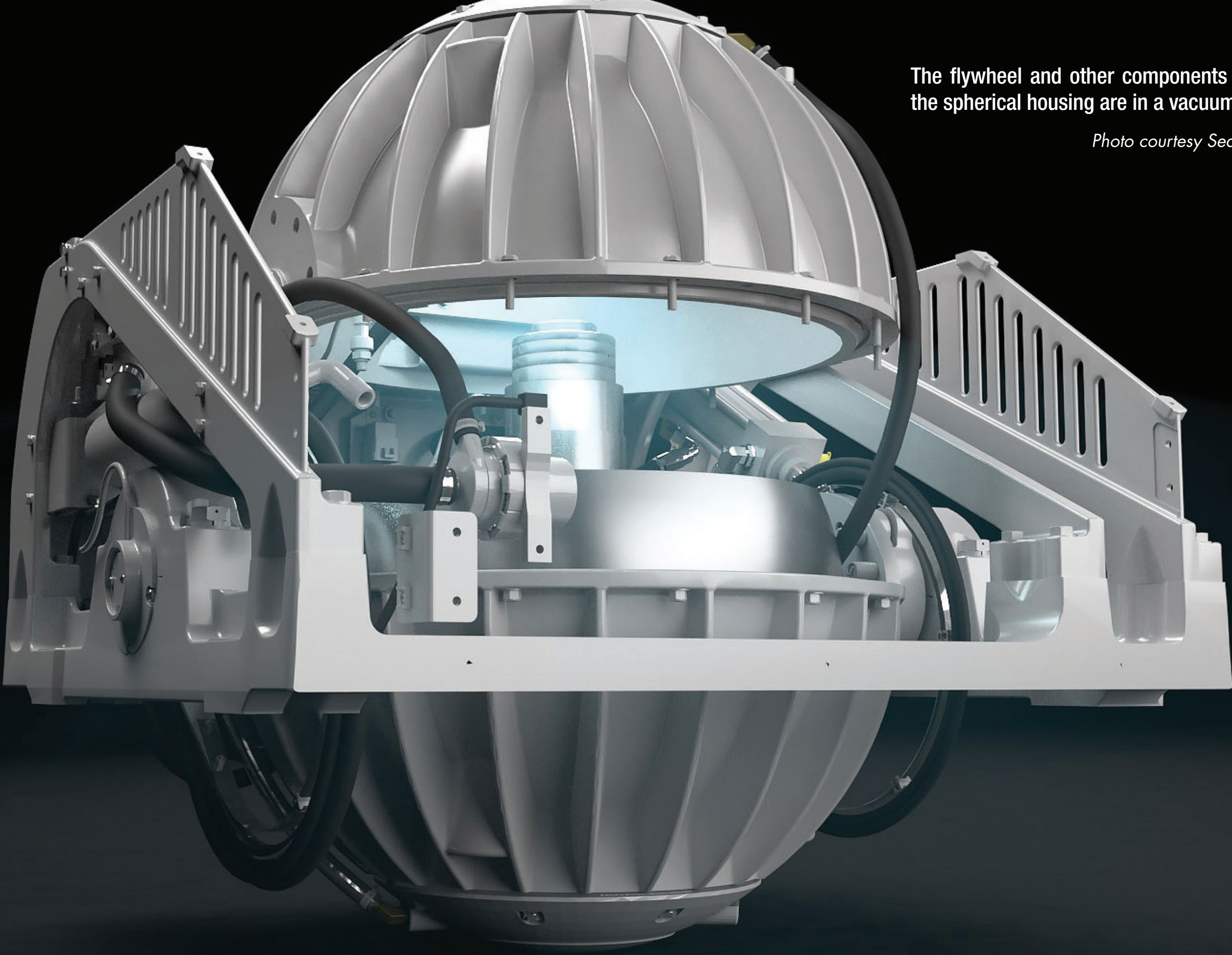

The flywheel and other components inside the spherical housing are in a vacuum.

Photo courtesy Seakeeper

A Look Inside the Seakeeper

How They Work, What They're Made Of

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Seakeeper gyrostabilizers have revolutionized the boating industry. The story of how beneficial Seakeepers can be for those who use them has been widely told. How they are made and exactly how they work, however, is as fascinating as the results they produce.

At its most basic level, a Seakeeper works by creating torque through rapidly spinning a flywheel inside of its housing. The force of the torque is then transferred to the hull of the boat. The force of this application keeps the boat steady, even as it would otherwise roll with wave action. Here is the expert breakdown:

How Seakeepers Work

Andrew Semprevivo, Seakeeper's Chief Operating Officer, provides some context as to how Seakeeper units reduce the roll of the boat on the ocean. "A gyroscopic roll stabi-

A Seakeeper is composed of a heavy flywheel that spins horizontally at a high rate of speed inside of a ball-shaped housing.

lizer is the most unintuitive technology you could imagine, but that is the magic of it. Something so small, quiet, and completely internal of the hull is creating such a great impact," he said as we got into the operational dynamics of the system.

He explained that the concept was not new and showed me pictures of a ship with two massive ball-shaped gyros from way back in 1905. The systems fell in and out of favor in the shipping industry because they were so large and heavy, but the basic principles were the same.

A Seakeeper is composed of a heavy flywheel that spins horizontally at a high rate of speed inside of a ball-shaped housing. To achieve its desired result, a Seakeeper applies torque created by the rapid spin of the flywheel using the angular momentum. Angular momentum represents to gyroscopes the equivalent of what horsepower is for an engine.

Angular momentum is the product of the flywheel mass, flywheel diameter, and how fast the flywheel is spinning (angular velocity, technically speaking). It is the angular momentum of the unit that will determine the amount of torque available over time. The faster the gyro tilts (precesses), the higher the peak torque that is available. Instantaneous peak torque, however, would not be the most effective use of the gyro's angular momentum.

To understand why requires a bit of a physics lesson. Ocean waves are not single bursts of energy. Rather, waves apply force to the boat sinusoidally (in a wave-like manner) over a period of three to seven seconds. Seakeeper uses its active control system to apply the force of the gyro to the boat in the most effective way possible. Seakeepers precisely apply torque to counter the sinusoidal application of the wave force over the course of this three to seven second period. Simply stated, as waves try to force the boat to roll, Seakeepers apply torque precisely when it best impedes the movement.

The torque created by the flywheel tilting (precessing) fore and aft is then applied to the transverse axis of the boat to dampen move-

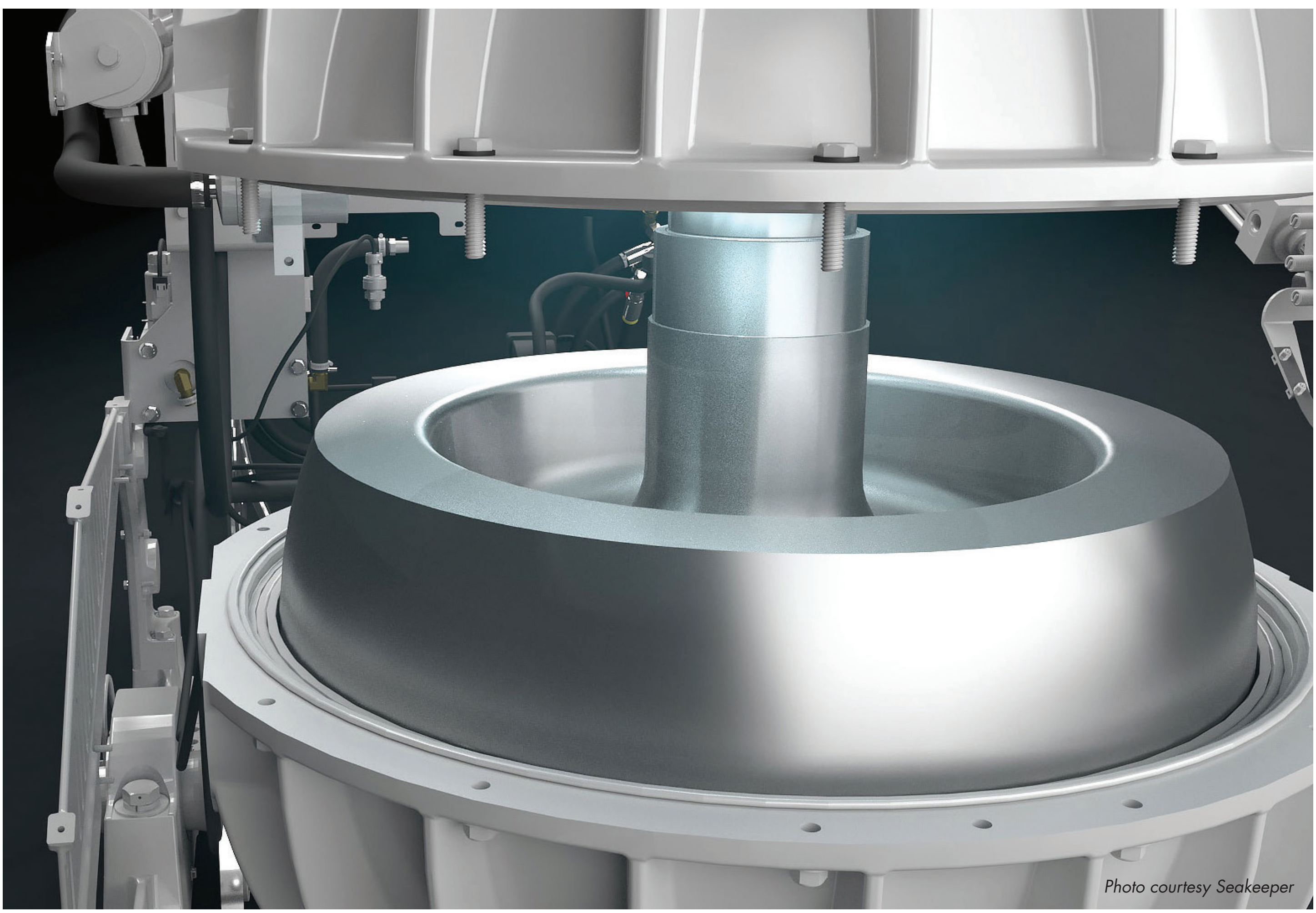


Photo courtesy Seakeeper

The flywheel spins at up to 557 miles per hour inside the sphere.

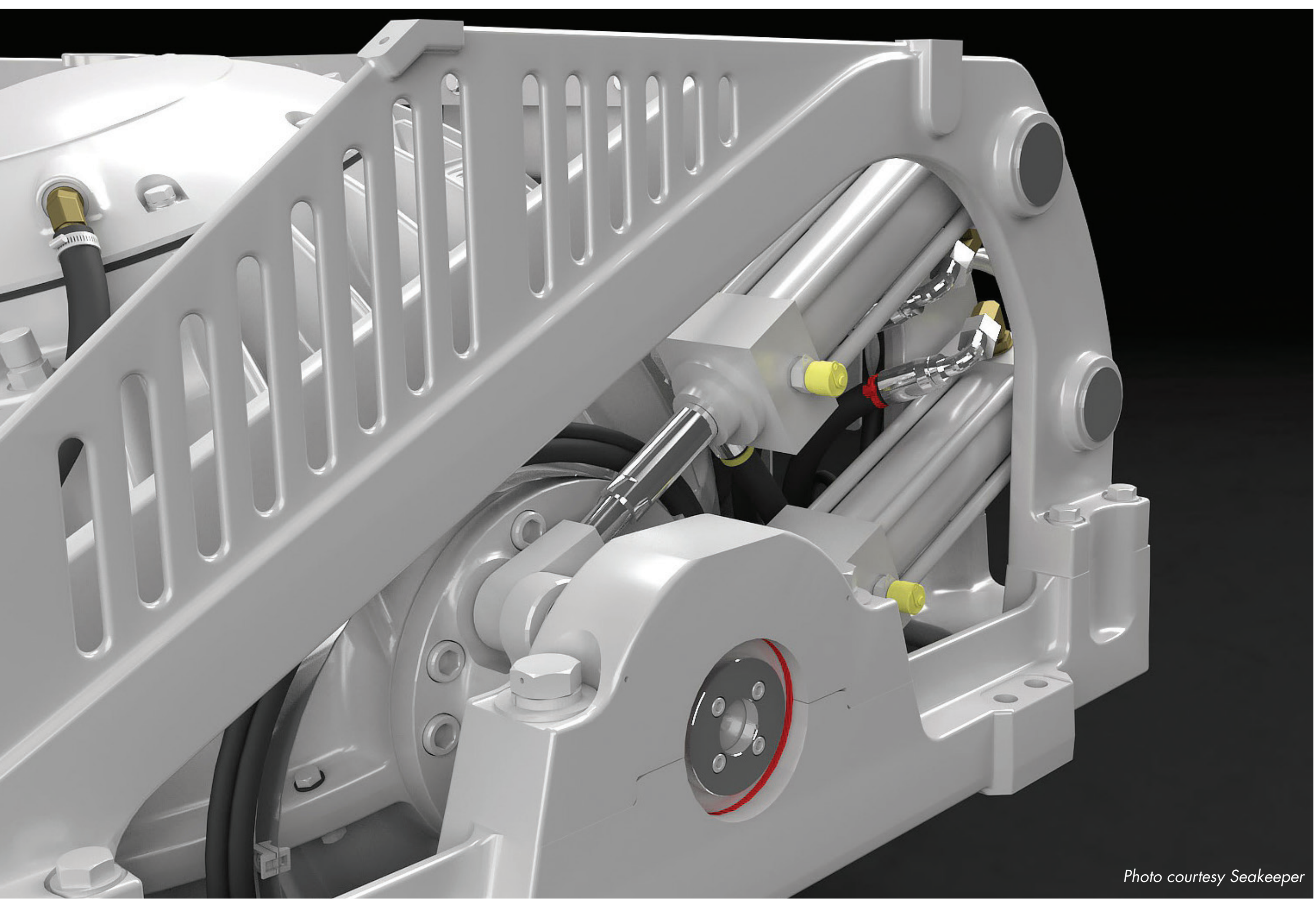
ment caused by wave action. The effect of the torque applied precisely in line with the transverse axis of the boat results in the of roll.

If you've ever played with one of those toy gyroscopes, you've experienced precession. When you hold the spinning toy still you don't feel any pressure being applied to your hand, but as soon as you begin turning it you can feel it apply force dampening against the movement.

Seakeeper has developed a sophisticated, active control system that combines motion sensors with a computer module that gauges the roll rate of the hull. The Seakeeper then uses its hydraulic braking system to dampen the precession rate and inertia generated by the spinning gyro. The effect of this system is to match the precession (tilt) of the unit to the roll rate of the boat on the waves.

The active control of precession is why you can stop the effects of the unit by locking it

A Seakeeper's flywheel is forged of a single piece of stainless steel. Spinning at high rates of speed within the housing, the flywheel creates the unit's torque.



The hydraulic brake cylinders are essential to the active control feature.

in a standby position, even as the flywheel is still spinning at thousands of revolutions per minute. This active control system is also why the Seakeeper can be used in any sea state, at any speed, without the need for manual adjustments. The computer automatically senses any change in conditions and instantaneously adjusts the gyro's precession with the hydraulic brakes to optimize the torque output with every roll cycle.

How a Seakeeper is Made

The technology that goes in to manufacturing a Seakeeper is nothing short of remarkable. The equipment housed in their facility and the expertise of the machinists and technicians that operate the dozens of high tech milling, balancing and testing machines is on a level commensurate with companies in the aerospace industry building components for fighter jets and the space shuttle.

The heart of the unit is the flywheel. To spin it at such high speeds, over 10,000 RPM in some models, requires machining a single massive steel forging. The gyro's components are ground to tolerances of 1/10,000th of an inch. To put this into perspective, that is roughly 1/3 the diameter of a strand of hair. This level of minute tolerances can only be achieved in a temperature controlled environment. Even a few degrees variance can cause expansion or contraction which could alter vital component fit.

There are very few "off the shelf" parts available for such an intricate build. The ceramic bearings the flywheel spins on are purpose-built for Seakeeper. Even the lubricants require special properties so they won't disperse while operating in a vacuum. The balancing of the flywheel is critical so the units run smoothly and do not impart vibrations to the boat.

The precision involved became evident when I placed my hand on the flywheel housing of a Seakeeper 26 spinning at 5,000 RPM on a test platform. The movement was almost imperceptible and it was so quiet I had to be told it was actually running. Now that's precision!

When Seakeeper first went into production almost every component was machined in house. As unit production increased, the company has contracted specialty manufacturers to cast and perform initial machining of certain parts and subassemblies. Today, all of the finishing and assembly is carried out

Seakeepers undergo extensive testing prior to shipment.

in house to maintain the critical tolerances required and assure overall quality control.

Once the flywheel and housing are complete, the assembly process begins with the installation of the ceramic bearings and the proprietary glycol cooling system components. The housing, consisting of two halves, is reassembled with the flywheel in place. The unit then moves to a test platform where the flywheel is spooled up for an initial run-in period. This ramp up period is critical to evenly dispersing the special bearing grease.

The entire assembly undergoes a second balancing process that uses laser measuring devices to detect even minute vibrations. The housing is then fully sealed and the air is removed, creating a vacuum. The unit is pumped down to zero torr, then backfilled to 10 torr of helium (a Torr is a unit of measure that describes pressure). Seakeeper units are filled with helium because of its thermal conductivity properties. Together these processes—run-in, creating the vacuum, and baking out the excess grease—take upwards of ten hours to complete on each unit. That doesn't even include machining, assembly, or testing.

Upon assembly and testing, the flywheel enclosure is mated to the unit frame and the final assembly process is underway. This stage includes the assembly and integration of the hydraulic brake, motor drive, computer control box, cooling system and wiring harnesses. The finished Seakeeper then undergoes a series of grueling quality control tests. These tests, designed to measure the unit's response and effectiveness, include a five-hour stint on a hydraulic tilt table that simulates real world, on board operation. Only after satisfying all of these requirements is a finished Seakeeper crated and prepped for shipping.

The Line Up

With the introduction of the diminutive Seakeeper 3 this year Seakeeper now offers six models that cover the recreational boat market from 30-feet to over 85-feet with displacements up to 100 tons. Larger vessels can be accommodated with multi-unit installations. Each unit is designed to provide the ideal amount of angular momentum at the rated RPM to impart the necessary torque required to arrest roll for the prescribed vessel size range. All Seakeeper units are designed to reduce vessel roll by up to 95 percent.

The Seakeeper 3 is shipping as you read this article. It is designed for boats from 30 to 39 feet in length with displacements of up to 10 tons. The unit is small enough to mount above or below decks and a new leaning post installation option will be available for center consoles. The unit weight 550-pounds and operates on a 12-volt electrical system.