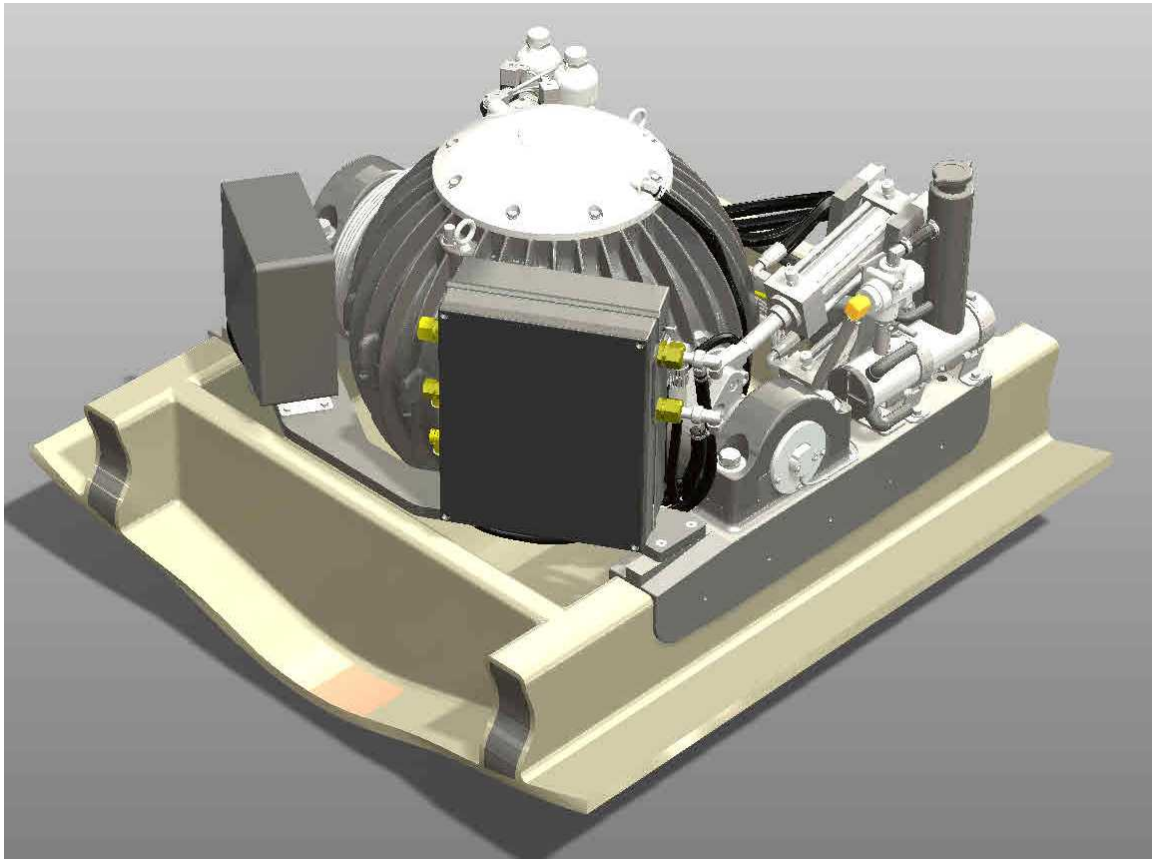
SEAKEEPER®

OPERATION MANUAL



MODEL MX GYRO

Rev 1 - APRIL 2012

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MODEL MX GYRO

OPERATION MANUAL

The MX Gyro is very similar to the M8000 Gyro from an operation standpoint. Because of this, the M8000 information contained in this manual should be used to guide the operation of the MX Gyro.

Contents:

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1.0 System Overview

The Seakeeper Model 8000 Gyro uses gyroscopic principles to reduce boat roll motions in waves and wakes independent of boat speed.

A Model 8000 Gyro consists of a Gyro assembly (including Gyro Control Box and Compact Motor Drive Box), serial communications cable, and operator Display and Keypad. Figure 1 illustrates the interconnection of these components and their interface with the boat.

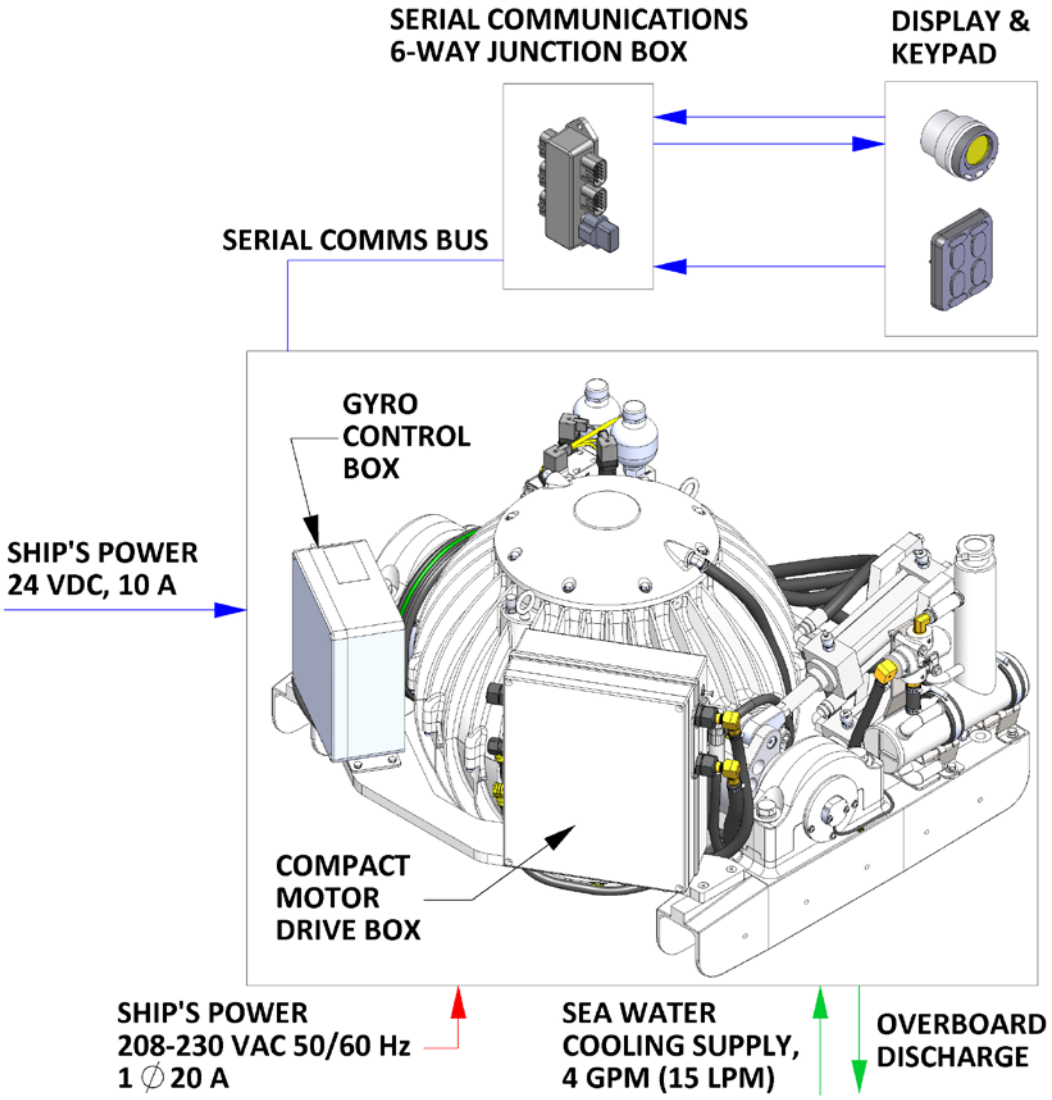

FIGURE 1 – MODEL 8000 GYRO STABILIZATION SYSTEM COMPONENTS

Technical specifications provided in Section 6 list the power consumption, total weight, and dimensions of the major components. Gyroscopic principals that apply to boat roll control are discussed on Seakeeper's web site at www.seakeeper.com. The Seakeeper web site also contains videos of gyro operation and videos of several different boats operating in waves with the Gyro on and off. It is recommended that the reader play these videos prior to reading the remainder of this manual.

The gyro's gimbal angle and the gyro's rate of rotation about the gimbal axis (termed precession rate) play an important role in its operation. These parameters are illustrated in Figure 2. At zero degree gimbal angle, the gyro is vertical; it can precess a maximum of +/- 60 degrees about this position. The amount of torque that the gyro exerts on a boat's hull to counter the wave induced roll is directly proportional to the precession rate. The further the gyro is from vertical (zero degrees) the lower the anti-roll torque. The vertical arrows in Figure 2 illustrate the direction of the forces that the gyro exerts on the boat's hull to damp roll motion.

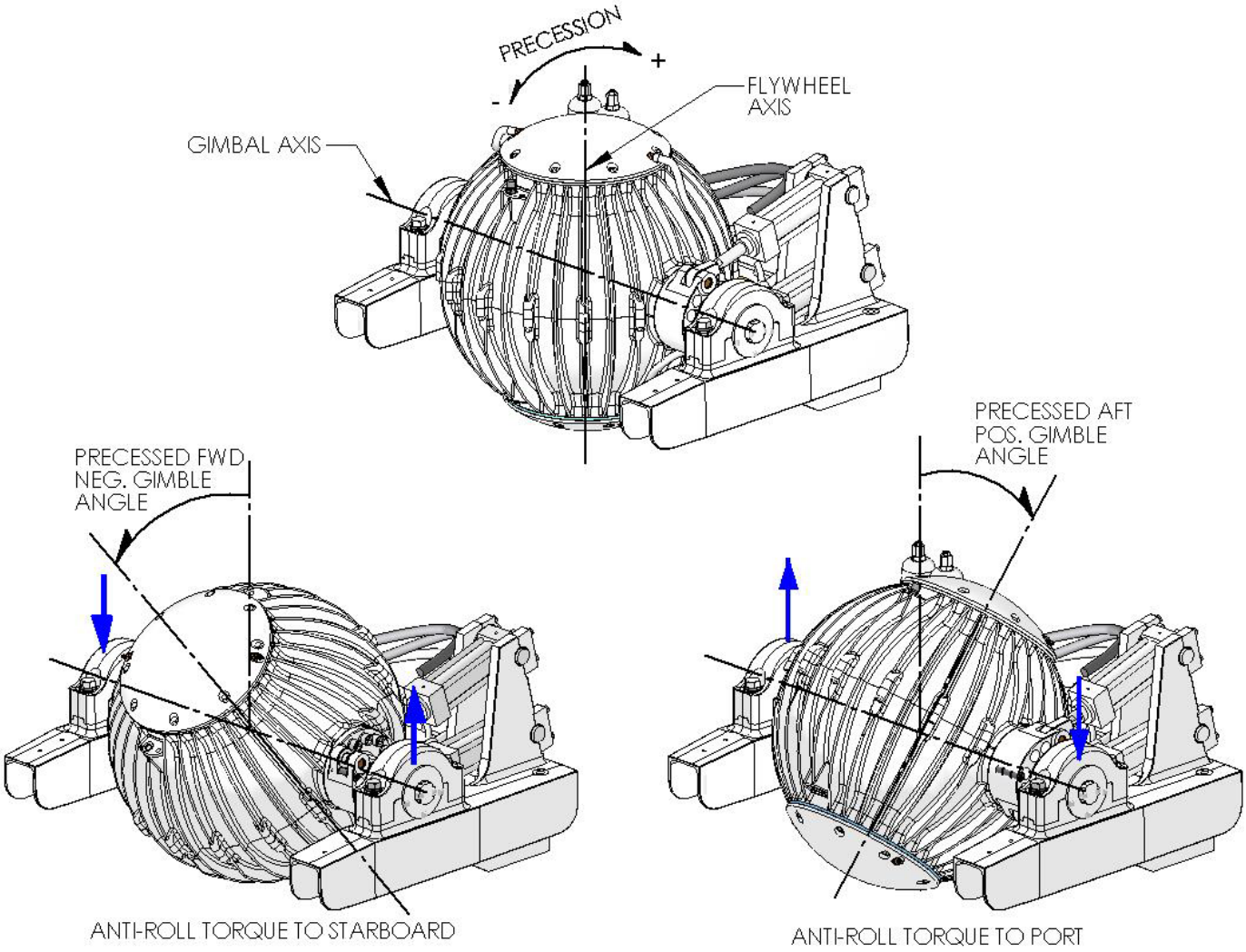

FIGURE 2 – GYRO PRECESSION

Seakeeper gyro precession is actively controlled by an electronic controller and a hydraulic brake throughout each roll cycle so the gyro supplies the maximum anti-roll torque and does not make mechanical contact with hard stops that limit the maximum gimbal angle travel to +/- 60°.

There is a large torque about the gimbal axis when the gyro is precessing. Therefore, the gyro should be housed in a compartment or installed in a cage so personnel cannot come into contact with the gyro while it is precessing. If it is ever necessary to touch the gyro while the flywheel is spinning, the Lock button on the Keypad must be depressed to stop the gyro from precessing. Gyro maintenance should not be attempted unless the gyro is locked and the flywheel has stopped spinning.

1.1 Gyro Assembly

The gyro assembly consists of a flywheel housed in a cast aluminum vacuum-tight enclosure. The flywheel spins about a vertical axis and is supported by upper and lower pairs of bearings. A DC brushless motor mounted inside the enclosure spins the flywheel at high speed.

The enclosure is fastened to two gimbal shafts that are supported by gimbal bearings on either side. These shafts establish an athwartship gimbal axis about which the flywheel and enclosure precess or rotate up to +/- 60 degrees during operation. Each of the gimbal bearings is supported by a saddle beam which is bonded to the hull structure. These beams transfer the loads that the gyro produces to the hull structure.

An active hydraulic brake mechanism is located on the gyro assembly to regulate the gyro's precession motions about the gimbal shaft. It includes two hydraulic cylinders mounted on the brake saddle beam and a hydraulic manifold on the non-brake saddle beam.

A coolant pump, heat exchanger with reservoir, and thermostatic mixing valve are located on the brake saddle beam near the hydraulic cylinders. Braces forward and aft of the enclosure connect the brake and non-brake saddle beams. A glycol/water mix is circulated thru a closed loop to the motor drive box, hydraulic manifold, and the end caps of the enclosure to remove heat.

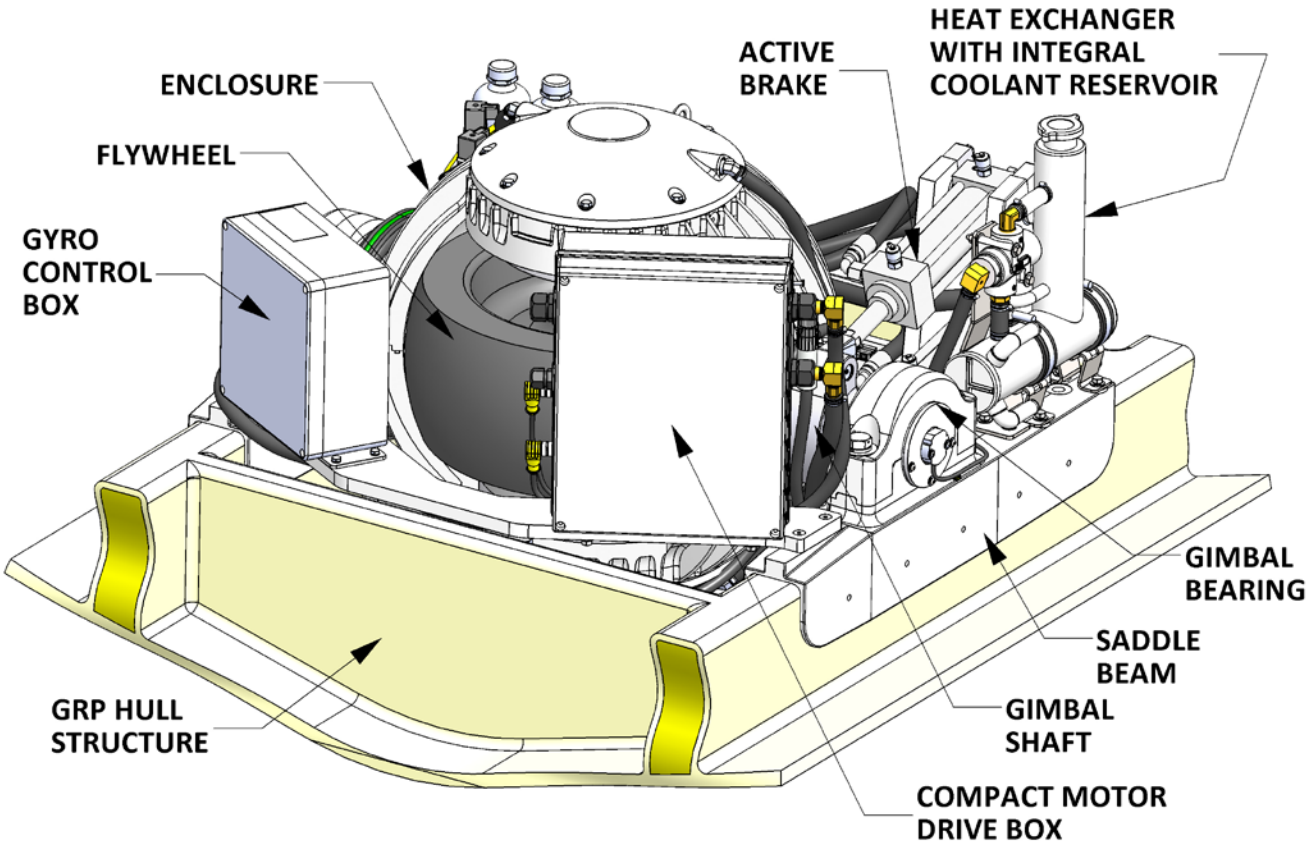

FIGURE 3 – GYRO ASSEMBLY

1.2 Keypad and Display

The keypad and display shown below are the user interface to the Model 8000 Gyro and should be mounted at the primary helm station. They are used to start, operate, monitor and shutdown the Gyro. Sensors, alarms and shutdowns are provided to allow unattended operation. However the gyro is a high-speed machine and special attention should be paid to vibration and noise as this could be the first hint of a mechanical problem.

The display provides the user with status information such as bearing, motor and drive temperatures, motor current, vacuum pressure, boat motion and gyro gimbal angle. The display also provides information in the event of an alarm or warning. Alarms cause precession to stop (LOCK) and the gyro to start coasting down (STOP). Warnings have no effect on gyro operations.

FIGURE 4 – OPERATOR KEYPAD

FIGURE 5 – OPERATOR DISPLAY

1.3 Compact Motor Drive Box

The Compact Motor Drive Box contains the electronic components that take 208-230 VAC at 50/60 Hz from the boat's generator or shore power and supply current to the flywheel motor according to commands from the Gyro Control Box. The glycol/water mix that cools the gyro is also circulated through a cold plate inside the drive box to remove heat from hi-power electronic components.

The Compact Motor Drive Box contains high voltage electronics and the cover should not be removed while the flywheel is spinning except by an authorized technician. This high voltage exists even if the flywheel is coasting down and the supply voltage has been shut off.

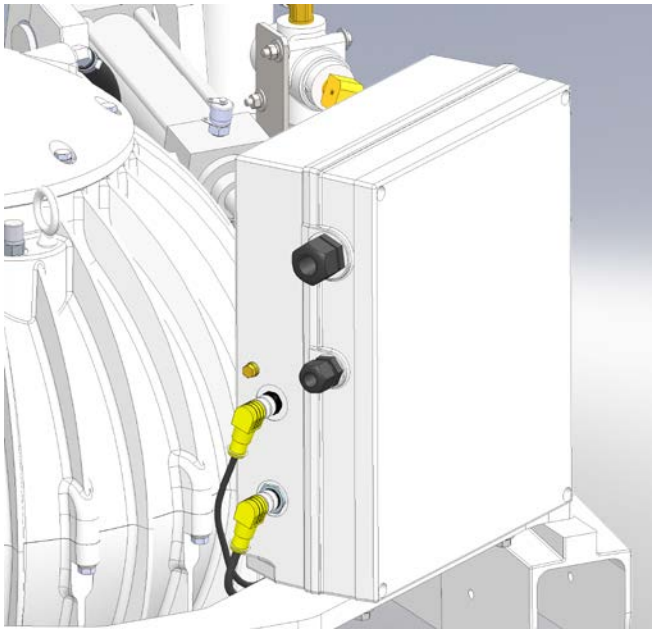

FIGURE 6 – COMPACT MOTOR DRIVE BOX (Left)

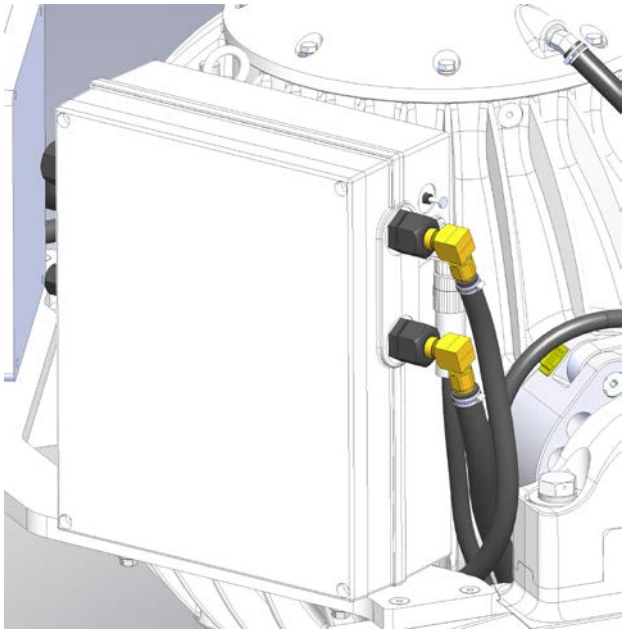

FIGURE 7 – COMPACT MOTOR DRIVE BOX (Right)

1.4 Gyro Control Box

The Gyro Control Box contains motion sensors and a controller module that monitors and automatically regulates operation of the gyro.

The motion sensor suite contains rate sensors that measure the angular movements of the vessel and accelerometers that measure the vertical and lateral boat movement.

The controller commands the motor speed and regulates the gyro's precession rate and gimbal angle. This is accomplished by commands to a high response flow control valve in the hydraulic brake circuit that increases or decreases brake pressure.

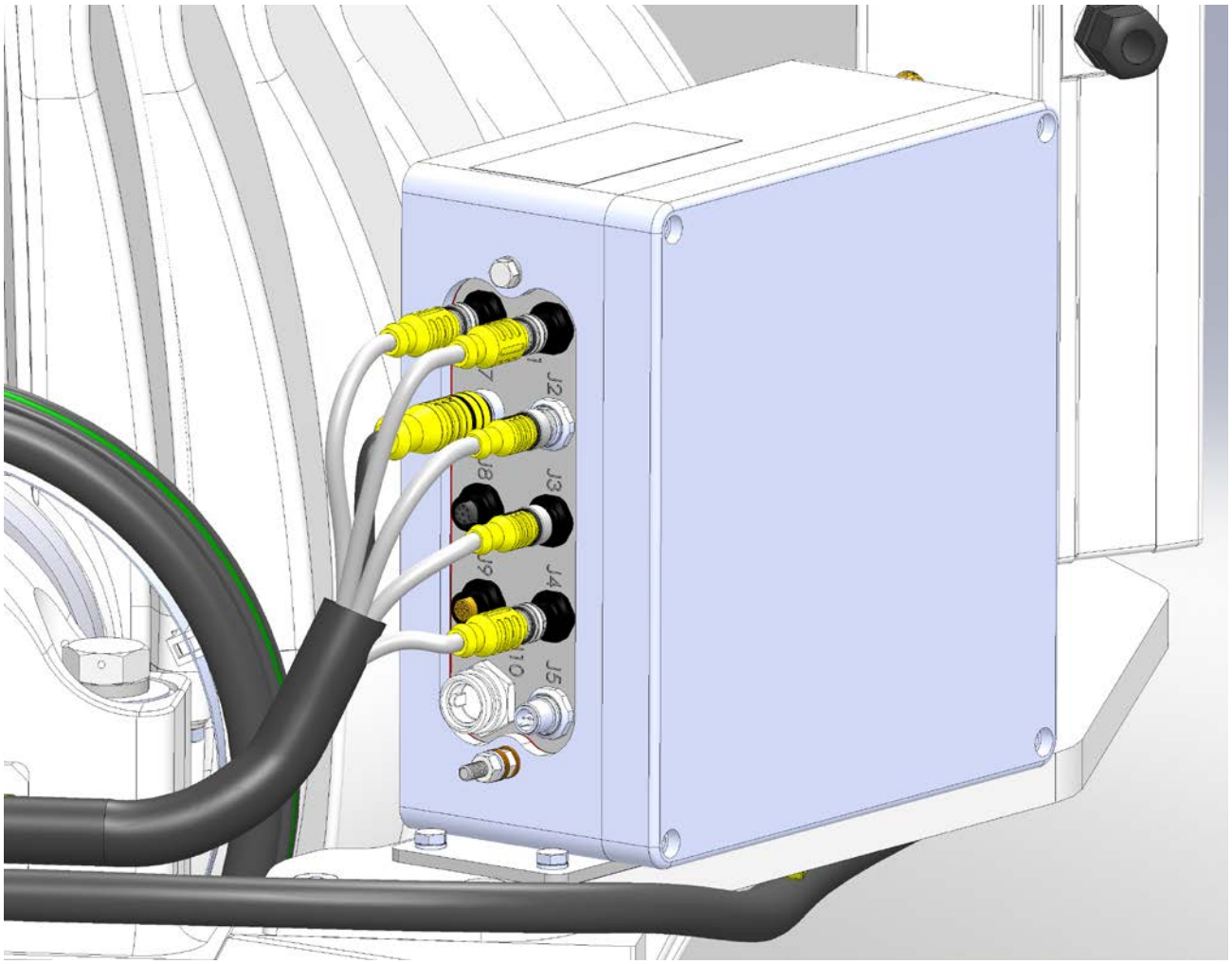

FIGURE 8 – GYRO MOUNTED CONTROL BOX

1.5 Brake

The brake mechanism consists of two hydraulic cylinders which are mounted on the brake saddle beam and attach to a crank arm on the gyro gimbal shaft. The hydraulic cylinders are plumbed to a manifold / valve assembly so when the gyro rotates about the gimbal axis, oil from one side of each cylinder is pushed through the high response flow control valve into the same side of the other cylinder. The gyro controller modulates how fast the oil can flow through the control valve thus controlling the precession rate of the gyro.

The brake hydraulic circuit is a pre-charged closed loop – that is, there is no pump, motor or reservoir in the circuit. Accumulators are installed in the circuit so the precharge pressure does not increase as the fluid temperature rises due to the braking action. Locking solenoids are installed in the circuit to lock the gyro so it cannot precess if there is a leak in the circuit or a mechanical problem with the gyro.

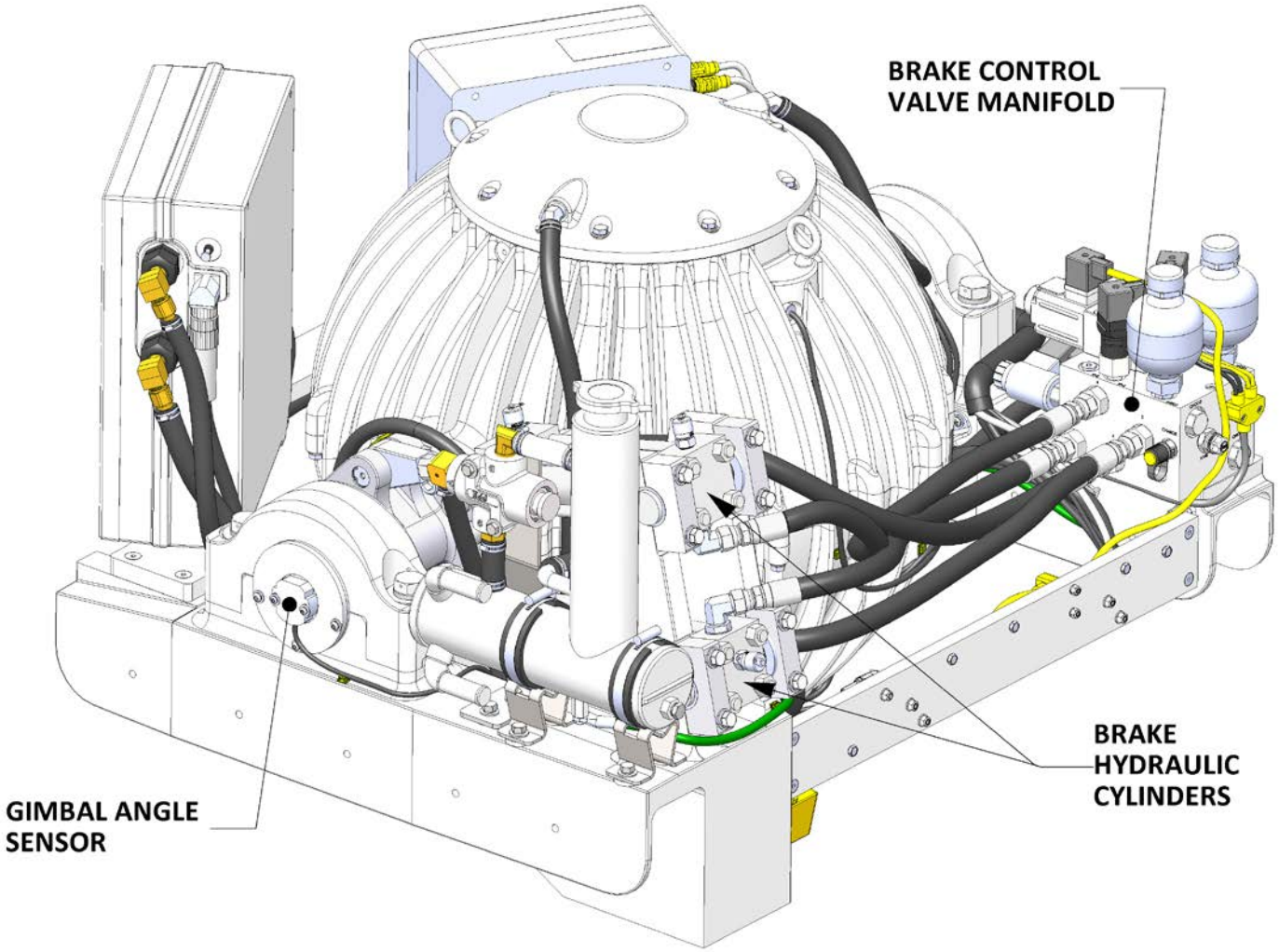

FIGURE 9 – BRAKE

1.6 Cooling

The cooling circuit is a closed loop that supplies a glycol/water (50% distilled water and 50% glycol) mix to:

- The motor drive box to remove heat from the drive electronics
- The brake manifold to remove heat from the brake hydraulic circuit
- The gyro enclosure water jackets to remove heat from the flywheel bearings

The heated fluid then passes through a thermostatic mixing valve before bypassing or flowing through a heat exchanger that has sea water on the cold side. The circuit also contains a coolant reservoir for coolant expansion and to make filling easy. The reservoir contains a 7 psi (0.5 bar) pressure cap.

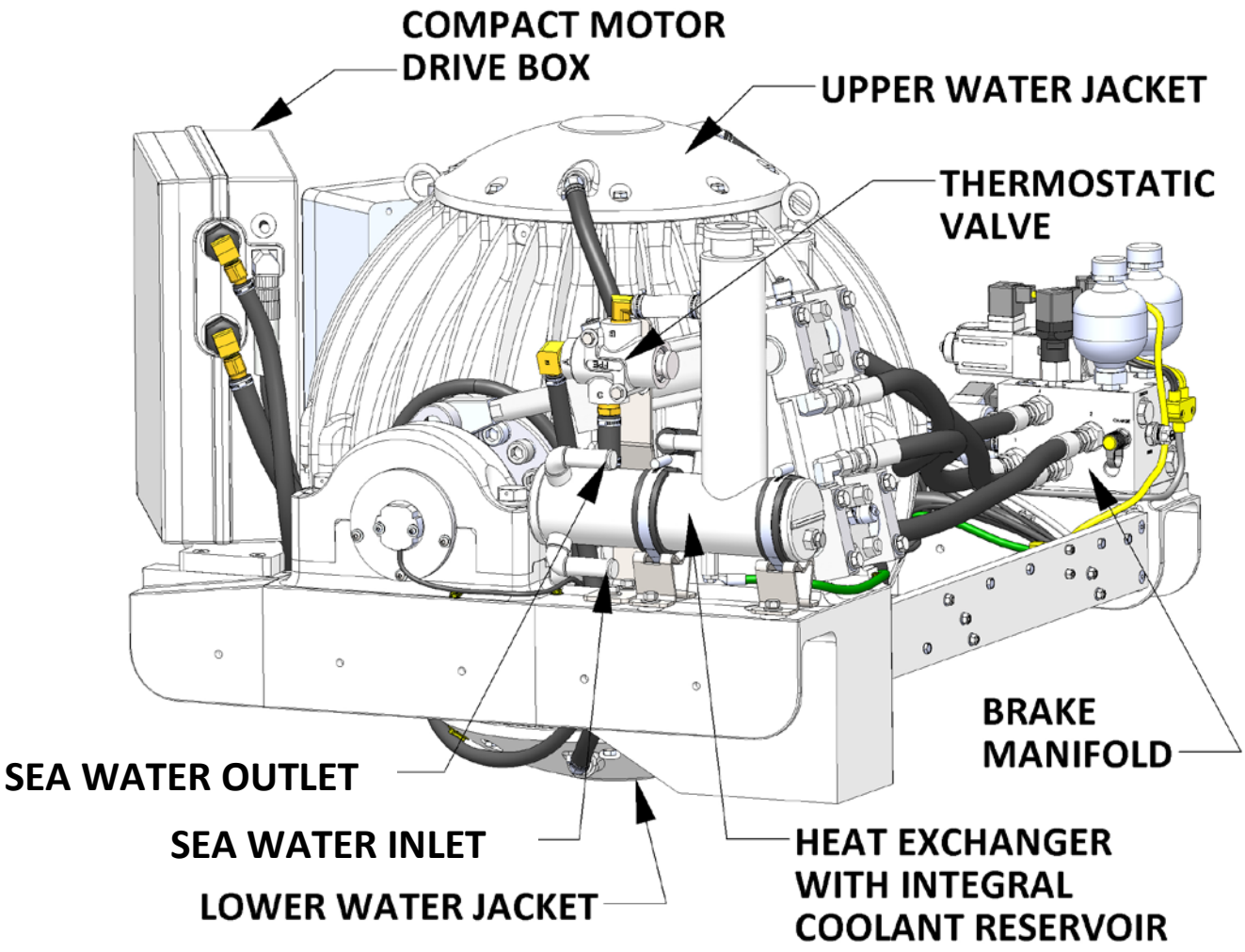

FIGURE 10 – COOLING SYSTEM COMPONENTS

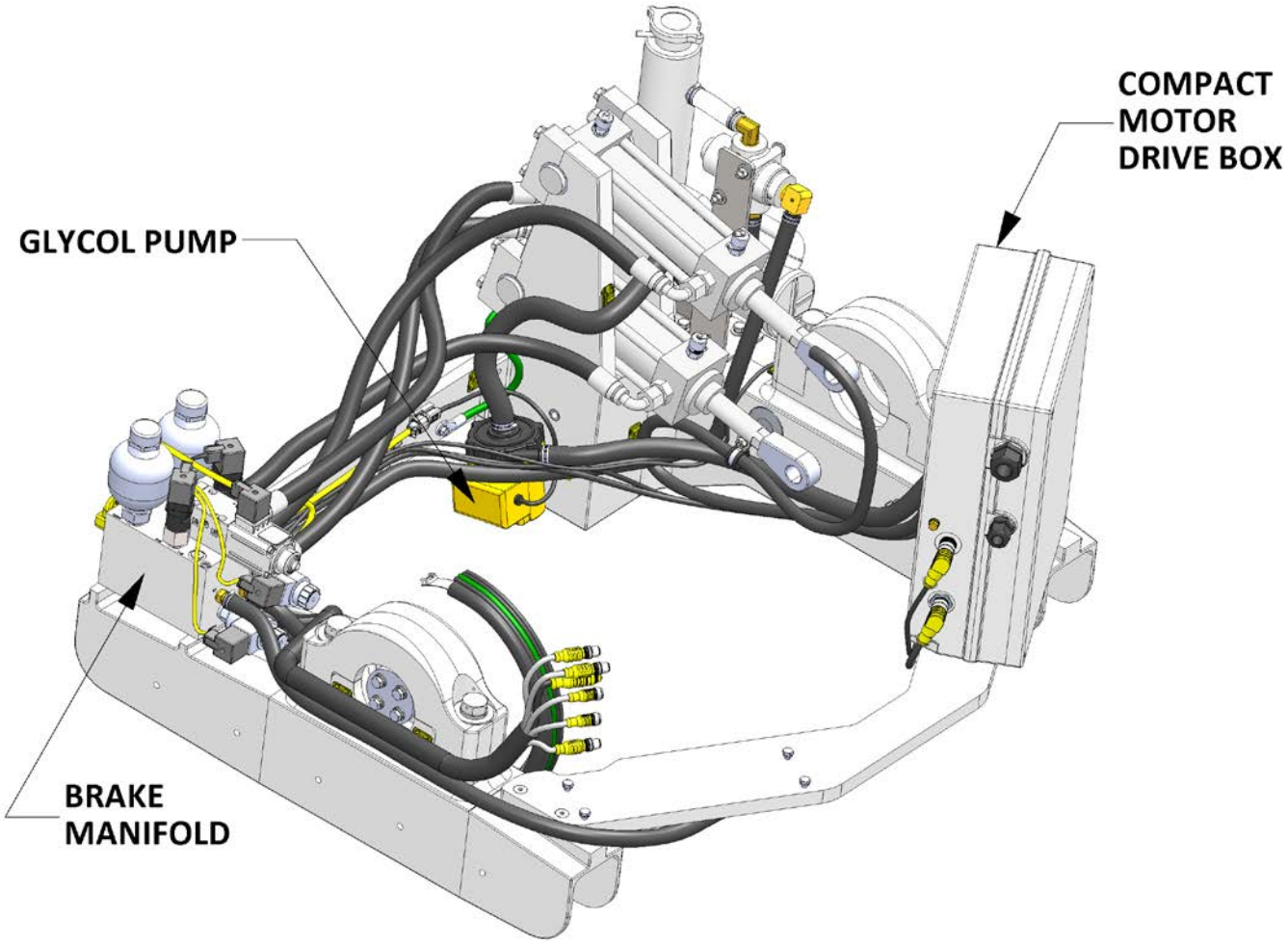

FIGURE 11 – COOLING SYSTEM COMPONENTS (Gyro Enclosure Hidden)

2.0 Introduction

This section describes operation of the Seakeeper Model 8000 Gyro system.

2.1 Start-up

1) Make sure AC and DC power are available.
2) Turn on the boat's DC circuit breaker that supplies power to the Gyro Control Box.
3) Turn on the boat's AC circuit breaker that supplies power to the Motor Drive Box.
4) In most cases, the seawater pump will be wired to turn on when the Gyro Control Box or Motor Drive Box is turned on. However, in some cases the seawater pump is on a separate AC or DC circuit breaker and it is necessary to turn it on.
5) At the Gyro Keypad, verify that the LOCK and STOP lights are on.

6) Verify there are no alarms. Alarms are shown on the RPM Page of the Gyro Display. (Press the Menu button on the Display to change pages.)

2.2 Boat Transit Without Stabilization

When cruising in waves without gyro stabilization, run the gyro at 1000 rpm to lubricate the high speed bearings. This ensures that the lubricant is not pushed out of the ball/raceway load zone over an extended period of time due to the accelerations associated with boat motion. If taken to an extreme, this can lead to a condition known as "false brinelling" which reduces bearing life. It is not necessary to do this when the boat is operating in calm water or gentle swell as the accelerations will be very low and will not cause this condition. The Gyro uses less than 150 watts of AC power in this mode.

1) At the Display, go to the Speed Command page. Set the speed command to 1000 RPM by pressing the DOWN key.

2) Press RUN.

- The Gyro Control Box will automatically turn on the boat's pump that supplies seawater to the Gyro heat exchanger unless the pump is on a separate circuit breaker.
- The RUN light will flash until the flywheel reaches 1000 rpm and then the light will be solid.

2.3 Stabilization

For stabilization at sea or at anchor:

1) Press RUN.

- The Gyro Control Box will automatically turn on the boat's pump that supplies seawater to the Gyro heat exchanger unless the pump is on a separate circuit breaker.
- The flywheel increases speed to 8000 rpm for stabilization. It takes approximately 35-50 minutes for the flywheel to reach 8000 rpm. The RUN light will flash until the flywheel reaches 6000 rpm. Above 6000 rpm the RUN light is solid indicating that stabilization can be activated. The LOCK light will remain lit indicating the Gyro is locked and will not stabilize the roll motion until SEA is pressed.

If it is necessary to shutoff power to the flywheel motor and slow the flywheel for any reason, press STOP and the RUN light will go out indicating the command has been accepted. Verify the SEA light also goes out and the LOCK button illuminates indicating that precession has stopped. It takes approximately 2 hours for the speed to drop from 8000 rpm to 4000 rpm and 4.5+ hours for the speed to drop to zero rpm.

2) Press SEA. (To turn on stabilization, the rpm must be above 6000.)

The LOCK light will go off and the SEA light will go on indicating that the Gyro is precessing and stabilizing the roll motion. SEA starts gradually; it takes 5-10 seconds to reach full effectiveness.

If it is necessary to stop Gyro motion for any reason press the LOCK button. The SEA light will go off and the LOCK light will go on indicating that the Gyro is locked. Never attempt to work on the gyro until the flywheel has stopped spinning. In the event, that the Gyro system has automatically locked the gyro due to an alarm or failure, no attempt should be made to bypass the alarm or automatic lock.

In some cases (such as on anchor at night) the sea condition may be very calm and the Gyro is only required to damp motions from light swell or the wakes from passing boats. In these situations, the operator can run the Gyro at 6400 rpm to reduce noise and power consumption without significantly reducing performance.

When the operator first presses the RUN button on the Keypad, the gyro will start accelerating to full speed (8000 rpm). To reduce the speed to 6400 rpm, go to the Speed Command page on the Gyro Display. Press the UP and DOWN keys to set the desired speed.

2.4 Display Operation

The Display has a number of pages for monitoring the Gyro System and changing system settings. The operator changes pages by pressing the MENU button.

RPM Page

The RPM page displays the gyro speed. The Display will indicate 8.0 KRPM once the Gyro reaches full speed.

The brightness of the Display backlight and Keypad lights can be adjusted with the UP and DOWN keys.

ANGLE Page

The ANGLE page displays the Gyro angle. Generally, the Gyro should stay between ± 50 degrees. During boat turns it may slowly go as high as ± 60 degrees.

BEARING Page

The BEARING page shows the temperature of the bearings. The bearings typically run 20° to 40° C hotter than the ambient sea water depending on the sea state. The rougher the sea state, the higher the bearing loads and the temperatures.

Pressing the UP key replaces the temperatures with the bearing numbers to which the temperatures correspond. Bearing numbers 1 and 2 are in the upper part of the gyro and bearing numbers 3 and 4 are in the lower.

MOTOR Page

The MOTOR page on the Display indicates the temperature and current of the flywheel motor. The motor typically runs 20° C hotter than the bearings. Amp readings represent the DC current command to the flywheel motor, not the AC line current.

Motor current is 22 amps when the motor starts spinning the flywheel. As speeds increases the motor current decreases so the Gyro does not draw more than 3 kW of AC power. Once the flywheel reaches full speed, the current typically drops down to about 6 amps in Lock. In SEA, the Gyro does not draw more than 2.0 kW of AC power.

DRIVE/ENCLOSURE Page

The DRIVE/ENCLOSURE page displays the temperature of the electronics inside the Motor Drive Junction Box and the pressure inside the Gyro's vacuum tight spherical enclosure.

The Drive temperature is typically 15-20° C hotter than the sea water during spin-up and typically 10-15° C hotter than the sea water in LOCK and SEA.

The enclosure pressure is typically between 5 and 30 Torr (or mmHg) at start-up depending on the ambient temperature. During operation, the Enclosure pressure slowly rises.

GYRO/ROLL RATE Page

The GYRO/ROLL RATE page displays the standard deviation of the gyro angle in degrees, the gyro angle rate in degrees/sec and the boat roll rate in degrees/sec. The standard deviation is a measure of movement. For example, as the gyro movement increases the gyro angle standard deviation increases proportionally.

This information is not required to operate the Gyro, but it is useful in assessing performance. For example, with the Gyro in LOCK, the operator can take roll rate readings with the boat in beam seas at zero speed for 5 minutes and get a quantitative measure of the boat's uncontrolled roll motions. If this test is repeated with the Gyro in SEA, the operator knows how much the Gyro reduced the roll motions. A test like this should be conducted for at least 5 minutes which correspond to roughly 100 roll cycles on a typical 15 to 25 ton boat.

RPM Page – Alarms

Alarms and warnings are displayed on the RPM page directly under the flywheel speed.

Alarms are conditions outside normal operation that require the Gyro system to shutdown (LOCK and STOP) for safety. RUN and SEA will not be allowed until all alarm conditions have cleared and the operator acknowledges the alarms. This is done by pressing any key on the Keypad.

The switched Alarm Output on receptacle J9 to CABLE 8 is used to activate suitable visual and audible alarms or to signal the boat's central Alarm & Monitoring System.

Warnings are conditions outside normal operation that do not cause an automatic shutdown and do not trigger alarm outputs on receptacle J9. The operator should investigate the warning until resolved. Warnings will be displayed until acknowledged by the operator. This is done by pressing any key on the Keypad.

The display will switch to the RPM page when an alarm occurs.

SERVICE Page

The SERVICE Page allows the operator access to pages that may be required during servicing or troubleshooting. Press UP or DOWN to select a service page and then press MENU to go that service page. To return to the RPM Page, select 'NEXT' and press MENU.

HISTORY Page

The HISTORY page displays the last 32 alarms and warnings that have occurred. They are in chronological order starting with the most recent. Only one is displayed at a time – press DOWN to view the entire history. Press MENU to return to the SERVICE page.

BRAKE Page

The BRAKE page is used for servicing the gyro's hydraulic brake as discussed in the Maintenance section of this manual. It will display "Service Brake Not Available" any time that the gyro is spinning. Press MENU to return to the SERVICE page.

HOURS Page

The HOURS page displays the number of hours that the gyro motor has run and the number of hours in SEA. Press MENU to return to the SERVICE page.

GLYCOL PUMP Page

The GLYCOL PUMP page is used for servicing the glycol coolant loop. It will display "Service Brake Not Available" any time that the gyro is spinning. Press MENU to return to the SERVICE page.

SEAWATER PUMP Page

The SEAWATER PUMP page is used for testing the seawater pump operation. It will display "Service Brake Not Available" any time that the gyro is spinning. Press MENU to return to the SERVICE page.

VERSION Page

The VERSION Page displays information about the controller firmware. Press MENU to return to the SERVICE page.

Note: The version number may not match the one shown in this picture.

2.5 Normal Shut-Down

1) Verify that no alarms are on the Gyro display. The gyro should be stopped when pulling into port and stabilization is no longer required. This maximizes long term life as it allows the gyro to start the coast down cycle before cooling is shutoff. Once the vessel is secured in the slip and the crew has shut down the generator and engines, the AC and DC breakers that control the gyro should be switched to the OFF position. The gyro will continue to spool down to zero rpm. No cooling is required during this time.

2) Press LOCK. The SEA light will go off and the LOCK light will flash. When the brake is locked, the LOCK light will be solid.

3) Press STOP. The RUN light will go off and the STOP light will flash. (When the flywheel stops spinning, the STOP light will be solid.)

4) The boat's AC and DC circuit breakers that supply power to the gyro and sea water pump can be turned off.

The circuit breakers should be left on as long as possible while the gyro is spinning to remove heat from the gyro. During normal operation, the gyro should be stopped when pulling into port and stabilization is no longer required. This maximizes long term life as it allows the gyro to start the coast down cycle before cooling is shutoff. Once the vessel is secured in the slip and the crew has shut down the generator and engines, the AC and DC breakers that control the gyro should be switched to the OFF position. The gyro will continue to spool down to zero rpm. No cooling is required during this time. Note gyro will take 4.5 hours to coast down to zero rpm from full speed.

3.0 Power Failures

There are two sources of power to the Seakeeper Model 8000 Gyro system:

- 24 Volts DC powers the Gyro Control Box for all the control electronics.
- 208 - 230 Volts AC powers the Motor Drive Box to drive the motor inside the Gyro.

These are supplied on Cables 1 and 2 which are shown on Seakeeper drawing 90149, Cable Block Diagram.

The Motor Drive Junction Box contains hazardous voltage and the cover should not be removed while the flywheel is spinning except by an authorized technician. This high voltage exists even if the flywheel is coasting down and the supply voltage has been shut off.

3.1 +24 VDC Failure

The display will be blank and the keypad lights will be off. Gyro flywheel speed will decrease. The brake is locked (no precession).

- Verify the boat's circuit breaker supplying +24 VDC has not tripped and the AC breaker is On.

  When +24 VDC is restored, the display and the keypad STOP and LOCK lights will be illuminated.

- Press RUN

  The Gyro flywheel speed should begin to increase and the RUN light will blink. When Gyro flywheel speed is above 6000 RPM, stabilization can resume.

- Press SEA

  Stabilization will begin and the SEA light will be on.

230 VAC Failure

If an AC failure longer than thirty seconds occurs, the motor will be disabled and the flywheel speed will start to decrease. The brake is locked and the gyro will stop moving. A "Drive Fault" alarm will occur.

- Verify the boat's circuit breaker supplying 230 VAC to the Motor Drive Box has not tripped.
- Verify that the circuit breaker on the Motor Drive Box has not tripped.

Once 230 VAC is restored:

- Press RUN

  The Gyro flywheel speed should begin to increase. If the flywheel speed does not increase, look for an alarm on the RPM page. If no alarm exists, be sure you have restored 230 VAC.

  When Gyro flywheel speed is above 6000 RPM stabilization can resume.

- Press SEA

  The SEA light will turn on and stabilization will begin.

3.2 230 VAC Fluctuation, Spike or Momentary Failure

If the AC voltage to the Motor Drive Box is outside Seakeeper's specified range (208 – 230 VAC) or if the AC voltage fails for less than thirty seconds, the Motor Drive Box will briefly shut down for protection, but will reset itself and continue operating. In this case a "Drive Fault" alarm will not occur. The operator will not be aware of the power disturbance unless there are 4 power disturbances in 1 hour. In this case, a FREQUENT DRIVE RESET warning will be issued. If this warning occurs, Seakeeper recommends that the cause of this large voltage variation be investigated as it could damage electronic components on the boat.

A brief fluctuation can happen when the generator is unable to regulate its output voltage, particularly when a large AC load is switched on or off. A momentary AC failure also happens during transition from shore power to ship's power.

3.3 Alarms

The Model 8000 Gyro issues an alarm when it detects a malfunction that could cause damage or erratic operation. When an alarm occurs the Gyro switches to Stop and Lock, and an alarm message is shown on the Display at the RPM page. If installed, the audible alarm will sound until the operator presses a key on the Keypad.

The alarm will not clear until the reset condition listed on the table below is achieved and the operator presses a key on the Keypad. The operator can then press RUN and SEA on the Keypad to continue active roll control. The Gyro will not automatically switch to RUN and SEA.

Display Indication	Description	Reset condition	Troubleshooting
BEARING 1 TEMP HIGH	Bearing 1 temperature above 80 °C	Bearing 1 temperature below 55 °C	Refer to Seakeeper Drawing 90149 & verify: (1) boat seawater pump is on, (2) seawater supplied to gyro heat exchanger (3) gyro glycol pump is running, and (4) no glycol leaks
BEARING 2 TEMP HIGH	Bearing 2 temperature above 80 °C	Bearing 2 temperature below 55 °C	Refer to Seakeeper Drawing 90149 & verify: (1) boat seawater pump is on, (2) seawater supplied to gyro heat exchanger (3) gyro glycol pump is running, and (4) no glycol leaks
BEARING 3 TEMP HIGH	Bearing 3 temperature above 80 °C	Bearing 3 temperature below 55 °C	Refer to Seakeeper Drawing 90149 & verify: (1) boat seawater pump is on, (2) seawater supplied to gyro heat exchanger (3) gyro glycol pump is running, and (4) no glycol leaks
BEARING 4 TEMP HIGH	Bearing 4 temperature above 80 °C	Bearing 4 temperature below 55 °C	Refer to Seakeeper Drawing 90149 & verify: (1) boat seawater pump is on, (2) seawater supplied to gyro heat exchanger (3) gyro glycol pump is running, and (4) no glycol leaks
FAULTS ON BEARINGS 1 & 2	'Bearing 1 Sensor Fault' and 'Bearing 2 Sensor Fault'	Bearing 1 temperature sensor working, or bearing 2 temperature sensor working, or both sensors working	Refer to Seakeeper Drawing 90149 Cable Block Diagram & check connector on Gyro Control Box
FAULTS ON BEARINGS 3 & 4	'Bearing 3 Sensor Fault' and 'Bearing 4 Sensor Fault'	Bearing 3 temperature sensor working, or bearing 4 temperature sensor working, or both sensors working	Refer to Seakeeper Drawing 90149 Cable Block Diagram & check connector on Gyro Control Box
MOTOR TEMP HIGH	Motor temperature above 110 °C	Motor temperature below 85 °C	Refer to Seakeeper Drawing 90149 & verify: (1) boat seawater pump is on, (2) seawater supplied to gyro heat exchanger (3) gyro glycol pump is running, and (4) no glycol leaks
DRIVE TEMP HIGH	Temperature of Motor Drive Box electronics above 55 °C	Temperature of Motor Drive Box electronics below 45 °C	Refer to Seakeeper Drawing 90149 & verify: (1) boat seawater pump is on, (2) seawater supplied to gyro heat exchanger (3) gyro glycol pump is running, and (4) no glycol leaks

Display Indication	Description	Reset condition	Troubleshooting
COOLANT PUMP FAULT	Coolant pump current draw less than 0.25 A indicating a bad connection, a bad pump, or a lack of coolant.	Coolant pump current draw more than 0.25 A.	1) Determine if the pump is running by sound or touch. 2) If the pump appears to be running but is noisy, then it is likely that there is air in the glycol loop. Add glycol/water to reservoir. 3) If pump is not running refer to Seakeeper Drawing 90149 Cable Block Diagram and check J2 connector on Gyro Control Box and pump connector on aft brace directly behind pump. 4) Contact Seakeeper distributor for cooling circuit parts and service.
SOLENOID VALVE 1 FAULT	One of the two brake solenoid valves is not operating correctly.	(none)	1) Refer to Seakeeper Drawing 90149 Cable Block Diagram & check connectors on Brake Solenoid Valves and on Gyro Control Box. 2) Contact Seakeeper distributor for brake circuit parts and service.
VALVE 1 CURRENT HIGH	One of the two brake solenoid valves is drawing more than 1.8A indicating a bad connection or a bad valve.	Brake solenoid current draw less than 1.8 A.	1) Refer to Seakeeper Drawing 90149 Cable Block Diagram & check connectors on Brake Solenoid Valves and on Gyro Control Box. 2) Contact Seakeeper distributor for brake circuit parts and service.
SOLENOID VALVE 2 FAULT	One of the two brake solenoid valves is not operating correctly.	(none)	1) Refer to Seakeeper Drawing 90149 Cable Block Diagram & check connectors on Brake Solenoid Valves and on Gyro Control Box. 2) Contact Seakeeper distributor for brake circuit parts and service.
VALVE 2 CURRENT HIGH	One of the two brake solenoid valves is drawing more than 1.8A indicating a bad connection or a bad valve.	Brake solenoid current draw less than 1.8 A.	1) Refer to Seakeeper Drawing 90149 Cable Block Diagram & check connectors on Brake Solenoid Valves and on Gyro Control Box. 2) Contact Seakeeper distributor for brake circuit parts and service.
LOW BRAKE PRESSURE	Hydraulic pressure in brake low	Hydraulic pressure in brake in normal range	1) Check all hydraulic components for leaks. 2) Refer to Seakeeper Drawing 90149 Cable Block Diagram & check connectors on Brake Pressure Switches and on Gyro Control Box. 3) Contact Seakeeper distributor for brake circuit parts and service.
DRIVE FAULT	Fault signal in Motor Drive Box	Motor off for 1 minute	1) Verify boat's AC breaker supplying power to the Gyro is on. 2) Refer to Seakeeper Drawing 90149 Cable Block Diagram & check for AC power. 3) Check motor connector on Motor Drive Box

Display Indication	Description	Reset condition	Troubleshooting
MOTOR FAULT	Flywheel not spinning when RUN commanded.	Motor off for 1 minute	1) Verify boat's AC breaker supplying power to the Gyro is on. 2) Refer to Seakeeper Drawing 90149 Cable Block Diagram & check for AC power. 3) Check connectors on Motor Drive Box.
ANGLE SENSOR FAULT	Gyro angle reading more than 64° from center indicating sensor misalignment, sensor damage, or a bad connection.	Gyro angle reading within 64° of center	1) Refer to Seakeeper Drawing 90149 Cable Block Diagram and check sensor connector on Gyro Control Box. 2) Confirm sensor is still firmly mounted to Gyro.
GYRO MOTION FAULT	Gyro angular rate more than 150 degrees per second	(none)	1) Confirm sensor is still firmly mounted to Gyro. 2) Inspect the brake system, including electrical, mechanical and hydraulic connections.
X RATE SENSOR FAULT	X Rate sensor inside Control Box not working	Functioning sensor	Contact Seakeeper distributor for service
Y RATE SENSOR FAULT	Y Rate sensor inside Control Box not working	Functioning sensor	Contact Seakeeper distributor for service
Z RATE SENSOR FAULT	Z Rate sensor inside Control Box not working	Functioning sensor	Contact Seakeeper distributor for service
X RATE SENSOR HIGH	Invalid reading from X Rate sensor inside Control Box	Valid readings from sensors	Contact Seakeeper distributor for service
Y RATE SENSOR HIGH	Invalid reading from Y Rate sensor inside Control Box	Valid readings from sensors	Contact Seakeeper distributor for service
Z RATE SENSOR HIGH	Invalid reading from Z Rate sensor inside Control Box	Valid readings from sensors	Contact Seakeeper distributor for service
VERTICAL ACCEL HIGH	Vertical boat acceleration above 2 g	Vertical boat accelerations below 2g for 1 min	If sea condition is this severe, operator should slow down and/or alter course to reduce boat motion.
LATERAL ACCEL HIGH	Lateral boat acceleration above 1 g	Lateral boat accelerations below 1g for 1 minute	If sea condition is this severe, operator should slow down and/or alter course to reduce boat motion.
DISPLAY FAULT	Display not communicating with Control Box	Display operational for 1 minute	Refer to Seakeeper Drawing 90149 Cable Block Diagram & check Display connector on Serial Comms Box.
KEYPAD FAULT	Keypad not communicating with Control Box	Display operational for 1 minute	Refer to Seakeeper Drawing 90149 Cable Block Diagram & check Keypad connector on Serial Comms Box.
INPUT POWER HIGH	DC power to Control Box above 32V	DC power between 17V and 32V	Verify DC input power is between 17V and 32V; excessive load

Display Indication	Description	Reset condition	Troubleshooting
INPUT POWER LOW	DC power to Control Box below 17V	DC power between 17V and 32V	Verify DC input power is between 17V and 32V; excessive load
CONTROL POWER HIGH	DC power to brake and coolant pump above 32V	DC control power between 17V and 32V	Verify DC input power is between 17V and 32V; excessive load
CONTROL POWER HIGH	DC power to brake and coolant pump below 17V	DC control power between 17V and 32V	Verify DC input power is between 17V and 32V; excessive load
SENSOR POWER HIGH	DC power from Control Box to Gyro Angle Sensor and Motor Drive Box above 5.25 V.	DC power from Control Box to between 4.75 V and 5.25 V.	Inspect gyro angle sensor for damage
SENSOR POWER LOW	DC power from Control Box to Gyro Angle Sensor and Motor Drive Box below 4.75 V.	DC power from Control Box to between 4.75 V and 5.25 V.	Inspect gyro angle sensor for damage
SPEED SENSOR FAULT	Three sensors inside the gyro are used for speed measurement and motor operation. One inoperable sensor will cause this alarm.	All three sensors working or the flywheel not spinning.	1) Refer to Seakeeper Drawing 90149 Cable Block Diagram & check connector on Gyro Motor Drive Box. 2) Contact Seakeeper distributor for service.
MOTOR OVERSPEED	Motor speed is over 9.0 KRPM.	Motor speed below 9.0 KRPM.	1) Check connectors on Motor Drive Box and Gyro Control Box. 2) Contact Seakeeper distributor for service.

3.4 Warnings

The Model 8000 Gyro issues a warning when it detects a malfunction that is not hazardous (but still should be corrected). Warning messages are shown on the Display at the RPM page. The warning message will clear after the reset condition listed on the table below is achieved and the operator presses a key on the Keypad.

Warnings

Display Indication	Description	Reset condition	Troubleshooting
BEARING 1 SENSOR FAULT	Bad sensor or bad connection	Functioning sensor	Refer to Seakeeper Drawing 90149 Cable Block Diagram & check connector on Gyro Control Box
BEARING 2 SENSOR FAULT	Bad sensor or bad connection	Functioning sensor	Refer to Seakeeper Drawing 90149 Cable Block Diagram & check connector on Gyro Control Box
BEARING 3 SENSOR FAULT	Bad sensor or bad connection	Functioning sensor	Refer to Seakeeper Drawing 90149 Cable Block Diagram & check connector on Gyro Control Box
BEARING 4 SENSOR FAULT	Bad sensor or bad connection	Functioning sensor	Refer to Seakeeper Drawing 90149 Cable Block Diagram & check connector on Gyro Control Box
MOTOR SENSOR FAULT	Bad sensor or bad connection	Functioning sensor	Refer to Seakeeper Drawing 90149 Cable Block Diagram & check connector on Gyro Control Box
DRIVE SENSOR FAULT	Bad sensor or bad connection	Functioning sensor	Refer to Seakeeper Drawing 90149 Cable Block Diagram & check connector on Gyro Control Box
X ACCEL SENSOR FAULT	Bad sensor or bad connection	Functioning sensor	Contact Seakeeper distributor for service
Y ACCEL SENSOR FAULT	Bad sensor or bad connection	Functioning sensor	Contact Seakeeper distributor for service
Z ACCEL SENSOR FAULT	Bad sensor or bad connection	Functioning sensor	Contact Seakeeper distributor for service
VACUUM LEAK	Enclosure pressure more than 50 torr	Enclosure pressure less than 45 torr	Contact Seakeeper distributor for service
VACUUM SENSOR FAULT	Bad sensor or bad connection	Functioning sensor	Refer to Seakeeper Drawing 90149 Cable Block Diagram & check connector on Gyro Control Box
FREQUENT DRIVE RESET	The Gyro will operate through AC power failures less than 30 seconds, e.g. ship to shore power transfers or voltage dips due to switching large generator loads. Four AC power disturbances in one hour produce this warning.	(none)	Verify AC power source is stable.

3.5 Alarm and Warning History

The History page on the Display shows the 32 most recent alarms and warnings. The alarms are in chronological order starting with the most recent.

1) At the Display, go to SERVICE page. Select HISTORY by pressing DOWN key. Press MENU.

2) View the alarms and warnings in the history by pressing UP and DOWN.

4.0 MAINTENANCE

The gyro system is designed to require as little maintenance as possible. However, since the system is comprised of mechanical and electrical components that operate in a marine environment, some periodic inspections and maintenance are recommended. Seakeeper recommends an annual inspection and a 2000 hr service interval to keep the gyro running trouble-free.

If the gyro is installed in a wet space, efforts should be made to keep gyro free of salt residue from either condensation or direct exposure to salt spray. If exposed, a regular wipe down with mild soap and water with a rinse will help limit corrosion and keep the gyro assembly in good cosmetic condition. Refer to Service Bulletin 90106 for details.

4.1 REFERENCES

- Seakeeper 90025, Service Bulletin, Brake Bleeding
- Seakeeper 90026, Service Bulletin, Gyro Paint Information
- Seakeeper 90083, Service Bulletin, Gimbal Angle Sensor Replacement and Calibration
- Seakeeper 90106, Service Bulletin, Fresh Water Rinse Notice
- Seakeeper 90133, Service Bulletin, Gyro Annual Inspection Instructions
- Seakeeper 90134, Service Bulletin, Gyro 2000 Hour Service Instructions

4.2 PRECAUTIONS

- **Gyro Hydraulic Hand Pump Kit, Part No. 10384, is required for servicing the brake. Pressure should NOT be relieved unless this tool is available.**
- **Never charge the nitrogen charged accumulators with oxygen or shop air!**

4.3 PARTS AND SPECIAL TOOLS

Part No.	Description	Comments
10384	Gyro Hydraulic Hand Pump Kit	Required for all brake service tasks.
10449	Brake Bushing Replacement Tool Kit	Contains tools used for changing bushings on all model gyros.
10512	Model 7000 Gyro Raw Water Fitting Kit	Contains bronze fittings for seawater ports in heat exchanger. Used on all M7000 gyros and on M7000A gyros with serial numbers of G269 and below.
10606	Model 7000/Model 7000A Gyro Hydraulic Brake Parts Kit	Contains parts required for 2000 hour hydraulic brake service.

4.4 SCHEDULED MAINTENANCE TABLE

- The following pages contain the scheduled maintenance table organized by systems: Mechanical, Hydraulic, Cooling, and Electrical.

SYSTEM / COMPONENT	TASK PER SERVICE BULLETIN 90133	INTERVAL	PARTS / SPECIAL TOOLS
Mechanical / Corrosion	Inspect unit for severely corroded areas and clean and touch up with paint. See Service Bulletin 90026.	Annual	
Hydraulic / Hoses	Check for cracks or chafing. If chafing found, reposition hose to provide clearance around hose. If chafing is severe, replace hose. Charge system per Service Bulletin 90025.	Annual	Hydraulic hand pump kit
Cooling / Zinc Anode	Replace zinc anode as needed.	With other zincs or Annual	
Cooling / Hoses	Check for cracks or chafing. If damaged, replace hose. Fill cooling system and purge air.	Annual	Anti-freeze
Cooling / Seawater side	Inspect heat exchanger for signs of leaks.	With other zincs or Annual	
Cooling / Seawater side	Fill with environmentally safe, marine anti-freeze during winter or periods of in-operation.	Winter	
Electrical / Connectors	Inspect all connectors for corrosion, clean as necessary, and treat with corrosion inhibitor.	Annual	
Electrical / Grounds	Inspect all ground points for corrosion, clean as necessary, and treat with corrosion inhibitor.	Annual	
Electrical / Gimbal Angle Sensor	Check calibration of sensor. See Service Bulletin 90083 for instructions.	Annual	
Electrical / Cables	Check all cables for cracks or chafing.	Annual	
Electrical / Power Input	Check for seal at cable glands.	Annual	
Electrical / Motor Power	Check integrity of motor power cable jacket.	Annual	

SYSTEM / COMPONENT	TASK PER SERVICE BULLETIN 90134	INTERVAL	PARTS / SPECIAL TOOLS
Mechanical / Hydraulic Brake	Replace brake bushings, hydraulic accumulators and check valves, and flush hydraulic oil.	2000 hrs	Hydraulic hand pump kit, Brake bushing replacement tool kit, Hydraulic brake parts kit
Cooling / System	Cooling system flush	2000 hrs	Fill reservoir or jug and tubing, antifreeze
Electrical / Motor Drive	Check internal circulator fan inside Motor Drive J-Box.	2000 hrs	

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5.0 WARRANTY, LIMITATION OF LIABILITY, PROPERTY RIGHTS

5.1 WARRANTY

Seakeeper warrants that the Goods sold hereunder are free from defects in material and workmanship for a period of 24 months of operation from the date of delivery to the End User or 36 months from the date of manufacture, whichever event occurs first. This express warranty is in lieu of and excludes all other warranties, express or implied, by operation or law or otherwise including THE WARRANTY OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE (WHETHER KNOWN TO SEAKEEPER OR NOT), all other such warranties being hereby expressly disclaimed by Seakeeper and waived by Buyer/User.

Written notice of claimed defects shall have been given to Seakeeper within the Warranty Period, and within thirty (30) days from the date any such defect is first discovered. The Goods or parts claimed to be defective must be returned to Seakeeper, accompanied by a Return Material Authorization (RMA) issued by Seakeeper's facility responsible for supplying Goods, with transportation prepaid by Buyer/User, with written specifications of the claimed defect.

If a warranty claim is valid, Seakeeper shall pay reasonable one-way costs of transportation of the defective Goods from either the original destination or the location where defect occurred, whichever is closest to Seakeeper's facility.

Under no circumstances shall Seakeeper be liable for removal of Seakeeper's Goods from Buyer's/User’s equipment or re-installation into Buyer's/User’s equipment. No person including any agent, distributor, or representative of Seakeeper is authorized to make any representation or warranty on behalf of Seakeeper concerning any Goods manufactured by Seakeeper.

5.2 LIMITATION OF LIABILITY

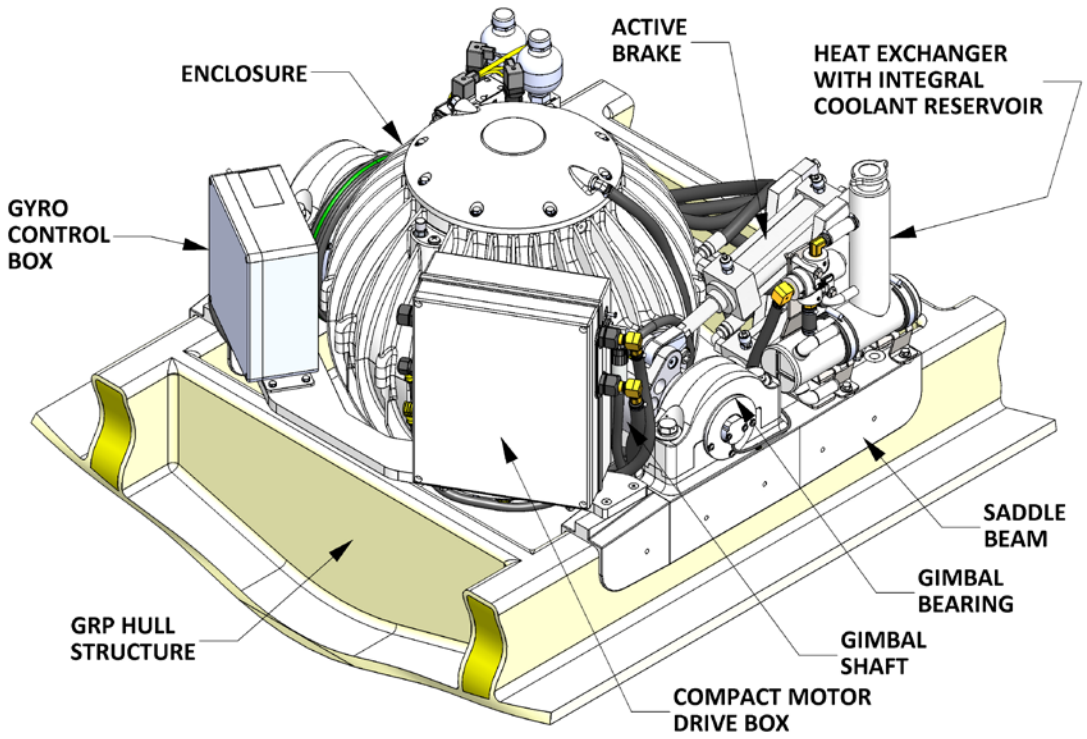
NOTWITHSTANDING ANYTHING TO THE CONTRARY, SEAKEEPER SHALL NOT BE LIABLE FOR ANY SPECIAL, INCIDENTAL, INDIRECT OR CONSEQUENTIAL DAMAGES INCLUDING BUT NOT LIMITED TO LOST PROFITS ARISING OUT OF THE PERFORMANCE, DELAYED PERFORMANCE OR BREACH OF PERFORMANCE OF THIS ORDER REGARDLESS WHETHER SUCH LIABILITY BE CLAIMED IN CONTRACT, EQUITY, TORT OR OTHERWISE. SEAKEEPER'S OBLIGATION IS LIMITED SOLELY TO REPAIRING OR REPLACING (AT ITS OPTION AND AS SET FORTH IN SECTION 5), AT ITS APPROVED REPAIR FACILITY, ANY GOODS OR PARTS WHICH PROVE TO SEAKEEPER'S SATISFACTION TO BE DEFECTIVE AS A RESULT OF DEFECTIVE MATERIALS OR WORKMANSHIP, IN ACCORDANCE WITH SEAKEEPER'S STATED WARRANTY. IN NO EVENT SHALL SEAKEEPER'S LIABILITY EXCEED THE TOTAL PURCHASE PRICE SET FORTH IN THIS ORDER.

5.3 PROPERTY RIGHTS

Except where otherwise expressly agreed, all patterns, tools, jigs and fixtures, drawings, designs, software and other materials and data developed, fabricated by Seakeeper shall be and shall remain Seakeeper's property. Except as specifically provided for in the order, Buyer shall have no right in any technical data, Intellectual Property Rights, and computer software associated with the order. Buyer shall not use or permit the use of the Goods that in any way could result in the disclosure of Seakeeper's proprietary information.

Model 8000 Gyro Specifications & Summary

Rated RPM	8000 RPM
Angular Momentum at Rated RPM	8,000 N-M-S
Anti-Rolling Torque at Rated RPM	17,143 N-M
Spool-up Time to Rated RPM	35 Minutes
Spool-up Time to Stabilization (70% Rated RPM)	20 Minutes
Spool-up Power	
AC Motor	3000 Watts Maximum
DC Control	240 Watts
Operating Power	
AC Motor (sea state dependent)	1500-2000 Watts
DC Control	240 Watts
AC Input Voltage	208-230 VAC, 50/60 Hz, Single Phase
DC Input Voltage	24 VDC @ 10 Amps
Ambient Sea Water Supply to Gyro Heat Exchanger	15.1 liters/min (4 gal/min)
Maximum Ambient Air Temperature	60 Deg C (122 Deg F)
Weight	549 Kg (1210 Lbs)



Arrangement

The Model 8000 Gyro System consists of the Gyro unit, Motor Drive Box, Gyro Control Box, Cooling Loop Components, Keypad, Display, and Cables (for cables not supplied by Seakeeper, refer to Seakeeper Drawing 90149).

Installation Location

The Gyro is a torque device and does not have to be installed in a specific hull location or on the centerline. However, the Gyro should not be installed forward of the longitudinal center of gravity in a planing vessel where the vertical accelerations exceed ±1 G.

Mounting Dimensions

See Seakeeper Installation Details Drawing 90123.

Loads

The installer is responsible for designing the foundation to which the Gyro's saddle beams are attached and for ensuring that this foundation can safely transfer the concentrated Gyro loads from the saddle beams to the adjacent hull structure. Loads that the Gyro imposes on the saddle beams are explained on page 6 of Seakeeper Drawing 90123.

Cooling

The Gyro bearings, Motor Drive Box, and hydraulic manifold are cooled by a closed water / glycol mix cooling loop that incorporates a sea water heat exchanger. The installer is responsible for providing 15.1 lpm (4 gpm) minimum and 30.3 lpm (8 gpm) maximum raw water at ambient sea temperature and 1.4 Bar (20 psi) maximum sea water pressure to the heat exchanger. The ambient air temperature in the compartment in which the Motor Drive Box is mounted should not exceed 60^{o} C.

Electrical

The installer is responsible for supplying 208-230 VAC, 50/60 Hz, single phase power on a 20A service to the Motor Drive Box and 24 VDC @ 10A service to the Gyro Control Box. Separate circuit breakers should be used for each Motor Drive Box in multiple gyro installations. Similarly, separate circuit breakers should be used for each Gyro Control Box in multiple gyro installations.

Operator Controls

A Keypad and small Display are provided to start, operate, monitor, and shutdown the Gyro.

Performance

Gyro reduction of boat roll is a function of the boat's displacement, transverse metacentric height (GM_T) and hull damping as well as the operating conditions (speed and heading with respect to waves) and sea state. The Gyro controller regulates the active hydraulic brake to ensure the Gyro's anti-roll torque is maximized irrespective of hull characteristics or operating conditions. In heavy seas, the Gyro rpm may droop when the required power exceeds 2000 watts – this is normal and is designed to limit large power demands at the expense of a small loss of performance

Alarm and Monitoring

Sensors, alarms and shutdowns are provided to allow unattended operation. Sensors measure flywheel bearing temperatures, motor and drive temperatures, vacuum pressure, gimbal angle, brake pressure, and ship motion. The Gyro controller sends sensor values and alarm information to the display and also locks the brake and shuts down the motor drive in the event of an alarm condition. Gyro operating history during faults or alarms is recorded in the controller's memory for subsequent recall if service is needed.

Safety

The brake automatically locks the Gyro so it cannot generate excessive anti-rolling torque loads in the event of a system fault or alarm, loss of electrical power or loss of brake pressure. The brake can be locked from the Keypad or by shutting off power locally at the Motor Drive Box or Gyro Control Box.

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