



COURSE SETTER 21 AUTOMATIC PILOT
PILOT HOUSE CONTROL
INSTALLATION, OPERATION AND
MAINTENANCE MANUAL

098-0307

Manufactured Under
U.S. Patent No. 3,436,635
Other Patents Pending



Benmar
wavy underline

Division of Cetec Corporation
3000 West Warner Avenue
Santa Ana, California 92704

March 1978

TABLE OF CONTENTS

SECTION	DESCRIPTION	PAGE
I	INTRODUCTION	1-1
II	SPECIFICATIONS	2-1
III	OPERATING INSTRUCTIONS	3-1
	3-1 General	3-1
	3-2 Operating the Automatic Pilot	3-1
	3-3 Dodging	3-4
	3-4 Power Steering	3-4
IV	DESCRIPTION	4-1
	4-1 General	4-1
	4-2 System Description	4-2
	4-3 System Operation	4-4
	4-4 Controls	4-5
V	INSTALLATION	5-1
	5-1 General	5-1
	5-2 Unpacking and Inspection	5-1
	5-3 Installation Accessories	5-2
	5-4 Typical Installation	5-2
	5-5 Mounting Location Restrictions	5-3
	5-6 Measurement of Boat Characteristics for Standard or "S" Power Units Only	5-3
	5-7 Pilot House Control Unit Installation	5-5
	5-8 Dockside Checkout for Standard or "S" Power Unit Only	5-7
	5-9 Dockside Checkout for Hydraulic Power Units	5-14
	5-10 Operational Checkout (Underway)	5-16

TABLE OF CONTENTS

SECTION	DESCRIPTION	PAGE
VI	SERVICING AND MAINTENANCE	6-1
	6-1 General	6-1
	6-2 Fuse Replacement	6-1
	6-3 Lamp Replacement	6-1
	6-4 Compass Maintenance	6-1
VII	CIRCUIT DESCRIPTION	7-1
	7-1 General	7-1
	7-2 Pilot House Control Unit (PHC)	7-1
VIII	TROUBLESHOOTING	8-1
	8-1 General	8-1
	8-2 Common New Installation Problems	8-1
	8-3 Troubleshooting	8-3
	8-4 Compass/Compass Lamp Installation/ Setup	8-3
	8-5 Remote Handswitch Circuit Logic	8-5

LIST OF TABLES

TABLE	DESCRIPTION	PAGE
8-1	Test Voltages	8-6

LIST OF ILLUSTRATIONS

FIGURE	DESCRIPTION	PAGE
1-1	Benmar Course Setter 21 Pilot House Control	1-1
3-1	Controls of Pilot House Control Unit	3-3
3-2	Remote Handswitch	3-5
4-1	CS21 Pilot House Control	4-1
4-2	Block Diagram, Course Setter 21 Family of Autopilots	4-4
5-1	Course Setter 21 PHC, Typical Installation	5-2
5-2	Measurement of Helm Torque	5-4
5-3	Compass Expansion Chamber	5-6
5-4	Gain Set Pot, Phase Switch and Gain Set Switch Location	5-8
5-5	Nomograph #1. Determination of Desired Total Fast Slew Helm Travel	5-11
5-6	Turn Response Diagram	5-17
6-1	Dial Lamp, Compass Lamp and Rotating Contacts	6-2
7-1	Circuit Board Location	7-3
8-1	PHC Fault Isolation Chart	8-7

SECTION I

INTRODUCTION

The Benmar Course Setter 21 Family of Automatic Pilots are manufactured by Cetec Corporation, Benmar Division, Santa Ana, California. The Course Setter 21 is a non-hunting, proportional rate marine autopilot system. It is a reliable and effective autopilot, easy to install and simple to operate. The Pilot House Control unit, containing the operator controls, is designed to blend with the styling of a modern vessel. Course selection is simplified to setting a dial. A Sea State Control allows adjustment of the pilot sea sensitivity.

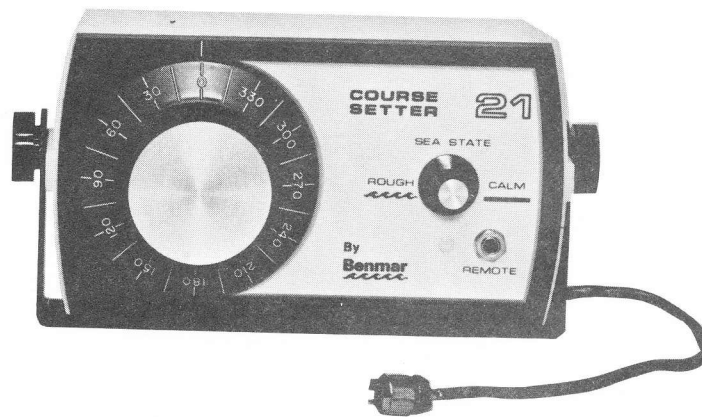


Figure 1-1
Benmar Course Setter 21 Pilot House Control

SECTION II
SPECIFICATIONS

OPERATING TEMPERATURE RANGE	0° TO 165° F.
DIAL CALIBRATION	$\pm 10^{\circ}$ HEADING
COURSE ERROR SENSITIVITY	.1°
COURSE ERROR (CALM TO SLIGHT SEA)	
AVERAGE	$\pm .5^{\circ}$
INSTANTANEOUS	$\pm 5^{\circ}$
PART NUMBER	000-0113
WEIGHT	3.8 POUNDS (1.7kg)
HEIGHT	6.3 INCHES (16.0cm)
WIDTH	11.5 INCHES (29.2cm)
DEPTH	5.6 INCHES (14.2cm)

SECTION III

OPERATING INSTRUCTIONS

3-1 GENERAL

The Course Setter 21 Automatic Pilot is operated by two controls on the Pilot House Control (PHC) unit and an ON/OFF switch or a push-pull clutch control. The ON/OFF switch or clutch control activates the autopilot. The large dial on the PHC is set to the desired course and the remaining control on the PHC is adjusted according to sea conditions.

3-2 OPERATING THE AUTOMATIC PILOT

Before operating the autopilot, read the following warning and caution.

WARNING

DO NOT ENGAGE OR OPERATE THE AUTOPILOT UNDER THE FOLLOWING CONDITIONS:

1. NEAR OR WHILE PASSING UNDER STEEL BRIDGES OR IN CLOSE PROXIMITY TO LARGE STEEL VESSELS. MAGNETIC INFLUENCES CREATED BY LARGE STEEL STRUCTURES MAY CAUSE AN INADVERTENT COURSE CHANGE.
2. WHILE IN HEAVY TRAFFIC OR IN NARROW CHANNELS.
3. IN SOME CASES WHILE KEYING A RADIO TRANSMITTER. TRANSMITTING WHILE UNDER AUTOPILOT CONTROL MAY CAUSE MOMENTARY ERRATIC AUTOPILOT OPERATION. THIS IS MOST NOTICEABLE WHEN THE RADIO TRANSMITTER OR ANTENNA IS LOCATED IN CLOSE PROXIMITY TO THE AUTOPILOT AND IS NOT PROPERLY LOADED INTO THE ANTENNA. RADIATION

OCCURS OUT OF THE RADIO, ANTENNA FEED-LINE OR INTO THE POWER LINES. BEFORE TRANSMITTING, INSURE THAT AN INADVERT-ENT COURSE CHANGE WILL CREATE NO DANGER.

CAUTION

DO NOT PLACE MAGNETIC ITEMS SUCH AS PORTABLE RADIOS, FLASHLITES, KEYS, ETC. NEAR THE PHC. MAGNETIC MATERIALS MAY CAUSE SUDDEN COURSE CHANGES OR ERRATIC OPERATION.

BECAUSE THE AUTOPILOT USES AN UNCOMPEN-SATED COMPASS, THE COURSE DIAL DEGREE MARKINGS MAY NOT AGREE WITH THE SHIP'S COMPASS ON SOME COURSES. THEREFORE, THE COURSE DIAL MARKINGS SHOULD BE USED FOR APPROXIMATE COURSE SETTING ONLY. ALL FINAL COURSE SETTINGS SHOULD BE MADE WITH REFERENCE TO THE SHIP'S COMPASS.

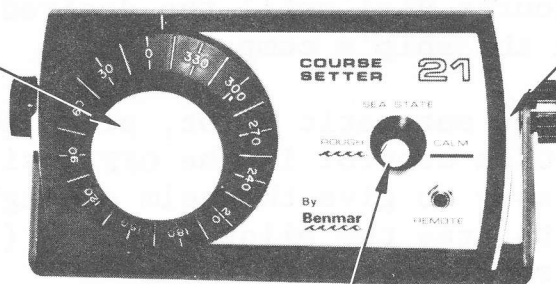
Before engaging the pilot, steer the vessel to the desired course and "steady up" on the heading. Refer to Figure 3-1 and operate the autopilot as follows:

- a. Set the PHC Course Dial to agree with the ship's compass. (Do not pull the knob out.)
- b. Engage the pilot by placing the ON/OFF switch in the "ON" position or by actuating the clutch control. There will be a 3 second delay (approximately) before the Power Unit activates.

If there is a slight change in the vessel's heading, adjust the Course Dial slowly until the desired course is indicated on the ship's compass.

If the PHC Course Dial calibration has been modified, there may be a major change in the vessel's heading. To re-calibrate the Course Dial to the ship's compass, pull the Course Dial straight out away from the panel,

COURSE DIAL



TO OPEN CASE, DEPRESS
RETAINING PIN IN HOLE
TO RELEASE CATCH

SEA STATE CONTROL

Figure 3-1
Controls of Pilot House Control Unit

being careful not to rotate it while pulling, and rotate the Course Dial to the heading indicated on the ship's compass and release.

- c. Setting of the SEA STATE control is not critical and will not need much attention. The SEA STATE control will normally be kept at CALM except in heavy seas or at other times when it is desirable to reduce the amount of helm action.

Over-correcting by the pilot can also be reduced by turning the SEA STATE control towards ROUGH. Operation of the pilot with the SEA STATE control near the ROUGH position in calm seas will greatly reduce autopilot response.

- d. Heading changes can be performed without disengaging the automatic pilot by adjusting the Course Dial to the new heading. Do not pull the Course Dial out when making course changes. Do not rotate the dial more than 60° at a time. Allow the vessel to catch up between dial adjustments. When making heading changes at high speeds, it is best to slowly rotate the Course Dial to limit the turn rate to be a comfortable amount.

Adjust the Course Dial until the desired course is indicated on the ship's compass.

- e. To turn off the automatic pilot, place the ON/OFF switch or clutch control in the OFF position. It may be necessary to give the helm a slight turn to either side to free the pilot's clutch (standard and "S" Power Unit).

3-3 DODGING

Dodging other vessels or objects can be performed without disengaging the autopilot by using the Course Dial as a steering wheel. After the dodging maneuver, simply adjust the dial to the original heading.

If a Remote Handswitch assembly, shown in Figure 3-2, is incorporated in the system, a dodging maneuver can be performed without changing the Course Dial. This is accomplished by depressing either the LEFT (red) or RIGHT (green) push button with the selector switch in the AUTO position. The Power Unit continually drives the rudder at a maximum slew rate while the LEFT or RIGHT push button is depressed. Therefore, the push buttons should be held down only long enough to provide enough rudder to be assured of completely dodging the obstacle. When the buttons are released, the pilot will return the vessel to the original heading. If a considerable amount of rudder has been applied to dodge the obstacle (there is a natural tendency to over apply rudder due to the delay in response of most boats), the return to course may take longer than desired. The opposite button should be depressed to quickly bring the rudder back thru midships and start the boat back toward its original course.

3-4 POWER STEERING

If the Remote Handswitch assembly is incorporated in the system, power steering is accomplished as follows:

- a. Set the selector switch to the PWR position.

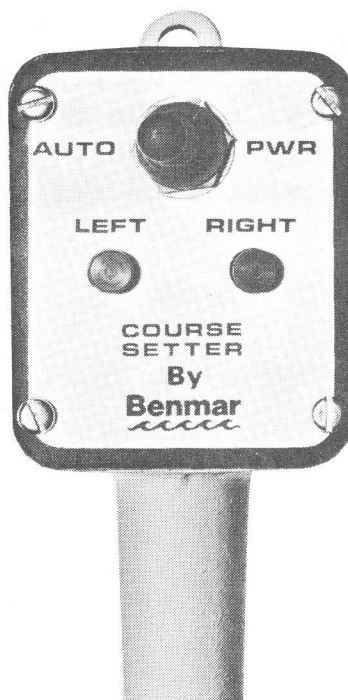


Figure 3-2
Remote Handswitch

- b. Depress the LEFT (red) push button switch to power steer to the left (port). Depress the RIGHT (green) push button switch to power steer to the right (starboard).
- c. When the push button is released the rudder will maintain its position. To return the vessel to a steady course, the opposite push button must be depressed to drive the rudder to the amidships position.

CAUTION

DO NOT SET SELECTOR SWITCH TO AUTO POSITION UNTIL PHC COURSE DIAL IS SET TO CORRESPOND WITH SHIP'S COMPASS (THE NEW HEADING), OTHERWISE THE AUTOMATIC PILOT WILL RETURN THE VESSEL TO THE ORIGINAL HEADING.

- d. When the new heading is determined after the power steering maneuvers, set the Course Dial to correspond with the ship's compass. Set the selector switch to AUTO position to return vessel to autopilot operation.

SECTION IV

DESCRIPTION

4-1 GENERAL

The standard Course Setter 21 Pilot House Control (PHC) is shown in Figure 4-1. The Pilot House Control unit contains a compass, the system controls, and the associated electronic circuitry. The Power Unit contains the motor that drives the vessel's steering system and the motor control circuitry. The PHC unit and the Power Unit are electrically interconnected through a pre-wired interconnecting cable. An ON/OFF control must also be installed near the PHC.

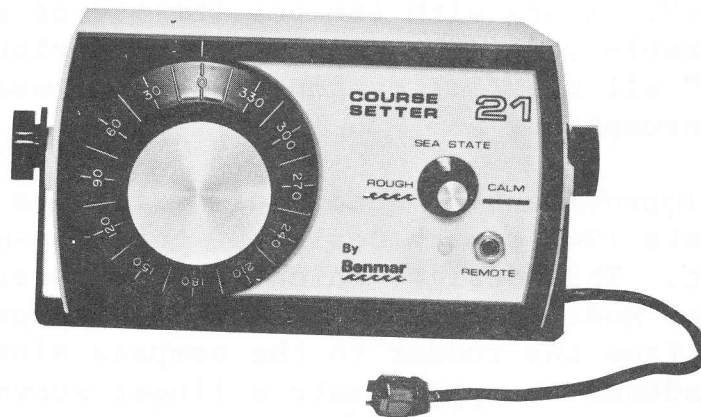


Figure 4-1
CS21 Pilot House Control

SYSTEM DESCRIPTION

The Course Setter 21 Family of Automatic Pilots incorporates some features which, although common for many years in industrial and aerospace control systems, are new to the marine industry. The following paragraph will attempt to describe in simple terms these features and the reason for their inclusion.

The development of marine autopilots has progressed more from necessity than through the analytical processes as were used in the development of aircraft and missile steering systems. The original marine autopilots of the 1930's used a compass which contained a switch or whisker contact. This switch closure was used through the use of a vacuum tube and a series of relays to control the steering motor. The motor was driven in one direction with the contacts closed and in the other direction when they opened. This would cause the vessel to cycle back and forth across the true heading; hence, the descriptive name "Hunting Autopilot". Along with the possibility of a rather uncomfortable ride, the hunting pilot obviously was "working" all the time causing excessive wear and power consumption.

A great improvement in autopilot design was developed in the late 1940's with design of the "Non-Hunting" autopilot. This design, which was the forerunner of the Benmar Model 14 and 16 pilots, uses a proportional feedback from the rudder to the compass along with a fixed deadband to approximate a linear servo system. The advantage is that the driving motor is never started until the boat is off course a certain number of degrees ($1/2$ the deadband) and then the motor drives the rudder to a predetermined angle which is a function of the course error. On some present day systems, the mechanical feedback from the rudder to the compass is replaced by an electrical signal using a potentiometer. It is then possible to vary the "rudder ratio" or number of rudder degrees for a given course error electrically. This is done to aid in stabilizing the operation of the vessel over wide variations in speed.

This is all very fine, except that the pilots described above do not simulate the way the average helmsman steers his vessel. One would not, for example, wait until the course heading error was, say, 3 degrees then quickly move the helm to provide a rudder change of 2 degrees in the direction to correct the error. Nor would one then leave the helm at this point until the course was corrected and then quickly return the helm to center.

The normal reaction would be to initiate movement of the helm the instant a course error was detected. This could cause a great deal of work for the helmsman, except that experience shows one that if the rate at which the helm is moved is made proportional to the detected course error, very little effort is required for most corrections. Only when large errors in course are detected is it necessary to quickly move the helm through a large angle, and since the experienced helmsman is continually correcting the small errors, this seldom occurs.

From the preceding discussion, it can be seen that three things are required to properly steer a vessel: (1) instantaneous detection of course error (and therefore no deadband); (2) a helm correction proportional to the course error and equally important (3) a rate of change of helm correction proportional to the course error.

Without number 3, items 1 and 2 would produce a "hunting pilot" which would be a giant step backwards. But, with the inclusion of the rate of change requirement, an efficient control system which is "on the job" at all times can be designed. It should also be noted that for an experienced helmsman, it is not necessary to know the exact rudder position, only its relative change from its last position. In a similar manner, the Course Setter 21 Family of Automatic Pilots requires no rudder feedback but instead relies on internally generated compensation signals to achieve system stability.

All of these design requirements are implemented in the Course Setter 21 Family of autopilots making them the most sophisticated of the Benmar line of autopilots. The block diagram of the Course Setter is shown in Figure 4-2.

SYSTEM OPERATION

Any deviation from the selected course heading will cause an output from the compass. This compass output is applied to a filter which can be adjusted by the operator. During normal operation in calm seas, very little filtering is required, but since it is desirable to "slow down" the pilot during heavy seas, the filter can be adjusted to make the pilot ignore the small changes in course caused by wave action and look only at the average of the course error. It should be noted that this is not the same as adding "deadband" since the ability of the autopilot to hold a precise course is not degraded.

If the average (over 20 or 30 seconds) course error changes as little as 0.1 degree, the system will respond. What it will not do is wear itself out or waste power trying to correct for every little change in course. The output of the filter is applied to an internal Gain control. This control allows the installer to adjust the response of the system to the

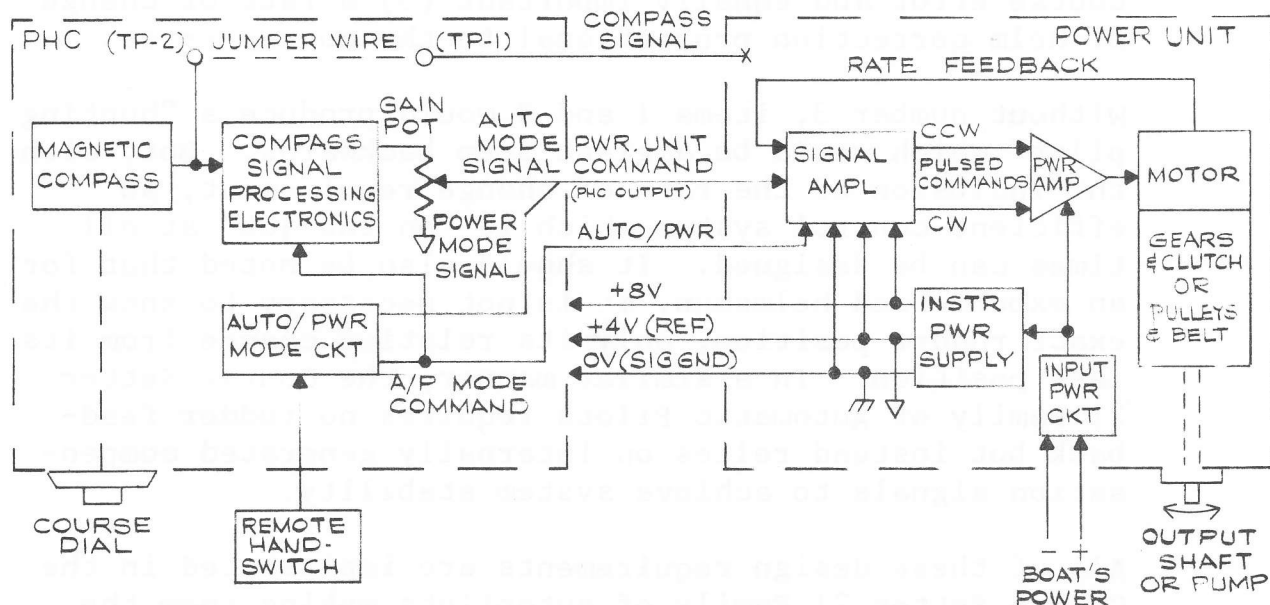


Figure 4-2
Block Diagram, Course Setter 21 Family of Autopilots

dynamics of the boat. The Power Unit contains a differential power amplifier which drives the motor. The amplifier compares the input from the Gain control against the signal from the rate network and drives the motor (and therefore the rudder) at a rate proportional to the input to the amplifier. It can be seen that for a change in input from the Gain control (caused by a course error) the rudder will be repositioned to correct the course error at a rate proportional to the error. In this manner, the Course Setter simulates the action of an experienced helmsman in steering his vessel.

4-4 CONTROLS

The standard Course Setter autopilot system contains three operator controls.

a. ON/OFF Switch - All Except Standard Power Unit

The ON/OFF switch is a push-pull switch which engages the autopilot to the steering system and places the autopilot in its operating mode.

Clutch Control - Standard Power Unit

The clutch control lever is located on the side of the Power Unit and provides two functions. It engages the autopilot to the steering system and actuates the on-off switch located in the Power Unit.

b. Course Dial

The Course Dial is adjusted to the desired course to be maintained by the autopilot. (Do not pull out the Course Dial when changing course or adjusting to a desired course.)

c. SEA STATE Control

The SEA STATE control determines the response of the helm for short term heading errors. The amount of helm movement for any long term (180 seconds or

greater) heading error will not be affected by the SEA STATE control. As the SEA STATE control is decreased (towards ROUGH), the helm movement is decreased. The SEA STATE control is used to decrease the amount of helm action in heavy seas. The total available helm travel or heading accuracy is not changed.

CONTROLS

The Standard Course Select subpanel system contains three operator controls.

a. W/PORT Switch - All Keypoint Standard Power Unit

The W/PORT switch is a push-button switch which energizes the autopilot to the steering system and places the autopilot in its operating mode.

Course Control - Standard Power Unit

The Course Control lever is located on the right side of the Power Unit and provides two functions. It energizes the autopilot to the steering system and actuates the off-off switch located in the Power Unit.

b. Course Dial

The Course Dial is adjusted to the desired course to be maintained by the autopilot. The dial is set out the Course Dial when changing course or adjusting to a desired course.

c. SEA STATE Control

The SEA STATE control determines the response of the helm for short term heading errors. The amount of helm movement for any long term (100 seconds or

SECTION V

INSTALLATION

5-1 GENERAL

Refer to the typical installation diagram of Figure 5-1 before proceeding with the installation. A necessary step in the installation of CS21 and CS21S is to determine the number of teeth on the driven and driving sprockets. The method of determining the sprocket teeth is explained in the appropriate Power Unit manual and requires measuring certain boat characteristics with the boat under way. If this is not possible, assumptions must be made as to boat characteristics.

The ability of the autopilot to steer the boat is dependent on the steering characteristics of the boat, and especially on the performance of the steering system. Any backlash (slop) in the steering system will give less than optimum performance in the autopilot mode, just as it will when the boat is under manual control. Backlash may also be caused by air in hydraulic steering systems from improper bleeding. As one might expect, the autopilot will cycle back and forth through the steering backlash in its attempt to steer the boat; the more backlash, the more work the pilot must perform and the more the course instability. The amount of course instability is a function of boat speed and steering characteristics, but as a general rule, steering backlash should not exceed 5% of the full helm range.

5-2 UNPACKING AND INSPECTION

Unpack the autopilot system and inspect the Pilot House Control Unit for cracks or breakage that may indicate shipping damage. The autopilot system should consist of the following items:

Pilot House Control Unit

One Instruction Manual

Refer to appropriate Power Unit manual
for items shipped with Power Unit.

5-3 INSTALLATION ACCESSORIES

Installation accessories such as sprockets, chain, etc. are available from your Benmar dealer. Refer to the Power Unit manual for detailed information.

5-4 TYPICAL INSTALLATION

Read all instructions completely before proceeding with the installation. Refer to Figure 5-1 for a typical installation of the PHC. Refer to the Power Unit manual for typical installation of the Power Unit.

PHC MUST BE LEVEL
IN ALL DIRECTIONS
TO ± 15 WHILE
UNDERWAY

PUSH-PULL
ON/OFF SWITCH
OR CABLE

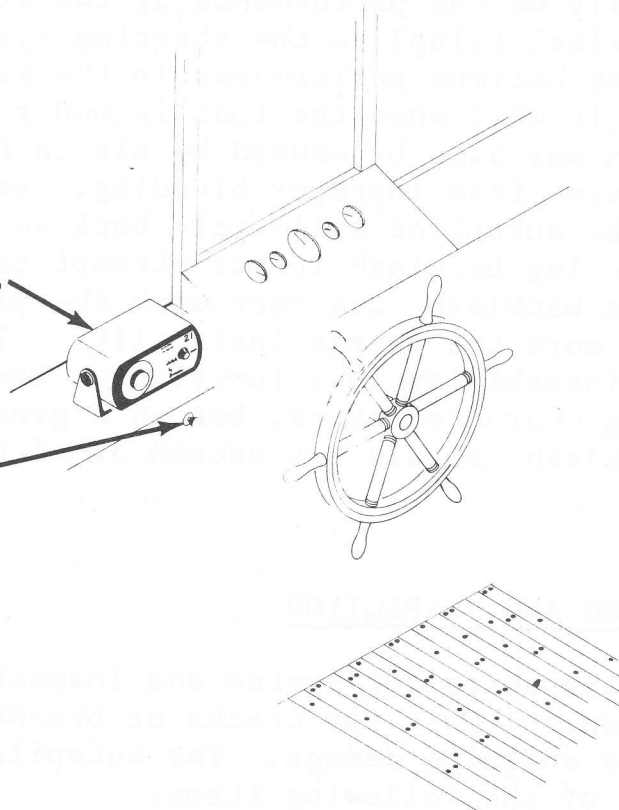


Figure 5-1
Course Setter 21 PHC, Typical Installation

MOUNTING LOCATION RESTRICTIONS

- a. Do not mount PHC or Power Unit where they may be exposed to spray or bilge water.
- b. Do not mount compass (PHC) near magnets, speakers, ship's compass, ferrous metal, etc.
- c. PHC and Power Unit mounting location must meet the following minimum requirements:

Minimum Mounting Distances

- | | |
|--|------------|
| 1. Power Unit to ship's compass | 36" (91cm) |
| 2. Power Unit to PHC | 36" (91cm) |
| 3. PHC to ship's compass | 36" (91cm) |
| 4. PHC to other instruments containing small magnets (radios, RDF, depth recorders, etc.) | 36" (91cm) |
| 5. PHC to current carrying wires (.5 amp) | 24" (61cm) |
| 6. Radar magnetrons | 8' (2.4m) |
| 7. Any large mass of soft iron or steel. Includes pilot house hold down rods or bolts. (Excluding non-magnetic stainless steel.) | 30" (76cm) |

- d. PHC must be level in all directions to $\pm 15^{\circ}$ while underway.

MEASUREMENT OF BOAT CHARACTERISTICS FOR STANDARD OR "S" POWER UNITS ONLY

- a. Required Boat Characteristics

The quantity which determines the proper sprocket ratio is the helm torque (effort to turn the wheel). The boat turn time also affects the sprocket ratio. This occurs on very responsive boats with turn times of less than 20 seconds. The helm torque measurement

must be the "worst case" and must be made while the boat is under way. Measurement should be made in a safe area with calm water and ample maneuvering room. (It is usually convenient at this time to also measure the boat turn time. Refer to paragraph 5-6c.)

b. Measurement of Helm Torque

Figure 5-2 shows the recommended method of measuring helm torque. A fish scale is used to measure the force. The distance in inches from the center of the wheel to the point of attachment of the fish scale is the radius. Make sure that you pull at right angles to the wheel radius.

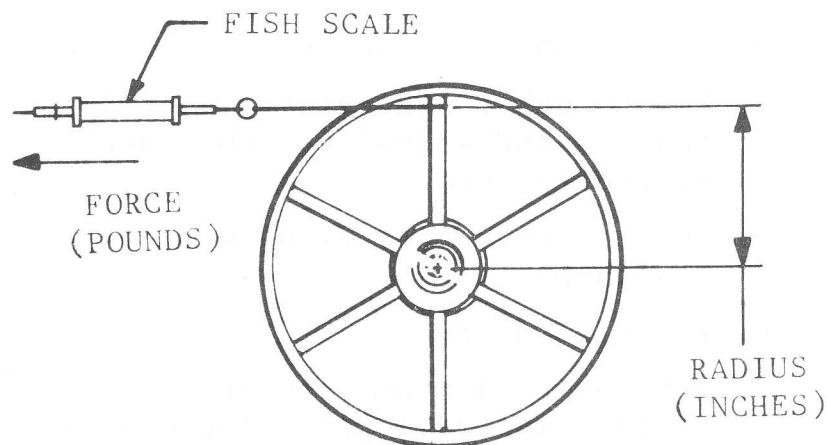


Figure 5-2
Measurement of Helm Torque

Maneuver the boat at various speeds. The effort required to turn the wheel will vary with speed. Make the torque measurement at the speed which requires the most effort (usually high speed). Put the boat into a turn by pulling on the fish scale. Record the force required (pounds) and the radius (inches). It is desirable to make several turns in both directions. Record the maximum of the readings. The force and radius will be used together with a nomograph in the Power Unit manual to determine the desired sprocket ratio.

c. Measurement of Turn Time

While the boat turn time is used after the autopilot is installed to set the autopilot gain at the dock, the turn time measurement will be described here at it is easily made at the same time the helm torque is being measured. In this test, the helm is turned by some fixed amount which is easy to measure; such as $1/2$, 1 or 2 turns. With the helm held in this position, the time required to complete a 360° turn is determined. This is most easily measured by establishing the turn and noting the time at which the boat first crosses some convenient heading (like north) and then the time at which the boat again crosses the same heading. The difference between the two times is the time required to turn 360° .

The turn time test should be made at cruise speed. The amount of helm used should be that normally used for a 180° turn at cruise speed.

To facilitate the determination of helm angle, a mark (a piece of tape works fine) should be put at the top of the wheel when the boat is cruising dead ahead. In setting up the turn, move this mark through the desired angle.

Record the helm turns and turn time in seconds for both a port and a starboard turn. These values will be used together with Nomograph #1 in Figure 5-5 to determine the desired autopilot gain setting.

5-7 PILOT HOUSE CONTROL UNIT INSTALLATION

a. Location of Pilot House Control

The Pilot House Control (PHC) should be located within reach of the steering wheel station. Because of the possibility of magnetic interference, the mounting location restrictions defined in paragraph 5-5 MUST be met.

The PHC must be mounted with its panel in a vertical plane and level within $\pm 15^\circ$ so the compass card in the unit will have an equal gimbaling arc in all directions. If the variation in boat trim with speed is in excess of 15° , compromise by positioning the PHC at the normal cruise speed.

b. Visual Compass Check

When the PHC is installed, the compass should be checked for the presence of an air bubble in the main body which has not worked its way back into the expansion chamber. In normal handling of the PHC, air will rise out of the expansion chamber and into the main body of the compass when turned upside down. If the air bubble remains in the main body, it will cause erratic autopilot operation as it passes thru the compass lamp and photocell optical path.

The air bubble may be exhausted into the expansion chamber by "rocking" the compass so the air bubble passes thru the center hole in the diaphragm between the main body and expansion chamber. See Figure 5-3.

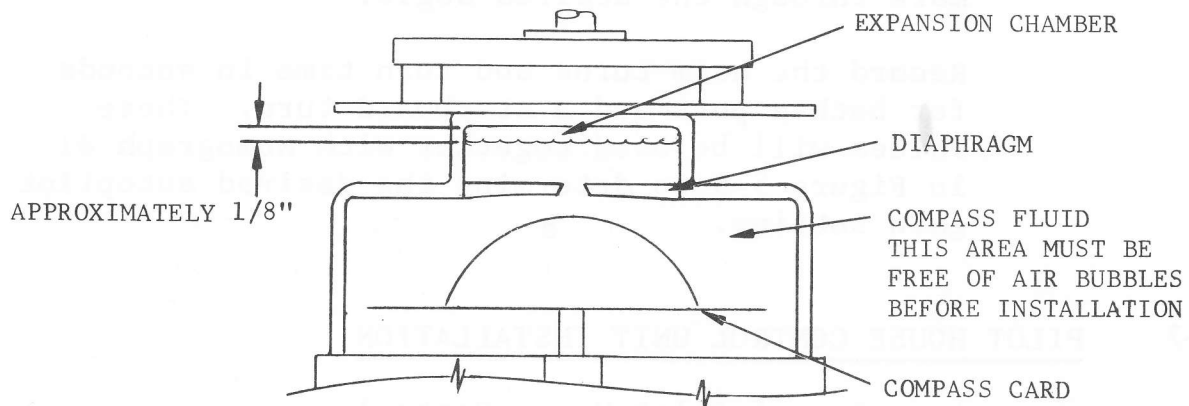


Figure 5-3
Compass Expansion Chamber

c. Dial Light Circuit Change

The dial light circuit in the PHC is terminated at terminals in the Power Unit. The dial light can be controlled by the ship's instrument panel light switch and dimmer or by the autopilot ON/OFF switch. The Power Unit is factory wired for the dial light to be controlled by the autopilot ON/OFF switch. If the dial light is to be controlled by the instrument panel circuit, refer to Power Unit manual for connection information.

5-8 DOCKSIDE CHECKOUT FOR STANDARD OR "S" POWER UNIT ONLY

This section contains the dockside checkout procedure for the standard and "S" mechanical Power Units only. For dockside checkout of hydraulic Power Units, see Section 5-9.

After the PHC and Power Unit have been installed, the following tests should be made with the boat at the dock or on a trailer.

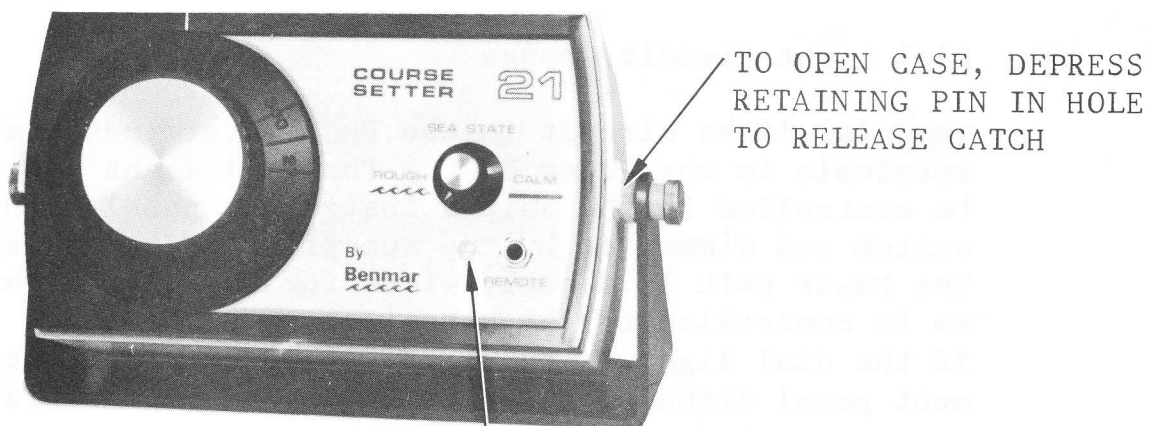
CAUTION

MAKE SURE THE HELM AND RUDDER ARE FREE TO MOVE. IF THE BOAT HAS AN IN/OUT DRIVE, THE DRIVE MUST BE LOWERED.

a. Establishing the Correct Autopilot Phasing

This section establishes that the autopilot will control the helm and will drive the helm in the direction necessary to correct a heading error.

Remove the PHC front panel from its case. Refer to Figure 5-4. Use the Course Dial to rotate the compass so that when the PHC panel is replaced,



REMOVE PLUG
FOR ACCESS
TO GAIN POT

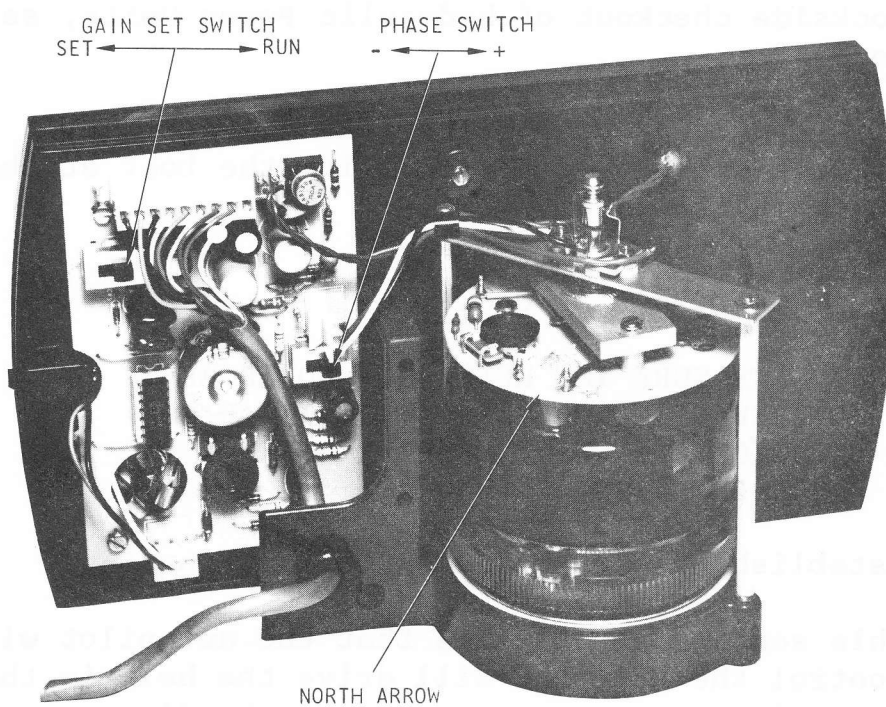


Figure 5-4
Gain Set Pot, Phase Switch
and Gain Set Switch Location

the arrow on top of the compass will point north. Move the Gain Set slide switch to the SET position. Place the PHC back in its case and remove the Gain pot adjustment plug. Engage the autopilot. The autopilot will typically drive the wheel to some position off the midships position and then continue to slowly drive the wheel in that direction.

Slowly turn the Course Dial in a direction opposite to that taken by the helm until the helm is driven back to the midships position. Verify that the helm moves to port when the Course Dial is moved slightly to port, and to starboard when the Course Dial is moved slightly to starboard. If the opposite is true, remove the PHC from its case and change the position of the Phase switch. Check that the arrow on the compass is still pointing north. Replace the PHC and repeat the check.

NOTE

MOVEMENTS OF THE COURSE DIAL OF GREATER THAN A FEW DEGREES CAUSE THE WHEEL TO FAST SLEW AN AMOUNT PROPORTIONAL TO THE COURSE DIAL MOVEMENT AND THEN CREEP (SLOW SLEW) AT A RATE PROPORTIONAL TO THE COURSE ERROR, I. E., DIFFERENCE BETWEEN COMPASS HEADING AND BOAT HEADING. THE AMOUNT OF FAST SLEW AND RATE OF SLOW SLEW ARE ALSO PROPORTIONAL TO THE GAIN POT SETTING. FULLY CCW GAIN POT SETTING WILL GIVE VERY LITTLE HELM MOVEMENT. FULLY CW WILL GIVE CONSIDERABLE HELM MOVEMENT AND MAY CAUSE CONSIDERABLE HELM MOVEMENT AS THE BOAT ROCKS OR MOVES SLIGHTLY AT THE DOCK. IF THE AUTOPILOT IS LEFT ON WITH A COURSE ERROR WHILE AT THE DOCK, THE HELM WILL CONTINUE TO CREEP UNTIL A LIMIT IS REACHED. WHEN THIS HAPPENS, EITHER ROTATE THE COURSE DIAL TO DRIVE THE HELM IN THE OTHER DIRECTION OR TURN THE AUTOPILOT OFF.

b. Matching Course Dial to Boat's Compass Heading

Slowly adjust the Course Dial to the position which results in the helm being driven to midships. This may be difficult if wave action is causing the boat to move significantly; however, this setting is not critical and as long as the helm is not being continually driven in one direction or another, it is satisfactory. With the Course Dial held in this position, note the course indicated on the ship's compass. Pull the Course Dial straight out away from the panel, being careful not to rotate it while pulling, and rotate the Course Dial to the heading indicated by the ship's compass and release.

Pulling out the Course Dial disengages the dial from the compass. This allows the dial to be calibrated to the ship's compass or other heading reference. This is normally done only once during initial setup. It may be necessary again to trim while under way or if someone inadvertently pulls out the Course Dial while changing course. DO NOT PULL OUT THE DIAL WHEN CHANGING COURSE OR DIALING TO AN INITIAL HEADING.

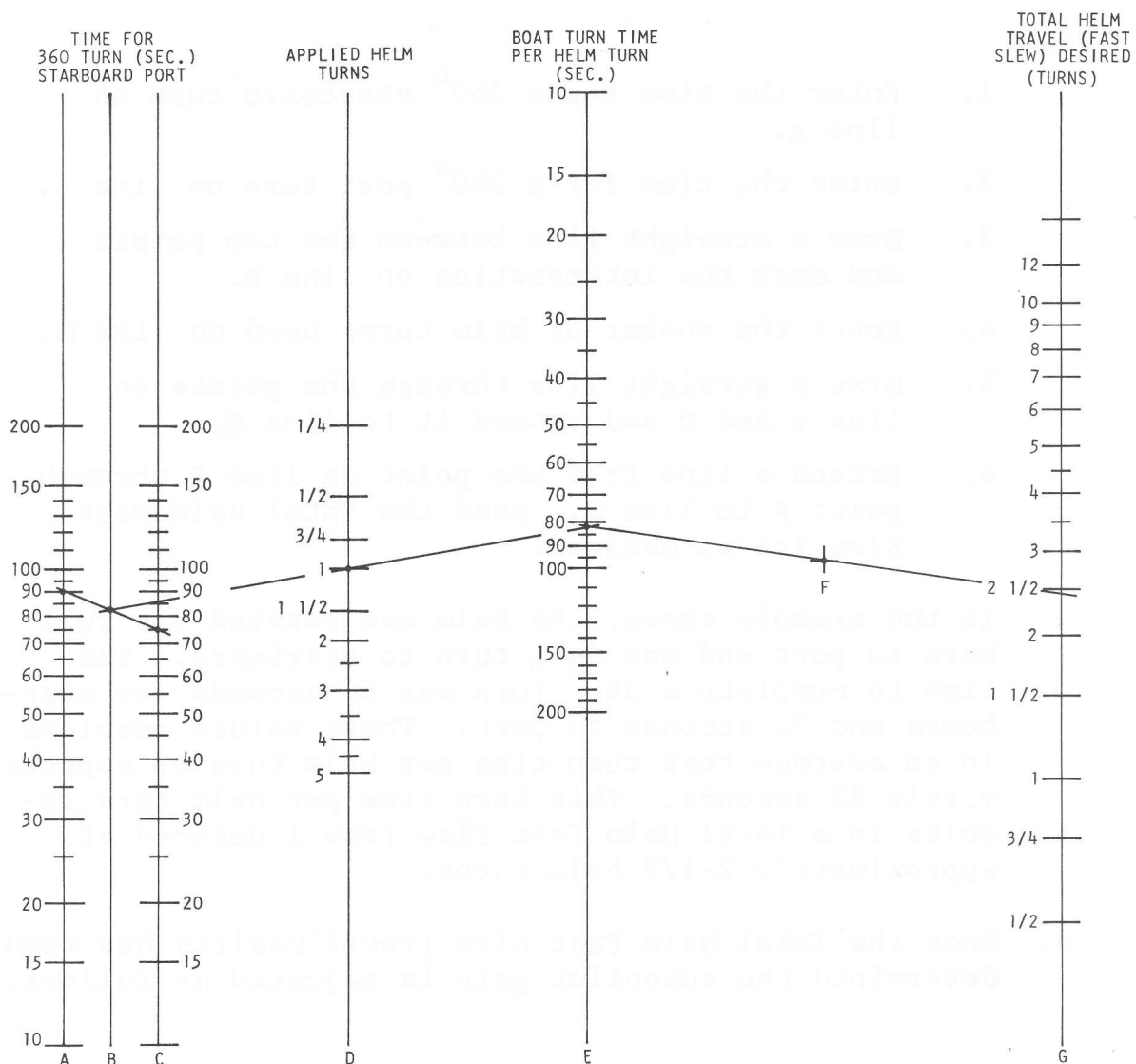
c. Establishing the Autopilot Gain

The autopilot gain may be set either at the dock, with the use of the boat turn time (paragraph 5.6c), or underway by observing the response. It is recommended that the gain be set initially at the dock, utilizing the boat turn time and Nomograph #1, Figure 5-5.

This section assures, at the dock, that the autopilot gain is matched to the boat gain for optimum autopilot response.

The autopilot gain is determined by moving the Course Dial back and forth through the actual boat heading and noting the Total Helm Fast Slew Travel. Be sure to rotate the Course Dial to 90° away from the true heading in each direction.

The desired Total Helm Fast Slew Travel is determined from the 360° boat turn time through the use of Nomograph #1 shown in Figure 5-5. Refer to this nomograph.



YOUR BOAT

Helm Angle
Used _____ turns

Boat Turn
Time _____ seconds

Starboard
360° Turn
Time _____ seconds

Total Helm
Fast Slew
Travel _____ turns

Port 360°
Turn Time _____ seconds

Figure 5-5
Nomograph #1. Determination of
Desired Total Fast Slew Helm Travel

1. Enter the time for a 360° starboard turn on line A.
2. Enter the time for a 360° port turn on line C.
3. Draw a straight line between the two points and mark the intersection on line B.
4. Enter the number of helm turns used on line D.
5. Draw a straight line through the points on line B and D and extend it to line E.
6. Extend a line from the point on line E through point F to line G. Read the Total Helm Fast Slew Travel Desired.

In the example shown, the helm was rotated one full turn to port and one full turn to starboard. The time to complete a 360° turn was 90 seconds to starboard and 76 seconds to port. These values resulted in an average boat turn time per helm turn of approximately 83 seconds. This turn time per helm turn results in a Total Helm Fast Slew Travel Desired of approximately 2-1/2 helm turns.

- d. Once the Total Helm Fast Slew Travel Desired has been determined the autopilot gain is adjusted as follows.

NOTE

ON SOME BOATS, THE DESIRED TOTAL HELM FAST SLEW TRAVEL FOUND WITH THE AID OF NOMOGRAPH #1 MAY EXCEED THE TOTAL LOCK TO LOCK HELM TURNS. ON THOSE FEW BOATS WHERE THIS MAY BE THE CASE THE AUTOPILOT GAIN CANNOT BE PRESET AT THE DOCK UNLESS AN AUTOPILOT TEST SET IS AVAILABLE. THE GAIN MUST THEN BE SET UNDERWAY AS DESCRIBED IN SECTION 5-10.

1. Remove the PHC partially from its case in order to allow access to the Gain Set slide switch. See Figure 5-4.

2. Check that the switch is in the SET position (away from the compass). Replace the PHC in its case.
3. With a non-magnetic screwdriver turn the Gain pot all the way counterclockwise and back 1/4 turn clockwise.
4. With the autopilot on and the Course Dial initially at midship setting, rotate the Course Dial 90° from the midship setting.

The helm should slew to one side of midships and then slowly creep in the same direction. Note the helm position at which it slows down and starts to creep.

5. Rotate the Course Dial through its midship setting to 90° on the other side of midship. The helm should slew back through the midship position and then slow down and start to creep at about the same distance on the other side. The total fast slew turns of the helm from one side to the other side is Total Helm Fast Slew Travel.
6. Use the Gain pot to adjust the Total Helm Fast Slew Travel to the desired value determined from the nomograph. Clockwise rotation of the Gain pot will increase the helm travel, counter-clockwise rotation will decrease the travel. Precise adjustment is not necessary. For example, a Total Helm Fast Slew Travel of between 2-1/4 turns and 2-3/4 turns would be satisfactory for the boat represented in the previous example.
7. Open the PHC and move the Gain Set slide switch to the RUN position and re-install the PHC into its case.
8. Re-check that the helm can be driven to the midships position by setting the Course Dial to the boat heading as indicated on the boat

compass. Some movement of the helm around the midships position is to be expected if the boat is in water (this is due to slight changes in the boat heading).

9. Check that movement of the Course Dial to port moves the helm to port and movement of the Course Dial to starboard moves the helm to starboard.

With the Gain Set switch in the RUN position, the Total Helm Fast Slew Travel will be different than with the switch in the SET position.

The autopilot is now ready for final checkout underway. Turn the autopilot off and replace the plug into the Gain adjustment hole.

5-9 DOCKSIDE CHECKOUT FOR HYDRAULIC POWER UNITS

With the boat at the dock or on a trailer, the following tests should be made.

CAUTION

MAKE SURE THE RUDDER IS FREE TO MOVE.
IF THE BOAT HAS AN IN/OUT DRIVE, THE
DRIVE MUST BE LOWERED.

a. Establishing the Correct Autopilot Phasing

This section establishes that the autopilot will control the rudder and will drive the rudder in the direction necessary to correct a heading error.

Remove the PHC front panel from its case. Refer to Figure 5-4. Use the Course Dial to rotate the compass so that when the PHC panel is replaced, the arrow on top of the compass will point north. Move the Gain Set slide switch to the SET position.

Place the PHC back in its case and remove the Gain pot adjustment plug. With a non-magnetic screwdriver, turn the Gain pot all the way counterclockwise and back 1/4 turn clockwise. Engage the autopilot. The autopilot will typically drive the rudder to some position off the midships position and then continue to slowly drive the rudder in that direction.

Slowly turn the Course Dial in a direction opposite to that taken by the rudder until the rudder is driven back to the midships position. Verify that the rudder moves to steer to port when the Course Dial is moved slightly counter-clockwise, and to steer to starboard when the Course Dial is moved slightly clockwise. If the opposite is true, remove the PHC from its case and change the position of the Phase switch. Check that the arrow on the compass is still pointing north. Replace the PHC and repeat the check.

NOTE

MOVEMENTS OF THE COURSE DIAL OF GREATER THAN A FEW DEGREES CAUSE THE RUDDER TO FAST SLEW AN AMOUNT PROPORTIONAL TO THE COURSE DIAL MOVEMENT AND THEN CREEP (SLOW SLEW) AT A RATE PROPORTIONAL TO THE COURSE ERROR, I. E., DIFFERENCE BETWEEN COMPASS HEADING AND BOAT HEADING. THE AMOUNT OF FAST SLEW AND RATE OF SLOW SLEW ARE ALSO PROPORTIONAL TO THE GAIN POT SETTING. FULLY CCW GAIN POT SETTING WILL GIVE VERY LITTLE RUDDER MOVEMENT. FULLY CW WILL GIVE CONSIDERABLE RUDDER MOVEMENT AND MAY CAUSE CONSIDERABLE RUDDER MOVEMENT AS THE BOAT ROCKS OR MOVES SLIGHTLY AT THE DOCK. IF THE AUTOPILOT IS LEFT ON WITH A COURSE ERROR WHILE AT THE DOCK, THE RUDDER WILL CONTINUE TO CREEP UNTIL THE LIMIT OF THE RAM IS REACHED. THE HYDRAULIC SYSTEM WILL THEN BE PRESSURIZED TO THE MAXIMUM

AVAILABLE PRESSURE OF THE PILOT. WHEN THIS HAPPENS, EITHER ROTATE THE COURSE DIAL TO DRIVE THE RUDDER IN THE OTHER DIRECTION OR TURN THE AUTOPILOT OFF.

b. Matching the Course Dial to Boat's Compass Heading

Slowly adjust the Course Dial to the position which results in the rudder being driven to midships. This may be difficult if wave action is causing the boat to move significantly; however, this setting is not critical and as long as the rudder is not being continually driven in one direction or another, it is satisfactory. With the Course Dial held in this position, note the course indicated on the ship's compass. Pull the Course Dial straight out away from the panel being careful not to rotate it while pulling, and rotate the Course Dial to the heading indicated by the ship's compass and release.

Pulling out the Course Dial disengages the dial from the compass. This allows the dial to be calibrated to the ship's compass or other heading reference. This is normally done only once during initial setup. It may be necessary again to trim while under way or if someone inadvertently pulls out the Course Dial while changing course. DO NOT PULL OUT THE DIAL WHEN CHANGING COURSE OR DIALING TO AN INITIAL HEADING.

Remove the PHC from its case and place the Gain Set slide switch in the RUN position. The autopilot is now ready for operational checkout (underway).

5-10 OPERATIONAL CHECKOUT (UNDERWAY)

The operational checkout (underway) applies to all Course Setter systems. Successful completion of the dockside checkout procedures assures that the Course Setter autopilot is properly set up and matched to the boat. It will normally be possible to steer the boat using the autopilot without further adjustments.

NOTE

THE GAIN SET SWITCH MUST BE IN THE "RUN" POSITION FOR PROPER UNDERWAY AUTOPILOT OPERATION.

a. Response

A properly set up Course Setter should maintain a satisfactory heading without 'S'ing at speeds from idle to maximum speed. Slight initial trimming of Gain pot may be required once underway to optimize performance.

All magnetic compasses are most sensitive on northerly or southerly courses, therefore, the gain should be set and optimized on southerly courses when in the northern hemisphere and on northerly courses when in the southern hemisphere. It should then be checked on all cardinal points.

With the SEA STATE control set to CALM, attempt 30° turns both to port and starboard at every 90 degrees of heading (i.e., N, S, E, W). Turn response should be rated by observing the boat's wake which should display one small overshoot as diagrammed in Figure 5-6.

If the response is as shown in Figure 5-6 A or C, the Gain pot should be adjusted slightly to optimize the turn response.

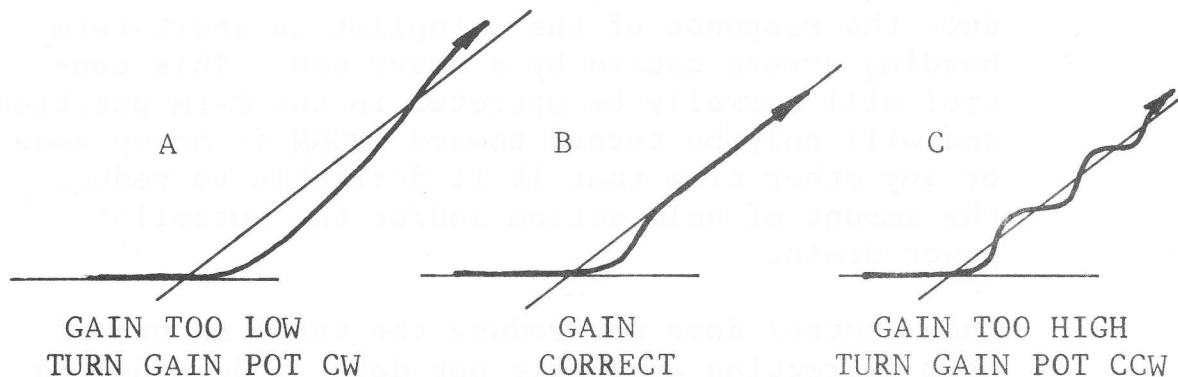


Figure 5-6
Turn Response Diagram

At slower speeds, the turn response may degrade somewhat, but this is due to the slower response of the boat, and is normal. Changing of the SEA

STATE control toward ROUGH will also degrade the response, and will cause the autopilot to take longer to come onto course. The SEA STATE control should always be set to CALM when precise maneuvering is required.

b. Compass Accuracy

With the response properly trimmed, align the Course Setter compass to the ship's compass at 0° heading and run the boat at every 45° increment (i.e., N, NW, W, etc.) and check that the Course Setter compass agrees with the ship's compass within +5°. If the error is greater than 5° but less than 10° at any heading, there is some magnetic disturbance which may cause some degradation of the pilot, but is probably acceptable. Errors of greater than 10° indicate an excessive disturbance and must be corrected by removing the cause of the interference or by relocating the PHC (assuming that the error is not in the ship's compass).

c. SEA STATE Control

The function of the SEA STATE control is to reduce the response of the autopilot to short term heading errors caused by a heavy sea. This control will normally be operated in the CALM position and will only be turned toward ROUGH in heavy seas or any other time that it is desirable to reduce the amount of helm action and/or the autopilot power drain.

This control does not reduce the total amount of helm correction available nor does it degrade the heading accuracy. It only reduces the short term movement of the helm.

SECTION VI SERVICING AND MAINTENANCE

6-1 GENERAL

The following servicing and maintenance instructions can be performed by the operator. No special tools or test equipment are required.

6-2 FUSE REPLACEMENT

The basic automatic pilot system contains one fuse located in the Power Unit. For fuse location and replacement, see applicable Power Unit manual.

6-3 LAMP REPLACEMENT

The Pilot House Control unit contains two lamps. One lamp is located in the compass assembly and requires removal of the Compass Printed Circuit Board from the compass and requires recalibration of the compass. This lamp should only be replaced by a qualified technician.

The dial illuminating lamp in the PHC unit is replaced by releasing the cover retaining pins, shown in Figure 3-1, and carefully pulling the unit from the case. The lamp is located behind the dial. Replace the lamp with a Benmar lamp, Part Number 001-1247.

6-4 COMPASS MAINTENANCE

The rotating compass contacts may occasionally oxidize and require cleaning. See Figure 6-1. Radio-TV contact cleaner can be used to clean the contacts. For an installation in which the PHC is continuously exposed to weather (such as flying bridge installation) this maintenance must be performed every 3 months.



Figure 6-1
Dial Lamp, Compass Lamp and Rotating Contacts

SECTION VII

CIRCUIT DESCRIPTION

7-1 GENERAL

Refer to the system block diagram and description in Section IV for a basic understanding of the Course Setter autopilot operation, and see the Power Unit manual for detailed information on Power Unit operation.

Refer to the system schematics for a more detailed circuit description. Circuit board location is shown in Figure 7-1.

The compass and compass electronics are contained in the Pilot House Control unit (PHC). Power supplies, motor drive circuitry, motor and output to the boat's steering system are contained in the Power Unit. The interconnections between the PHC and the Power Unit are made by an Interconnecting Cable furnished with the Power Unit. The auxiliary Remote Handswitch plugs into the front of the PHC.

The PHC, Interconnecting Cable and Remote Handswitch are identical for 12V, 24V and 32V systems. The PHC derives its power and reference voltages from the Power Unit.

7-2 PILOT HOUSE CONTROL UNIT (PHC)

a. Compass

The compass contains the compass card, lamp (DS1) and photocell (V1) which supply a course error voltage to the compass electronics. The compass null voltage ("on-course") is +4.0 VDC, identical to the reference voltage. "Off-course", the compass output is above or below the 4.0 VDC reference, indicating right or left course error.

Resistors R1, R2 and potentiometer R3 set the current through the lamp DS1.

b. Filter and Front Panel Controls

Amplifier U1 and its associated components R1, R3, R4, R5, R12, R13, R14, R15, R16, R17, R18, C1, C2, C3, C4, C8, C11, C13, CR6 and CR7 constitute a variable filter, buffer and gain control which process the compass output signal. SEA STATE control R4 adjusts the filter time constant for varying compass inputs, "averaging" the input so the Power Unit will not respond to increased wave motion. Gain pot R16 sets the autopilot gain as described in Section V.

c. Gain Set Switch

Gain Set switch, S2, is used to set up and adjust the autopilot during installation and checkout. When in the Set position, it disables the pilot's filter compensation and allows the unfiltered compass output to be applied to the Power Unit. For normal Course Setter operation, the switch must be set at the Run position.

d. Phase Switch

The Phase switch, S1, reverses the phase of both the compass output voltage and the Handswitch output voltage by reversing their voltage inputs: +8V and signal ground. The Phase switch is used to select the direction of Power Unit output, dependent on the installation geometry and how the Power Unit output is connected to the boat's rudder drive system.

e. Remote Handswitch Circuitry

IC switches U2-A thru D, R6, R7, R8, R9, R10, R11, R19, R20, R21, C5, C6, C7, CR1, CR2, CR3, CR4 and CR5 provide the Auto/Pwr voltage (+8V for Pwr mode, 0V for Auto mode) and the left/right forcing voltage (+8V or 0V which is applied at the PHC output in the Pwr mode.

In the Auto mode, switch U2-B is turned on thru R10, which allows the Auto/Pwr line to be pulled to ground thru R10. In the Pwr mode U2-B is turned off by a ground at J2-2, J2-3, or both (thru the remote handset) allowing the Auto/Pwr line to be pulled to +8V through the low impedance of R11. In addition to performing functions in the Power Unit, +8V on the Auto/Pwr line turns on switch U2-A which applies the reference voltage to the input of U1, thus commanding reference on the PHC output and no rotation from the Power Unit. If ground is then removed from J2-2 or J2-3 (but not both) either switch U2-D or U2-C will be turned on, applying either +8V or ground, through the Phase Switch, to the PHC output forcing the Power Unit to run at full slew rate either CW or CCW.

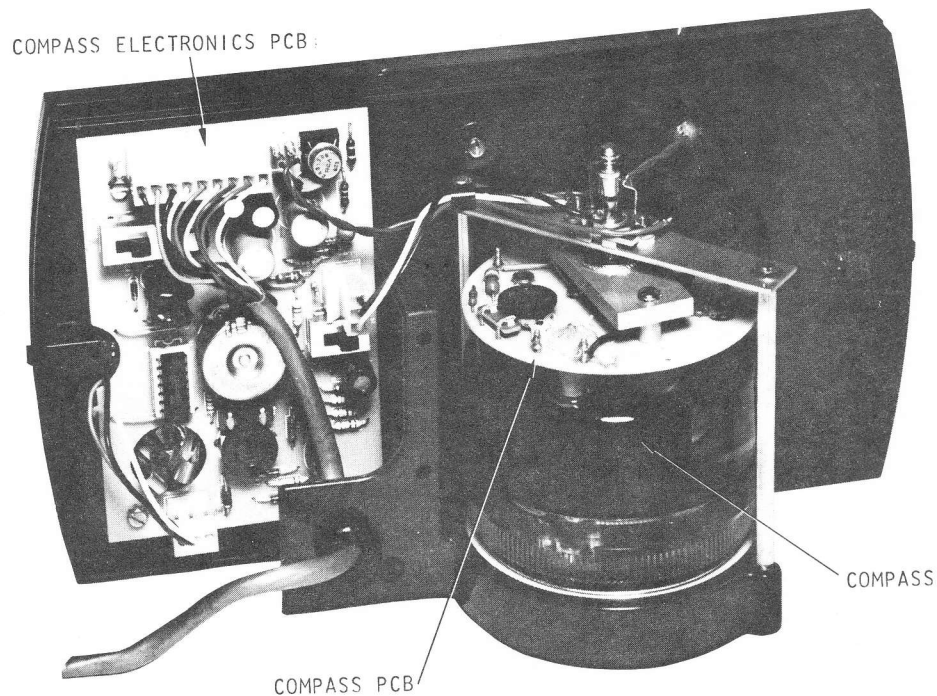


Figure 7-1
Circuit Board Location

SECTION VIII

TROUBLESHOOTING

8-1 GENERAL

Troubleshooting the autopilot should be performed by a qualified technician. The circuit description, Section VII and the system schematic should be referred to for a thorough understanding of circuit function prior to troubleshooting. The Power Unit manual contains the system troubleshooting chart. The voltages in the PHC depend on Power Unit voltages being within tolerance, therefore, the voltages in the Power Unit troubleshooting chart must be checked before troubleshooting the PHC.

8-2 COMMON NEW INSTALLATION PROBLEMS

Listed below are the most common problems encountered on new installations. As can be seen the majority of these problems occur during installation and setup, all of which could be avoided if the installation and setup instructions had been read and followed. WHEN ALL ELSE FAILS, READ THE MANUAL.

- a. Gain not properly set or not set at all - usually too low resulting in sluggish response. Although this is self-explanatory, it is one of the biggest problems encountered in new installations. Refer to Sections 5-8, 5-9 and 5-10.
- b. Compass operating on the wrong side and Phase switch in the wrong position - can't stabilize the autopilot. If the Phase switch is in the wrong position and the compass lamp/photocell is positioned over the back or abrupt side of the compass card rather than the front or linear side, the phase will appear to be correct. The autopilot will be erratic and nearly impossible to stabilize. If it is at all stable, the gain will be set very low. Refer to paragraph 5-8a or 5-9a.

- c. Gain Set switch left in SET position. Autopilot unstable. The Gain Set switch must be in the RUN position for proper underway autopilot operation.
- d. PHC too close to external magnetic influence. Autopilot unstable and/or sluggish on some courses. Gross disagreement between ship's compass and autopilot Course Dial. Refer to paragraph 5-5 and 5-10b. Magnetic materials come in many forms; i.e., small motors, other electronic equipment, speakers, etc., (a steel medicine cabinet had to be removed in one boat).
- e. Air bubble trapped in main body of the compass. Autopilot will steer erratically on some courses. Refer to paragraph 5-7b.
- f. Input power leads too small and/or too long - autopilot will be erratic and impossible to stabilize. Peak current demands of the Course Setter may drop the voltage input to the Power Unit below the specified level for short periods of time causing erratic operation. The problem may be a poorly regulated battery or power supply, corroded power lead connections, or too fine a gauge of input wire for the length of wire used. This problem most often observed on CS21S Power Units. See Electrical Connections, Section V in the appropriate Power Unit manual for input wire requirements.
- g. On hydraulic systems the 3rd or return line not connected. On some installations, the autopilot will be sluggish; on others, it will not operate at all. The autopilot return line must be connected to the return or reservoir in the hydraulic system on all installations. Failure to do so will void the warranty on the Power Unit. Refer to Section 5-5 in the Power Unit manual.
- h. Compass contacts dirty - autopilot will be erratic. Compass lamp flickers as Course Dial is rotated. Refer to Section 6-4.

TROUBLESHOOTING

If a malfunction occurs, refer to the trouble analysis chart, Figure 8-1, the Test Voltage Table, Table 8-1, and the corresponding chart and table in the Power Unit. manual. These will assist in isolating the specific circuit boards or functional circuit block that may be the cause of the malfunction. Replacement printed circuit boards, as well as other components, may be obtained from Benmar. Refer to the Part Lists for Component Description and Benmar Part Number.

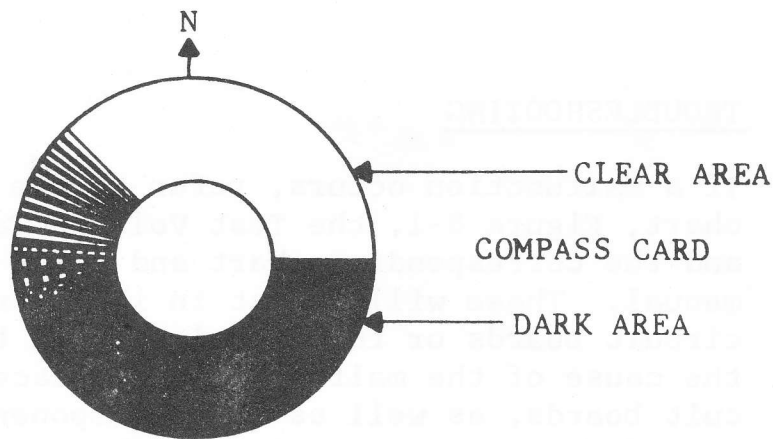
COMPASS/COMPASS LAMP INSTALLATION/SETUP

When a new compass lamp is installed in the compass, the lamp current must be adjusted for the proper compass output voltage. When a new compass is installed this setting must be checked. This adjustment is set on new compasses at the factory, however, normal component tolerances in the PHC circuitry may necessitate a slight adjustment during installation.

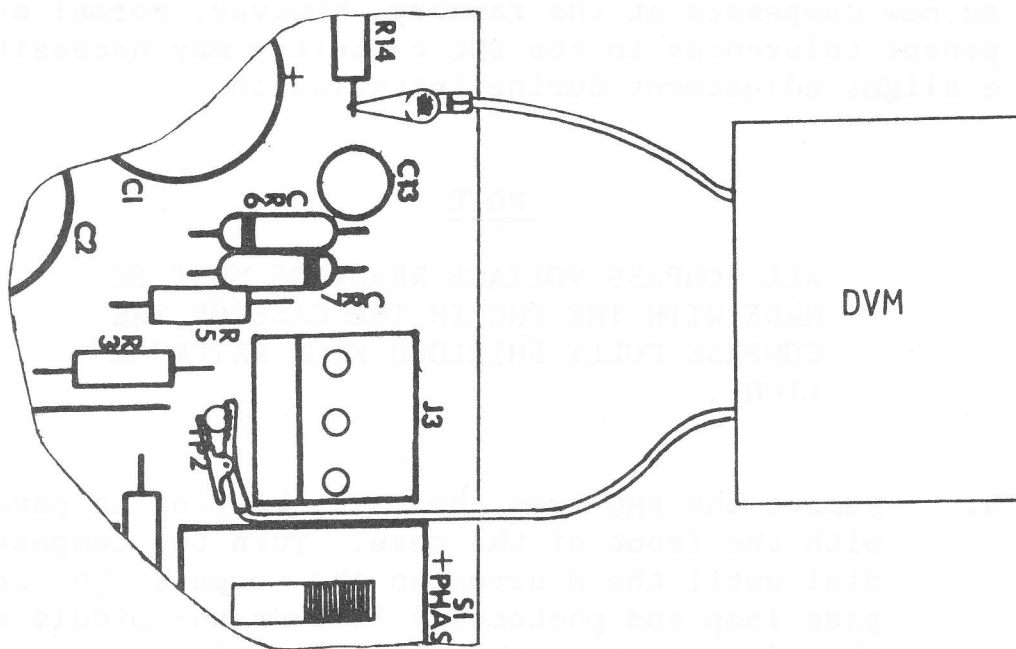
NOTE

ALL COMPASS VOLTAGE READINGS MUST BE MADE WITH THE PHC IN THE CASE OR THE COMPASS FULLY SHIELDED FROM EXTERNAL LIGHT.

- a. Remove the PHC from the case, keeping it parallel with the front of the case. Turn the compass dial until the N arrow on the compass (the compass lamp and photocell) is over the middle of the clear area on the compass card.



- b. Connect a DVM or VTVM from the compass output test point (TP2) to the end of R14 nearest J3 (+4V reference) on the compass electronics board. (The "positive" meter lead should be connected to the compass output test point.)



- c. Re-install the PHC in the case or shield the compass from all external light. The compass output voltage with the lamp/photocell midway on the light side of the compass card shall be $1.75 \text{ VDC} \pm 0.05 \text{ VDC}$. (If the Phase switch is

in the + position, the voltage shall be -1.75V. If it is in the - position, the voltage shall be +1.75V.) This voltage is adjusted to the specified value by potentiometer R3 on the compass. R3 must be adjusted and then the PHC re-installed in the case to read the compass output. When the compass is then rotated 180°, i.e., when the photocell is midway on the dark side of the compass card, the compass output voltage shall be between 1.5 and 2.0V DC; + if the phase switch is in the + position and - if the phase switch in the - position.

8-5 REMOTE HANDSWITCH CIRCUIT LOGIC

The following table relates the switch positions of the Remote Handswitch, the circuit conditions at PHC plug P2, the Auto/Power voltage levels, and the PHC output voltage. The voltages are relative to signal ground, and are given for both the + and - settings of Phase switch S1. ("Compass" indicates that the output voltage is dependent upon the compass output.)

REMOTE HANDSWITCH			P2		+ PHASE		- PHASE	
A/P S3	RIGHT S2	LEFT S1	-3	-2	A/P	PHC OUT	A/P	PHC OUT
AUTO	Norm.	Norm.	Open	Open	<1V	Compass	<1V	Compass
AUTO	Oper.	Norm.	Gnd	Open	>6V	>6V	>6V	<1V
AUTO	Norm.	Oper.	Open	Gnd	>6V	<1V	>6V	>6V
*AUTO	Oper.	Oper.	Open	Open	<1V	Compass	<1V	Compass
PWR	Norm.	Norm.	Gnd	Gnd	>6V	+4V	>6V	+4V
PWR	Oper.	Norm.	Gnd	Open	>6V	>6V	>6V	<1V
PWR	Norm.	Oper.	Open	Gnd	>6V	<1V	>6V	>6V
*PWR	Oper.	Oper.	Open	Open	<1V	Compass	<1V	Compass

*Abnormal switch settings; shown for logic only.

VOLTAGE CHECK	TEST POINTS	CONDITIONS	SPEC VOLTAGE
Input Power: 12V System 24V System 32V System	See Power Unit Manual	PWR switch ON (for all tests)	+11 to +15 VDC +22 to +30 VDC +29 to +40 VDC
Voltage Regulator	PHC J5-4 to J5-7 or Power Unit		+7.7 to +8.3 VDC
Reference Voltage	PHC J5-6 or J5-7 or Power Unit		+3.6 to +4.4 VDC
PHC Output	PHC J5-5 to J5-6 or Power Unit	PHC closed or shielded from light. GAIN SET switch at SET. GAIN pot full CW. Slowly rotate compass dial over 360° range.	Varies between +3.6 to +4.2V max. and -3.6 to -4.2V min.
Compass Output (clear side)	PHC TP-2 to J5-6	PHC closed or shielded from light. PHASE switch at +. Compass lamp near center of clear side of compass card.	-1.65 to -1.85 VDC
Compass Output (dark side)	PHC TP-2 to J5-6	PHC closed or shielded from light. PHASE switch at +. Compass lamp near center of dark side of compass card.	+1.5 to +2.0 VDC
Compass Amplifier Gain	PHC J5-5 to J5-6	Compass plug (P3) removed from J3. 0.5V PP 1.0 Hz in- put applied be- tween J3-3 and J5-6. GAIN SET switch at RUN. GAIN pot full CW. SEA STATE (R4) full CW (CALM): SEA STATE (R4) full CCW (ROUGH):	 4.3 to 5.8V PP 1.5 to 2.0V PP
AUTO/PWR (Ref. Para. 8-4)	PHC J5-8 to J5-6	Remote handset at AUTO (or unplugged) Remote handset at PWR:	-3.0 to -4.2 VDC +3.0 to +4.2 VDC

Table 8-1
Test Voltages

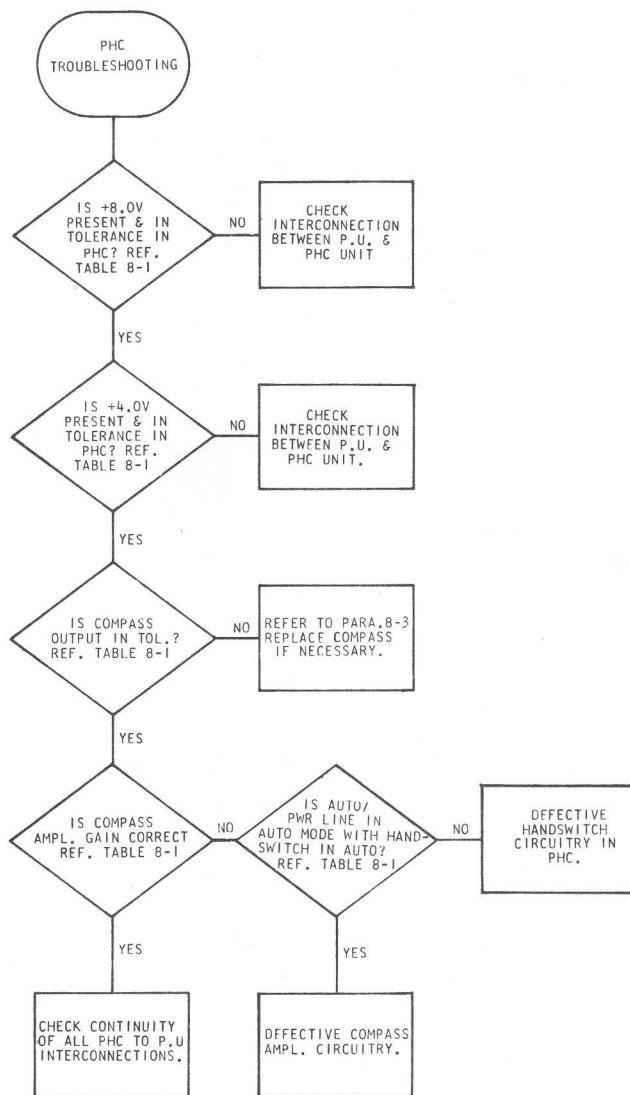


Figure 8-1
PHC Fault Isolation Chart