



S:E:AutoPilot

- RELAY AND SOLENOID CONTROL -

INSTALLATION & OPERATING MANUAL

**READ THIS MANUAL CAREFULLY BEFORE ATTEMPTING
INSTALLATION or OPERATION of AUTOPILOT**

**THE SPECIAL NOTICE ON THE BACK
OF THIS PAGE IS FOR YOUR SAFETY**

PLEASE READ IT

SALES AND SERVICE IN OVER 60 COUNTRIES

**Ref. No.
790-004**

**ISSUE:
September/84**

SPECIAL NOTICE

An Autopilot is not intended to take the place of a man, but rather assist him in steering the vessel.

It is the responsibility of the man (and a requirement by law) to ensure and maintain safe navigation and control of the vessel at all times in accordance with the Rules of the Road.

An Autopilot is intended for operation in open waters, clear of all obstructions and other vessels. The heading of the vessel must be observed constantly.

It may be necessary to regain manual steering control quickly and to deactivate the Autopilot pumpset if the vessel alters or fails to maintain the set course or if the set course may jeopardize the vessel.

DEACTIVATING WAGNER HYDRAULIC PUMPSETS

1. WAGNER Type 2A, PV125C-XX-SC, and PV125R-XX-RC pumpsets can be deactivated by disconnecting the power going to terminals 1 and 2 in the pumpset electrical connection boxes. Install a separate switch if necessary.
2. Electrical motor driven pumpsets can be deactivated by disconnecting the power going to the electric motor. Install a separate switch or breaker if necessary.
3. Engine-driven pumpsets with No. 1 and No. 2 Uniblocks can only be deactivated by turning the Uniblock flow control knob to the "OFF" Position. Read Section E of the No. 1 and No. 2 Uniblock Manual. (Ref. No. 190-0006)

After turning the Uniblock flow control knob to the "OFF" position, confirm that the Autopilot will NOT operate the rudder,

Reset the flow rate to produce between 14 and 18 seconds rudder hardover to hardover. Secure flow control knob locking screw. DO NOT secure this screw too tightly. Be certain that the flow control knob can, with effort, be turned to the "OFF" position in an emergency.

INSTALLATION AND OPERATING MANUAL

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WARRANTY OF WAGNER ENGINEERING LTD.

(HEREINAFTER CALLED **WAGNER**)

WAGNER warrants that all products of its manufacture meet high standards of quality and performance and are warranted to be free from defective materials and workmanship when used in the manner and service intended for a period of twelve months after delivery.

This warranty provides labour during normal working hours only, and on the premises of WAGNER.

In the event that WAGNER is required to perform warranty work outside their normal working hours or place of business, the following costs or expenses shall be paid for by the customer:

1. All transportation to the job site and return to the normal place of business.
2. All travelling time to the job site and return to the normal place of business -- at current service rates.
3. All labour for gaining access to, removing, servicing, replacing and testing WAGNER products, including waiting time -- at current service rates.
4. All labour performed by others.
5. Reasonable living expenses if personnel are unable to return to their normal place of business in the same day.
6. All communication charges.
7. All customs duties.

WAGNER will not assume any costs or expenses for special, direct, incidental or consequential damages.

No other warranty or conditions, express or implied, shall be binding upon WAGNER ENGINEERING LTD.

In the case of products supplied, but not manufactured by WAGNER the warranty will be that of the original manufacturer only.

All products eligible for warranty claims must be sent freight prepaid to WAGNER accompanied by a copy of the original delivery documentation and details of the complaint. All goods will be returned freight collect by the least expensive means unless advised otherwise. The warranty will not be honoured if, upon examination, it is determined that the equipment has been abused, modified, misapplied, misused, neglected, or contaminated.

To ensure prompt handling, please register your warranty claim with your WAGNER sales representative prior to returning goods.

Address returned goods to:

Warranty Claims
WAGNER ENGINEERING LTD.
40 Gostick Place
NORTH VANCOUVER, B.C.
Canada V7M 3G2

Phone: (604) 988-1111

Telex: 04-352755

Cable: "WAGENG"

GENERAL DESCRIPTION of the WAGNER S. E. AUTOPILOT

The WAGNER S.E. AUTOPILOT is a complete automatic steering control System incorporating the latest solid state components. The basic system consists of a control unit and a magnetic compass with a course sensor. The autopilot system operates on any voltage from 10 to 40 VOC without modification.

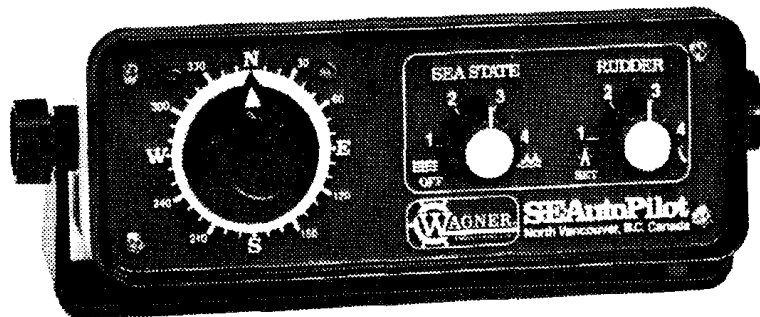
The control unit has wide range controls and uses proportional, integral and differential circuits. SEA STATE (damping) control with a maximum sensitivity of 0.5 degrees optimizes course accuracy in all sea conditions. RUDDER control alters the amount of rudder applied in response to sea and speed changes. A counter rudder circuit senses the rate of change of the course heading and varies the amount of rudder applied accordingly. Automatic rudder trim counteracts persistent course errors due to side winds, waves, current or imbalance of the vessel. Port and starboard indicator lights assist course setting and display steering activity.

The S.E. AUTOPILOT operates with hydraulic and mechanical steering systems controlled by either relays or solenoids which in turn control the length of time and in which direction the steering gear will operate. The relay or solenoid controlled 'drive unit' may be a WAGNER product or be supplied by the customer after verifying system compatibility.

A hand-held remote course setting station, Model RP-50, which includes a 'DODGER' switch is optionally available.

The S.E. AUTOPILOT can also be guided by the ultra-precise automated navigation capabilities of most Loran C receivers and some Satnavs and Decca receivers through the addition of the Wagner Tracker LT180S.

A Wind Vane control unit, also available as an option, will permit sailboat owners to select the wind as a heading reference for their S.E. AUTOPILOT,



SECTION I: AUTOPILOT CONTROLS

SEA STATE

This control adjusts the response time of the autopilot. Decrease SEA STATE in calm seas to optimize course accuracy. Increase SEA STATE in rough seas to prevent unnecessary rudder corrections. This control also features an 'ON/OFF' function in the extreme CCW position.

RUDDER

This control adjusts the amount of correcting rudder applied. Decrease at high speeds by turning CCW to prevent oversteering. Increase by turning CW at low speeds, or when operating in following seas, on heavy displacement vessel, etc. This control also features a SET function in the extreme CCW position -- See following description for COURSE SETTING. After the course is set, the knob may be moved CW beyond the SET detent in order to activate the RUDDER.

The RUDDER control knob has a third function, enabling it to activate the remote control (if installed) by pulling the knob outward -- See following description for OPERATION of REMOTE COURSE SETTING STATIONS.

COURSE SETTING

With SEA STATE at 'OFF' (fully CCW), turn RUDDER to 'SET' (fully CCW). Then switch the unit 'ON' by turning SEA STATE in a clockwise direction. Steer the vessel to the desired heading and rotate the course setting dial until the red and green lights above the dial are both out. (NOTE: Both lights will go out on the desired heading as well as on a 180 degree opposite course. Check the magnetic compass card *if in doubt*.) Activate the pilot by rotating RUDDER in clockwise direction. Adjust SEA STATE and RUDDER to suit the vessel and the sea conditions. To change course, simply turn the course dial to the new heading.

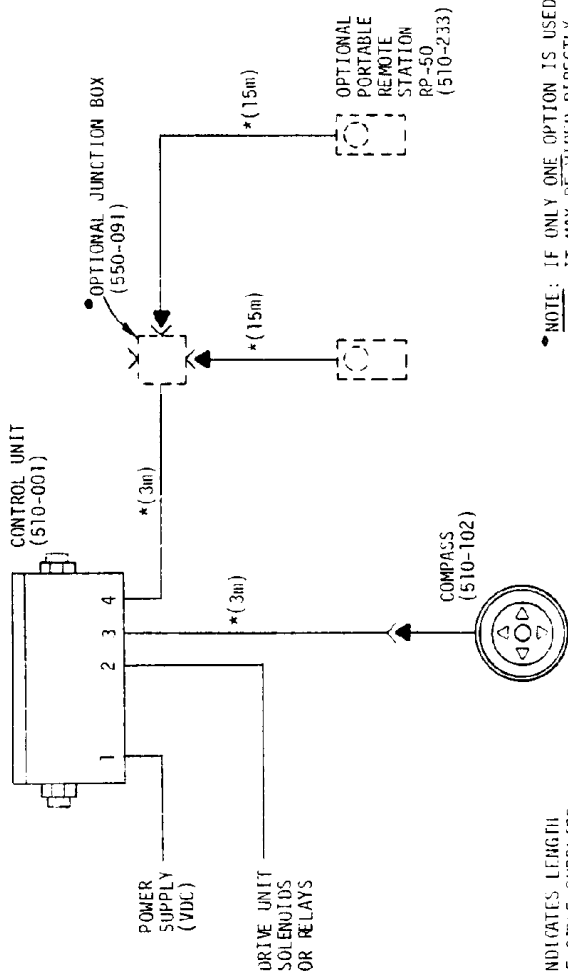
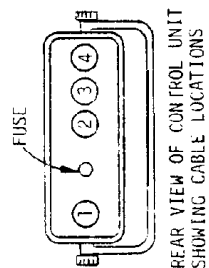
OPERATION of REMOTE COURSE SETTING STATIONS

With the autopilot steering the vessel and SEA STATE and RUDDER in their adjusted positions, pull the RUDDER control outward. This will disable the autopilot. Go to the remote station, select the desired heading and switch to 'ON'. To change course, simply turn the course dial on the remote station to the new heading. To dodge an object in the water, press and hold the spring-centered DODGER switch to 'PORT' or 'STBD' as required. The autopilot will return the vessel to the remote station course dial heading when the switch is released. The DODGER switch will not function again until the vessel has returned to the autopilot heading.

To return steering to the control unit, switch the remote station 'OFF'. Go to the control unit, select the course heading, push the RUDDER control inward and autopilot control is returned to the control unit. (The remote station must be turned 'OFF' when not in use, otherwise it will adversely affect the operation of the autopilot.)

* A remote course setting station may also be used as a non follow-up controller by turning RUDDER on the control unit to the 'SET' position and simply operating the DODGER switch. (The remote station does not need to be switched 'ON'.) The autopilot will not function and the rudder will remain at its immediate position when the DODGER switch is released.

* CW -- clockwise
ccw -- counter clockwise



* NOTE: IF ONLY ONE OPTION IS USED, IT MAY BE WIRED DIRECTLY INTO (4) ON THE CONTROL UNIT. THE JUNCTION BOX IS NOT REQUIRED.

* INDICATES LENGTH OF CABLE SUPPLIED 1 metre = 3.3 feet
ALL OTHER CABLES SUPPLIED BY CUSTOMER

S. E. AUTOPILOT CABLING DIAGRAM

WAGNER ENGINEERING LTD.

40 GOSTICK PLACE, NORTH VANCOUVER, B. C. CANADA V7M3G2
Manufacturers of MARINE HYDRAULIC STEERING GEARS and AUTOMATIC PILOTS

DATE	DWG No.	REV.
OCT/82		
DRAWN		
C. S.	A-8-217	

SECTION II: INSTALLATION PROCEDURE

A. MOUNTING BASIC COMPONENTS

1. **WAGNER COMPASS** - The autopilot compass may be used as the main steering compass or it may be remotely located in a position of minimum magnetic interference for best steering accuracy.

To ensure course setting dial accuracy, the compass lubber line must be carefully aligned with the fore-aft line of the vessel.

(NOTE: This compass must not be mounted close to any engines, tanks, motors, speakers, transmitting antennas, etc.)

Minimum safe mounting distances are:

- 2 to 3 meters (6 to 9 ft.) from electric winches, engines, radars, electric motors, electric meters or large iron masses (particularly anemeters, their connecting wires and the steering system drive unit.)
- 1.5 to 2 meters (4 to 6 ft.) from steering compasses, depth sounders, radiophones, etc.
- 1 meter (3 ft.) from any steel structure, structural support or large fastener.

After installation, the compass should be checked for accuracy and if necessary corrected by a qualified compass adjuster.

(Note: If the compass used is NOT a standard 5 inch model supplied by Wagner, refer to SECTION V, C. for installation and adjustment instructions.)

2. **CONTROL UNIT** - This unit should be mounted close to the helm and away from direct sea spray.

Consideration should be given to the ease of cable installation and access for future maintenance when mounting this unit.

Refer to Dwg. No. A-7-251 and A-8-217 for battery and solenoid or relay connections. The wires to the control unit from the batteries and the drive unit solenoids/relays must be #18. Note that the battery supply to the solenoids/relays MUST be connected through the control unit and NOT directly at the pumpset. If an electric motor driven drive unit is installed, this connection avoids the voltage variations created when the drive unit motor operates. A separate power supply cable between the batteries and drive unit motor is required.

NOTE: The front panel of the control unit must be removed to install the inter-connecting cables. Remove the corner screws and pull straight out. The main circuit board is supported at two points at the rear of the case and the circuit board must be positioned correctly when putting it back into the case.

A length of approximately 9 inches of loose wire should be provided between the watertight gland and the end of each wire connected to the terminal strip to permit easy connection and future access to the circuit board without releasing the watertight gland.

3. DRIVE UNIT - This unit should be mounted where convenient connections can be made to the steering lines and where the cable can be run to the batteries. A warm, dry location such as the engine room is usually suitable. Also, it should be mounted on a resilient base to isolate vibration and noise from the hull of the boat.

The unit should be electrically bonded to the vessel's ground for R.F. shielding purposes. This must be negative or neutral ground.

The installation of distribution panel switches and/or breakers is left to the discretion of the installer/owner. If a Wagner drive unit is installed, consult the manual supplied to determine the current requirements. The maximum current draw of the control unit is 0.5 amps. The solenoid or relay current draw, when energized, must be added to determine the total current draw.

IMPORTANT (Refer to Dwg. No. C-7-247)

* An auxiliary transistor switch, Q7, capable of switching a maximum of 3 amps, is provided in the control unit. This is sufficient to turn on the electric motor of a Wagner Type 2A (constant running) pumpset for example, or energize the electric clutch of a mechanical drive unit. These functions are selectable by a moveable jumper on the control circuit board.

* The control unit is supplied with the jumper in position "B" (connecting battery positive and Terminal 1 on the terminal strip, TBI). This allows a motor starter relay to be activated when the control unit is turned 'ON' and also permits "jog steering" with a remote course setting station when the RUDDER control is in the 'SET' position.

* When the S.E. Autopilot is to be used with a mechanical drive unit with an electric clutch, the jumper must be changed from position "B" to position "A" so that the clutch will engage when the RUDDER control is advanced clockwise (out of the 'SET' position).

* Jumper position "A" is also used with a Wagner PV125R-xx-RC/SBP hydraulic pumpset. This relay controlled pumpset is installed when a hydraulic cylinder is used to drive the rudder quadrant of a mechanical steering system. When the autopilot is turned 'OFF' the solenoid

bypass valve on the pumpset centers (or bypasses) to permit the autopilot cylinder to be stroked back and forth by the quadrant and not interfere with the manual operation of the steering gear.

When using the S.E. Autopilot control unit in retrofit installations with drive units other than Wagner, it must be done with careful consideration for the protection of the drive unit, the steering gear, and in the case of mechanical steering, the operator's safety. Features such as limit switches, relief valves, overload slip clutches and over-current cut-outs may or may not be incorporated.

Provision should be made to utilize existing protective devices and/or add such protection if it has not been provided. If in doubt, consult your dealer or the factory for recommendations concerning any specific installation.

4. REMOTE STATIONS - Optional remote course setting stations are located where convenient for installation and service, and where protected from direct rain or sea spray.

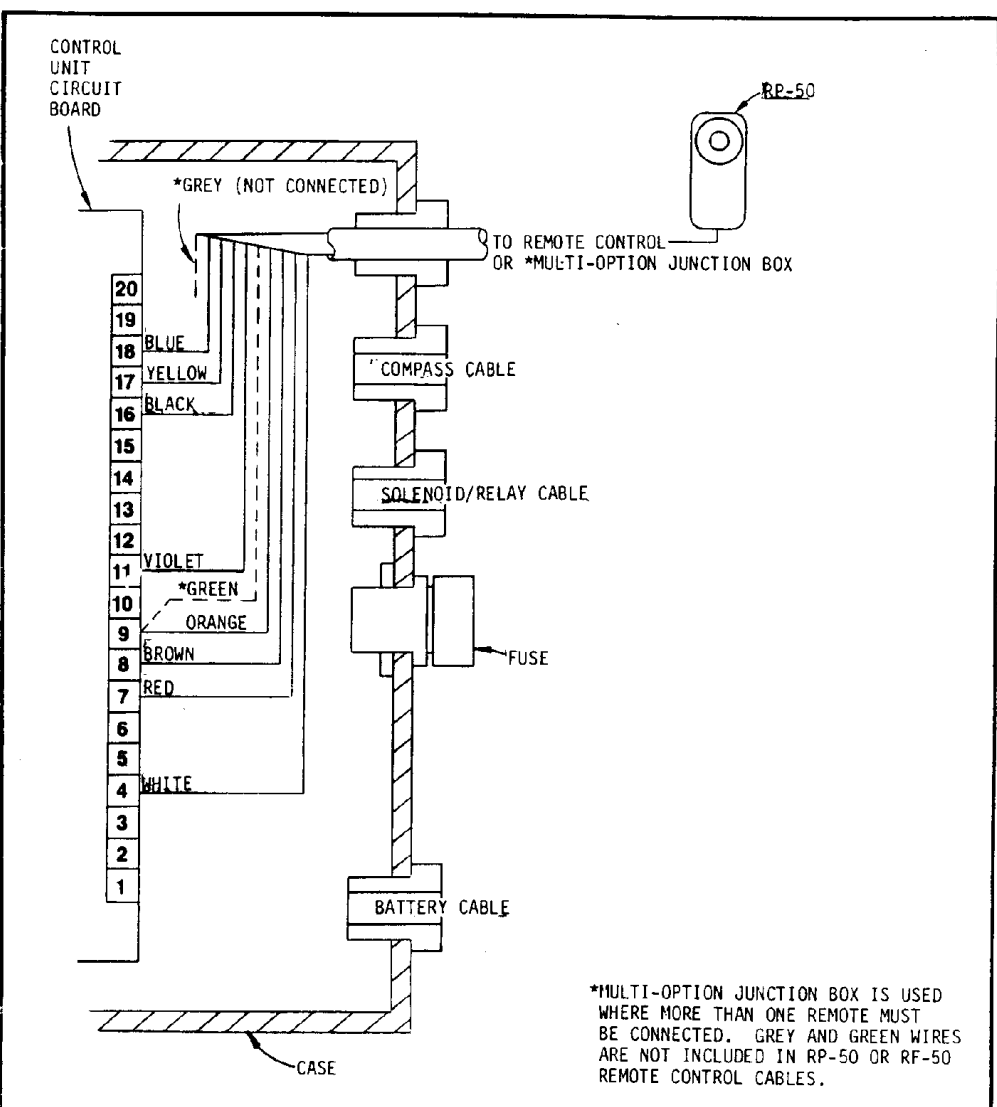
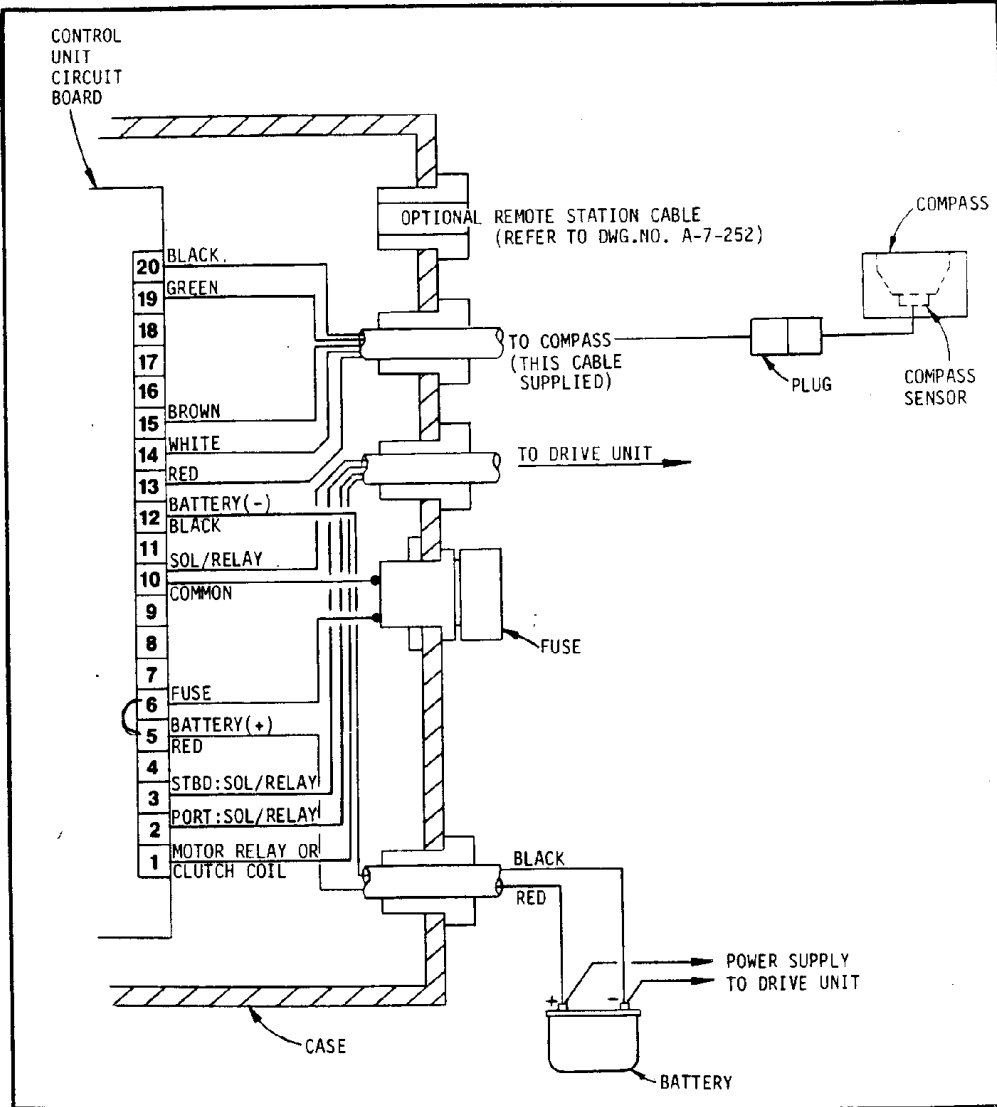
See wiring diagram, Dwg. No. A-7-252. Remote stations are supplied with 15 meters (50 feet) of cable. The plug supplied on this cable must be cut off, the individual wires stripped and then connected through the correct watertight gland to the terminal strip in the control unit as described in 2. CONTROL UNIT above.

B. INTERCONNECTING CABLES (Refer to Dwg. No. A-7-251)

The compass cable, fitted with a plug, is prewired into the control unit. All other cables required to interconnect a basic system must be supplied by the customer.

The wires to the control unit from the batteries and the drive unit solenoids/relays must be #18. Generally, if the drive unit is driven by an electric motor, #10 wires are normally recommended from the batteries to the electric motor. If the length of these wires is over 10M (30 ft), #8 wire is suggested. If a Wagner drive unit is installed, follow the specifications listed in the manual.

Wagner has a selection of cable available to complete the installation of an S.E. Autopilot as a service to their customers and will provide a quotation upon specific request. The customer is requested to determine his cable length requirements before contacting Wagner.



*MULTI-OPTION JUNCTION BOX IS USED WHERE MORE THAN ONE REMOTE MUST BE CONNECTED. GREY AND GREEN WIRES ARE NOT INCLUDED IN RP-50 OR RF-50 REMOTE CONTROL CABLES.

S.E. AUTOPILOT CONTROL UNIT WIRING DIAGRAM

S.E. AUTOPILOT REMOTE STATION WIRING DIAGRAM

WAGNER ENGINEERING LTD.
 40 GOSTICK PLACE, NORTH VANCOUVER, B. C. CANADA V7M3G2
 Manufacturers of MARINE HYDRAULIC STEERING GEARS and AUTOMATIC PILOTS

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WAGNER ENGINEERING LTD.
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SECTION III: TESTS and ADJUSTMENTS

A. DOCKSIDE TESTS (TO BE COMPLETED IN THE ORDER LISTED)

-- In case of problems, refer to SECTION V: SERVICE

1. VISUAL CHECKS - All wiring and component mounting must be carefully inspected to avoid possible damage from vibration, chafing, strain, overheating and short circuits from loose wires.

2. POLARITY CHECK - If the autopilot will not turn on and power is available, the power supply connections may be reversed. RED is POSITIVE. BLACK is NEGATIVE. If the polarity is reversed, the fuse, located on the rear of the control unit, will blow and must be replaced before testing can proceed.

3. RUDDER SPEED - Before any of the following adjustments are made, it is advisable to continue moving the steering gear from hardover to hardover until the steering gear responds instantly. (i.e. Most of the air must be purged from the system.)

* Turn the autopilot 'ON' with the SEA STATE control knob. Turn the RUDDER control knob to the extreme clockwise position. Examine the magnetic compass heading and turn the course dial to the same heading until the "null position" is found. Both port and starboard lights will be out in the null position. By moving the course knob to approximately 30 degrees either side of this null position, the steering gear can be made to go from hardover to hardover. The rudder speed can be timed during this hardover to hardover manoeuver.

* The steering gear should optimally move from hardover to hardover in 14 seconds. If a WAGNER PV125R-XX-RC or PV125C-XX-SC hydraulic pumpset (drive unit) is used on a large steering gear, 14 seconds may not be obtainable even at the maximum flow setting. Hardover to hardover times as much as 18 seconds may be acceptable with minimum loss of performance. A larger drive unit is required if 18 seconds cannot be achieved. To increase or decrease the flow rates of WAGNER pumpsets, refer to the manual for the pumpset being used.

Type 2A pumpset:	Manual Ref. No. 190-007
PV125R-XX-RC pumpset:	Manual Ref. No. 790-026
Engine-driven pump with No. 1 or No. 2 Uniblock:	Manual Ref. No. 190-006
MDU20-XX-RC mechanical drive unit:	Manual Ref. No. 790-018

When using an electric motor driven pumpset, such as WAGNER Type 2A, PV125R-XX-RC or PV125C-XX-SC, the maximum pressure must be checked in the hard-over position to be certain that the motor is not drawing excessive current. With an ammeter in series with one pumpset power lead, adjust the relief valve pressure so that the current does not exceed the maximum continuous current rating recommended for the pumpset. WAGNER PV125 type pumpsets must not exceed 20 amps on a 12 VDC system and 10 amps on a 24 VDC system. All WAGNER Type 2A pumpsets are factory preset to a pressure setting of 1000 psi. The Type 2A pumpset has its own circuit

breaker. BEFORE sea testing, it would be advisable to run the pumps with the steering gear in the hard-over position for 3 to 4 minutes to be certain that the pumpset circuit breaker or vessel fuses do not open.

4. INITIAL TEST - Centre the rudder using manual steering. Select the 'SET' position on the RUDDER control. Switch the unit 'ON' by turning SEA STATE in a clockwise direction. Rotate the course setting dial slowly until both the RED and GREEN lights go out. This will occur at two places (180 degrees apart). One heading will be within 2 degrees of the required compass course. This is the correct dial setting. Note that the dial must be turned clockwise to extinguish the red light and counter clockwise to extinguish the green.

The compass Index Mark (lubber line) should be forward, if not, the indicated course will not be correct.

Rotate the course setting dial for a GREEN (starboard) light (about 30 degrees from the course heading) e.g. -- If the compass heading is 090, then turn the dial to 120 degrees.

Switch to pilot by turning RUDDER in a clockwise direction. The GREEN light will go on and the rudder will move approximately 10 degrees to starboard with RUDDER at minimum; further if RUDDER is increased. The GREEN light will remain on and the rudder will increase further to starboard (automatic trim action).

IF THE RUDDER MOVES TO PORT, shut the power off and reverse the pumpset connections as follows:

WAGNER Drive Unit Model	
Type 2A	Reverse connections to terminals 5 and 7
PV125R-XX-RC	Reverse connections to terminals 3 and 5
MDU20-XX-RC	Reverse connections to terminals 3 and 5
Solenoid Controlled (e.g. Uniblock)	Reverse connections to Port and Starboard Solenoids

When the rudder is moving in the correct direction, check that the rudder will move both ways by setting courses about 30 degrees off the compass heading to both port and starboard.

B. SEA TESTS

These tests should be done in an area free of obstacles and where large course changes and steering corrections may be made. Start with a slow vessel speed.

1. DRIVE UNIT CURRENT DRAW - Test the steering gear for 3 or 4 minutes in the hardover position as previously described under TESTS and ADJUSTMENTS A. 3.

2. COURSE SETTING - Switch the autopilot to 'SET' and adjust the course setting dial to the heading being hand steered (both-lights-out condition). REMEMBER, turn the dial clockwise to extinguish the red light and counter clockwise to extinguish the green.
3. OPERATIONAL CHECK - Activate the pilot by rotating RUDDER in a clockwise direction. The autopilot should try to hold the vessel on course. If the vessel goes hardover, recheck that a 180 degree opposite heading was not selected. If necessary, repeat the dockside tests. If the course is set correctly and the rudder still goes hardover, repeat DOCKSIDE TEST A. 4.

The autopilot course holding can be improved by adjusting SEA STATE and RUDDER -- see SECTION I: AUTOPILOT CONTROLS

The SEA STATE control should be adjusted for minimum steering corrections with best course accuracy. This sets the autopilot response time to the sea conditions. In rough weather, SEA STATE is increased so that the autopilot is not constantly working. In calm seas, SEA STATE is decreased.

The RUDDER control adjusts the amount of correcting rudder applied. If the vessel is moving slowly or operating in following seas, a large rudder movement may be necessary to return to course, therefore, increase RUDDER. If the vessel is travelling at high speed, only a small rudder movement is required and RUDDER should be decreased. Due to wide range adaptive circuits in the autopilot, it may not be necessary to adjust this control for different conditions once an optimum setting has been determined.

Try the autopilot at varying vessel speeds and different courses to develop a 'feel' for adjusting the controls.

* If the vessel follows an 'S' shaped course in calm seas with both SEA STATE and RUDDER at the minimum settings, the rudder speed should be decreased (up to approximately 18 seconds). If a WAGNER pumpset is used, refer to the appropriate manual as listed under DOCKSIDE TESTS, 3. to adjust the speed.

* The pounding motion of a high speed boat in rough water may cause the gimballed compass to swing violently or even tumble 360 degrees, resulting in very erratic autopilot performance. Some form of gimbal restriction should be considered, such as foam rubber, if this is a normal operating condition. A non-gimballed compass could also be considered, in which case the factory should be consulted.

- * 4. INTERNAL SETTINGS (Refer to Control Circuit Board Component Layout)
 - a) Counter Rudder - Two counter rudder adjustments, RV-3 and RV-4, are mounted on the main circuit board in the control unit. They are accessible for screw-driver adjustment from the right-hand side of the panel/circuit board assembly when it is removed from the case. (The panel/board assembly is held in place by four screws located at the corners of the front panel.)

RV-3 adjusts the rate sensing of the counter rudder circuit. It is factory preset to the optimum for boats up to approximately 15 metres (50 feet) in length. It should only be adjusted by a competent autopilot technician. For larger boats, the setting should be increased in the clockwise direction for optimum course holding with minimum rudder deflections.

An alternate method of setting this adjustment is possible by making moderate course changes (20 to 30 degrees) on the course setting dial and adjusting RV-3 for the minimum overshoot coming onto the new course. (This overshoot should be observed on the autopilot compass.) Increasing this rate sensing control too far will set up oversteering oscillations.

RV-4 is the counter rudder gain control, factory preset for boats with good directional stability and rudder control. For boats that are directionally unstable and/or have poor rudder effectiveness, (especially at small rudder angles) increasing this gain control (clockwise) will increase the amount of rudder applied in response to falling off course rapidly. This increased momentary rudder action will hold course deviations to a minimum. Increasing this gain too far, however, will set up oversteering oscillations.

Some high speed boats may need less gain to reduce oversteering. Turn RV-4 counter clockwise.

- b) Rudder Limit - Adjustment RV-2 is located at the front and near the middle of the main circuit board, just behind the front panel. (Do not confuse with RV-1, about 2 cm away.) This rudder limit adjustment is preset fully clockwise to limit the compass signal at ± 3 VDC (from V Ref.). It has a control range from ± 0.5 to ± 3 VDC.

The purpose of this adjustment is to limit the rudder deflection and therefore rate of turn when a large course change is commanded from the course dial. If, after setting RV-3, RV-4 and the SEA STATE and RUDDER controls for normal cruising conditions, the turn rate when dialing course changes is uncomfortably or dangerously high, rotate RV-2 counter clockwise until a satisfactory turn rate is achieved. Note that the rudder limit set this way will vary with the RUDDER control setting. This means that at low speeds when the rudder control is increased, the rudder limiting circuit will allow a higher rudder deflection. This is a desirable feature, especially for net or trawl fishermen who require large rudder deflections to maintain course when fishing at low speeds but need to limit turn rate at high speeds.

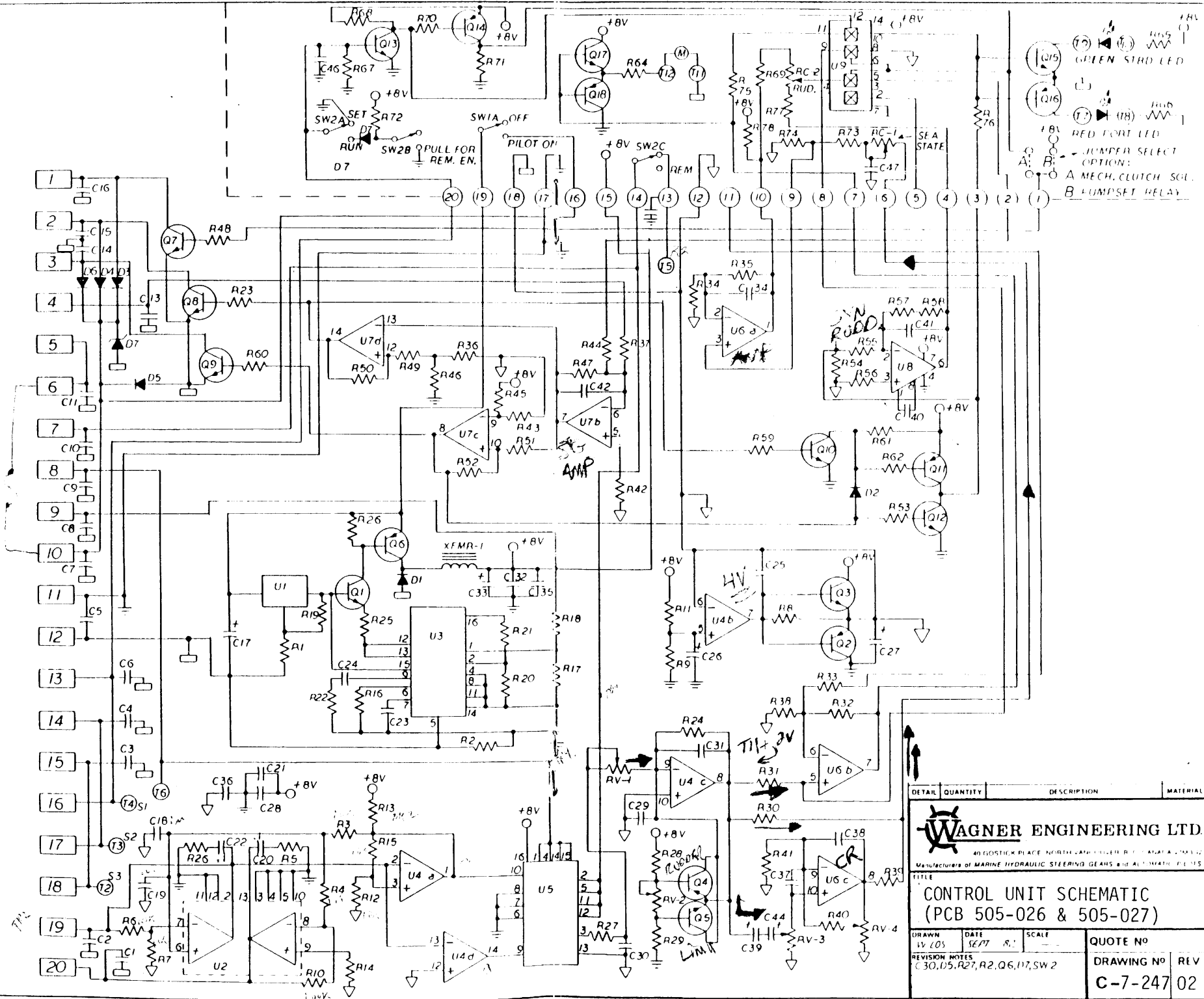
- c) Compass Gain - Adjustment RV-1 is factory preset and should only be reset by a competent technician using the proper test equipment. Normally, adjustment will only be required when the compass is not a Wagner 5 inch compass and after repair or replacement of circuit boards.

* To reset the compass gain, first remove any rudder limiting by rotating RV-2 full clockwise. Then measure the compass amplifier output (with a good quality voltmeter) between U4, pin 8 and +4 V Ref. (on AMP Terminal T11, on control circuit board). Rotate the course setting dial until both lights go out and the voltage drops to zero. Note the dial setting. Rotate the course dial clockwise 20 degrees and adjust RV-1 to obtain +2 VDC output. Rotate the dial 40 degrees to port and check that the output is ± 2 VDC. These settings do not have to be precise. A tolerance of $\pm 10\%$ is permissible.

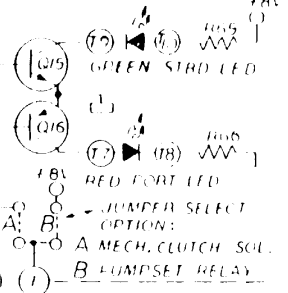
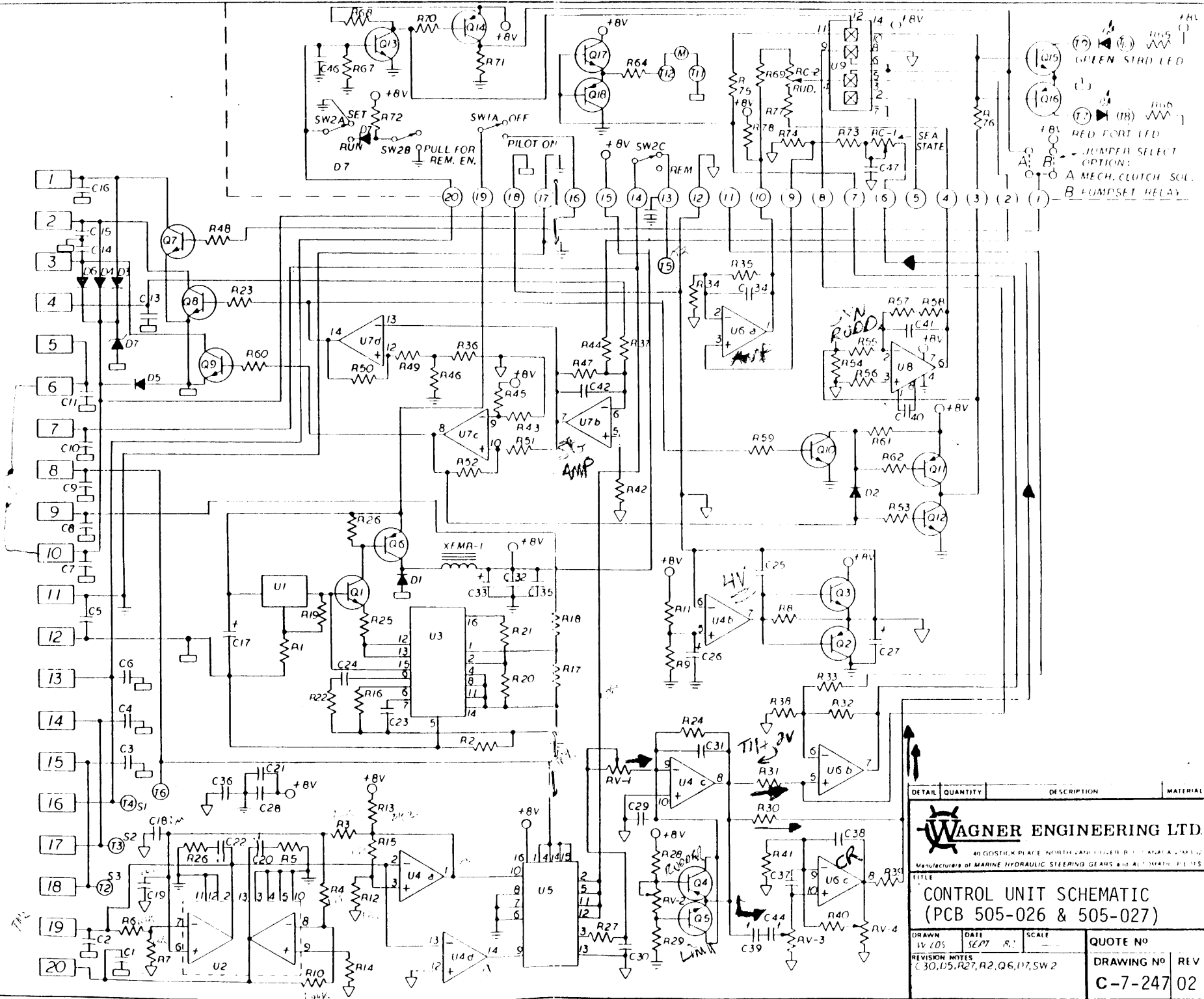
If the RV-1 setting required to achieve ± 2 VDC is clockwise more than a two o'clock position (when viewed facing the front panel), the compass magnets are weak or too far from the sensor and course dial accuracy and stability could be degraded.

PARTS LIST for S. E. AUTOPILOT CONTROL UNIT

<u>PART DESCRIPTION</u>	<u>PART NO.</u>
Main and control circuit board subassembly	550-028
Compass cable assembly	550-008
Cable gland	610-009
Cable gland nut	610-010
Course synchro transformer	470-016
Course synchro adaptor shaft	650-078
Course synchro adaptor shaft seal	615-029
Front panel housing	650-176
Front panel label	660-137
Front panel seal	615-018
Front panel sealing screw	603-148
Fuse holder	421-009
Fuse (5 amp)	420-004
Knob - course setting	620-023
Knob - SEA STATE/RUDDER control	620-024
L. E. D. - red	303-013
L. E. D. - green	303-014
Mounting bracket	650-177
Mounting bracket screw knob	620-025
Rear housing	655-116
Sealing nut - SEA STATE/RUDDER control	211-001
Wire terminals, snap-on	431-072



DETAIL	QUANTITY	DESCRIPTION	MATERIAL
 WAGNER ENGINEERING LTD. <small>40 GLOSTOCK PLACE, NORTH LAKESHORE, B.V. 1104 A.A. THE NETHERLANDS</small> <small>Manufacturers of MARINE HYDRAULIC STEERING GEARS and ALL SYNTHETIC P.E. 15</small>			
CONTROL UNIT SCHEMATIC (PCB 505-026 & 505-027)			
DRAWN SV 105	DATE SEP 77	SCALE A:	QUOTE NO
<small>REVISION NOTES</small> C30, D5, R27, R2, Q6, D7, SW 2			DRAWING NO C-7-247
			REV 02

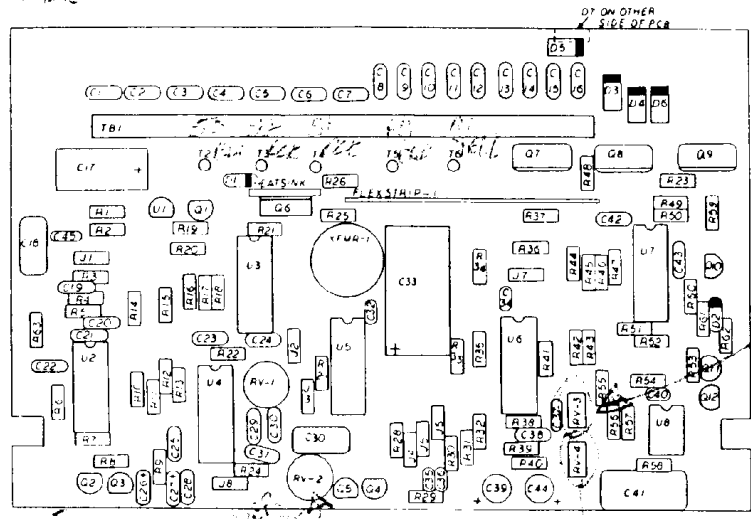


DETAIL	QUANTITY	DESCRIPTION	MATERIAL
WAGNER ENGINEERING LTD. <small>40 GOSWICK PLACE NORTH LAKESHORE NSW 1570 AUSTRALIA</small> <small>Manufacturers of MARINE HYDRAULIC STEERING GEARS and ALL SYNTHETIC FLUIDS</small>			
CONTROL UNIT SCHEMATIC (PCB 505-026 & 505-027)			
<small>DRAWN</small> SV 205	<small>DATE</small> SEP 77	<small>SCALE</small> A:1	<small>QUOTE NO</small> ---
<small>REVISION NOTES</small> C30, D5, R27, R2, Q6, D7, SW 2			<small>DRAWING NO</small> C-7-247
			<small>REV</small> 02

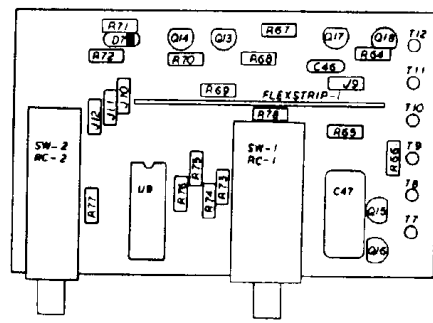
COMPONENTS LIST for S.E. AUTOPILOT CONTROL UNIT

COMPONENT	VALUE	PART NO.	COMPONENT	VALUE	PART NO.
C1-12,14-16, 19, 20, 22, 24, 25, 28, 30, 32, 35, 36, 42, 43, 45	.1 mfd	400-024	R19, 28, 29	1K/1/2W	115-039
C13, 19, 34	.01 mfd	400-010	R23, 25, 48, 60	270/1/2W	100-020
C18, 41, 47	1 mfd	400-004	R24, 30, 39	270K/1/2W	115-053
C17	100 mfd/63V	401-048	R26	68/1/2W	100-079
C21, 39, 44	4.7 mfd/50V	401-037	R32	1M/1/2W	100-044
C23	470 pfd	400-028	R34, 74	470K/1/2W	115-054
C26, 27	22 mfd/16V	401-027	R35, 57	10M/1/2W	115-058
C31	.047 mfd	400-011	R36, 43	390/1/2W	115-037
C33	1000 mfd/25V	401-049	R40	2.7M/1/2W	115-056
C37, 40	1 nfd	400-029	R41	1.5M/1/2W	100-040
C46	3.3 mfd/50V	401-029	R44, 69, 71, 72, 75, 77	4.7K/1/2W	115-042
D1	IN4936	300-020	R49, 51	68K/1/2W	115-050
D2	IN4005	300-003	R50, 52	2.2M/1/2W	100-014
D3-6	IN5402	300-019	R54	560/1/2W	100-036
D7	IN5369	302-022	R55, 56	8.2M/1/2W	100-090
J1-12	0 ohm jumper	115-060	R58	22M/1/2W	115-059
Multi-wire strip	20 wire, 2 inch	441-041	R64	10/1/2W	100-024
Q1, 3, 5, 10, 12, 13, 15, 17	2N401	310-006	R73	4.7M/1/2W	100-041
Q2, 4, 11, 14, 16, 18	2N4403	311-004	R78	3.3K/1/2W	100-047
Q6	MJE15029	313-014	RC-1/SW-1	5M pot./switch	131-002
Q7, 8, 9	TIP 141	312-016	RC-2/SW-2	10K pot./switch	131-005
R1	15K/1/2W	100-031	RV-1	100K pot.	130-023
R2	0.27/1W	103-005	RV-2	10K pot.	130-021
R3, 4, 7, 12, 14, 15, 20, 21, 22, 27, 42, 45, 46, 53, 59, 61, 62, 68, 70, 76	10K/1/2W	115-045	RV-3	1M pot.	130-053
R5, 63	4.7/1/2W	100-070	RV-4	10K pot.	130-055
R6, 10, 31, 33, 38, 47, 67	100K/1/2W	115-051	TB1	W18A 8180/20	430-027
R8, 65, 66	51/1/2W	100-019	T2-12	AMP 60874-1	431-013
R9, 11	1K/1/2W (1%)	114-003	U1	LM317L	315-018
R13, 37	2.2K/1/2W	115-040	U2	LM1877N	350-010
R16	33K/1/2W	115-048	U3	CA3524	315-019
R17	12K/1/2W	100-073	U5	MC14052	360-043
R18	27K/1/2W	115-047	U4, 6, 7	LM324N	350-005
			U8	LM308H	350-011
			U9	MC14066	360-012
			XFMR-1	Wagner subassembly	550-003
			Z01	IN5369	302-022

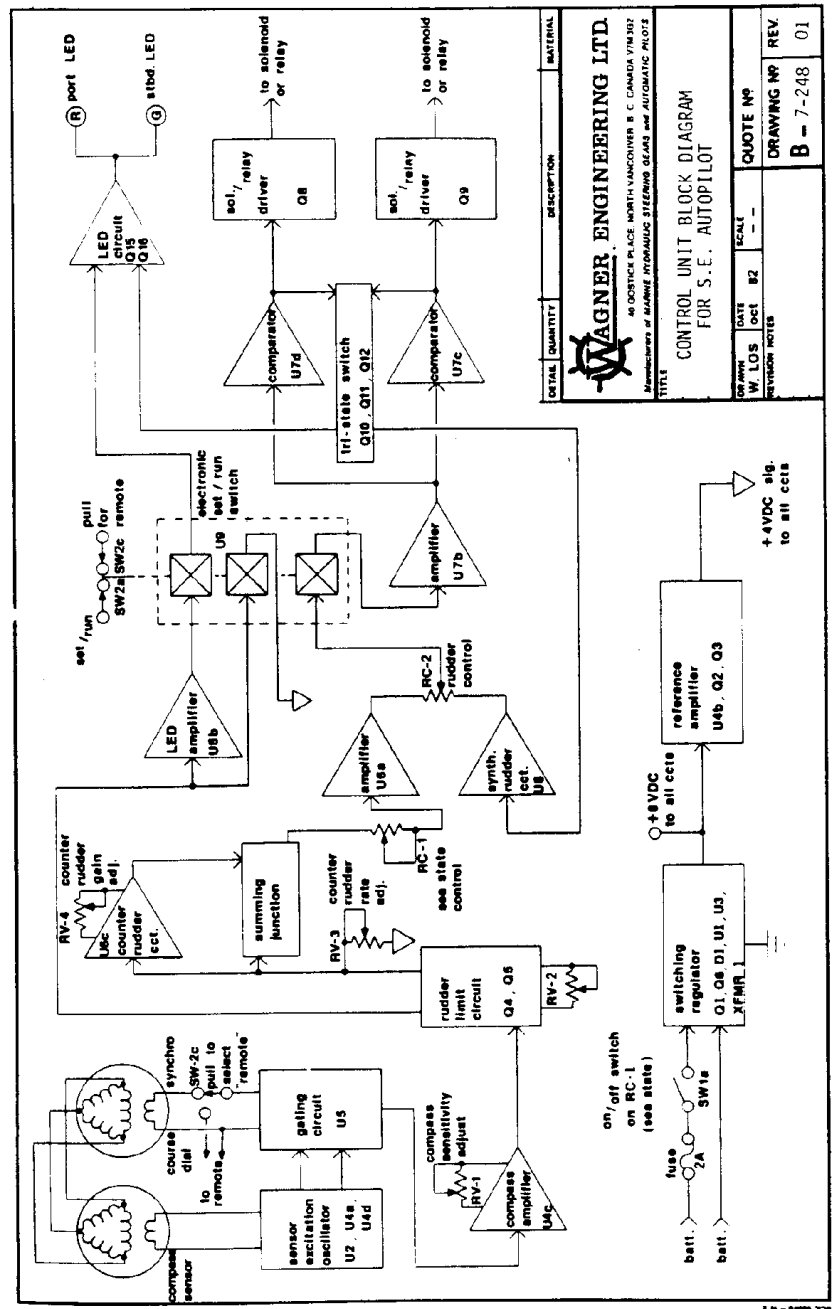
R1 - BLUE
 R2 - RED
 R3 - BLUE
 R4 - YELLOW
 R5 - BLUE



MAIN CIRCUIT BOARD COMPONENT LAYOUT
 (PCB 505-026)



CONTROL CIRCUIT BOARD COMPONENT LAYOUT
 (PCB 505-027)



DETAIL	QUANTITY	DESCRIPTION	MATERIAL
WAGNER ENGINEERING LTD. <small>40 DORRICE PLACE NORTH VANCOUVER B. C. CANADA V1M 3D7</small> <small>Manufacturers of MARINE HYDRAULIC STEERING GEAR and AUTOMATIC PILOTS</small>			
CONTROL UNIT BLOCK DIAGRAM FOR S.E. AUTOPILOT			
DATE	SCALE	QUOTE NO.	REV.
W. LOS	B2		B - 7-248
REVISION NOTES			01

SECTION IV: TECHNICAL DESCRIPTION

The S.E. Autopilot, although simple in appearance, employs very sophisticated electronic circuitry. We recommend that internal parts replacement and service be performed by factory authorized technicians if the following circuit theory and details are not fully understood.

Replacement of an entire unit, assembly or circuit board will generally result in faster and more economical field servicing.

A. COMPASS SENSOR

The Wagner compass sensor is a toroidal magnetic flux detector. It is mounted on the underside of the compass bowl. The compass itself is a standard externally gimballed type.

Signals generated in the compass sensor by the magnetic field of the compass card are transmitted to a synchro receiver. This synchro receiver is directly connected to the course setting dial in the control unit and the remote stations. The output signal of the synchro is phase detected to give an error signal proportional to the difference between the compass card heading and the synchro position. With the RUDDER control in the 'SET' position, this signal is used to switch the RED and GREEN course setting lights. When the autopilot is activated, this signal is used to steer the vessel.

B. CIRCUITRY

Refer to Dwg. No. B-7-250: Test Point Waveforms and C-7-247: Schematic.

The switching regulator accepts any input voltage from 10 VDC to 40 VDC and provides +8 VDC power for all internal circuits.

A fuse is provided to protect against short circuits and reversed battery connections. Diode D5 short circuits reversed battery voltage, protecting the circuitry until the fuse opens.

The signal reference amplifier divides the regulated 8 volt supply voltage in half ($\pm 2\%$) and provides a low impedance 4 volt reference bus (common wire) for the signal processing circuits.

The sensor excitation oscillator is comprised of two comparators, U4-Section A and U4-Section B, an integrator (R3 and C18) and a dual power amplifier, U2, in a positive feedback loop. This circuit outputs two 420 Hz square wave gating signals 90 degrees out-of-phase to the demodulator and two complementary (180 degrees out-of-phase) triangle waves to the sensor primary winding. Typical waveforms are shown in Dwg. No. B-7-250 and respective test points are: Waveform 1 at U4, pin 1; Waveform 2 at pins 19 and 20 of the terminal strip, T1, and Waveform 3 at U4, pin 14.

The primary excitation induces second harmonic signals in the secondary windings of the sensor. In the absence of any magnetic field, the net output is zero because the three secondary windings are connected in opposition to each other. When in the presence of the magnetic field of the compass however, unbalance second harmonic pulses can be measured between any two of the three sensor secondary lines. (Waveforms 4 and 5 at terminals 13, 14 and 15 of the terminal strip, T1.) These output signals correspond to the strength and direction of the magnetic field and are resolved to a two-wire signal in the course setting synchro transformer. The amplitude of this synchro output signal (waveforms 4 and 5 between pins T5 and T6) will vary with rotation of the compass or the course setting dial, dropping to a minimum of two points 180 degrees apart with peaks 90 degrees between the nulls. This is the unprocessed compass error signal. One minimum (or null) is chosen as the operating point of the autopilot and is the point where the compass reading and the course dial must agree. Gating circuit, U5, synchronously demodulates this signal which is then smoothed and amplified by U4-Section C. The output (on pin 8) is a DC signal, factory preset by RV-1 to a level of 100 millivolts per degree of compass error. This is measured between the signal reference bus (Pin T11 on the control circuit board) and U4-Section C, pin 8 and is set to 2 volts at 20 degrees compass error (the difference between the compass reading and the dial reading). This can be set to starboard of null, or to port, but the port reading will be negative 2 VDC.

The calibrated compass signal can be limited in peak amplitude by the "Rudder Limit" circuit. This limit is set during sea trials (see SECTION III.B.4.b.) to prevent the autopilot from applying too much rudder during course changes.

The proportional, limited, compass signal is further processed by the counter rudder circuit which senses the rate of change of the compass signal (set by RV-3) and outputs the amplified derivative (gain set by RV-4) which is added to the proportional signal. The four pole electronic switch, U9, gates the processed compass signal to the L.E.D. port and starboard indicators when the 'SET' switch is activated at the fully counter clockwise position of RC2, the RUDDER control. This aids the correct setting of the course dial and also provides a "steer-by-lights" feature.

When the RUDDER control is advanced clockwise from the 'SET' position, the compass signal is removed from the L.E.D. circuit and gated to RC-1, the SEA STATE control. The SEA STATE circuit averages the compass signal to cut down unnecessary wear and tear and power consumption of the rudder actuator. The averaging time increases from 0.1 seconds in the counter clockwise position (for calm seas) to 5 seconds in the fully clockwise position (for heavy weather conditions).

From the SEA STATE circuit, the compass signal goes to one end of the RUDDER control. The output of the synthesized rudder circuit goes to the other end of the RUDDER control. The wiper of the RUDDER control selects the amount of rudder movement commanded by the autopilot for a given amount of change of the boat heading from the course selected (compass error).

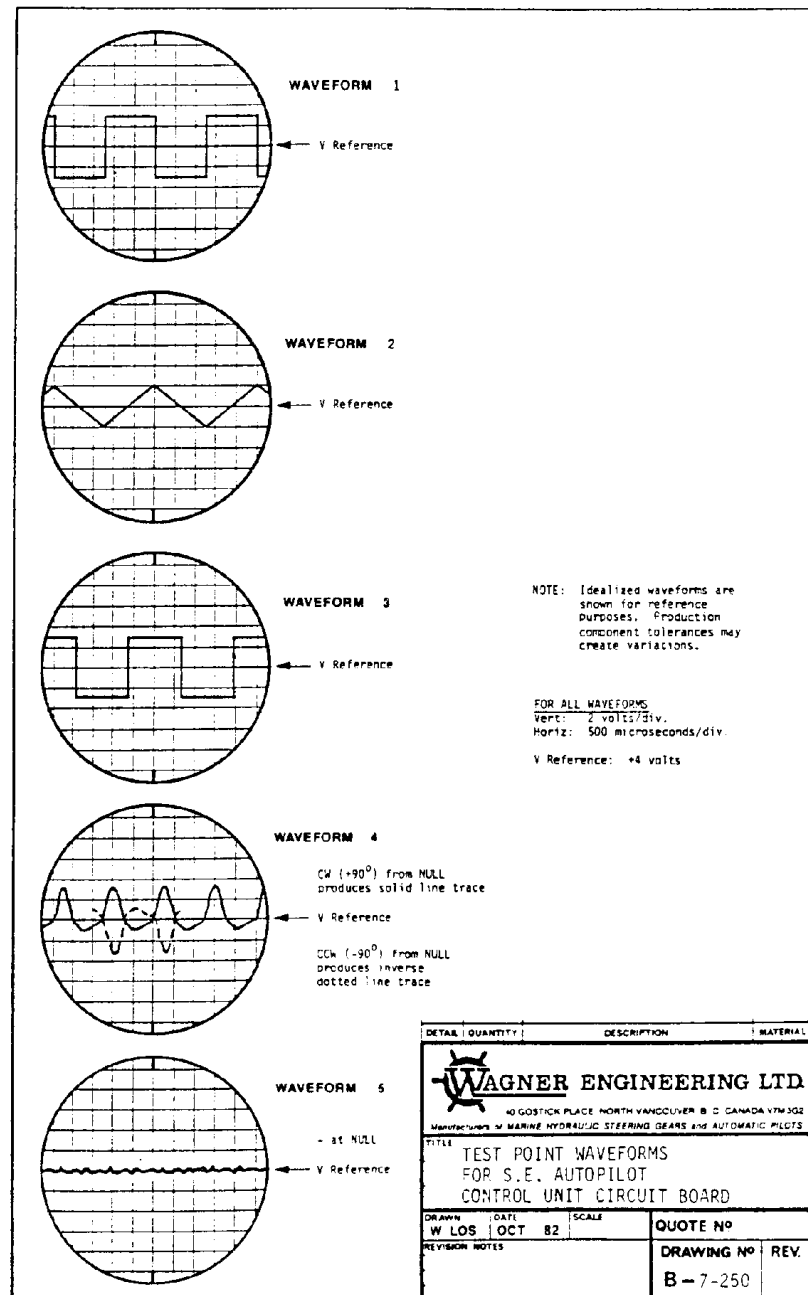
In the fully counter clockwise position the autopilot will apply one third of a degree of rudder correction when the boat falls off 1 degree, and 3 degrees correction in the fully clockwise position. Switching circuit, U9, disconnects this rudder correction signal from the output circuits when the RUDDER control is in the 'SET' position.

When the RUDDER control is advanced clockwise from 'SET', the rudder signal is connected to amplifier, U7-Section b, and then applied to two comparators which provide a finite positive (U7-Section C: Starboard) and negative (U7-Section D: Port) switching point to trigger the respective solenoid/relay driver transistor, Q9 or Q8, moving the rudder in the desired direction.

The comparators also turn on the tri-state switch formed by Q10, Q11 and Q12. The output of this switch gates the synthesized rudder circuit and the L.E.D. circuit, which indicates "green" when a starboard correction is made and "red" to port.

The synthesized rudder circuit is an integrator which simulates the signal of a rudder follow-up potentiometer. For example, when a starboard rudder correction is being made the output voltage goes negative at a rate equivalent to the speed of the rudder until the compass error voltage on the other end of the RUDDER control potentiometer is balanced at zero voltage on the wiper, turning off the comparator, driver transistor, and the tri-state switch. This equilibrium position is maintained until the rudder correction produces the desired heading correction. The port circuitry then triggers and restores the rudder to the midships position.

The synthesized rudder circuit, in addition to controlling large rudder movements in proportion to compass errors, provides a rudder trim function. It constantly averages rudder action over a period of 30 seconds and makes slow adjustments to the rudder position such that the average compass heading error is always zero in spite of helm bias, wind, off-center loading or drag created by fishing gear, etc. The synthesized rudder circuit, in place of a rudder transmitter, drastically reduces installation time, maintenance down-time and costs generally by eliminating this common source of autopilot failures.



SECTION V: SERVICE

A. ROUTINE MAINTENANCE

The S.E. Autopilot is all solid state construction and no routine electrical maintenance is required other than periodic performance checks. Maintenance instructions for Wagner drive units are included in the manuals supplied separately.

B. TROUBLE SHOOTING

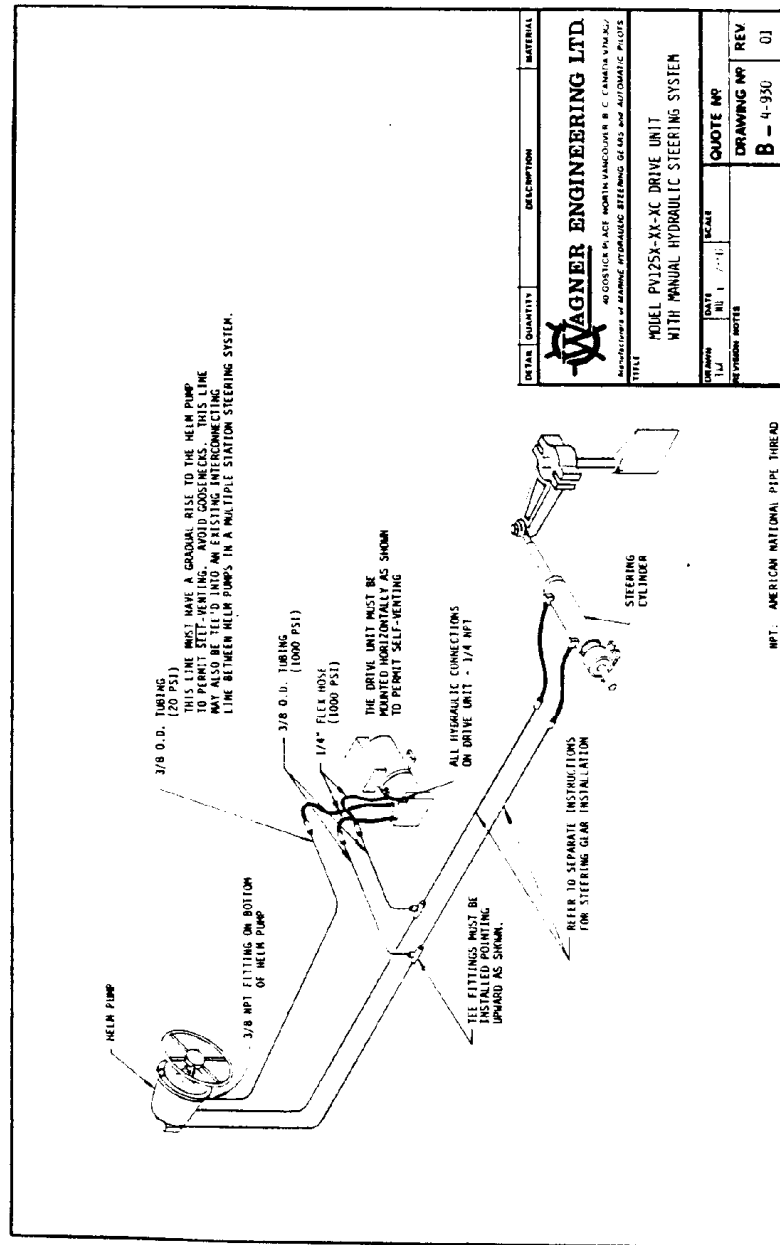
The following test procedure is confined to external checks due to the sophisticated nature of the electronic circuitry. The schematic diagrams accompanying the TECHNICAL DESCRIPTION will allow a competent technician to diagnose any internal component problem. FIELD SERVICE SHOULD ONLY BE ATTEMPTED IF THE OPERATIONAL CHARACTERISTICS OF THE AUTOPILOT ARE FULLY UNDERSTOOD AND ONLY AFTER THE EXTERNAL CHECKS ARE PERFORMED. If all external operations and voltages appear normal yet the autopilot does not function properly, carefully repeat all installation and test procedures in SECTIONS II and III.

NOTE: A good quality voltmeter will be necessary to assure the reliability of required measurements. When making measurements, be certain that the meter probes penetrate the protective lacquer coating applied to both sides of the printed circuit boards.

1. Turn RUDDER control to 'SET' position (fully CCW)
2. Turn SEA STATE control to 'ON' position (rotate CW)
3. Rotate the course setting dial through 360 degrees -- the RED (port) lamp should be on for 180 degrees of the rotation and the GREEN (starboard) lamp for the remaining 180 degrees.
4. If neither lamp goes on, check the following:
 - a) The battery voltage with the electric motor operating. MINIMUM is 10 VDC for a 12 volt system, 20 VDC for a 24 volt system and 26 VDC for a 32 volt system.
 - b) The regulated voltage (across C33 in the control unit). The READING SHOULD BE 7.6 - 8.4 VDC.
 - c) The V Reference voltage (measured between pin T5 on the control circuit board and the ground line). THE READING SHOULD BE ONE-HALF OF REGULATED VOLTAGE MEASURED IN b) above.

If the regulated voltage is not correct, the problem is most likely a defective integrated circuit in the switching regulator. If either the regulated voltage or the +4 VDC Reference voltage is not correct, refer to a qualified technician for servicing.

5. If one lamp remains illuminated for more than 180 degrees of the dial or both lamps go out at several places on the dial, check the following:
 - a) The compass cable and sensor are properly plugged in.
 - b) The cable is not damaged.
 - c) The sensor is properly mounted to the underside of the compass. A very close mounting of the sensor to a powerful compass may cause this. Refer to the factory.
 - d) The synchro windings or slip rings are not open circuit or intermittent.
5. If the autopilot appears to operate, but follows the wrong course, check the following:
 - a) The compass is mounted with the lubber aligned parallel to the fore-aft line of the vessel.
 - b) The sensor fore-aft line is aligned with the compass lubber line. The 'F' (fore) mark on the sensor must be forward.
 - c) The compass dial or synchro mounting is not loose or misaligned.
 - d) The rudder turns in a direction to steer the vessel to starboard when the GREEN lamp is on.
 - e) The desired course is being set correctly. See SECTION I: AUTOPILOT CONTROLS.
7. If the drive unit does not operate, or only operates the rudder in one direction, the following tests must be made.
 - a) Check that the cable from the control unit to the drive unit is not damaged and is properly connected at the terminal block in the control unit. Inspect the wiring and connections to the pumpset relays or solenoid valve.
 - b) Check both solenoids (or relays) to ensure one or both are not sticking or open circuited.



SECTION VI: HYDRAULICS

A. DRIVE UNITS (PUMPSETS)

The S.E. Autopilot operates with hydraulic and mechanical steering systems controlled by either relays or solenoids. This section of the manual deals specifically with hydraulic drive units (pumpsets). Several Wagner pumpsets are available and installation details are enclosed with the individual units. The following is a list of Wagner pumpsets and the reference numbers of their manuals.

PUMPSET DESCRIPTION	MANUAL REF. NO.
Type 2A	190-0007
PV125R-XX-RC	790-026
Engine driven (No. 1 or 2 Uniblock)	190-0006

The pumpset must be matched to the displacement of the steering system it is intended to operate. That is, it must provide the correct oil flow to operate the steering system from one hard-over position to the other within 14 to 18 seconds to obtain optimum performance. A high flow rate, causing excessively fast operation, will cause course overshoot. A lower flow rate, causing excessively slow operation, will result in a wandering course and generally unsatisfactory performance.

The steering cylinder must be an equal displacement type in order to obtain the same rudder speed when moving in both the port and starboard directions.

The desirable flow rate must be obtainable from the pumpset at the maximum hull speed of the vessel. In this condition, the pressure developed by the pumpset must be adequate to move the rudder through the ± 15 degree control range. This will ensure that the 'DODGER' switch on the remote control will operate within this rudder angle. (NOTE: The DODGER switch is not intended as a power steering switch when the autopilot is operating. To obtain more than 15 degrees of rudder with the DODGER switch, the RUDDER control should be in the 'SET' position. If the pumpset is not powerful enough, full rudder angle at full speed will not be obtainable.)

The S.E. Autopilot can also be used with most relay or solenoid controlled drive units offered by other autopilot manufacturers. However, in these applications, WAGNER, while guaranteeing their own products, cannot accept total responsibility for the system performance as the quality of drive units varies widely. Refer to SECTION II, A.3. for installation and wiring information.

B. INSTALLATION (Refer to DWG. No. B-4-930-02)

It is assumed that the hydraulic steering system has been previously installed. If this autopilot was purchased at the same time as the steering system, the steering should be installed first (but not filled with oil). The tee fittings for the connection of the drive unit (pumpset) should be put in place during the installation of the steering lines.

PIPING THE SYSTEM - Keep working conditions as clean as possible. Contamination of any form must be prevented from entering the system. Some common contaminants are Teflon tape, pipe fitting compound, metal filings, any form of dust and pieces of wiping rags. It is essential that all hydraulic tubing is clean inside before starting the installation.

Teflon tape or pipe fitting compounds, commonly used to seal threaded NPT joints, must be used sparingly and applied only to the male threads. The first two threads of the fitting should not be covered. If it is necessary to remove a fitting for any reason, the female thread must be cleaned before reinstalling the fitting.

Soft refrigeration-type copper tubing is recommended and should be at least 3/8 outside diameter and capable of the working pressures as indicated on DWG. E-4-930-01. Long lengths of flexible hose must not be used in place of the recommended tubing as it will adversely affect the performance of the system.

The tubing should be installed with lengths as straight as possible. Bends should be as gradual as possible. Goosenecks (a vertical bend resembling an inverted drain trap, commonly used on the waste drain of a wash basin) must be avoided, otherwise vent plugs must be installed at the high point of the bend to provide a means for removing entrapped air.

Flare-type fittings are recommended for problem-free connections rather than in-line compression-type fittings.

2. **RECOMMENDED OILS** - Any oil suitable for hydraulic winch drives is acceptable, but the following listed oils are preferred, due to their superior qualities.

CHEVRON: AW Machine 32, EP Hydraulic M

ESSO : Nuto H32

GULF : Harmony AV32, Harmony HVI 36

MOBILE : DTE 24, DTE 13

SHELL : Tellus 32, Tellus T37

TEXACO : Rando H032, Rando HD AZ

DO NOT USE BRAKE FLUID

(A limited stock of the preferred type oil is available and may be ordered from the Wagner factory.)

3. **FILLING THE SYSTEM** - The main steering lines between the helm pump(s) and cylinder must be filled first. The system is filled through a header tank (if installed) or the highest (or only) helm pump in the system. The filler hole on all other helm pumps must be closed with a pipe plug. Refer to the piping diagram in the appropriate pumpset installation manual.

Pour oil slowly into the header tank or filler tube of the highest helm pump and begin turning the steering wheel at this highest (or only) helm pump steadily in one direction only, checking the oil level periodically to prevent pumping air, until the system begins to feel solid. If the steering system is a type N with bleed fittings at the cylinder ports, one fitting can be opened slightly (on the side being filled) to purge entrapped air from the lines quickly. If the system does not contain these fittings, the cylinder tubing fitting can be backed out slightly, but wiping rags must be placed under the cylinder to contain the expelled oil.

Now turn the helm pump steadily in the opposite direction until the system again begins to feel solid.

Progress to the next lower pump and repeat this procedure. Remember to periodically check the oil level in the header tank or the highest helm pump. When all pumps have been turned as described, the steering system should be sufficiently full to be operated by the autopilot pumpset.

The drive unit should not be operated until the drive unit pump is filled with oil. The tubing fitting on the reservoir connection on top of the pump should be backed out to ensure that the pump is full. Loosening this fitting will release air trapped in the reservoir line. If the pump seems extremely noisy, it should only be operated in 10 - 15 second intervals until the flow evens out. If the pump is allowed to operate without oil, damage may result.

It will take time for all the air to be removed from the system but working it for 10 - 15 minutes and then allowing it to rest for a few hours is the fastest method of removing the air. It is advisable to keep a wiping rag around the filler during this initial rest period in case oil is foamed out with venting air. The system will not be smoothly responsive until most of the air is expelled.

When the system is full, refer to SECTION III: TESTS and ADJUSTMENTS, A. 4 INITIAL TEST and 8. SEA TESTS to test the installation of the autopilot system.

C. SERVICE

The oil should be checked periodically to make sure no leaks have developed. An external inspection of the system components is also suggested to ensure that leakage or other problems are not developing. Normally, no routine maintenance will be required on a properly installed system. All seals are designed for long life in normal service.

The following descriptions of problems and their most likely causes are listed to assist owner field servicing. If a problem cannot be resolved, refer to the factory.

1. If the steering wheel is stiff to turn or the pumpset will not operate the cylinder, check the following:

- a) The rudder stock for binding in its bearings. Remove the cylinder clevis pin and operate the wheel and also the pumpset again. If the cylinder operates, the problem is not in the steering system. If the cylinder does not move and the wheel is still hard to turn, check:
- b) The system is free of entrapped air.
- c) The system is piped using only the recommended copper tubing and the two short lengths of flex hose supplied for the cylinder connection.
- d) The hydraulic oil is one of the types recommended, that is, not more viscous (thicker) than automatic transmission fluid.
- e) The copper tubing used is at least the size recommended.
- f) The fittings on the steering cylinder are not screwed in too far and are jamming the piston rod. IF THE ROD IS SCRATCHED, IT MUST BE REPLACED and PISTON ROD SEAL DAMAGE IS ALSO LIKELY.

2. If the steering wheel continues to turn easily and the cylinder does not feel like it reaches hardover or the pumpset appears to be pumping, but the cylinder is not responding, check the following:

- a) The cylinder bypass valve (if installed) has been left in the open position. It must be closed.
- b) That all system fittings are tight.
- c) The system is free of entrapped air. If air is in the system the wheel will spring back when turned and released.
- d) A lockvalve on another helm pump is not contaminated. This is indicated by the wheel turning at that station. That lockvalve must be disassembled and cleaned. When removing the slotted inserts, take care not to lose the retained spring and steel ball or to damage the seals.
- e) The cylinder piston seals are not damaged. All of the above should be checked and determined to be satisfactory first. Remove the cylinder clevis pin and attempt to push the cylinder rod fully back and forth by hand. If the rod moves, the piston seals must be replaced. Oil leaking along the cylinder rod from either end of the cylinder indicates the rod seals are defective and must be replaced.

If there is contamination in the steering system, all components, including the helm pumps must be disassembled and cleaned and the tubing flushed. Kerosene, Varsol or Diesel oil is suitable for this flushing operation.

If the quality of the hydraulic oil is questionable, or water appears to be in the system, the system oil should be replaced with new oil from the recommended list.

3. If the pumpset operates the cylinder erratically, or the number of wheel turns is different when turning hardover to port and hardover to starboard, check the following:

- a) The system is free of entrapped air.
- b) The system is piped using only the recommended copper tubing and the two short lengths of flex hose supplied for the cylinder connection.



40 Gostick Place,
North Vancouver, B.C.
Canada V7M 3G2
Telephone (604) 988-1 111
Telex 04-352755

Wagner-
dependable
since 1937