SPEED LOG

There are different types of speed log in use from past till now. some of them are:

1- Patent rotor log.

2- Impeller log.

3- Electro magnetic log.

4- Acoustic correlation log.

5- Doppler log.

Patent rotor log:

This consist of a rotator manufactured in phosphor bronze, which is towed astern of the vessel. The towline used to be man-made fibre line of an 8 mm diameter size. The number of rotations is recorded by a clock mechanism secured to the after rail of the vessel.

With the advent of the electric, trident register, the recording repeaters can be positioned on the bridge.

Component of patent rotator speed log:

1- Clock: the clock, which is attached to the vessel, converts the turns of rotator into distance, like the distance recorder in a car, the rotation of the log line being geared down so that nautical miles are registered.

2- Governor: this wheel is to provide steadiness to the inner spindle of the log clock as it revolves due to action of the rotator. Frog and rotator : the frog and the rotator are made of either brass or phosphor bronze to resist the corrosive action of salt water.

3- The rotator is a hollow tube having curved vanes attached to the sides and seized to a hollow frog (bottle) by short length of sennet laid line.

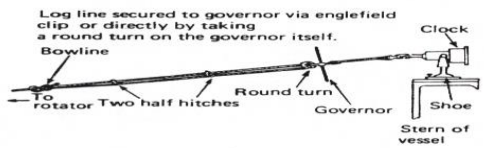


Figure 2.1 Securing patent log.

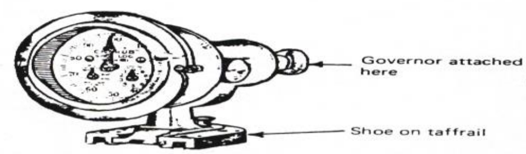
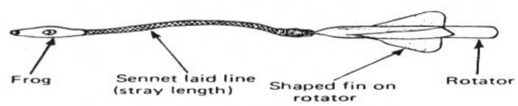


Figure 2.3 Log clock.



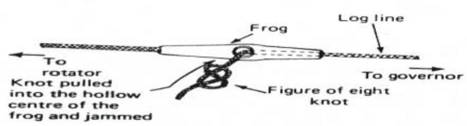


Figure 2.2 Securing logline to frog.

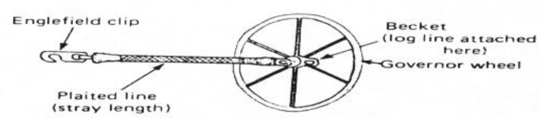


Figure 2.4 Governor.

The impeller log may be considered an electric log, since its operations is all electrical, except for the mechanical rotation of the impeller.

The principle of operation is based on turning an impeller by a flow of water, the speed of rotation being proportional to the rate of flow past the impeller (turbine principle) a pick-up coil transmits the generated pulses via an amplifier to an electromagnetic counter the signal is then displayed by a speed indicator and distance recorder.

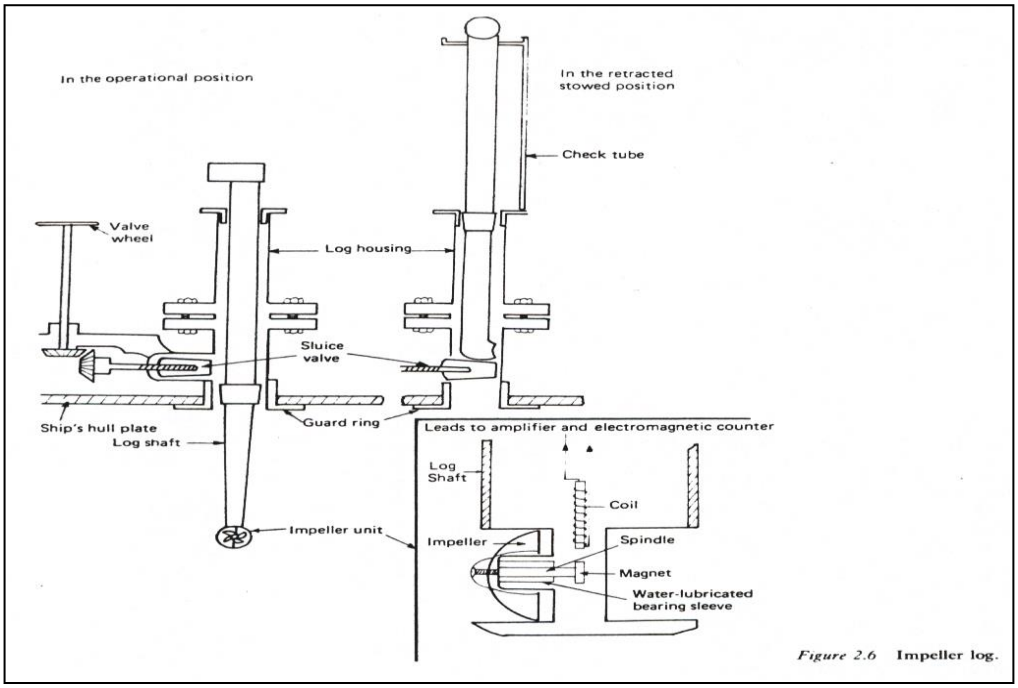


Figure 2.6 Impeller log.

<u>PRESSURE TUBE LOG :</u>

This is a simple instrument which works on pitot tube principle. It consists of pressure chamber at bottom of the ship .There are two tubes which connect the chamber to the sea .One of them is static / dynamic

tube which lets the water out of the chamber .There is a diaphragm connected to a mechanical linkage inside the chamber

If there is no relative fluid movement then the static pressure in each tube will be the same ,hence the pressures on each side of diaphragm will be equal . Relative fluid movement an additional dynamic pressure will be created in s/d tube and hence on bottom side of diaphragm causing an upward movement of the linkage rod. ٢

As per pitot's law p = v2 .k and as the movement of the rod varies directly with p , a measure of v can be obtained .if a time input is now introduced then the speed may be integrated with respect to time , to continuously give a distance readout. This instrument is a good current meter when the ship is stopped. when going in channel or in shallow water the s / d tube must be pulled up in engine room to avoid any damages .

SOURCES OF ERROR:

1- Calibration must be carefully done when installed. Allows for shape of vessel and flow of water into dynamic tube.

2- 2-Pressure / speed relationship means not very accurate at very low or high speeds .

3-Obstruction in tubes e.g marine growth can cause problem.

4-Error in time input will cause incorrect distance reading.

5-Only forward speed can be measured

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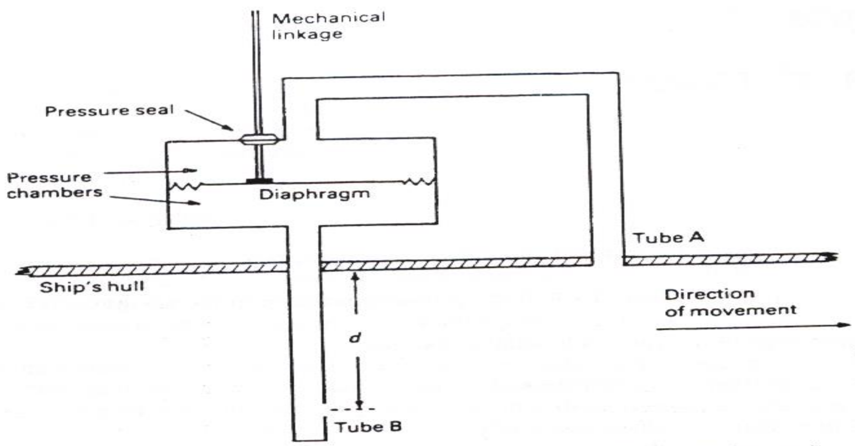


Figure 3.1 The pressure tank and tube intakes of a pressure tube speed logging system.

EM LOG:

This instrument uses the principle of the generator i.e if a conductor is moved across a magnetic field the conductor will have a small electro-motive force (E.M.F) induced into it .The magnitude of the E.M.F is proportional to the rate at which the conductor will cuts the magnetic lines of force .

Equally if the conductor remains stationary and the magnetic field moves , the E.M.F is similarly induced .In the case of the E.M.LOG ,the water is the conductor and a probe produced the magnetic field from a coil. The E.M.LOG consists of a probe with two sensors ,an indicator / transmitter and a remote control switch.

The flow sensor CAN BE a streamlined rod which projects out through the underwater portion of the ship’s hull . It’s outer surface is insulate except for two copper nickel electrodes ,one on each side .The rod projects such that these electrodes are clear of the turbulent water around the ship’s hull.

Inside the flow sensor is a soft iron bar inside a solenoid, forming an electro-magnet.the current for this magnet may be A.C or D.C ,but A.C usually 50/60 hz,1 Amp gives better result. This magnet sets up a magnetic flux filed .The water plane around the sensor probes forms the conductor and the ship’s motion allows this conductor to cut the magnetic flux lines .

The induced voltage is converted electronically into speed. An integrator converts the speed into distance run.

V = B X L X v X SIN θ

V = induced voltage ,

L = length of the conductor

θ = Angle of cutting lines of force

B = magnetic induction

v = speed of the v/l AS B , L , SIN θ are constant V = v

This log , like other logs should be calibrated at regular interval. The sensor electrodes should be cleaned at least once per month by drawing the probe into the hull and polishing the electrodes manually .The speed may be shown on a dial or a digital display. the speed will be indicated on the bridge front and in the chart room ز .

Conclusion : A voltage is induced in a conductor by moving magnetic field . A sensor attached to the hull of the vessel produces an electromagnetic field by using the water as the conductor . An output is generated as the vessel progresses relative to the ship's speed through the water .

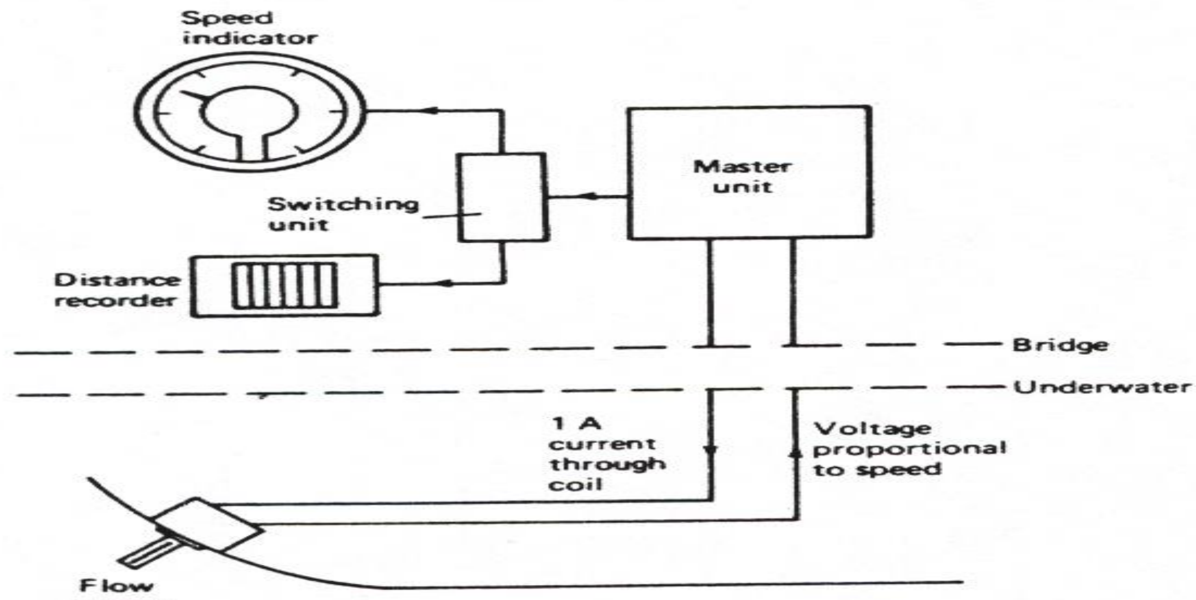


Figure 2.42 Block diagram of the electromagnetic log system

Typically the E.M.LOG system consist of :

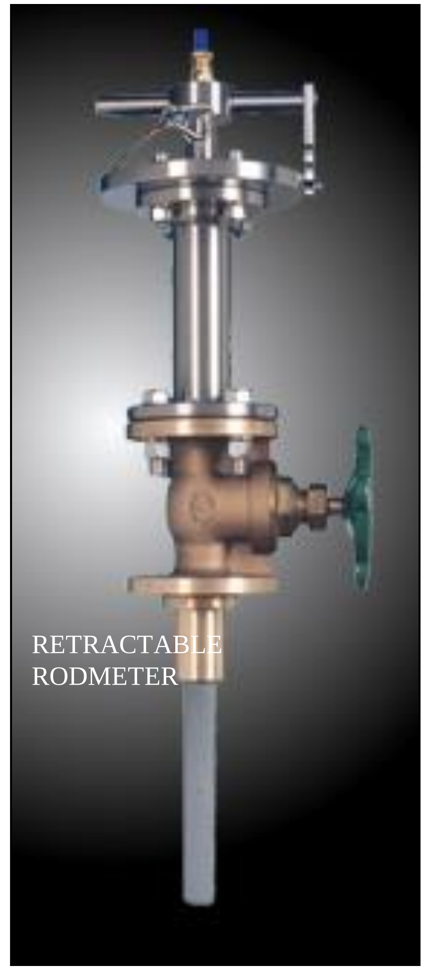
1- Main electronic unit . (MEU)This houses the system electronics , power supply and output facilities for displays and interfacing to the ship's navigation system , if any .

2- User interface panel ; (UIP) provides speed and distance displayed and calibration facilities .

3- Under water sensors : This can be any types , e,g fixed probe , fin probe , flush probe or retractable rodmeter .

4- speed and distance Repeaters ; they can be in either digital or analogue format .

UNDER WATER SENSORS :



DOPPLER SPEED LOG

The Doppler speed log is based on measurement of the Doppler effect that is ,if a moving ship transmits an acoustic signal , the frequency of a received return signal after reflection is different from the frequency of the original transmitted signal . The shift in frequency is proportional to the speed of movement of the transmitter .

Fd = Ft – Fr , **Ft = transmitted wave frequency**

Fr = received wave frequency

Doppler shift formula : Fd = 2.V.Ft /C

V= velocity of the ship

C= velocity of sonar wave , 1500 m/s

$$f_r = f_s \frac{c + v_r}{c - v_s} \qquad (2.1)$$

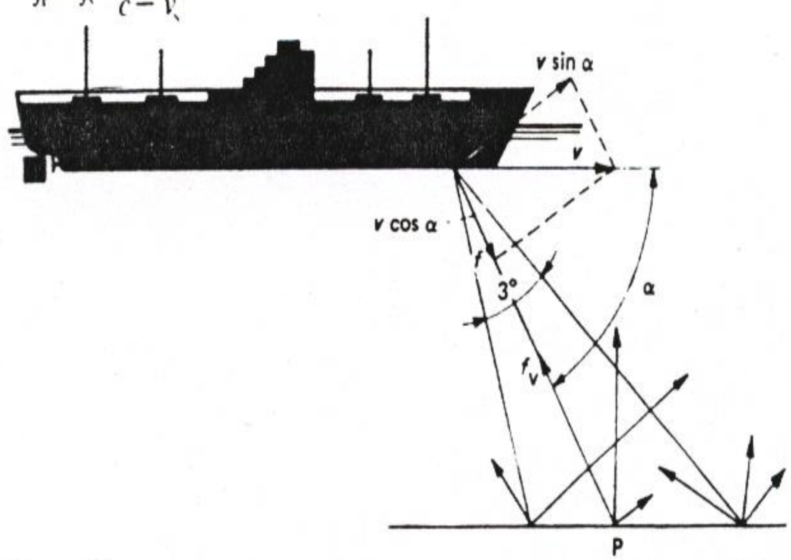


Figure 2.27 Doppler log. The transmitting and receiving transducers of the forward beam move towards the sea bottom at the velocity $v \cos \alpha$, which produces a Doppler effect

The Doppler log uses the sea bottom as the reflector ,but clearly the ship is not moving towards the sea bottom .

Hence the beam is angled in a forward direction and it has been found that directing the beam at an angle of 30 deg to the vertical produces the best result . The angle between the horizontal plane and the transmission must now be applied to the basic Doppler formula .

Fd = 2V x Ft x Cosine ɵ / C in HRZ , Cosine ɵ = 0.5 ,Fd = V.Ft / C

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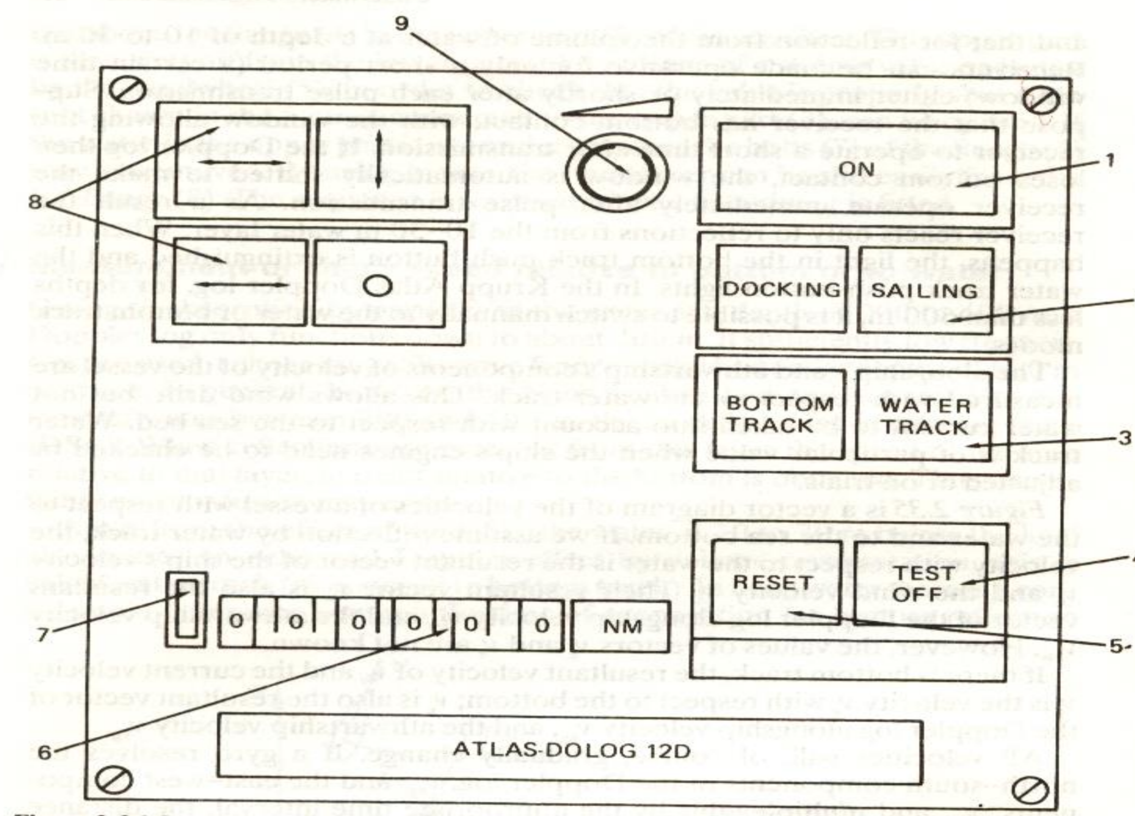


Figure 2.36 Control panel: 1 = on/off switch; 2 = docking/sailing switch; 3 = bottom track (BT)/water track (WT) switch; 4 = test/off; 5 = resets the distance travelled on the digital display in *Figure 2.37;* 6 = indicator of distance travelled; 7 resets distance travelled counter; 8, the lighted panels indicate which units are ready for operation; 9 = dimmer

Vertical movement of the ship, the effects of pitching and changing trim can all largely be accounted for by having not just a single beam pointing forward but by also having a second beam pointing astern at the same angle.

The unwanted vectors of motion then cancel each other out in the Doppler calculation .Such an arrangement is known as a Janus configuration.

Most Doppler log transmit the energy in a pulse form rather than continuous wave . This means that one transducer can be used as both transmitter and receiver .The beam is about 3º wide and the frequency is in the region of 100 – 600 KHZ.

GROUND SPEED AND WATER SPEED:

In depths greater than 200m the return echo is too weak to be useful and the log will no longer give ground speed .

The water layers at 10 – 30 meters below the keel also cause an echo and Doppler effect ,this is used to give speed relative to the water .It is known as water track as distinct from bottom track and speed log automatically Shift to this mode when ground contact is lost . An indicator light displays which mode the log is .

A time input will give distance when speed are integrated. Certain Doppler log are dual axis, i . e they also have two beams in a transverse axis so that lateral speed can also be measured . This can be particularly useful in the docking of tanker .

Environmental factors affecting the accuracy of speed logs :

unfortunately environmental factors can introduce errors and/ or produce sporadic indications in any system that relies for its operation on the transmission and reception of acoustic waves in salt water.

- water clarity. in exceptional cases the purity of the seawater may lead to insufficient scattering of the acoustic energy and prevent an adequate signal return. it is not likely to be a significant factor because most seawater holds the suspended particles and micro-organisms that adequately scatter an acoustic beam.
- aeration. aerated water bubbles beneath the transducer face may reflect acoustic energy of sufficient strength to be interpreted erroneously as sea bottom returns producing inaccurate depth indications and reduced speed accuracy. proper sitting of the transducer. away from bow thrusters. for instance. will reduce this error factor.
- vessel trim and list. a change in the vessel's trim from the calibrated normal will affect fore/aft speed indication and an excessive list will affect athwart ship speed. a janus configuration transducer reduces this error .
- ocean current profile. this effect is prevalent in areas with strong tides or ocean currents. in the water track mode. a speed log measures velocity relative to multiple thermo cline layers several feet down in the water. if these layers are moving in opposite directions to the surface water. an error may be introduced.
- ocean eddy currents. whilst most ocean currents produce eddies their effect is minimal. this problem is more likely to be found in restricted waters with big tidal changes or in river months.
- sea state. following

ACOUSTIC CORRELATION LOG :

This type of speed log derives the vessel speed by the use of a patented , acoustic correlation , method . This is the way of combining the properties of sonic wave in sea water with the correlation technique .

Speed measurement is achieved by bottom tracking to a maximum depth of 200m , the system automatically switches to water tracking and will record the vessel's speed with respect to a water mass approximately 12m below the keel .

The transducer transmits pulses of energy at the frequency of 150 KHZ from its two active Piezo-ceramic elements which are arranged in the fore and aft line of the vessel . Each Element transmits in a wide lobe perpendicular to the sea bed , As with an echo sounder , the transducer elements are switched to the receive mode after transmission has taken place .The sea bed or water mass , reflected signal posses a time delay(T) dependent upon the counter of the sea bed . Thus the received echo is uniquely a function of the instantaneous position of each sensor element and the ship's speed .

The echo signal . therefore , in one channel will be identical with that in the other channel but will posses a time delay as indicated in below figure .

The time delay (T) can be presented : $T = 0.5 \times S/V$ in seconds

S = the distance between the receiving elements.

V = the ship's velocity .

The distance between the transducer elements (S) is precisely fixed , therefore when the time (T) has been determined , the speed of the vessel (V) can be accurately calculated .

It should be noted that the time delay , T , calculated is that between the two transducer echoes and not that between transmission and reception .

Summary of speed log
_ to be accurate, speed must be calculated with reference to a known datum.
_ At sea, speed is measured with reference to the ocean floor (ground-tracking (G/T)) or water flowing past the hull (water-tracking (W/T)).
_ Traditionally, maritime speed logging devices use water pressure, electromagnetic induction, or the transmission of low frequency radio waves as mediums for indicating velocity.

_ A water pressure speed log, occasionally called a Pitot log:
(a) Measures Water-tracking speed only;
(b) Requires a complex arrangement of pressure tubes and chambers mounted in the engine room of a ship and a Pitot tube protruding through the hull;
(c) Produces a non-linear indication of speed which must be converted to a linear indication to be of any value. This is achieved either mechanically or electrically in the system;
(d) Speed indication is affected by the non-linear characteristics of the vessel's hull and by the
Vessel pitching and rolling;
(e) Possesses mechanical sections that require regular maintenance.

_ An electromagnetic speed log:
(a) Measures W/T speed only;
(b) produces a linear speed indication;
(c) Operates by inducing a magnetic field in the salt water flowing past the hull and detecting a minute change in the field;
(d) Produces a varying speed indication as the conductivity of the seawater changes.
(e) Indication may be affected by the vessel pitching and rolling in heavy weather.
_ Speed logs that use a frequency or phase shift between a transmitted and the received radio wave
Generally use a frequency in the range 100–500 kHz. They also use a pulsed transmission format.

_ A log using the acoustic correlation technique for speed calculation:
(a) Can operate in either W/T or G/T mode. G/T speed is also measured with respect to a water mass;
(b) Measures a time delay between transmitted and received pulses;
(c) Produces a speed indication, the accuracy of which is subject to all the environmental problems affecting the propagation of an acoustic wave into salt water.

_ Doppler frequency shift is a natural phenomenon that has been used for many years to measure velocity. If a transmitter (TX) and receiver (RX) are both stationary, the received signal will be the same frequency as that transmitted. However, if either the TX or the RX move during transmission,

Then the received frequency will be shifted. If the TX and/or RX move to reduce the distance between them, the wavelength is compressed and the received frequency is increased. The opposite effect occurs if the TX and/or RX move apart.

_ A Doppler speed logging system:

(a) transmits a frequency (typically 100 kHz) towards the ocean floor and calculates the vessel's speed from the frequency shift detected;

(b) Measures both W/T and G/T speed;

(c) Produces a speed indication, the accuracy of which is subject to all the environmental problems affecting the propagation of an acoustic wave in salt water;

(d) uses a Janus transducer arrangement to virtually eliminate the effects of the vessel pitching in heavy weather;

(e) May use more than one transducer arrangement. One at the bow and another at the stern to show vessel movement during turn maneuvers.

Glossary

Aeration: The formation of bubbles on the transducer face causing errors in the System.

Beamwidth : The width of the transmitted acoustic pulsed wave. The beam spreads the further it travels away from a transducer.

CW mode: Continuous wave transmission. Both the transmitter and receiver are active the whole time. Requires two transducers.

Distance integrator: The section of a speed log that produces an indication of distance travelled from speed and time data.

Doppler principle: A well-documented natural phenomenon enabling velocity to be calculated from a frequency shift detected between transmission and reception of a radio signal.

E.M. log: An electronic logging system relying on the induction of electromagnetic energy in seawater to produce an indication of velocity.

G/T : Ground-tracking or ground referenced speed.

NMEA: National Marine Electronic Association. Interfacing standards.

Pitot log: An electromechanical speed logging system using changing water pressure to indicate velocity.

Pulse mode: Acoustic energy is transmitted in the form of pulses similar to an echo sounding device or RADAR

Transducer: The transmitter/receiver part of a logging system that is in contact with the water. Similar to an antenna in a communications system.

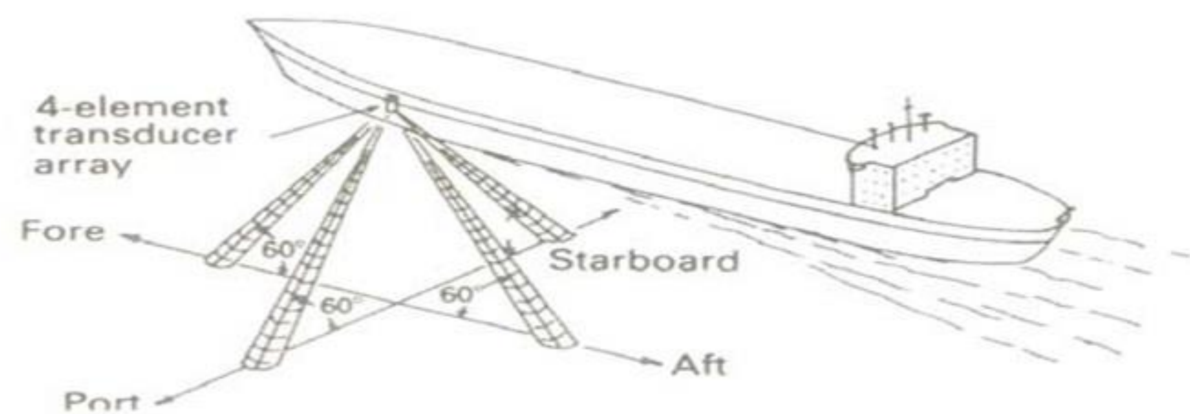
Translating system: The electronic section of a logging system that produces the speed indication from a variety of data.
W/T : Water-tracking or water referenced speed.

What is Janus Configuration?

Most <u>Doppler logs</u> have Janus Configuration where

- ***Transducers pointing ahead measures speed.***
- ***Transducer pointing Astern is used for accuracy check.***
- ***Transducers point abeam to measure athwart ship speed (while berthing).***

Use of Doppler logs for measuring athwartship speed has become mandatory on large tankers. Human judgment of speed and the distance is not accurate enough to handle huge tankers while mooring or unmooring (alongside or single point) or low speed cruising. For example, when a 200,000 Tonnes tanker with a residual speed of 0.2 knots is tying up, the pier, dolphin or the ships side has to absorb energy which is = 0.5 mv ^{2} ***– 10,00,000 joules. In this situation, an accurate Doppler Log can be of great help here. Currently, a combination of Doppler and EM log provides a robust, reliable system for the measurement of ship's speed over the ground and water, in both forward and athwart ship direction.***



Gyro compass

A magnetic compass has several problems when used on moving platforms like ships and airplanes. It must be level, and it tends to correct itself rather slowly when the platform turns. Because of this tendency, most ships and airplanes use gyroscopic compasses instead.

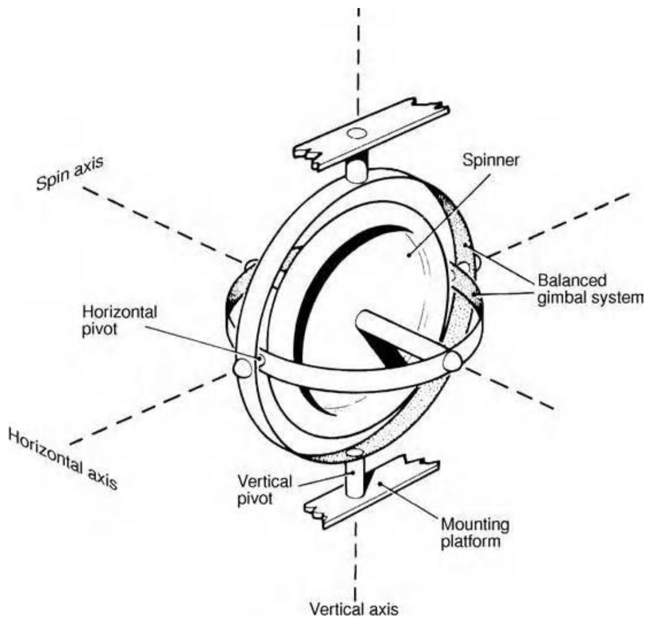
A spinning gyroscope, if supported in a gimbaled frame and spun up, will maintain the direction it is pointing even if the frame moves or rotates. In a gyrocompass, this tendency is used to emulate a magnetic compass. At the start of the trip, the axis of the gyrocompass is pointed toward north using a magnetic compass as a reference. A motor inside the gyrocompass keeps the gyroscope spinning, so the gyrocompass will continue pointing toward north and will adjust itself swiftly and accurately even if the boat is in rough seas or the plane hits turbulence. Periodically, the gyrocompass is checked against the magnetic compass to correct any error it might pick up.

Marine gyro compass

Free gyro principle

It has 3 degrees of freedom:

1. It is free to spin about spinning axis, i.e. spin.
2. It is free to rotate about vertical axis, i.e. drift.
3. It is free to rotate about horizontal axis, i.e. tilt.



Properties of a free gyro

1. **Gyroscopic inertia(Rigidity in space)**

   This is the property that keeps the gyro spin axis direction fixed in space, even though the gimbals are moved. (When no force is exerted on spin axis direct)

2. **Precession**

   Precession is the term used to describe the movement of the axle of a gyro under the influence of an external force. The direction of torque (force) on a free gyro rotor will be 90 degrees different to the direction of its effect, i.e. if we apply a torque about horizontal axis, the direction of movement will be around vertical axis. Here is said that gyre is precessed around vertical axis or vice versa.

Gyro axis movement at different locations on the earth

At poles

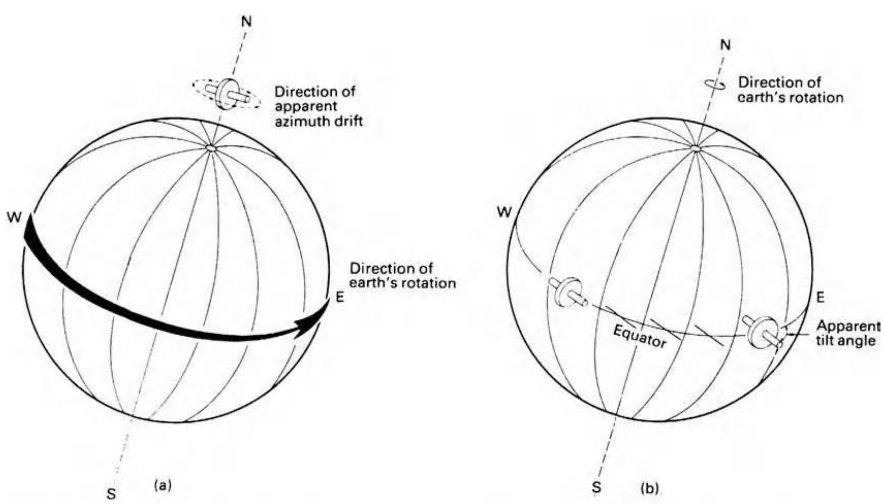
1. With gyro spin axis settled parallel to earth's surface: Gyro drifts at the rate of 15°/h (360° in 24 hours) & No tilt.
2. With spin axis settled vertical to the earth's surface: There will be no apparent movement of gyro spin axis (no drift & no tilt).

$$\text{Drift} = 15°/\text{h} \sin(\text{latitude})$$

On equator

1. With spin axis parallel to earth and at E-W direction: There will be maximum tilt (15°/h) & no drift.
2. With spin axis in N-S direction pointing the pole star: There will be no tilt and no drift.

$$\text{Tilt} = 15°/\text{h} \cos(\text{latitude}) \sin(\text{azimuth})$$



Drift of the N end of the spin axis is to the E in the northern hemisphere and to the W in the southern hemisphere

Tilt of the N end of the spin axis is upwards if the N end is to the east of the meridian and downwards if it is to the W of the meridian

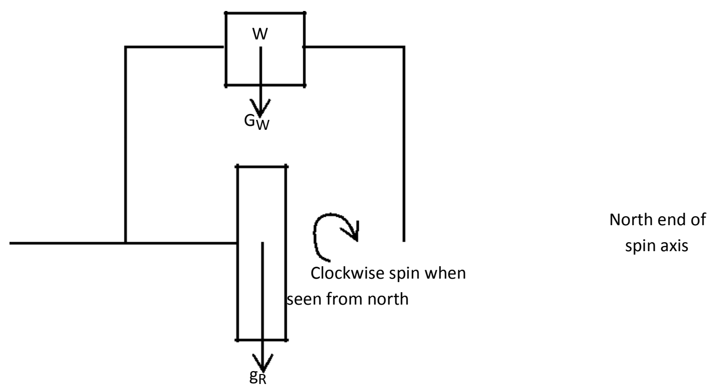
Remarks

Note 1: Drift in northern hemisphere is always eastward and in south hemisphere is westward.

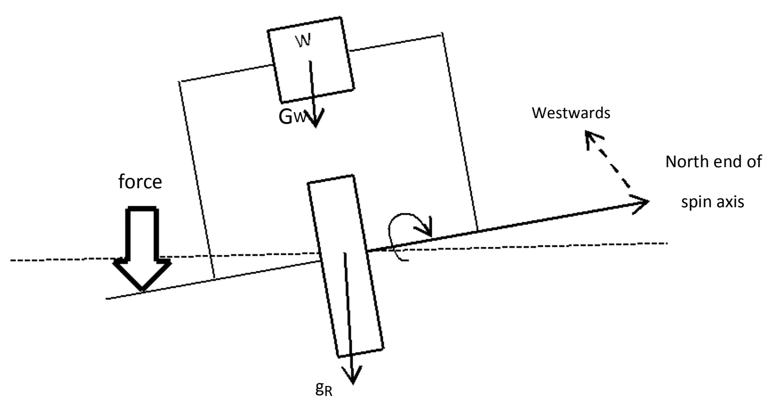
Note 2: If spin axis points east of the meridian the rate of tilt is upwards and if it points west ofmeridian rate of tilt is downwards.

Control Forces

1. Top Heavy Control Force

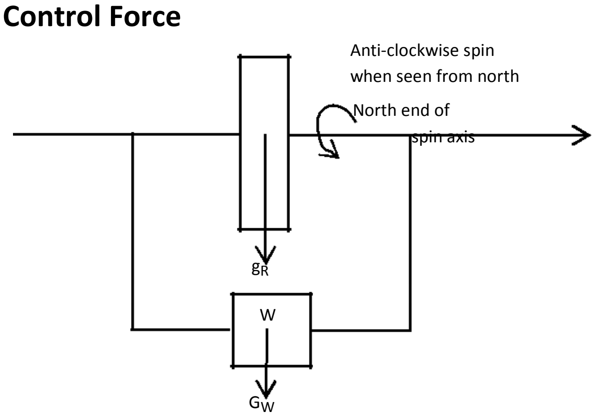


When spin axis is parallel to the earth's surface then G_W and g_R are in one direction and no force is applied to rotor south end or north end.

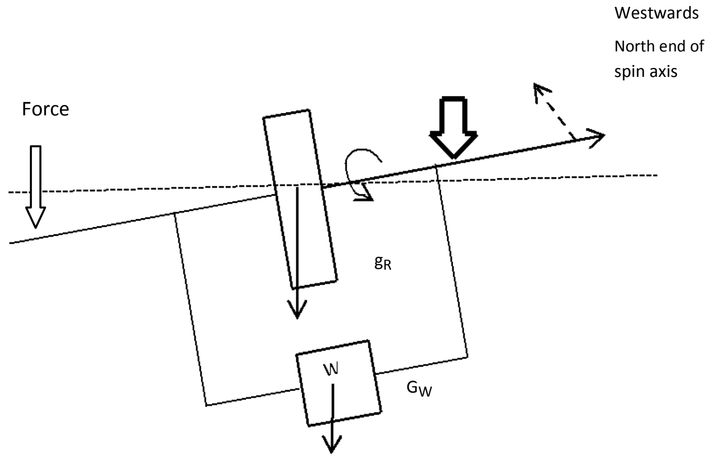


If the gyro spin axis tilts up, then G_W and g_R are no more in one line. A force is applied to the south end of axis. The precession of north end of axis will be towards the paper. (Westwards)

2. Bottom Heavy Control Force



When spin axis is parallel to earth's surface, then G_W and g_R are in one line, no force is exerted to spin axis.

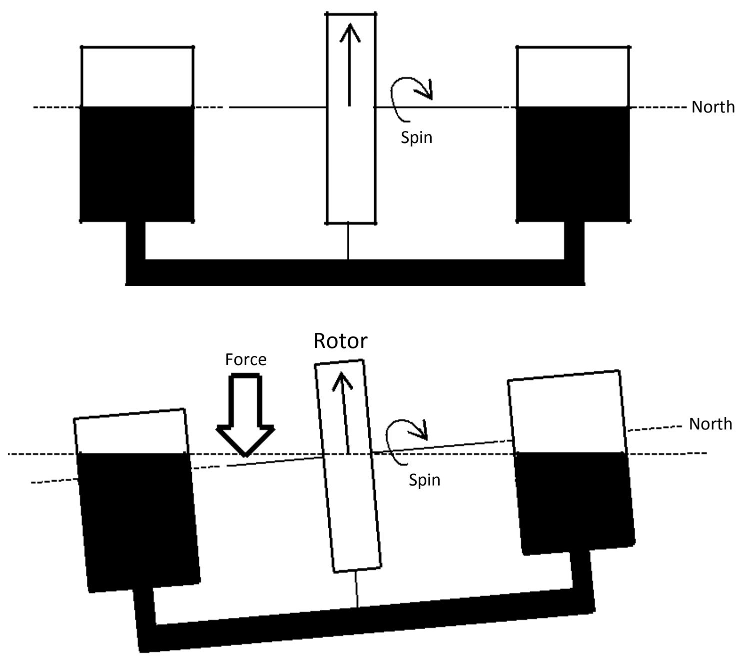


If the gyro tilts up, then G_W and g_R are no more in one line. As seen it is like a force is applied to north end of gyro axle. The precession will be inside the paper. (Westwards)

Top heavy control using Liquid Ballistic Method

Simple methods of control are not practical in commercial compasses, because of the problems encountered with ship's movement. An improvement is to use a LIQUID BALLASTIC to give a form of gravity as shown below. (Used in Sperry)

Rotor



Liquid flows between the north and south ends of the rotor under the influence of gravity, when the gyro has an angle of tilt.

The principle is similar to that of top heavy gyro. The rotor spin direction is clockwise, as seen from north end, and hence when the gyro tilts up, it will produce a precession which moves the north end of spin axis to the west.

The advantage of the system is that the liquid is chosen such that it is slow to respond to sudden changes caused by ship's movement but will still respond to gradual changes produced by the earth's movement.

Movement of the controlled or north seeking gyro

The figure shows the movement of the projection of the spin axis of a controlled gyro in the northern hemisphere. The gyro was initially set up parallel to the earth's surface pointing slightly east of the meridian.

The following abbreviations are used in the figure:

P_C: Represents the gyro's precession due to the control force. This depends on the gyro's angle of tilt.

D: Represents the gyro's rate of drift due to the earth's rotation. The nearer gyro's angle of tilt to the elevation of the pole star, the less rate of drift.

T: Represents the rate of change and direction of tilt. It depends on how far in azimuth the gyro is from the meridian.

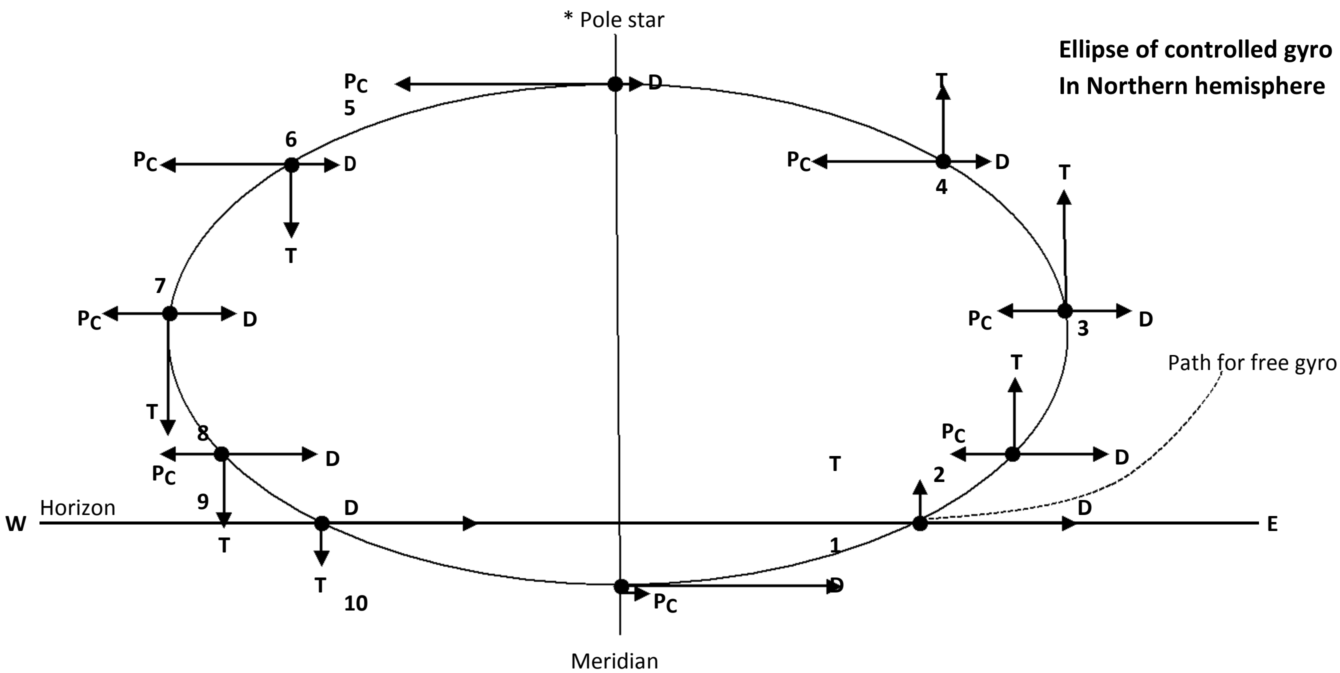
Point 1: This is where the gyro was initially set up, slightly to the east of meridian, but parallel to the earth's surface. The control precession P_C will be zero. D & T will be the same as for the free gyro.

Point 2: The gyro has now gained an angle of tilt, therefore a control force is developed which will produce precession P_C opposing the eastward drift. The rate of drift "D" will have decreased because the gyro is closer to the elevation of pole star. The rate of tilt upwards will have increased, because the gyro is pointing further east of the meridian.

Point 3: The angle of tilt has increased such that P_C now equals D, so there is no further eastward drift. The rate of tilt is therefore at its maximum upwards.

Point 4: The angle of tilt is now such that P_C is greater than D, which is still reducing as the gyro approaches the elevation of the pole star. The gyro moves westward towards the meridian. This reduces the rate of tilt increase upwards.

Point 5: The westward movement has brought the gyro to the meridian, which means there isno increase in tilt. The angle of tilt is now a maximum and therefore D is a minimum and P_C is a maximum. The gyro therefore continues its westward movement past the meridian.



Point 6: The gyro is west of the meridian, therefore the rate of change of tilt is increasing, but in a downwards direction, reducing the angle of tilt. The reduction in angle of tilt reduces P_C and increases D, thus reducing the rate of westward movement.

Point 7: The angle of tilt has decreased such that P_C equals D. This is the most westward the gyro will travel. Therefore the rate of decrease in tilt T is at its maximum.

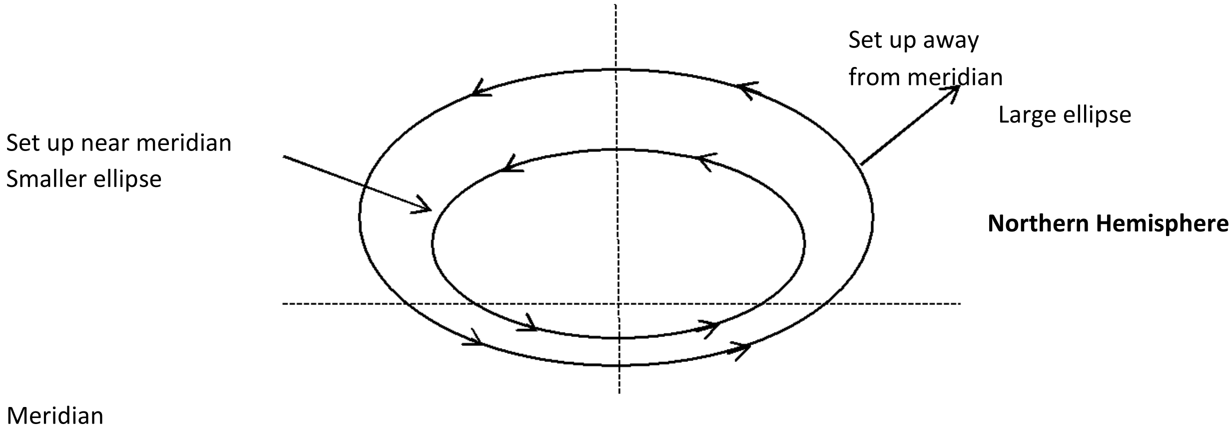
Point 8: The angle of tilt has decreased such that P_C is less than D, and the gyro drifts eastwards. This movement towards the meridian reduces the rate of decrease in angle of tilt.

Point 9: The gyro is again parallel to the earth's surface, so P_C is zero. The spin axis is pointing west of the meridian, so the movement of tilt is still downwards. The drift D is to the east and increasing as the spin axis moves away from the pole star.

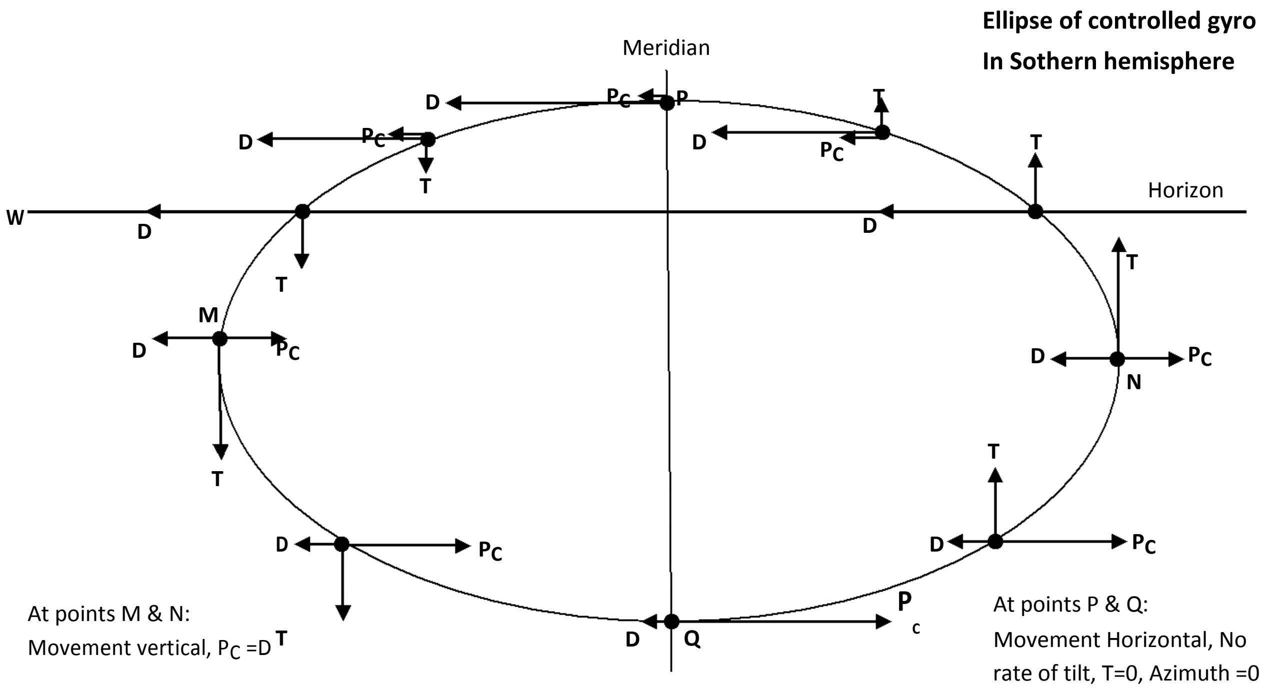
Point 10: The gyro has again reached the meridian, so there is no further change in tilt. The angle of tilt is downward, so P_C now assists the eastward drift. This is a maximum since the gyro's elevation is as far below the pole star as it will reach. The gyro therefore moves past the meridian back to point 1.

The gyro will then repeat its path around the ellipse, continuously moving around the meridian. The controlled gyro is therefore said to be NORTH SEEKING.

The size of the ellipse depends on where the gyro was initially set up, the closer to the meridian, the smaller ellipse. (Refer to the figure below)



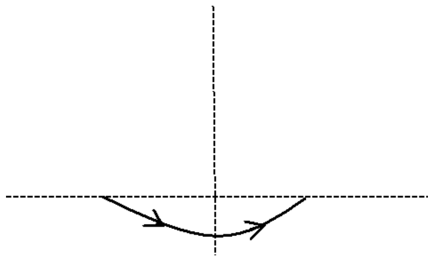
It also depends on latitude, being smaller closer to the equator.



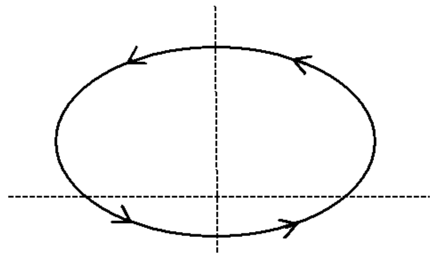
Damping the ellipse

The north seeking gyro is still unsuitable as a gyro compass because it does not indicate north continuously. In order to make a gyro settle, and point to a fixed direction on earth and not space, it is necessary to impose a further precession which will damp out the gravity controlled elliptical path, traced only by spin axis, i.e. damping makes the gyro “NORTH INDICATING” or “NORTH SETTLING”.

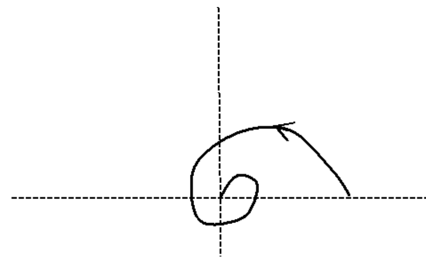
Each diagram represents the apparent movement of the north end of the gyro axle on a vertical backcloth.



Free Gyre
(24 Hours)



Gravity controlled
(Generally 84 minutes)



Damped

There are two methods of damping:

1. **Damping in tilt**

   In this method a force is applied in the horizontal plane (a torque to the vertical axis) which results in a precession in the vertical plane, reducing the tilt. This is the method used in the Sperry MK 20.

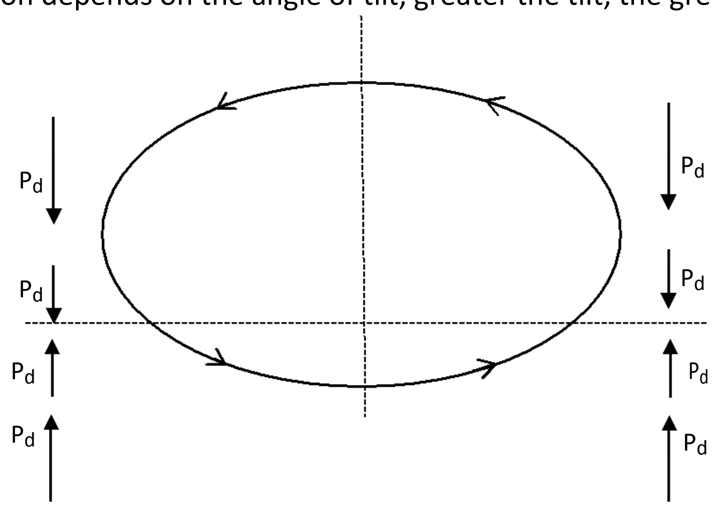
2. **Damping in azimuth**

   In this method a precession is developed which assists the movement in the azimuth plane when the axis moves towards the meridian, and opposes the movement when the spin axis moves away from the meridian.

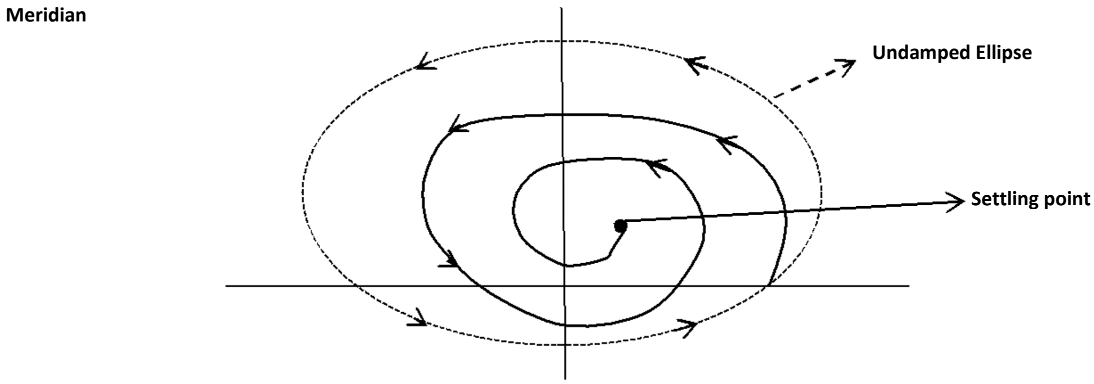
Damping in tilt

In this method of damping, the damping precession P_d opposes the movement of the spin axis when the spin axis is moving away from the horizon and assists it when moving towards the horizon. A torque about the vertical axis causes damping precession in tilt, i.e. up or down.

Damping precession depends on the angle of tilt, greater the tilt, the greater the damping precession.



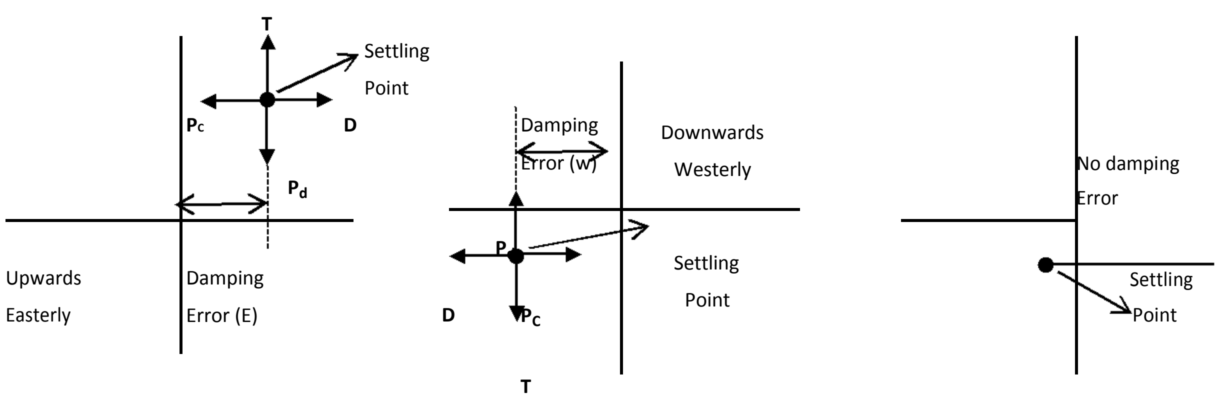
Effect of damping in tilt on the ellipse



As the controlled gyro follows the first part of the ellipse, the damping precession will oppose the tilting. This means the gyro's angle of tilt when reaching the meridian, is not as great as for the un damped gyro. Thus the control precession is less and the eastward drift is greater, therefore the gyro spin axis will not travel as far west. As the gyro spin axis returns to the horizon the damping precession will assist its return. As the axis tilts below horizon the damping precession will oppose it, reducing the maximum angle of tilt downward and thus reducing the eastward drift and control precession. The gyro therefore does not travel as Far East. Next time around the ellipse, the damping precession will again appose movement away from the horizon, so again the maximum angle of tilt will be reduced making the ellipse smaller. Eventually the gyro will settle where the control precession cancels the drift and the damping precession cancels the movement of tilt, i.e. P_c=D and P_d=T.

Damping error (Latitude error)

From the above it can be deduced that in the northern hemisphere, an angle of tilt must exist to provide the control precession to cancel the drift. This angle of tilt produces a damping precession which must be controlled by the movement of the tilt. For this movement of tilt to exist, the gyro spin axis must be pointing east of the meridian. Therefore in the northern hemisphere the spin axis settles with an angle of tilt upwards and pointing slightly to the east of the meridian. The small amount the gyro axis settles out of the meridian called "Damping Error" or "Latitude Error". In the southern hemisphere the gyro will settle with an angle of tilt downwards and pointing the west of the meridian. On the equator there will be no error.



Northern Hemisphere **Sothern Hemisphere** **Equator**

The magnitude of damping error is a function of latitude. This is because as the latitude increases, so does the value of the drift (D ~ Sin (Latitude)). Therefore a greater control precession is required to balance the drift. To obtain a greater control precession a larger angle of tilt is required which in turn will give a bigger damping precession. To balance this damping precession the axle must move further out of the meridian to produce a bigger rate of tilting, hence the damping error increases.

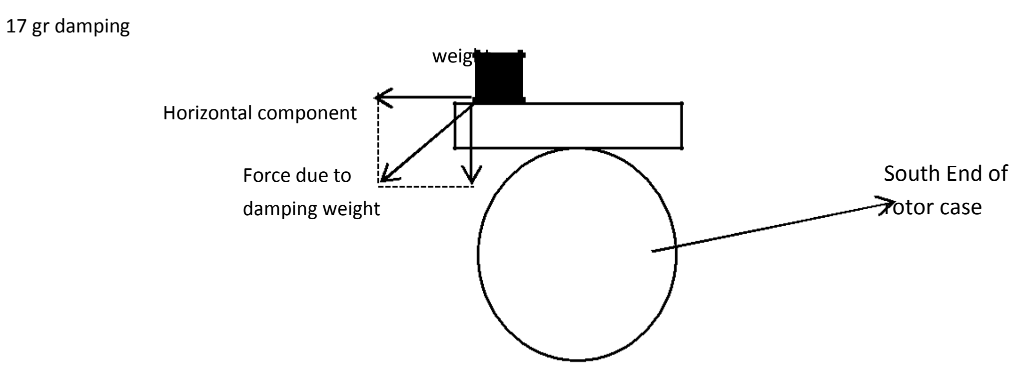
It can be shown that: Sin (Damping error) ~ tan (Latitude)

For small angle of damping error: Damping error ≈ tan (Latitude)

The error can be very large in high latitudes. Typical values are 1.5 degrees at 45 degrees (north or south) and over 5 degrees at 75 degrees (north or south).

Applying damping in tilt

Damping in tilt is achieved in the Sperry MK 20 gyro compass by adding a small weight (17 gr) on the top of the rotor case. The weight is offset to the west of the vertical axis.



With the spin axle horizontal, weight is directly above the tilt bearings and hence causes no precession. When the axle tilts, the weight has a tipping effect on gyro. Since the weight is offset, the tipping will have a vertical and horizontal component.

The vertical component generates a torque around horizontal axis which causes a precession around vertical axis at the same direction of P_c. this component is seen / calculated within the control force. The horizontal component generates a torque about vertical axis which causes a precession (P_d) around horizontal axis. This opposes the tilt and brings the spin axis towards horizon.

How to compensate the damping error?

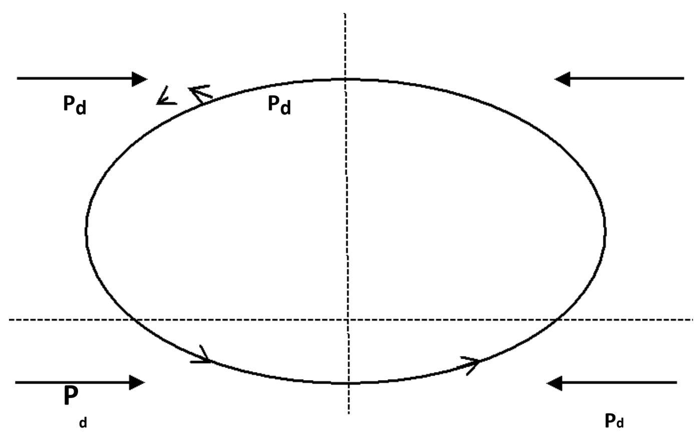
The damping error in gyro compasses which utilize damping in tilt is to be removed. (Like Sperry gyro compasses)

1. First method is by a mechanical means in which the latitude is set. The whole phantom ring turns according to the set latitude therefore the compass card turns to eliminate the damping error.
2. By using a torque motor which produces a precession to cancel the drift at settling point and hence causing the spin axis to point north. This is the same motor used for correcting the speed error.
3. In digital gyro compasses, this error is simply corrected by feeding (inputting) the latitude to the microcomputer unit.

Damping in azimuth

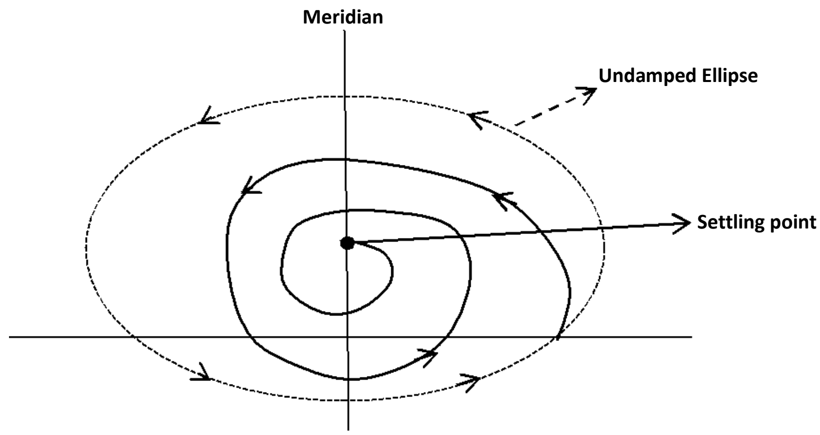
In this method of damping, the damping precession opposes the movement of the gyro spin axis when it is moving away from the meridian, and assists the movement when moving towards the meridian.

A torque about the horizontal axis will cause a damping precession in azimuth. It depends on the rate of tilting, greater the rate of tilt, the greater the damping precession.



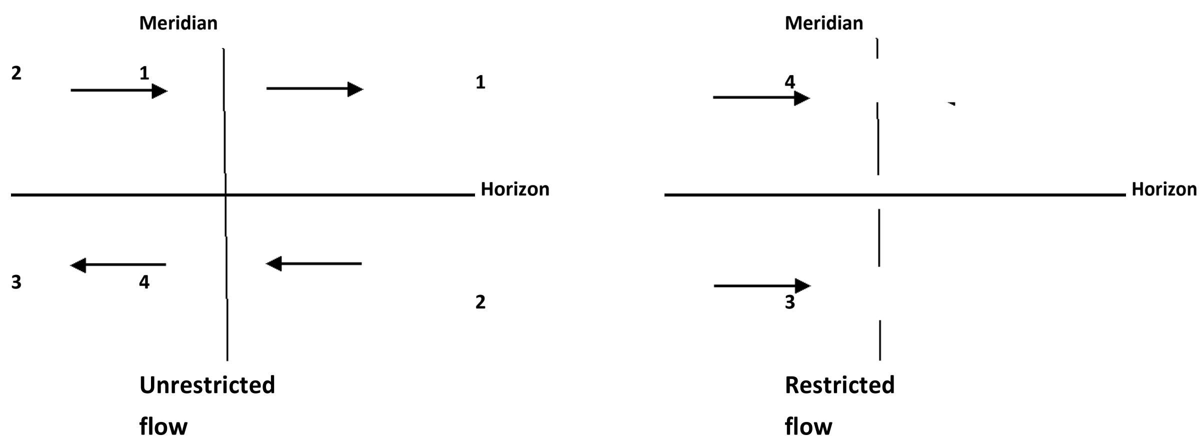
At the beginning of the ellipse, as the gyro spin axis is moving east, the damping precession opposes the movement. Therefore the spin axis will not move as far East. This reduces the rate of tilt, so that the maximum angle of tilt is reduced. This will reduce the westward movement which is also reduced by the damping precession. In this way the size of the ellipse is steadily reduced until the gyro settles.

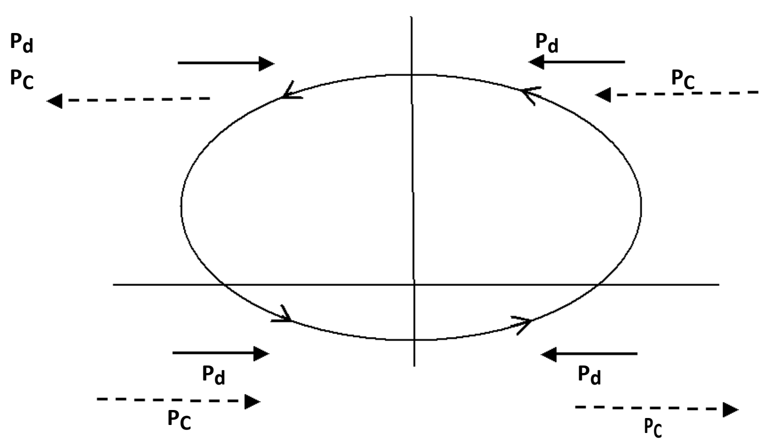
The settling point will be on the meridian, i.e. there will be no damping error (Latitude error). The gyro will settle with an angle of tilt upwards in the northern hemisphere and downwards in the southern hemisphere. This angle of tilt is required to develop a control precession to cancel the drift.

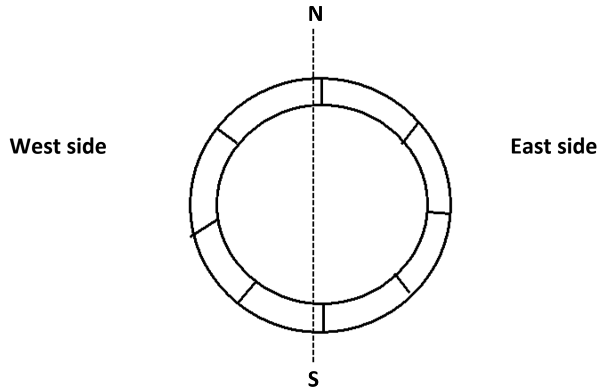


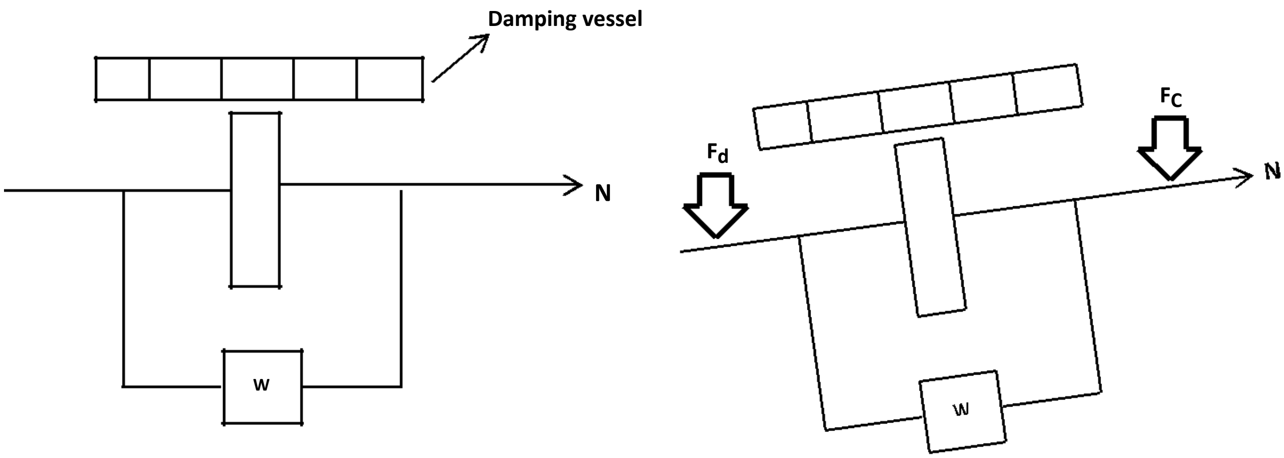
Applying damping in azimuth

Anschutz gyro compasses use this form of damping. It is usually achieved by a liquid ballistic. This ballistic is similar to the control liquid ballistic; by delays the liquid flow by means of a restriction. This restriction delays the precession as shown below producing the required damping precession.









F_c is the force due to control weight which causes P_c, but here another force is added which causes a precession (P_d).

Within the upper part of the sphere, an annular damping vessel is fixed which contains high viscosity oil. This vessel is divided into sections by partitions. The sections are connected by small bore pipes under them to each other. These pipes allow the oil to flow from one section to other when spin axis tilts up or down.

Compass errors

- **Static errors**
  1. **Alignment error**

     An alignment error can be:

     - An error existing between the indicated heading and the vessel's lubber line.
     - An error existing between the indicated lubber line and the fore and aft line of the vessel.

Both of these errors can be accurately eliminated by critically aligning the compass with the ship's lubber line at installation.

2. **Transmission error**

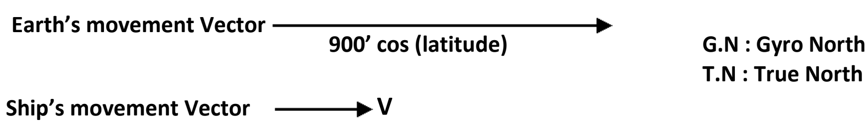
   An error existing between the indicated heading on the master compass and the heading produced by any remote repeater is a transmission error. Transmission errors are kept to a minimum by the use of multispeed pulse transmission.

- **Variable errors (Dynamic errors)**

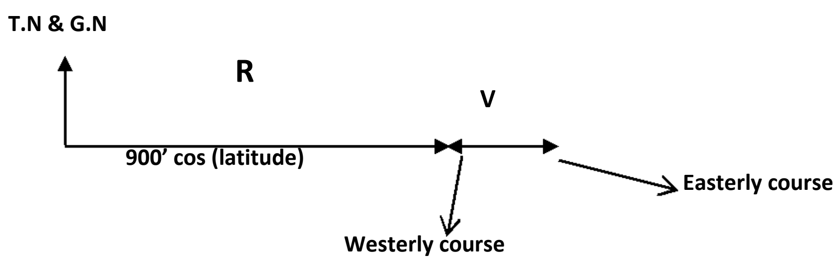
LCS (Latitude, speed, course) error (or speed error)

This error is due to earth's rotation and the apparent tilting effect it produces, which is responded by the gyro's gravity control system. The gyro tries to align itself at right angle to its motion through space. When the vessel is moving across the earth, the spin axis tries (Seeks) to align itself at right angle to the resultant motion of the earth and the ship.

Now let's consider the ship movement at different directions:

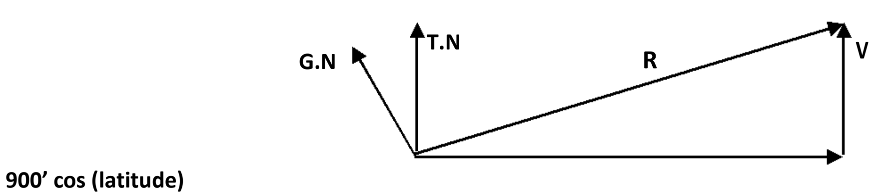


A. Vessel moving at E-W direction.



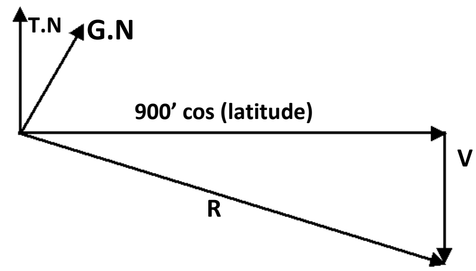
At these two courses the amount of LCS error is zero and no error.

B. Vessel moving on a northerly course (Exactly on zero degrees heading).



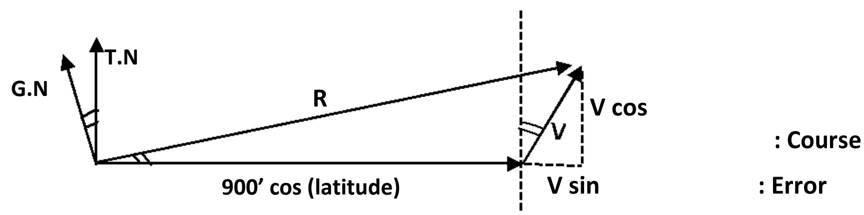
Here we have maximum error. The gyro error is westerly.

C. Vessel moving on southerly course (Exactly on 180 degrees heading).



Here we have maximum easterly error.

D. Now calculate the magnitude of error at any course.



= ——————————————

At most latitudes:

Therefore:

= ——————————

From the above formula it is evident that the N-S component of the ship's motion (V cos) causes a tilting of the gyro which it is unable to distinguish from the tilting due to earth's rotation.

An examination of above equation shows:

1. The error is directly proportional to the speed of the ship. For example if the speed is doubled, the error also will be doubled.
2. The error is directly proportional to the cosine of the course. Maximum on zero and 180°, Zero when steering 90° and 270°.

3. On all northerly courses the error is westerly, and on all southerly courses the error is easterly.
4. It is inversely proportional to the cosine of the latitude. It means that any error on equator will become twice when in latitude 60° and would become larger at higher latitudes. At latitudes near to 90° the cosine will be very small and therefore the error is very high and gyro is useless.

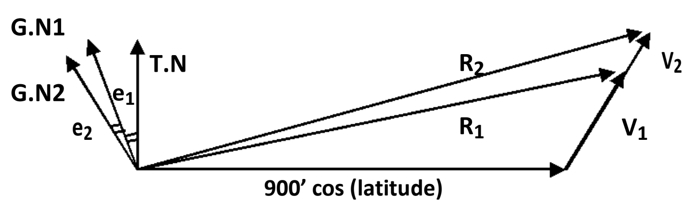
Compensation of LCS errors

1. Leave uncompensated (like Anschutz), Find the error either by tables provided by manufacturer and apply it to the bearing (Or determine by its formula).
2. In Sperry MK 20 gyro compasses, a torque motor is employed to provide sufficient precession to counteract V cos and hence eliminates the error. This motor is the same motor used to eliminate damping error.

Change in course and speed error

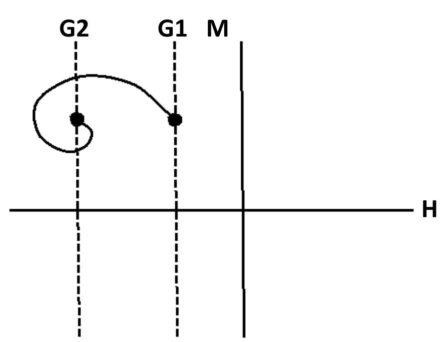
If course and speed errors are not eliminated (Anschutz gyro), then if the vessel changes its course or speed, or both, the gyro axle moves to a new direction.

Suppose the vessel has increased the speed in a northerly course. Initial speed is V_1 and increased speed is V_2:



Change in error due to speed variation: $e_2 - e_1$

The gyro axle does not move directly to its new position. But it traces out a small damped spiral before it finally settles, meaning that during alterations (and just after) the gyro is unsteady and not accurate.



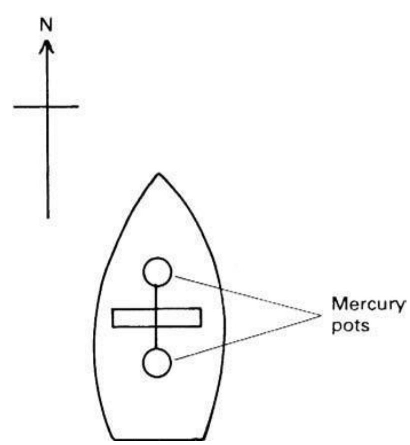
Ballistic deflection error

When a vessel alters her course and / or speed, the gyro will be subjected to horizontal acceleration. These accelerations act on the gravity control element producing top or bottom heavy effect which causes the gyro to precess. Suppose the vessel has accelerated (increased speed) in a northerly course. This will cause the increase of westerly error due to speed increase. But at the same time due to ballistic deflection the gyro becomes south heavy producing a force on spin axis which will makes the gyro precessing further west. Fortunately this is the same direction as change of course and speed error. If the magnitude of ballistic deflection is made equal to the change of course and speed error, then the gyro is pushed instantaneously into its new position and it does not make spiral. The gyro is not wonder and is nearly steady during alterations of course and speed. This is achieved by making the un damped period 84.5 minutes in Anschutz.

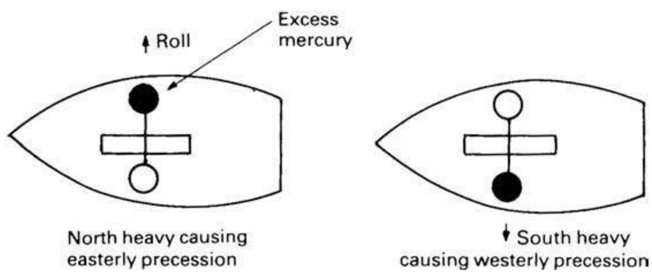
In Sperry gyro compasses where the speed error is compensated, then the ballistic deflection causes the gyro to wonder during alterations. This is minimized by making the un damped period about 120 minutes.

Rolling error

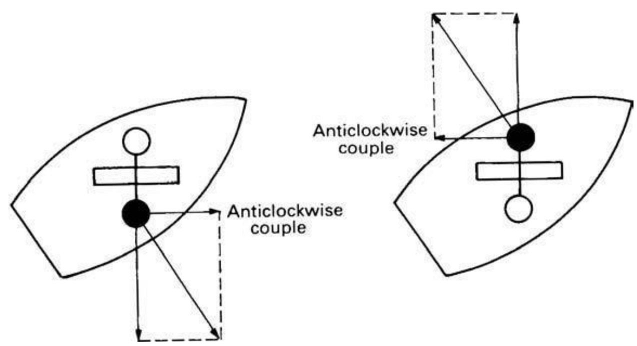
The gyrocompass is made to settle on the meridian under the influence of weights. Thus it will also be caused to shift due to other forces acting upon those weights. When a vessel rolls, the compass is swung like a pendulum causing a twisting motion that tends to move the plane of the sensitive element towards the plane of the swing. For a simple explanation of the error consider the surge of mercury caused in both the north and south reservoirs by a vessel rolling. If the ship is steaming due north or south, no redistribution of mercury occurs due to roll and there will be no error (see Figure below).



But with a ship steaming due east or west, maximum lateral acceleration occurs in the north/south direction causing precession of the compass. However, rolls to port and starboard are equal, producing equivalent easterly and westerly precession. The resulting mean-error is therefore zero, as illustrated in Figure below.



If the ship is on an intercardinal course the force exerted by the mercury (or pendulum) must be resolved into north/south and east/west components (see Figure below).



The result of the combined forces is that precession of the compass occurs under the influence of an effective anticlockwise torque. Damping the pendulum system can dramatically reduce rolling error. In a top-heavy gyrocompass, this is achieved by restricting the flow of mercury between the two pots. The damping delay introduced needs to be shorter than the damping period of the compass and much greater than the period of roll of the vessel. Both of these conditions are easily achieved.

Electrically-controlled compasses are roll-damped by the use of a viscous fluid damping the gravity pendulum. Such a fluid is identified by a manufacturer's code and a viscosity number. For example, in the code number 200/20, 200 refers to the manufacturer and 20 the viscosity. A higher second number indicates a more viscous silicon fluid. One viscous fluid should never be substituted for another bearing a different code number. Additionally since roll error is caused by lateral acceleration, mounting the gyrocompass low in the vessel and as close as possible to the center of roll will reduce this error still further.

FOLLOW UP SYSTEM

The spin axis of the gyro rotor will align itself with the meridian and will remain in this position irrespective of the ship's movements.

FIG 1

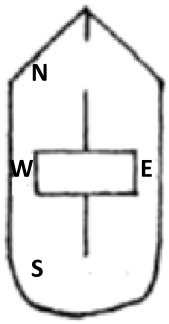


FIG 2

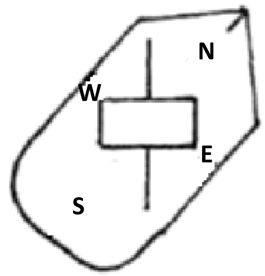
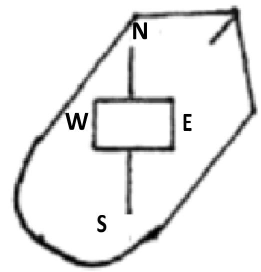


FIG 3



The follow up system is used to maintain the phantom ring in line with the spin axis of the gyro rotor. Since the compass card is attached to the phantom ring, it will therefore indicate north. Should the vessel change its heading (FIG2) the phantom ring, horizontal and vertical rings will instantaneously move with the vessel. This movement causes the secondaries of the follow up transformer to move with respect to the primary, thus one secondary winding will have a larger EMF induced into it than the other, resulting in an error signal. This signal is amplified by the follow up amplifier and fed to the control winding of a two phase servo motor, known as the AZIMUTH MOTOR. The amplified error signal causes the Azimuth motor to rotate, moving the Phantom ring and therefore compass card, via a gearbox. The movement of the Phantom ring is such that the secondary of the follow up transformer move in such a direction as to reduce the error signal.

The error signal will disappear when the secondary of the follow up transformer are again symmetrical about the primary. This will occur when the Phantom Ring and therefore compass card are in line with the rotor spin axis and therefore again indicating NORTH (Fig 3).

The follow up system maintains the vertical ring in the same plane as the rotor, and as the phantom ring is always at right angles (in Azimuth) to the vertical ring it keeps the phantom ring in the same plane as the spin axis. Remember that the spin axis is designed to point North, so the phantom ring will always point north and hence the attached compass card will always point north. So by taking a reading off the compass card at the lubber line indicator we are given an accurate bearing of our course.

The vertical ring must follow the rotor as the spin axis seeks and settles in the meridian and must remained aligned with the rotor when the ship alters course in order that the wire suspension does not twist and apply a torque to the rotor.

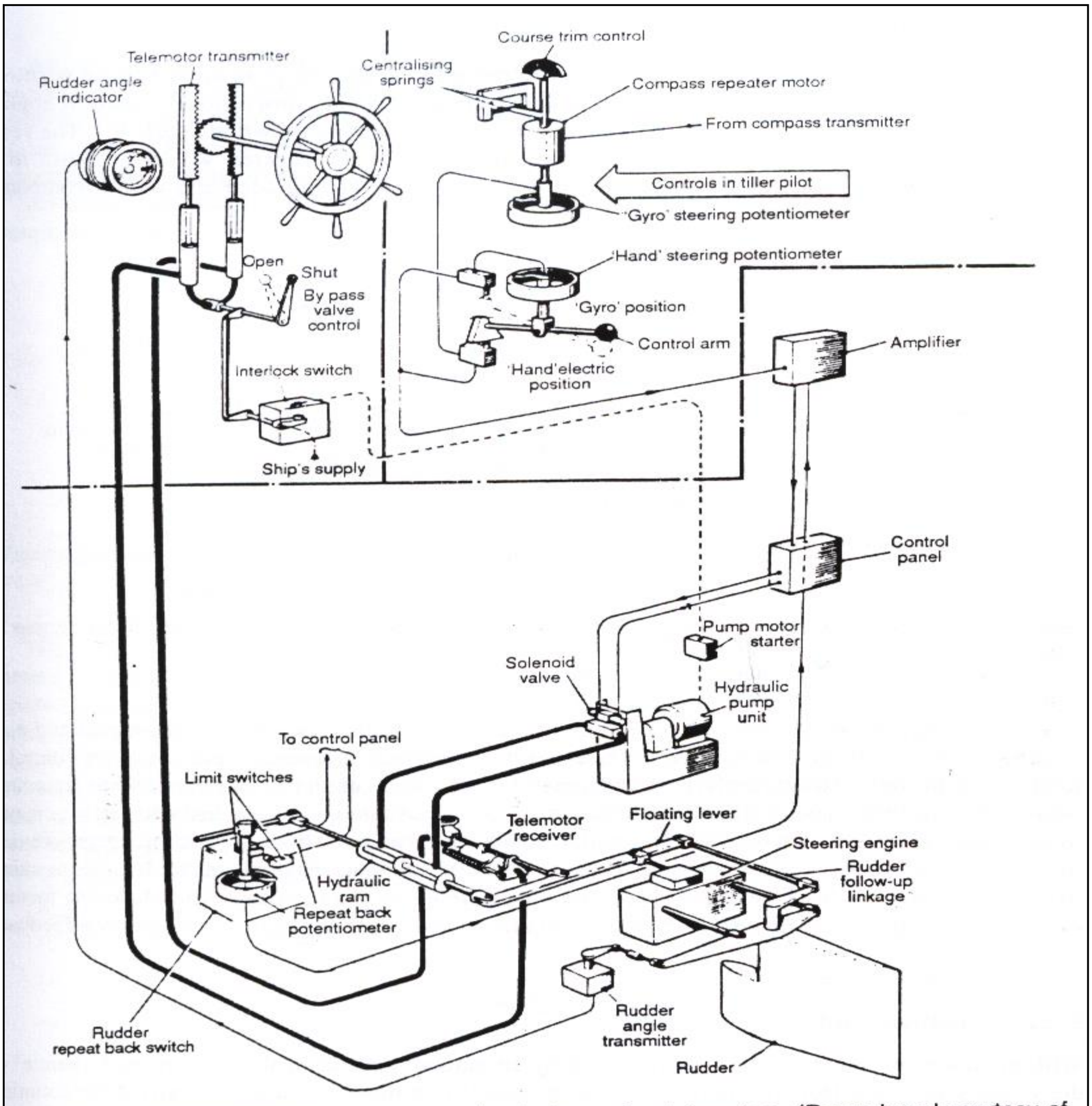
AUTOMATIC PILOT

Auto pilot is an automatic steering device whose purpose is :

1- To maintain automatically a constant heading. (course keeping)

2-To change course when necessary. (course changing)

3-To replace the dull and fatiguing job of a helmsman .



gure 9.1 An early electro-mechanical autopilot system using telemotors. (Reproduced courtesy of
perry Ltd.)

ADVANTAGES:

1- Since there is no need for a helmsman to be continuously at the wheel , a reduction can be made in the number of the ship's crew ,thus reducing the expenditure .

2- The vessel keeps her course with little deviation and greater speed of advance , thus saving fuel , minimizing steering gear wear /tear.

Most ships are equipped these days with an auto pilot . Auto pilot is primarily used for navigation in open waters .However with the modern developments taking place in producing very sophisticated auto pilots . It is becoming possible to use them in more complex situations .

Principle :

The Autopilot works on the principle of the closed loop system . The actual heading of the ship obtained from the gyro or magnetic compass is continuously compared with the desired value of the , demanded , course to be steered .

If there is any difference between these two an error signal proportional to the magnitude and sign of the off course error is produced . This error signal is amplified ,differentiated and integrated and then fed to a rudder actuating circuit which makes the rudder move in the required direction . The movement of the rudder produces the rudder feed back signal which reduce the off course error , closes the control loop and finally stops the action .

Autopilot system

There are four main components to all auto pilot systems, they are:

1- Heading sensor :

This is used to obtain a course error signal . A gyro repeater motor can be use to obtain this or in the case of a magnetic compass , a flux gate sensor .

2- Rudder position transmitter : (rudder feed back)

This supplies continuous rudder angle information to the controller unit which is necessary to ensure that rudder is driven to ordered position .

3- Actuator :

A power device which on command from the controller unit develops mechanical or hydraulic power , generally by an electric motor and applies it to the steering gear which moves the rudder .

4- Controller unit :

Analyses course error , rate of change of course error and rudder angle feed back information and decide the magnitude / direction of steering corrections.

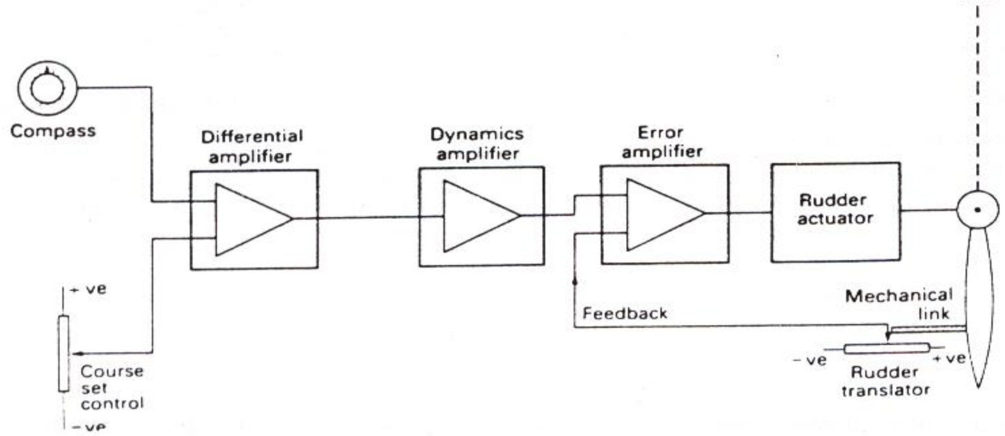


Figure 9.6 A simple autopilot system.

CONTROLLER UNIT provide P.I.D controller action ;

A) <u>Proportional controller action :</u>

Orders a rudder angle that is proportional to the course error , e.g 1º rudder ordered for 1º course error .If used by itself ,the vessel will oscillate about the desired course , the oscillation will not be damped out .

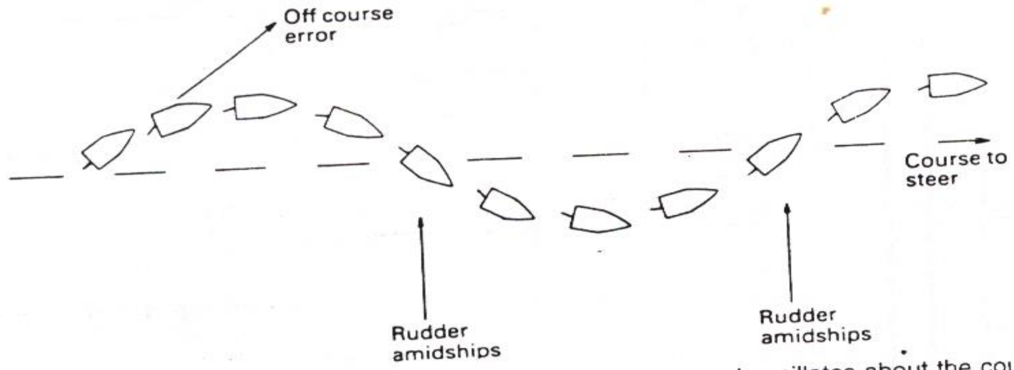


Figure 9.2 The effect of applying proportional control only. The vessel oscillates about the course to steer.

<u>B) Derivative controller action :</u>

The rate of change of course error is measured and counter rudder ordered that is proportional to this rate of change of error . Derivative control by itself will only check the swing of the vessel after it has moved off course and will not bring the vessel back to its desired course . It is always used in conjunction with proportional control and any rudder ordered is in addition to that needed for proportional control .

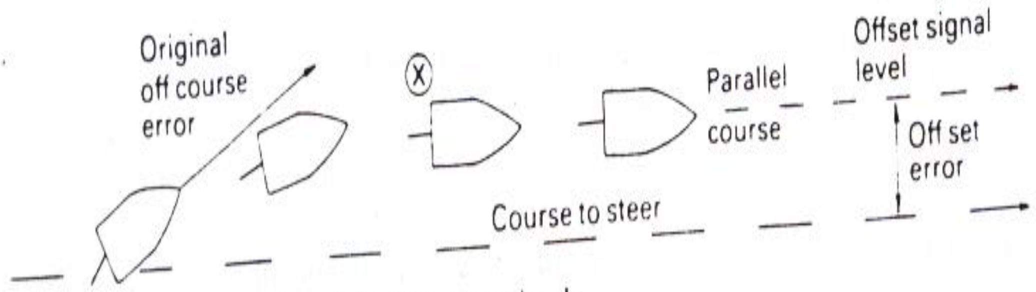


Figure 9.3 The effect of applying derivative control only.

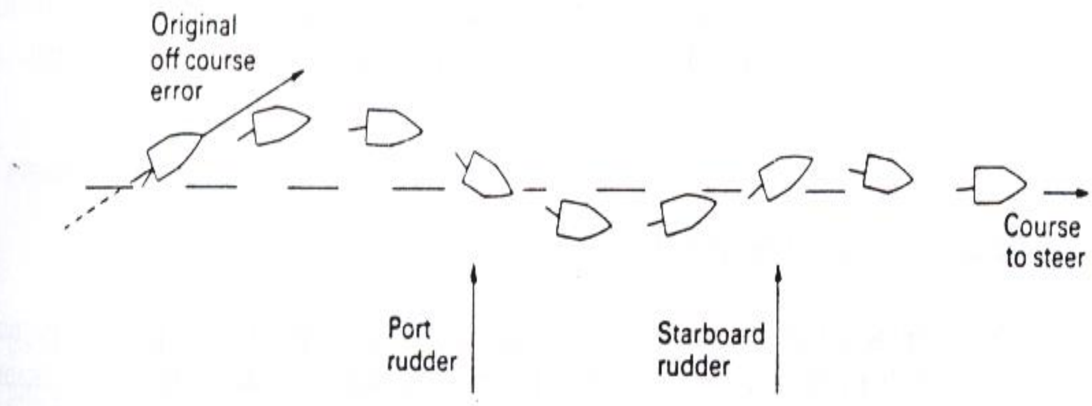


Figure 9.4 Applying a combination of proportional and derivative control brings the vessel back on track.

C) <u>Integral control action :</u>

Continuously compares the course being steered with the set course and if a long term error exists i.e the vessel being set more off course more to one side than the other a permanent rudder angle bias is ordered .

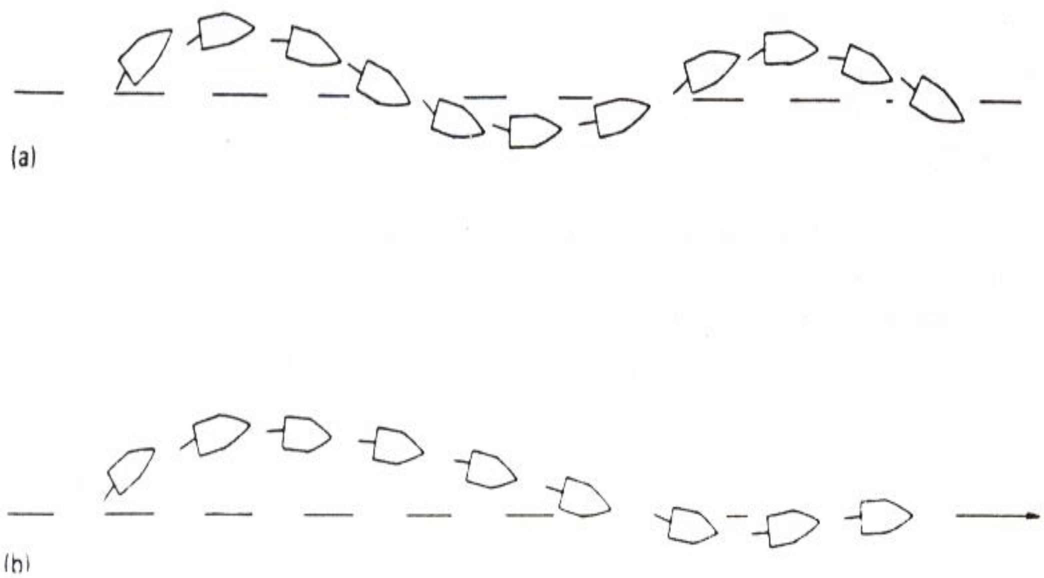


Figure 9.5 (a) If 'counter rudder' and 'rudder' controls are set too high, severe oscillations are produced before the equipment settles.(b) If 'counter rudder' and 'rudder' controls are set too low, there will be little overshoot and a sluggish return to the course.

Manual operator controls :

A vessel steering characteristics will vary under different condition Hence additional controls must be provided to alter the action of the autopilot in similar way that a helmsman would alter his actions under the same condition.

The common operator controls found on an autopilot are:

1-Course setting : Course is usually set by means of a compass card to the , demanded , heading . The difference between the demanded heading and actual heading is then sensed and the difference removed by altering the course of the ship .

2-Rudder angle or rudder limit : This control sets the maximum rudder angle which the autopilot may apply .This limit overrides the angle commanded by the automatic control circuitry .

3-Rudder : This control alters the ratio between the instantaneous course error and the amount of the helm.

It determines the absolute degree of rudder command for every degree of heading error .

e.g if this control set to 2 the rudder may move two degree

for every degree of heading error . the higher the setting , the tighter will be the control of the heading , but may result in overshooting . if too low , the movement of the ship will be sluggish .

4-Counter rudder : This control determines the degree of opposite helm to be applied when required . Counter rudder is applied when there is a change of sign of the rate of change of heading data .

The amount to be applied can be varied according the condition of the vessel The greater the moment of inertia of the ship , the greater should be the counter rudder setting .

5-Weather or sensitivity : This sets the amount by which the vessel is allowed to be off course before correction is applied .it will be uses during rough weather ,so less helm command will be used . In calm weather it will be set to zero. The heaver the weather , the higher the setting allowing the ship to recover naturally when under the influence of repetitive yaw .Hence the steering gear will not be subjected to continuous port / starboard commands causing un-necessary working of the gear and added the drag due to rudder action .

6-PERMANENT HELM:

This control applies a permanent rudder angle bias such that ruder may be applied even when no course error exists . It is used when the vessel falls off course more to one side then the other to wind or sea conditions or the steering stability of the vessel .

Note : Permanent helm is frequently applied automatically (Integral controller Action) where it is automatically reset after each course change .

6-Function selector switch :

This switch has usually three positions .

a) Non follow – up mode .NFU

In this mode the rudder is controlled by means of spring loaded lever or wheel having two positions (port/stbd)

This lever energizes the directional valves on the hydraulic power unit directly, bypassing the rudder position feedback . There is no feedback from the rudder to close the loop . the rudder is now under open loop control .

As long as the lever is in one of the two position the rudder will continue to move in that direction . When the lever is released , the rudder will stop moving .

b) Follow-up mode , fu and manual steering :

In this mode manual steering is done by the helmsman as if there were no autopilot . The FU tiller control voltage is compared with the rudder feedback voltage to obtain the error signal .Rudder action is now under the influence of a singled closed loop .

ADAPTIVE STEERING MODULE (ASM)

In order that good course keeping is maintained at all times the watch officer will have to make frequent adjustments to the manual controls, eg rudder , weather, counter rudder etc .

This is not always possible when the officers workload is high and when course, speed, wind and sea conditions are continuously changing .

An ASM is simply an autopilot using PID control techniques linked to a microcomputer .

Contained in the computer is date relating to the heavier of a " model ship " . Course keeping performance is continuously fed to the computer where it is compared against that of the model ship and rudder commands for the actual ship are predicted . The computer ensure that corrective rudder is only used when course keeping is affected by environmental conditions and not by the natural yaw of the vessel . An ASM will continuously adjust the rudder commanded to

meet the prevailing conditions and there is no need for the watch officer to make manual adjustment .

<u>The benefits of an ASM are :</u>

(i) Removes the need for operator adjustments .

(ii) Ships natural yow not smoothed out which reduces the need for excessive rudder angles of movements resulting in less rudder drag and wear on the steering gear .

(iii) Improves fuel consumption .

(iv) Achieves good course changing stability which is important in coastal waters .

Operator Warning!

An Autopilot is an aid to navigation only. It is not intended or designed to replace the man on watch. Always be in position to monitor the ship's heading and to watch for navigational hazards. Be prepared to revert to manual steering immediately, if an undesired change of heading occurs, if the heading is not maintained within reasonable limits, or when navigating in a hazardous situation.
Always remember: Whenever underway, a qualified man on watch is required .

<u>Course recorder :</u>

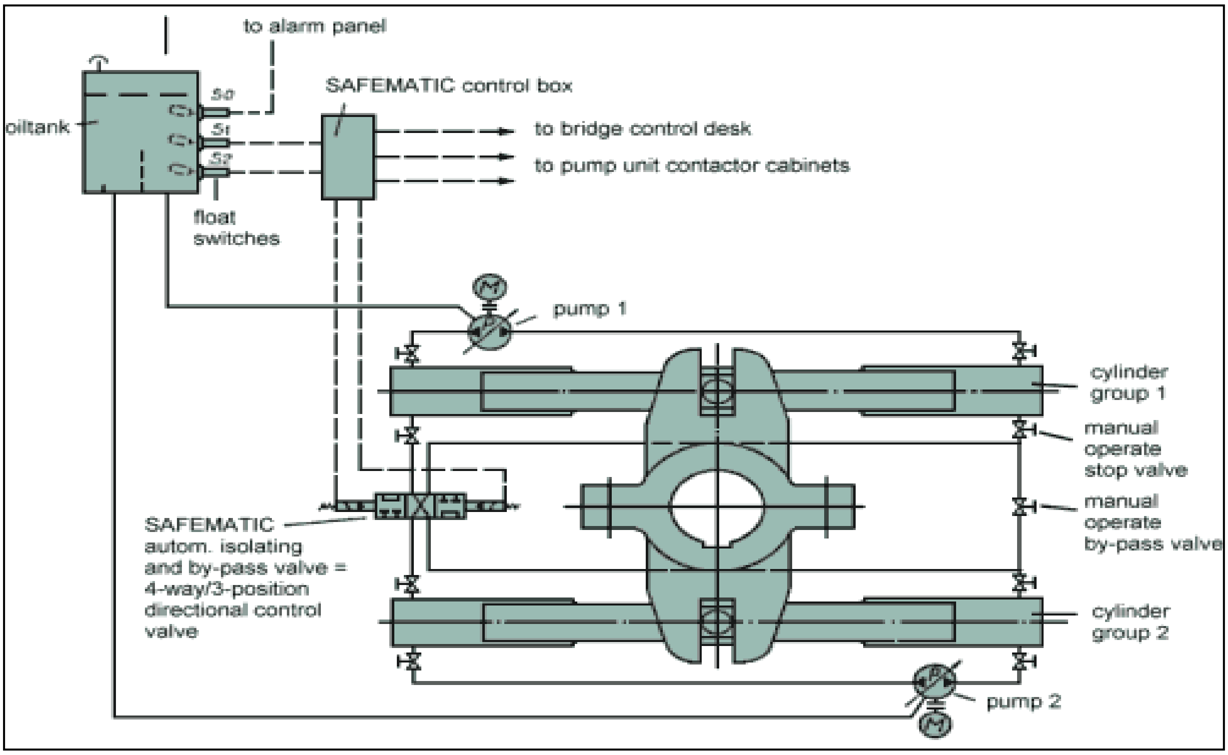
In the past course has been recorded with a pen-plotter and highly expensive custom graph paper. The system was connected to the gyro compass ,the paper had time scale (24 hours) ,heading scale(000º – 360º) . The new generation uses a low cost dot matrix printer and plain paper (roll or fan-fold), and it prints intelligently in plain text, along with time.

The data may be recorded on a PC using a free data logging program, as a simple Voyage Data Recorder. GPS input provides timing. A routine log of position and speed over ground is printed. The output data rate is variable, automatically, to this simple rule, to minimize the use of paper.

Printout every 6 minutes and Printout every 10 seconds, if heading changes more than 2 degrees from last printout.

Steering system :

1- **Automatic isolation system for 4-cylinder / 2-ram type steering gears. Designed acc. to latest rules of class. societies and IMO for automatic isolation of one cylinder group in case of leakage, failure or emergency.**



Twin-Actuator Steering Gears

- Compact design with integrated, working oil lubricated rudder carrier and guide bearing

- Suitable for standard as well as high-duty rudders up to 2 x 65° rudder angle

- Integrated mechanical stoppers

- Hydraulic shrink (keyless) fit of rudder stock

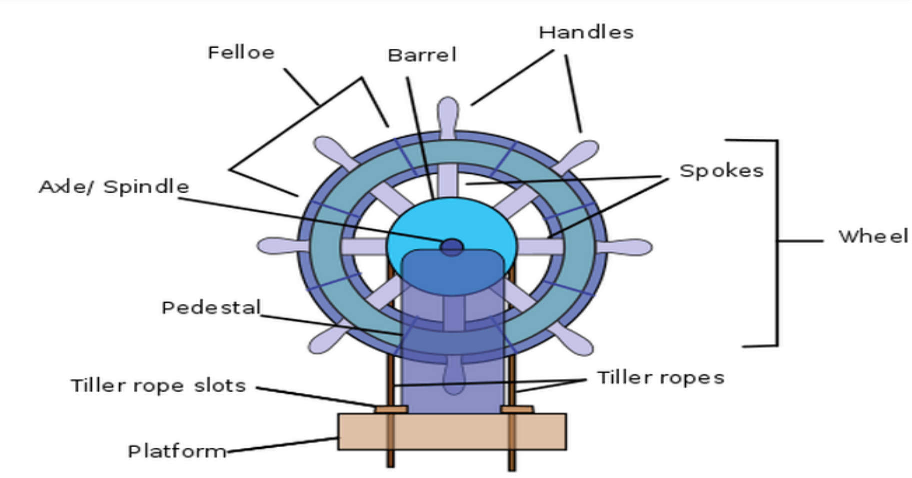
- Simple foundation work and easy installation

- Automatic switch-over system in case of pressure loss, if required

- Pumps with variable displacement for analogue steering control or constant delivery

Understanding Steering Gear in Ships

We are all familiar with the use of a rudder, which helps in turning a ship as and when required. Rudders are the principal system for the entire motion and control of the ships. But we mustn’t forget that the entire rudder action is dependent on another pivotal system called the ***Steering Gear***. Steering Gear integrated with the rudder system defines the complete ‘turning mechanism’ mandatory for each and every ship irrespective of size, type and operation. Steering gear system has been an indispensable part of the ship’s machinery since the advent of the very early ships, which were operated by hand.



Hand operated steering wheel at helm for olden ships

Steering Gear System In Ship

The efficiency of performance of steering gear depends on some main aspects. These basic requirements to be invariably met by all steering gears are guided by rules set by classification societies. They can be briefly outlined as:

- As per standard requirements, the steering gear should be capable of steering the ship from 35 degrees port to 35 degrees starboard and vice-versa with the vessel plying forwards at a steady head-on speed for maximum continuous rated shaft rpm. and summer load waterline within a time frame of maximum 28 seconds
- With one of the power units inoperative, the rudder shall be capable of turning 15 degrees port to 15 degrees starboard (and vice-versa) within a time frame of 1 minute with the vessel moving at half its rated maximum speed or 7 knots (whichever is greater) at summer load line
- The major power units and the control systems are to be duplicated so that if one of them fails, the other can easily substitute for them as standby

- Emergency Power Supply: The steering gear system is to be provided with additional power unit (hydraulic pump etc.) connected to the emergency power supply from Emergency Generator, which shall be capable of turning the rudder from 15 degrees from one side to other side within 60 seconds with the vessel moving at a maximum service speed or 7 knots, whichever is greater

Types of Steering Gears On Ships

As ships continued to grow in size and became faster, modern systems easing human effort were incorporated. Basically, there are two types of commonly used steering gear systems present:

- Hydraulic
- Electro-hydraulic type

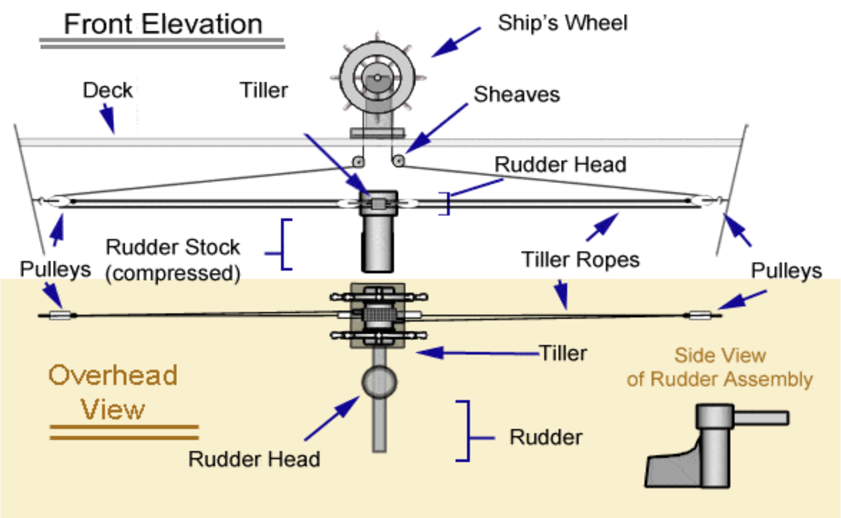
Though the system has undergone some major evolution, the basic physics of operation remains the same.

Modern day advanced steering control at helm

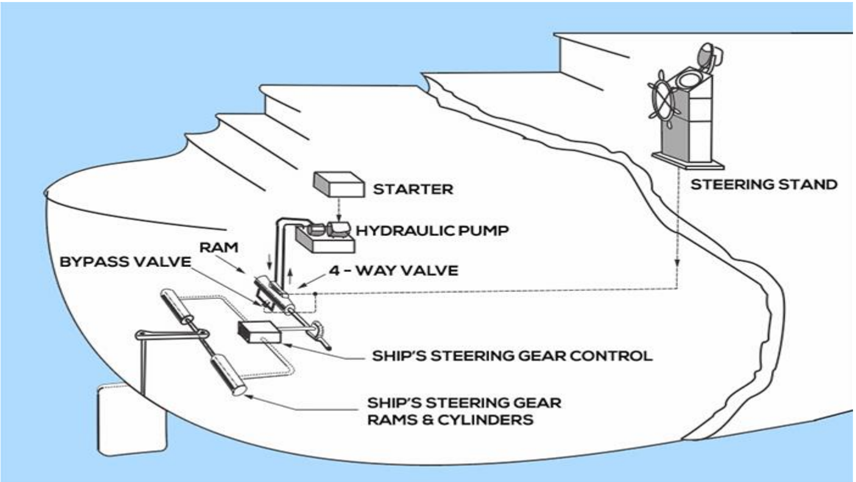
The main control of the steering operations is given from the helm of any ship, similar to an automobile where the entire control of the vehicle's "steer-ability" rests on the steering wheel of the driver. The 'control force' for turning is triggered off from the wheel at the helm, which reaches the steering gear system.

The steering gear system generates a torsional force at a certain scale which is then, in turn, is transmitted to the rudder stock that turns the rudder. The intermediate steering systems of a modern day ship can be multifarious with each small component having its own unique function. We omit to discuss each and every such component in detail.

A better illustration for the exact work sequence of in a simple rudder system is given in the following figure.



Primitive Steering Gear System layout



Representative image of Steering Gear arrangement in a ship
The rudder system consists of the following:

- Rudder actuators
- Power units
- Other auxiliary equipment needed to apply turn the rudder by applying torque
- Hydraulic pumps and valves

- In hydraulic and electro-hydraulic systems, hydraulic pressure is developed by hydraulic pumps which are mainly driven by electric motors (electro-hydraulic systems) or sometimes through purely mechanical means (hydraulic systems).

However, mainly advanced electro-hydraulic systems are predominant in ships nowadays. These hydraulic pumps play a crucial role in generating the required pressure to create motions in the steering gear which can trigger the necessary rotary moments in the rudder system.

These pumps are basically of two major types:

- Radial piston type (Hele-Shaw)
- Axial Piston type (Swash plate)

Actuators mediate the coordination between the generated hydraulic pressure from pumps (driven electrically, of course) and the rudder stock by converting it into a mechanical force creating a turning moment for the rudder. Actuators are now mainly electrically driven by power units.

These actuators, in turn, can be of two types:

- *Piston or cylindrical arrangement*
- *Vane type rotor*

The types of actuator systems depict the types of steering gears present on ships, which are also segregated as Ram type and Rotary Vane type arrangements accordingly.

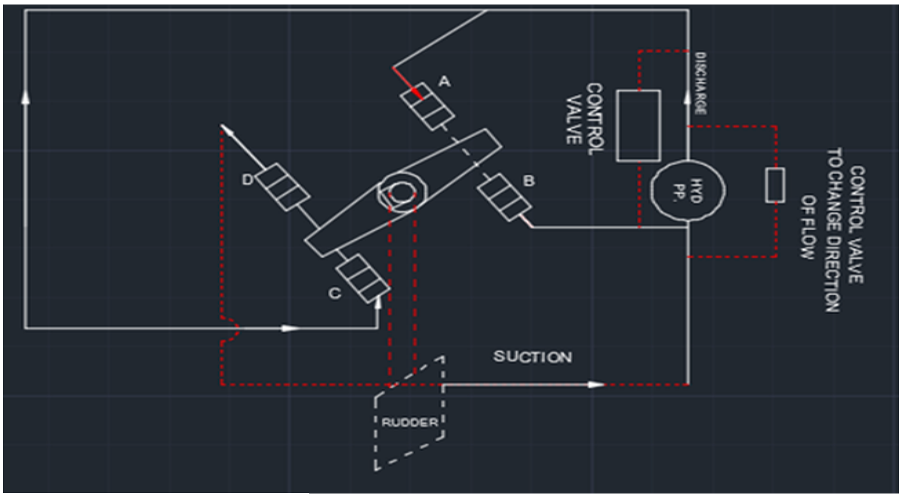
Let’s discuss them in brief.

Ram Type Steering Gear System

Ram type steering gear is one of the commonly used steering gear construction and is quite expensive in construction. The basic principle is same as that of a hydraulically-driven motor engine or lift.

There are four hydraulic cylinders attached to the two arms of the actuator disc, on both sides. These cylinders are directly coupled to electrically driven hydraulic pumps which generate hydraulic pressure through pipes. This hydraulic pressure field present in the pumps imparts motion to the hydraulic cylinders, which in turn corresponds with the actuator to act upon the rudder stock. As we know, rudder stock is an indispensable part of the entire steering gear arrangement of ships and dictates the exact behaviour of the rudder response.

The sense of turning the rudder is guided by the action of the hydraulic pump. The physics behind its function can be explained better with the help of the following figure.



Ram type steering Gear

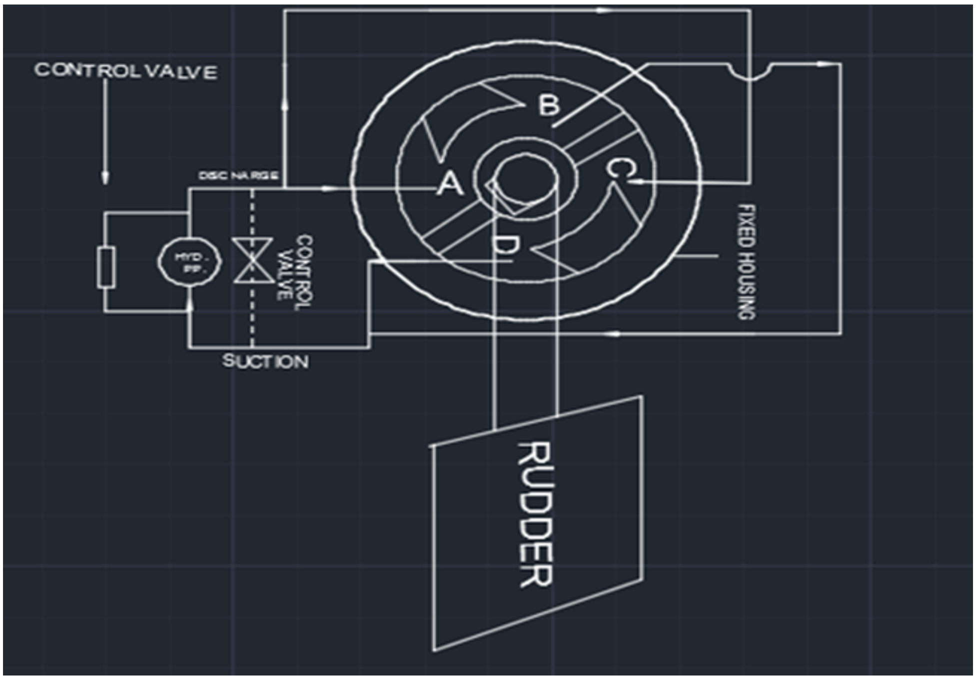
Here the cylinders denoted A and C are connected to the discharge side of the pump. This generates a positive pressure in the piston cylinders. On the contrary, the other two cylinders B and D are connected to the suction side of the pump. This creates a negative pressure in the cylinders. The resultant forces create a clockwise moment in the rudder. To put it simply, positive and negative pressures from pumps generate lateral forces on the rams which create a couple for turning the rudder stock.

Similarly, to put it in a anticlockwise turning sense, the reverse is carried out, viz. the discharge ends of the pumps are connected to the cylinders B and D, while the suction side of the pumps are to A and C. This reverse pressure flow from hydraulic pumps is achieved with the help of control valves operated from the wheelhouse.

The ram type steering gear arrangement produces a considerably high value of torque for a given applied power. The hydraulic oil pressure varies from *100 bars to 175 bar*s depending on the size of the rudder and torque required.

Rotary Vane Steering Gear

In rotary vane steering gear, there is a fixed housing in which two vanes rotate. The housing along with the vanes form four chambers. The physics behind its operation is similar to the ram type with a small difference.



Rotary Vane type Steering Gear

When chambers A and C are pressurized, there is an anticlockwise rotation of the vanes. A and C are connected to the discharge side of the pump while chambers B and D are connected to the suction side of the pump.

Similarly, when clockwise rotation is required, B and D are connected to the discharge side of the pump while A and C are connected to the suction side of the pump. As above, this is also operated by specialised control valves.

Thus, differential pressurization of the chambers cause rotational moments in the vane.

Rotary vane type arrangement is used when the pressure requirement is *60 to 100 bar* for producing required torque. This is the main advantage of rotary vane type steering gear, requiring lesser hydraulic pressure and thus power for producing the same amount of torque as ram type.

There are 3 fixed and 3 moving vanes, which can make rudder angles up to 70 degrees, i.e 35 degrees on each side.

This arrangement has several other advantages like lower installation cost, less weight and smaller space required.

The fixed and rotating vanes are of spheroidal graphite cast iron. Keys are often provided in the rotary vanes for proper strength and orientation.

What are the advantages of rotary vane type over ram type ?

- Smaller space required
- Low installation cost
- Less weight
- Smaller power required, for the same load, because it can transmit pure torque to the rudder stock.

What are the disadvantages of rotary vane type over ram type ?

- Synthetic rubber backed steel sealing strips at vane tops are not strong enough for large ship gear.
- Can be used for rudder stock ratings of about 1700 KNm and less torque generated by two ram is 120 to 160 KNm and for four ram 250 to 10,000KNm.

What are the requirements for steering gear ?

- To move the rudder in either direction instantly when required
- Should come to reset immediately in the position corresponding to that shown on indicator on the bridge.
- Provision must be made to protect the steering gear from damage should a heavy sea strike the rudder.
- The design should be sample, the construction robust and its performance reliable at all times.

What are steering system regulations ?

1. Every ship shall be provided with a main steering gear and an auxiliary steering gear.
2. The failure of one of them will not render the other one inoperative.
3. Relief valves shall be fitted to any part of the hydraulic system.
4. The main steering gear and rudder stock shall be:
5. (a) of adequate strength and capable of steering the ship at maximum ahead service speed.
   (b) capable of putting the rudder over from 35′ on one side to 35′ on the other side with the ship at its deepest sea going draught and running ahead at maximum ahead service speed and, under the same conditions, from 35′ on either side to 30′ on the other side in not more than 28 seconds.
   (c) So that they will not be damaged at maximum astern speed.
6. The auxiliary steering gear shall be: (a) of adequate strength and capable of steering the ship at navigable speed and of being brought speedily into action in an emergency. (b) capable of putting the redder over from 15′ on one side to 15′ on the other side in not more than 60 seconds with the ship at its deepest seagoing draught and running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater.

7. In every tanker, chemical tanker or gas carrier of 10,000 gross ton and upwards and in every ships of 70,000 gross ton and upwards, the main steering gear shall comprise two or more identical power units.

Q- With reference to an auto pilot which uses three terms controller system:

a- Identify the three terms. **(4m)**

b- Name each with its corresponding auto pilot control. **(4m)**

c- Describe the function of each item. **(12m)**

a- Proportional, Derivative & Integral terms

b-

- A quantity proportional to heading deviation ' The Proportional Term'.
- A quantity proportional to the rate of change of the heading deviation ' The Derivative Term'.
- A quantity proportional to the integration of the heading deviation ' The Integral Term'.

c-

Proportional term: The proportional circuit produces signal when heading deviation is present and the gain determines the rudder angle achieved for each degree of heading deviation. The related gain control can be labelled gain, rudder, rudder multiplier, rudder, ratio and rudder response.

The controller adjust the gain between approximately 0.5 and 3 . Thus for example 3 degrees of heading error will result in rudder angle any where between 1.5 and 9 degrees depending on gain setting.

It is set as lowest as possible without the ship wondering from the demanded heading. A higher setting is required when the ship is loaded or is operating at reduced speed. Too high setting without further control features causes instability or oscillation about the demanded heading.

Derivative term: The derivative circuit produce a signal when the heading of the vessel is changing. The high inertia of the ship and the proportional gain setting will cause to over shoot and oscillate about the demanded heading. The derivative signal will provide damping and reduction of the setting time. The gain of the derivative term is used to compensate for low changes. A ship in ballast needs less counter rudder.

The related gain control can be labelled counter rudder or rate multiplier.

Integral term: Due to wind hitting the ship's structure, tides and the effect of the ship's proportion, it may be that with rudder in mid-position, the ship steer slightly to port and starboard. The integral circuit give a bias to the rudder to maintain ship's heading on the demanded heading. The related gain is normally pre-set during ship's trial. In some auto pilot the rudder bias is manually applied by a control which can be labelled: standing helm, permanent helm, weather helm, rudder off set or rudder trim.