1. ECHO SOUNDER

1.0 General.

The echo sounding machine works on the principleof measuring the time taken by a sound wave to travel from the ship to the sea bed and back again. The instrument transmits the signal, detects the echo and measures the elapsed time interval.

1.1 Principle.

The principle of measurement is as follows:
In the water beneath the ship, short pulses of sound vibrations are transmitted at the rate of 5 - 600 per minute to the bottom of the sea. The sea bed reflects these pulses and after a time which depends on the depth,m the echo pulse is received back at the ship.During this time, the pulse has travelled a path equal to **TWICE** thedistance between the keel of the ship and the sea bed.

1.2 How the echo sounder works.

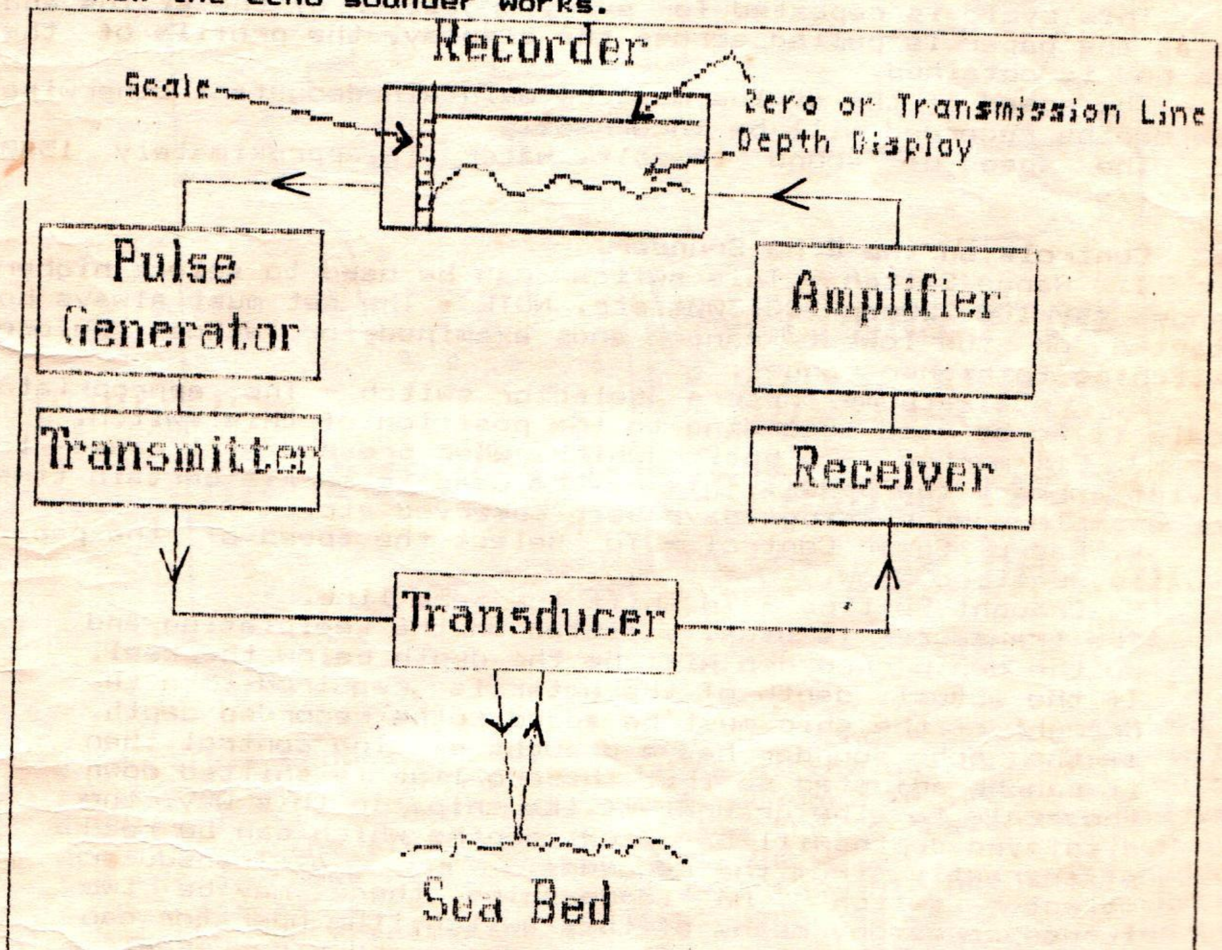


Figure 1: Simplified Block diagram of Echo Sounder.

Within the recorder unit, a stylus is mounted on a continuous circular belt which is driven at a constant speed by the stylus motor. A magnet fixed on the belt triggers the transmitter to transmit a pulse every rotation of the belt when the stylus is at the zero mark on the paper scale. The transmission of the sound pulse from thetransducer on the ship's bottomis synchronized with the stylus at the zero mark.

The pulse of energy is beamed towards the sea bed but some energy leaks back to the receiver through the water and ship's plating and the stylus makes amark at the zero position. Thisline formedis called the **Zero Line orTransmission Line.** This zero line is a good indication thatthe echo sounder is transmittingsignals.

The echo from the sea bed is received at the receiver and after being converted to an electric pulse is fed to the stylus. During the time taken for the echo to returnfrom the sea bed, the stylus has moved down away from the zero mark and hence makes a mark on the paper at a distance proportionate to the depth. A marked scale isprovided on the side in meters, fathoms or feet to help read the depth.

This cycle is repeated for every rotation of the stylus and so as the paper is pulled across the display, the profile of the sea bed is obtained.

The speed of the stylus must be maintainedconstant otherwise the depths recorded will be incorrect.

The speed of sound in salt water is approximately 1500 meters/sec.

1.3 Controls on the Echo Sounder.

1. Range Switch - This switch can be used to select higher ranges say 100-200mor 200-300m etc. NOTE - The set must always be started on the lowest range and examined for echoes before switching to higher ranges.

2. Feet/ Fathoms/ Meters selector switch - The appropriate scale is to be used according to the position of this switch.

3. Fix marker - A button which when pressed will cause stylus to mark the paper. This may be used to mark a certain time for example when bearings have been observed etc.

4. Paper Speed Control - To select the speed of the paper usually, Fast or Slow.

5. Draught Setting - To shift the zero line.
The transducer is usually fitted on the keelplating and so the depth recorded will be the depth below the keel. If the actual depth of the water is required then the draught of the ship must be added tothe recorded depth. If the echo sounder has a draught setting control then it can be adjusted so that thezero line is shifted down the scale to the draught of the ship. In this way, the displayed depthswill be actual depths which can be read off directly from the recorder. 6. Transducer selector switch - On large ships there may be two transducers soby means of this switch, the operator can switch from forward to aft transducer and vice versa.

7. Gain or Sensitivity - To make the echoes darker on the paper in case they are weak.

8. Dimmer - To adjust the illumination of the display.

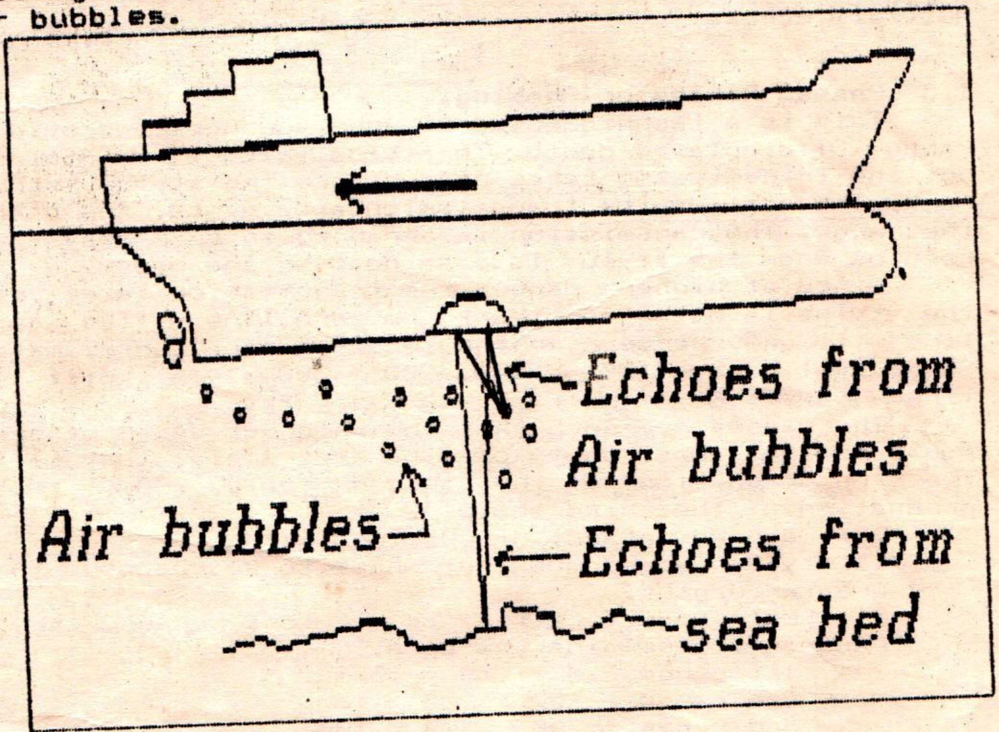
3

1.4 Errors.

1. Velocity Error -The velocity of sound increases when temperature, pressure, and salinity increase. This change in velocity will causeincorrect readings to be displayed.For example in the Red Sea due to high salinity and temperature, displayed depths must be increased by 5%.

2. Aeration - This is caused byair bubbles in the water under the transducers usually whilegoing astern. The airbubbles reflect the sound waves and incorrect echoes will be received at the transducer. In such a case the echoes from the sea bed may disappear altogether. Other causes for aeration are:

i) Turbulence by putting rudder hard over.
ii) Pitching heavily in light condition.
iii) Breaking water over shoals.
iv) Sailing through water where bad weather has left pockets of air bubbles.

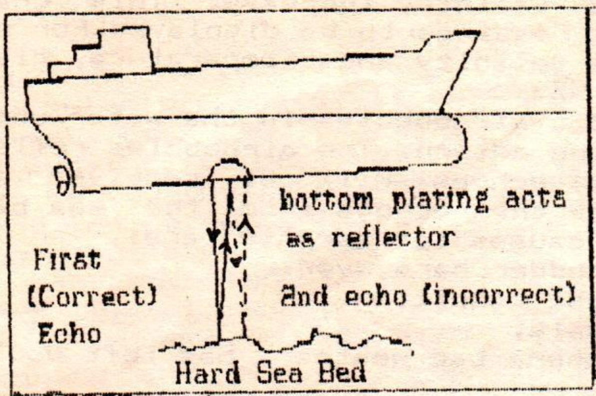


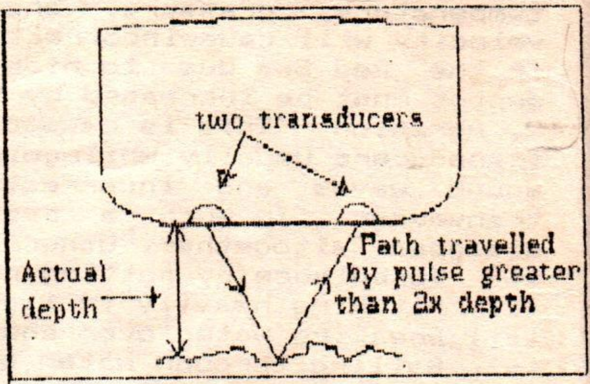
Aeration

3. Multiple Echoes- In shallow waters, echoes maybe received from first, second, or third reflections of the sea bed. These will be displayed as second and third echoes. In case of such an occurrence, the first echo is always the correct one. The second and third echoes will usually be weaker.

4. Pythagoras' Error - Thisoccurs if the ship has twotransducers, one acting as transmitter and the other as receiver separated by some distance. In shallow waters, the distance travelled by the pulse will be greater than the depth of the sea bed below the plating.

5. False bottom echoes - This usually occurs in deep waterwhen an echo may be received after the stylus has completed one rotation and begun the next cycle.





Pythagoras Multiple echoes

Pythagoras' Error

1.5 Phased Ranges or Phasing.

This is a techniqueused in echo sounders toprovide increased ranges of displayed depth. Thestylus speed is maintained constant but the transmission takes placebefore the stylus reaches thezero mark. The earlier the transmissiontakes place, the deeper will be the range. Thetransmission is arranged in such away that the echo returns when the stylus is passing over the paper.

Since at higher ranges the transmission takes place before the stylus is atthe zero mark, no zero line willbe seen. The zero line will only be seen on the lowest range, for example 0 - 100m. Subsequent ranges 100 - 200m, 200 - 300m, etc. will have no zero line.

The ranges are such that the highest depth of one scale is equal to the lowest depth of the next scale, that is for example the top graduation of the second scale, 200m, is the lowest graduation of the third scale.

The main advantages of phasing is that:

i) Stylus speed does not have to be changed to sound greater depths.

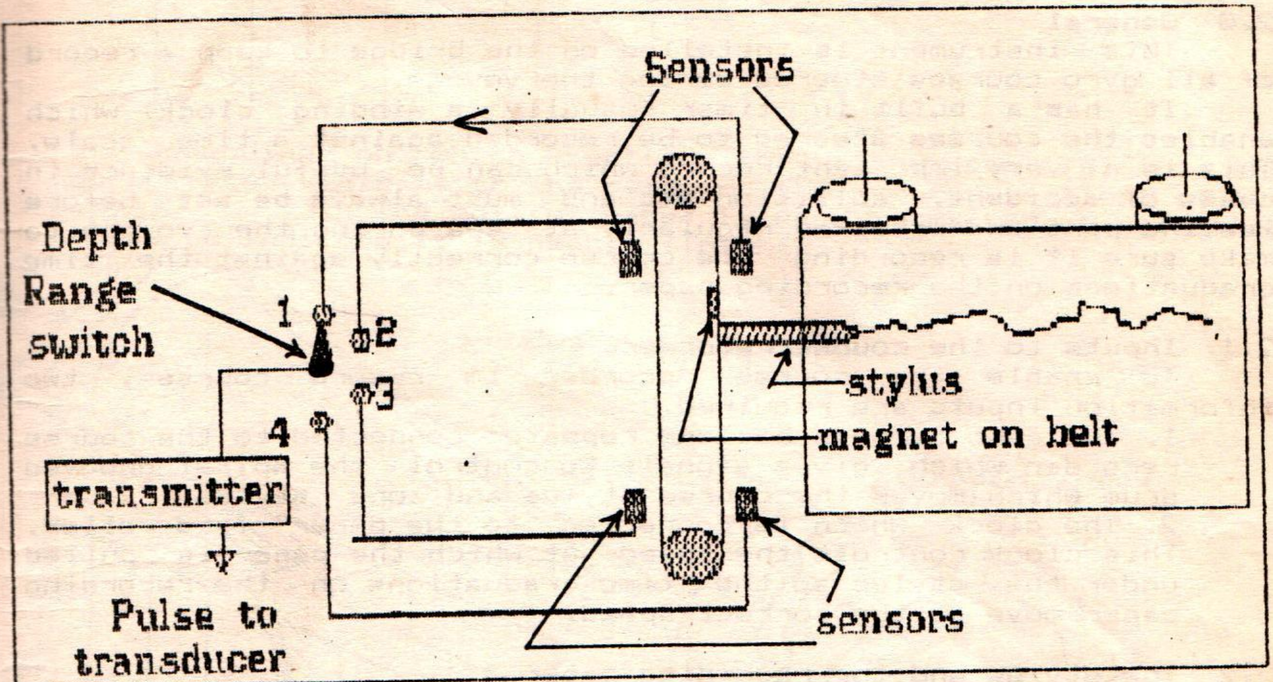
ii) Scale magnification is not lost because the scale range still remains the same.

1st range - 0 - 100 = 100m
2nd range - 100 - 200 = 100m
3rd range - 200 - 300 = 100m....

Caution when using phased ranges.
When using phased ranges, we must be careful to always start sounding at the lowest range and check for echoes on the paper before changing to a higher range otherwise echoes returning earlier might be missed.

1.6 Grounding of ships.

Many ships have run aground because the navigating officer has not switched on the Echo sounder at an early stage. This instrument must always be used frequently at sea especially in shallow waters as it can give good indications of the ships position as well as depth under the keel.
ALL AVAILABLE NAVIGATION AIDS SHOULD USED TO NAVIGATE THE SHIP TO IMPROVE THE SAFETY OF NAVIGATION.



Principle of Phasing

- The depth range switch selects the sensorto be activated by the magnet. In the drawing No. 1 sensor is selected.
- the depth range will the lowest, that is 0-100m say.
- If sensor2 is selected then transmissionwill be earlier and the depth range displayed will be 100-200m.

**Remember, echoes are only displayed when the stylus is on the paper.

2. COURSE RECORDER

2.0 General

This instrument is installed on the bridge to keep a record of all gyro courses steered during the voyage.

It has a built in timer (usually a winding clock) which enables the courses steered to be recorded against a time scale. This is a very important record which can be useful evidence in cases of accident, collision etc and must always be set before leaving port and checked regularly at sea during the voyage to make sure it is recording the course correctly against the time graduations on the recording paper.

2.1 Inputs to the course recorder.

To enable the course recorder to record courses, two information inputs are required.

1. The gyro compass has one repeater connected to the course recorder which gives signals to control the spiral grooved drum which moves the course stylus and zone stylus.
2. The clock which is connected to the paper feed roller. This clock controls the speed at which the paper is pulled under the stylus so the time graduations on the recording paper move at the correct speed.

2.2 The stylus and the recording paper.

The stylus (pen) may be of two types:
On older course recorder they used to be ink pens which had
to be filled with slow drying ink say, once a week.
More modern course recorders eg. Anschutz have pens which
are simply conducting wires which make a black mark on the
paper touching the back metal plate.

The paper is supplied in a roll which has to be installed as per manufacturers instructions. Most course recorders are designed to feed the paper vertically (from top to bottom).

The paper itself is nothing but a graph paper with vertical graduations as the time scale and horizontal graduations as the course scale.

The paper consists of three sections:

1. The time scale - is usually found on the left of the paper and enables the operator to set the paper to show the correct time in hours and decimals of an hour. The time set on the course recorder is normally G.M.T., however, this practice varies from ship to ship.

2. The course section - occupies the middle of the paper and is graduated in quadrants marked thus;

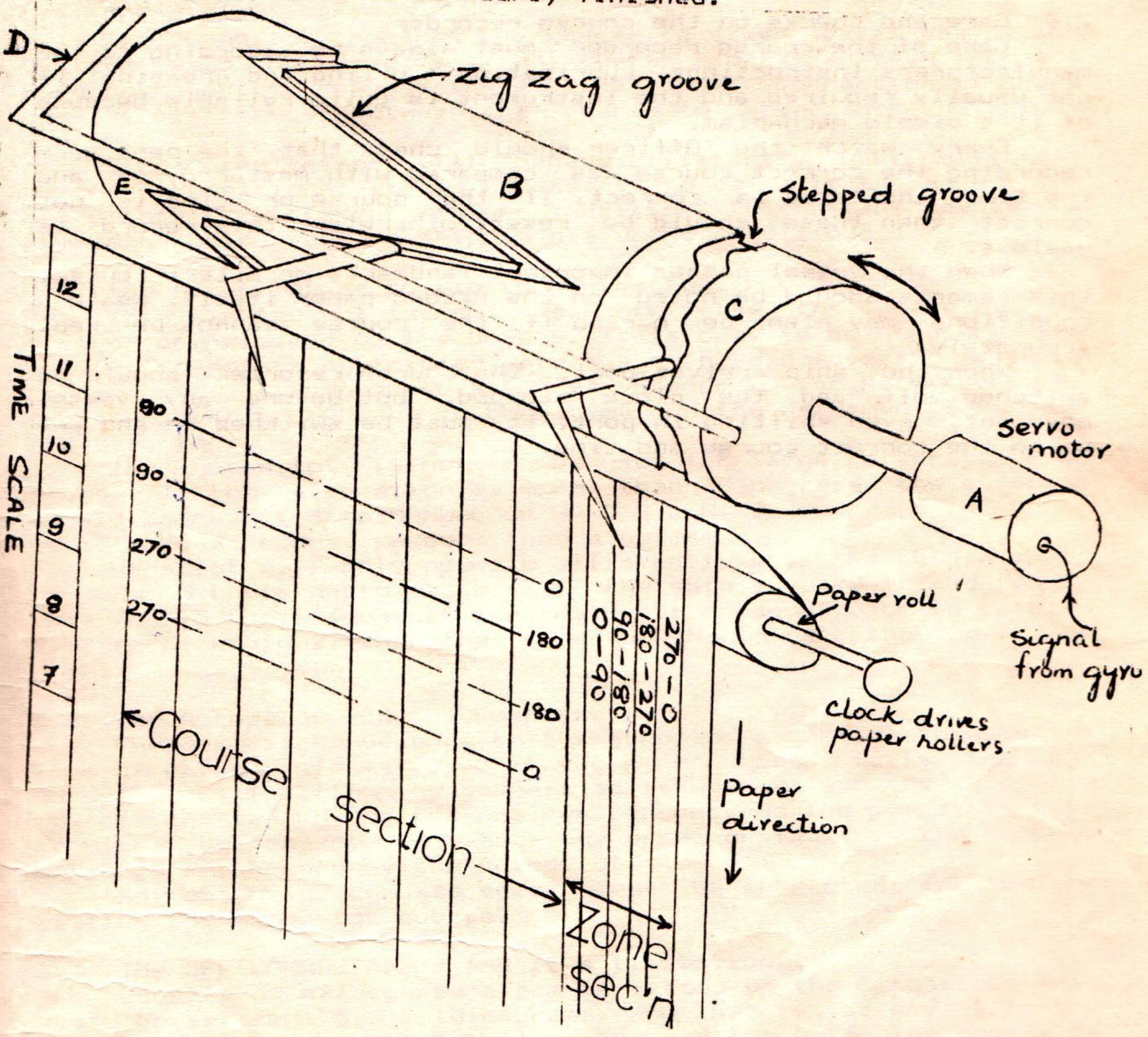
0,	10,	20,	30,	40,..........	70,	80,	90
180,	170,	160,	150,..............		110,	100,	90
180,	190,	200,	210,.............		250,	260,	270
0,	350,	340,	330,.............		290,	280,	270

The scale is sufficiently magnified to be able to read the course steered to the nearest degree. Since the same scale is being used for four quadrants, there must be some way of identifying the correct quadrant. The zone section helps to remove this ambiguity.

3. The zone section - This is usually on the right side of the paper and consists of four columns marked:

0-90	90-180	180-270	270-0

Depending on which section the zone pen is in, the appropriate scale is to be read on the course section of the paper. The roll of paper is usually marked by a colored stripe to indicate it is nearly finished.



2.3 How the course recorder works.

The gyro signal (giving the ship's head) is amplified and drives the drum servo motor (A) in the direction indicated. The drum consists of two sections; one with a continuous zig zag groove cut in it going round the drum (B) and the other with a continuous stepped groove running round the drum (C).

There is also a horizontal guide bar with a slit in it (D) through which the pens are fitted and run.

On a signal from the gyro the servo motor rotates and turns the drum. The course pen moves along the zig-zag groove across the paper. In the figure if the drum turns clockwise, the course pen will move to the left and vice versa. The zone pen will stay in it's present groove (180 - 270) until the course has reached the junction C. If the drum turns any more clockwise, the course pen will begin to move to the right and the zone pen will slip into the 270 - 000 zone.

The course being steered can be read by simply checking in which zone section the zone pen is (eg. 180 - 270). Then we use that scale i.e. 180 - 270 on the course section of the paper to read the course being steered as indicated by the course pen.

2.4 Care and checks on the course recorder.

Care of the course recorder must always be according to the manufacturers instructions. Lubrication (oiling and greasing) is not usually required and the instrument is quite reliable because of it's simple mechanism.

Every watch, the Officer should check that the pens are recording the correct course (as compared with master gyro) and the time indicated is correct. If the course or time is not correct then these should be reset, otherwise this record is useless.

When the vessel passes important landmarks or alters course, this remarks should be noted on the record paper itself. Weather conditions may also be marked if the course cannot be kept accurately.

When the ship arrives port, the course recorder should be switched off and the clock stopped, but before any vessel movement, even shifting in port, it must be switched on and set up to the correct course and time.

3. AUTOMATIC PILOT.

3.0 General.

A good automatic pilot can improve the profit of a vessel in two ways;

i) Reduction in the number of ship's personnel on the bridge for watchkeeping.

ii) Considerable saving in fuel is achieved if the vessel makes good it's course with the least deviation.

3.1 Principle.

The Autopilot compares the course to steer (data) set by the Officer with the vessel's actual course (data) as seen from the gyro or magnetic compass and applies rudder correction if there is any difference between the course to steer and the actual course.

Since the vessel will behave differently under different weather conditions, it is necessary to be able to adjust the autopilot for different weather conditions in the same way as the helmsman would steer a ship in different conditions.

3.2 The Autopilot as an aid to navigation.

This instrument is NOT meant to take the place of the Officer or helmsman on the bridge. It is only to be used when the vessel is not in restricted waters and no manoeuvering is to be carried out. If any manoeuvering is intended, the helm should be switched over to MANUAL in good time and the helmsman take over the steering.

The Autopilot is not to be used for large alterations of course. If the alteration is more than 10 degrees the steering should be reverted to MANUAL OR HAND STEERING.

It is more a "course keeper" than a helmsman.

The Autopilot will only operate efficiently when the ship's speed exceeds 5 knots approximately. If the ship's speed is reduced to less than 5 knots (consult the instruction manual) or in case of failure of engines, then the steering should be changed over to HAND.

3.3 The Autopilot and the Compass.

The Autopilot depends on the gyro (or magnetic) compass for it's direction information. If the gyro compass fails, then the Autopilot will follow the compass as it wanders and the ship will go off course and collide or run aground. So the compasses must regularly be compared to detect any error or fault in the compass which is being used by the Autopilot.

Any observed compass error must be corrected for before setting the Autopilot course.

3.4 The OFF COURSE Alarm and it's limitations.

Usually an off course alarm is fitted on the Autopilot. This must be set for 5 or 10 degrees, so that if at any time the difference between the actual course and the Autopilot course is more than 5 or 10 degrees, an alarm will warn the Officer. Sometimes in heavy seas or high beam winds, the Autopilot might not give enough helm to keep the vessel on course so the off course alarm must always be set and switched on.

There is however, one limitation which should be noted. In case the gyro compass itself begins to wander, the autopilot will steer so as to follow the wandering compass and the off course alarm will not sound, because it does not ring unless the difference between the course setting and gyro heading is more than the pre-set limit.

3.5 Controls.

The controls provided on the Autopilot must be clearly understood and set, otherwise the Autopilot will not steer a steady course and the steering gear will be unnecessarily over loaded because of excessive helm orders. Excessive helm orders lead to loss of speed and increased consumption of fuel because of an unsteady course steered.

3.5.1 Manual Operator Controls.

These controls only come into operation when the Autopilot is on. They do not work when steering is on HAND.

1) Permanent Helm - this control is to be used only if there is a constant external influence for example a cross wind or beam sea so that a constant rudder offset is required eg Starboard 5 for a strong wind on the starboard side. The Autopilot will now oscillate about the Starboard 5 position.
It must be reset to Ø when not required.

2) Rudder - This setting is to be adjusted for the speed of the ship and the loading condition for example Loaded or ballast.
If this control is set to "2", the Autopilot will move the rudder 2 degrees for every degree of heading error.

3) Counter Rudder - The control determines the amount of opposite or counter helm to be applied and this depends on the loading conditions and speed of the ship.

4) Weather - The effect of weather and sea conditions can be effectively counteracted by the use of this control.
The **deadband width** is increased by this control. The higher the setting of the weather control the wider will be the deadband. This is very useful when the vessel is yawing excessively. The steering gear is not subjected to continual helm orders.

3.5.2 Steering Modes.

Auto / Manual Follow up / Manual Follow up (Tiller)

This switch has two or three positions depending on the make of the system. When the switch is in the Auto mode, the Autopilot and all it's controls are in operation. The wheel and tiller are inoperative.
This switch should only be normally operated when the rudder is in the midships position.

3.6 **To switch from Manual to Auto.**

1) Steer the vessel on hand until she is dead steady on the course to be steered - The vessel should not be swinging.
2) Keep the rudder amidships exactly.
3) Turn the Autopilot course setting pointer to the course to be steered. This should be on the lubber line now.
4) Adjust all Autopilot controls as required.
5) Switch over to Auto.
6) Switch on the off course alarm and set it as desired.
7) Observe the steering to see if the rudder is applied correctly when the vessel goes off course.
8) Compare gyro and magnetic compasses and record them on the course board.

3.7 To switch from Auto to Manual.

This may be done anytime by putting the switch from Auto-Manual and the vessel can then be steered by hand.
The steering MUST be reverted to HAND at least once a watch and steered for some time before returning to AUTO.

3.8 Manual Follow up / Non Follow up.

In follow up mode the rudder action is controlled by the wheel position - that is if the wheel is put to Starboard 10, the rudder will also be turned to Starboard 10 as long as the wheel is kept on Starboard 10. When the wheel is returned to midships, the rudder returns to midships too.

In the Non follow up mode, if the helmsman wants the rudder on Starboard 10, he must put the tiller on to the starboard side and watch the rudder indicator. The rudder will begin to move to starboard and when the rudder is nearly at Starboard 10, he must put the tiller over to port (always watching the rudder indicator). The rudder will slow down and stop at Starboard 10 now. When the rudder stops at Starboard 10, the tiller must be returned to the upright position. The rudder will now remain at Starboard 10 until the tiller is moved again.

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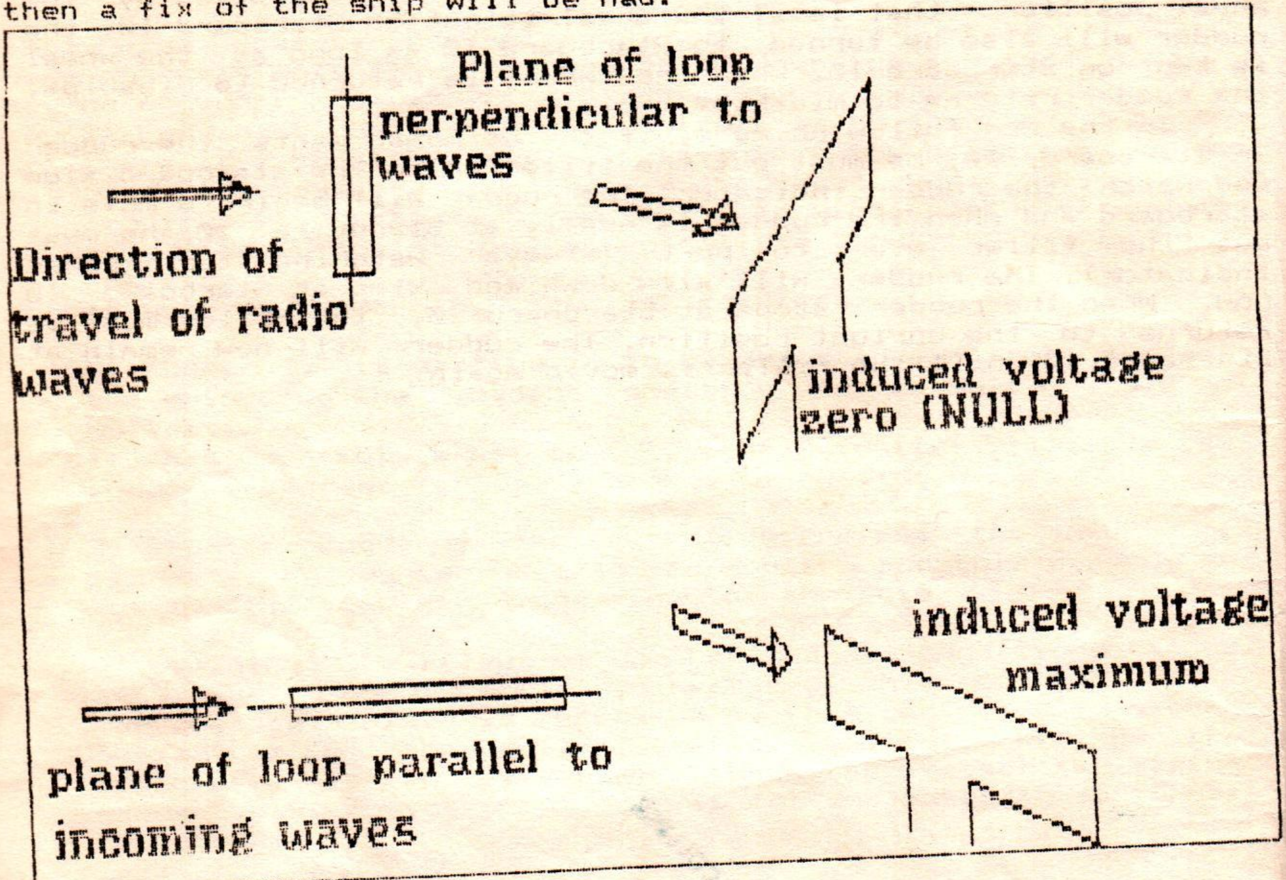
4. DIRECTION FINDER.

4.0 General.

The Direction Finder is basically a radio receiver connected toa directional antenna system which enables the direction of the incoming radio signal to be determined.

The radio signal may come from a radio station on the coast or from a ship transmitting on a radio frequency. Having obtained a DF bearing we get a position line which after correcting can be laid on thechart. If at the same time another bearing is obtained then a fix of the ship will be had.



Basic Principles of DF

4.1 Basic Principles of Radio Direction Finding.

All DF receivers, automatic or manual, operate on the principle that when a coil or loop antenna is rotated in the path of a radio signal, coming from a radio transmitter, an EMF (electromotive force) voltage is induced in the coil or loop antenna as follows;

a) when the plane of the loop is parallel to the direction of travel of the radio waves, the EMF induced is maximum.

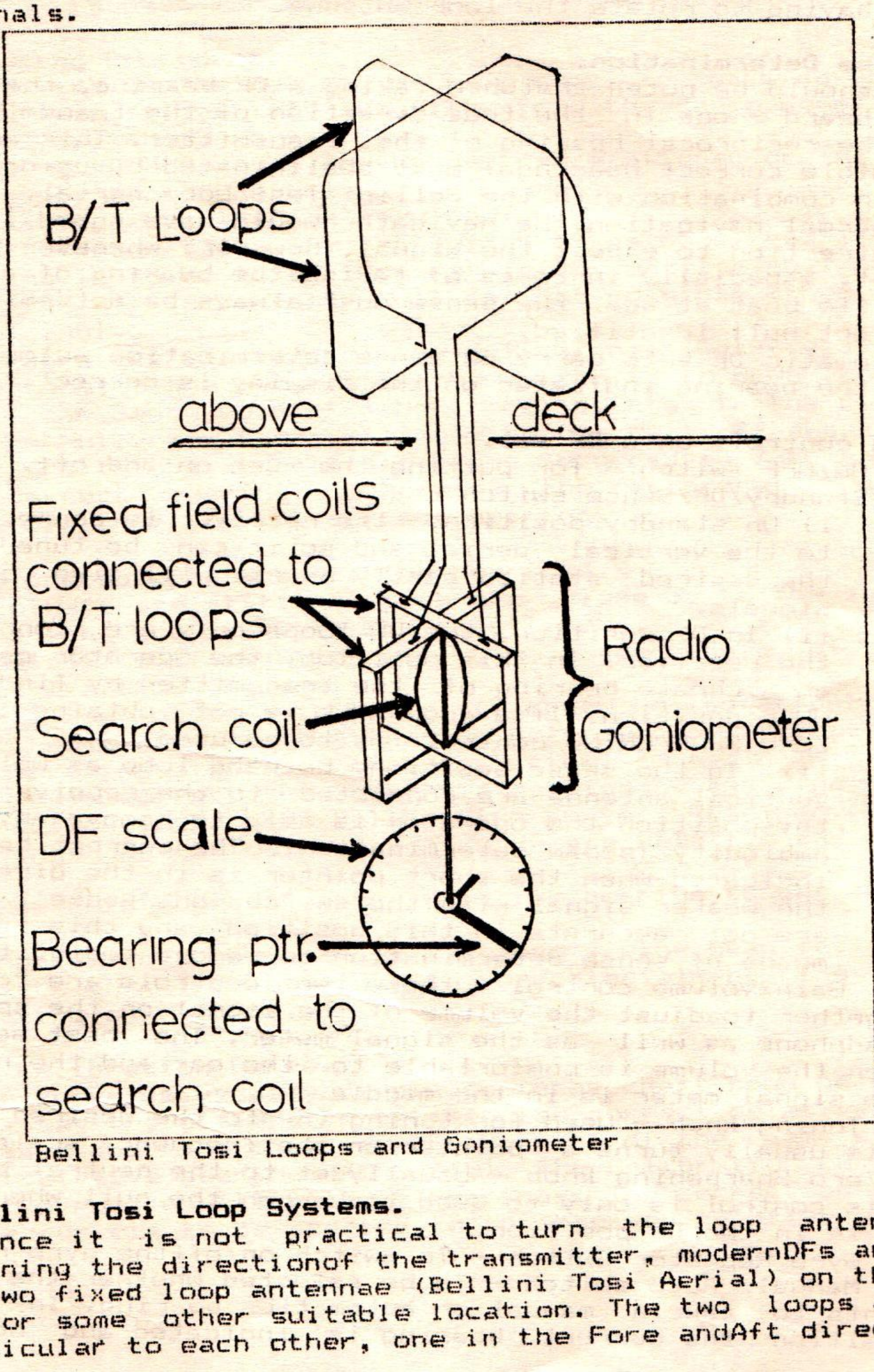
b) when the plane of the loop is perpendicular to the direction of travel of the radio waves, the EMF induced is zero. This minimum signal is called a "null".

Thus by listening to the volume of the incoming signal (through headphones or speaker), the operator can determine the direction of incoming radio signals and obtain a radio line of position.

The NULL signal is always used in DFs to determine direction because;

a) the null can be more accurately determined because a slight turn of the loop in this position causes a large change in induced EMF.

b) The human ear cansense weaker sounds better thanloud signals.



Bellini Tosi Loops and Goniometer

4.2 Bellini Tosi Loop Systems.

Since it is not practical to turn the loop antenna, when determining the directionof the transmitter, modernDFs are fitted with two fixed loop antennae (Bellini Tosi Aerial) on the monkey island or some other suitable location. The two loops are fixed perpendicular to each other, one in the Fore andAft direction and the other in the Athwartships direction.

The loops are connected to field coils in the receiver and a search coil within the field coils is turned to determine the direction of the signal.This arrangement of field coilsand search coil is called a **radio goniometer**.

The operatoris thus able to take a bearing in the chart room without having to rotate the loop antenna.

4.3 Sense Determination.

It should be noted thatwhen taking a DF bearing, that2 nulls will be heard - one in the true direction of the transmitter and one in the reciprocal bearing of the transmitter. This ambiguity (twopossible correct bearings) must beeliminated by using a sense aerial in combination with the Bellini Tosi Loop aerial.

In normal navigation,the navigator would have agood idea from which direction to expect the signal, however, whenever there is any doubt, especially in cases of taking the bearing of adistress ship orlife boat at sea, the sense must always be determined i.e. the correct null identified.

Automatic DF sets carry outsense determination automatically so that the bearing indicated on the display is correct.

4.4 Main controls on a DF set.

1. ON/OFF switch - for putting the set on and off.
2. Standby/DF/Sense switch

   i) On standby position, the receiver is connected to the vertical aerial and so it can be tuned to the desired station easily as it will give good signals.

   ii) In DF position, the DF loops only are connected to the receiver. In this position, the operator can obtain an accurate bearing of the transmitter by finding the NULL position. If a good NULL is not obtained then the ZERO SHARPENING control is to be used.

   iii) In the sense position, boththe loop as well as the vertical antenna are connected to the receiver and in thisposition the operator is able to remove any bearing ambiguity (sense determination). The correct bearing is indicated when the short pointer is in the direction of the weaker signal with the switch on 'sense'. Bearings are not accurate in this position and this is only a means of sense determination to remove ambiguity.

3. Gain/Volume control - these two controls are to be used together toadjust the volume of the signal on the speaker or headphone as well as the signal meter. The best setting is when the volume is comfortable to the ear and the needle on the signal meter is in the middle.
4. Tuning knob - Used for tuning in to the desired station. This usually turns a pointer on the frequency scale.
5. Zero Sharpening knob - Usuallyset to the neutral position. This control is only to used tosharpen the null when control #2 is in the DF position.
6. Gyro Repeater Switch - To switch on/offthe gyro repeater.
7. Manual/ Auto switch - To be selected whether the operator wants to take a manual or automatic bearing. In the Auto position the correct bearing is indicated and no bearing

ambiguity exists - The red tipped pointer shows the correct bearing.
8. Goniometer knob - Rotates the search coil in the receiver andalso the bearing pointer (Relative/True) when #2 is in DF position. If #2 is in the 'sense' position then the short pointer is used for removing bearing ambiguity.

4.5 Operating Procedure.

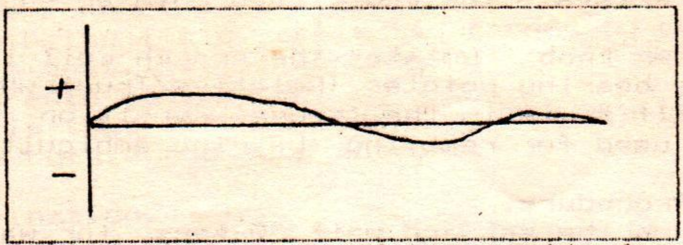
1. Switch on the set and wait 30 secs. for warming up.
2. Isolate all aerials (usually from the Radio Room).
3. Set Switch #2 to standby.
4. Using knob #4 tune to the desired stationaccording to the frequency from ALRS Vol. 5.
5. Adjust control #3 as required.
6. Set switch #2 to DF. Set Switch #7 as required. If Manual bearing is to be taken then rotate #8 until a null point is achieved. If a perfect Null is not possible then use #5 accordingly.
7. Record the bearing of the null signal (Relative).
8. Determine the sense with the switch #2 to SENSE.Rotate #8 until the Sense pointer (short one) points in the direction of the Null. Now there willonly be one Null. If aweak signal is heard in the general direction recorded in 7.then this is the correct bearing, otherwise the reciprocal of that recorded in 7. is the correct bearing.

4.6 Some precautions when taking bearings.

1. Always use stations which are close by to the ship and which are close to the coastline.
2. Select stations which will give a good angle of cut of at least 30 degrees.
3. All the other ship's aerials must be isolated from the Radio Room so that they do not have any effect on the incoming signal from the station.
4. Always correct the observed bearing by applying the correction from the Calibration Curve. Remember the bearings on the Calibration Curve are Relative and not True.
5. Add Ship's Head to the relative bearing to get True bearing.
6. Apply1/2 Convergency (1/2 d'long x sine mean lat) to convert the True bearing to Mercatorial bearing for plotting on a chart.

4.7 The Calibration Curve.

This curve is usually displayed inthe chart room near the DF set. It shows the difference between the correct relative bearing of a signal and the observed DF bearing of the same signal on differentrelative bearings (0 - 360). The Calibration Curve shows the total errors on allrelative bearings. The correction obtained from this curveis to be applied to theobserved relative bearing.



Calibration curve for a particular ship

4.8 Errors.

ERRORS

- Due to loop siting
  - Quadrantal Error
  - Semi Circular Error
- Due to Environmental causes
  - Land Effect
  - Night Effect

4.8.1 Errors due to Loop siting.

Since the ship is made of steel which is a conductor of signals, whenever a signal is received by the ship, the steel of the ship and it's masts, derricks etc.reradiate the signal so the DF aerial receives two signals, one from the station arriving directly and one reradiated signal coming from the direction of the ship's structure eg. rightaft from the funnel. The reradiated signal causes errors in the DF bearing.

i) Quadrantal Error – caused due to reradiated signal from the ship's hull which tends to affect radio signals coming from the ship's bows and quarters.
Maximum error due to this cause occurs for signals coming from 45 degrees on the Port and Starboard bows and quarters. Minimum error is for signals coming fromright ahead, astern, and Port and Starboard beams.

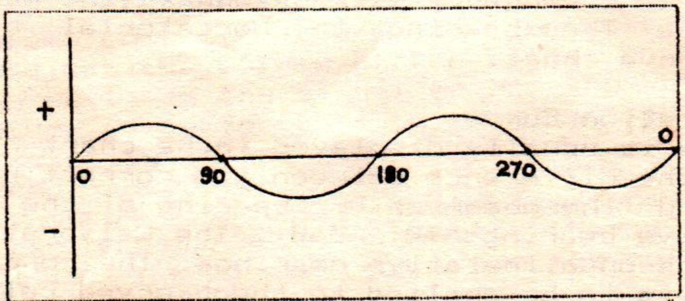


Figure 3a. Typical curve of Quadrantal Error

ii) Semi circular Error - caused due to reradiated signals from the vertical conductors of the ship for example masts, posts, derricks, and ship's wireless aerial.
Thiserror changes sign every 180 degrees and is maximum when the signals come from the Port or Starboard beam.

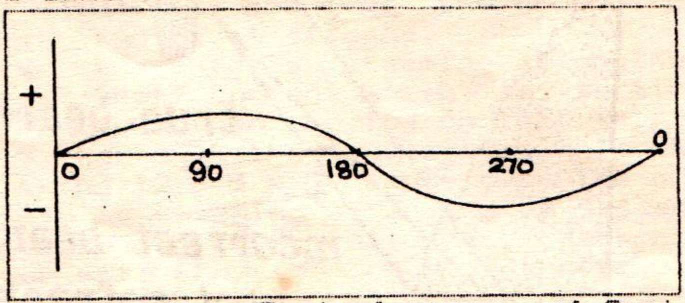
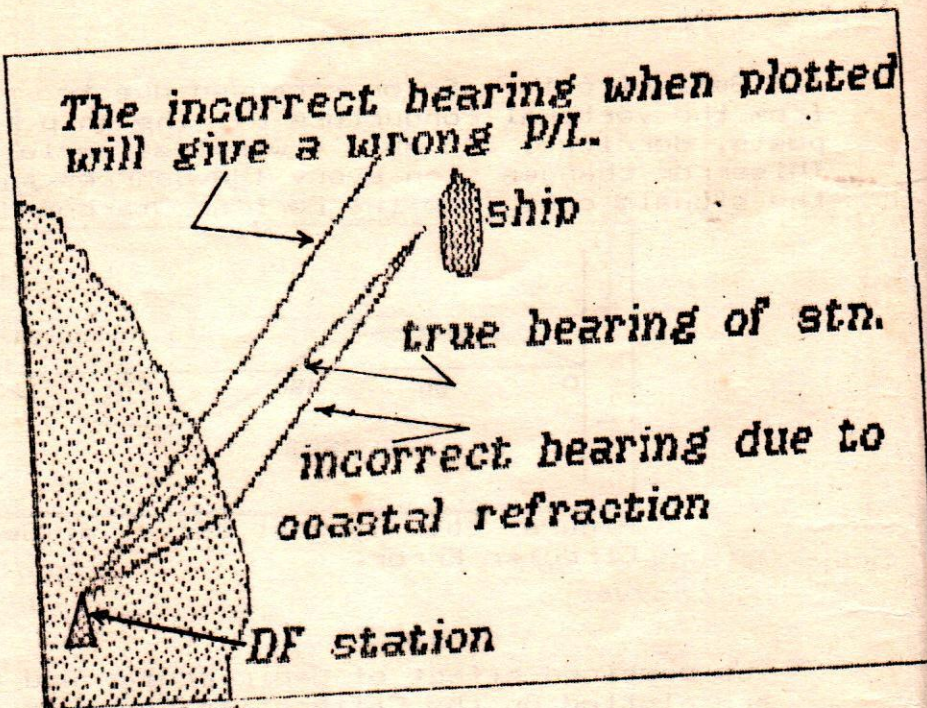


Figure 3b. Typical curve of Semi Circular Error.

The combined effect of Semicircular and Quadrantal Errors are plotted on the Calibration Curve as described in 4.7.

4.8.2 **Errors due to Environmental causes.**
i) Land or Coast Effect. - This occurs due to refraction at land/sea faces. This takes placewhen a radio wave passesfrom land to sea or vice versa.
Errors in bearings will be large if the line of bearing and coastline make a small angle. Therefore we must always whenever possible try to use stations whose line of bearing is perpendicular to the coastline. Also we should try to use marine radio beacons which are situated close to the coast. Error due to land effect can be quite large.
ii) Night Effect. - When a signal is transmitted from a station, some of it travels along the surface of the earth (called ground wave) and some may travel upwards until it reaches the ionospheric layers. Usually between sunset and sunrise these layers are not ionized by the sun and at such times they reflect the wave back (called skywave) to earth. In this way, a ship would receive both ground wave and skywave.
The skywave reception causes errors in bearingsand fading of signals. To prevent night effect from affecting bearings, we usually only take bearings of stations less than 25 miles distant during night time.

4.8.3 **Half Convergency Correction.**
The radio wave follows a Great Circlepath and so the bearing observed is a Great Circle bearing. This G.C. bearing must be converted to a Mercatorial bearing to be plotted on a Mercator chart.
1/2 Convergency = 1/2 d'long x sine mean lat.(ship & DF stn)
Half Convergency must always beapplied whenever the difference of longitude between ship and station is more than four degrees.



Land Effect

4.9 Sample correction of DF bearing.

Observed Relative brg. from DF	-	220
Correction from Calibration Curve	-	-2
Corrected Relative bearing	-	218
Ship's Head	-	100
True bearing	-	318
1/2 Convergency correction	-	-1
Corrected Mercatorial bearing	-	317

5. LOGS.

5.0. General.

The log is an instrument for measuring speed and distance travelled by the ship.

It is important to note that the speed measured by the log is **THROUGH THE WATER and not over the ground.** Log speeds are affected by current and tidal streams.

For example; If a ship is steaming at engine speed 12 knots in a 3-knot current which is setting in the opposite direction then the log on that ship will show 12 + 3 = 15 knots on the indicator. This ship is in fact only making 12 - 3 = 9 knots over the ground.

If a ship is steaming at an engine speed 15 knots in a 4-knot tide which is coming from astern then the log indicator will show 15 - 4 = 11 knots. This ship is actually moving over the ground at 15 + 4 = 19 knots. If a ship is anchored in a river which is flowing at a rate of 5 knots, then her log will show 5 knots speed on the indicator. The ship is in fact stopped.

These examples should help to explain the meaning of speed through the water and speed over the ground.

These bottom logs have several advantages;

1. They can have repeaters for other navigational aids like radar, satellite navigator etc.
2. They can be retracted very easily as compared to towed logs.
3. Displays on the bridge itself and in the engine room, Captain's cabin etc.
4. More accurate than towed logs.
5. They do not get fouled up with surface objects such as fishing nets, buoys etc.
6. They can be used to measure even low speeds especially when coming to anchor or berthing. A towed log can only measure speed when more than 5 knots.

There are two main types of logs namely;

1. The towed or Patent log - this type of log is usually towed astern of the ship through the water.
2. The Bottom Log. - This log is fitted on the bottom of the ship usually on the bottom plating. It can be withdrawn into the ship's hull when not required from the bridge itself. There are three main types of bottom log:

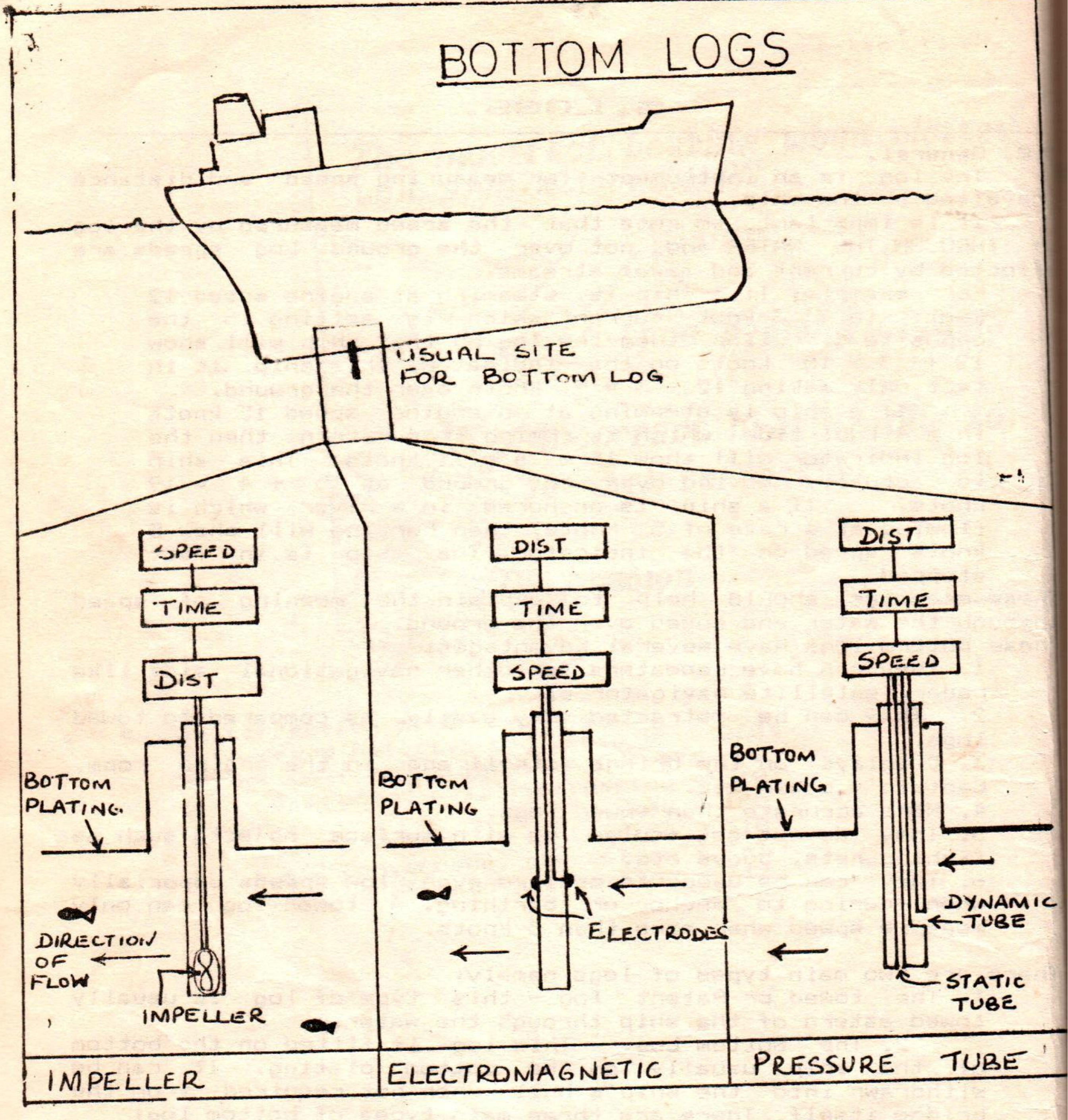
5.1 Impeller Log.

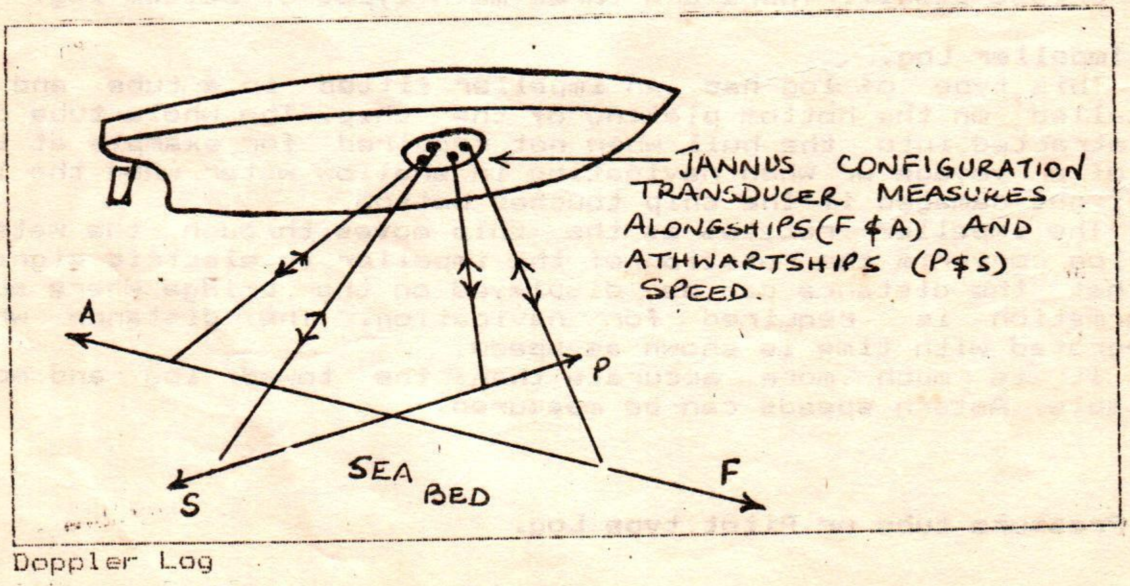
This type of log has an impeller fitted in a tube and is installed on the bottom plating of the ship. The whole tube can be retracted into the hull when not required for example at the end of a voyage or when navigating in shallow water when the log might get damaged if the ship touches bottom.

The impeller rotates as the ship moves through the water. The log converts the rotation of the impeller to electric signals so that the distance can be displayed on the bridge where such information is required for navigation. The distance when integrated with time is shown as speed.

It is much more accurate than the towed log and more reliable. Astern speeds can be measured.

5.2 Pressure tube or Pitot type Log.


BOTTOM LOGS
USUAL SITE
FOR BOTTOM LOG
SPEED
TIME
DIST
BOTTOM
PLATING
DIRECTION
OF
FLOW
IMPELLER
DIST
TIME
SPEED
BOTTOM
PLATING
ELECTRODES
DIST
TIME
SPEED
BOTTOM
PLATING
DYNAMIC
TUBE
STATIC
TUBE
IMPELLER
ELECTROMAGNETIC
PRESSURE TUBE


JANNUS CONFIGURATION
TRANSDUCER MEASURES
ALONGSHIPS (F & A) AND
ATHWARTSHIPS (P & S)
SPEED.
A
P
S
F
SEA
BED

Doppler Log

5.2 Pressure tube or Pitot type Log.

This log also has a tube which extends out of the bottom plating and which can be retracted back into the hull when not required.

The tube has two pipes fitted to it; one facing the forward direction called the DYNAMIC tube and the other facing downwards called the STATIC tube.

When the ship is stopped and there is no current or tide, the pressure in both tubes will be equal to the depth of the tube below the water line.

When the ship moves ahead, the pressure in the dynamic pipe will be greater than the static pipe (facing down). The **DIFFERENCE IN PRESSURE** is converted in to electrical signals and is proportional to the speed of the ship through the water. This is displayed as speed and when integrated with time can be fed to a distance counter.

5.3 The Electromagnetic Log.

This log works on the principle that if any conductor cuts through a magnetic field, a small EMF will be induced within itself which is proportional to the speed of movement of the conductor.

In the case of the log, the conductor is the seawater, the magnetic field is created by a coil in the tube and the induced EMF is measured by two sensors on the side of the tube.

Since sea water is a conductor of electricity, when it cuts through the magnetic field of the coil in the tube, a small voltage will be induced which is measured by two sensors (electrodes) on the sides of the tube. This induced voltage is proportional to the speed of the ship through the water. The speed is integrated with time to display distance.

5.4 The Doppler Log.

This operation of this log is based on the measurement of the Doppler effect. A transducer fitted on the bottom of the ship emits a continuous beam of sound vibrations in the water at an angle of about 60 degrees to the keel in the forward direction. The beam is bounced off the sea bed or a layer of water and received back at the transducer. The difference in frequency between the transmitted and received signals is measured and is proportional to the speed of the ship.

When the signal is bounced off the sea bed (called Bottom Track), the speed indicated will be in relation to the fixed sea bed and will therefore be Speed over the ground. If however, the bed cannot be tracked especially in deeper water, then the signal is bounced off a water layer (Water Track) and the speed indicated will be Speed through the water.

Most doppler logs have transducers to measure both fore and aft speeds (ahead and astern) as well as athwartship transducers to measure speed in the athwartship direction (useful when berthing). Such a transducer which measures both alongship as well as athwartship speed is called JANNUS CONFIGURATION.

This log is the most accurate of all the logs described and is useful both for ocean navigation as well as berthing and manoeuvering in close waters.

6. GYRO COMPASS

6.0 General.

A gyroscope may be considered to be any weight mounted on an axle and made to spin at a very high speed.

6.1 The Free Gyroscope.

This consists of a rapidly spinning body having three degrees of angular freedom (X, Y, Z axes). This freedom is achieved by mounting the gyroscope on gimbals.

6.1.1 Properties of a free gyroscope.

1) **Gyroscopic inertia OR Rigidity in space.**
Once a free gyroscope is set spinning, it will maintain a fixed direction in space (point to a fixed star), as long as there are no disturbing forces.
However, due to the rotation of the earth on it's axis, the axle of the gyroscope will seem to **DRIFT** (horizontally) and TILT (vertically).

2) **Precession**
If force is applied to the axle of the spinning gyroscope, the axle rotates in a plane 90° in the direction of rotation of the gyroscope.

6.2 The Gyro Compass.

The gyro compass is distinct and separate from the magnetic compass, and does not use the earth's magnetic field as reference but depends on the above two properties for it's directional properties..

A free gyroscope is therefore not a very useful instrument for direction finding unless we can get it's axle to point in a fixed direction, say North. The gyroscope has therefore to be damped using different methods eg. gravity control or ballistic methods.

When the instrument is started at sea, it must be able to seek North from any starting direction.

So when a gyroscope is damped and controlled it will automatically direct it's axle in a northerly direction in an elliptical spiral motion. The time taken to settle in the true meridian (i.e.North) varies depending on where the axle was when the gyro was started.

If the axle was out by more than 20° then it might take 5 - 6 hours to settle down but if is only 1° out then it will take about half an hour to settle down.

6.3 Operation of the gyro compass (Sperry).

Preparing to start.

1. Make preparations at least 4 hours before the compass is required for service.
2. Check that all supply switches are open.
3. If any oil level window is provided, then check that the oil is sufficient (up to indicated mark).
4. Adjust latitude and speed settings accordingly.
5. Switch on the alternator and wait for ten seconds until it gains full speed.
6. Switch on the compass and Azimuth motor switch.

The compass will settle down faster in dock than at sea and also depends on how much the axle was out of the meridian when it was started.

7. After the heading is steady, the repeaters switches may be switched on and all repeaters synchronized to the Master.
8. Test the alarm switch on the alarm panel.

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9. If there is a vent fan, then check that this cuts in automatically when the temperature rises eg. in Anchutz.

Stopping the compass. → note down gyro heading.

1) Open repeater switches.
2) Open the Azimuth motor switch and silence the buzzer.
3) Switch off the alternator.
4) Lock the rotor.

NO UNAUTHORIZED PERSONS ALLOWED IN THE GYRO ROOM!!!!!!!!!!!!!!!!!

6.4 Speed and Latitude Correction.

When the compass is in operation, the corrector should be set for the approximate speed and latitude of the ship. These settings need not be changed for small variations in speed and latitude but should be kept within 3° and 3 knots respectively.

6.5 Maintenance.

1) Each Watch.
   a) Check repeaters with master compass to ensure that repeaters are functioning properly. If power fails, repeaters may have to be reset.
   b) Check compass error by azimuth.
   c) Speed and latitude corrector should be reset as necessary.
   d) Inspect compass to guard against any abnormal condition of operation.
2) Monthly.
   a) Check alarm buzzer.
   b) Clean and oil any parts as INDICATED IN MANUFACTURERS INSTRUCTIONS.
   c) General cleanliness should be checked.

Repairs and maintenance should only be carried out by a technician.

6.6 Errors.

1) Settling Errors. These errors are caused due to torques within the system and they cannot be corrected for by the user. They are usually corrected for within the instrument.

2) Speed and Latitude Error. This error is caused because the gyro compass installed on the ship senses an apparent motion what is a combination of the earth's movement and ship's movement. If the ships course is northerly then the error is westerly and if the course is southerly, the error is easterly. For example, in latitude 50°, the latitude and speed error is about 1° for each 10 knots of northerly speed. The latitude also has to be corrected for because the earth's rotational speed is 900'/hr on the equator and 0'/hr on the pole. In other latitudes, it varies as the cosine of the latitude. This error is corrected for by adjusting the latitude and speed corrector as the vessel changes her speed, and latitude.

3) Ballistic Errors. These may be experienced when the ship accelerates on her course or when she alters course. This error cannot be corrected for in ordinary gyro systems and is not usually appreciable.

7. BRIDGE ALARM DEVICES.

7.0 General.

The alarm devices provided on the bridge of a ship are designed to alert the Officer on watch whenever he may have overlooked any particular aspect of the navigation of the ship. The alarms usually sound different and within a week of watchkeeping the Officer is familiar with them all. Some indicate an immediate emergency, while others are not so important, but could lead to an emergency.

7.1 Off Course Alarm

If the vessel is on Auto pilot and she deviates from the preset heading by a certain limit (chosen by the Officer), then this alarm sounds.

Action - Cancel the alarm, check the gyro course and compare it with the standard compass heading recorded on the course board. If there is any difference, suspect the gyro compass, change over to Hand steering and steer by Magnetic compass. Sometimes, the settings on the Autopilot may not have been set properly and this may cause the ship to stray away from her course. This can be remedied by setting the Auto pilot controls according to the present conditions. Inform the Master if the gyro compass has failed.

7.2 Navigation Light Alarm

This alarm indicates the failure of on of the Navigation Lights. The light which has failed will be indicated on the Navigation Light Panel.

Action - Cancel buzzer and after ascertaining the faulty light, switch over to the alternative light. Each light has two bulbs. Arrange to replace the faulty bulb as soon as possible.

7.3 On cargo ships - Smoke Detector Alarm

This indicates that the detector has sensed smoke in some compartment which it has sampled. Often it may be a false alarm especially when sweeping of holds is in progress and there is a lot of dust. The detector is unable to distinguish between dust and smoke.

Action - On hearing this alarm, cancel the buzzer and look in to the display of the detector to locate the compartment. Since the samples are taken in turn (compartment by compartment), you may have to wait a minute or so until you are able to identify the compartment from which the smoke is issuing. Once the compartment is located, if you know that cleaning is in progress, then send a man there to make sure. If you are not sure - raise an alarm immediately and inform the Master.

7.4 On tankers - Tank Pressure Alarm

This alarm sounds when the Inert Gas pressure in the tanks is high or low. The appropriate light will indicate whether it is high or low.

Action - Cancel the buzzer, and check whether the High or Low pressure alarm has gone. The High pressure alarm may go off if inerting is in progress and in such a

case, contact Control Room for further instructions.
Usually on hot days, the high pressure alarm sounds because the decks have heated up. In such a case, you have to vent off the excess gas to atmosphere. All precautions will have to be taken before this is done. If the Low pressure alarm sounds, contact Control Room for further instructions. If no operations are in progress, then it will be necessary to start the inert gas plant and press up the tanks to normal pressure. Inform the Cargo Officer. Observe all standing instructions laid down.

7.5 Auto alarm

This alarm indicates that the Auto Keying Device of a ship or lifeboat transmitter on 500 kHz has been set off. This means a distress message is being transmitted.

Action - Contact the Radio Operator and switch on the Direction Finder. Tune to 500 kHz, and take a DF bearing of the homing signals. Inform the Master and switch on the VHF to Channel 16.

7.6 2182 kHz alarm

This indicates that the 2182 kHz distress alarm (Two tone) has been received.

Action - The speaker automatically comes on and the Officer should increase the volume and listen for the distress message which will follow the two tone alarm. The Radio Operator is to be contacted and the Master informed as well. Record any positions which are broadcast.

7.7 Satellite Navigator Alarms

i) Satellite Acquisition - A satellite is being acquired - no action.

ii) Satfix - A fix has been calculated - no action.

iii) Way point alarms - Indicate that the ship has reached a Way point - check position by other means and alter course accordingly.

iv) Heading to steer - The ship is not steering the course required to reach a designated way point. Check position or cancel alarm if not required.

7.8 Steering Motor Alarm

Indicates failure of the Steering Motor.

Action - Switch on the other steering motor immediately. Inform the Engine Room and watch the Rudder Indicator closely. Switch over to Hand Steering.

7.9 Telegraph Alarm

This alarm sounds if any engine orders are passed between Bridge and Engine Room on the telegraph.

Action - When this alarm sounds, the telegraph handle and the telegraph pointer will not be matched. The alarm will continue to sound until the two are matched. If the alarm sounds on the Bridge, then answer the telegraph and take appropriate action. Often this might happen at sea, when the Engine Room wishes to reduce speed etc. If the speed is reduced drastically or stopped then it will be necessary to change over to hand steering.

7.13 Gyro Alarm
Indicates a malfunction or failure of the gyro compass.
Action - Switch over to Hand Steering and steer by Magnetic compass. Cancel the buzzer and ascertain the problem. Inform the Master and the Officer in charge of the equipment.

8. HYPERBOLIC NAVIGATION POSITION FIXING SYSTEMS

8.0 Hyperbolic systems.

If two guns A and B in Figure are fired simultaneously, each consecutive ring in the figure will represent a distance of 340 meters travelled by the sound in one second.. Thus a craft anywhere on GH, the perpendicular bisector of AB, would hear both guns simultaneously. A craft 340 meters closer to the gun A will hear the gun B one second later and will lie anywhere on the hyperbola CD. A craft 680 meters closer to the gunA will hear gun B two seconds later and will lie anywhere on the hyperbola EF. Hence by timing the interval between hearing gun A and gun B, it is possible to find on which hyperbola of position the observer is located if the interval were an exact second. Other hyperbolae drawn proportionately represent intervals of fractions of a second.

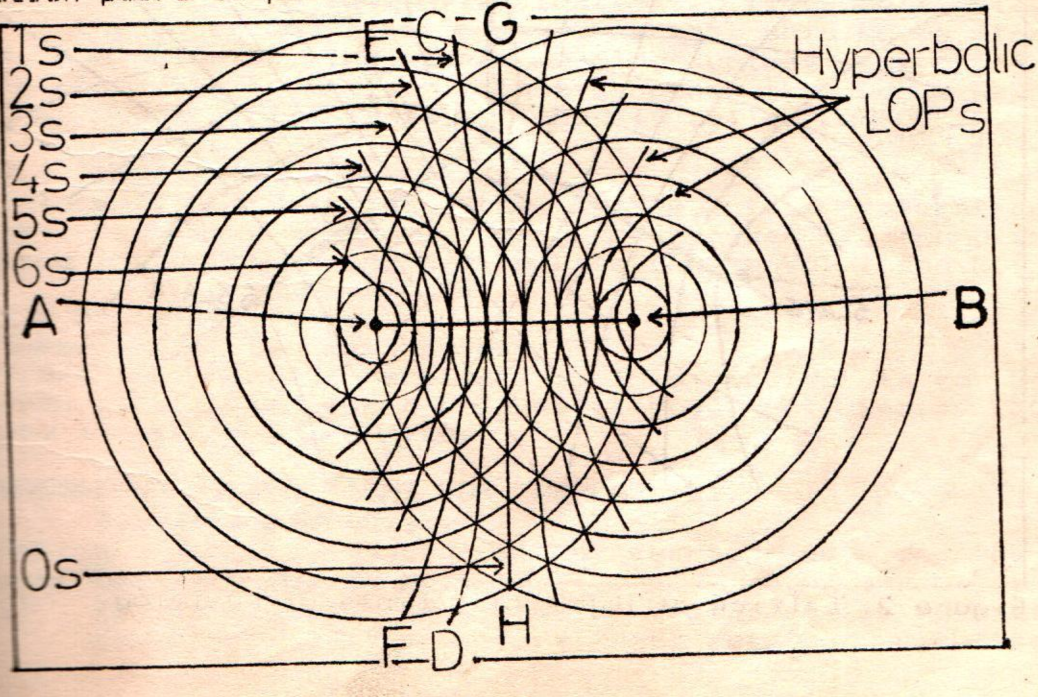
Since the distance and time taken are directly related we may state that:

The principle of hyperbolic position fixing systems is based on the determination of the **Difference in distance** between two transmitting stations A and B. A line joining all points of equal distance difference between the two stations is called a **Hyperbolic Line of Position.**

In hyperbolic navigation systems the firing of guns is replaced by electromagnetic transmissions. In this way, long ranges of coverage can be achieved. The main advantage of the hyperbolic navigation system is that the reciever (ship) only has to measure the difference in times of arrival (or the phase difference in Decca and Omega) of the incoming signals and a Line of position is obtained. The timing of transmissions and synchronization of the transmitter stations controlled independantly by the stations themselves. In this way, the shipboard receiver is a relatively simple electronic device.

Since a hyperbolic line cannot be easily drawn, it is usual to over-print the normal navigational chart with family of hyperbolic LOPs of fixed time or phase differences from stations of known geographical positions. Each station pair will yield a complete set of LOPs. To fix the position of the ship at least two LOPs are required and so at least two station pairs must be used.

A collection of hyperbolae typically from three or four station pairs is plotted on a chart. This is called a **LATTICE.**



Each LOP represents a DIFFERENCE OF DISTANCE between the Master/Slave station pair.

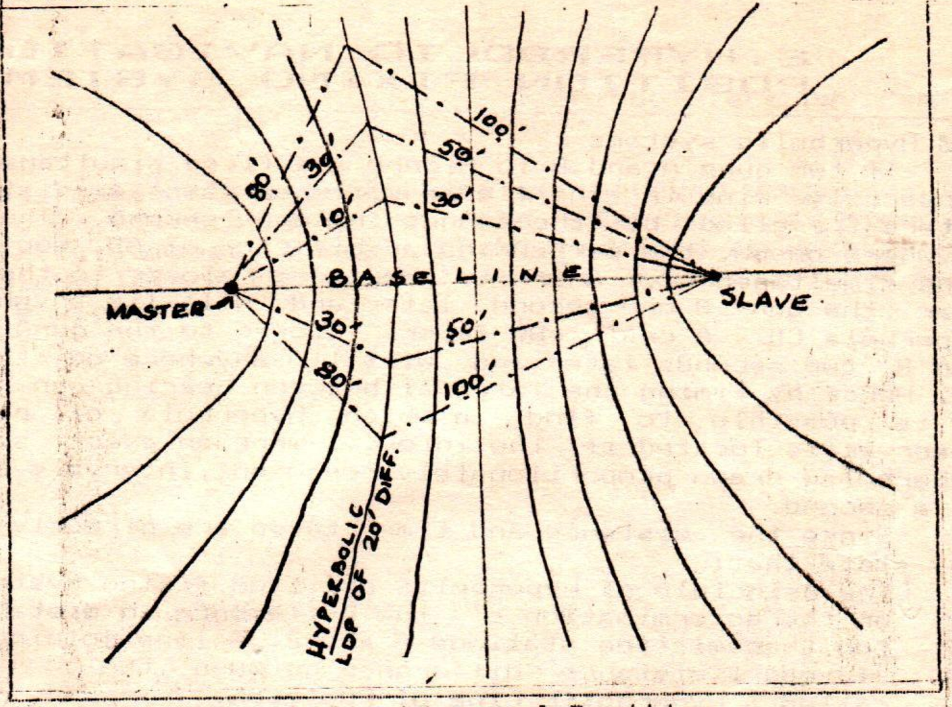


Figure 1. Hyperbolic Lines of Position

- The whole family of hyperbolic Lines of position is called a LATTICE. Each Masterwill have three or fourslaves and each Master/Slave pair has its own set of hyperbolic LOPs.
- Thetime or phase difference from atleast two station pairs is required for a navigational fix.

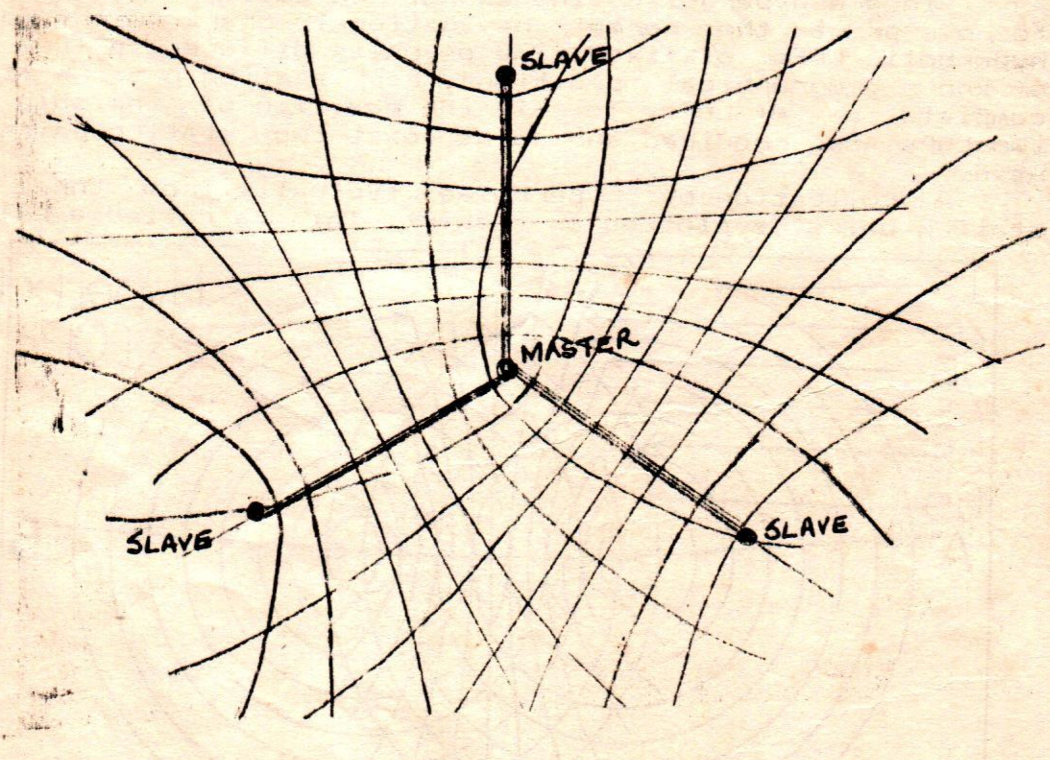


Figure 2. Lattice of Hyperbolic Lines of Position.

9. DECCA NAVIGATOR SYSTEM.

9.0 General.

Decca is a medium range electronic position fixing system based on hyperbolic principles of phase difference measurement. Each chain has a range which varies between about 250 miles by night and 400 miles by day. The range is reduced by night because of skywave interference. These ranges may vary considerably due to atmospheric conditions.

9.1 Decca Chains.

Each Decca system is called a **CHAIN**, made up of one Master station and two or three slave stations. There are more than 50 chains in the world. Each chain has an identification letter and number, eg. 3B. The Decca lattice on charts is divided into **LANES AND ZONES.**

There are 24 red lanes in a red zone
18 green lanes in a green zone
and 30 purple lanes in a purple zone.

The zones are identified by letters eg. A, B, C etc and the lanes by numbers and decimals eg. 20.2 etc.

9.2 Fixing the ship's position by Decca.

The zone and lane number of each color can be read from the little window above it's respective decometer. The decimal of the lane is read from the decometer itself.

To fix the ship's position, we require at least two Decca readings eg. Red A12.2, and Green D39.4.

9.3 Principle of operation.

Each station transmits signals which are received on board by the receiver. The **Phase Difference between the received signals is measured** and displayed on the three decometers.

The red decometer displays the phase difference in 1/100ths of a lane between the Master and Red slave. The green decometer displays the phase difference between the Master and green slave. Same for the Purple decometer.

When the ship enters a Decca chain from outside, or sails out from a port, the correct readings (zone and lane) should be taken from the Decca latticed chart and input to the decometers, when switching on the set. After that, it will automatically keep count of the zones and lanes crossed as the ship moves along her course and display the lane reading unless there is some interference (See Errors). If this happens, the Decca Navigator will lose count of the lanes and this is called **LANE SLIP.**

9.4 Information about Decca.

Information regarding the system, it's operation and services provided, accuracy, errors etc. can be found in the **Operating Instructions and Marine Data Sheets Vol 1 and 2.**

9.5 Decca receivers.

These are of two main types;

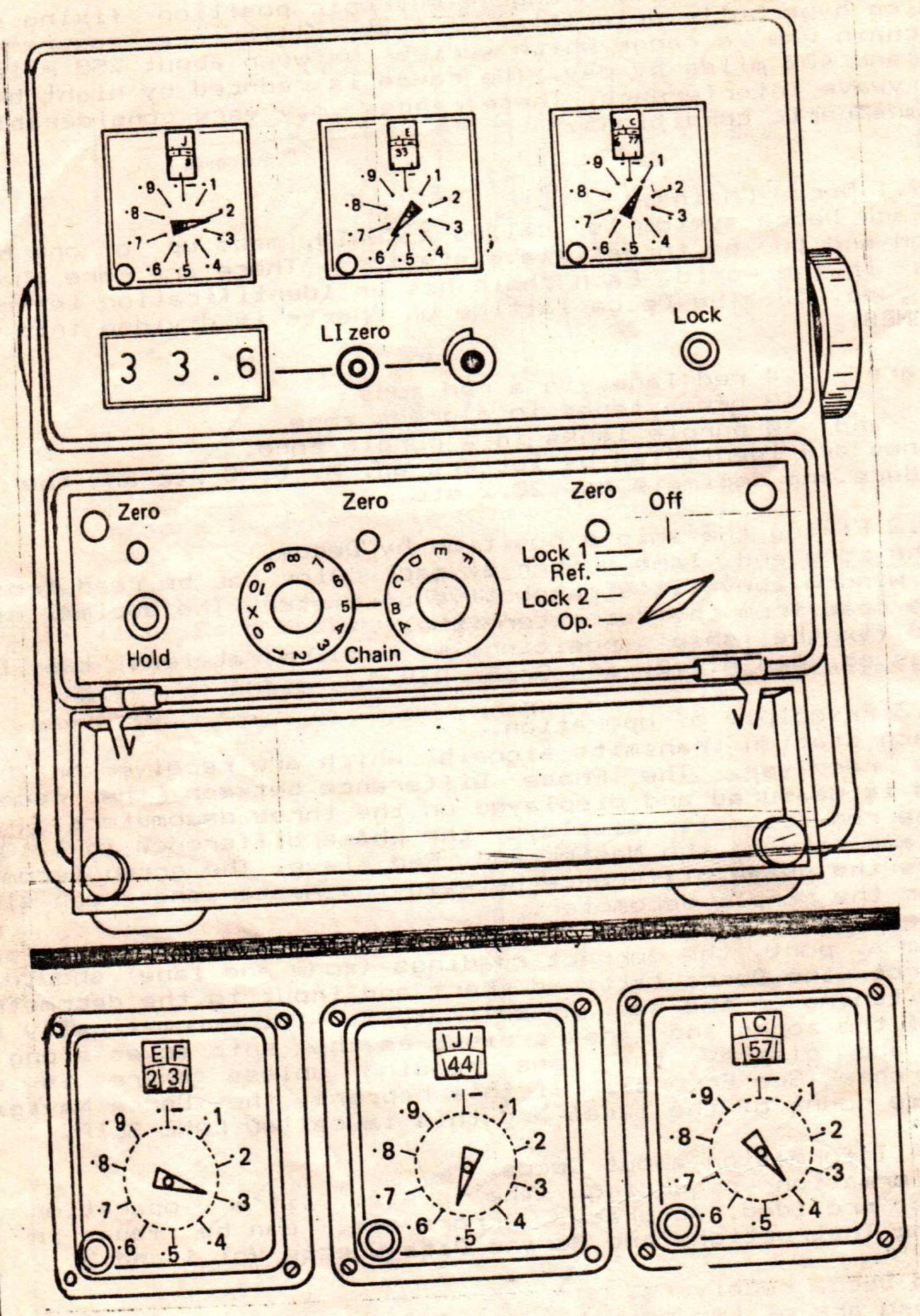
9.5.1 The Mark 21 receiver -: This receiver is to be used with a latticed chart because it does not display latitude and longitude coordinates.

OPERATING INSTRUCTIONS FOR THE MARK 21.

See attached sheet.

Periodic checks that must be carried out on the Decca Navigator before a fix is plotted:

i) Before taking the decometer readings for plotting on the chart, always compare these readings with those of



The Decca Mk 21 receiver

i) Before taking the decometer readings for plotting on the chart, always compare these readings with those of the LI display and make sure that there is less than 0.5 lane difference between the two displays. If there is more than 0.5 lane difference (eg. Decometer reading of red B/14.8 and LI of red 15.6) then do not accept the decometer reading but continue to observe the decometer and LI reading. If the difference of more than 0.5 lane persists over several sequences (LI sequences repeat three times every minute) then Lane slip must be suspected and the decometer will have to be reset such that the difference between decometer and LI is less than 0.5 lane. Whenever a decometer is reset, an entry must be made in the Decca Log. Also check the ship's position with some other position fixing method, either visual or electronic.

ii) At every LI sequence, four numbers are flashed on the LI display. First the Master LI reading, then the Red, then Green and finally Purple. Always ensure that the Master reading is either 23.8, 23.9, 00.0, 00.1, or 00.2. If the Master LI does not register within this range, press and release the LI ZERO button beside the LI display once and release. Then wait for the next sequence and ensure that the Master is within the acceptable limits.

iii) Once every watch, the set must be referenced. This is to make sure that any noise generated within the set is not affecting the decometer readings. The procedure is simple, however, there is a danger that lane count might be lost when the set is referenced since the ship is moving but the antenna is disconnected for referencing. The following procedure will help to prevent this.

Press the HOLD button and keep it depressed.
Turn the function switch to REF.
After 10 secs release the HOLD button.
Check that all decometer pointers are at exactly zero. If not, then adjust then with the respective ZERO control.
Press HOLD button and keep it depressed.
Turn function switch to LOCK 2.
When LOCK lamp is steady, turn function switch to OPerate.
Release HOLD button.

9.5.2 Various automatic receivers which track the signals and convert them into Latitude/Longitude information. With such receivers no special charts are required. A warning light is usually displayed when the readings are unreliable.

With the cost of sophisticated electronics falling, these automatic receivers are becoming more and more popular on board all marine craft, both leisure and professional. While the Mark 21 Navigator is still found on quite a lot of ships, its presence is on the decline because it does not offer the facilities of a modern electronic navigator.

	Automatic Receivers	Decca Mark 21
1	Auto locking in to local chain. Easy setting up.	Chain has to be selected.
2	Displays Lat/Long or Decca coordinates. Decca chart not necessary.	Displays only Decca coordinates therby necessitating the use of a Decca latticed chart.
3	Compares LI and Comparison Frequency phase differences automatically and checks for lane slip. If any lane slip is detected it is corrected autmatically.	LI and Decometer comparison has to be made visually before each fix and should lane slip be detected, the decometers have to be made manually.
4	Fixed errors are built into the software and corrected automatically.	Fixed errors have to be lifted off from the Data Sheets and the decometer readings corrected arithmetically.
5	Variable Errors built into the software. Can be displayed at the press of a button.	Tedious process of extracting the variable errors from the Data Sheets. Because of the clumsiness of the process, navigators tend to neglect this error.
6	Self checks carried out regularly and any faults detected will be brought to the notice of the operator.	No self checks. Referencing has to be done manually.
7	Wide range of "navigator" facilities available for example, waypoint navigation (Rhumbline or Great Circle), Velocity over the ground (by Decca fixes), Course made good, DR computation, numerous alarms, Man over'oard etc.	No facilities available.

The facilities and degree of sophistication of the software in the automatic receiver differes from set to set, however, reliability is good and this is the reason why these automatic sets are being increasingly used.

It should be clearly stated that all such automatic navigators and other electronic equipment for example ARPA fitted on ships are only "AIDS TO NAVIGATION" and cannot take the place of good seamanship practice, alertness and positive decision making on the part of the OOW. Conventional position fixing techniques like celestial navigation, visual land navigation must always be practiced whenever the circumstances allow.

All available means must be used for position fixing at all times and no one aid to naivigation should be relied upon <u>if it can be helped.</u>

A typical automatic Deccca receiver is described briefly to give the reader an appreciation. Specific sequences, displays and controls will vary from set to set and no set should ever be operated or used without having first read the operating instructions provided on the bridge.

The **NAVSTAR — 2000D** Navigator

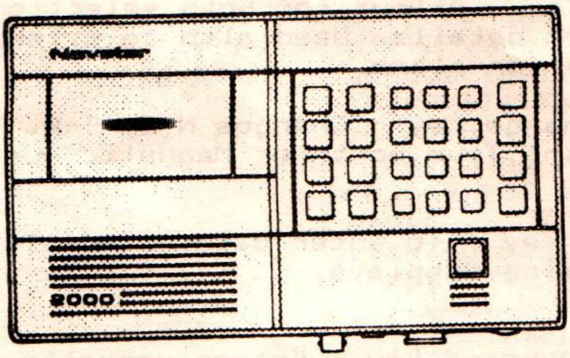


Figure 3: The Navstar 2000D

The set receives and processes signals transmitted by the Decca Navigator chains. In normal operation, the 2000D automatically:

1 Selects the best Decca chain for the area.

2 Tunes to the four stations - Master, Red, Green, Purple.

It determines and displays the vessel's position in either Lat/Long or Decca coordinates. Two LOPs yielding the best angle of cut are selected for the determination of position, the third being used to check the fix only. The navigator can continue to be used outside of coverage as a DR computer after inputting course, speed, current and rate.

The Keyboard.

PRG	Program Key - Used repeatedly to enter initial data for example, date, time, initial position, datum, deviation, etc.
WPT	Waypoint Key - Entry and display of waypointnavigation. 99 WPts can be entered by defining the Lat/Long of the WPt.
VEL	Velocity Key - Enter Vessel's speed/ heading, current, rate. Displays CMG/SMG, Distance/Time run etc.
POS	Position Key - Displays Vessel's present position in Lat/Long or in Decca coordinates.
CHN	Chain Key - Enables Auto/Manual Decca chain selection and preference of station pairs.

RTE — Selects up to 9 routes which have been fed in earlier. A route consists of several waypoints.

STA — Status Key - Displays the quality of Decca reception.

 Alarm Key - Allows for both selection as well asdisplay of alarm details. Used also to silence alarm anddisplay reasons for alarm.

 Interchange Key - Changes N-S, E-W, Y-N, +--. Also for selecting True north or Magnetic north.

ENT — Enter Key - To enter data. Used also for freezing/ unfreezing displays.

 Man Overboard key - Enters vessel's present position as a waypoint and immediately displays the range and bearing to that position.

NAV — Navigation Mode Key - Selects levels of display.
Level 1 - Basic display
Level 2 - Advanced Navigational facilities.

Initial Programming.

Power ON.
Select display brightness.
Select units (NM, Km, or M etc).
Enter date, time (24 hr. clock).
Enter Initial position. This must be within 3NM of v/l's position.
Select chart datum (WGS72, India, UK etc.)

Autolocation mode may be used if the initial position is not known correctly.

Entries of Nav.data (Level 1) -

Enter Waypoints (lat/long, in sequential order i.e. 01,02 etc.
Select alarms - WPt. alarm, specify radius from WPt. when alarm should sound.

Display of data (Level 1)

i) Position - present Decca position or if in DR mode then DR position.
ii) Wpt. range/bearing(RL or GC) from present position.
iii) Wpt. range/bearing between any selected waypoints example 2-3, or 4-5 etc.
iv) Predicted accuracy - shows variable errors (Summer daylight or Winter Night)
v) Speed/Course over ground averaged over the previous minutes of Decca fixes.

Entries for Nav. Level 2

- Select Mode "Level 2"
- Enter Speed and direction of tide and/or current
- Route - a route consists of a series of waypoints. 9 routes consisting of 25 wpts. each can be entered.
- Manual chain selection is possible in this mode. Two preffered station pairs will have to be chosen.example R/P or G/P etc.
An alarm clock facility is also available.

Displays for Level 2

- Position in Lat/Long or Decca coordinates is possible.
- Lane identification - displays the three LI values together with its respective difference from the three values obtained during normal transmission. Any LI differences greater than 0.5 of a lane will be corrected automatically. In manual mode, this will have to be manually entered.
- Waypoint range, bearing and course to steer (R/L or G/C) making allowance for tide/current.
- Wpt. XTE (cross track error)

To Track << 8.9NM

Vessel is 8.9NM to the right of the course line to next WPt.
- Time to Wpt. Estimated time to go to next waypoint based on Speed over the ground over last 4 mins.
- Speed/Course made good/ run time/ distance run.

Alarms

1 Near a waypoint - Alerts the operator that he is approaching an alteration of course point.
2 Near new chain - Warns the operator that he is about to enter a new chain.
3 Switched chain - indicates that the receiver has now started a new chain.
4 Position/Decca signal suspect.
5 Signal lost/ Antenna failure.

Autolocation

This is a technique which may have to be used if the initial position is not known to within three nautical miles. The receiver works out a series of "Best Fix" positions in order of preference which it will display and allow the user to accept or reject.

9.7 Errors of the Decca System.

The errors of the Decca system are divided into two categories, namely, **Fixed or Systematic Errors** and **Random or Variable Errors.**

Fixed or Systematic Errors.

There are two main causes of fixed errors namely:

i) The speed of propagation of electromagnetic waves changes when crossing from land to sea and vice versa. This means that if the Decca signals coming from a station have to cross land or sea to arrive at a receiver then their phase will get affected and cause errors in postion on the ship.

ii) The Decca signals also get affected by other sources like magnetic anomalies and interferences

- The skywave arrives a littlelater than the ground wave because it has travelled a longer path.
- The skywave also arrives out of phase with the ground wave. This causes:
  1. Lane slip in Decca.
  2. Night effect in DF.

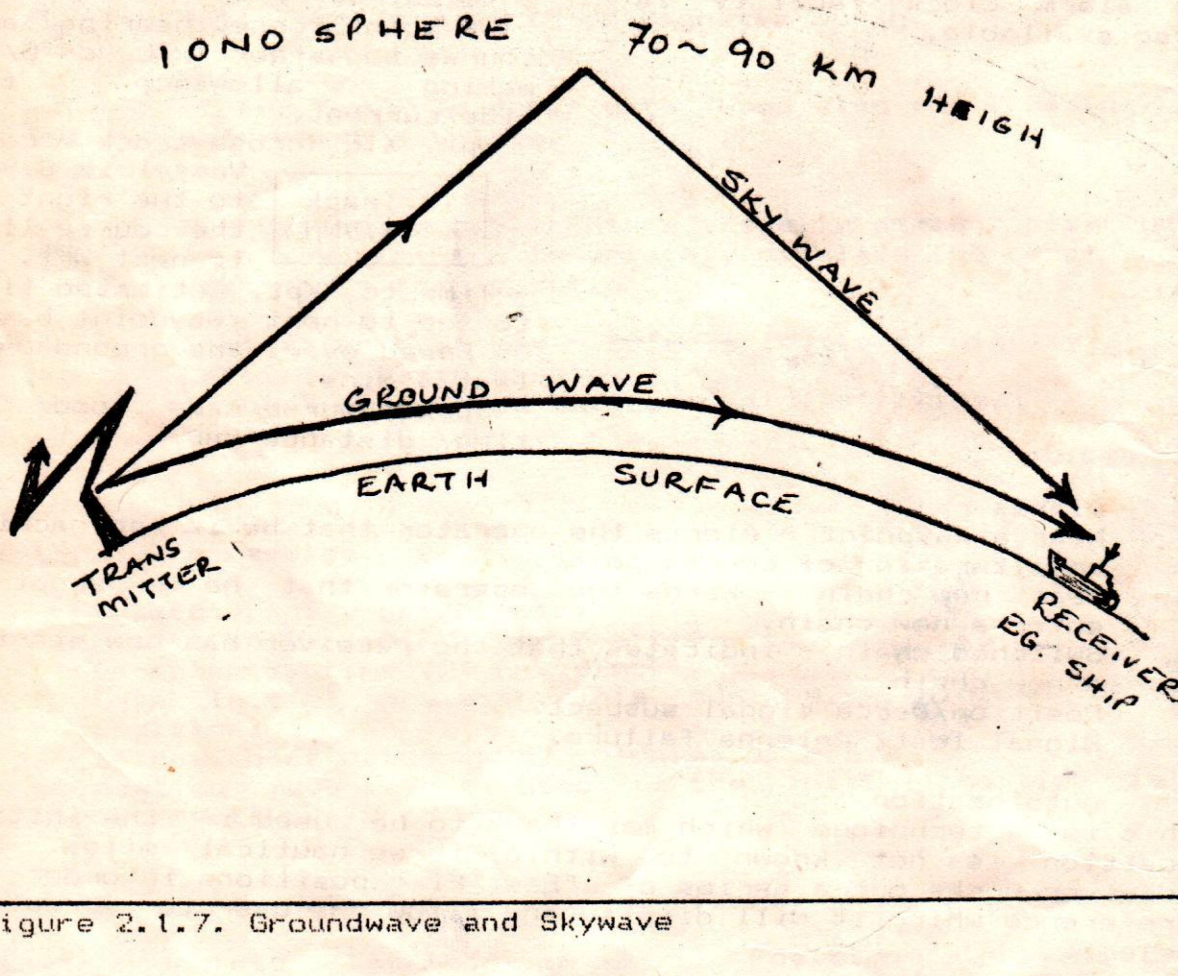


Figure 2.1.7. Groundwave and Skywave

which may be present in a particular geographuical location.

The lattice on the chart is computer generated and hence does not take into account these effects which deviate from the perfect hyperbolic pattern.

These errors do not change at an place with time of day or season and can be found in the Marine Data Sheets for each Chain and each station. They are given in centilanes.

If the error is not encircled, then it is to be added to the reading on the decometer before plotting on the chart.

If the error in the Data sheets is encircled, then it is to be subtracted to the reading on the decometer.

Variable or Random Errors.

These errors change with season, time of day, etc. and cannot be applied like fixed errors. The user should be aware that they exist and how much they may be and accordingly make allowance for them.

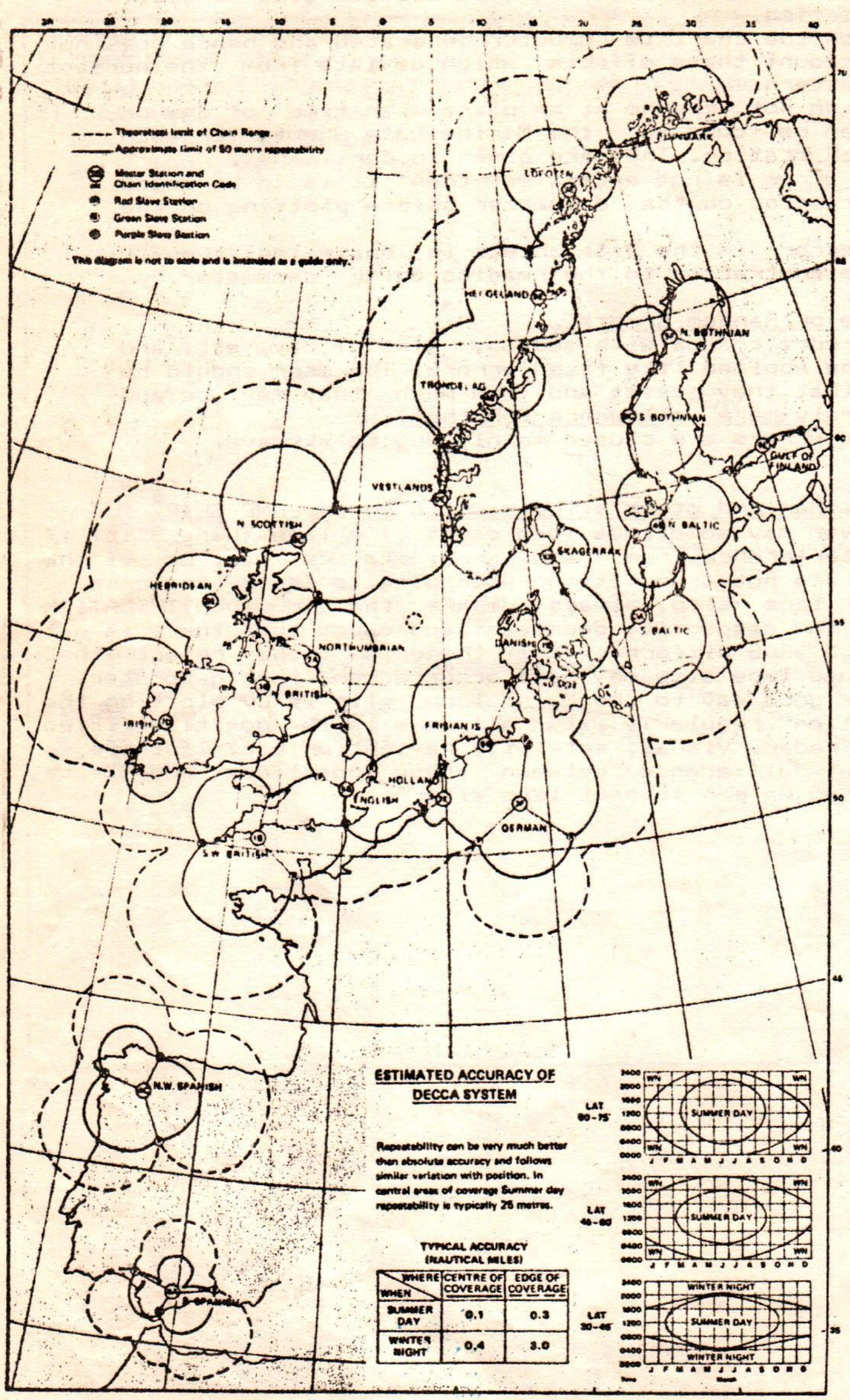
Variable errors are caused mainly due to skywave.

9.8 Weather and other effects which cause LANE SLIP.

The receiver may sometimes lose count of a lane (Lane Slip) if there is interference from rain, snow, statics etc. or if the transmitters are not transmitting according to their sequence. To check for lane slip, always compare the LANE IDENTIFICATION display with the respective decometer and check that there is not more than 0.5 lane difference. If there is , then reject that reading because lane slip may have occurred on that decometer.

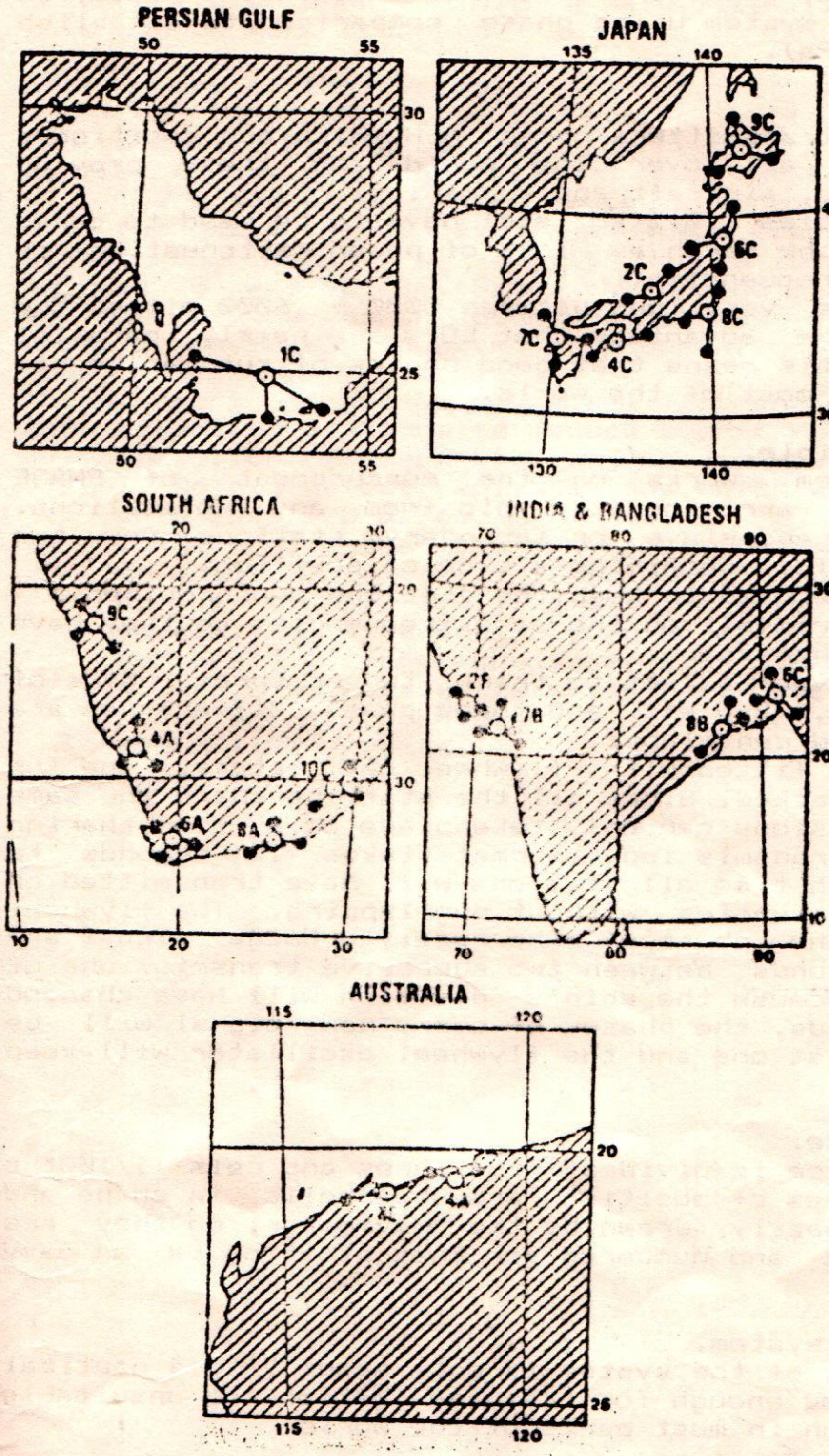
Another good way to check for lane slip is by plotting the ship's position regularly with all available position fixing methods like radar, visual, satellite navigation etc. If there is a significant difference between these positions and Decca positions, then we can suspect lane slip.

CURRENT EUROPEAN DECCA CHAIN CODES



NO	CHAIN
0A	S. BALTIC
0E	VESTLANDET
1B	S.W. BRITISH
2A	NORTHUMBRIAN
2E	HOLLAND
3B	N. BRITISH
3E	LOFOTEN
4B	N. BALTIC
4C	N.W. SPANISH
4E	TRONDELAG
5B	ENGLISH
5F	N. BOTHNIAN
6A	S. SPANISH
6C	N. SCOTTISH
6E	GULF OF FINLAN
7B	DANISH
7D	IRISH
7E	FINNMARK
8C	S. BOTHNIAN
8E	HEBRIDEAN
9B	FRISIAN ISLANDS
9E	HELGELAND
10B	SKAGERRAK

CURRENT NON-EUROPEAN DECCA CHAIN CODES



CHAIN NO	CHAIN
1C	S. PERSIAN GULF
2C	HOKURIKO
2F	SALAYA
4A	NAMAQUA
4A	PORT HEDLAND
4C	SHIKOKU
6A	CAPE
6C	BANGLADESH
6C	TOHOKU
7B	BOMBAY
7C	KYUSHU
8A	E. PROVINCE
8B	CALCUTTA
8C	KANTO
8E	DAMPIER
9C	HOKKAIDO
9C	S.W. AFRICA
10C	NATAL

10. OMEGA NAVIGATION SYSTEM

10.1 General.

This is a very long range electronic position fixing system of the hyperbolic type, providing global coverage. Like Decca, it is a continuous wave system using phase comparison to establish Lines of Position (LOPs).

10.2 The System.

There are eight transmitters named A-H which are positioned in different places all over the world and these provide positions for shipping, aircraft and submarines.

Very Low Frequencies (10.2 kHz etc) have to be used to cover long distances over the earth as loss of power (attenuation) is less using very low frequencies.

The baselines are very long between 5000 - 6000 miles. The long baselines have the advantage that LOPs are nearly parallel for long distances. This means that good angles of cut can be had using Omega LOPs over most of the world.

10.3 The Omega Principle.

The Omega system works on the measurement of PHASE DIFFERENCE of signals arriving at a ship from any two stations. There are no master and slave or secondary stations. Any two stations can be used for obtaining a Line of position.

Atomic clocks are used to keep the stations synchronized.

Omega stations transmit on the same frequencies so they have to share times of transmission.

The Omega receiver is set to track two or three pairs of stations eg. A-C, D-F, B-G etc. and these phase differences are displayed in lanes and centilanes.

The receiver is fitted with flywheel oscillators, one for each station being tracked. Since all the stations share the same frequencies, transmissions can only take place on a time sharing basis. The Omega transmission format takes 10 seconds to complete, during which time all stations will have transmitted on their respective frequencies without overlapping. The flywheel oscillator accepts the phase of the received Omega signal and retains it for 10 seconds between two succesive transmissions of the same station. Because the ship's position will have changed during this 10 seconds, the phase of every new signal will be different from the last one and the flywheel oscillator will keep on getting updated.

10.4 The Omega Lattice.

The Omega lattice is divided into lanes and cels (1/100ths of a lane). The lines of position are hyperbolic in shape and therefore cannot be easily drawn by the navigator, so they are printed on the chart and numbered so that plotting is an easy task.

10.5 Accuracy of the system.

Overall accuracy of the system is only about 2 to 4 nautical miles and is only good enough for ocean navigation and unsuitable for coastal navigation in most parts of the world.

10.6 Omega receivers.

Modern receivers are mainly automatic in operation and need only to correctly identify the stations. After this they automatically track and display the lane numbers. There is no tuning required as the sets have fixed crystals.

Some sets display the lane numbers while others are designed to display the latitude and longitude of the vessel. This is automatically updated as the vessel moves along her course. Some sets are also coupled with a satellite navigation receiver and this can be more accurate.

10.7 Errors of the System.

The FIXED ERRORS of the system are to be found in the Omega tables called Path Propagation Correction tables. These are to be applied to the readings obtained from the set.

There are other errors which are not fixed and they change with the time of the day, season and place. During the day and night, the height of the ionosphere D layer varies usually between 70 and 90 km. Since the Omega signals travel over the surface of the earth bouncing between the D layer and earth surface, obviously the time of propagation will vary from hour to hour.

These errors cannot be corrected for and so we must be careful when selecting stations to reduce such errors.

Selection of Omega Stations to reduce Variable Errors.

1. Do not select any stations which are closer to the ship than 500 miles.
2. Make sure that the position lines which you get give an angle of cut of at least 30°.
3. The signals arriving at the ship should as far as possible have passed only over water. The signals get seriously affected when they pass over land.
4. Avoid using signals which are coming from over the polar areas. These signals will have suffered POLAR CAP ABSORPTION effects.

11. LORAN C NAVIGATION SYSTEM

11.1 The System.
LORAN stands for LOng RAnge Navigation system.
It operates on 100kHz and is a hyperbolic system that is, the lines of position obtained from the display are hyperbolae. The **DIFFERENCE IN TIME** between arrival of signals is measured and displayed as a **Time difference in microseconds.**

The Loran system has a range of about 1500 nautical miles from the stations and each chain of stations consists of one Master and three or four Slave or Secondary stations. Each Loran chain is numbered and identified by it's **GRI (Group Repetition Interval)** eg 9980.

The stations transmit series of pulses, the Master transmits 8+1 pulses and the Secondary station 8 pulses. The Master transmits first. Each secondary station after receiving the Master signal transmits it's pulses after a time delay called the **Coding Delay**. In this way, the master signal will always be received first on board ship followed by secondary stations X, Y, Z.

11.2 Measurement of Time Difference.

The Loran C system uses two techniques to measure the time difference between signals of the master and slaves.

1. Pulse Envelope Matching - by comparing the pulse envelopes of the received signals.
2. Third Cycle Matching. - by comparing the Third cycles of the received signals.

The first method is a coarse method of measuring time difference and gives a coarse time difference. The second technique is much more accurate and gives a time difference to the nearest tenths of a microsecond. Most receivers use both techniques to obtain the time difference.

11.3 Loran C Receivers.

Receivers vary considerably from model to model and the operating instructions of each must always be consulted before operating the set.
Most sets are automatic and after being initially set up, they automatically identify and track the signals, measure time differences and display them. Usually two time differences would be displayed giving two LOPs which can be plotted on the LORAN chart after applying corrections. A Loran fix is thus obtained.

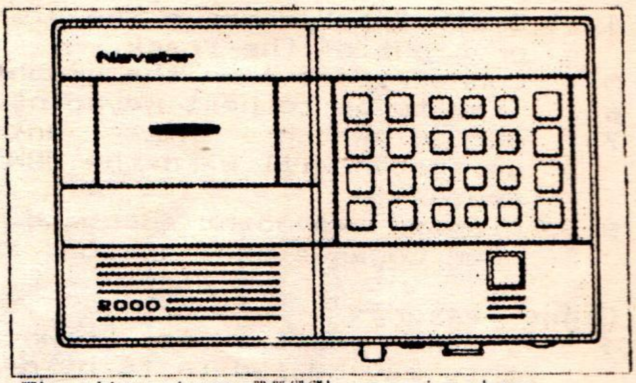
If reception of signals is poor or weak then the receiver blinks the display to warn the operator. At such times, the readings may be unreliable.

A typical automatic Loran navigator the Navstar 2000L is described here. This set is much more than just a Loran receiver and is outfitted with sophisticated software for navigation as well.

11.3.1 The Navstar 2000L.
Keyboard

| PRG | Program Key - Used to enter initial data like position, mode, variation etc. |

| POS | Position Key - to display vessels present position. Also for checking radius for anchor watch. |



The Navstar 2000L navigator

TD — Position expressed in time differences. Also for entry of ASF.

WPT — Waypoint Key - For entry of waypoint lat/long. Displays range/bearing to next waypoint etc.

GRI — Group Repetition Interval key - Used in manual selection of Loran chain. Also for manual selection of Secondary station.

RTE — Route Key - Selects upto 9 routes and the waypoints forming each Route.

NAV — Navigation Key - Display of Cross track error, course/speed over the ground, speed made good, time to go to next waypoint. Also for entry of set and drift.

Man overboard key - Enters the vessel's present position, as a waypoint and displays the bearing and range to this position.

Alarm key - Cancels alarm. Also for displaying alarm reason.

Interchange key - Used to change signs, names etc. like E - W, N - S, + - - etc.

ENT — Enter key - Allows entry of data in different parts of the display.

STA — Status key - Shows status of Loran reception. Also for various tests.

Initial programming

1) Power ON
2) Select Loran or DR mode - Loran mode within Loran coverage and DR mode outside of Loran areas.
3) Enter inital position Lat/Long.
4) Enter any way points for navigational requirements.
5) Enter year.
6) Select Magnetic or True North.

The set will now select and begin to track the appropriate Loran chain.

Waypoints can be entered by one of three methods:

1. By range/bearing from vessel's present position.
2. By lat/long of waypoint itself.
3. By Loran Time Differences eg. 23128.79 etc.

Navigational displays

1 Present Loran position (corrected for ASF). This may be displayed as lat/long or Loran Time Differences.

2 Way point range/ bearing - distance and course to steer to next way point.

3 Range/brg between preselected waypoints.

4 Cross track error - The distance the vessel is to the left or right of the track.
5 Course/speed over the ground over the last 4 mins.
6 Time to go to next waypoint.
7 Anchor watch - After entereing a desired radiius, the navigator will warn the OOW if the vessel moves out of this radius.
8 Alarms - Waypoint approach, Anchor watch, cross track error, poor Loran signal status, and antenna failure.

Other features
1 If the position is known accurately by some other means, this may be fed in to help update the Loran positions.
2 Manual chain/station selection possible.
3 ASF corrections can be applied manually.
4 DR mode - when not in Loran coverage, the navigator can be fed with course, speed, current and rate and it will display the DR position continuously.

11.4 Errors.

1. Systematic Errors.

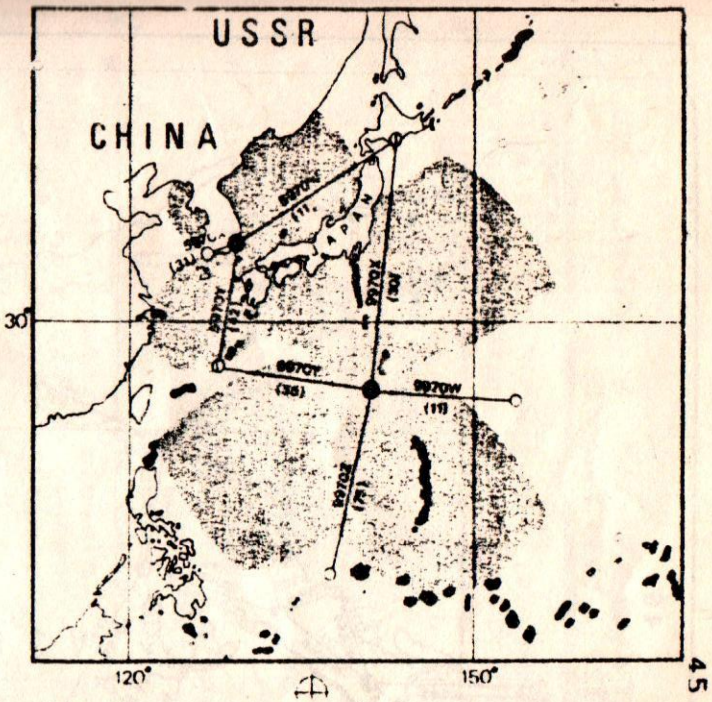
These are caused mainly due to the change in speed of propagation of waves when passing over land and sea. These changes affect the measurement of time differences.

Loran Correction tables called **ADDITIONAL SECONDARY PHASE correction** have to be applied to the observed Loran readings before plotting on the chart.

2. Variable or Random Errors.

Errors caused due to skywave reception in some places can be corrected for by applying appropriate skywave corrections. These corrections are found on the LORAN chart itself. In the Loran system, skywave reception can also be used for position fixing. This is useful because it increases the range of coverage up to 1000-1500 nautical miles from the stations.

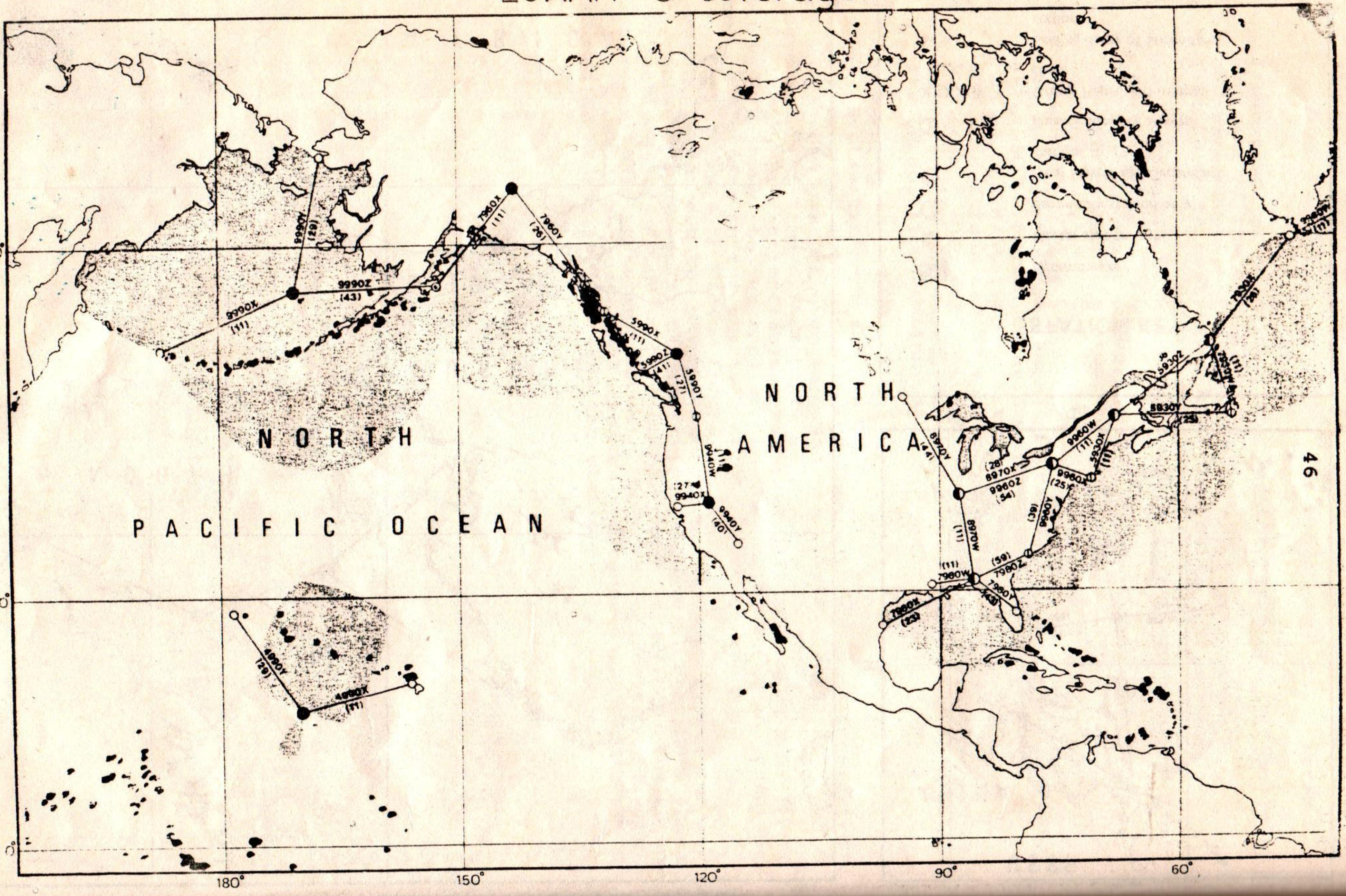
LORAN - COVERAGE



STATION KEY

- Groundwave
- Master station only
- Secondary station only
- Dual Master and Secondary station
- Dual Secondary station
- XXXX W (X, Y, Z) — Group Repitition Interval of chain
- (X X) — Coding delay of Secondary station

LORAN-C coverage



12. NAVY NAVIGATION SATELLITE SYSTEM (TRANSIT)

12.0 General

Transit or NNSS (Navy Navigation Satellite System) is an accurate, all weather, world wide navigation system suitable for submarines, surface shipping and aircraft.

12.1 The Transit System.

The System consists of three main segments;

1. The Earth-based back up segment - This consists of a control station and several tracking stations which track and determine the position of the satellites accurately.
2. The satellite segment - The satellites are on polar orbits and they are so positioned to form a bird cage inside which the earth rotates. There are six polar orbit satellites at a height of 1075 km. which continuously transmit time and satellite position information signals.
3. The receiver segment - a) The antenna receives signals from the satellite.

   b) The keyboard helps the operator to interface with the computer.

   c) Receives inputs from other systems like log, gyro, etc.

   d) The computer which computes the ship's position from the received signals.

   e) The display which displays all relevant information.

12.2 Principles of operation

The system works on the principle of doppler shift of signals transmitted by polar orbiting satellites.

These signals are transmitted on 150 and 400 MHz.

The receiver on board a ship receives satellite signals and measures the doppler shift of frequency of the signals as the satellite passes the ship.

This measurement is made during the period that the satellite is above the observer's horizon.

From these doppler shift measurements, the position of the vessel is computed by the computer in the receiver.

The fix is calculated and displayed in latitude/longitude whenever a satellite passes and a fix is obtained. Between fixes, the DR of the ship is displayed using the course of the ship and speed input or from a log.

The DR is automatically updated on the display when a new fix is obtained. The clock in the receiver is also updated every time a satellite passes so the correct GMT is always on the screen.

12.3 Initial Setup.

When initially setting up the set, the following information is to be input.

1) DR Latitude and Longitude.
2) Approx. GMT.
3) Ship's course and speed.
4) Antenna height above sea level.

12.4 Other functions of the computer.

12.4 Other functions of the computer.

The satellite navigator can also perform other navigational duties;

1) Way point navigation by Great Circle or Rhumbline.
The way points (or alter course points) are fed into the computer and the course to steer and distance (great circle or rhumbline) between way points can be calculated and displayed.

2) The receiver can also be set to warn (by alarm and visually) the operator when he is not steering the desired course or when he has reached a way point (alteration or course).

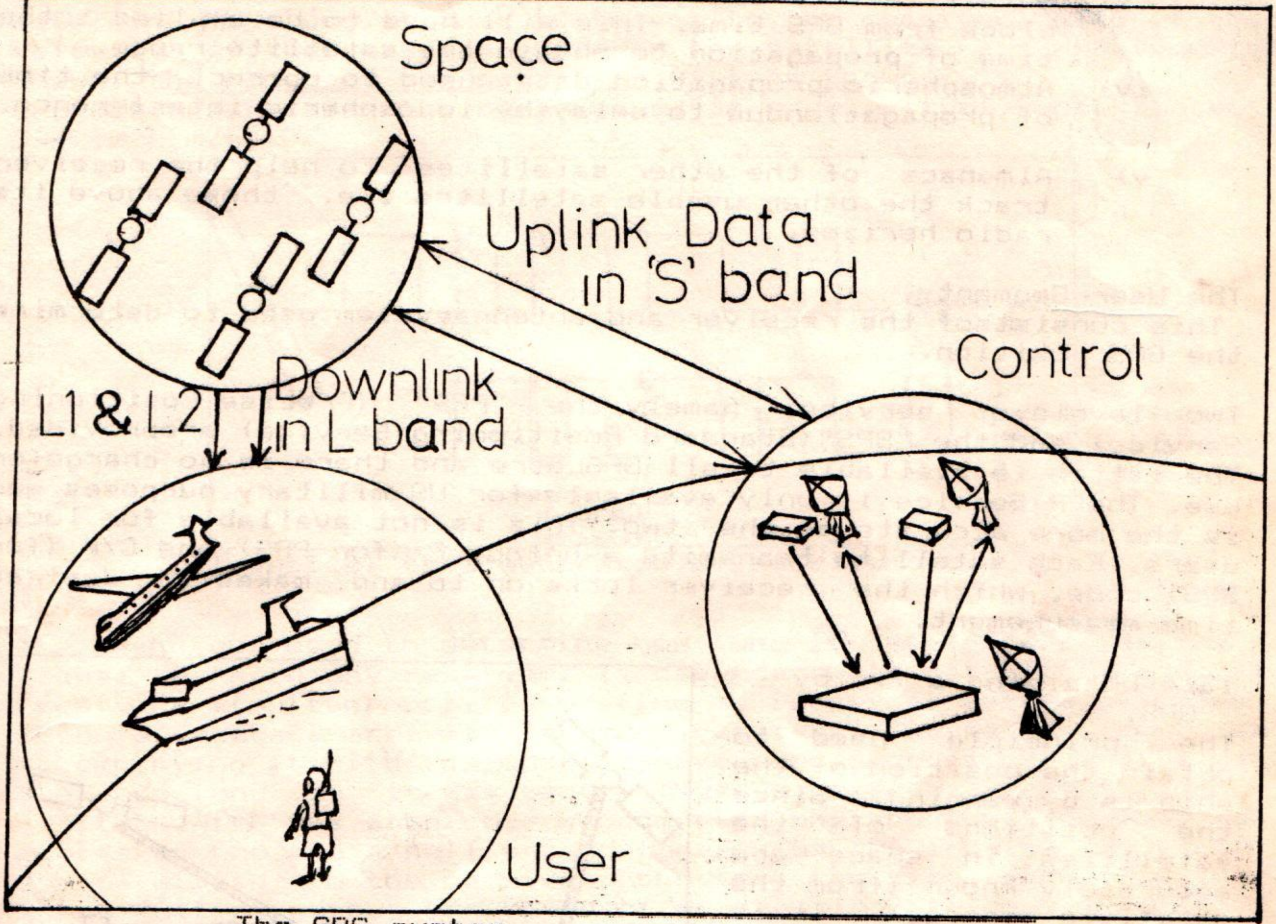
12.5 Errors

1. High and Low Satellite passes.
The satellite must have an elevation of between 10 and 70 degrees. If the elevation is less than 10° or more than 70°, errors in position will result.
2. Satellite position errors.
The exact position of the satellite must be known when tracking it. If the satellite position is incorrect then the calculated fix will also be incorrect.
3. Refraction of the ionosphere.
The satellite signals get affected as they pass through the ionosphere and so doppler measurements may get upset. This error is overcome by using two frequencies, 150 and 400 MHz.
4. Course and speed input errors.
If the course and speed of the ship is not correctly known during the passage of a satellite, then this causes errors to result in the position calculated.
5. Antenna Height Error.
Wrong input or antenna height will result in an error in calculated longitude of the ship.

13. Global Positioning System Navstar

13.1 The Global Positioning systemrepresents the state of the art in precise, continuous world-wide satellite navigation.

It is a very versatile system which can be used at sea, on land, in the air and even the Space shuttle uses this for its navigation.



The GPS system

13.2 The GPS Structure.

The system comprises three segments, control, space and user.

The Control Segment

These ground stations monitor the satellites and they are located in various parts of the world. The whole system depends very heavily on the accuracy of two main parameters namely, satellite clock error control andthe satellite positional information. Both must be known very accurately otherwise precise positions cannot be achieved. The satellites need to be updated with correct *information regularly so that they can include this in their* messages.

The Space Segment

This consists of 18 (at present) satellites orbiting the earth at about 20000 kmaltitude in orbits inclined about 55 degrees to the Equator with three satellites ineach orbit. Each satellite has an orbital period of about 12 hours.

The positioning ofsatellites is such that atleast four satellites are always above the users horizon.

The satellites transmit on two frequenciesL1, 1575.42 MHz and L2, 1227.6 MHz.

data code (PRN code) Pseudo Random Noise (Nav. message)
→ C/A code
→ P code

13.3 The Satellite Message.

The satellite message consists of :

i) A code(C/A,coarse acquisition) which isused to identify the satellite and make a range measurement of the satellite from the receiver.

ii) The satellite ephemeris, consisting ofsatellite orbital parameters to determine the exact position of the satellite when the range is measured.

iii) Satelliteclock bias, that is any error of the satellite clock from GPS time. This will have to be applied tothe time of propagation to obtain the satellite range.

iv) Atmospheric propagation data, used to correct the time of propagationdue to delaysby ionospheric interference.

v) Almanacs of the other satellites to help the receiver track the other usable satellites i.e. those above its radio horizon.

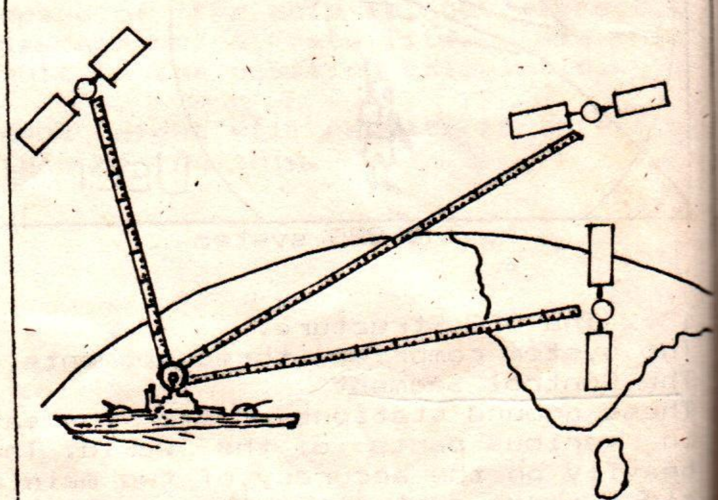
The User Segment

This consistsof the receiver and antennasystem used to determine the GPS position.

Two levels of service, namely the "PPS" (Precise Positioning Service) and the "SPS"(Standard Positioning Service) areprovided. The latter is available to all GPSusers and there is no chargefor use. ThePP Service is only available for US military purposes and is the more accurate of the two. This is not available for local users. Each satellite transmits a unique P (for PPS) and C/A (for SPS) code, which the receiver locks on to and makes the desired time measurement.

13.4 Obtaining a fix by GPS.

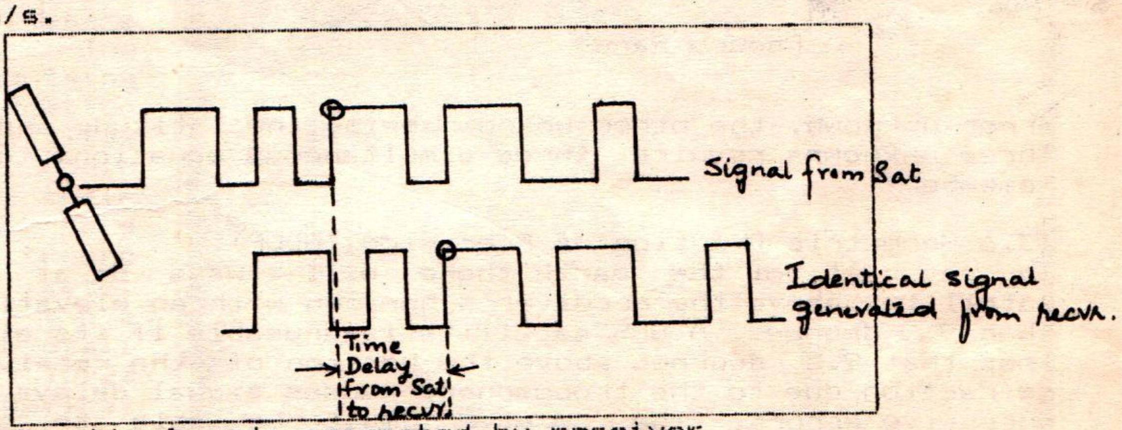
The principle used to obtain the position of the ship is by ranging. Since the positions of the satellites in space are accurately known (from the satellite message), it is possibleto obtain a fix if the ranges of three satellites are measured. If we know the location ofone satellite and the distance to it, all we can calculate from thatis that weare located somewhere on the theoretical surface of a theoretical sphere with its center at the location of the satellite, that is a spheroid of position. We can find our position in free space by knowing the position of three satellites and simultaneously measuring the distances from our location to the location of the satellites. We solve for the three unknowns (our position, eg. x,y,z) with three range equations.



Ranging Principle

To find the range to the satellite, we take advantage of the relationship among distance, velocity and time. If we can send something with aknown velocity from point A topoint B and measure

how long the trip takes, we can figure out the distance.
For example; If a traintravelling steadily at avelocity of 100 km/h takes 2 hours to travel from A to B then we can immediately say that A is 2 x 100=200 km.
In the samemanner, if a message is sent from the satellite to the ground that recorded the time that the message was sent, then by noting the time the message was received, it is possible to determine how long it took to travel to the receiver. Also if the velocity of that message between the satellite and receiver is known, the range of the satellite will be known.
GPS messages are sentby radio waves at a velocityof approximately 3 x 10^8 m/s.

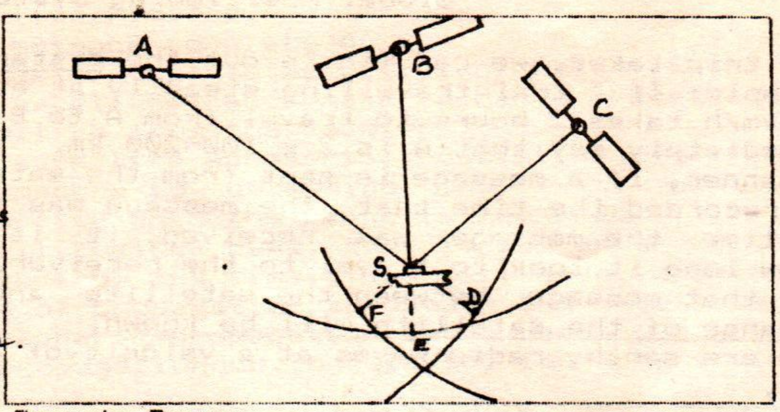


Identical code generated by receiver

The technique used to determine how long it takes the satellite's signal to reach any receiver. It depends onall satellites and all receivers simultaneously generating an identical series of codes. When a message arrives at our receiver, we match the code accompanying it with the code we have been generating, and we can see how long ago it was sent. Thus, a message arriving at our position with the same code wegenerated one and a half second ago has taken one and a half second toreach us. Obviously, the closer the satellite to the receiver, the less the time taken. The time taken multiplied by the speed of propagation yields the range of the satellite.

13.5 Pseudo Ranges and True ranges.
Since the timedifferences involved are very small(in nanoseconds) only atomic clocks can be used to measure them. The errors in ordinary clocks would not beacceptable. Each satellite isequipped with four atomic clocks. However, itis not possible to outfiteach shipboard receiver with one of these sophisticated gadgets. The receiver clock is not as accurate and therefore a constantunknown (User clock offset)gets included in our range measurements - this remains constant in allthe three range equations andtherefore can be resolved easily. This User clock offset bias represents the difference between our receiver's time and GPS time.
The range thus measured which includes the user clock offset is called the Pseudo Range.
True Range = Pseudo Range +/- Clock error range
In actual fact, if a two dimensional fix (lat/long) is required then if there was no user clock error, it would only be necessary to measure the ranges of two satellites. However, due to user clock error, it becomes necessary to measure the ranges of three satellites (yielding three range equations) to resolve the clock

A,B,C - Satellites
AD, BE, CF - Pseudo Ranges.
AS, BS, CS - True Ranges
SD, SE, SF - Range error due to user clock error.
S - Fix.



Pseudo Range

error unknown, the other unknownsbeing the latitude andlongitude. Three unknowns require three simultaneous equations to resolve, remember?

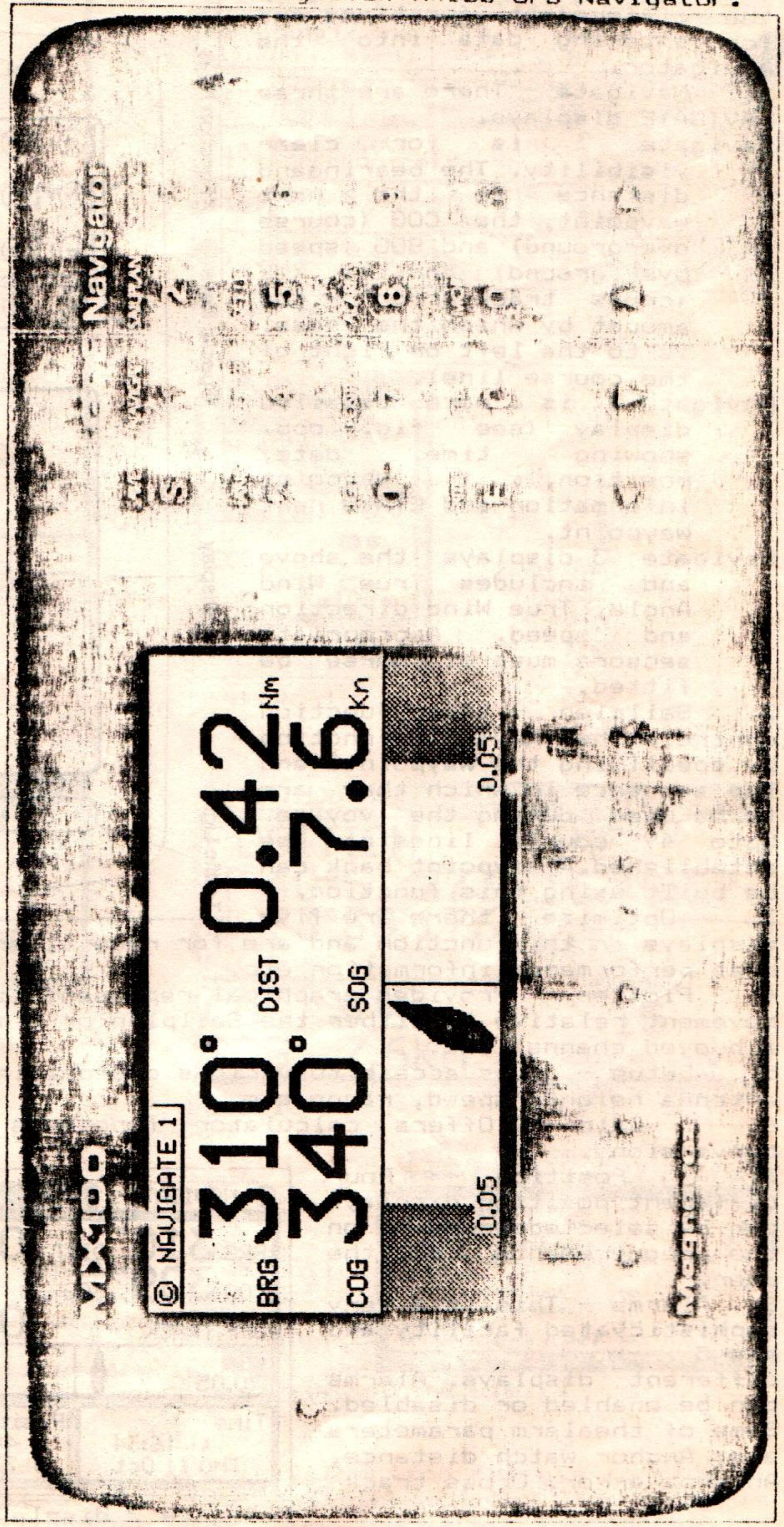
13.6 Geometric Dilution of Precision (GDOP).
In any part of the earth there will always be at least four satellites above the receiver's horizon with an elevation of more than 9.5 degrees. A GPS satellite is unusable if its elevation is less that 9.5 degrees above the horizon of the receiver because refraction due to the troposphere causes signal delays leading to excessive errors. The receiver must be able to select the satellites it will use for ranging. The process of selection of suitablesatellites is called Geometric Dilution of Precision. For example a good configuration of satellites for a two dimensional fix i.e. lat/long would be three satellites separated by 120 degrees in azimuth and low in altitude.
Due to the motion of the satellites as well as the receiver, the configuration of satellites cannot remain the same and so the receiver continuously keeps on calculating the GDOP in order to select the most suitable satellites.

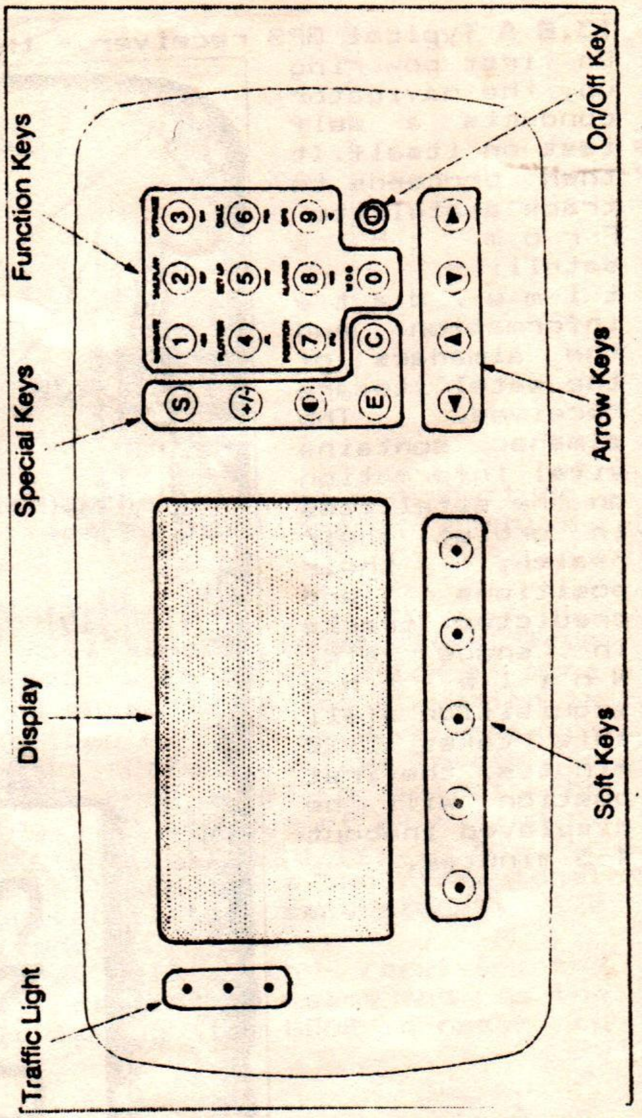
13.7 Accuracy of GPS.
For a PPS user, fixes of +/- 5-10 meters accuracy are possible on the surface of the earth and in space.
For a SPS user, the accuracy is about +/- 100 m. All commercial receivers use SPS.

13.8 Errors of the system.
1. GDOP - if the configuration of the available satellites is not suitable, accuracy of the fix is affected.
2. Ionospheric and Tropospheric delays of signals - While ultra high frequency signals are used for transmissions, yet the ionosphere and troposphererefract the signalscausing delays which lead to inaccuracy of positions. These delays can be reasonably predicted and are fed into a mathematical model built into the software of the receiver.
3. Satellite clock error -any errors in the clocks on board the satellites will lead to errors in time measurement.
4. User clock error - same as above.This is eliminated by using an extra satellite equation.
5. Deviations of satellites from their predicted orbits - Since the position of the satellites needs to be known very accurately, it is obvious that if thesatellite deviates from its orbit for any reason, then inaccuracy in fixes will result.
6. Receiver errors - these are small and are caused due to internal noise, computational errors etc.

13.8 A Typical GPS receiver - the Magnavox MX100 GPS Navigator.

On first powering up, the navigator conducts a self test on itself. It then proceeds to track asatellite. From this satellite, time/date information and the almanacs of the satel'itesare received. The almanac contains vital information on the satellites in orbiut, their health, their positions and predicted tracks in space etc. While the acquisition ofall this takes 15-20 minutes, thefirst postion will be displayed inabout 4-5 minutes.





The Function Keys
These are used for calling up the differerent. functions and for entering data into the navigator.

1. Navigate - There are three NAVIGATE displays.

Navigate 1 is for clear visibility. The bearingand distance to the next waypoint, the COG (course overground) and SOG (speed over ground) and the XTE (cross track error - the amount by which the vessel is to the left or right of the course line).

Navigate 2 is a more detailed display (see fig. opp) showing time, date, position, waypoint information and ETAto next waypoint.

Navigate 3 displays the above and includes True Wind Angle, True Wind direction and speed. Appropriate sensors must of course be fitted.

2. Sailplan - this function controls the NAVIGATE function by specifying the waypoints and the sequence in which they are to be used during the voyage. Upto 49 course lines can be established.A waypoint bank can be built using this function.

3. Optimize - there are five displays in thisfunction and are for race timers,lap timers, sail boat performance information etc.

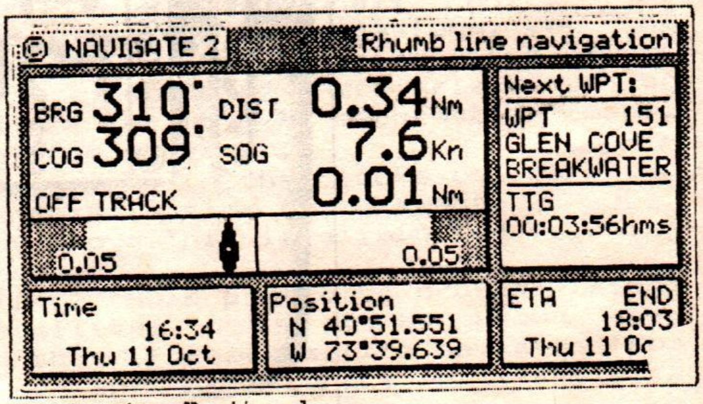
4. Plotter - Provides graphical representations of the ship's movement relative to either the Sailplan or a marker position eg. a buoyed channel etc.

5. Setup - gives access to various customizing facilities, like antenna height, speed, range etc.

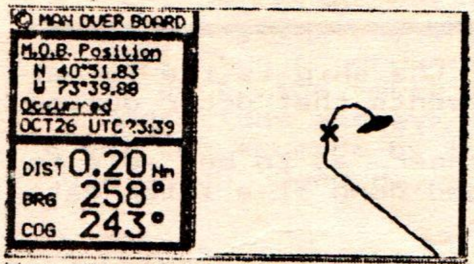
6. Calc - Offers calculator functions and other handy conversions.

7. Position - Four different position displays can be selecteddepending on the requirements of the user.

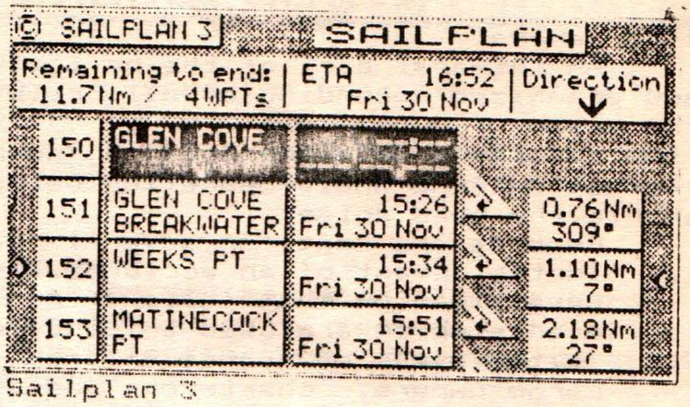
8. Alarms - This is a very sophisticvated facility and has 5 different displays. Alarms can be enabled or disabled. Some of thealarm parameters are; Anchor watch distance, Antenna error, Cross track



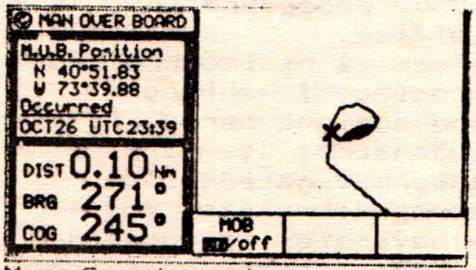
Navigate 2 display



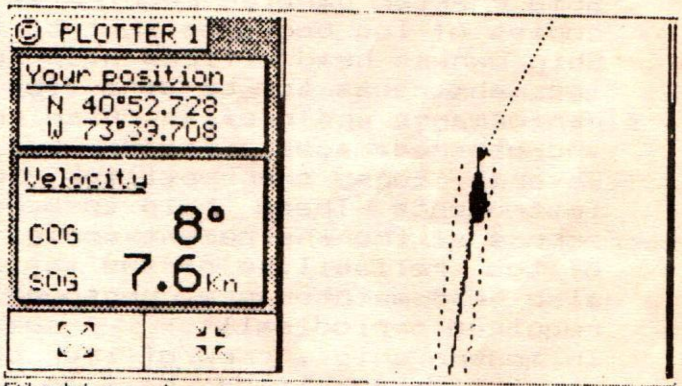
Man Overboard



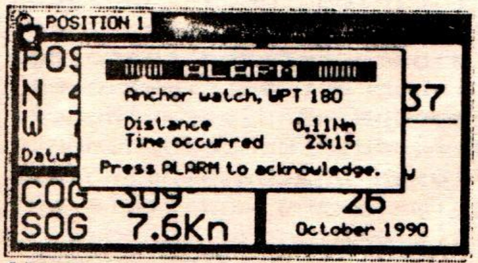
Sailplan 3



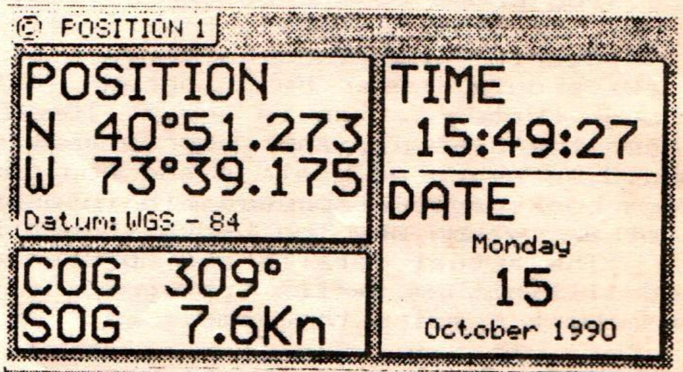
Man Overboard



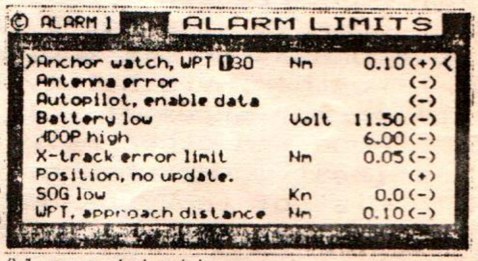
Plotter 1



Alarm



Position 1



Alarm Limits

error limit, Wpt approach, Autopilot alarm, Alarm clock, Warning areas etc.

9. GPS - Provides an estimate of the current accuracy of the position and also canshow which satellites are in orbit and their "health" and also those satellites which are visible etc.

10. MOB - This is an important safety function for use in case of a man overboard situation. The position of the incident is immediately stored together with time and date. The course and distance is immediately available to return to the scene.

14. LOG BOOKS

14.0 General.

An integral part of the navigation of the ship is the formal and organized recording of all relevant events that occur during the watch.

Records should be made in such a manner as to be able to reconstruct the whole operation being logged down at a later date should the need arise.

Records are kept for several reasons:

1. In the event of an accident, the Court of enquiry and investigation that follows require a detailed record of events which are used to study the case.
2. In the event of cargo claims, delays, cargo damage etc. the cargo owners, charterers and other interested parties usually require to inspect the log books.
   Some charter parties require as standard procedure that copies of log books be sent to their office.
3. Ship owners head offices also require copies of log books or log abstracts to be sent for monitoring of ship's performance and profits. Also to defend against cargo claims and other damages.
4. Several logs are kept for important navigational instruments. These help to monitor the performance and errors of the instrument and give the navigator a good idea of the reliability of the instrument. These instrument logs also help maintenance personnel to assess what repairs are required periodically.
5. In modern ships, crew/officer changes are effected in a very short time sometimes half an hour. In such cases, the relieving officers do not have the benefit of being briefed by the out going crew and they would have to depend on the log books to assess the reliability of the equipment.

Bearing in mind the above, it should be stressed that log books should never be "flogged" (making incorrect entries) even though thetemptation is great. These logs can be used as evidence incourt and should any incorrectentries be found, such a document would be rendered useless and couldeven be used against the ship. Log books are also used in insurance claim cases and this is another reason why log books should be kept clean.

The actual details and procedures of maintaining log books and fillingthem varies from company to company however, the basic framework remains the same.

14.1 Deck (Mates) Log Book.

This is the main record book maintained by the Bridge team. Entries include:

1. Courses steered, gyro and magnetic, alteration of courses, compass errors and set/leeway applied, log reading.
2. Weather, visibility experienced, pressure, temperature, wind force, skies etc.
3. Noon and other relevant positions, one fix per watch at least whenever possible.
4. List of lookouts and helmsmen.
5. Soundings of bilges, ballast and peak tanks - AM and PM.
6. Sick list.
7. Signals and lights displayed eg. NUC, navigation lights etc.
8. Remarks: positions of alteration course, compass error obtained, all relevant happenings during the watch, fixes obtained, celestial or electronic, alteration of clocks, any cargo operations eg. hold ventilation, inerting of cargo tanks, tank cleaning etc.
   Arrival/departure details - time of anchoring, stand by,

EOP, berthing details, FWE, all fast F and A, tugs used, controls tested, instruments found OK, any incidence of collision or grounding.

9. In port, the deck log book is used for recording all operations and events between FWE and SBE.

The entries aremade by the Duty Mate and signed by him at the end of his watch. Each day'spage is also signed by the Chief Mate and Master.

14.2 Azimuth (compass error) Log Book.

Details of all azimuths observed and calculated are entered. Compass (magnetic and gyro) error observed is recorded together with the ship's head and UTC. The celestial body observed is also entered too.

The compass error must be checked and entered at least once a watch and signed.

14.3 Chronometer journal.

Record of the error and daily rate of each chronometer is kept. The error is checked against a radio time signal and it's error entered. Temperature in the cabinet is also recorded.

The rate of change of error (daily rate) can be seen easily from the book and thus extrapolated.

If there is a winding chronometer then anentry is to be made when it is run down and when it is restarted.

In the case of an electronic/quartz chronometer, date of change of battery may be entered.

14.4 Sounding Log.

This isa record book which is kept to log soundings taken by hand lead or echo sounder. The soundings would usually be taken together with position fixes so that they can be compared with charteddepths. Notable events like timeof crossing 100m, 20m etc. contours and also nature of bottom may be recorded.

14.5 Movement (Bridge Orders) Book.

The log records events to do with orders to Engine Room, and other manoeuvering details:

Testing controls, SBE, All engine movements, Pilots, lines ashore, anchoring time, all fast forward and aft, details of river/canal piloting etc.

On ships with automatic telegraph loggers, at testing of controls and synchronization of clocks, the telegraph clock should be synchronized as well so that all print outs are perfectly timed. Then at the end of stations, the printout can be attached to the relevant page of the Movement book.

14.6 Decca Log Book.

This book os kept to record all operations of the Decca Navigator receiver.

Details ofswitching on, DR position,chain used, referencing, and initial inputs are entered.

Every Decca fix that is plotted must be entered in this book - Both decometer readings as well as LI readings.

Due to lane slip ifthe difference between decometer readings and LI readings exceeds 0.5 lane over several sequences, this should be recorded and the decometer reset.

14.7 Radar Log Book.

Thisrecord is to be filledout every time the radar equipment is used. One log book is maintained for every radar set on the ship. The radar log consists of four sections as follows:

i) General Information. - Name of radar, make, serial number, frequency, length of performance monitor plume, etc.

ii) Watchkeepers entries and remarks section. Time on/ time off Whether used for collision avoidance or navigation. Weather conditions, visibility. Problems experienced.

This section is to be filled in by the watchkeeper at the end of his watch and signed. This is to be filled in accurately as it is useful for the maintenance team to decide what maintenance should be carried out and whether replacements are necessary etc.

iii) Pick up ranges - this is compiled by the navigation team. Various landmarks are listed and their actual pick up ranges on the particular set. This is helpful for future use and voyages to the particular place to help determine when landfall will be made.

iv) Maintenance section - Filled out by the maintenance technicians and consist of details of maintenance carried out on the set and any parts replaced etc.

14.8 Night Order Book.

Even though this is not a log book like the others described above it is worth mentioning here.

This book contains instructions from the Master to the watchkeepers during the night watches 2000-2400, 0000-0400, 0400-0800 hours regarding safety of navigation, callmaster, notices to be given to Engine Room etc.

This will be signed by both Master and watchkeeper every time the Master makes an entry.

14.9 Bridge Note Book.

This book is maintained in conjunction with the passage planning details which have been made out by the Navigating Officer. It contains all relevant details for the safe conduct of the sea passage being undertaken. Details contained therein may include;

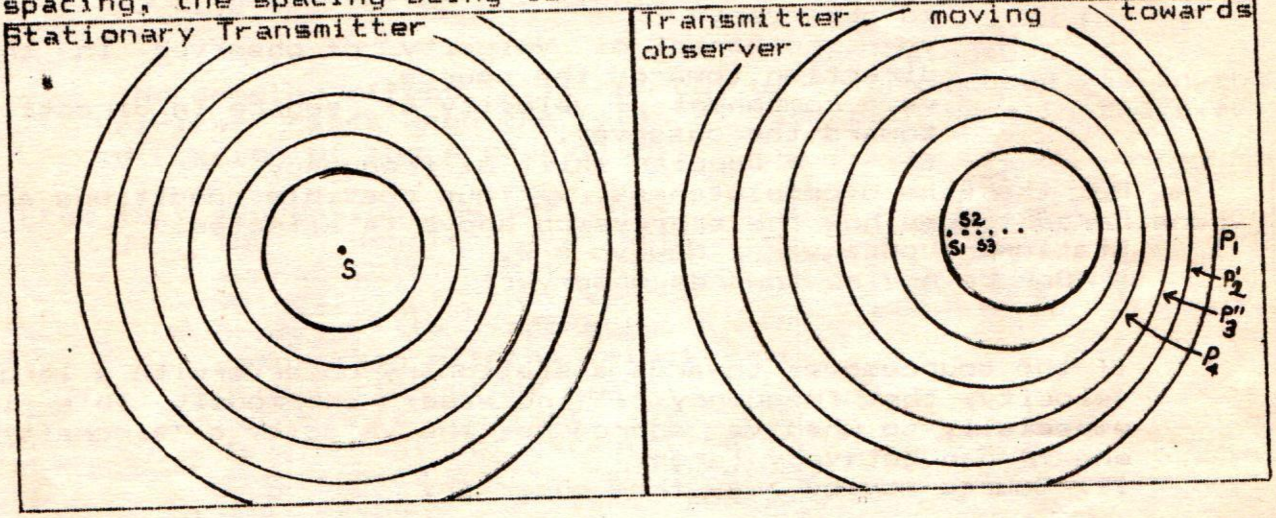
- Publications to be consulted;
- Navigational Warnings;
- Relevant Local Laws and requirements;
- Notices to be served, for example Pilots, Coast Guard etc.;
- Land marks for position fixing, chains to be used etc.;
- Parallel Index Distances, safety margins, Turn details etc.

This book is to be consulted at all points of the voyageto ensure that the passage plan is followed as closely as possible.

15. DOPPLER EFFECT

The Doppler effect is the difference between the real frequency of the source of sound, and the apparent frequency estimated by an observer, that is the frequency with which the waves are received by the observer.This difference occurs, in general, when the source, theobserver, or both are movingrelative to the medium in which the waves are propagated. When a racing car goes by, the high pitched whine of the approaching engine falls to a low pitched growl as it disappears into the distance. By measuring the change of engine note, it is possible to measure the speed of the racing car.

If a source of sound(constant frequency) is stationary in a homogenous mediumthe pressure pulses forming the sound spread out in all directions as a system of concentric spheres with equal spacing, the spacing being termed the wavelength of the wave.



If the source moves and emits pulses at the successive positions S1, S2, S3 etc., shown in the diagram, each position in turn becomes a fixed center of a spherical wave which grows with the velocity of propagation of the sound. At the instant represented in the diagram, the pulse which started from the source at S1 has spread to the sphericalfront P1 P'1 and that fromS2 to the sphere P2 P'2, etc.Hence the spacing of the spheres,i.e. the wavelength, is reduced ahead of the source, shown by pulses P1, P2, P3. The pitch of a note heard depends on the frequency with which these wavefronts pass the observer. This frequency depends on the particularwavelength at the position ofthe observer, the velocity of propagation and the rate of movement of the observer. If the observer moves continuallytoward the source hereceives the pulses more rapidly than if he remained still, and if he moves away he receives them less rapidly.

A distinction needs to be drawn between the case in which the source moves towards a stationary listener, and the case in which the listener moves towards a stationary source.

In the first case, if the source moves towards a fixed observer with a velocity vs, waves emitted with a frequency f appear to have their wavelength shortened in the ratio (c-vs)/c, because of a crowding of the waves, which arrive at a velocity of c.

In the second case, if the listener moves toward the fixed source, the waves appear to him to arrive with a velocity (c+vo). The wavelength of thepropagation in this caseremains unchanged, but the relative velocity increases.

It may be shown that the frequency f', of the sound received is given by the expression ;

$$f' = \frac{(c +/- vo)}{(c +/- vs)} f$$

Where:

the frequency of the source

c - the velocity of propagation including the component of wind or current velocity from source to observer.

vo - component of velocity of observer in the direction towards the source.

vs - component of velocity of source in direction toward the observer.

f' - f = Doppler shift of frequency.

For the sake ofcompleteness, various possible conditions are considered to see how the expression above is affected.

1 Stationary observer : Now vo = 0.

i) Source moving towards observer:

$$f' = \frac{c}{c-vs} f$$

If the sourcemoves towards a stationary observerwith a large velocity, the frequency f' increases enormously. This is especially so when vs approaches the velocity c (aircraft), and f' can get very large.

ii) Source moving away from observer:

$$f'' = \frac{c}{c+vs} f$$

Therefore, a train or a car giving a whistle or a horn and crossing a stationary observer, the apparent frequency estimated by the observer falls from f' to f" as it crosses him.

2 Stationary source: Now vs=0.

i) Observer moving towards source:

$$f' = \frac{c+vo}{c} f$$

Comparing this case with 1(i) above, it should be noted that the doppler shift of frequency is not as pronounced as in 1(i). Even when c=vo, f' is only 2f.

ii) Observer moving away from source:

$$f'' = \frac{c-vo}{c} f$$

The apparent frequency in the above casedecreases from f' to f".

3 Source and observer moving at vs and vo respectively:

i) vo and vs in same direction as c:

$$f' = \frac{c-vo}{c-vs} f$$

ii) Source and observer moving towards each other:

$$f'' = \frac{c+vo}{c-vs} f$$

In this case, there will be a large shift (increase) of frequency.

iii) Source and observer receding from each other:

$$f'' = \frac{c-vo}{c+vs} f$$

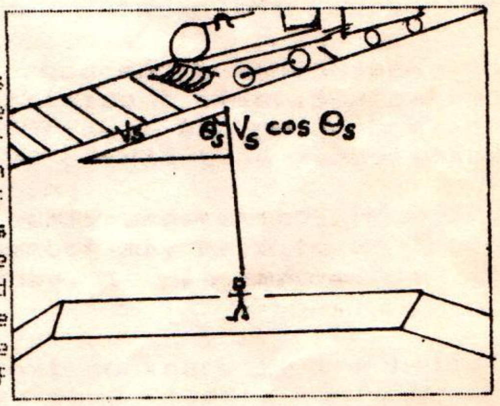
In this case there will be a large shift (decrease) of frequency.

4 Source moving at vs which is greater than c; stationary observer: The sound waves are left behind by thesource as it moves forward. No sound is heard by the observer until the source crosses him. The waves left behind are crowded into a cone and the intensity is greatly increased. These waves are called shock waves andthis effect is called Macheffect. This phenomenon can be experienced when fighter jets fly overhead at supersonic (Mach) speeds.

5 Source and observer moving in different directions making angles of Os and Oo with direction of the velocity of sound c. The expression now becomes:

$$f' = \frac{c-(vo.\cos Oo)}{c-(vs.\cos Os)} f$$

The doppler effect will now not be so pronounced as in the earlier cases when the rates of approach were in the exact direction of the propagation.



From this expression, we see that:

1) The doppler effect is appreciable only when the velocity of the source or observer is appreciable in comparison withthe velocity of propagation ofthe signal. This point is offset by the development of sophisticated electronics which can receive and measure a very subtle Doppler shift of frequency of even a few Hertz.
2) The frequency of reception, f' changes at a high rate if the source and observer pass at close range.
3) f' iszero, i.e. no sound is heard if the observer moves away at the same rate as the sound following him.

The above discussion has been based on sound so that the reader can readily identifywith this everyday phenomena forexample while standing on the railway platform or when travelling on a trainand hearing the whistle of another passing train whether overtaking or travelling in a reciprocal direction. In marine navigation however, sound is not used to any great extent. Ultrasonic and Very High Frequencies are more commonly used.

Uses of Doppler Effect in Navigation

1) Doppler Log - Ultrasonic frequency waves are bounced off the sea bed from the bottom of the ship at an angle and received back. Due to the motion of the craft, the received frequency will be different from thattransmitted and the doppler shift of frequency determines the speed of the craft. Both speeds in the fore and aft as well as athwartships direction can be measured.
2) Berthing Aids - Ultrasonic frequency transmitters are positioned on oil tanker berths and sea islands (usually one forward and one aft). When a tanker manoeuvres alongside, it is imperativethat the vessel has a very low rate of approach velocity, otherwise the berth or ship may be damaged. The ultrasonic of known frequency arebounced off the ship's side and her rate of approach determined by the doppler shift of frequencybetween the transmitted and received frequency. The

rate of approach is then displayed on a large screen for the Pilot and Master to see from the bridge.

3) Satellite Navigation- Satellites orbiting the earth in polar orbits at a height of about 1075 km. are used to transmit VHF/UHF signals. The satellite transmits a steady radio frequency and a receiver in the surface craft detects the shift of frequency as the satellite approachesand draws away from it. The speed at which the note changes establishes how far away the satellite is, just as one can detect how close a racing car is by the abruptness with which the engine note drops from a whine to a growl as it passes. Several Doppler count measurements are made and the position ofthe craft can be derived from these counts.

4) Doppler Radar- This is a radar system which uses the doppler shift of frequency of transmitted and received signals to determine the position and speed of targets. It is a concept which is more popular in avionics than in marine craft.

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16. Navigational Watch Keeping

16.0 General.

Bridge procedures and Watchkeeping arrangements adopted on the bridge vary from ship to ship, depending on some of the following factors:

1) the number of watch keepers per watch.
2) The degree of sophistication of the equipment on the ship.
3) The type of ship, for example tanker, cargo, etc.
4) The roûte/voyage which the vessel is undertaking i.e. open sea navigation, narrow channels etc.
5) Whether there is a Pilot on board.
6) Whether the vessel is at anchor, in port or at sea.

Theseare just a few considerations. Many companies have their own standing instructions which outline procedures and duties to be performedby the various watch keepers.these are extremely helpful because they help the junior officer to understand clearly his responsibilitiesas a member of the bridgeteam. They also give him a right perspective of his role in the navigation of the ship.

The efficiency of agood bridge team to a greatextent depends on the relationships and rapportmaintained between the master and officers.

Manning levels on modern ships are reduced in many cases and each member has to bealert and fully participant ifthe navigation is to be a success. Spectators on the bridge are dangerous and deceptive especially when the rest of the bridge team members are not fully aware that a person is spectating.

Each members function should be clearly understood. However, there will be many occasions when one member may have to do "more than his bit" to back up another member. It is impossible to demarcate duties so finely.

Safety First.

It should be clearly highlighted here that contrary to the belief of many ship's officers, Safety does come first. Safety of navigation always precedes prompt execution of the voyage. Unnecessary delays should of course, be avoided. Commercial pressures should never be used as an excuse to ignore regulations or take unnecessary risks.

Awareness.

It is necessary during any procedure, for all members of the team to have an understanding of the whole operation in addition to their own role in the overall effort. In this way, efficiency is improved by the elimination of misunderstandings, duplication of efforts and the overlooking of important items.

Another problem faced by ship's officers is routines which have to repeated so many times that there is a great tendency to start assuming things and checks. The problem is a real one and cannot be over emphasized.

Human beings are prone to errors. They forget, become confused, make mistakes and one can never be certain that instructions will be followed as intended. Bridge organization should take this into account so this risk due to error is minimized. Undetected instrumental errors are anothermajor source of accidents. Gyro errors, erratic logs, Decca navigators with undetectedlane slip, insufficient knowledge of radio navigational aids coupled with ignorance, slackness and lack of training must not be overlooked.

Navigation methods learnt ashore are seldom practicedat sea. The ship is usually plotted relative to the track at intervals, allowances beingmade for current and leeway by ch ge of heading. Dead reckoning is seldom carried out and tidal information like vectors from tidal atlases is hardly ever used. Navigation is essentially reducedto monitoring cross trackerror. Parallel index techniques provide a more positive approach to navigation in restricted waters.

16.1 The Bridge Procedures Guide (by International Chamber of Shipping)

This guide is a must on all ships today and is intended to supplement and not replace any standing orders from the Master, company or any local or national laws.

The guide should have been read and understood by all the members of the bridge team.

While it is impossible to outline procedures for every ship, the guidelines contained in this guide arevery instructive and it is strongly recommended that they be followed or adapted for each ship.

Outline of the contents of the Bridge Procedures Guide

The guide is presented in three parts:

Part A Guidance to masters and navigating officers
Part B Bridge Check Lists
Part C Emergency Check Lists

Section A: Guidance to Masters and navigating officers

Bridge Organization - Considerations to ensure a sound and efficient bridge system.
Clear instructions on matters which the master should issue in writing.
The master to ensure that no passage is undertaken without a plan having been made prior.
Safety systems - maintenance and readiness of LSA, FFA, drills, training of personnel and awareness.

Passage Planning - Delegation of a responsible officer for this duty.
Pilotage and passage planning - the role of the pilot in the plan.
Notes on passage planning - Passage planning is necessary to avoid undetected errors which may have disastrous consequences.
Parallel Index plotting - Use of this powerful tool on both relative and true motion displays.

Duties of the Officer of the Watch - The officer of the watch is the master's representative, and his primary responsibility at all times is the safety of the ship.
What it means to keep a good watch.
Mainengines, their availability,limitations, characteristics etc.
Changing over the watch, periodic checks of navigational equipment, helmsman/automatic pilot, navigation in coastal waters, restricted visibility, calling themaster, navigation with pilot embarked, watchkeeping personnel, Search and rescue, helicopter operations, logbooks bridge and emergency check lists, ship at anchor, ship's draught and manoeuvreing information and bridge located systems like fire detection, machinery condition, cargo condition sensors etc.

Operation and maintenance of navigational equipment - The importance ofthe officers' thorough familiarization with all navigational equipment, checks, limitations and how-to-get-the-best-out-of-it techniques cannot be over emphasized.

Annex 1 - Pilot Information Exchange Card -can be adapted to each particular ship.

Annex 2 - Wheelhouse poster - containing dimensions, performance curves, particulars, manoeuvreing characteristics etc.

Annex 3 - Guidance of steering gear test routines.
Annex 4 - Use of VHF.
Annex 5 - Boarding arrangements for Pilot.

Part 2 - Bridge Check Lists
These check lists are extremely useful and are provided in handy laminated cards which can be carried around and practically used for the following situations. It should be understood that the check lists are not an end in themselves but only ensure that important items are not left out. More items can be added and irrelevant ones omitted.

- Familiarization with bridge equipment
- Daily tests and checks
- Preparation for sea
- Embarkation/disembarkation of pilot
- Master/pilot information exchange
- Navigation, deep sea
- Navigation, coastal and in Traffic Separation schemes
- Changing over the watch
- Preparation for arrival in port
- Anchoring and anchor watch
- Restricted visibility
- Navigation in heavy weather or in a Tropical Storm area
- Navigating in ice

Part 3 - Emergency Check Lists

- Main engine failure
- Steering failure
- Gyro/compass failure
- Bridge Control / telegraph failure
- Imminent collision/collision
- Stranding
- Fire
- Flooding
- Boat/liferaft stations
- Man overboard
- Search and rescue.

16.2 Principles of Watchkeeping arrangements for a navigational watch.

1. Watch arrangements.

a) The composition of the watch shall at all times be adequate and appropriateto the prevailing circumstancesand conditions and shall take into account the needfor maintaining a proper look out.

b) Whendeciding the composition of thewatch on the bridge which may include appropriate deck ratings, the following factors, inter alia, shall be taken into account.
i) at no time shall the bridge be left unattended,
ii) weather conditions, visibility and whether there is daylight or darkness,
iii) proximity of navigational hazards which may makeit necessary for theofficer in charge of thewatch to carry out additional navigational duties, iv) use and operational condition of navigational aids such as radar or electronic position-indicating devices and any other equipment affecting the safe navigation of the ship, v) whether the ship is fittedwith automatic steering, vi) any unusual demands on the navigational watch that may arise as a result of special operational circumstances.

2. Fitness for duty.
The watch system shall be such that theefficiency of watchkeeping officers and watchkeepingrating is not impairedby fatigue. Duties shall be so organized that the first watch at the commencement of a voyage and the subsequent relieving watches are sufficiently rested and otherwise fit for duty.

3. Navigation.
a) The intended voyage shall be planned in advance taking into consideration all pertinent information and any course laid down shall be checked before the voyage commences.
b) During the watch the coursesteered, position and speed shall be checked at sufficiently frequent intervals, using any availablenavigational aids necessary, toensure that the ship follows the planned course.
c) The officer of the watch shall have full knowledge of the location and operation of all safety and navigational equipment on board the ship and shall be aware and take account of the operating limitations of such equipment.
d) The officer in charge of a navigational watch shall not be assigned or undertake any duties which would interfere with the safe navigation of the ship.

4. Navigation Equipment.
a) The officer in charge of the watch shall make the most effective use of all navigational equipment at his disposal.
b) When using radar, the officer ofthe watch shall bear in mind the necessity to comply at all times with the provisions on the use of radar contained in the applicable regulations for preventing collisions at sea.
c) In cases of need the officer of the watch shall not hesitate to use the helm, engines and sound signalling appliances.

5. Navigational duties and responsibilities.
a) The officer of the watch shall:
   i) keep his watch on the bridge which he shall in no circumstances leave until properly relieved,
   ii) continue to be responsible for the safe navigation of the ship, despite the presence of the master on the bridge, until the master informs him specifically that he has assumed that responsibility and this is mutually understood,
   iii) notify the master when in any doubt as to whataction to take in the interest of safety,
   iv) not hand over the watch to the relieving officer if he has reason to believe that the latter is obviously not capable of carrying outhis duties effectively, in which case he shall notify the master accordingly.
b) On taking over the watch the relieving officer shall satisfy himself as to the ship's estimated or true position and confirm it's intended track, course and speed and shall note any dangers to navigation expected to be encountered during his watch.
c) A proper record shall be kept of the movementsand activities during the watch relating to the navigation of the ship.

6. Look-out.
In addition to maintaining a proper look-out for the purpose of fully appraising the situation and risk of collision, stranding and other dangers to navigation, the duties of the look-out shall

include the detectionof ships or aircraftin distress, shipwrecked persons, wrecks and debris. Inmaintaining a look-out thefollowing shall be observed:

a) The look-out must be able to give full attention to the keeping of a proper look-out and no other duties shall be undertaken or assigned which could interfere with that task.

b) The duties of the look-out and helmsman are separate and the helmsman shall not be considered to be the look-out while steering, except in small ships where an unobstructed all round view is provided at the steering position and there is no impairment of night vision or other impediment to the keeping of a proper look-out. The officer in charge of the watch may be the sole look-out in daylight provided that on each such occasion;
   - i) the situation hasbeen carefully assessed and ithas been established without doubt that it is safe to do so.
   - ii) full account has been taken of all relevant factors including, but not limited to:
     - state of weather
     - visibility
     - traffic density
     - proximity of danger to navigation
     - the attention necessary when navigating in or near traffic separation schemes
   - iii) assistance is immediately available to be summoned to the bridge when any change in thesituation so requires.

7. Navigation with pilot embarked.
Notwithstanding the duties and obligationsof a pilot, hispresence on boardshall not relieve the master or officer in charge of the watchfrom their duties and obligations forthe safety of the ship. The master and the pilot shall exchange information regarding navigation procedures, local conditions and the ship's characteristics. The master and officer of the watch shall co-operate closely with the pilot and maintain an accurate check of the ship's position and movement.

8. Protection of the marine environment.
The master and officer in charge of the watch shall be aware of the serious effects of operationaland accidental pollution of the marine environment and shall take all possible precautions to prevent such pollution, particularly within the framework of relevant international and port regulations.

16.3 Operational guidance for offecers in charge of a navigational watch.

1. Taking over the navigational watch.
The relieving officer should not take over the watch until his vision is fully adjusted to the light conditions and he has personally satisfied himself regarding:
   - a) standing orders and other special instructions of the master relating to the navigation of the ship.
   - b) position, course, speed and draught of the ship.
   - c) prevailing and predicted tides, currents, weather, visibility and the effect of these factors upon course and speed.
   - d) navigational situation, including butnot limited to the following;
     - i) operational condition of all navigational and safety equipment being used or likely to be used during the watch,
     - ii) errors of gyro and magnetic compasses,

iii) the presence and movement ofships in sight or known to be in the vicinity,

iv) conditions and hazards likely to be encountered during his watch,

v) the possible effects of trim, heel, water density and squat on underkeel clearance.

If at the time the officer of the watch is to be relieved, a manoeuver or other action to avoid any hazard is taking place, the relief of the officer should be deferred until such action is completed.

2. Periodic checks of navigational equipment.

Operational tests of shipboard navigational equipment should be carried out at sea as frequently as practicable and as circumstances permit, inparticular when hazardous conditions affecting navigation are expected: where appropriate these tests should be recorded.

The officer of the watch shouldmake regular checks to ensure that:

a) The helmsman or the automatic pilot is steering the correct course,

b) The standard compass error is determined at least once a watch and when possible, after any major alteration of course; the standard gyro-compasses are frequently compared and repeaters are synchronized with their master compass,

c) the automatic pilot is tested manually at least once a watch,

d) the navigation and signal lights and other navigation and signal lights and other navigational equipment are functioning properly.

3. Automatic pilot.

The officer of the watch should bear in mind thenecessity to comply at all times with the requirements of Regulation 19, Chapter V of the International Convention for the Safety of Life at Sea, 1974. He should take into account the need to station the helmsman and to put the steering into manual control in good time to allow any potentially hazardous situation to be dealt with in a safe manner. With a ship under automatic steering it is highly dangerous to allow a situation to develop to the point where the officer of the watch is without assistance and has to break the continuity of the lookout in order to take emergency action. The change over from automatic to manual steering and vice versa should be made by, or under the supervision of,. a responsible officer.

4. Electronic Navigational Aids.

The officer of the watch should be thoroughly familiar with the use of the electronic navigational aids carried, including their capabilities and limitations.

Theecho sounder is a valuable navigational aid and should be used whenever appropriate.

5. Radar.

The officer of the watch should use the radar when appropriate and whenever restricted visibilityis encountered or expected, and at all times in congested waters having due regard to it's limitations. Whenever radar is in use, the officer of the watch should select an appropriate range

scale, observe the display carefully and plot effectively. The officer of the watch should ensure that range scales employed are changed at sufficiently frequent intervals so that echoes are detected as early as possible.
It should be borne in mind that small or poor echoes may escape detection.
The officer of the watch should ensure that plotting or systematic analysis is commenced in ample time.
Inclear weather, whenever possible, the officer of the watch should carry out radar practice.

6. Navigation in coastal waters.
The largest scale chart on board, suitable for the area and corrected with the latest available information, should be used. Fixes should be taken at frequent intervals: whenever circumstances allow, fixing should be carried out be more than one method.
The officer of the watch should positively identify all relevant navigation marks.

7. Clear Weather.
The officer of the watch should take frequent and accurate compass bearings of approaching ships as a means of early detectionof risk of collision: such risk may sometimes exist even when an appreciable bearing change is evident, particularly when approaching a very large ship or a tow or when approaching a ship at close range. He should also take early and positive action in compliance with the applicable regulations forpreventing collisions at sea and subsequently check that such action is having the desired effect.

8. Restricted Visibility.
When restricted visibility is encountered or expected, the firstresponsibility of the officer of the watch is to comply with the relevant rules of the applicable regulations for preventing collisions at sea, with particular regard to the sounding of fog signals, proceeding at a safe speed and having the engines ready for immediate manoeuvres. In addition, he should:

a) Inform the master (see para 9).
b) Post a proper lookout and helmsman and, in congested waters, revert to hand steering immediately;
c) Exhibit navigation lights;
d) Operate and use radar.

It is important that the officer of the watch should know the handling characteristics of his ship, including it's stopping distance, and should appreciate that other ships may have different handling characteristics.

9. Calling the master.
Theofficer of the watch should notify the master immediately in the following circumstances:

a) If restricted visibility is encountered or suspected;
b) if the traffic conditions or the movements of other ships are causing concern;
c) if difficulty is experienced in maintaining course;
d) on failure to sight land, a navigation mark or toobtain soundings by the expected time;
e) if, unexpectedly, land or a navigation mark is sighted or change in soundings occurs;
f) on the break down of the engines, steering gear or any essential damage;
g) in heavy weather, if in any doubt about the possibility

of weather damage;

h) if the ship meets any hazards to navigation, such as ice or derelicts;

i) in any other emergency or situation in which he is in any doubt.

Despite the requirement to notify the master immediately in the foregoing circumstances, the officer of the watch, should in addition not hesitate to take immediate action for the safety of the ship, where circumstances so require.

10. Navigation with pilot embarked.
If the officer of the watch is in any doubtas to the pilot's actions or intentions, he should seek clarification from the pilot; if doubt still exists, he should notify the master immediately and take whatever action is necessary before the master arrives.

11. Watchkeeping personnel.
The officer of the watch should give watchkeeping personnel all appropriate instructions and information which will ensure the keeping of a safe watch including the keeping of a proper look out....'