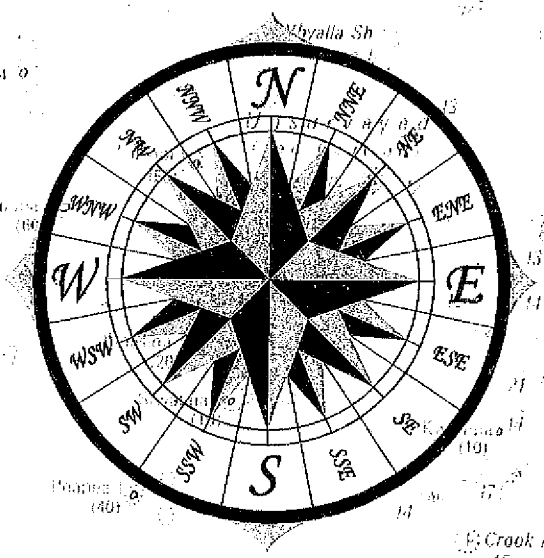
# Pacific Island Qualified Fishing Deckhand



## MODULE 3

# The Marine Compass and Automatic Pilot


Coastal Fisheries Program
Training Section

South Pacific Commission

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**MODULE 3:**

# THE MARINE COMPASS AND AUTOMATIC PILOT

## LEARNING OUTCOMES:

On completion of this module the student should be able to:-

- use a compass to take bearings relative to compass north and the ship's head
- state the causes of error in gyro compasses and recognize the importance of comparing gyro and magnetic compass headings as a means of checking compass error
- calculate the angular difference between magnetic and gyro compass headings for the local area
- list the limitations of the automatic pilot with reference to the maintenance of a good course and safety of the ship
- list te circumstances when an automatic pilot should not be used
- state the cardinal and inter-cardinal points of a marine compass
- explain why a magnetic compass points to magnetic north
- list the causes for deviation of a magnetic compass.

## CONTENT OUTLINE:

### Lesson 3.1 The Marine Compass

History and Background

Use of Compasses at Sea

Reading a Compass

The Magnetic Compass

Magnetic Principles and Variation

Magnetic Deviation

Correcting the Magnetic Compass

### Lesson 3.2 The Gyro Compass and Automatic Pilot

The Gyro Compass

The Automatic Pilot

Pilot Errors

Potential Dangers

### Lesson 3.3 Taking Bearings

Taking Bearings

Methods of Taking Bearings

# Lesson 3.1 The Marine Compass

## HISTORY AND BACKGROUND

The compass has been used as a tool for navigation since 1100AD when early Chinese discovered that a piece of loadstone (iron ore), if allowed to swing freely, would always end up pointing in the same direction.

The first compasses were made by stroking a needle to magnetise it then floating it on a bowl of water by piercing it through a piece of wood. The points of the compass were marked around the edge of the compass bowl and the bowl turned to align the north mark with the direction in which the "north" end of the needle was pointing.

This idea was developed further with the needle being replaced by two parallel magnets. A circular card marked with the points of the compass was placed on top of the magnets with the north/south line on the card aligned with the axis of the magnets. To protect the compass and to compensate for the rolling of the ship the device was placed in a gimballed bowl marked with the direction of the ship's head (lubber line) and this secured in a stand called a binnacle. Comparing the points of the compass with the ship's head and lubber line allowed the ship to travel in a known and constant direction.

This compass was called the "dry card" magnetic compass. An improvement to this was made by sealing the bowl and filling it with liquid. The liquid restricted the movement of the compass card and made it more steady. This type of compass, which is extensively used today is the wet card or "dead beat" compass. Refer Figure 3.1.1 "The Magnetic Compass".

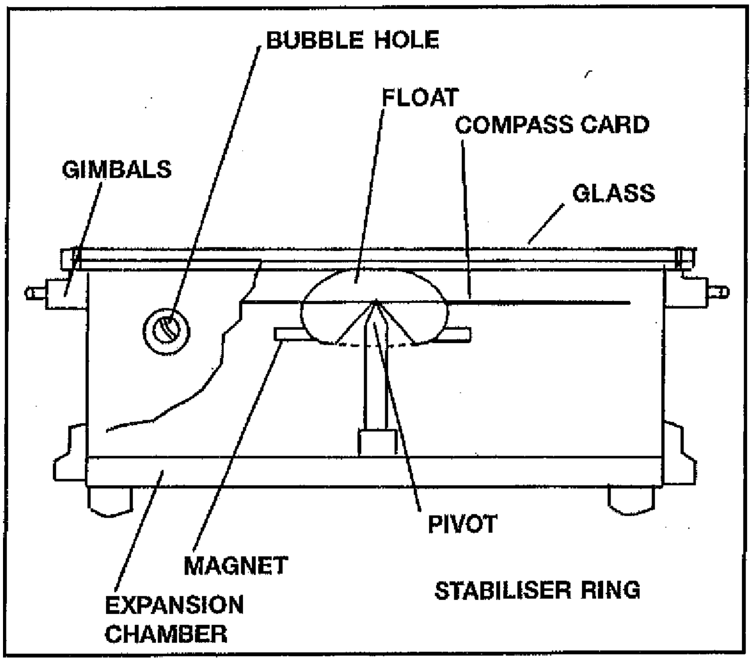



**Figure 3.1.1 The Magnetic Compass**

The magnetic compass was the main instrument for determing direction at sea until the early 20th century when the Germans first developed the gyro compass. The gyro compass uses the principal that a free-spinning wheel which is able to move in all axes (a gyroscope), can be made to point true north when specific forces are applied to it. The gyro compass has the advantages that it points to true north, is very steady, and is not affected by the variety of things which cause errors in the magnetic compass. The gyro is much more expensive than a magnetic compass, more complicated to repair, and requires a constant supply of power to keep it operating.

## USES OF COMPASSES AT SEA

All fishing boats use a compass for steering and knowing direction at sea. Also as a means of obtaining the ship's position by taking compass bearings of known points of land. Gyro compasses have largely superseded magnetic compasses on larger vessels but most smaller fishing vessels continue to use the magnetic compass. Larger fishing vessels will have a gyro compass on the bridge for steering, naturally xand this may be connected to several repeater compasses for taking bearings. For safety reasons and in case of power failure they will also have a magnetic compass which is usually placed on the flying bridge or "monkey island". In some vessels this compass can be read on the bridge below by means of a periscope fitted underneath the compass bowl, which has a glass bottom. This magnetic compass is called the "standard compass." Frequent checks should be made between the stering and standard compasses to ensure neither have developed errors.

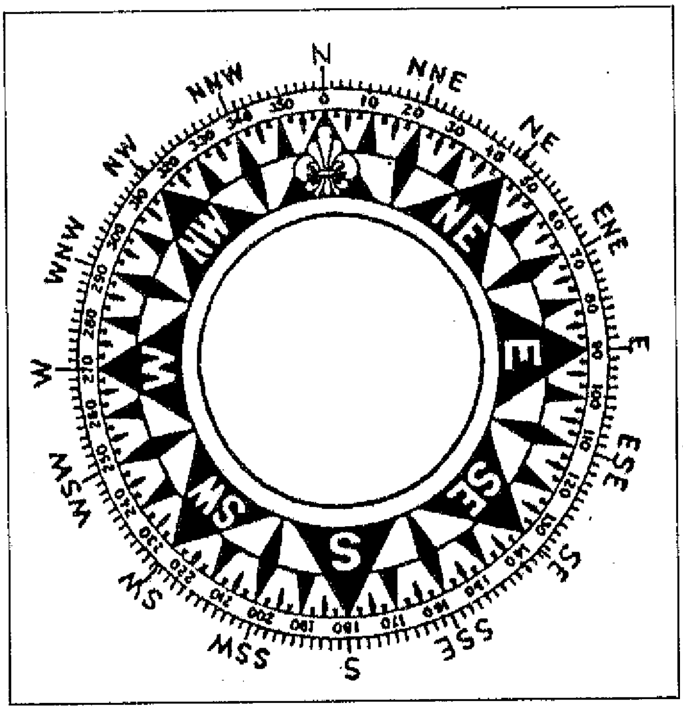



**Figure 3.1.2 The Compass Card**

## READING A COMPASS

Early compasses were marked in points and quarter points but now all courses and bearings on fishing vessels are given using the three figure notation. North is 000° (or 360°) and the direction is named in a clockwise rotation with east being 90°, south being 180°, west being 270° and finally back to north as 360°.

Gyro compass cards are marked using the three figure notation only. Most magnetic compass cards are also marked using cardinal (north south east and west) and intercardinal points (northeast, southeast, southwest and northwest). A compass card is shown in Figure 3.1.2.

While the three figure notation is used for navigation the terminology for direction at sea is usually given using cardinal and inter-cardinal points.

## THE MAGNETIC COMPASS

The magnetic compass does not often point to true north but will point to magnetic north, a little to the east or west of true north depending on the ship's position on the earth's surface. In addition the magnetic compass can deviate from this heading due to a variety of causes and can be unstable due to the rolling and pitching of the ship.

## MAGNETIC PRINCIPLES AND VARIATION

To understand the behaviour of the magnetic compass some of the principles of magnetism should be known.

If a bar magnet is freely suspended one end will always turn to point towards magnetic north. This end is called the north-seeking end or the north pole of the magnet. If this north end is put close to the north end of another magnet it will push it away, while if it is put against the other end (the south end) it will pull it towards it.

> ***REMEMBER***
>
> **Like ends repel - unlike ends attract**

The Compass points north because the earth, due to the magnetism of its molten core, has a magnetic effect (field) similar to that of a small but powerful magnet situated at the centre of the earth. The overall effect of this is for the earth to have magnetic poles situated at each end of the earth close to, but not at, the geographic poles. If a magnet is allowed to swing freely (i.e. a magnetic compass) the north seeking end will be attracted by the North end of the earth and swing to point north. The opposite will happen to the south end.

As the magnetic pole of the earth is not situated directly at the north geographic pole the compass will not usually point to true north. It will point to magnetic north which, depending on where the ship is situated on the earth's surface, will be either to the east or to the west of true north.

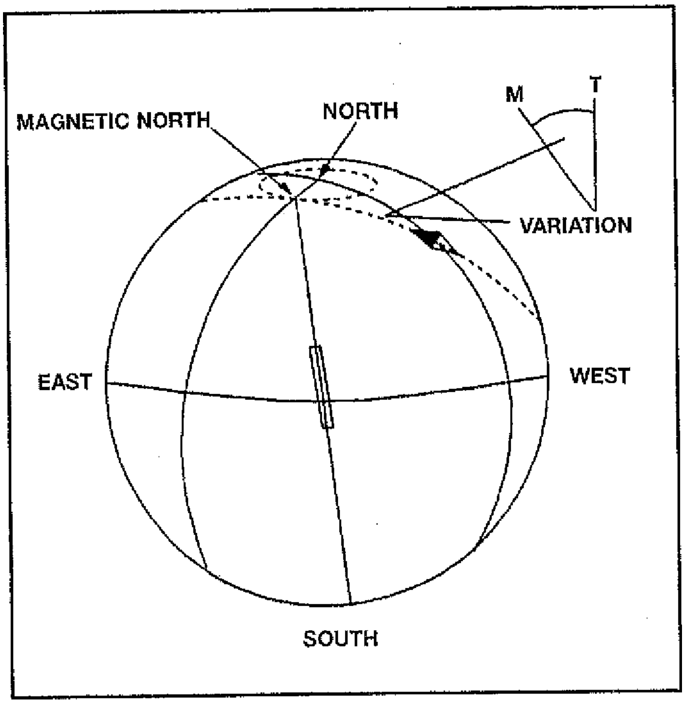



Figure 3.1.3 Variation

This difference is called the magnetic variation. Variation will vary from 25deg E to 25°W as the ship moves around the world. In some places the compass will point directly to true north so that in these places the variation will be zero. This is called the magnetic equator.

The value of the variation is marked on the chart, inside the compass rose or on lines of equal variation drawn across the chart. The skipper of the ship will make allowancees for the variation when plotting a course on the chart or when fixing the position by magnetic compass bearings. The difference between the magnetic course as shown on the magnetic compass and the gyro course as is shown on the gyro compass should be close to the value of the magnetic variation for that location.

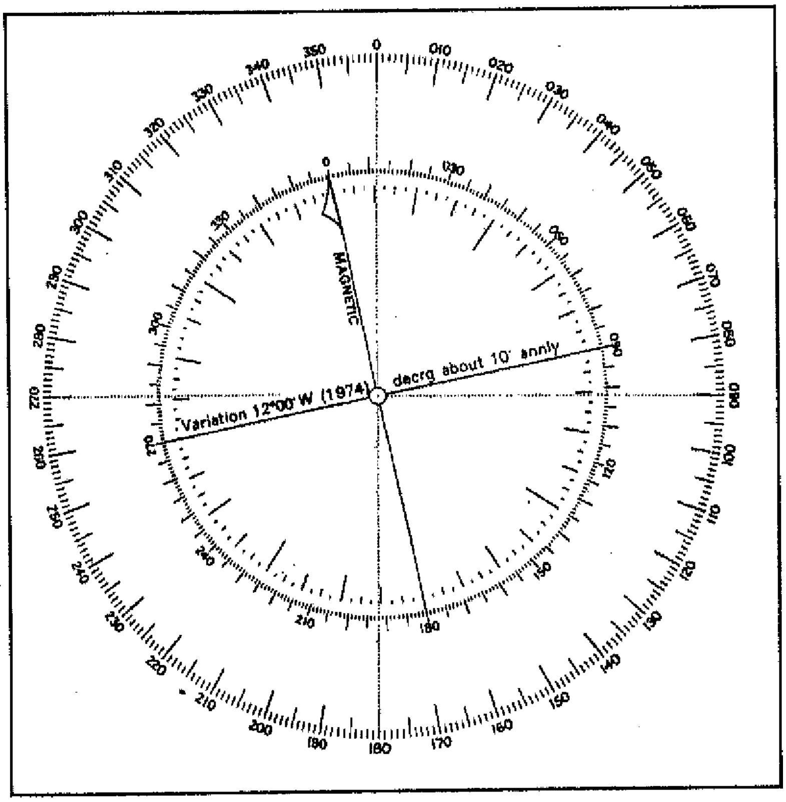



Figure 3.1.4 The Compass Rose

## MAGNETIC DEVIATION

As a compass is made of a free swinging magnet it will also be affected by other magnets close to it and by any iron objects which also have a magnetic force. Most of the electronic equipment on the ship's bridge such as radios and radar have magnets in them; many ships are made of iron or have iron components close to the compass. All of this can have an overall effect of moving the compass from pointing to magnetic north. This movement of the compass from pointing to magnetic to compass north is called magnetic deviation.

### Magnetic Compass Correction

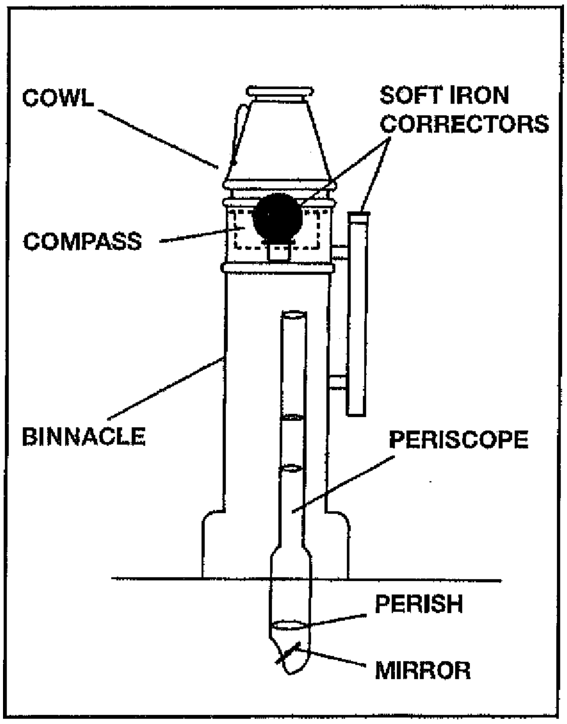



**Figure 3.1.5 The Binnacles**

The effect of deviation is corrected by a compass adjuster who compensates for the iron on the ship by placing magnets (blue and red bars), soft iron spheres and soft iron bars around the compass in a way that their effect is equal and opposite to the effect of the iron on the ship, thus leaving only the effect of the earth. These correctors should never be moved otherwise the magnetic compass will not read correctly.

This is called "swinging the compass" as the ship is swung around in a circle to point in several headings while the correction is in progress. After the compass is swung it will be back to pointing to magnetic north, or very close to it on all headings. The adjuster will issue a deviation card which lists any deviation remaining and the positions of the correctors.

To ensure the compass remains accurate, crew members must take care not to do anything which might cause additional deviation. This might include:-

- Placing anything made of iron close to the compass. This could be a variety of things such as spanners in a locker below, a metal torch placed close to the compass or a tin cup of tea placed close to the compass.
- Anything with a magnet in it such as a transistor radio placed alongside the compass.
- Moving any of the correctors.

Only iron deviates the compass. The compass will not be affected by brass, aluminium, marine-grade stainless steel, wood, plastics and other non-metallic substances.

# Lesson 3.2
# The Gyro Compass and Automatic Pilot

## THE GYRO COMPASS

The Gyro compass is a complicated instrument and the internal adjustments should only be touched by those having experience in its use. The gyro is basically a spinning wheel placed inside a set of gimbals which allows the axis to move in all directions. Due to the forces of its own rotation and the rotation of the earth when the gyro axis is weighted in specific ways it can be made to point true north.

Gyro compasses have the advantage that they need not be adjusted for variation nor are they affected by any external objects as are magnetic compasses. Gyros are very steady, not being affected by the motion of the vessel. An additional advantage is that the master gyro can run several repeater compasses fitted in convenient places.

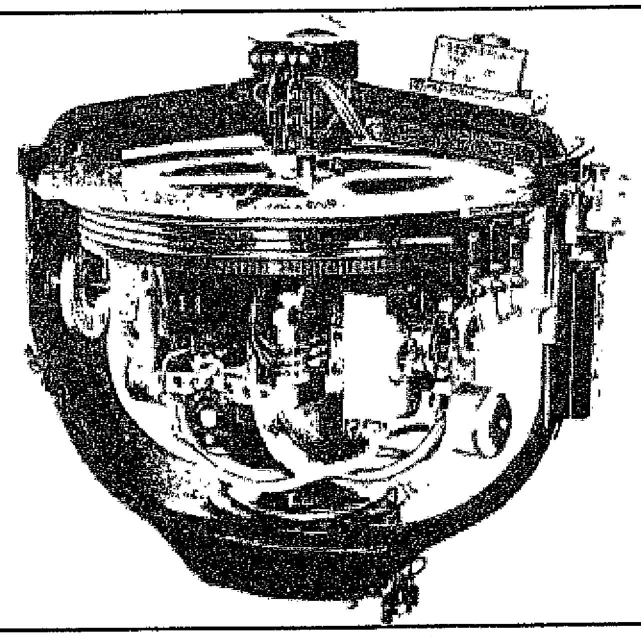


**Figure 3.2.1 The Gyro Compass**

Gyro compasses are reliable but this is dependent on the gyro spinning at a constant speed. Also when the gyro is started it takes up to two hours to settle down to point true north. When the gyro compass is first started it will, very slowly, oscillate each side of north with these oscillations becoming smaller until it settles to point to north. If there is a power failure for any significant length of time the gyro will start to slow down and start to oscillate again. There will be a period after the time the power is re-started before it can be relied on to be reading correctly.

During bridge watch, the gyro compass must be compared with the magnetic compass at regular intervals (every half hour) to ensure that neither has developed any error. This is particularly important if there hs been a power failure for even a short time. The difference between the two compasses should be the same as, or very close to the value of the variation for the vessel's position.

## THE AUTOMATIC PILOT

Most fishing boats use automatic pilots. They can normally steer the boat as well as or better than human hands, freeing the deckhand for more productive tasks. Automatic pilots do not get bored or tired, they are generally reliable, do not get paid overtime and do not speak back. Despite these benefits they are unthinking machines which can go wrong and there have been a significant number of accidents where the use or misuse of the automatic pilot has been a contributing factor.

All automatic pilots need a compass to tell them which way to steer the boat. This compass may be the ship's gyro or magnetic compass or a designated compass built into the auto pilot. The pilot is controlled by this compass which will be equally affected by all of the previous compass errors. If the compass which controls the auto pilot is wrong, the course the auto pilot is steering is also wrong. Similar to compasses the automatic pilot should be checked at regular intervals, at least every half hour.

## PILOT ERRORS

As the sea gets up, steering becomes more difficult, both for the deckhand and for the automatic pilot. As the boat and the compass swing heavily, an experienced helmsman can often anticipate and meet the swing or do nothing knowing that the boat will swing back onto course as the swell passes beneath. The auto pilot does not think and will blindly follow a swinging compass. If not adjusted it will try to counteract every movement of the compass, in many cases encouraging the boat to swing even more erratically.

Automatic pilots have damping controls which allow them to ignore small swings of the compass and to steer better in bad weather. Experience with the behaviour of a boat and its auto pilot will assist in using the controls to the best effect. In certain sea conditions or extremes of bad weather the boat cannot be steered by the auto pilot and it is necessary to revert to hand steering. This is particularly important when running before a big following sea when the auto pilot may overreact to the vessel's swing and may even cause her to broach, a very dangerous condition.

The unreliability of the auto pilot is itself an inherent danger. Watch-keepers can become reliant upon it and, if a good regime for constantly checking the ship's course is not in place, deviations from the correct course may go unnoticed. Also on the bridge, especially at night after several days' hard fishing, with no one to talk to, (or the necessity of hand steering) a fatigued watch-keeper can fall asleep.

## POTENTIAL DANGERS

The dangers associated with the use of the auto pilot can be summarized as follows:

- a single watch-keeper on bridge falls asleep and the auto pilot steers the boat onto the beach.
- the auto pilot compass is not operating correctly (perhaps deviated by nearby iron) resulting in the vessel not steering the given course.
- the ship steers badly or broaches in bad weather.
- the auto pilot swings off course and settles down on a completely new course.

There are also times when it is not safe for the vessel to be on auto pilot, mainly because too much is happening around the ship for the watch-keeper to pay attention to manipulating the auto pilot. These times are:-

- when entering or leaving port
- when there are lots of other vessels close by
- during tricky navigation such as entering a reef passage
- poor visibility
- when there is bad weather beyond the auto pilot's capabilities.

# Lesson 3.3
# Taking Bearings

Compass bearings are used to fix the vessel's position and to determine whether risk of collision exists. Such bearings can be measured from compass north, called compass bearings or from the ship's head or lubber line, called relative bearings.

Compass bearings are given using the three figure notation. Relative bearings can be given in the three figure notation measuring in a clockwise direction from the ship's head. More often they are measured from either side of the ship's head e.g. "20 degrees on the starboard bow". These are shown on Figure 3.3.1 Reporting Bearings.

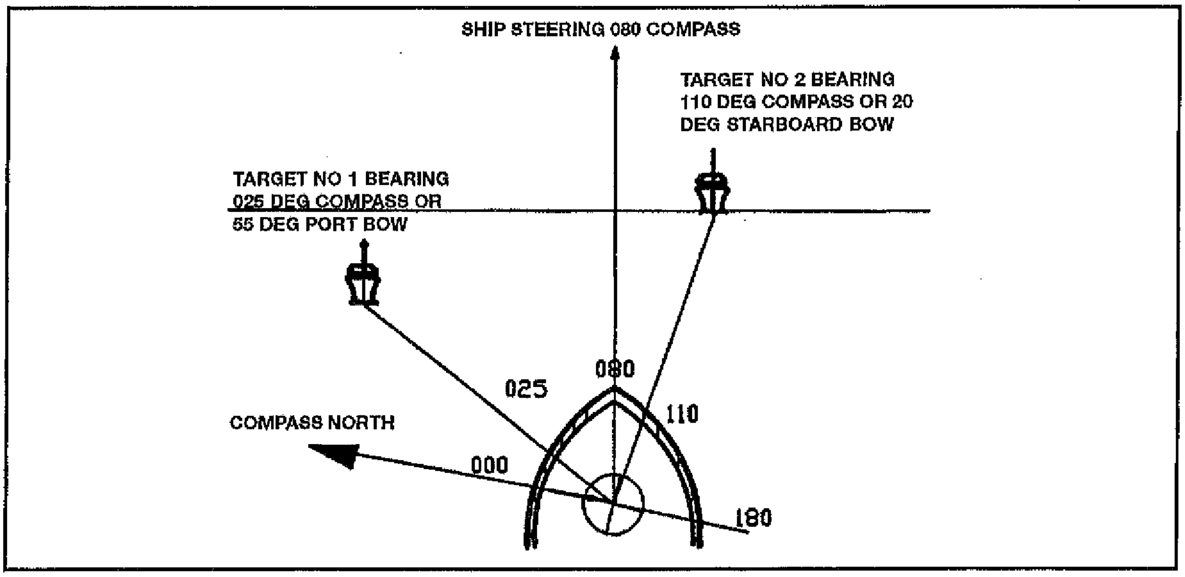



**Figure 3.3.1 Reporting Bearings**

## METHODS OF TAKING A BEARING

When keeping a lookout, relative bearings of objects may be estimated by looking across the compass or by lining up a target with a part of your ship. However, when navigating or determining whether a risk of collision exists it is necessary to be more careful. A simple method of taking bearings is to use a shadow pin which fits on the centre of the compass. On larger ships, standard compasses will be fitted with Azimuth rings for taking bearings while on smaller ships where the steering compass is unsighted a portable hand-bearing compass can be used to take bearings. Both the azimuth ring and the hand-gearing compass incorporate a prism to reflect the bearing object and the compass card simultaneously. This gives an accurate bearing. Deckhands, especially those who will keep a navigational watch must practise and become proficient in the use of these instruments.

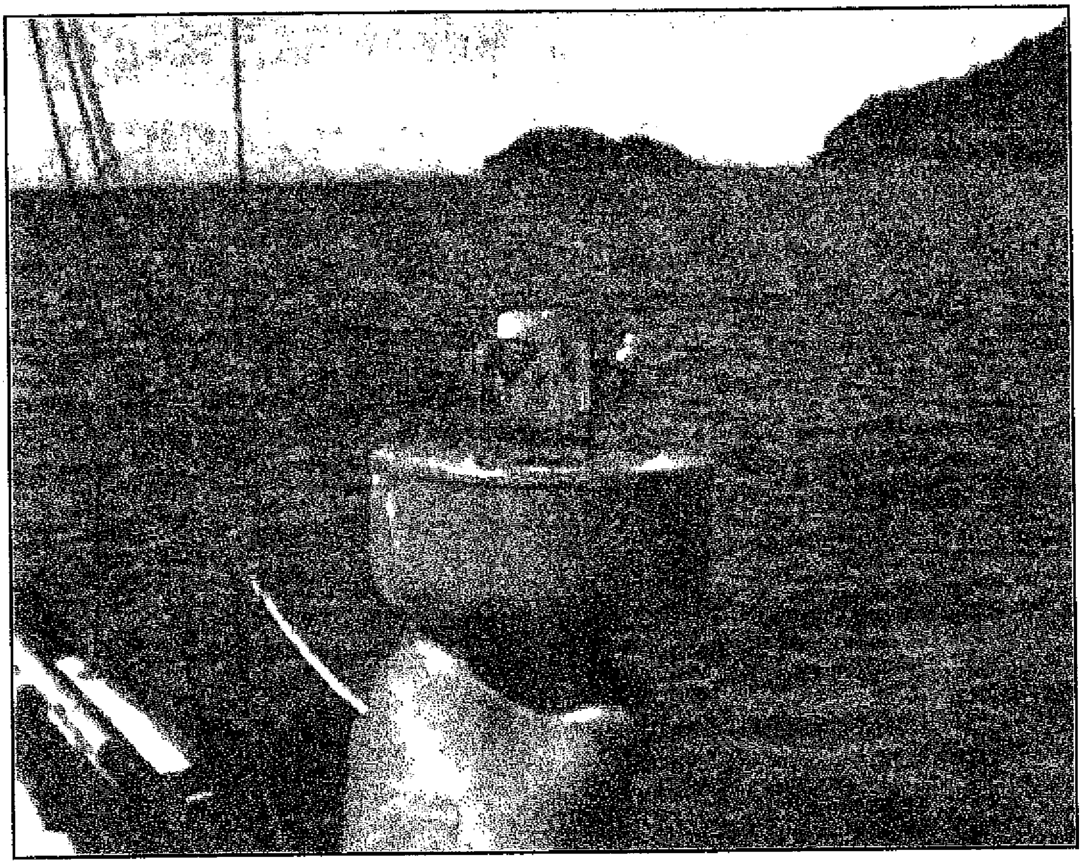


Figure 3.3.2 Instruments for Taking Bearings

# Teaching Notes

## LESSON 3.1

### The Marine Compass

Materials needed for this lesson:

- A magnetic compass
- 2 bar magnets (preferably corrector magnets with red and blue ends)
- Some pieces of iron with some magnetic field
- Some pieces of brass, aluminium, plastic and wood
- OHPs 3.1.1 The Magnet Compass
  3.1.2 The Compass Card
  3.1.3 Magnetic Variation
  3.1.4 The Compass Rose
  3.1.5 The Binnacle
- Local chart with the compass rose and variation marked on it
- Iron filings and sheet of paper

Using the notes explain the development of the magnetic and gyro compass.

Use OHP 3.1.1 to show the parts of a magnetic compass.

Use OHP 3.1.2 to illustrate the points of the compass.

Explain the magnetic principles as follows:-

- Hang a bar magnet on a piece of string so that it is free to spin. It will slowly settle in a N/S line. Ask the class if they know why this happens. Explain.
- Hold a second bar magnet aginst this hanging magnet to show "like poles repel and unlike poles attract". Ask the class how this happens.
- Sprinkle iron filings onto a sheet of paper above a bar magnet to show the "magnetic field" of the magnet. Explain this.

- Explain that the earth has a magnetic field as if it had a bar magnet in the centre of the earth. Use OHP 3.1.3 to explain this. Also explain magnetic north and variation.
- Show the students where variation is recorded on your local chart or use OHP 3.1.4.
- Use the second magnet to show how much a magnet affects the compass. Follow this with the iron which will also affect the magnetic compass and the other materials which will not. Explain deviation in simple terms.
- Use OHP 3.1.5 to illustrate the binnacle and corectors.
- Show AV3.1.1 to illustrate cardinal and inter-cardinal points.

Ask students to read section in course notes and get them to do the assignment in lesson 3.1, to reinforce the learning outcomes of this section.

# Assignments

**LESSON 3.1**
**The Magnetic Compass**

**Mark the following questions true or false:-**

1. A magnetic compass will be deviated by nearby iron.
2. The variation changes with the position on earth.
3. Marine stainless steel will deviate the magnetic compass.
4. A compass adjuster will place magnets around the compass to compensate for the ship's own magnetism.
5. The earth's magnetic pole is situated at the North pole.
6. A magnetic compass points to true north.
7. A magnetic compass will not function if the power is turned off.
8. Brass and aluminium will deviate the magnetic compass.
9. A magnetic compass is used to fix position and to set a course.
10. Larger fishing vessels carry both a gyro compass and a magnetic compass.
11. The standard compass is used for steering.
12. Gyro compasses are more complicated than magnetic compasses.
13. The north end of a magnet will attract the north end of a nearby magnet.
14. The earth has the same effect as a gigantic magnet.
15. Variation is the difference between true north and magnetic north.

**Complete the following multiple choice questions:-**

1. A magnetic compass points to:-

   a. true north

   b. the lubber line

   c. the magnetic bearing

   d. magnetic north

2. The difference between true north and magnetic north is:-

   a. called the variation

   b. is always the same

   c. can be found from a chart where the vessel is operating

   d. is called the deviation

   e. is both a and c

3. A lubber line:-

   a. points ture north

   b. points magnetic north

   c. marks the direction the ship is travelling

   d. is only needed on a gyro compass

   d. none of the above

4. A magnetic compass will be affected by:-

   a. a metal torch

   b. a transistor radio which is not switched on

   c. a chrome-plated spanner

   d. a magnet in a wooden box

   e. all of the above

   f. none of the above

5. Two iron spheres are placed either side of the magnetic compass to:-

   a. keep it balanced as the ship rolls

   b. give the watch-keeper something to hold on to in rough weather

   c. turn it into a gyro compass

   d. compensate for the effect of the ship's iron

**Write answers to the following questions:-**

1. List the cardinal and inter-cardinal points of the compass clockwise from north.
2. List 5 things which will make a magnetic compass reasd incorrectly.
3. Explain why larger fishing vessels have both a gyro and a magnetic compass.
5. What would happen if you removed one of the red and blue magnets from underneath the compass.
6. Draw a diagram of the magnetic compass naming the parts.

# List of Overheads

OHP 3.1.1 The Magnetic Compass

OHP 3.1.2 The Compass Card

OHP 3.1.3 Magnetic Variation

OHP 3.1.4 The Compass Rose

OHP 3.1.5 The Binnacle

# Teaching Notes

**LESSON 3.2**

**The Gyro Compass and Automatic Pilot**

Go over the points made in the notes, use participants' personal experience where possible, ask them what kind of compasses they have on their vessels, where they are situated, how they are corrected.

Ask them to recount their experiences with the use of auto pilots emphasising any difficulty or "close shaves" while using the auto pilot.

Show AV 3.2.1 The Gyro Compass

# Assignments

**LESSON 3.2**

**The Gyro Compass and Automatic Pilot**

**Mark the following questions true or false:-**

1. A gyro compass points to true north.
2. The difference between a magnetic ompass heading and a gyro compass heading will be close to the variation of the area.
3. A gyro compass is sued to fix position and to set a course.
4. A magnetic and a gyro compass can never read the same.
5. A gyro compass can never be wrong as long as the power is on.
6. A gyro compass needs to be compensated by placing soft iron spheres and magnets around it.
7. The gyro compass should be compared with the magnetic compass once a day.

**Write answers to the following questions:-**

1. Give three reasons why an auto pilot may not steer a correct course.
2. What are the dangers of relying on the auto pilot when you are tired?
3. List the circumstances whn it would not be safe to use the auto pilot.

# List of Overheads

OHP 3.2.1 The Gyro Compass

# Teaching Notes

**LESSON 3.3**

**Bearings**

Use the notes and OHP 3.3.1 to explain the different bearings. If possible show the students a shadow pin, an azimuth ring and a hand-bearing compass. Demonstrate how they work, otherwise show AV 3.3.2 to explain how they work.

# Assignment

**LESSON 3.3**

**Taking Bearings**

Have students practise taking bearings reporting these as both a compass bearing and a relative beraing until they have consistent accuracy.

You can play a "game" by hiding small prizes (e.g. chocolate bars) and have the students find them by taking bearings from given objects. This is usually good for a bit of fun.

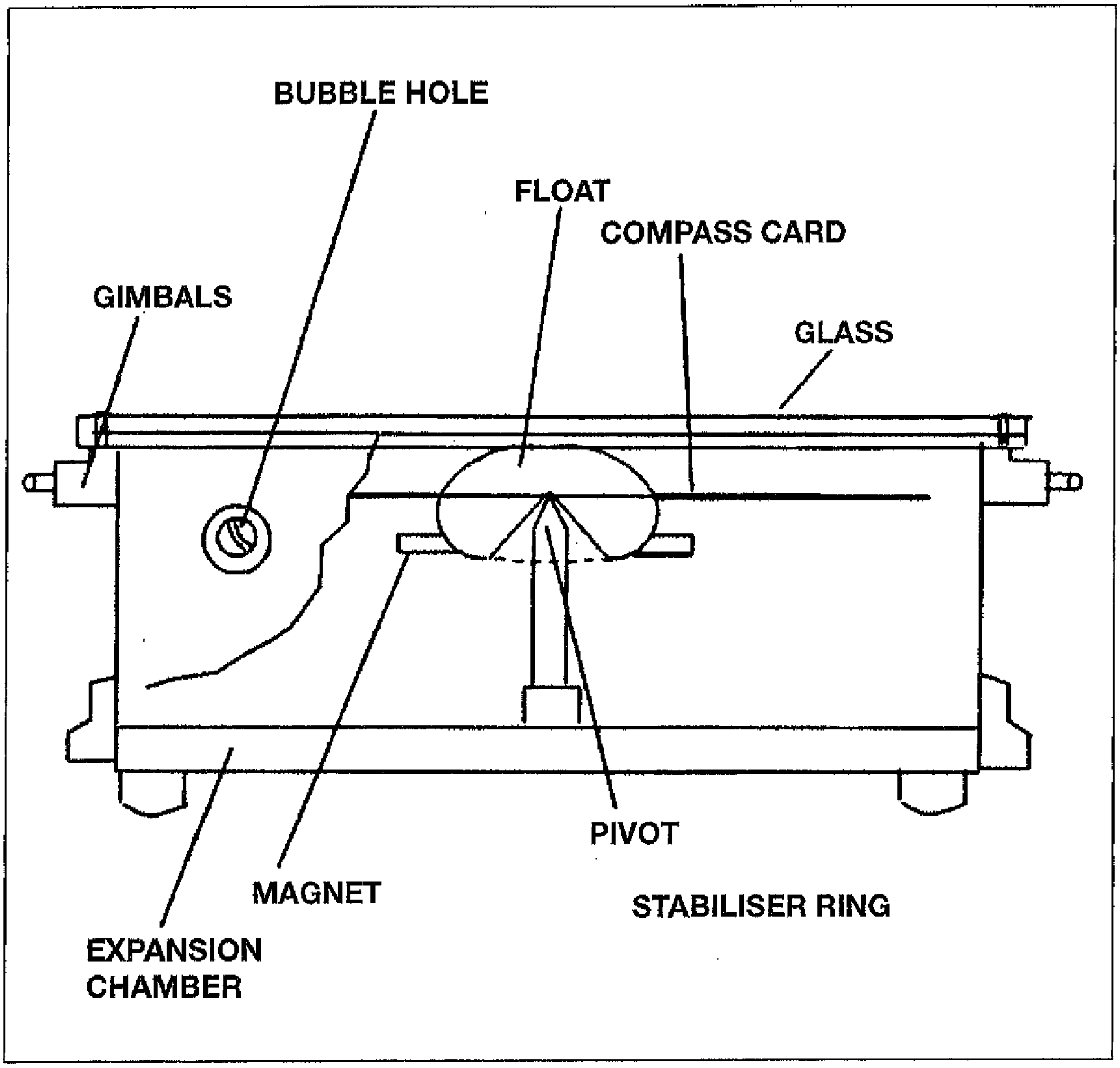
# List of Overheads

OHP 3.3.1 Reporting Bearings

OHP 3.3.2 Instruments for Taking Bearings.

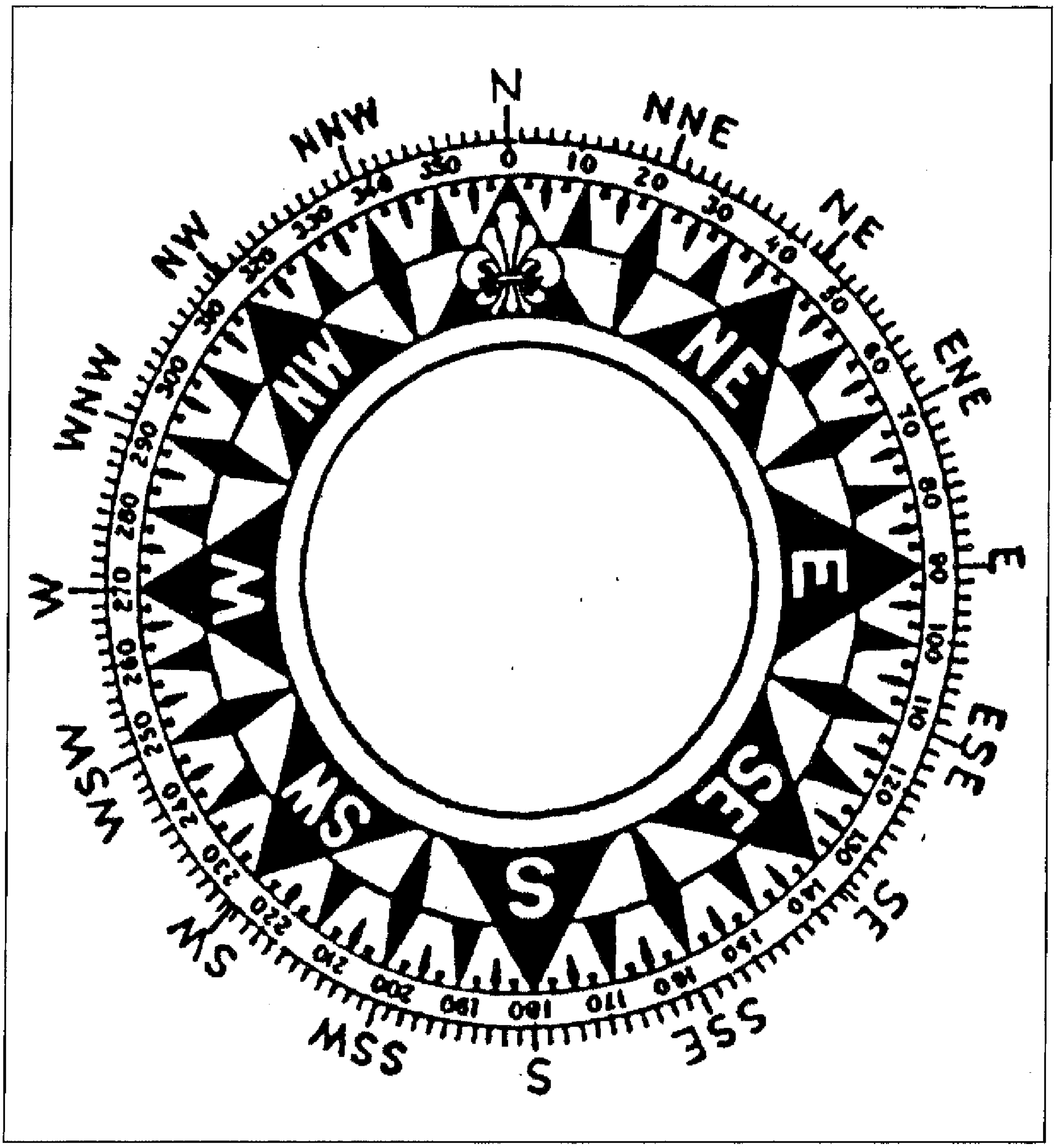
# OHP 3.1.1

## THE MAGNETIC COMPASS



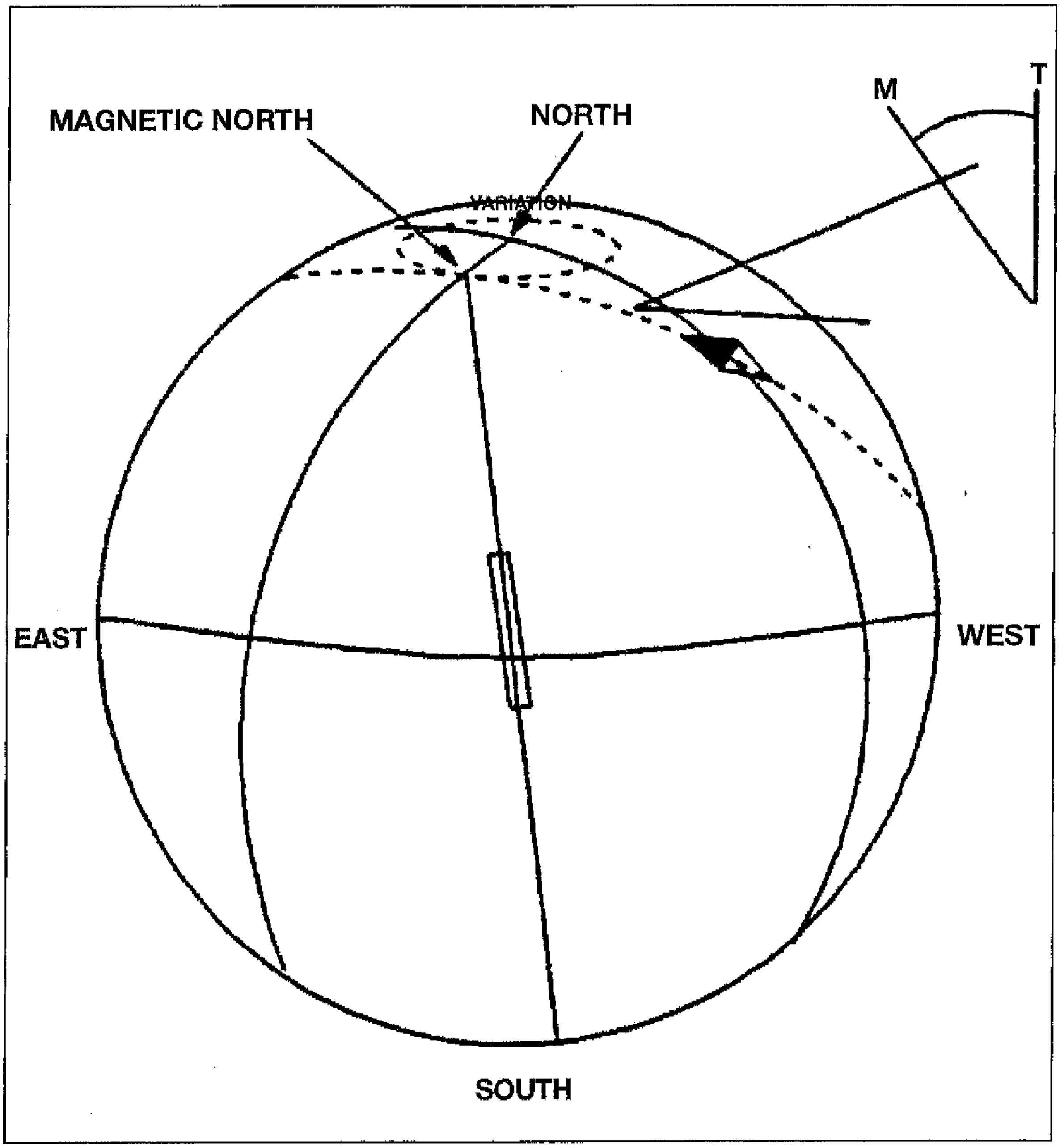
# OHP 3.1.2

## THE COMPASS CARD



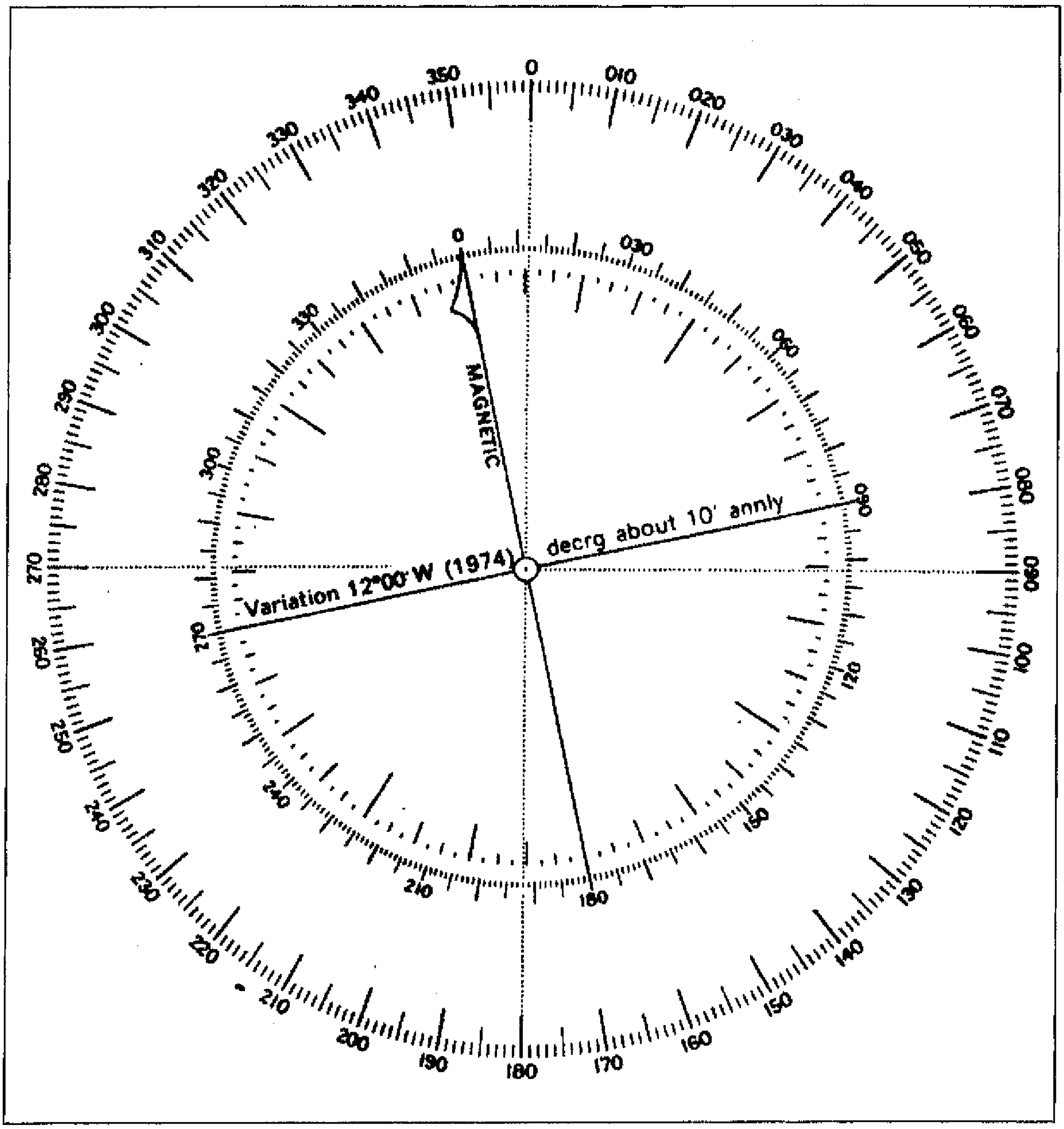
# OHP 3.1.3

## MAGNETIC VARIATION



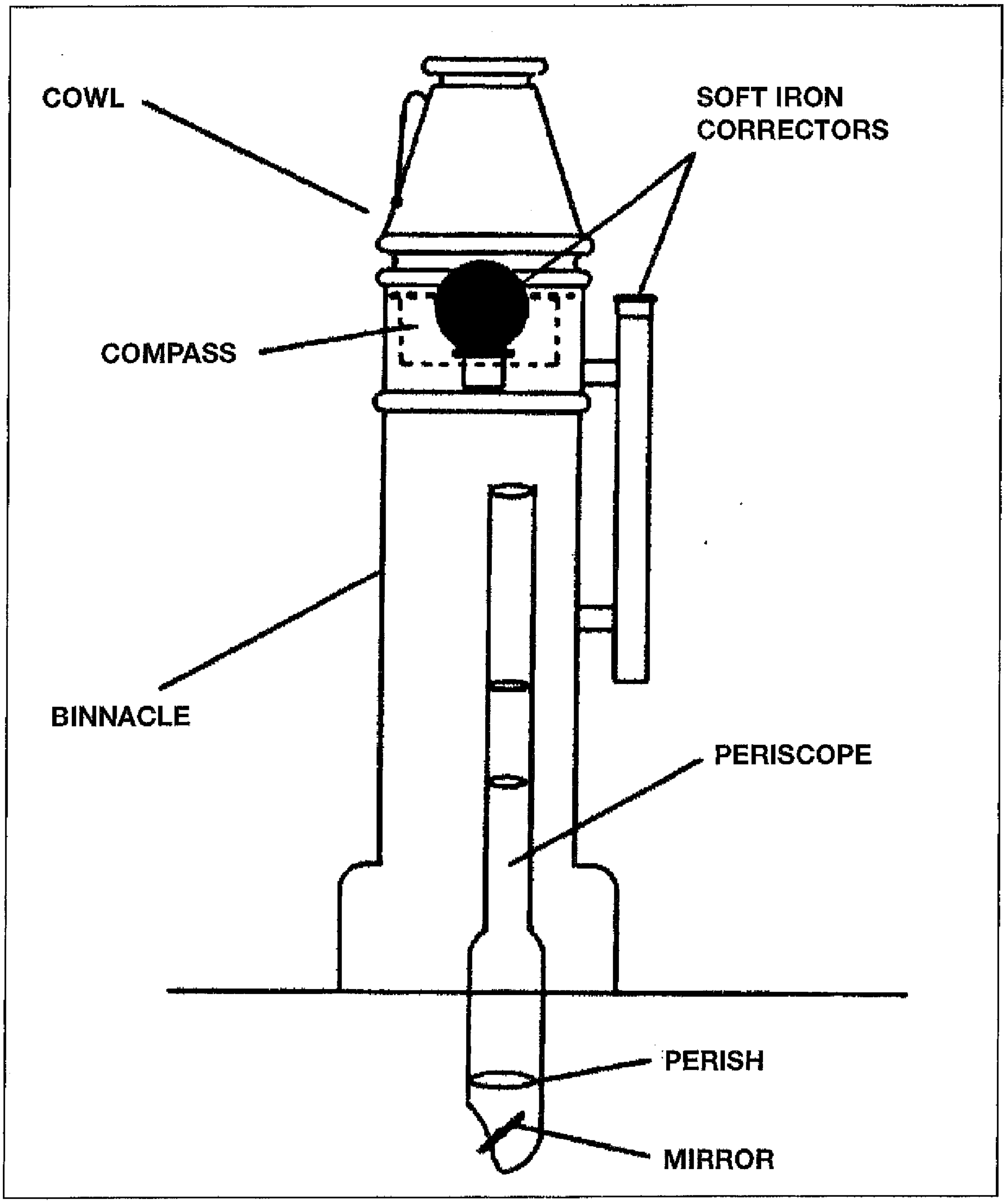
# OHP 3.1.4

## THE COMPASS ROSE



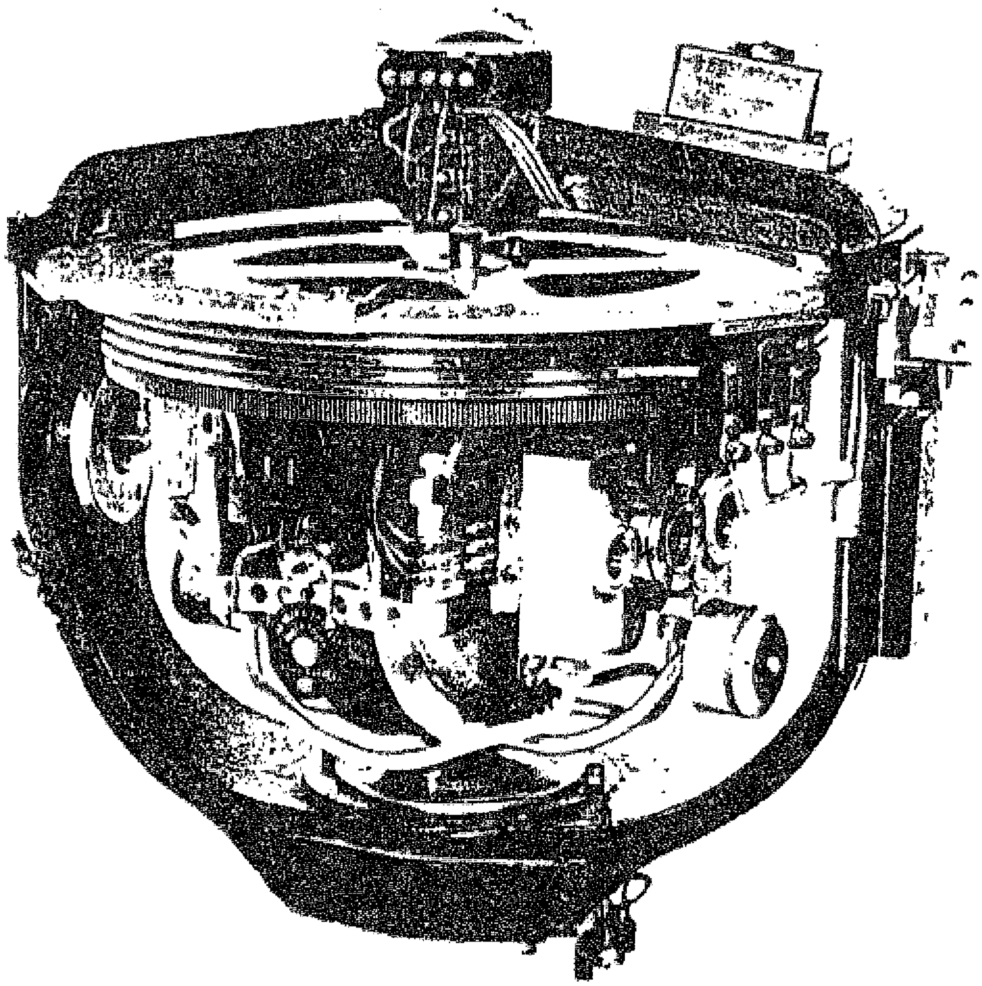
# OHP 3.1.5

## THE BINNACLE



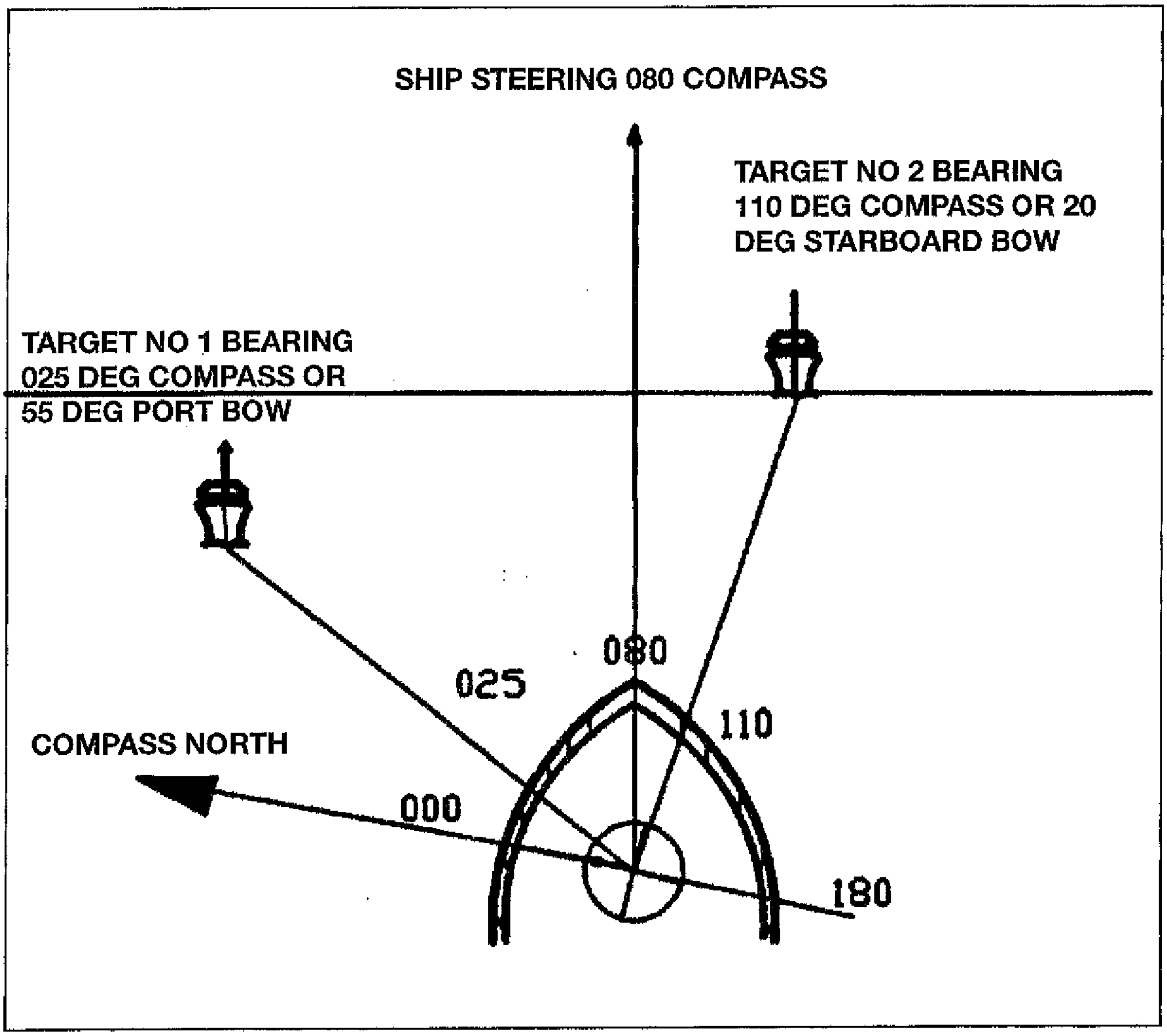
# OHP 3.2.1

## THE GYRO COMPASS



# OHP 3.3.1

## REPORTING BEARINGS



# OHP 3.2.2

## INSTRUMENTS FOR TAKING BEARINGS