MAGNETIC COMPASS

Magnet :

Magnetic lines of force of a bar magnet can be shown by iron filings on paper. A magnet is an object that has a magnetic field.

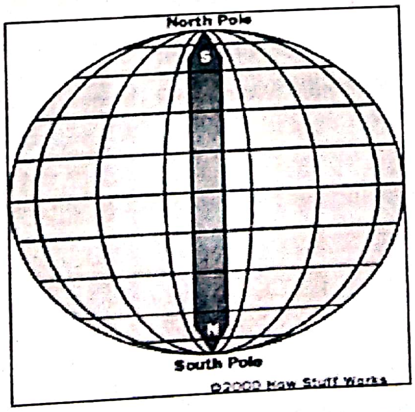
A so-called *permanent* magnet is made of a ferromagnetic material. Such materials consist of atoms or molecules that have a magnetic field (resulting from the spin angular momentum of electrons within them), but objects composed of these materials have magnetic fields only to the extent that these microscopic magnetic fields are positioned to reinforce rather than cancel each other.

An electromagnet has a field produced by a current, typically through a loop or a coil of many turns; its field becomes insignificant when the current ceases.

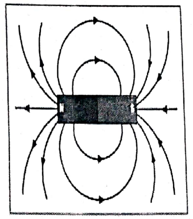
Various materials (soft iron is a frequent example), when exposed to a magnetic field, direct and concentrate it, and consequently share many of the properties of permanent and electro- magnets. Their behavior is often described as induced magnetism. Combinations of electromagnets with such materials, for the sake of this behavior, are often designed as a form of enhanced electromagnet.

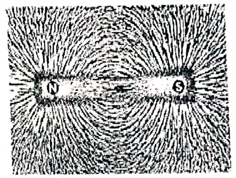
A magnet is a magnetic dipole. That is not really a statement about "having two poles", but about the mathematical properties of its magnetic field, which are reflected in the "magnetic field lines" or "lines of force". The poles are not a pair of things on or inside the magnet, but rather, for the purposes of this article, the two areas on the surface that look as they do in the image. (That look is a consequence of the highest surface intensity of the magnetic field strength occurring there.)

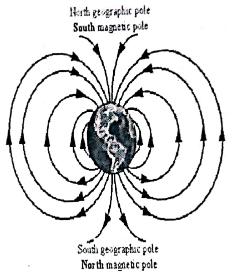
A standard naming system for the poles of magnets is important. A magnet can be regarded as having two magnetic poles; one "north" and one "south"



A freely suspended magnet will eventually orient itself north-to-south, because of its attraction to the north and south magnetic poles of the earth. The end that points towards the Earth's geographical North Pole is called the magnetic north pole; correspondingly, the other end that ends up pointing south is the magnetic South Pole. Note that since the north pole of the magnet is attracted to the south pole of another magnet, the Earth's *geographic north* is actually a *magnetic south*.







Using this approach as a definition of terminology for magnetic poles and fields would require a clarification about the terms not being interchanged when the earth's magnetic field undergoes its next reversal. Without addressing the details, a formal definition in terms of direction of current in an electromagnet and a "right-hand rule" defines north and south for magnetic fields.

The mistaken idea of a magnetic pole is that cutting a magnet in half should separate the two poles. separation of parts of such a magnet produces smaller magnets with weaker dipole fields, each with ends that we label north and south. we will never see a north pole without a south one, because in all the magnets that have been found or created they are complementary directions rather than two separable things.

The Earth's magnetic field has a north and south pole. We can use the magnetic field of the Earth to help navigate by using a magnetic compass.

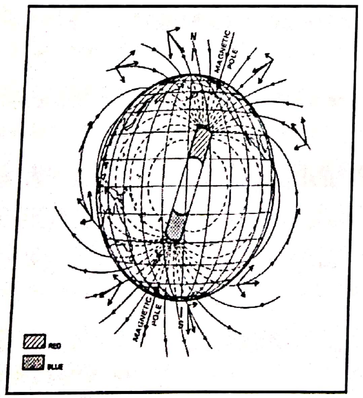
Compasses can also be used to figure out which side of a magnet is the north or south pole of that magnet.

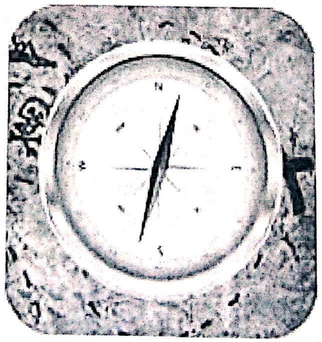
Earth's magnetic field :

The earth, like all other magnets, has a magnetic north pole and magnetic south pole. The axis of the dipole is offset from the axis of the Earth's rotation by approximately 11 degrees. The magnetic north pole is located at an approximate latitude and longitude of 74° N and 101° W. The magnetic south pole is located at an approximate latitude and longitude of 68° S and 144° E. These magnetic poles are distinguished from the true North Pole, latitude of 90° N and the true South Pole, latitude of 90° S.

---The magnetic lines of force that connect the magnetic poles are called "magnetic meridians." These meridians are not great circles. Because of the irregular distribution of magnetic material in the earth, the meridians are irregular, and the planes of the magnetic meridians do not pass through the center of the earth. Approximately midway between the magnetic poles is a line called the "magnetic equator." The magnetic equator is an irregular arc, varying in latitude from 15° S in South America to 20° S in Africa.

--- Colors have been assigned to avoid confusion when speaking of the action of poles. The earth's north magnetic pole is designated as "blue" and the south magnetic pole is designated as "red." A law of magnetism states that "unlike poles" attract each other while "like poles" repel. Therefore, the north-seeking pole of a magnet is attracted to the earth's north magnetic pole and is "red" while the south-seeking pole is attracted by the earth's south magnetic pole and is "blue."





Geographic South Pole :

The Geographic South Pole is the point where the earth's axis of rotation intersects the surface. This is the point usually meant when an unspecified "south pole" is mentioned.

At present, Antarctica is located over the South Pole, although this has not been the case for all of Earth's history because of continental drift.

Magnetic South Pole:

The Magnetic South Pole is the point nearest the Geographic north Pole where the field lines of Earth's magnetic field point directly into the ground.

The earth's magnetism undergoes changes. These changes consist of the following:

Diurnal Changes: These are daily changes which are caused by the movement of the magnetic poles in an orbit having a diameter of about 50 miles.

Annual Changes: These simply represent the yearly permanent changes in the earth's magnetic field.

Secular Changes: These are changes which occur over a period of years.

Some useful definitions

Angle of dip : The angle between the direction of inclination of line of force and the earth's horizontal surface is called dip .Somewhere near the earth geographic equator , each line of force becomes parallel to the earth and the dip becomes zero .

Magnetic equator : An imaginary line on the earth surface joining all places where the dip is zero is called magnetic equator .

Geomagnetic latitude(magnetic latitude) is a parameter analogous to geographic latitude, except that bearing is with respect to the magnetic poles, as opposed to the geographic poles. An angular distance north or south of the magnetic equator , The angle is equal to the magnetic dip or the magnetic inclination

Magnetic materials : These are substances which are capable of being magnetized. They are mainly ferrous materials.

What is the difference between Hard-iron and Soft-iron?

Hard-iron distortions are caused by permanent magnets and magnetized steel or iron object within close proximity to the sensors. This type of distortion will remain constant and in fixed location relative to the sensors for all heading orientations.

Soft-iron distortions are the result of interactions between a magnetic field such as the earth's magnetic field and any magnetically "soft" material within close proximity to the sensors. In technical terms, soft materials have a high permeability. The permeability of a given material is a measure of how well it serves as

a path for magnetic lines of force

.Induced magnetism : Magnetism which is present only when the material is under the influence of an external field .

Permanent magnetism : Magnetism which remains for long period without any appreciable reduction , unless the substances is subjected to a demagnetizing force , is called permanent magnetism .

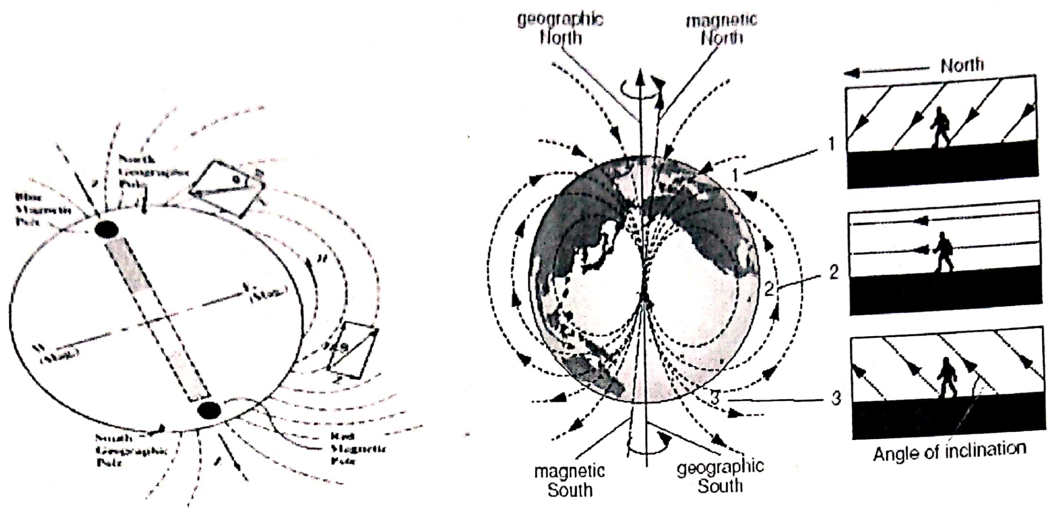
Residual magnetism : That part which remains after magnetizing is removed .

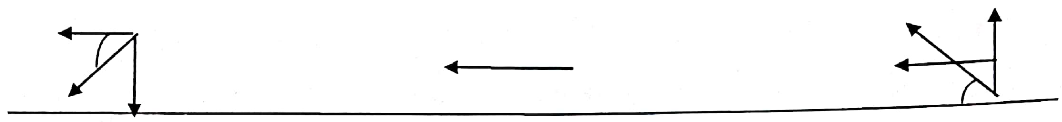
Intensity of magnetization : The strength of magnetization that is much greater in a bar than in the surrounding .

Magnetic Susceptibility : Is a ratio between the intensity of the magnet station and the intensity of magnetizing force causing magnetization .

Magnetic permeability :is the measure of the ability of a material to support the formation of a magnetic field within itself. Hence, it is the degree of magnetization that a material obtains in response to an applied magnetic field.

The earth magnetic field split in to horizontal and vertical components. The horizontal component of the earth magnetic field is a directive force at the compass needle which cause it to lie in the magnetic meridian and show the poles. The vertical component just tilts the needle head toward down or up. In the magnetic equator only horizontal component presents and in the Poles where the lines of Earth's magnetic field point directly into or out of the ground only vertical component presents, there is no horizontal directive component to guide the compass needle toward poles, so magnetic compass does not work in the magnetic poles and it isn't effective in the area near the magnetic poles.





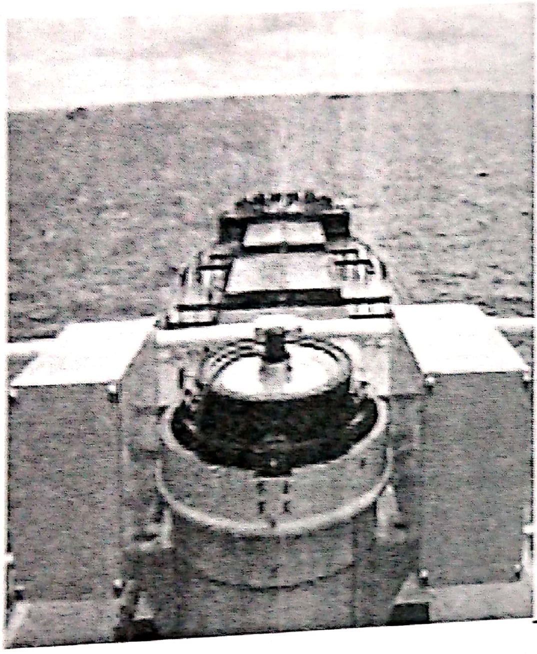
<u>Magnetic compass :</u>

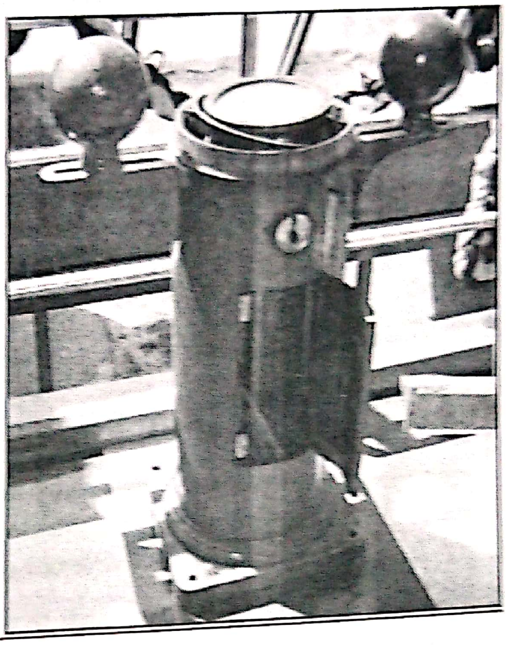
A compass (or mariner's compass) is navigational instrument for finding directions. It consists of a magnetized pointer free to align itself accurately with Earth's magnetic field. A compass provides a known reference direction which is of great assistance in navigation. The cardinal points are north, south, east and west. A compass can be used in conjunction with a clock and a sextant to provide a very accurate navigation capability. This device greatly improved maritime trade by making travel safer and more efficient.

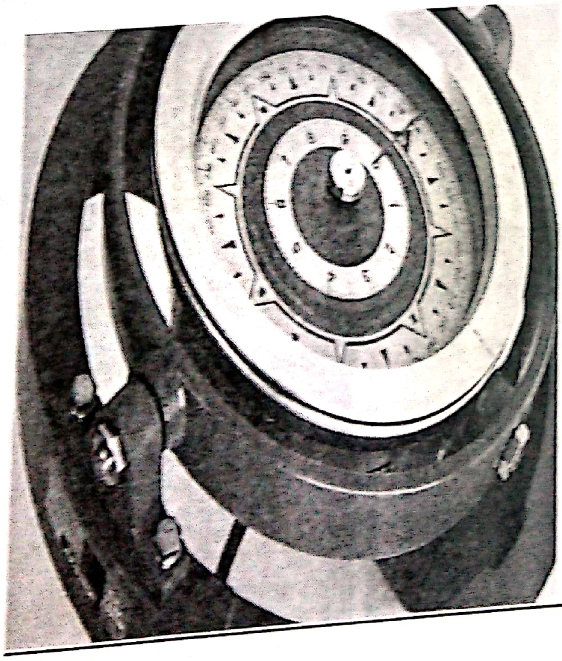
A *compass* can be any magnetic device using a needle to indicate the direction of the magnetic north of a planet's magnetosphere. Any instrument with a magnetized bar or needle turning freely upon a pivot and pointing in a northerly and southerly direction can be considered a compass

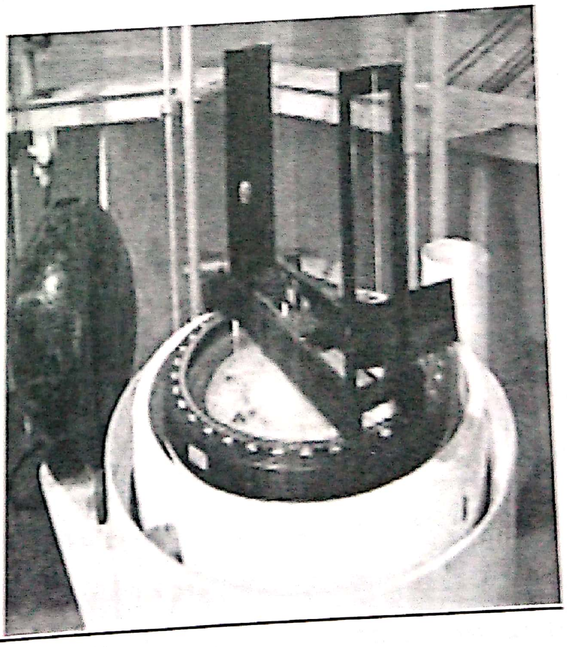
<u>Compass Designation :</u>

The magnetic compass onboard ship may be classified or named according to its location or use. The magnetic compass located in a position favorable for taking bearings and used in navigation is called the standard compass. The magnetic compass at the steering station (used normally for steering or as a standby when the steering gyro repeater fails) is called the steering compass. Direction from either of these instruments must be labeled as "per standard compass" or "per steering compass" for identification. The ship magnetic compass is usually housed on the 'monkey island' above the navigating bridge and reflected into the bridge by means of a periscope like device, so a helmsman can easily read the compass when he is steering the ship.

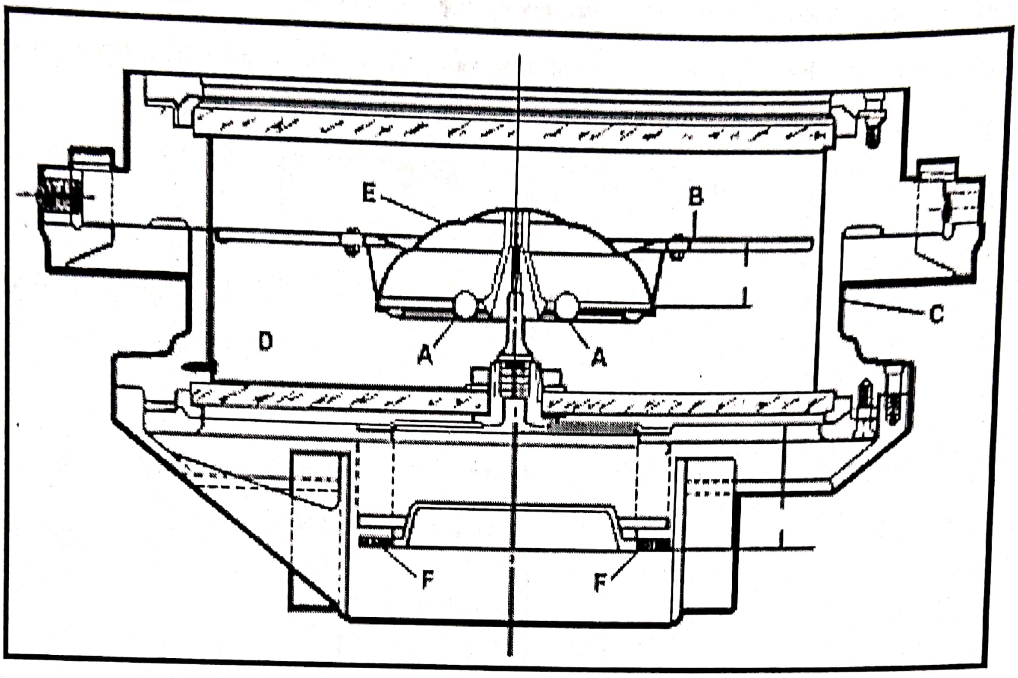








Component of a magnetic compasses:



Magnets (A): These are four (two in older compasses) cylindrical bundles of magnetic steel wire or bar magnets which are attached to the compass card to supply directive force.

Compass Card (B) : This is an aluminum disc, graduated in degrees from 0° to 360° . It also shows cardinal and inter cardinal points. Being attached to the magnets, the compass card provides a means of reading direction.

Compass bowl (C): This is a bowl-shaped container of nonmagnetic material (brass) which serves to contain the magnetic elements, a reference mark, and the fluid. Part of the bottom may be transparent (glass) to permit light to shine upward against the compass card.

Fluid (D) : This is liquid surrounding the magnetic element. According to principle of buoyancy, a reduction of weight results in a reduction of friction, making possible closer alignment of the compass needle with the magnetic meridian. Any friction present will tend to prevent complete alignment with the magnetic meridian. Today's compasses contain a highly refined petroleum distillate similar to Varsol, which increases stability and efficiency and neither freezes nor becomes viscous at low temperatures.

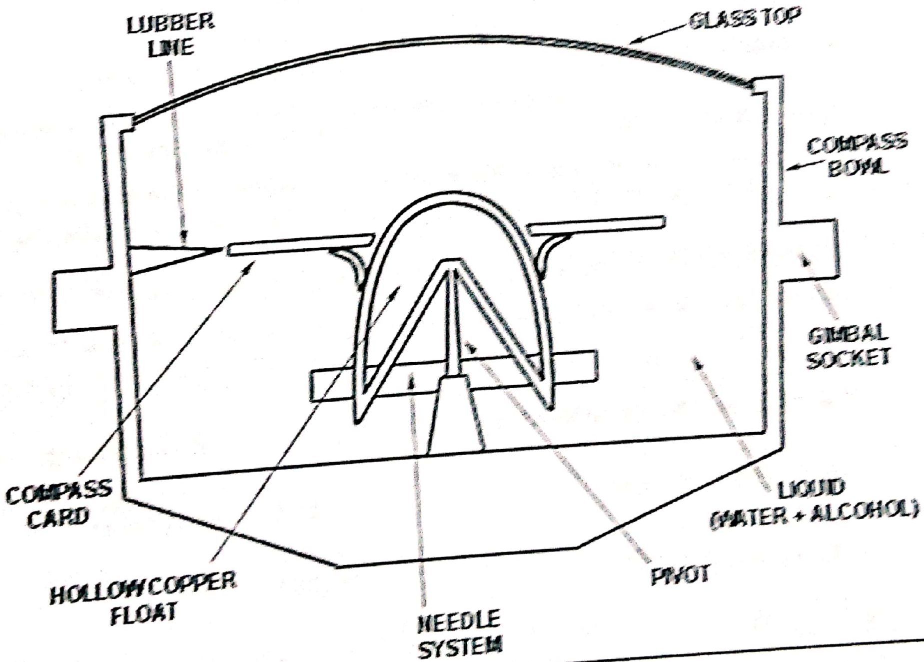
Float (E) : This is an aluminum, air-filled chamber in the center of the compass card. This further reduces weight and friction at the pivot point.

Expansion bellows (F): This is an arrangement in the bottom of the compass bowl. This operates to keep the compass bowl completely filled with liquid, allowing for temperature changes. A filling screw facilitates addition of liquid, which may become necessary notwithstanding the expansion bellows.

NOTE: sometimes an air bubble formed in the compass bowl, this bubbles shall remove by adding fluid to the bowl as per compass maker instruction.

Lubber line : This is a reference mark on the inside of the compass bowl. It is aligned with the ship's fore and aft axis or keel line of the ship. The lubber line is a reference for the reading of direction from the compass card. The reading of the compass card on the lubber line at any time is the "ship's heading."

. Gimbals : This is a metal ring on two pivots in which the compass bowl is placed. The compass is also on two pivots which permits it to tilt freely in any direction and remain almost horizontal in spite of the ship's motion. An important concept is that regardless of the movement of the ship, the compass card remains fixed



LIMITATIONS OF THE MAGNETIC COMPASS :

The following characteristics of the magnetic compass limit its direction-finding ability:

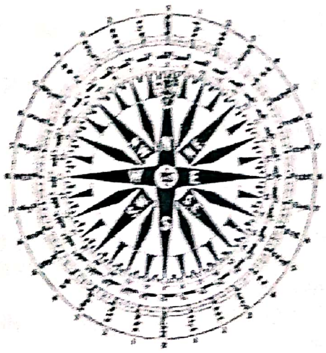
- Sensitive to any magnetic disturbance. So it's important to keep electromagnetic equipment such as walkie talkie away from magnetic compass
- Useless at the magnetic poles and is sluggish and unreliable in areas near the poles.
- Deviation (explained later) changes as a ship's magnetic properties change. The magnetic properties also change with changes in the ship's structure or magnetic cargo.
- Deviation changes with heading. The ship as well as the earth may be considered as a magnet. The effect of the ship's magnetism upon the compass changes with the heading.
- Does not point to true north.

Points of the compass :Boxing the compass

The mariner's compass card is divided into thirty-two equally spaced points. Four of these - east, west, north, and south - are the cardinal points, and the names of the others are derived from these.

REPEAT THE COMPASS.	
N. Stands for North.	S. by W., South by West.
N. by E., North by East.	S. S. W., South South-West.
N. N. E., North North-East.	S.W. by S., South-West by South.
N. E. by N., North-East by North,	S. W., South-West.
N . E., Nort-East.	S. W, by W., South-West by West.
N. E. by E., North-East by East.	W. S. W., West South-West.
E. N. E., East North-East.	W. by S., West by South.
E. by N., East by North.	W., West.
E., East.	W. by N. West by North.
E. by S., East by South.	W. N. W., West North-West.
E. S. E., East South-East.	N.W. by W., North-West by West

S. E. by E., South-East by East.	N. W., North-West.
S. E., South-East.	N.W. by N., North-West by North.
S. E. by S., South-East by South.	N. N. W., North North-West.
S. S. E., South South-East.	N, by W., North by West.
S. by E. South by East.	N., North.



Do iron ships pose particular problems for magnetic compasses?

Yes. The magnetic field of the iron body of the ship itself affects the reading on the compass. When iron and steel ships became common, many scientists studied the problem. One of the earliest was the Astronomer Royal, Sir G.B. Airy, who in 1838 used the iron steamer Rainbow for his experiments. Airy thought of a method of neutralizing a ship's magnetism by placing magnets and pieces of unmagnified iron near the compass. The compass needle effected by earth magnetic field, permanent and induced magnetic fields from ship's iron. The needle will stay in direction with resultant of all magnetic field available.

How was the problem of magnetic variation solved?

Variations do not worry navigators now because of the introduction of the gyroscopic compass. It was invented in 1908. This uses a spinning gyroscope which keeps the compass pointing not to the magnetic north, but to Earth's true North. A rapidly spinning gyroscope is at the heart of the gyrocompass. Once the gyroscope is set spinning, it remains pointing in the same direction, regardless of the ship's heaving motion.Today, a ship anywhere in the world can check its exact position by means of a signal from a satellite in orbit. However, all navigators still have a compass on board as well.

<u>Compass Error</u>

Direction relative to the Geographic North Pole is regarded as TRUE direction. Anything that affects our compass reading, that is, anything that alters it from the direction of true north, is called compass error. We need to understand what forces will do this so that we can correct these errors and derive our actual heading.

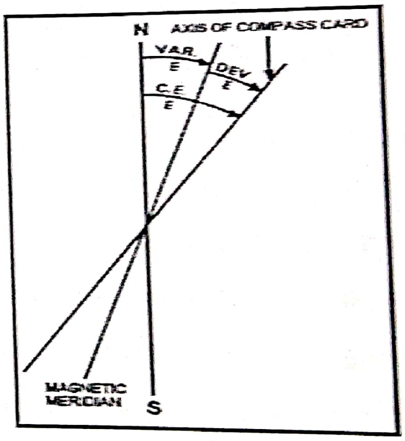
<u>Variation :</u>

As previously mentioned, the magnetic poles correspond roughly with the actual geographical poles. Close, but no cigar. The north magnetic pole is located at approximately 78.9°N latitude and 103.8°W , over 600 miles from the geological north pole. And while your compass doesn't point exactly towards the north magnetic pole, it does point to a location near it.

The problem that's created here is that a compass will point to a direction other than true north, the difference between the two depending where on Earth the compass is.

This error is called *Variation*, and it's the angular difference between true north and magnetic north.

Look at the fig.



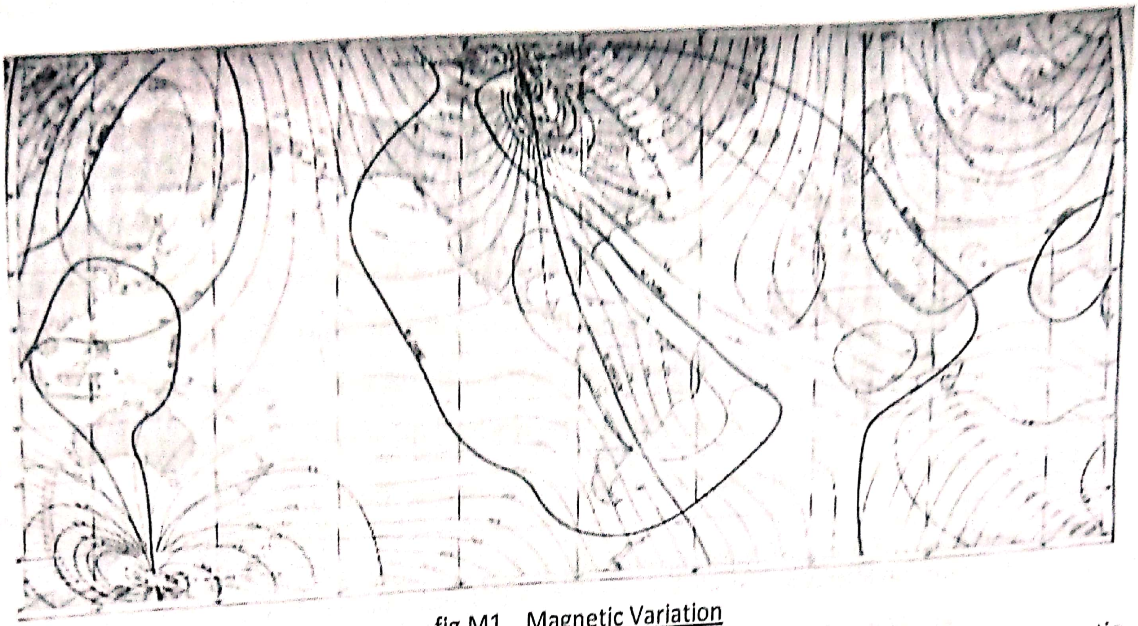


fig.M1 Magnetic Variation

Variation is determined by measuring the angular difference between true north and magnetic north. So, if we are located on Long Island, NY, magnetic north (the direction that our compass points to barring any other errors) is about 14° *west* of the true, geographic north, so our variation is 14°W. Now let's go to the Aleutian Islands of Alaska. Here magnetic north is about 15° *east* of true north, and our variation is 15°E.

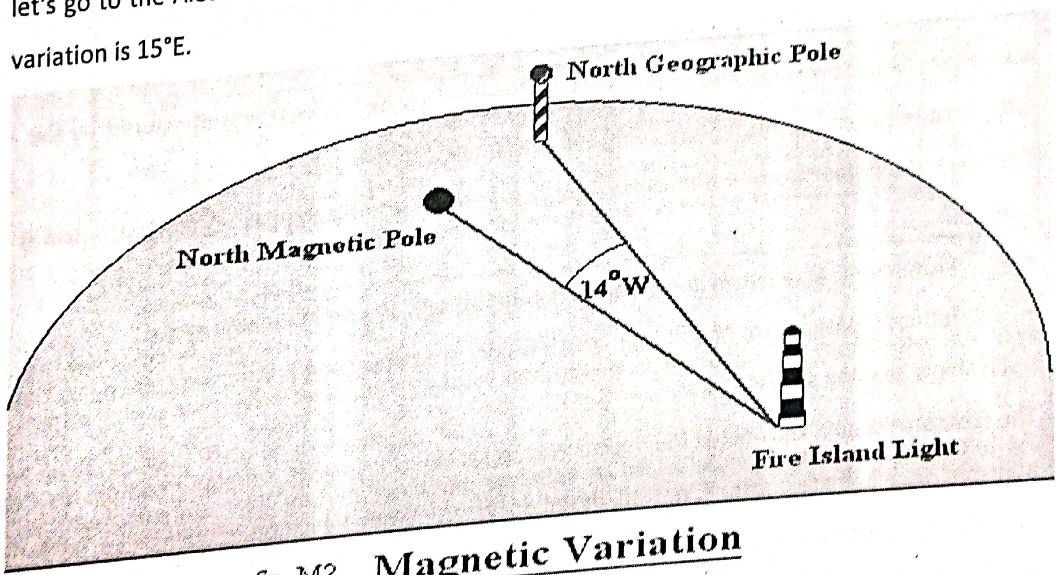


fig. M2 **Magnetic Variation**

Let's look at an example of variation. As shown in fig. M2 above, if we look at our compass as we sail next to the Fire Island Light, we know that the local variation is 14° West. That means that all of our compass readings (barring additional errors) are going to be 14° west of the true direction. Say our compass says we are heading on a course of 090° psc (per ship's compass). We are actually heading 076° ***true***. If the compass reads 015°, we're on a course of 001°.

Some things to remember:

- Another name for variation is *declination*.
- An area's local variation can be found within the Compass Rose of your nautical chart. It changes a very slight amount every year due to the slow migration of the Earth's magnetic poles so check the year that your chart was printed and note the annual increase or decrease in variation.
- Some places have no variation. Other areas have extreme magnetic disturbances, to the point where conventional magnetic compasses are useless. These areas will be marked on charts of the area.
- Variation affects devices that rely on the Earth's magnetic field to work. Gyroscopic compasses, radio direction finders, and global positioning instruments are not effected by variation.

Deviation :

Another force that acts upon your compass to create error is *deviation*. Deviation is the influence of the immediate environment upon your compass. Being a magnet, your compass will be attracted to (or repelled by) iron bearing metal and other magnets (including magnetic fields created by flowing electricity). Unlike variation, deviation is not constant, it's different in every ship, and it's even different within the same ship, depending on which heading she's sailing. Deviation is measured by the angular difference between the magnetic heading and the compass heading.

The magnetic properties of a ship cause deviation in the magnetic compass. Ship magnetism is of two types:

- Permanent: Magnetism in steel or hard iron that acts as a permanent magnet.
- Induced: Magnetism of soft iron, which is only temporary and is constantly changing depending upon ship's heading and latitude.

The navigator should know what the deviation is on his vessel. most quality compasses can be adjusted to eliminate most, if not all deviation error. What deviation remains can be found and documented on a *Deviation Card*.

This card or graph will list the deviation for various compass courses and is referred to by the navigator when compass courses need to be corrected.

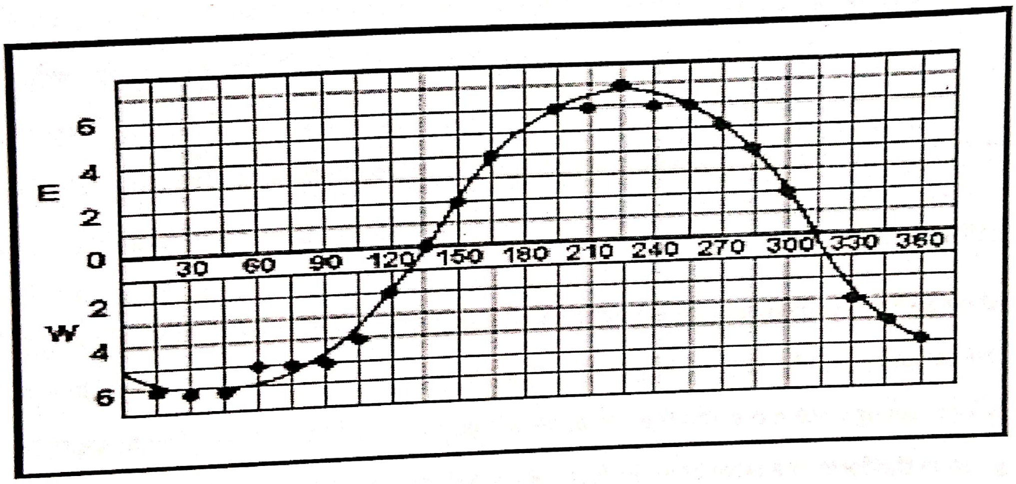
METHODS OF DETERMINING DEVIATION

The most convenient method of determining deviation, and the one most commonly used, is to check the compass on each 15 heading against a properly functioning gyrocompass. Because the ship must be on a magnetic heading when determining deviation, gyro error and local variation must be applied to each gyro heading to obtain magnetic heading. With comparing magnetic heading and compass heading deviation will found for each heading. As much as possible the deviation will be removed by placing permanent magnetic & soft iron near to magnetic compass. The residual deviation will be given in the form of a table or in the form of a graph called the deviation curve.

Some more facts about deviation:

- A common mistake we make as cops is to place the portable radio next to the compass. This is guaranteed to add a huge error to our compass readings.

Sample of deviation card :



<u>Applying compass error:</u>

There many ways to remember how to apply compass error , here we have mentioned one : Error East –Compass Least / Error West – Compass Best.

Our true course is 045° and we know our variation to be 14°W, while our deviation card gives our deviation on this course to be 4°E. First we plug in the numbers:

TRUE	VARIATION	MAGNETIC	DEVIATION	COMPASS
045°	14°W		4°E	

Since we're working from left to right, that is we know our true course and need to find our compass course to steer, we will add west errors and subtract east errors.

TRUE	VARIATION	MAGNETIC	DEVIATION	COMPASS
045°	14°W	059°	4°E	055°

Which gives us a compass course of 055°.

Let's try another one. Here our compass reads 232°, our local variation is 8°E, and our deviation for this course is 6°W. What is our True Course?

TRUE	VARIATION	MAGNETIC	DEVIATION	COMPASS
	8°E		6°W	232°

This time we are working from right to left, so instead of adding west errors, we subtract them (and add east errors) which gives us ....

TRUE	VARIATION	MAGNETIC	DEVIATION	COMPASS
234°	8°E	226°	6°W	232°

<u>Swinging ship :</u>

when a ship is completed ,she is swung and the deviation is found for all headings .As much as possible the deviation will be removed by contracting the ship's polarity with permanent magnets .The vessel will be swung once more and the deviation will be found for all headings .The residual deviation will be given in the form of a table or in the form of a graph called the deviation curve .

This will be done every two years or after any dry dock . It should be noted that different cargoes will have different effects on the ship's polarity and this will affect the deviation

- At dry dock the swing normally will be carried by a compass adjuster .A complete adjustment and swing should be carried out in the following cases:

1- A new ship after her sea trial and prior to her maiden voyage .

2- When there is a large structural changes to the hull .

3- When the ship has been in collision or stranded and subsequently repaired .

4- When the ship has been stricken by lightning .

5- After being laid up for a long time .

6- After a major fire on board .

- A swing should be carried out and deviations tabulated in the following cases :

1- Once a year .
2- After any dry dock .

3- After carriage of cargoes of magnetic nature .

4- After using of electromagnetic cranes .

5- After changing any correctors on board .

6- When considerable change in magnetic latitude or when 50 nm from magnetic equator .

7- When operating in an area remote from the last place of swing .

<u>When we need to check the compass:(taking compass error)</u>

1- After carriage of cargo possessing magnetic properties.

2- After loading or discharging in which electromagnetic crane is used.

3- At least once a watch.

4- Several minutes after any alteration of course.

The deviation so obtained should be recorded in the compass error book.

<u>Care and maintenance of magnetic compass:</u>

1- Keep the binnacle door locked.

2- Keep a record of position of all magnets, spheres, length of filnder bars.

3- Keep the hood on the binnacle to avoid spray and sun lights.

4- Keep free from bubbles, if necessary top up.

5- Check the pivot system move freely.

6- Check no dev. Change when binnacle light on / off.

7- Check the heeling error bucket , chain free to move.

8- Check safe distance from the electro magnetic materials.

9- No portable radio to be placed near to compass.

10- Check the deviation book for any changing pattern from previous voyage.

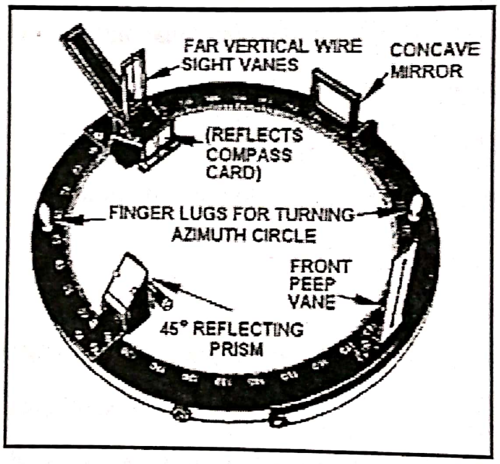
11- If the V/L strike by lighting check the card , magnets and deviation.

12- Check azimuth mirror regularly.

Azimuth Circle

This is a nonmagnetic metal ring. The inner lip is marked in degrees from 0° to 360° counterclockwise for measuring relative bearings. The azimuth circle is fitted with two sighting vanes. The forward or far vane has a vertical wire and the after or near vane has a peep sight. Two finger lugs are used to position the instrument while aligning the vanes. A hinged reflector vane mounted at the base and beyond the forward vane is used for reflecting stars and planets when observing azimuths. Beneath the forward vane are mounted a reflecting mirror and the extended vertical wire.

This lets the mate read the bearing or azimuth from the reflected portion of the compass card. For taking azimuths of the sun, an additional reflecting mirror and housing are mounted on the ring, each midway between the forward and after vanes. The sun's rays are reflected by the mirror to the housing, where a vertical slit admits a line of light. This admitted light passes through a 45 reflecting prism and is projected on the compass card from which the azimuth is directly read. In observing both bearings and azimuths, two attached spirit levels are used to level the instrument.



Fluxgate Compass

The basic fluxgate compass is a simple electromagnetic device that employs two or more small coils of wire around a core of highly permeable magnetic material, to directly sense the direction of the horizontal component of the earth's magnetic field. It can be single core or dual core.

A fluxgate compass is a very important and unique tool in marine navigation as it does not operate automatically like other magnetic compasses. Technically a fluxgate compass is an electromagnetic compass which solves the purpose of a conventional compass.

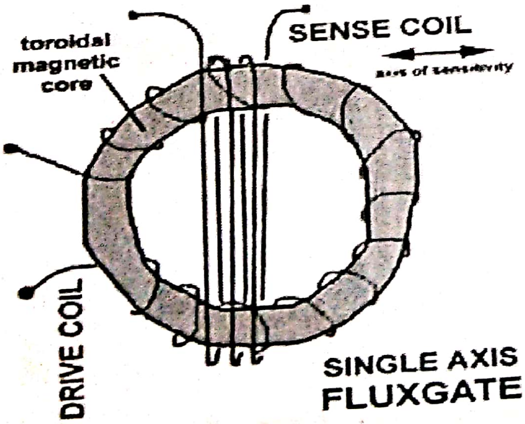
The fluxgate compass is used in ships mainly for the purpose of steering. Since the compass is an electronic one, the scope of errors is greatly reduced.

The difference between a magnetic compass and an electronic compass is that in the former variety there is a pointer that constantly moves indicating the direction. However, in an electronic compass there are no pointers that specify the direction. Electric currents that pass through coils of wire that are kept inside the compass indicate the geographic direction through signals that are displayed digitally. (Solid state type)

Construction & Advantages

There are two coils of wire that are located perpendicular to each other around a permeable magnetic material. When electric current is passed through the coils the core material works an electromagnet and senses the direction of the horizontal component of the earth's magnetic field. This completely eradicates the problem caused due to the interference of the magnetic north is completely avoided. Another advantage of installing this type of compass in the ship is that these types of compasses are unaffected by their placement on the ship. They can be placed anywhere and the directions pointed by the compass can be relied on completely. Fluxgate compass can prove very useful during rough seas as they are unaffected by position and unusual movements.

However, the disadvantage of having an electronic compass is that if there is a complete lack of electricity on the ship then the device will not function making the shipmen rely again on the magnetic compass.



Working principle

the fluxgate compass consists of a coil wound around a permeable core which again, is surrounded by a second coil. This core is magnetically saturated by an alternating cycle in opposing directions called excitation. This will result into a plus and minus saturation of the core. When no external magnetic field present, the flux in one half cancels out the flux in the other coil. When an external magnetic field is briefly applied, a net flux imbalance will occur between the two coils which means the two coils do not cancel out each other anymore.

At this stage current pulses are induced in the second coil which result in a signal that is dependent on polarity and the external magnetic field. This particular signal can be used for finding of the magnetic heading.

The most common use for the fluxgate compass is for steering, giving direct feedback to the pilot or the captain through a display. In the case of using autopilot the fluxgate compass can be used as immediate feedback for the autopilot equipment. A digital signal is sent to the equipment which provides the input for the right steering adjustments. The digital output can also be used for other navigational equipment like radar and chart plotters.

A transmitting magnetic compass (TMC) is used to take the magnetic heading and convert it into a digital signal. By feeding DEV & VAR can show the true heading. This can be used for a variety of reasons including:

- Replacing the periscope
- A back up heading to the auto pilot
- An independent off course alarm
- Showing the magnetic heading in more than one place