The Magnetic Compass

The 12th Century Compass

Due to a natural phenomenon called magnetism, a magnetic object on the earth, if suspended from a thin string so that it is free to rotate in any direction, will always come to rest in the same orientation. Chinese seafarers in the 12th century were using "lodestones" pieces of magnetite, (magnetic iron ore) for navigation.

If you hang a long linear and magnetic object such as a steel needle in this way and it does the same thing. The direction in which it points, depending on where you are on the earth, is generally in a North-South orientation. This is because the earth itself has magnetism and the lines of magnetic force just happen to lie broadly in a North-South orientation. Observation of this phenomenon and making use of it led to the development of the magnetic compass, an invention almost as important to humankind as the wheel.

Because a compass needle always points north-south of course, you can move along a path which is in a steady direction, with your compass, because all you have to do is keep the needle pointing in the same direction relative to you. Thus early explorers were able to travel in a straight line and arrive somewhere that they intended, rather than wandering aimlessly across the planet and discovering new lands by accident.

Marking your Card

There are however certain limitations on its use for following a heading. For example, when you travel north, the needle obliging points in the direction you are going. Travel in any other direction and it doesn't. So you need a mark on your compass dial (the "card") with which to line up the needle so that you can check that you are still travelling in the direction intended. So the compass "card" quickly evolved with north, south, east and west and other subdivisions in between like north-west, south-east. Centuries of sophistication and the ability to navigate more precisely further subdivided the scale into points such as north-north-east and further again such as "nor' nor' east by east".

Eventually divisions of 11.25^{o} (the angle between north-north east and nor' nor' east by east) became too coarse. Divisions of 11.25^{o} were fine for finding a big landmass, but you might miss the port you are aiming for if you were one division adrift. It was then that using degrees instead of named compass points came into use. In aviation this was essential because airfields are even harder to find than harbours.

The Compass in Aviation

Long before the days of gyroscopic direction indicators the magnetic compass was the sole navigational instrument available to aviators. As late as World War II aircraft were being built with no gyros, just a compass. The compass in general use in the RAF at that time was the "P-type" compass, so which had evolved through a number of versions, P2, P4 etc. up to P8 as fitted in the Lancaster Bomber (although the Lanc. Had gyro compasses too).

The P-type Compass

The P-type compass is a fairly massive piece of engineering with compensation magnets built in to correct for any stray undesirable magnetism from iron parts of an aircraft, and filled with oil to act as a damper.

The compass bezel was made to rotate so that you simply rotated the bezel until the heading you wished to steer was against the line marked on the fascia on the aircrafts longitudinal axis (the lubber line) then turn the aircraft until the red painted north point of the needle pointed to the large red N for North on the bezel (hence the expression, "Red on Red").

There were issues with the P-type compass, and one particular problem arose in service, which could (and did) have fatal consequences on occasion during WWII. It was all the more dangerous because it is an insidious problem of human perception.

You had to remember that when you wanted to get home, you had to make sure that you re-set the course home. For example, if the course to enemy territory was 150 degrees on the way out, then on the way back the pilot had to set 330 degrees, the way back home, and then make sure that the pointer with the red cross was back on 'N.'

The only problem was that, in the heat of combat, pilots could (and frequently did) forget to set the reciprocal course home, and then blindly keep turning until they had put 'N' on the pointer with the cross, head farther and farther away from home, and run out of fuel, with its usually horrendous results. In fact, this problem was so severe that some squadrons used to block off the bottom or Southern half of the grid ring as a reminder - but - you still had to re-set the course home.

Directional Gyros

One can't emphasise enough how the Gyrosyn or Gyro-Magnetic or Remote Indicating Compass (which is a gyro compass which senses the earth's magnetic field) would have eased the pain. Although these existed from the thirties, such compasses were not fitted on several of the British service aircraft of WWII, especially fighters. British bombers such as the Avro Lancaster and some others had Remote Indicating Compasses, or RIC's as well as P-type compasses.

Whereas most British aeroplanes had the P-Type compass, most American ones had the simple E-Type magnetic compass in which you could simply read your heading on the face of the instrument.

The directional gyro (Direction Indicator – D.I.) made things much easier again. Once the instrument's internal gyro was up to speed it would stay in that position so long as it was spinning – sort of! As part of the pre-flight checks, the D.I. was set to the compass heading. A simple magnetic compass remains an essential instrument in all today's aircraft because it needs no calibration or power supply and almost never fails.

So having set the D.I. you steer the required course by reference to the D.I. and not the compass. After a while, because of gyroscopic precession caused by the earth's rotation, you notice that although you are steering the correct course on your D.I. the compass shows a different heading. So you adjust the D.I. to read the same as the compass, and steer by the D.I

as before for another 10 or 20 minutes or so when you have to do the cross check again.

The amount of precession on the D.I. depends on how well it has been adjusted for the Latitude that you are flying in. There is a Latitude Nut that a technician will adjust to make the "drift" minimal for the band of Latitude that you usually fly in. You might on a good one be able to fly for 40 minutes without perceptible error...On a bad one or well away from the Latitude it is adjusted for, you might need to reset it every 5 minutes.

MS have made things easy for us by slaving the DI to Magnetic North in FS and even if you have "Gyro Drift" selected you merely have to press the "D" key on your keyboard to realign it.

The P-type Compass in Flight Simulator

One of the default aircraft in Flight Simulator 9, the DeHavilland Comet racing aircraft has a P8 compass available as a pop-up window, the first time this instrument had been modelled for FS. This nicely modelled instrument has been copied into a number of other 3rd party built aircraft in which, in the real world, they would have been fitted.

Unfortunately, the Flight Simulator P8 compass fitted in the FS9 DeHavilland Comet has one fundamental flaw. The needle does not point North; it points to the heading you are flying. Try it on the ground. Start facing north with the compass needle also pointing north. Now slew the aircraft clockwise 90 degrees to point East. The compass needle should rotate anticlockwise 90 degrees in order to keep pointing North.

It doesn't though. It rotates ***clockwise*** 90 degrees and points to East, whereas it should point to West when your aircraft is facing East. If you have not spent much time using a magnetic compass – you were never a Boy Scout or a mountaineer – then this behaviour might not seem odd. You are facing East, the needle points east – what's wrong with that, you may ask? Well a ***real*** compass doesn't do that – the needle always points North.

Microsoft also decided that not only should the needle move in the wrong way and point to the wrong bearing, but the bezel should not be capable of being rotated. This means that the big red N remains in the 12 o'clock position and navigation using this compass becomes a significant mental arithmetic exercise when under pressure, as outlined above. What Microsoft actually presented Flight Simmers with in 2004 was a very nicely modelled instrument which never had existed – the P8 quasi-magnetic direction indicator.

This makes navigation significantly more of a mental exercise than it already is. You want to fly a heading of 040°, say. You have to steer a course such that the compass Needle points to –40° – or 320°. Now if you need to make a big heading change – say from 040° to 220°, what should you expect the compass needle to do? Sitting quietly with no other distraction, you can mentally picture the needle north point moving from 320° to 140° but it isn't a trivial task and takes upwards of a minute. It is also so easy to get it wrong and turn until the needle points to 220°.

A Proper P-Type Compass for Flight Simulator

Because the FS9 P8 compass is an XML gauge, fortunately it can be easily changed to behave correctly, including making the bezel rotate. The Plane Design Avro Lancaster (www.plane-design.com) has the bezel able to be rotated correctly, but still has the needle rotating wrongly. Only one aircraft that the author is aware of has a correctly functioning P-type magnetic compass – and that is the John Woodside DeHavilland Tiger Moth for which the author designed his own panel – and P-type compass!

Using the P-Type Compass

To fly a heading using the P-type compass is easy by making use of the rotating bezel. Simply rotate the bezel by holding down the mouse pointer to the right hand side of the bezel to turn it clockwise and to the left side of the bezel to rotate it anticlockwise. A mouse wheel also rotates the bezel if this is preferred.

Rotate the bezel until the heading you wish to fly is against the "Lubber Line" the small white line in the 12 o'clock position on the top of the compass casing. Then turn the aircraft until the north point of the arrow is pointing to the big red "N" and keep it there as you fly. (known in the RAF as "flying red on red"). The crosswires on the glass are a visual aid, particularly when glancing down at the slant view. Keep the needle within the two parallel lines and preferable parallel to them and you will not stray too far off course. Peter Dodds's panel for John Woodside's Tiger Moth in FS has a clickable hot spot which displays the compass in a pop-up window for easier reading.

The later models of P-type compass had the cross hairs in a T shape and the tail of the needle had a short crossbar added. As well as red on red, pilots now flew "tee to tee" keeping the tee on the needle in the same orientation as the tee-shaped crosswires. This modification was to alleviate the problem of tired pilots flying the reciprocal heading in error – keeping the needle between the parallel crosswires, but 180^{o} wrong!

Turning Onto Your Heading

The earth's lines of magnetic force do not lie parallel to the surface but are inclined towards the poles (magnetic inclination). For reasons to do with the way the compass compensates for this with balance weights, the needle does not always point north when the aircraft is turning.

When turning north, the needle actually moves ahead of the aircraft's rotation, and when turning south, the needle lags behind the aircraft's turn. This leads to one of those numerous mnemonics with which aviation abounds – UNOS. "Understeer north – oversteer south".

When turning north, turn until the needle points <u>beyond</u> the north point on the bezel. When turning clockwise (from west to north) let the needle swing to a heading in the region of 030^{o} and when turning anticlockwise, let it swing into the 330^{o} region. As you roll wings level, the needle will continue to move, and if you have got it right, settle down pointing north.

Similarly when turning south, roll out wings level when the needle points some 30^{o} <u>before</u> north. So when turning clockwise (from east to south) roll out of the turn when the needle points to around 030^{o} and when turning anticlockwise, turn as the needle approaches the 330^{o} region. As

you roll wings level, the needle will fall back, and if you have got it right, settle down pointing north.

The good news is that when turning east or west the effect is cancelled out and you can roll wings level as the “10^{o} before heading” comes up, the same as for a D.I.

The precise amount of understeer and oversteer necessary is a function of several factors – turn rate, heading required, climbing and descending, accelerating or decelerating for example, but it can easily be 30^{o} or more. You can only get it right reliably with experience. Go and practice it - it is one of the fun things about flying vintage aircraft in FS.

Peter Dodds

14/03/07