D/F GENERAL

The theory of D/F and its service application is contained in Admiralty Handbook of W/T (1931) paragraphs 786 to 817 inclusive.

As stated on page AC4 the letter "S" prefixes all D/F apparatus (except D/F training units, see section F) and the following table shows the items in detail :-

SA to SZ - Independent W/T Receiving Outfits for D/F termed "D.F Outfits" (In some cases where the primary use of the Outfit is for normal reception they are termed "Receiver Outfits").

S1 to S19 - Frame coils for D/F

S20 to S39 - Radiogoniometers for D/F.

S40 to S59 - Sensefinders for D/F.

S60 to S79 - Semi Circular Correctors for D/F.

There are two main types of D/F installation fitted in H M Ships :-

(a) The Bellini-Tosi System (See Admiralty Handbook of W/T (1931) paragraph 792) employing two large crossed aerial loops. D/F Outfit SD is of this type and is described on page LA6.

(b) The Rotating Frame Coil System (see Admiralty Handbook of W/T (1931) paragraph 788). Receiver Outfit SF (see page LA13) and D/F Outfit SGX (see page LA14) are of this type

The relative advantages of the two systems are summarised below (see also Admiralty Handbook of W/T (1931) paragraphs 795 and 813).

Bellini-Tosi.
1. Higher speed of operation.
2. Greater sensitivity.

Rotating Frame.
1. Electrically more simple.
2. Free from risk of errors due to movement of loops or bad contacts.
3. If well situated, is unaffected by other aerials
4. If well situated, can be used on the higher frequencies.

D/F ERRORS

All systems of D/F are liable to certain errors which can be considered under two headings:-

(a) Errors due to pecularities of the wave being received. These cannot be corrected, but their presence can sometimes be detected by the operator.

(b) Errors due to the gear being fitted in a warship. These may be to a large extent avoided or corrected.

ERRORS DUE TO THE WAVE.

Night Effect. At present (February 1932) Naval D/F gear is capable of indicating accurately the great circle bearing of a transmitting station provided that the wave being received has followed the earth's surface, i.e., provided it is the "direct wave". A wave which has travelled via the upper atmosphere will not be travelling horizontally when it passes the D/F gear, nor will its magnetic field be necessarily horizontal. The result of these facts is that bearings taken with either a rotating frame or Bellini-Tosi apparatus cease to be accurate whenever such a wave-i.e., the "indirect wave"- predominates. This effect may cause an error in the zero or a blurring or both. By day, on medium and low frequencies, the direct wave nearly always predominates sufficiently to remove all risk of this effect, but at night it is liable to occur on any frequency, except at fairly short ranges (about 30 miles). For this reason it is called "Night Effect" and is generally at its worst within an hour either side of sunrise and sunset, when the changes in the state of ionisation of the atmosphere are particularly violent. On high frequencies - except at short ranges - the indirect wave normally constitutes the greater part - if not all - of the signal, and so the effect is experienced by day as well as by night. As it is impossible for any correction to be applied for this error, it is essential that the risk of its presence should be understood. The fact that a very unusual setting of the semi-circular corrector is necessary to obtain a sharp zero, or that it is suddenly impossible to get any satisfactory setting, is an almost CERTAIN indication of the presence of "Night Effect".

Land Effect. If a wave crosses the coast line at an angle of 20° or less, its direction of travel is appreciably altered, and so the bearing obtained of the wave is no longer the bearing of the transmitting station. The effect is particularly pronounced when either station is near the coast, especially if high land intervenes. High land behind a transmitting station may also cause misleading reflections, for instance, bearings taken of ships transmitting in Gibraltar harbour are unreliable.

Convergency Error. As a W/T wave travels along a great circle, it may be necessary to apply a correction before laying off the bearing on a Mercator Chart. Particulars of this correction are given in the "Admiralty List of W/T Signals".

ERRORS DUE TO THE SHIP.

General Considerations. As the hull of a ship is a conductor, a passing wave will induce currents in it. The resulting field together with similar fields from superstructure, funnels, masts, stays, aerials etc., - will affect the D/F gear. The errors thus produced may be resolved into two components.

D/F ERRORS

(a) Quadrantal Error. This is due to the component of the ship field which is in phase with the wave. It produces a definite angular error which is called "Quadrantal" as it is normally zero ahead, astern and on the beams and maximum on the bows and quarters. The effect is always to seem to "pull" the bearing towards the fore and aft line. In Bellini-Tosi sets this error is corrected by reducing the effect of the fore and aft loop in the first place by making it smaller than the beam loop, and in the second place by adding impedance by means of correcting inductances. The determination of these corrections - known as "Balancing the Loops" - is carried out during calibration, and a final "curve of correction" is obtained by trial so that any remaining deviations on particular arcs may be allowed for. In Rotating Frame sets a curve of correction must be found by trial, and the necessary correction applied in each case by the operator, unless a cam corrector is fitted to the pointer to correct it automatically.

(b) Semi-Circular Effect. This is due to the component of the ship field which is 90° out of phase with the wave, and produces a "Rotating Field". This means that wherever the Rotating Frame or Goniometer search coil is placed there will be always some signal heard, i.e. the zero is "blurred". This effect is found to be worst on the beams and nil ahead and astern and is therefore called "Semi-Circular Effect".

It is corrected by introducing a correcting E.M.F. equal and opposite to that which produces it, by means of a "Semi-Circular Corrector", which, when correctly adjusted, makes the zeros absolutely sharp.

Variation of "Ship Errors" with frequency. With L/F waves, the errors due to the ship do not vary with the frequency. When, however, the frequency increases until it corresponds to a wavelength equal to or shorter than about five times the length of the ship, the error becomes rapidly more pronounced. We therefore find that -

(a) Quadrantal Error is usually constant on frequencies below about 300 kc/s and increases on higher frequencies (the amount being determined during calibration).

(b) Semi-Circular Effect increases similarly with frequency and so the amount of correction necessary will also increase.

With still higher frequencies, the above become not only greater but more complex owing to various conductors approaching resonance at these frequencies. A limiting frequency is therefore reached with every ship installation, above which D/F bearings can no longer be taken, even at short ranges. A frame coil placed above the foretop, where it is above the main aerial and as far as possible from other conductors, is greatly superior to the other D/F outfits on the higher frequencies. The Bellini-Tosi loops cannot easily be so advantageously placed; moreover, trouble is experienced owing to the tendency of one or other loops suddenly to tune at these frequencies, and to the increasing effect of the capacity of the leads from the loops to the goniometer.

ERRORS DUE TO FAULTY GEAR.

Although "Ship Errors" can be corrected as described above, for accuracy to be obtained great care is necessary in the fitting-out, calibration and maintenance of the D/F gear. Otherwise, errors are liable to occur for the following reasons:-

(a) Unequal impedance in the two sides of one or both loops; hence the necessity for checking the insulation and ohmic resistances of the loops and their individual symmetry.

(b) Asymmetrical distribution of conductors near the frame or loops. The initial choice of site is most important; after calibration, any change in the position of neighbouring conductors must be avoided.

(c) Loops not at right angles to and not bisecting each other.

The above are liable to cause error in zero, blurring or both.

(d) Aerials wrongly connected to goniometer (the zero appears in the wrong quadrant).

(e) Pointer error, causing a constant all-round deviation.

(f) Repeater scale on goniometer being out of step with ship's master gyro. The operator should check this frequently and correct it if necessary; he should also know, and report, which of the master gyros is driving his repeater scale.

(g) Goniometer coils not being exactly at right angles to each other. This is the reason for zeros taken with each loop separately not being 90° apart. A new goniometer is required.

(h) Lay-out of instruments in the D/F office.

(i) It is essential that the E.M.F. produced in the amplifier should originate entirely from the search coil (or rotating frame). It follows that, not only must the whole office be effectively screened but there must be no direct induction from the aerial leads-in, owing to insufficient spacing of gear. Either of the above cause signals to be heard whatever the position of search coil (or frame) and so blur the zero.

(ii) Spacing must also be sufficient to prevent any mutual induction between aerial leads in or between correcting inductances, as this may introduce an error in the zero.

(iii) Mutual induction between the goniometer primary and the tuned circuit would cause zeros to be not exactly 180° apart. With modern screened goniometers this should not occur provided the screen is earthed and the goniometer is at least 18 inches from other instruments.

D/F ERRORS

MAINTENANCE OF ACCURACY AFTER CALIBRATION.

The process of calibration eliminates errors due to faulty gear and determines the necessary corrections for quadrantal error on all frequencies. The following points must, however, continue to receive attention, and "check calibrations" should be carried out periodically.

(a) The pointer must not slip.

(b) The position of the loops must not be altered in the smallest degree. If the beam loop has to be slipped for boat-hoisting, it must ALWAYS be correctly replaced.

(c) All switches, terminals, etc., must be kept scrupulously clean, so as to keep ohmic resistances down to their proper value.

(d) Steps should be taken to ascertain whether unavoidable changes such as the elevating and training of guns, movement of davits between sea and harbour positions, change of stowage of paraffin drums, etc., have any appreciable effect.

(e) The main aerial is so close to the D/F gear in most ships that it is almost certain to affect it. As it is insulated in the office just below the deck insulator (in Type 36S by removing the top link) during calibration, it MUST be in the same condition whenever bearings are taken. A receiving aerial tuned to the same frequency as the D/F set may also cause an error. A rotating frame coil fitted above the main aerial is generally free from these limitations in which case aerials need not be insulated.