A.D.F.
(Automatic Direction Finding)

V.O.R.
(Visual Omni Range)

Practical Application and Inflight Interpretation

By Bruce Wall
441 Church Street, Hay, N.S.W. 2711

INTRODUCTION

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This text is written in the light of assuming that the reader, (who will undoubtedly be a qualified pilot) possesses some knowledge of the basic fundamentals of ADF and VOR.

It is also assumed that the reader will be familiar with the physical layout of ADF and VOR airborn instrumentation,- and familiar with the basic terminology associated with ADF and VOR.

For simplicity of explanation of the various functions of ADF and VOR, the writer has implied that these radio navigation aids are free from 'indication error', and free from 'aid limitation'.

It is, however, stressed that this is not in fact correct.

ADF and VOR are subject to many and varied 'indication errors' and 'aid limitations', all of which must be treated with respect.

Information concerning 'aid limitations' and 'indication errors', may be obtained from the appropriate D.C.A. publications, which are available on request from the D.C.A.

Many text books are available on the subjects of ADF and VOR radio navigation, however, most appear to concentrate on the theoretical aspects of operation, consequently providing only limited information concerning the practical application and associated inflight pilot interpretation of these radio navigation aids.

It is not the intention of the writer to cover every aspect of practical inflight application of ADF and VOR. There are many refinements of IFR usage, that can only be understood and appreciated during actual inflight training.

It is rather the intention of the writer to provide meaningful and useful information in respect of 'pilot interpretation' and 'actual application' of these radio navigation aids in an area that appears to have been previously neglected.

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Bruce Wall

ADF (Automatic Direction Finding)

VOR (Visual Omni Range)

'Practical Application and Inflight Pilot Interpretation'

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FOREWORD

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An ironic situation is evolving where increasing numbers of costly ADF and VOR installations are becoming evident in modern VFR light aircraft.

It is obvious that the capital outlay and associated maintenance costs of these installations contribute significantly to the overall operating cost of modern light aircraft.

It is, at this point, where the irony becomes apparent. Many pilots are virtually 'sponsoring' the very existence of equipment that they cannot effectively use.

The situation becomes more ironic, when one considers the fact that modern technology is producing 'VFR only' equipment, exhibiting standards of accuracy and reliability previously considered improbabl Modern technology will no doubt continue to produce such equipment with further improvements in accuracy and reliability. This equipment will undoubtedly find its way into modern VFR light aircraft in increasing quantities.

The resultant 'ironic gap' between 'instrument capability' and 'pilot capability' must surely widen, unless a concerted effort is made by pilots to obtain more knowledge of the 'practical applicatior of these radio navigation aids.

This publication is directed towards assisting pilots in this category to obtain a better knowledge of 'practical application' of ADF and VOR in an endeavour to alleviate this situation that now exis

There are, to-day, many pilots aspiring to class 4 and higher instrument ratings, and the information contained herein is also directed towards assisting pilots in this category to obtain an insight into the operational use and understanding of ADF and VOR.

ADF and VOR, each provide three main functions which may be separated as follows.

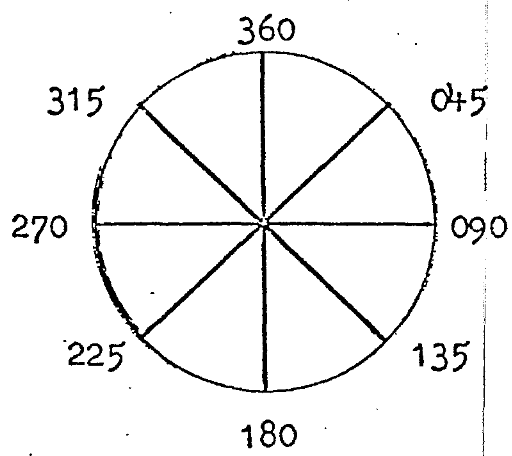
(i) Orientation (ii) Track Interception (iii) Track Maintenance.

Orientation may be defined simply as:- Determining the position and heading of the aircraft, relative to the ground station, and consequently to any radial or inbound track of that ground station.

Track Interception: To intercept a pre-determined radial by choice or by requirement, for the purpose of tracking inbound to, or outbound from, a ground station along this radial.

Track Maintenance: To maintain a track to or from a ground station along a radial, compensating for drift as necessary.

To facilitate a clear understanding of ADF and VOR ground stations, think in terms of these ground stations having 360 radials, ie. 001 - 360, radiating out like the spokes from the hub of a wheel.



An aircraft may track outbound along a radial, or may track inbound along a radial. An aircraft may track 090 outbound along the 090 radial, or may track 270 inbound along the 090 radial.

Each radial has its own reciprocal inbound track, 180 degrees removed.
Examples: 090/270 040/220 197/017.

The term 'radial', is not as frequently associated with ADF as it is with VOR, but it is quite necessary with certain ADF procedures. It is however, expedient in the initial stages of ADF familiarisation at least, to think in terms of ADF ground stations as having 360 radials.

In order to obtain the full and proper benefits offered by ADF and VOR, the pilot must at all times, maintain a complete 'mental picture'. The foundation of this 'mental picture' is the compass rose, (centre and radials, like the hub and spokes of a wheel) with the aircraft appropriately positioned on a radial, or inbound track, and with the appropriate heading.

'Flying the radio range' is not simply a matter of flying by numbers, even when flying IFR in IMC.

The ability of a pilot to quickly and efficiently form and maintain this mental picture, is the singularly most important aspect of all, and forms the basic foundation of all instrument flying and associated use of radio navigation aids.

It is impossible to over stress this very important point, for the moment the pilot loses this mental picture, he becomes instantly lost.

For the pilot aspiring to class 4 or higher instrument rating, it will be necessary to obtain a full and complete understanding of orientation techniques.

For the VFR pilot who wishes only to 'upgrade' his ability to use the ADF and VOR radio navigation aids, it will not be essential to obtain a complete understanding of orientation techniques, nor certain 'close in' track interception procedures. However, the degree of ability to make correct and full use of these aids, will be directly proportionate to the pilot's understanding of orientation. It is therefore strongly recommended that a pilot in this category, strive to obtain a comprehensive insight into all aspects of orientation.

It may be noted at this point, that <u>all</u> inflight calculations associated with orientation, track interception and track maintenance, must be conducted using mental arithmetical processes only. There is simply insufficient time available for a pilot to become involved in written calculations, and at the same time, 'fly the aircraft' within the required close tolerances.

It is therefore essential that 'short cut' methods be employed for simplification of the various mathematical problems encountered, and as a result, many such techniques have evolved over recent years.

The writer has selected for explanation, those techniques considered most appropriate to the situation involved.

ORIENTATION........ ADF.

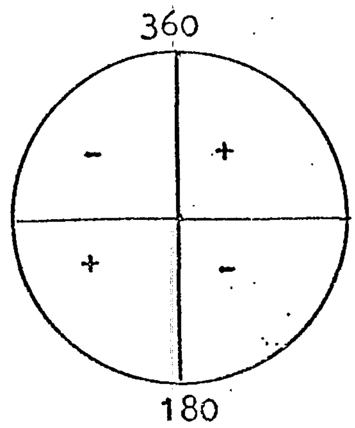
The ADF ground station is referred to as a 'Non Directional Beacon', (NDB).

The ADF indicator, which is installed in the aircraft instrument panel, comprises a compass rose dial with a centre pivoted indicator needle.

The ADF indicator provides the pilot with information concerning the direction of the NDB, to or from the aircraft, relative to the fore/aft axis of the aircraft. To establish the actual direction of the aircraft to or from the NDB, the ADF indicator reading must be related to the compass heading of the aircraft.

One technique employed to simplify this task of relating the two readings, (ADF/Hdg.) in order to 'place' the aircraft on a radial or on an inbound track in your mental picture, is described as follows.

Imagine the ADF indicator dial as such, having four quadrants labelled........



The angular deflection of the ADF indicator needle right or left of the 360 datum when in the top half, and right or left of the 180 datum when in the bottom half, is the only angle required to be found.

Examples:-

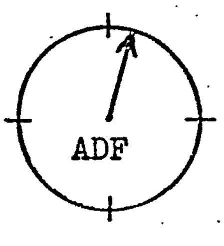
ADF	ADF	ADF
020 = (+20)	130 = (-50)	280 = (-80)
350 = (-10)	220 = (+40)	170 = (-10)

Having found the 'plus' or 'minus' factor by the method described above, this factor is then applied direct to the compass heading to obtain a 'line' through the NDB from the aircraft.

If the ADF needle is in the bottom half, the answer derived will be a bearing 'from', or in other words, the aircraft is 'on that radial'.

If the ADF indicator needle is in the top half, then the answer derived will be a bearing 'to', or in other words, the aircraft is 'on that inbound track'. This bearing 'to', may then be if required, converted to its reciprocal to obtain the radial on which the aircraft is located.

Example: (a)

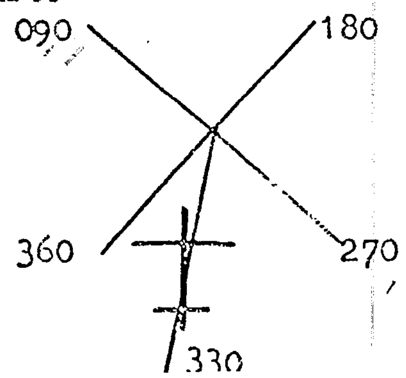


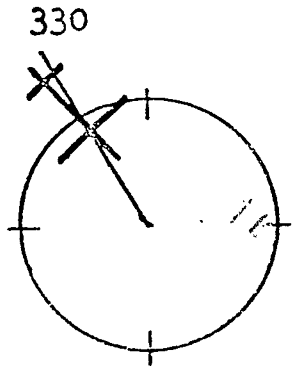
Hdg. 140 ADF 010 (+10 factor)

therefore... 140 + 10 = 150

The ADF needle is positioned in the top half, so the answer of 150 is a 'bearing to'. By converting this 'bearing to' of 150 to it's **reciprocal** of 330, we then have the information necessary to form our mental picture.

Subjective mental picture.

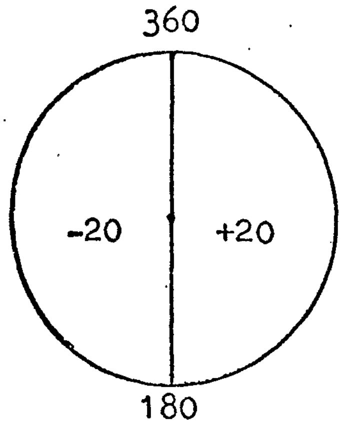




Objective mental picture.

One such technique employed for simplification of this task of either subtracting, or adding 180, is described as follows.

Imagine the compass rose divided in two, by a line passing through north to south.



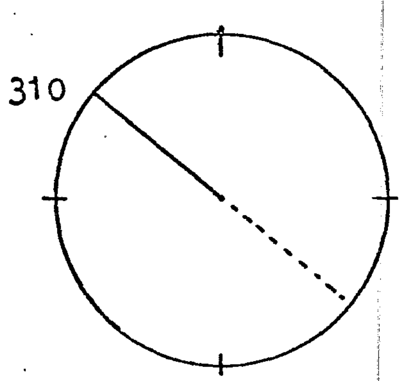
The eastern half having a " +20 factor "

The western half having a " -20 factor "

When required to convert a track/radial which is positioned in the western half to its reciprocal, - think in terms of its reciprocal being positioned in the eastern half, and as a result incurring a " +20 factor ".

We apply this +20 factor to the last two figures of the original track/radial, which allows us to calculate with ease, the last two figures of the reciprocal, and commonsense dictates the first figure.

Example:- To convert 310 radial to its reciprocal.



310 + 20 = ?30

A knowledge of the commonsense placement of radials/tracks, dictate that the only answer available ending in 20 more than 10, is 130.

Commonsense tells us that it could not be 030, 230, nor 330.

To facilitate commonsense placement of radials/tracks, a knowledge of the compass rose is essential. Learn to recognise instantly, which one of the four quadrants contains the radials and tracks concerned. N.E. (360-090) S.E. (090-180) S.W. (180-270) N.W. (270-360).

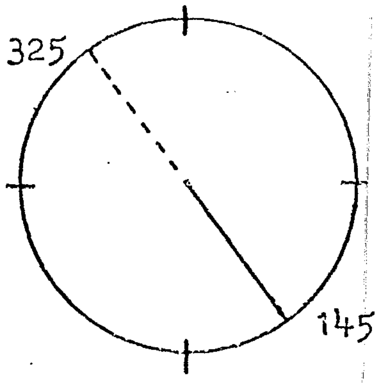
A radial positioned in the S.W. quadrant 235, - will have its reciprocal positioned diagonally opposite in the N.E. quadrant, and, bearing in mind that the answer will end in 20 more than 35, - and at the same time be positioned in the N.E. quadrant, then the only available answer would be 055.

When converting a radial/track which is situated in the eastern half to its reciprocal, think in terms of its reciprocal being positioned in the western half, and as a result, incurring a -20 factor. The same principle of converting applies, except that a -20 factor is used in lieu of a +20 factor.

Example:- To convert 145 radial to its reciprocal.

145 - 20 = ?25

Picture the 145 radial in the S.E. quadrant, and consequently the reciprocal in the diagonally opposite N.W. quadrant.



The obvious answer is 325.

On page 3, example (a), we saw a situation which demonstrated the necessity for a pilot to be able quickly to convert reciprocals.

A '<u>bearing to</u>', which was obtained from relating the two readi of ADF and compass, was converted to its <u>reciprocal</u> and pictured as a <u>radial</u>.

<u>TRACK INTERCEPTION..... ADF.</u>

Track interceptions may be placed into the following four categories.

(i) <u>Outbound to Outbound.</u>

The interception of an outbound track, from a position where th aircraft is presently heading outbound; ie. from a position where t ground station is ' behind' an abeam line through the aircraft.

(ii) <u>Outbound to Inbound.</u>

The interception of an inbound track, from a position where th aircraft is presently heading outbound; ie. from a position where ground station is 'behind' an abeam line through the aircraft.

(iii) <u>Inbound to Inbound.</u>

The interception of an inbound track, from a position where the aircraft is presently heading inbound; ie. from a position where th ground station is 'ahead' of an abeam line through the aircraft.

(iv) <u>Inbound to Outbound.</u>

The interception of an outbound track, from a position where the aircraft is presently heading inbound; ie. from a position where th ground station is 'ahead' of an abeam line through the aircraft.

If given the task of intercepting a certain track, it would be only logical to assume that one must know where one is, before attempting to fly towards the required track.

By orientating the aircraft to the ground station, we accomplish this requirement.

OUTBOUND TRACK INTERCEPTION...... ADF.

The relative location of the track required is calculated by orientating the aircraft to the NDB.

(i) Which radial am I on ?

(ii) Which radial do I require ?

(iii) what is the heading of the aircraft ?

A mental picture is formed, and the aircraft is flown towards the required radial at a predetermined intercept angle. (The selection of an intercept angle, and the pilot interpretation of the ADF indicator needle deflection, at the point of track intercept, are fully described and illustrated in the following excercises on ADF tr[illegible]k interception.)

Example 1. The following information is displayed to the pilot of an aircraft flying approx. 3 miles from the NDB.

Hdg. 115 ADF 140

Excercise:-

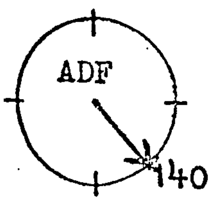
To intercept an outbound track of 160.

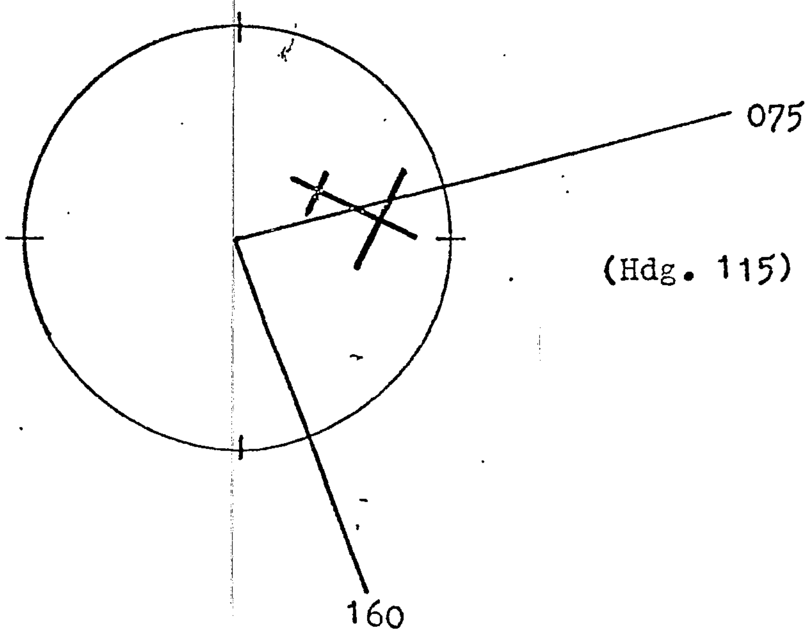
Step 1. Which radial am I on ?
Which radial do I require ?

ADF 140 = (-40), Hdg. 115
therefore..... 115 - 40 = 075.

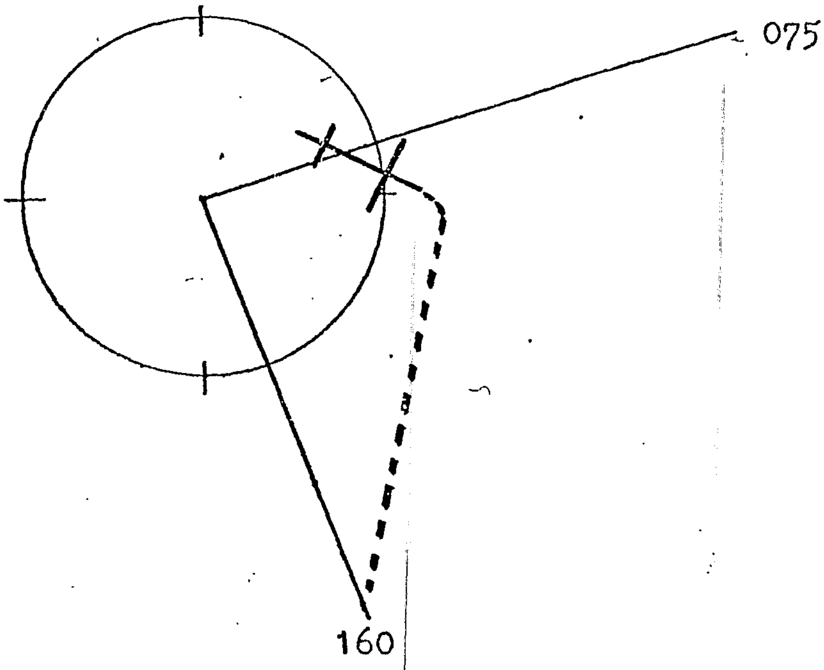
The needle is positioned in the bottom half, so the answer derived is a 'bearing from', ie. the aircraft is positioned on the 075 radial, wi[illegible] a heading of 115.

A mental picture is now formed, based on the information obtained from orientating the aircraft to the NDB.





Example 1. continued........



The aircraft is then turned onto a heading to intercept the 160 radial, (outbound track).

The angle selected for intercept will vary dependant on the combined effects of the following factors.

(i) Wind Velocity:
If a strong westerly wind was apparent, a larger intercept angle would be selected than in nil wind conditions.

(ii) Proximity to the NDB.
Close to the NDB... small angle because of danger of overshooting.
Further from the NDB... larger angle to expedite intercept.

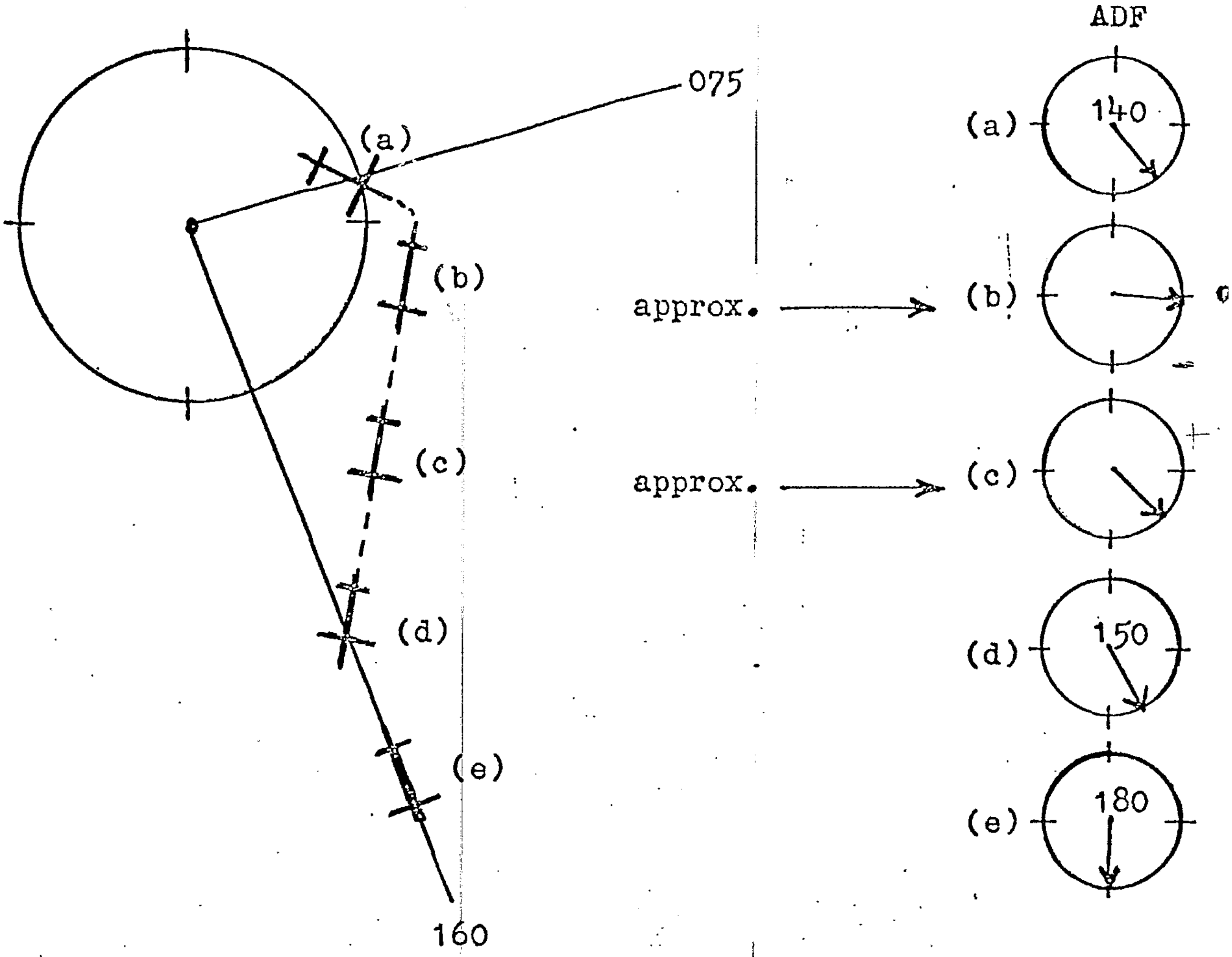
(iii) Proximity of the aircraft to the required radial.
Close... small angle because of danger of overshooting.
Further away... larger angle to expedite intercept.

The ability to select the optimum angle for intercept, is obtained only with practice and experience.

For the purpose of this example, an intercept angle of 30 deg. has been selected. It can be seen that in order to intercept the 160 radial outbound from the aircraft's present position, a heading 'greater' than 160 is required. The heading for this intercept is therefore 190.

The angle of intercept, is always the angle measured between, (i) Heading....(ii) Track Required.

With the assistance of the accompanying sketch on page 9 over leaf, we will follow this intercept, step by step from the point at which the aircraft is orientated to the NDB, until the intercept has been attained.



At point (a), ADF 140 Hdg. 115.
ADF 140 = (-40), therefore 115 - 40 = 075 (bearing from)

<u>At point (b)</u>... After taking up a heading of 190 in order to intercept the 160 radial by 30 deg., the ADF will read 'somewhere abeam'.

<u>At point (c)</u>...As the aircraft progresses towards the intercept of the 160 radial, the ADF needle will progessively move down.

<u>At point (d)</u>...At this moment the ADF reads 150, (30 deg. deflection) and the intercept has been attained.

<u>To Prove:</u> Hdg. 190 ADF 150 = (-30), therefore 190-30 = 160.
The needle is in the bottom half, so therefore the answer derived is a bearing from, ie. the aircraft is 'on' the 160 radial.

<u>At point (e)</u>... Having attained the intercept at (d), the aircraft heading was decreased by 30 deg., from 190 to 160, and as a result of this turn, the ADF needle (which always points to the station) increas by the same amount, (30 deg.) from 150 to 180.

In actual pratice, the turn onto 160 track at (d) would be commenced just prior to attaining the intercept; so as to avoid overshooting the radial. The amount of 'lead in', is determined after assessing the likely effects of any known wind, the angle being used, and the proximity of the aircraft to the NDB.

Good judgement of this lead in technique is acquired with experienc

Outbound Track Interception... ADF example 2.

Problem:- To intercept an outbound track which is situated on the 'other side' of the NDB.

Excercise:- To intercept an outbound track of 215.

The aircraft is flying approx. 4 miles from the NDB, and the following information is displayed to the pilot.

Hdg. 330 ADF 230

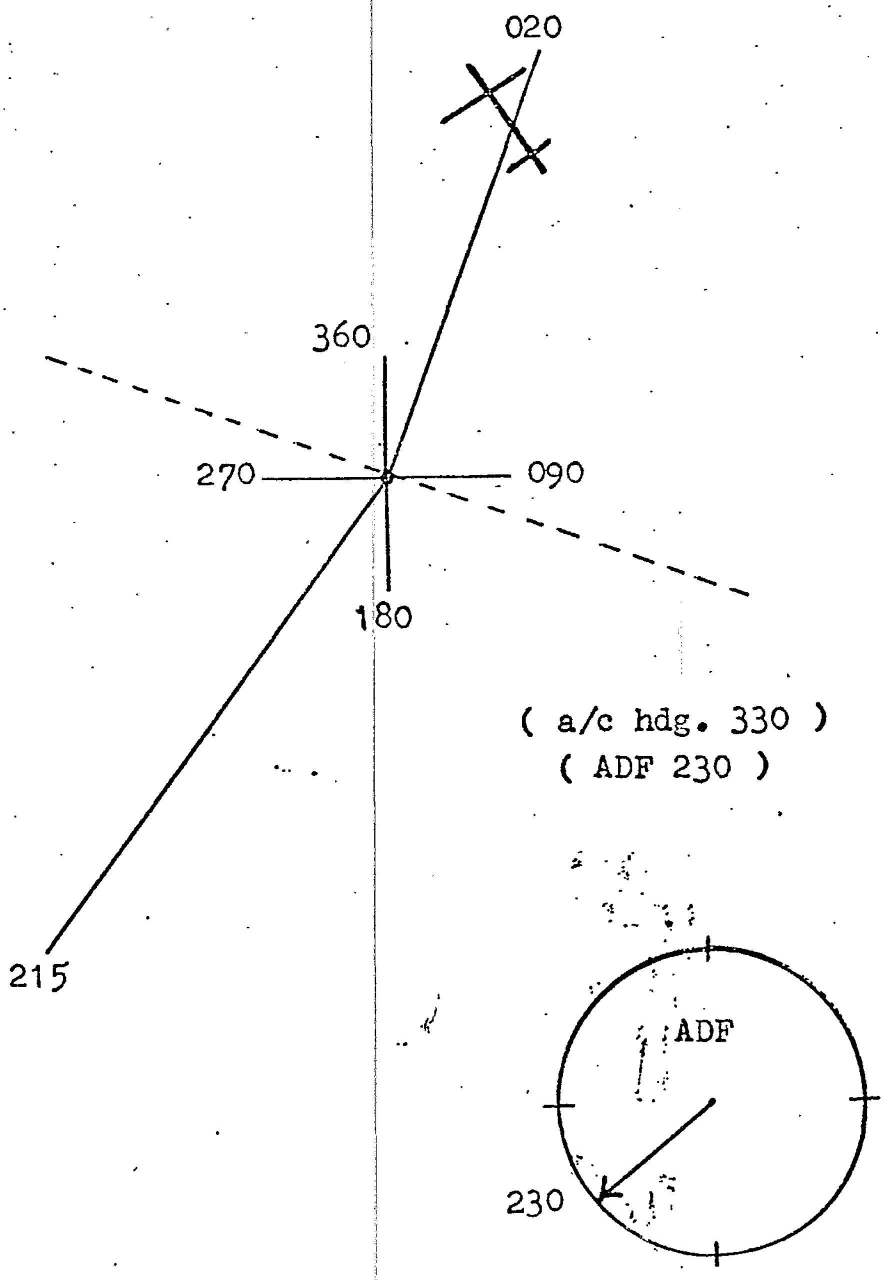
The aircraft is orientated in the normal manner....

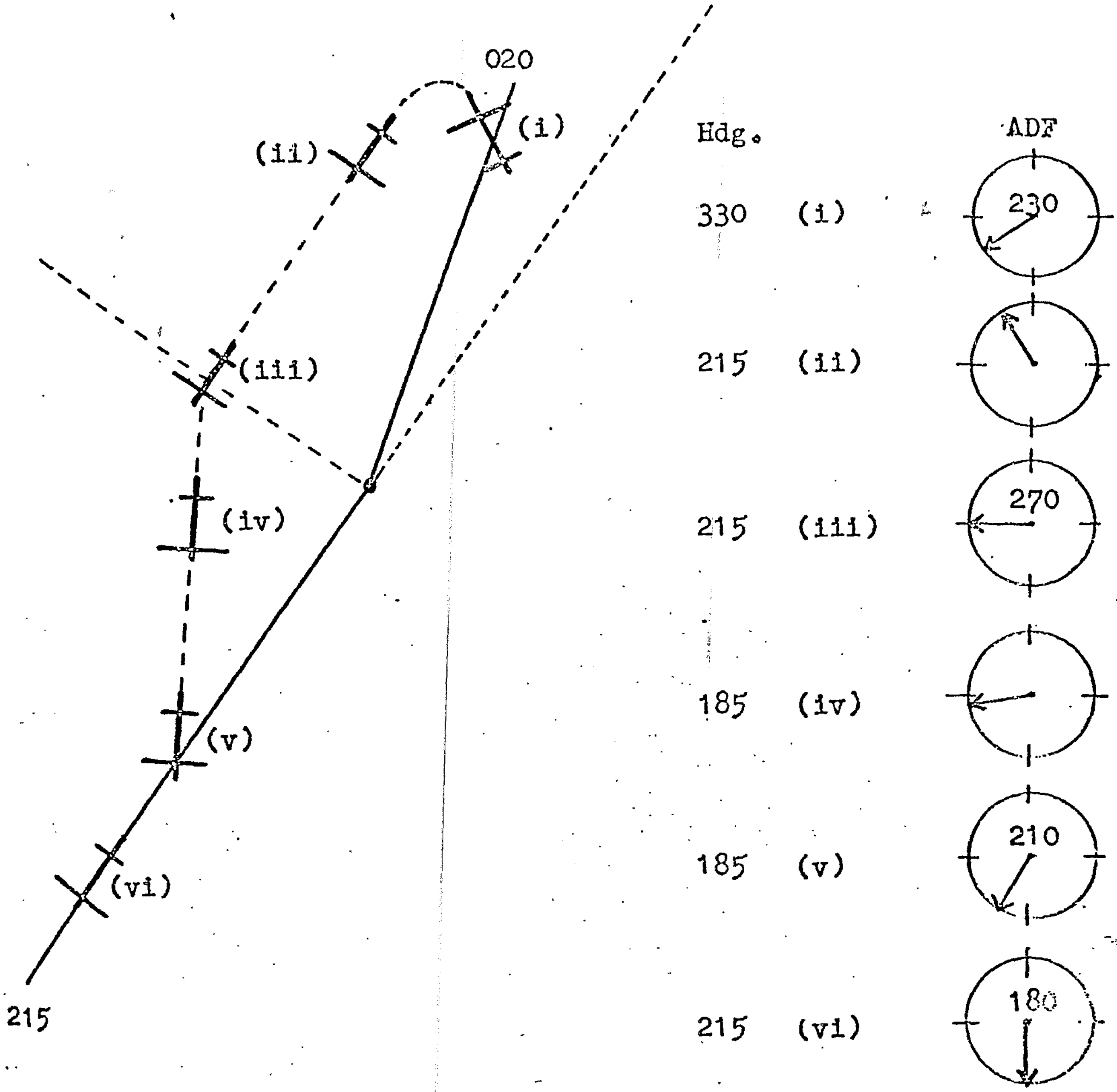
Which radial am I on ? - ADF 230 =(+50), therefore 330 + 50 = 020

Which radial do I require ? = 215.

A mental picture is now formed, based on the information obtained from orientating the aircraft to the NDB.

After forming this mental picture, it will be immediately apparent that the 'required radial' is on the 'other side' of the NDB.





Interpret the ADF needle in terms of 'deflection angle'.

After forming this mental picture, the next step is to turn the aircraft onto a heading the same as required track, confirming your mental picture by noting the ADF indicator needle deflection left of the 360 datum, and ahead of the 'abeam' datum of 270. (refer to sketch, aircraft position (ii).

As the aircraft passes abeam the NDB, the ADF will indicate 270. (refer to sketch, aircraft position (iii).

At this point, the aircraft is turned left onto the pre-determine intercept heading. For this example, an intercept angle of 30 deg. has been selected, which will of course, result in an intercept heading of 185.

As the aircraft progresses towards the 215 radial, the ADF indicator needle will slowly move down, (always pointing to the station) and at position (v), will read 210, (30 deg. deflection from the 180 datum) indicating that the intercept has been attained.

To Prove:- Hdg. 185 ADF 210 = (+30), therefore 185 + 30 = 215.

At this point, the aircraft is turned right through 30 deg. from an intercept hdg. of 185 to 215. The ADF needle will move anticlockw by the same amount of 30 deg., from 210 to 180. (refer a/c position

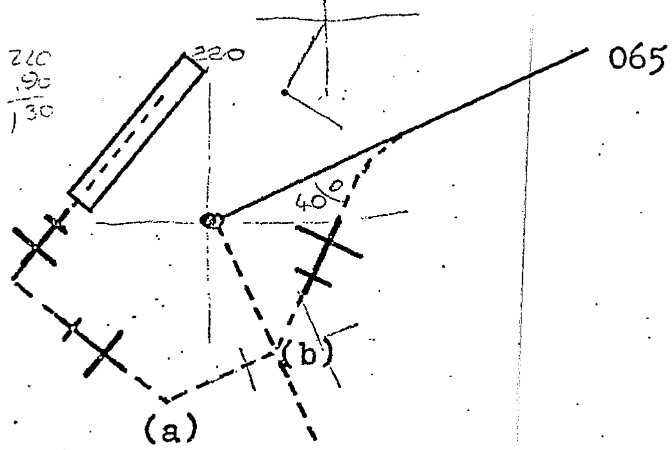
In practice, the turn onto 215 would be commenced just prior to attaining the intercept, to avoid overshooting the track during the turn.

The ability of a pilot to intercept an outbound track which is situated on the 'other side' of the NDB, is often beneficial in circumstances where the NDB is situated at, or in close proximity to the aerodrome of departure.

This next example will demonstrate a typical situation where this ability may be applied.

Example 3.

Excercise:- An IFR departure on runway 22, with a requirement to intercept an outbound track from the NDB of 065, without flying over the NDB.



Runway	22
Cross wind leg	130
(a to b)	065
Intercept heading	025

The aircraft has taken off from runway 22 and initiates a normal left hand circuit pattern, by commencing a turn onto 130 degrees at 500 ft. A.G.L. (above ground level)

At position (a), the aircraft has attained 1500 ft. A.G.L., and is 'clear' of the circuit.

At this point the aircraft is turned onto a heading of 065 to parallel track, and the pilot confirms his mental picture by noting the ADF needle being positioned 'ahead of the abeam datum', and to the left of the 360 datum.

The heading of 065 is maintained until 'abeam' the NDB, (position b) at which point the aircraft is turned left to intercept the required outbound track of 065.

Assuming an intercept angle of 40 degrees has been selected, then the intercept will be attained when the ADF reads 220.

To Prove:- Hdg. 025 ADF 220 = (+40) therefore, 025 + 40 = 065.

In a situation such as just described, it would be more common procedure to fly direct to the NDB when 'clear' of the aerodrome circuit, (above 1500 ft. A.G.L.). In some circumstances however, this may be precluded by some other procedural requirement at the time.

INBOUND TRACK INTERCEPTION..... ADF.

When orientating the aircraft to the NDB, we do not always think in terms of radial to radial relationship when forming our mental picture. When conducting an inbound track intercept from an 'inbound heading situation', we form our mental picture in respect of inbound track to inbound track relationship.

Pilot interpretation of the ADF indicator needle when conducting inbound track intercepts, is basically the same as previously described in the excercises on ADF outbound track interception. The main difference being that the deflection angle as indicated by the ADF, is measured from the 360 datum in lieu of the 180 datum.

Whereas for outbound track interception, the intercept angle is more simply 'guesstimated', the inbound intercept angle must be calculated. By presenting a pratical excercise, the necessity to calculate an inbound intercept angle, rather than simply just choose one, is demonstrated.

Problem:- To intercept an inbound track of 300, when the aircraft is positioned 'somewhere south' of the 300 inbound track. (Inbound to Inbound situation.)

315

Hdg. 040 ADF 315 = (-45)

You may orientate the aircraft to the inbound track of 355, by reference to the ADF and compass, and form your mental picture, (which will be correct procedure in itself) but it will provide no guarantee that you can guess the correct heading to take up to intercept the required inbound track of 300.

As an example, you may elect to intercept the required inbound track of 300 using an intercept angle of 30 degrees, and so take up a heading of 330. (30 degrees greater than required track.)

You could be forgiven for assuming this to be the logical thing to do.

The accompanying sketch illustrates quite clearly that this inbound intercept will never occur, and that the aircraft will pass by the wrong side of the NDB.

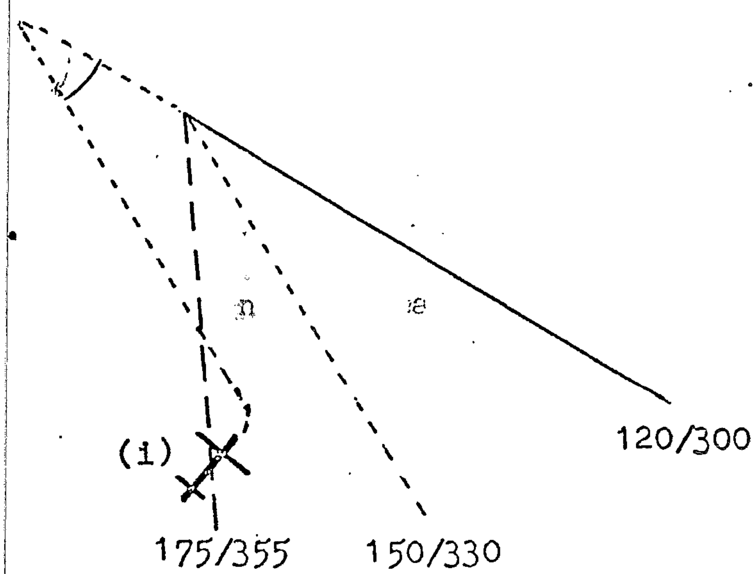
At aircraft position (i)

Hdg. 040

ADF 315 = (-45)

therefore, 040 - 45 = 355 TO.

Intercept heading, 330.



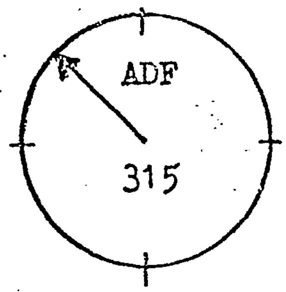
The failure of this intercept to occur, was caused simply because we did not realise that the angular displacement between the radial that the aircraft was positioned on, and the radial required exceeded the 30 deg. intercept angle that we elected to use.

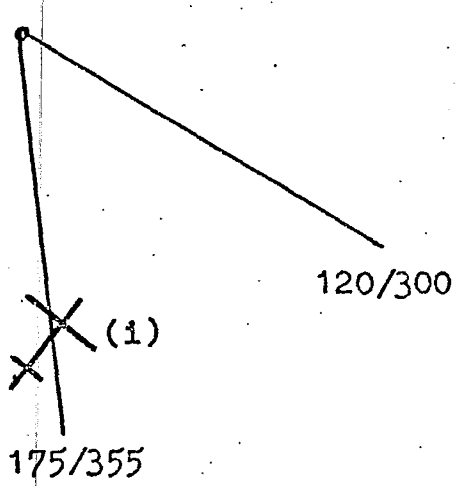
Refer back to sketch on page 13, and assess that the angular displacement between these two radials is 55 deg.

We now realise that in order to succesfully intercept an inbound track, the angle of intercept must be greater than the angular displacement of the two radials concerned.

We could, if we wanted to, calculate the displacement by mental arithmetic, and then conclude that our intercept angle must be greater than this angle of displacement. With VOR inbound intercepts, this is actually the method used, but the fact that the ADF needle always points to the station, enables us to 'short cut' this requirement. This technique is described in the following excercise.

Using the correct technique, we will conduct step by step, an intercept of the 300 inbound track from the aircraft position (i) on the 355 inbound track. (175 radial)





At aircraft position (i)
Hdg. 040
ADF 315 = (-45)

Step 1.

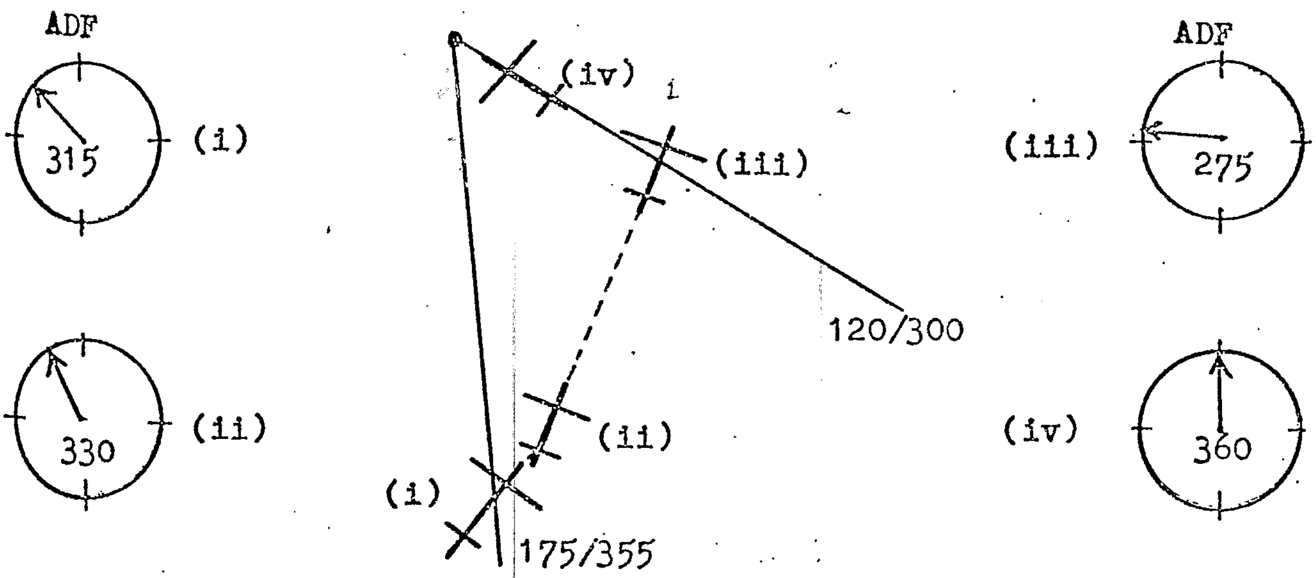
Which inbound track am I on ?
Which inbound track do I require ?
Which basic direction of flight is required to intercept ?
Which way is the most expedient turn from present heading, to this basic direction. ?
Which side of the nose to position the NDB when on intercept heading ?

(learn the above sequence, and firmly commit it to memory)

Which inbound track am I on ? = 355
Which inbound track do I require ? = 300
(now form mental picture)

Which basic direction of flight is required to intercept ? = Northerly.
Which way is the most expedient turn to this direction ? = Left.
Which side to position the NDB, when on intercept heading ? = Left.

The information obtained from the first two questions, enables a mental picture to be formed, and subsequently from this mental picture the remaining questions are answered.



Position (i)	Hdg. 040	ADF	315
Position (ii)	Hdg. 025	ADF	330
Position (iii)	Hdg. 025	ADF	275
Position (iv)	Hdg. 300	ADF	360

Step 2.

Whilst maintaining this mental picture, commence a turn to the left towards a northerly direction of flight until the ADF needle shows a deflection of approx. 30 deg. left of the 360 datum. (NDB is left of the nose). Roll out of this turn and hold heading.

Now bearing in mind that the angle of intercept is measured between heading and track required, we note this difference. Our heading would be say 025, and track required is 300. Therefore our intercept angle is 85 degrees.

At position (ii), the ADF will show a deflection of 30 deg. left of the 360 datum, and as the aircraft flies towards the 300 inbound track, the ADF needle will progessively drop back, until it reaches a point 85 deg. left of the 360 datum.

At this point, position (iii), the aircraft has intercepted the required inbound track of 300.

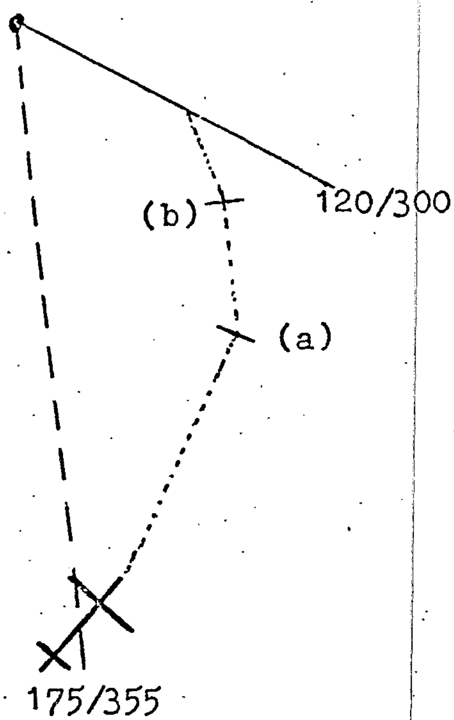
Now turn the aircraft left through 85 deg., and the heading will decrease from 025 to 300, and the ADF needle will move clockwise by the same amount (85 deg.) from 275 to 360.

This intercept angle as 'calculated', was rather a large angle, but was necessary because of the large angular displacement between the two radials concerned.

This technique of allowing the ADF needle to 'position' the aircraft on the intercept heading by displacing the needle approx. 30 deg. left of the datum, also results in the track intercept occurring at a 'reasonable' distance from the NDB.

A refinement of this large intercept angle of 85 deg., would in practice be necessary to avoid overshooting the track. The probabilit of overshooting the track with such a large turn of 85 deg. required, would be imminent, unless the aircraft was some distance from the NDB.

In fact, if the aircraft did overshoot the track during the turn, the track could of course be re-intercepted. It is however, far bette technique to 'stay in front' of the situation, and take the necessary action to prevent the overshoot from occuring. This is accomplished by progressively reducing the angle of intercept as the aircraft approaches the required track. This technique is described as follows.



After the aircraft has been positioned by the ADF needle displacement, and flies towards the 300 inbound track on a heading of 025, the ADF needle will progressiv drop back until at position (a), t ADF indicator needle will show a deflection left of the 360 datum of approx. 60 deg., (remember that a deflection of 85 deg. would indicate track intercept). At this point (a), the aircraft is turned left until the ADF needle indicates approx. 30 deg. deflection left of the datum. The aircraft is rolled out of the turn at this moment, and the heading noted.

This turn and resultant new heading, has reduced the angle of intercept from 85 deg. to 55 deg., (new hdg. 355.... track required 300, therefore angle of intercept = 55 deg).

If the aircraft was in close proximity to the NDB, this angle of 55 deg. would be still too large, particularly if the aircraft was flying in conditions of S.W. wind, when a further reduction of this intercept angle would certainly be necessary.

At position (b), the ADF indicator will show a deflection of approx. 45 deg., (remember that on this existing heading of 355, a deflection of 55 deg. would indicate track intercept).

At this point the aircraft is again turned left until the ADF needle comes up from 45 deg. deflection, to approx. 30 deg. deflecti left of datum. At this point we note new heading, and subsequently calculate a new intercept angle.

This turn will result in the new heading being 340, in which cas the new intercept angle becomes 40 deg. This 40 deg. intercept angle be further reduced if considered necessary, by again turning the aircraft left as the ADF needle approaches 40 deg. deflection.

The foregoing is a description of basic technique only. The actual angles involved, and the frequency of heading change etc., will vary dependant on the combined effects of many circumstances.

A full appreciation and understanding of the techniques involved, can only be obtained with practical inflight training and experience.

It may be recalled that during these excercises, repeated reference was made to, ' a turn through a certain number of degrees, resulting in exactly the same ADF needle movement'. This however, is not strictly correct.

As an example; When turning the aircraft 'towards' the NDB, from 60 degrees ADF deflection to 30 degrees ADF deflection, the aircraft will turn through slightly more than 30 degrees, due to the distance travelled during the turn. When turning 'away' from the NDB, the converse applies.

This difference will vary with proximity of the aircraft to the NDB, and would be noticeable only when very close to the NDB.

This aspect however, is quite 'academic' and has little consequence on pilot interpretation of the ADF and compass. It is however, advisable to be aware of this aspect when conducting IFR holding pattern entries, close in procedure turns, and track intercepts requiring a turn 'towards' the NDB. This consideration can be quite important, particularly in conditions of strong wind.

TRACK MAINTENANCE.......... ADF.

In conditions of absolutely nil wind, maintaining a track would require only the maintenance of a constant heading. However, nil wind conditions very rarely exist, and as a result, drift is almost always apparent. Proper interpretation of the ADF indicator, will nevertheless enable a pilot to actually maintain a prescribed track, to or from a NDB, compensating for drift as necessary.

OUTBOUND TRACK MAINTENANCE: To maintain an 'outbound' track by reference to an ADF ' back bearing'.

At the point of intercepting an outbound track, the aircraft takes up a heading the same as required track, and consequently the ADF indicator needle will be positioned on the 180 datum.

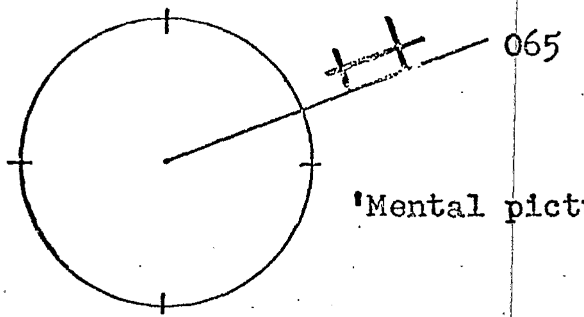
The heading is then held constant until any track deviation becomes apparent. If the aircraft does encounter drift, it will become apparent by the subsequent movement of the ADF indicator needle, either right or left of the 180 datum.

Example 1.

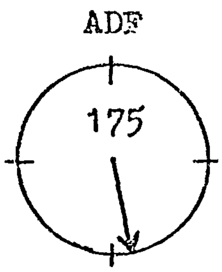
An aircraft has successfully intercepted an outbound track of 065, and takes up a heading of 065, with the ADF needle subsequently positioned on the 180 datum.

After flying for some few minutes, the ADF indicator reads 175, (5 degrees deflection). This reading indicates to the pilot that the aircraft has drifted to port of required track.

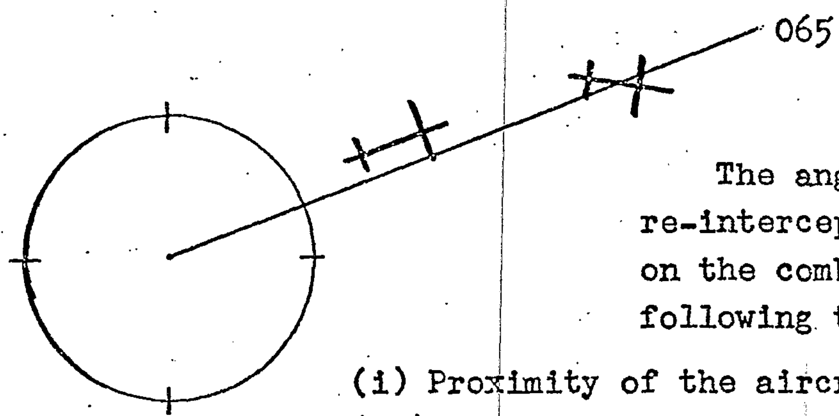
Hdg. 065 ADF 175 = (-5) therefore, 065 - 5 = 060.



'Mental picture'



The actual amount of drift is unknown at this stage, but corrective measures are now employed, and the aircraft is turned right, to re-intercept the required outbound track of 065.



The angle selected for re-intercept, will be dependant on the combined effects of the following three factors.

(i) Proximity of the aircraft to the station.
(ii) Proximity of aircraft to required track.
(iii) Known wind conditions.

Bearing in mind this combined effect, an angle of say 45 degrees is selected. The aircraft is turned right towards the required track, from a heading of 065, onto an intercept heading of 110.

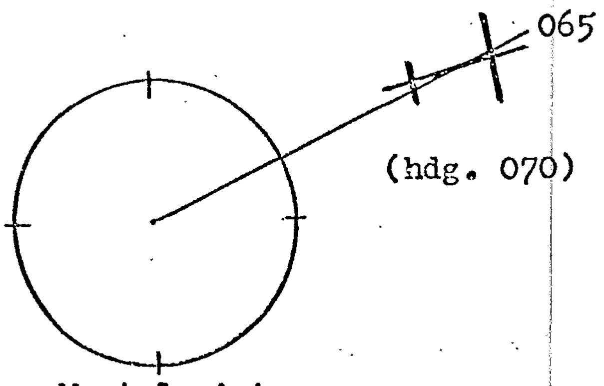
As the aircraft turns right through 45 degrees, the ADF indicator needle will move up anticlockwise by approx. 45 degrees, from 175 to 130. (The ADF bearing of 130, is interpreted <u>only as a ' deflectio angle' of 50 degrees</u>.)

As the aircraft flies towards the 065 outbound track, the ADF needle will progressively move down from a <u>deflection of 50 degrees</u>, to a <u>deflection of 45 degrees</u>. Remembering that the angle of intercep is always measured between <u>heading</u> and <u>track required</u>, the re-intercept will be attained when the ADF <u>deflection</u> reaches 45 degrees.

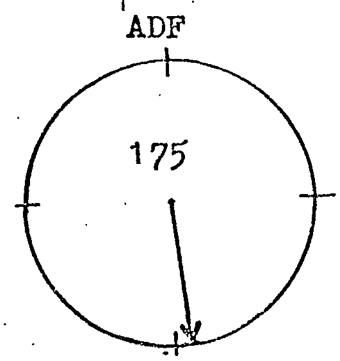
After successful re-interception of the 065 outbound track, the aircraft is turned left from the intercept heading of 110 to 070. (port drift has been recognised, and an allowance of 5 deg. is made.)

At this point, the aircraft heading will be 070, and the ADF needle will indicate 175.

Hdg. 070 ADF 175 = (-5), therefore 070 - 5 = 065.



Mental picture



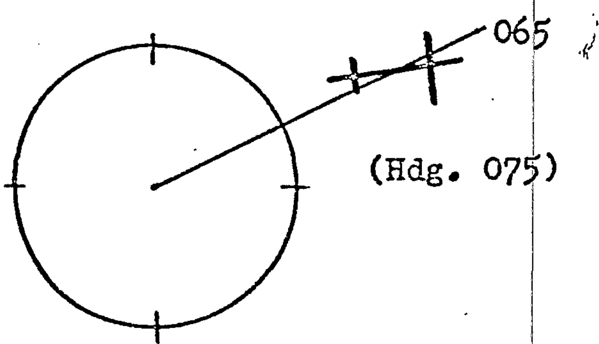
The new heading of 070 is held constant, and the 175 'mark' on the ADF dial now becomes the 'new reference datum' for noting any further track deviation. It may be that too much, or, too little has been allowed for drift compensation. If either too much, or too little has been allowed, then this will be apparent from the subsequent movement of the ADF needle either side of the 175 datum.

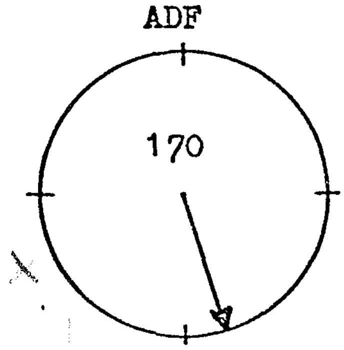
If insufficient allowance has been made, then the aircraft will again drift to port of required track. If this does occur, it will be apparent from the subsequent movement of the ADF needle to the right of the 175 datum, towards 170.

Assuming this to be the case; when this further ADF needle movement is confirmed, the aircraft is again turned to the right to re-intercept required track in the same manner as before.

When track has been successfully re-intercepted again, an allowance of 10 deg. is made for drift compensation. The aircraft would then take up a heading of 075, and the ADF needle would indicate 170.

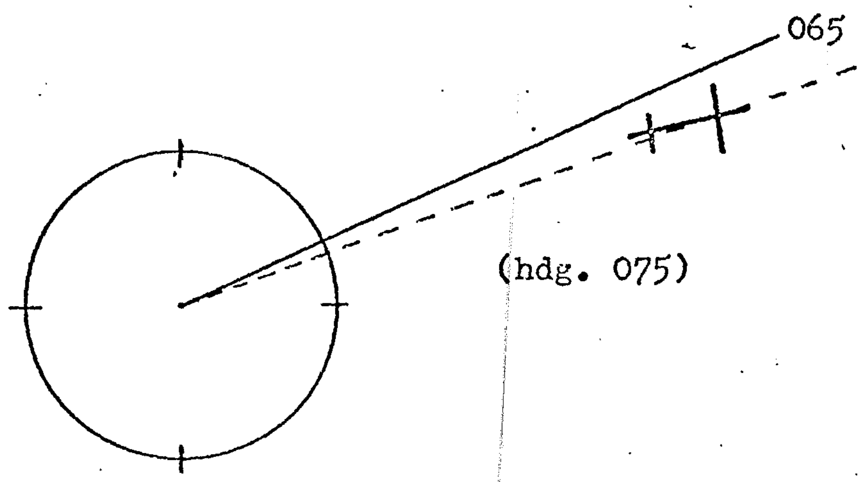
Hdg. 075 ADF 170 = (-10), therefore 075 - 10 = 065.

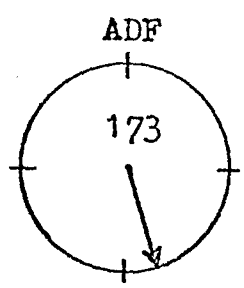




The new heading of 075 is held constant, and the 170 'mark' on the ADF dial, now becomes the new reference datum for noting any further track deviation.

If the allowance of 10 degrees is 'too much', then the aircraft will 'fly through' the track with the subsequent indication of the ADF needle moving to the left of the 170 datum.





To Prove:
Hdg. 075 ADF 173 = (-7) therefore, 075 - 7 = 068.

In practice, it may be necessary to re-intercept required track two or three times in order to 'peg down the drift'.

A further refinement of this technique in known wind conditions, is to take up an initial heading allowing for 'planned' drift, immediately after initial track interception.

Referring again to the example under discussion,- if the 'planned' drift was 12 degrees port, then the initial heading would be 077, and the ADF reference datum would be 168. The pilot would then monitor the 168 datum, noting any movement of the ADF needle right or left from this datum.

If the ADF needle moved to the right of 168, it would indicate to the pilot that the aircraft had drifted to port of required track, (065) and that the allowance of 12 degrees was not sufficient

If the ADF needle moved to the left of 168, it would indicate to the pilot that the aircraft had 'flown through' the required track, (065) and that the allowance of 12 degrees was 'too much'.

With practice and experience, these re-intercepts are conducted quickly and without fuss, before allowing the aircraft to deviate far from track.

TRACK MAINTENANCE........ ADF.

To maintain an 'inbound' track to a NDB, by reference to an ADF 'front bearing'.

To maintain an inbound track, the same technique as decribed in 'outbound' track maintenance is employed, except that the 360 datum is used in lieu of the 180 datum.

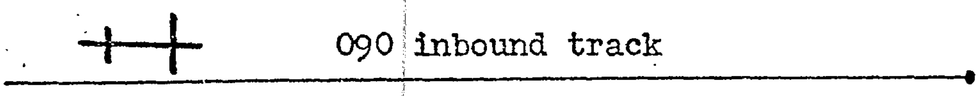
Example 1.

An aircraft tracking inbound, with a flight planned track of 090 to the NDB, has just come within rated coverage of the NDB, and the pilot has just tuned this NDB.

The pilot had earlier established the existance of 5 degrees port drift, and had subsequently been maintaining a heading of 095.

After tuning the NDB, the ADF indicator needle displays a r ding of 005.

090 inbound track

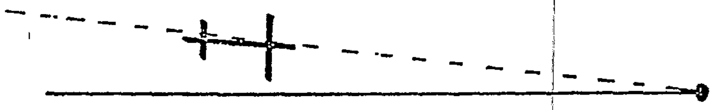


Hdg. 095 ADF 005 = (+5) therefore, 095 + 5 = 100 (TO).

We have now established that this aircraft is 'located' on the 100 inbound track, when in fact it should be 'located' on the 090 inbound track.

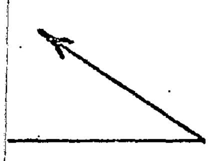
Conclusion... (5 degrees allowance has been insufficient).

100 inbound track.



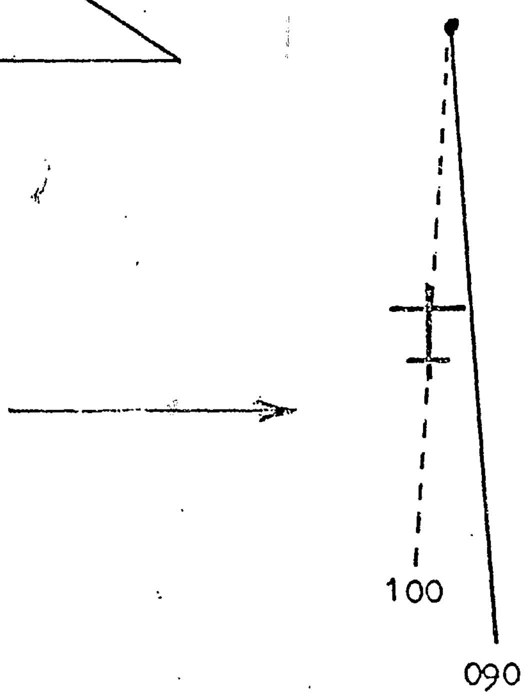
090 inbound track.

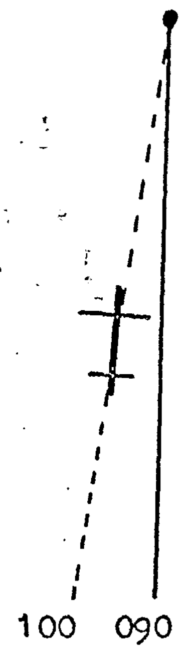
Objective mental picture.



(Hdg. 095)
(ADF 005)

Subjective mental picture.





(hdg.095)(ADF 005)

We will now board the aircraft and take control.

Turn the aircraft right, towards the required inbound track of 090 until the ADF needle is deflected by approx. 30 deg. left of the 360 datum;(maintain that mental picture)

We note that the new heading is 130, consequently our intercept angle is 40 deg.

As we fly towards the 090 inbound track, the ADF needle will commence to move down from 30 deg. deflection, towards 40 deg. deflection. The aircraft is 'some distance' from the NDB, so lead in will not be required and we wait until the ADF needle indicates 40 deg. deflection. At this point, the intercept has been attained.

Now bearing in mind that 5 deg. allowance for drift was found to be insufficient, we elect to 'try' 10 deg., so after successfully re-intercepting the 090 inbound track, we turn the aircraft left, from the intercept heading of 130, to 100. The ADF needle will move clockwise during this turn by the same amount, from 320 (40 deg. deflection) to 350.

This new heading of 100 is held constant, and the 350 mark on the ADF dial, now becomes the new reference datum for noting any further track deviation.

It may of course be necessary to re-intercept the required track two or three times in order to 'peg down' the actual drift being encountered.

When conducting a VFR flight, it will at times when tracking inbound, be unnecessary to actually re-intercept flight planned track, and so would be more expedient to track direct from the presen 'off track' position to the NDB.

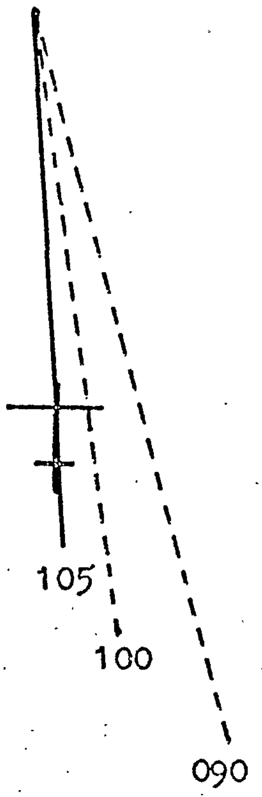
If this were to be the case in the circumstances just encountered then we would 'set out to maintain' an inbound track of 100, rather than re-intercept the flight planned track of 090 inbound.

We would realise as before, that the aircraft was encountering 'more than' 5 deg. drift, so may elect to 'try 10 deg.' - in which case we would take up a heading of 110. (Track required 100 + 10 deg. drift allowance = Hdg. 110)

As before, we would hold heading constant, and monitor the new ADF reference datum of 350, noting any further track deviation.

If the aircraft did in fact deviate from track, say further to port, then this would be apparent by the ADF needle moving to the right of the 350 datum, to say 355. The aircraft would then be positioned on the 105 inbound track.

Hdg. 110 ADF 355 = (-5) therefore, 110 - 5 = 105 (TO).



We would then realise that the aircraft was encountering more than the 'amended' 10 degrees allowance, and so we would 'try' 15 degrees,- in which case we would take up a heading of 120. (Track required 105 + 15 degrees drift allowance = Hdg. 120.)

As before, we would hold heading constant and monitor the new ADF reference datum of 345. (15 degrees deflection.)

A further simplification of 'VFR inbound track maintenance' is described as follows.

On first contact with the 'inbound NDB', position the ADF indicator needle on the 360 datum, noting any movement of the ADF needle from this datum.

If the ADF needle moves from this datum, turn the aircraft to position the nose on the 'upwind side of the NDB', by displacing the ADF needle to the appropriate side of the 360 datum,- by an amount equal to guesstimated drift. Hold this new heading constant, and monitor the new ADF reference datum, noting any rther track deviation.

If further track deviation is apparent, simply amend the drift allowance by amending the ADF needle displacement.

If, on first contact with the 'inbound NDB', the approx. drift is known, the need to first position the ADF needle on the 360 datum is negated. Just turn the aircraft to position the nose on the 'upwind side of the NDB',- hold heading constant and monitor the new ADF reference datum.

Get that mental picture going, and keep it going, or POOF !

GENERAL SUMMARY...... ADF.

Orientation and track interception, really forms the foundation and backbone of all radio navigation. -

If a pilot is competent in this field, he will obviously be competent at radio navigation,- full stop.

One can become competent in this field of orientation and track interception, if one attacks the problem in a logical manner.

In the initial stages of learning something strange and complex, it is invariably of great benefit to adopt a,- 'set pattern of events' attitude.

As one gains experience and becomes more familiar with 'events', this regimental approach towards the problem tends to diminish to the extent where - 'things seem to happen more naturally'.

To assist the pilot in the initial stages of learning, the following 'sequence of events' is tabulated. It is strongly recommended that these 'sequences' be learned, and committed to memory.

To orientate an aircraft to a NDB and form a mental picture, three factors are required.

(i) The radial that the aircraft is on.
(ii) The radial required.
(iii) The aircraft heading.

or,

(i) The inbound track that the aircraft is on.
(ii) The inbound track required.
(iii) The aircraft heading.

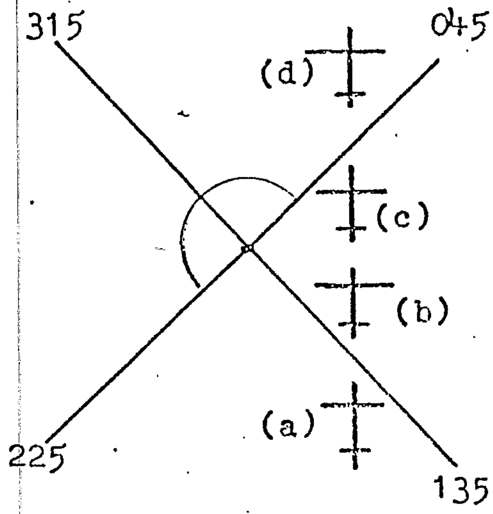
Track Interception: (ADF)

Outbound to Outbound, and Inbound to Outbound.

(i) Which radial am I on ?
(ii) Which radial do I require ?
(iii) Form mental picture, bearing in mind the aircraft heading.
(iv) What heading to intercept ?
(v) Which way is the most expedient turn onto intercept heading ?
(vi) Turn onto intercept heading.

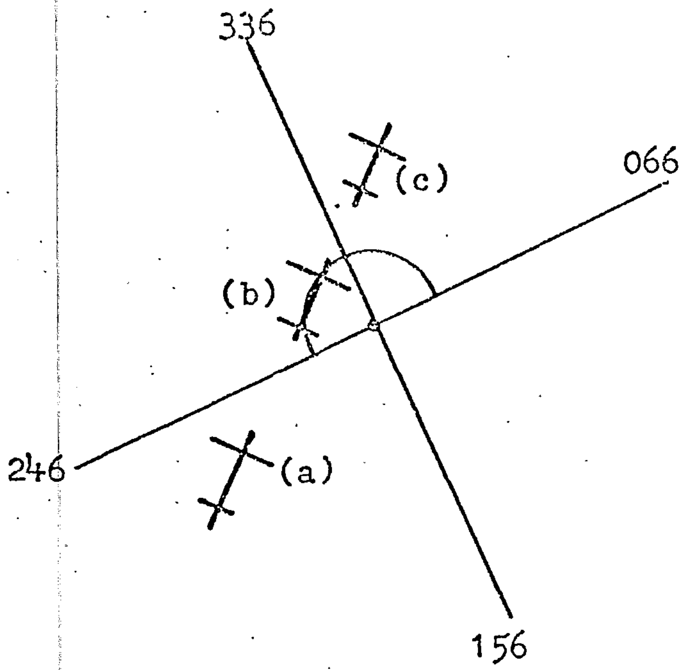
OBS set track 315

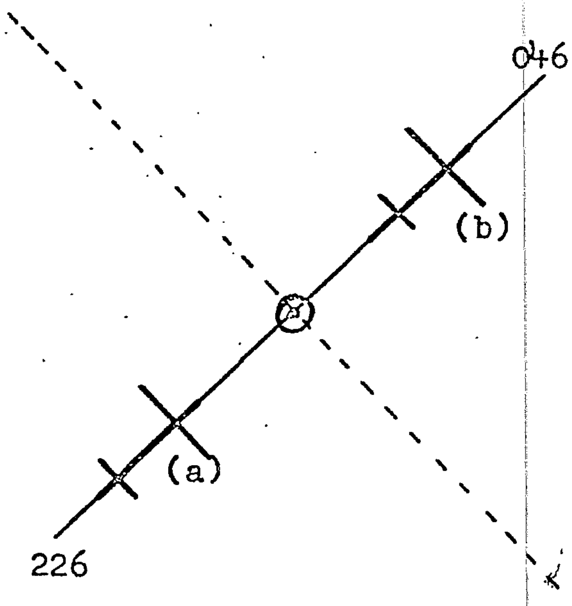
(a) TO window
(b) TO window
(c) TO window
(d) FROM window



OBS set track 336

(a) TO window
(b) FROM window
(c) FROM window





OBS set track 046

(a) TO window
(b) FROM window

An aircraft tracking 046 inbound (a) with OBS set track 046 and overflying the OMNI, would show a TO window whilst tracking inbound, and the indication would change automatically to FROM, as the aircraft passed over the Omni.

Track Interception: (ADF) continued......

Outbound to Inbound.

(i) Which radial am I on ?
(ii) Which radial do I require ?
(iii) Form mental picture, bearing in mind the aircraft heading.

(iv) Which basic direction of flight required to intercept ?
(v) Which way is the most expedient turn to this basic direction ?
(vi) Which side of the nose to position the NDB when on intercept heading ?
(vii) Turn towards the basic direction of flight required, and position the ADF needle deflection as required.

Inbound to Inbound.

(i) Which inbound track am I on ?
(ii) Which inbound track do I require ?
(iii) Form mental picture, bearing in mind the aircraft heading.

(iv) Which basic direction of flight required to intercept ?
(v) Which way is the most expedient turn to this basic direction ?
(vi) Which side of the nose to position the NDB when on intercept heading ?
(vii) Turn towards the basic direction of flight required, and position ADF needle deflection as required.

When conducting inbound intercepts, it is only necessary to displace the ADF needle by approx. 30 degrees. It will be found beneficial to 'roll out of the turn' onto an intercept heading at ıe point resulting in either of the following.

(i) A heading to the nearest 10 degrees,- for simplification of reading the directional gyro, and subsequent accurate intercept heading maintenance.

(ii) A heading that will provide for an intercept angle (and subsequent ADF deflection) being a multiple of 10. In example:- If track required was 173, then an intercept heading ending in 3, would provide for an intercept angle being a multiple of 10, subsequently presenting an 'easier to read' ADF deflection.

Track Intercept Angle = angular difference between....

(i) Heading and (ii) Track required.

The actual track that the aircraft flies while on the intercept heading, has no consequence to the actual intercept. The aircraft may drift right or left of the 'intercept track', but this will only effect the distance at which the intercept will be made along the required track.

It will be necessary, particularly for the aspiring IFR pilot, to practice the mental arithmetical problems associated with reciprocal calculations, and the ADF plus and minus factor applications, until a high standard of proficiency is obtained.

When tracking inbound close to a NDB, such as in an IFR holding pattern, or when on final approach during a NDB approach, the 'need' to displace the ADF needle by 30 degrees for re-interception of track, is somewhat refined. In fact most times the change in heading for re-interception is quite small, as any deviation from track must be realised and acted upon immediately it becomes apparent,- with subsequently only a 'small' needle displacement being necessary.

The refinements of this aspect of 'close in' 'close tolerance' ADF track maintenance, can be learned only with inflight training and experience.

When tracking outbound from a NDB, the ADF indications become progressively less sensitive, less accurate, and consequently less reliable because of the combined effects of the following two reasons.

(a) i The increasing distance from the transmitter.
ii The increasing lateral displacement of the diverging radials.

When tracking inbound to a NDB, the converse applies. There is a progressive increase in sensitivity, accuracy and reliability of the ADF indications because of the combined effects of the following two reasons.

(b) i The decreasing distance from the transmitter.
ii The decreasing lateral displacement of converging radials

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PART 2. VOR (Visual Omni Range)

The VOR is a VHF radio navigation aid, providing accurate track guidance for aircraft.

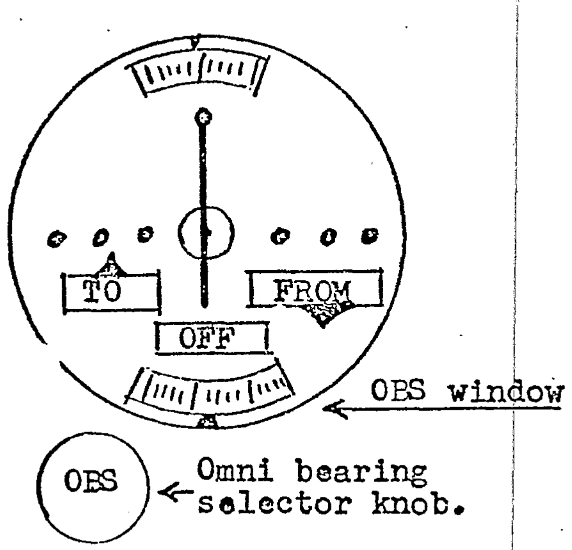
The airborn VOR indicator and radio receiver, interpret a two phased, VHF line of sight transmission from a ground station commonly referred to as an 'Omni'.

Inflight pilot interpretation of the VOR indicator, is generally considered to be easier than with ADF. However there are many aspects of VOR operation that require a concise knowledge of fundamental principles if effective benefits are to be obtained from the use of this particular navigation aid.

Many pilots experience difficulties associated with the interpretation of the VOR indicator needle in respect of 'left' or 'right' indications, and, confusion regarding the related TO - FROM window indications.

It is therefore essential that a knowledge of the basic fundamentals of VOR be obtained before proceeding with practical application of this radio navigation aid.

A typical VOR indicator is illustrated below.



The OBS knob enables the pilot to: (i) Orientate the aircraft to the Omni, by rotating the OBS compass rose scale, until the indicator needle is centred, and subsequently read direct from the OBS window, the bearing TO, or the bearing FROM the Omni. (It is possible to centre the needle by rotation of the OBS on two settings, subsequently obtaining either a bearing TO, or a bearing FROM the Omni. Example:- 240 FROM or 060 TO.)

If when orientating the aircraft to the Omni, a bearing TO is displayed after centering the needle, and it would be more convenient to display a FROM window, then one simply rotates the OBS scale through 180 degrees. (156 TO.... rotate OBS through 180 degrees and obtain a display of 336 FROM.)

(ii) The OBS knob enables the pilot to rotate the OBS compass rose scale, and set a required track in the 'OBS window'.

The indicator needle is hinged from the top, and moves across the scale from centre to 10 degrees each side of centre. The outer edge of the inner target circle representing 2 degrees, and each subsequent dot a further 2 degrees, with the outer edge of the scale representing 10 degrees deflection.

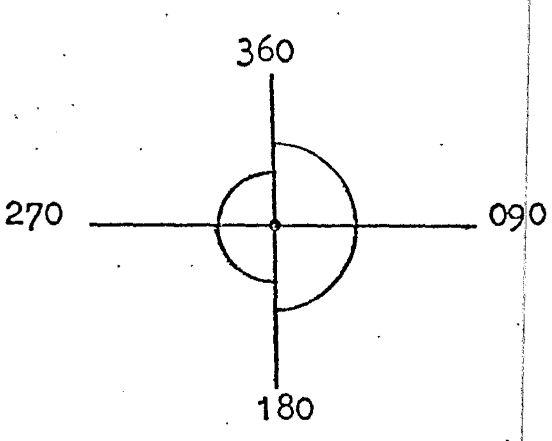
The VOR indicator needle will provide information concerning the actual displacement of the aircraft from the OBS set track, but only when the aircraft is within a 10 degree sector either side of that OBS set track.

Repeated reference will be made throughout this section on VOR, of the term 'OBS set track', or more simply, 'set track'. This term can be simply defined as; the track required to be flown.

The track set by the OBS, may be an inbound track or an outbound track.

If the pilot of an aircraft, which was positioned east of the Omni, was required to "track to the Omni via the 090 radial", he might perhaps orientate the aircraft in terms of radial to radial relationship, but, having done so, would set 270 in the OBS window by rotating the OBS knob, and would subsequently interpret the VOR indications in respect of the OBS set track of 270.

The basic principle of function of the TO - FROM windows, can be best described by reference to the accompanying sketches. For simplification, the function of the indicator needle will be completely ignored; in fact, for practical purposes it can be considered quite seperately from the function of the TO - FROM windows.

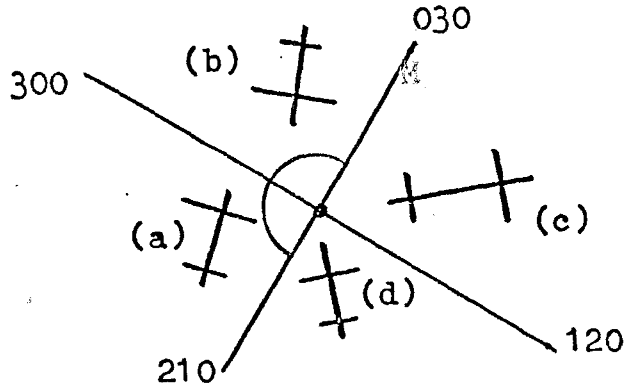


An aircraft with 090 OBS set track, will always show a FROM window when east of the N/S line, irrespective of the heading of the aircraft, and, subsequently will always show a TO window when west of the N/S line, irrespective of the heading of the aircraft.

An aircraft will always show a FROM window when situated within a 90 degree sector each side of an OBS set outbound track, (radial) irrespective of the heading of the aircraft, and subsequently will always show a TO window when positioned 'across the border' in the other half of the compass rose.

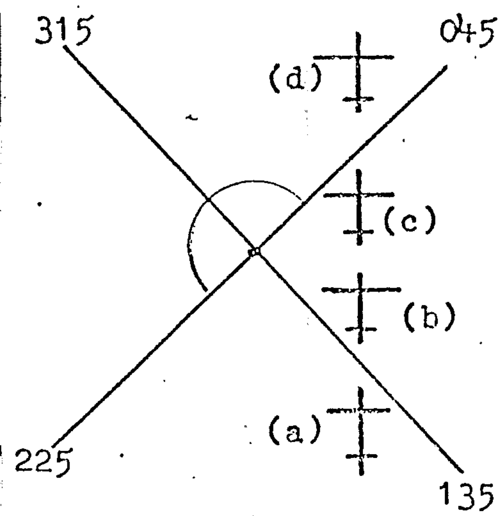
Examples illustrating this principle:-
Each of the aircraft in each sketch, have the same OBS set track.

OBS set track 300
(a) FROM window
(b) FROM window
(c) TO window
(d) TO window



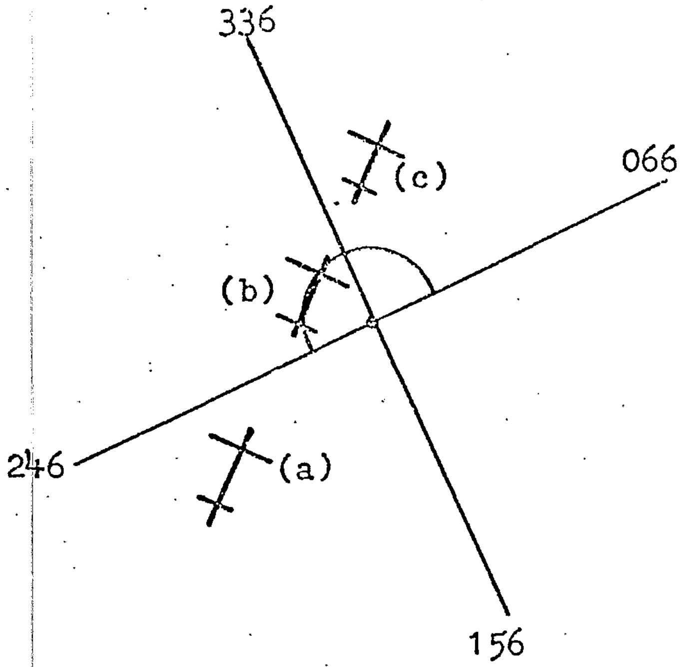
OBS set track 315

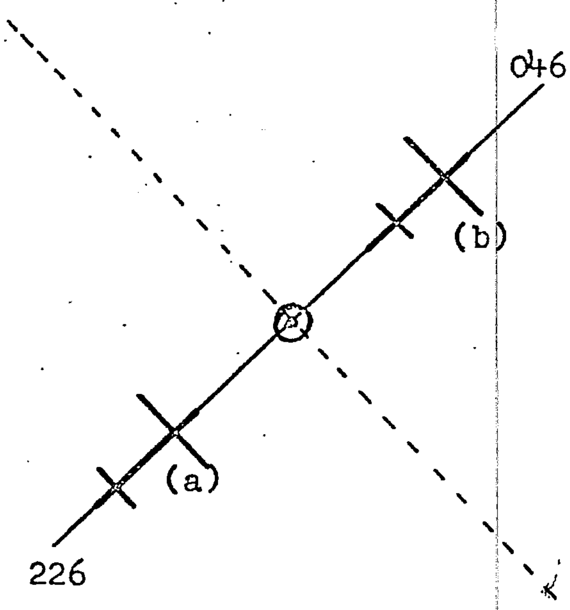
(a) TO window
(b) TO window
(c) TO window
(d) FROM window



OBS set track 336

(a) TO window
(b) FROM window
(c) FROM window





OBS set track 046

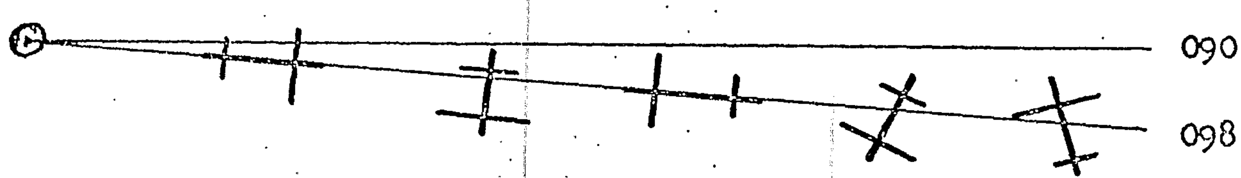
(a) TO window
(b) FROM window

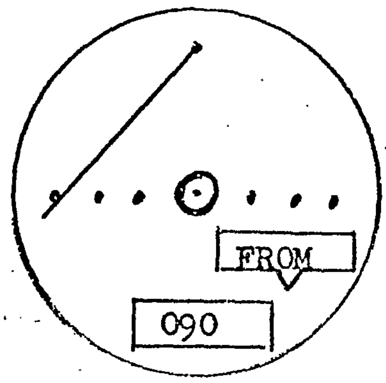
An aircraft tracking 046 inbound (a) with OBS set track 046 and overflying the OMNI, would show a TO window whilst tracking inbound, and the indication would change automatically to FROM, as the aircraft passed over the Omni.

Unlike the ADF indicator needle, the VOR indicator needle does not point to the station, nor does it consequently have any affinity with the heading of the aircraft.

The VOR indicator needle shows only the angular displacement of the aircraft from 'set track', when the aircraft is located within a sector 10 degrees either side of that set track. If the aircraft is further removed than 10 degrees from set track, then the needle will indicate full scale deflection.

If all the aircraft in the sketch below, were to have 090 set in the OBS window, the VOR indications to each pilot in each aircraft would be identical.





VOR indication to each pilot.

(needle is indicating 8 deg. displacement in relation to 'set track'.)

We now realise, that it would be catastrophic to interpret the VOR indicator needle in terms of set track being right or left of the aircraft heading.

The function and interpretation of the VOR indicator needle is described in the following excercises, but first, we learn one very important rule concerning the interpretation of the left/right deflections of this indicator needle.

This rule applies without exception, whether intercepting an inbound track, whether intercepting an outbound track, or even when making minor adjustments to heading to rejoin and maintain any OBS set track, irrespective of the heading and position of the aircraft in relation to the Omni.

Needle Left:

A heading less than OBS set and displayed track, is required to intercept OBS set and displayed track.

Needle Right:

A heading greater than OBS set and displayed track, is required to intercept OBS set and displayed track.

At this stage it will be more expedient to explain the various functions and applications of VOR, by graphically presenting examples of inflight useage. Some of these examples will have to be rather 'academic' in order that a full appreciation of this radio navigation aid be obtained.

OUTBOUND TRACK INTERCEPTION..... VOR.

Example (i). You are piloting an aircraft 'somewhere' within 5 miles of the Omni, and you are required to intercept an outbound track of 090, from an unknown position.

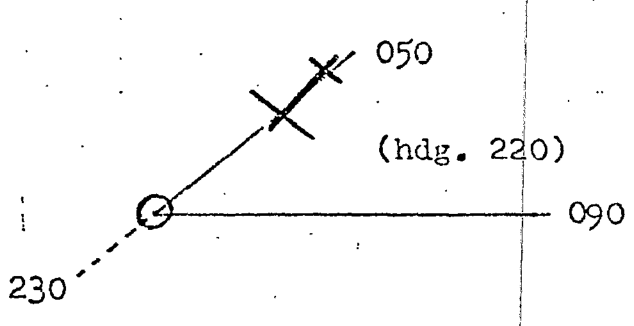
Step 1. (a) which radial am I on ?
(b) which radial do I require ?

Rotate the OBS until the indicator needle is centred, then read direct from THE OBS window a bearing, noting whether a TO, or a FROM window. If after centering the indicator needle, the indication is a TO, then calculate the reciprocal for the answer to (a), or, just simply read from the reciprocal scale in the top reciprocal window.

From the foregoing, the aircraft is orientated to the Omni and a mental picture formed.

For the purpose of this excercise, we will assume a heading of 220, and a VOR indication of 230 TO.

Our mental picture would be thus.........



Step 2.
(a) Set the required track with the OBS. (090)
(b) Note the VOR indications and confirm what you would expect to see, ie. full scale needle deflection right, and a FROM window.

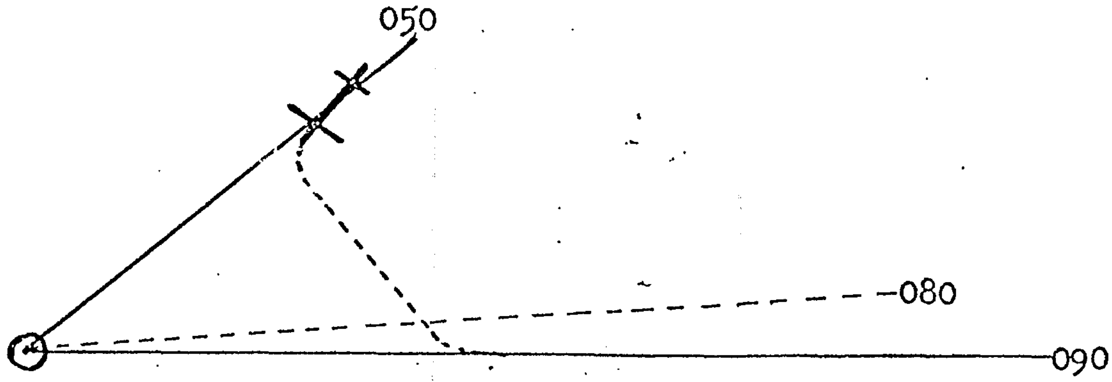
Interpret the needle deflection as;

Needle right.... therefore heading required to intercept OBS set and displayed track of 090, must be greater than 090.

(Now bearing in mind the combined effects of aircraft proximity to required track and station, and known wind conditions, an intercept angle is selected, - we will assume an intercept angle of 50 degrees, which will result in an intercept heading of 140.)

(c) Turn the aircraft left from a heading of 220 to 140.

(It is pertinent to note that, even though the VOR indicator needle is showing full scale deflection right, the aircraft is turned left from a heading of 220, to the intercept heading of 140, in order to intercept the OBS set and displayed track of 090 FROM.)



The VOR indicator needle will remain at full scale deflection right, until the aircraft reaches the 080 radial, (10 deg. full scale deflection) at which point, the indicator needle will commence to move in towards centre.

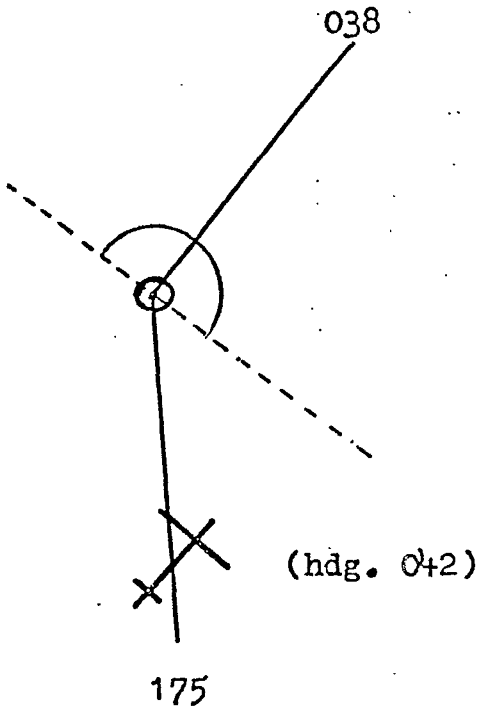
When the indicator needle is centred, the intercept has been attained and the aircraft is turned left from the intercept heading of 140, to that of required track, 090.

The rate at which the indicator needle moves in towards centre, (after the aircraft has reached the 080 radial) provides the pilot with an indication of how fast the aircraft is 'closing' on the set track.This information subsequently provides the opportunity to 'adjust' this rate of closure, by minor alterations to heading.

Example (ii). Hdg. 042 VOR 355 TO. (after centering needle)
Problem: To intercept an outbound track of 038.

Step 1. which radial am I on ? = 175
which radial do I require ? = 038

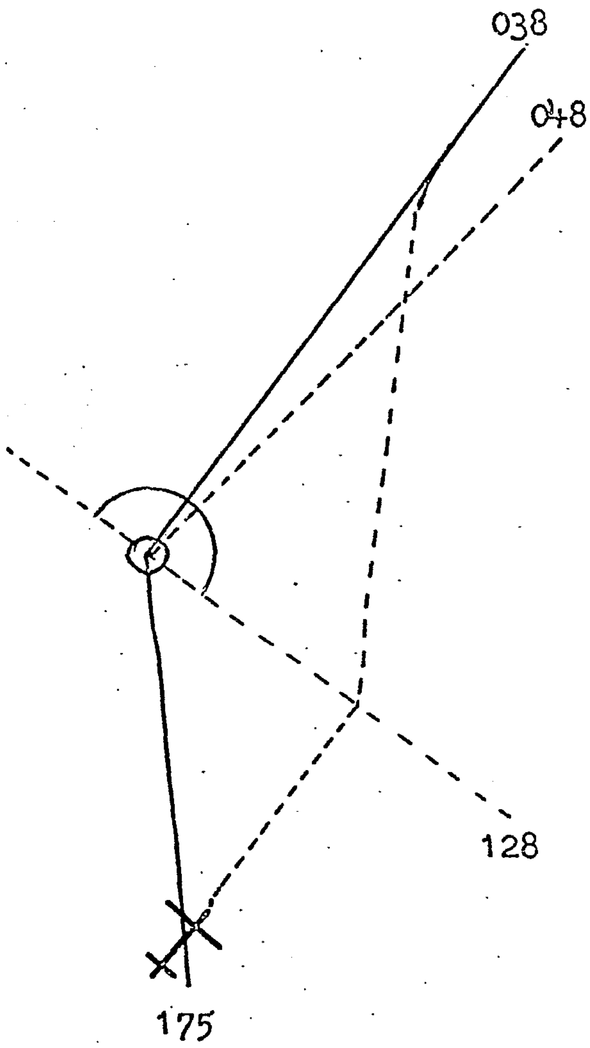
(now form your mental picture)



Now you may, or may not realise at this stage, that you are 'outside' the 90 degree quadrants of the required outbound track of 038, that you are 'about to set' with the OBS.

Step 2. (a) Set the required track of 038 with the OBS. (The needle will indicate full scale deflection left, and the automatic appearance of the TO window, will confirm that you are outside the 90 degree quadrants of the required outbound track of 038, ie. "across the border"..... in the TO sector.)

(b) Take up a heading to parallel the required outbound track, (038) and maintain this heading until the TO window automatically changes to a FROM window. The FROM window will appear as the aircraft passes through the 128 radial.



N.B. After setting the required track of 038 with the OBS, the indicator needle will be positioned at full scale deflection left, before and after passing the 128 radial, and will only commence to move in towards centre, as the aircraft passes through the 048 raial, (10 deg. to go).

(c) Immediately the TO window changes to a FROM window, turn the aircraft onto a heading less than that of set track, ie. less than 038. You may decide on a 30 degree intercept angle, in which case you would turn the aircraft left, from a heading of 038 to 008.

The VOR indication will remain static until the aircraft flies within a 10 degree sector either side of OBS set track. In other words, the indicator needle will remain at full scale deflection left, until the aircraft reaches the 048 radial, at which point it will commence to move in towards centre.

The rate at which the needle moves in towards centre, will indicate to the pilot, the rate at which the aircraft is 'closing' on the set track of 038.

INBOUND TRACK INTERCEPTION....... VOR.

The earlier excercises on ADF track interception, revealed that inbound track interception angles had to be 'calculated', rather than 'guesstimated'.

With ADF, this was simply accomplished by displacing the ADF indicator needle to one side of the 360 datum, by an amount appropriate to the occasion. (In our excercises we elected to use 30 degree displacement).

There is also a requirement to 'calculate' an inbound intercept angle when conducting VOR inbound track intercepts. The requirement is for the same reason, but because the VOR indicator needle does not 'point to the station', as does the ADF indicator needle, the same technique cannot be used.

The technique used to calculate an inbound track intercept angle, and subsequently apply it to obtain an inbound intercept heading when using VOR, is described as follows.

(i) Orientate the aircraft to the 'present inbound track position' by centering the needle.

(ii) Calculate the angular displacement between 'present inbound track position', and, 'required inbound track', and at the same time form your mental picture.

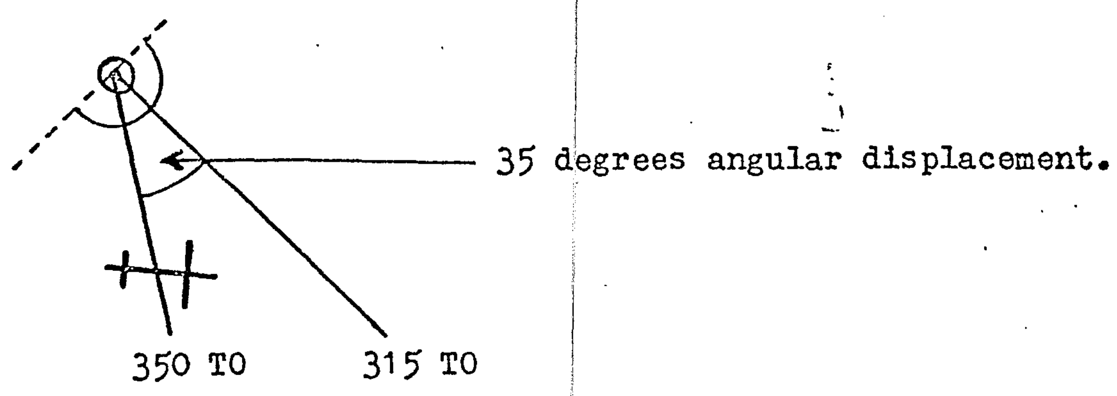
(iii) To this angular displacement, a constant 30 degree factor is added, - and this sum total, (angle of intercept) is then 'applied' to the required inbound track to obtain an intercept heading. The right or left needle displacement after setting the required track, will determine, (and confirm your mental picture) whether 'this angle' is either subtracted from, or added to the track required.

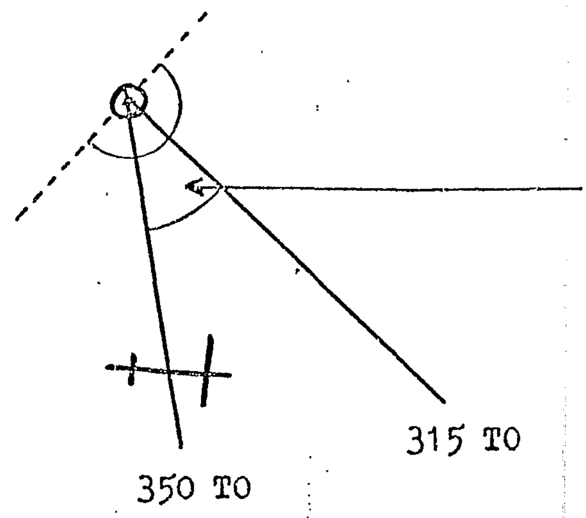
Example 1. Hdg. 095 VOR 170 FROM. (after centering needle)
Problem: To intercept an inbound track of 315 from an unknown position. (The aircraft is flying within 5 miles of the Omni.)

Step 1. which inbound track am I on ? = 350
which inbound track do I require ? = 315

A mental picture is now formed, noting at the same time, the angular displacement of 35 degrees between these two inbound tracks.

To this displacement figure, add the constant factor of 30 degrees, and derive the answer of 65 degrees.





<u>Step 2.</u> (a) Set the required track with the OBS. (315)

(b) Note the VOR indications, and confirm what you would expect to see, ie. full scale needle deflection right, and a TO window....... needle right = intercept heading must be <u>greater</u> than set and displayed track of 315, ie. greater by the amount just calculated:- 315 + 65 = 020.

(c) Turn the aircraft left from a heading of 095, onto the intercept heading of 020.

The VOR indicator needle will remain at full scale deflection right, until the aircraft reaches the 325 inbound track, (10 deg. to go at which point the needle will commence to move in towards centre.

Bearing in mind that an intercept angle of 65 degrees, is quite large, it will be necessary to progressively reduce this angle, using the rate of needle movement as an indication of the rate of closure of the aircraft to the required inbound track of 315.

The needle movement will of course only occur when the aircraft comes within 10 degrees of set track.

The 'art' of judging the rate of closure by observation of the rate of needle movement, is obtained only with inflight practice and experience.

This last excercise has highlighted the necessity for the aspiring IFR pilot, to obtain an ability to orientate an aircraft to a ground station, in terms of 'inbound track' to 'inbound track' relationship.

As mentioned earlier, it is essential to obtain a real knowledge of the layout of the compass rose, in terms of being able to 'instantly picture' the location of all radials and inbound tracks.

This next example of an inbound track interception, is given in circumstances that would be highly improbable in practice, but has been chosen so that the validity and consistency of fundamental VOR rules can be confirmed, and again demonstrated, despite how peculiar the situation may be.

Example 2.

Problem: To intercept an inbound track of 040, at least 3 miles from the Omni, from a position where the aircraft is positioned 'across the border' in the north east sector.

The following information is displayed to the pilot.

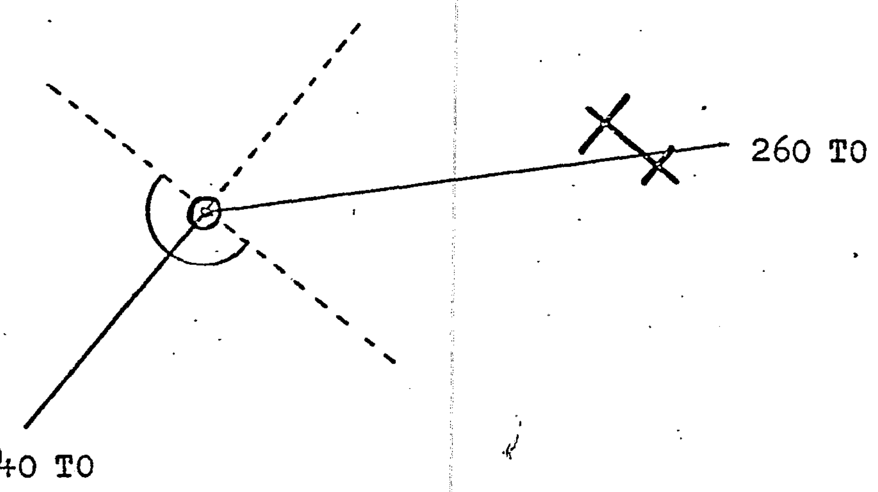
Hdg. 310 VOR 260 TO. (after centering the needle)

(It is sometimes a matter of personal preference whether the aircraft is orientated on the basis of radial to radial relationship, or whether on the basis of inbound track to inbound track relationship. This excercise could be successfully conducted using either method, however we will use the 'inbound track relationship' to orientate the aircraft and form our mental picture.)

Step 1. (a) which inbound track am I on ? = 260

(b) which inbound track do I require ? = 040

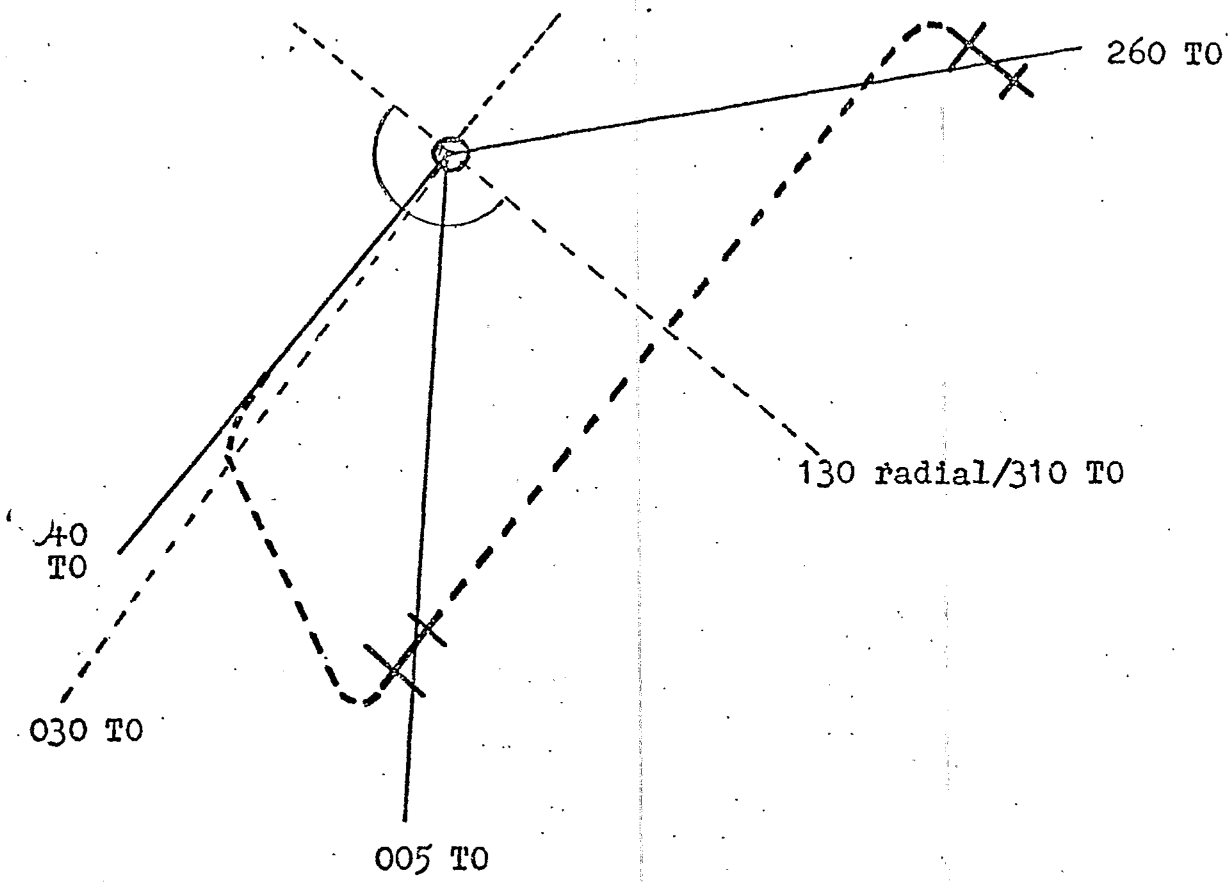
A mental picture is now formed, and it is immediately apparent that an intercept of the 040 inbound track cannot be undertaken from 'this side of the border'. We therefore conclude that the aircraft will first have to be positioned in the 'TO' sector of the required inbound track. (040)



Step 2. (a) Set required track with OBS. (040)

(b) Note the VOR indications, and confirm your mental picture; ie. full scale needle deflection left, and the appearance of the FROM window. (The FROM window is confirming your mental picture of the aircraft being located within a 90 degree sector either side of 040 FROM.)

Step 2. cont..... (c) Take up a heading to parallel the reciprocal of the required inbound track of 040. (left turn is the most expedient, - onto 220, and leave the required track set in the OBS window.)



As the aircraft tracks 220, (approx.) 'station passage' will be evidenced by the FROM window changing to a TO window, as the aircraft 'crosses the border' over the 130 radial, (310 inbound track).

(d) Maintain heading for approx. 2 minutes after station passage, nd orientate the aircraft to the Omni in order to calculate an intercept angle. In example, the aircraft is orientated to the 005 inbound track by rotating the OBS, and obtaining a 005 TO indication.

We can now 'update' our mental picture, noting the angular displacement between 005 inbound and 040 inbound, as being 35 degrees.

This displacement angle of 35 degrees, is then added to the constant factor of 30 degrees, and the answer of 65 degrees is derived.

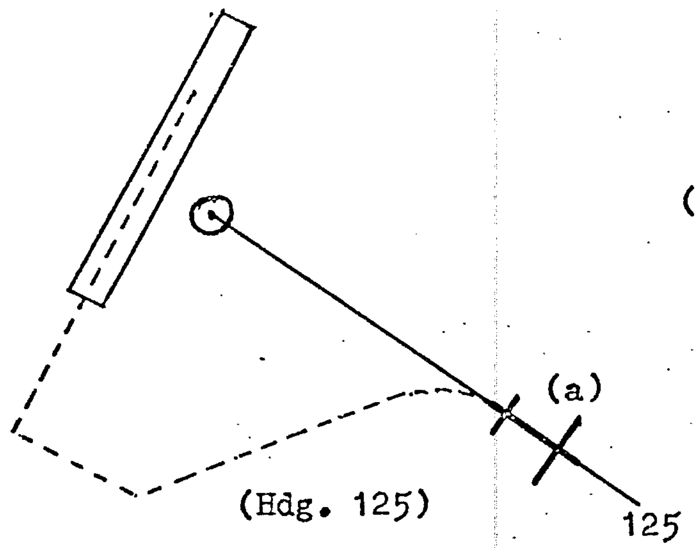
(e) Set required track (040) by the OBS, and confirm the anticipated VOR indications of: 040 TO - full scale needle deflection left....needle left = intercept heading required, must be less than set and displayed track; therefore, intercept heading = 040 - 65 = 335.

(f) Turn the aircraft right from a heading of 220, to the intercept heading of 335. (The indicator needle will of course remain at full scale left, until the aircraft reaches the 030 inbound track, at which point it will commence to move towards centre, and from this point, the rate of closu... can be controlled by reference to the rate of needle movement.)

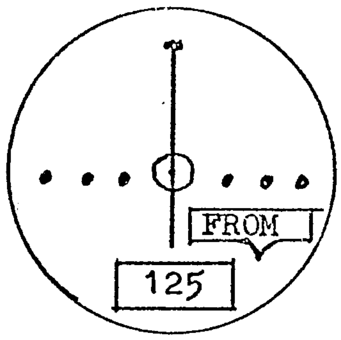
OUTBOUND TRACK MAINTENANCE..... VOR.

Once established on track immediately after interception, the aircraft heading is held constant, and if drift is encountered, it will be evident by the movement of the indicator needle, either right or left of centre.

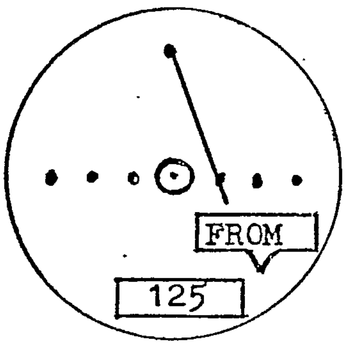
Example 1. An aircraft has departed an aerodrome, and has successfully intercepted the required outbound track of 125.



(a)



Approx. three minutes after intercepting track and setting heading, the VOR indicator needle has moved to 2 dots displacement, (4 degrees right). (refer to sketch below, aircraft position b.)

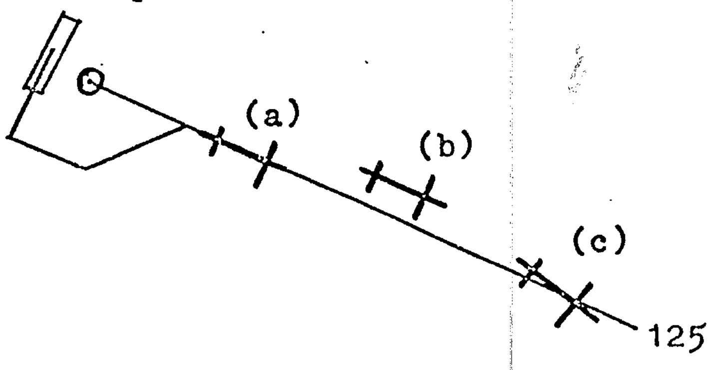


(b)

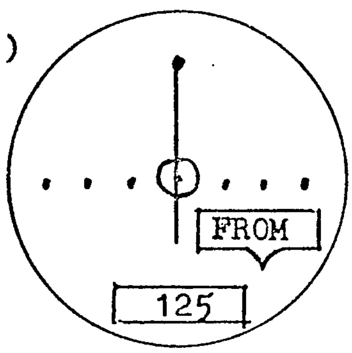
This indication is interpreted by the pilot in the same manner as previously described; ie. Needle right = intercept heading required is greater than set track. (Port drift is being encountered.)

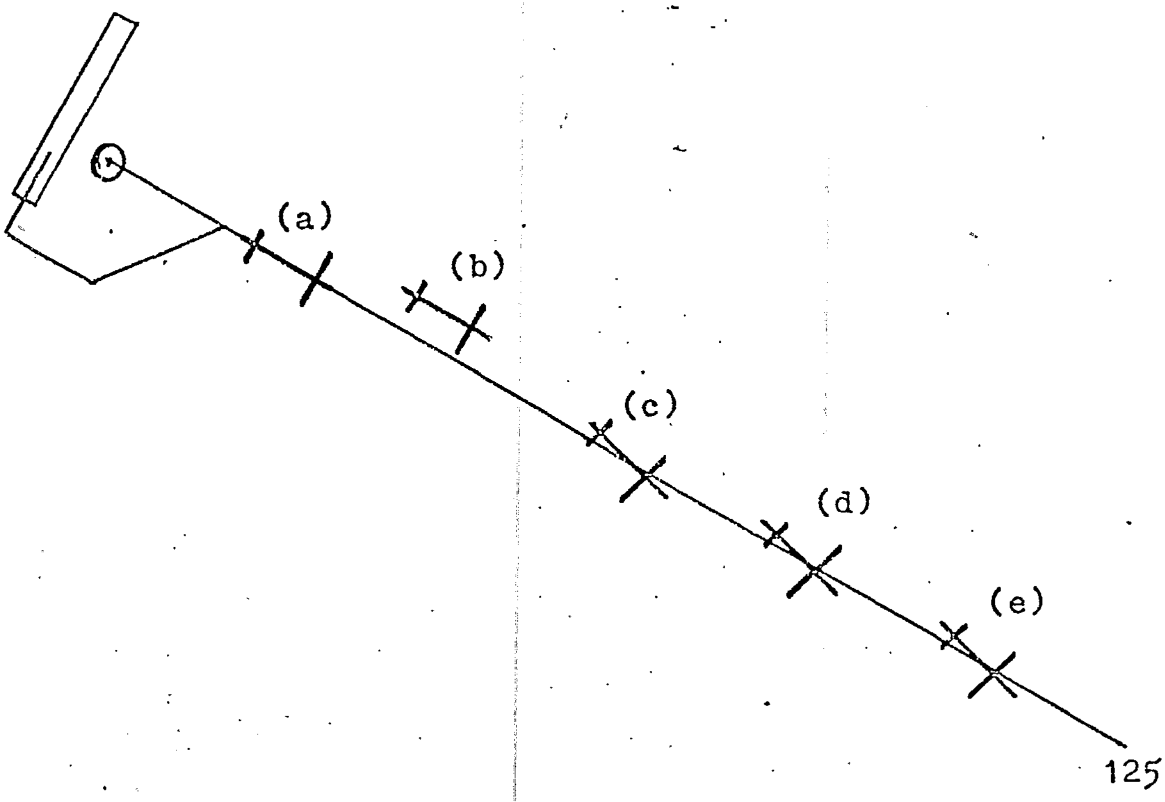
The aircraft is turned right by an appropriate amount for re-intercept. As the aircraft closes on set track, the needle will commence to move in towards centre.

Successful re-interception of track will be indicated by the needle returning to centre, at which point the aircraft is turned left towards track, but makes an allowance of 10 degrees for port drift encountered, and would therefore take up a heading of 135. (aircraft position c.)



(c)





If the actual drift was 10 degrees, then the aircraft would maintain track with a heading of 135, and the VOR indicator needle would remain centred. (d) and (e).

If any further drift was encountered, then this would be apparent by the movement of the indicator needle from centre. If this was the case, then the track would be re-intercepted, and a further allowance made. The new heading would be held constant, and the VOR indicator needle monitored for any further track deviation.

The VOR indicator needle will not provide the pilot with information concerning the actual amount of drift being 'laid off', but will simply indicate whether or not track is being maintained.

The actual amount of drift being encountered, can be determined in the difference between heading and track, whilst maintaining the VOR indicator needle centred.

INBOUND TRACK MAINTENANCE.... VOR.

There is virtually no basic difference in pilot interpretation of the VOR when conducting inbound or outbound track maintenance. Simply, - needle left = intercept heading required, is less than set track, and of course conversely with needle right.

Bearing in mind that the VOR indicator needle has a full scale deflection of 10 degrees either side of centre, and assuming that inbound track maintenance can be confined to within a sector 10 degrees either side of set track, then the pilot knows at a glance the displacement of the aircraft from set track. This subsequently negates the necessity to 'orientate' the aircraft and calculate an intercept angle.

The pilot will nevertheless interpret the 'needle left = heading to intercept is less', but will normally only require relatively minor changes in heading to re-intercept set track.

As discussed in the section on ADF inbound track maintenance, it will at times, when conducting a VFR flight, be unnecessary to re-intercept flight planned inbound track from an 'off track' position. It will in many circumstances, be more expedient to simply track direct to the Omni from the 'off track' position.

The same principle applies with VOR as it does with ADF; that is,. locate the aircraft to 'present inbound track', and set out to maintain this inbound track.

Example.... An aircraft which has been tracking inbound towards the destination aerodrome, comes within range of the Omni which is situated at the destination aerodrome, and consequently the pilot tunes the VOR.

The flight planned inbound track is 250, but the pilot 'locates' the aircraft on an inbound track of 240 by simply rotating the OBS until the needle is centred with a TO window.

The pilot at this stage, is unsure of the existing wind conditions so elects to take up a heading the same as track, (240). At this point, the VOR indication would be 'needle centre', and a display of '240 TO'.

After maintaining this heading for 10 minutes, the VOR needle indicates 2 dots right. Conclusion... = Port drift, ie. the aircraft has drifted to port of the required inbound track of 240, and is now located on the 244 inbound track. (2 dots = 4 degrees) .
(Draw this situation in your mind without resorting to pen and paper.)

Now rather than re-intercept the inbound track of 240, the pilot 'sets out' to maintain an inbound track of 244. (By rotating the OBS window from 240 to 244, the indicator needle will be 'brought back' to centre, - or if you like, - simply centre the needle and read 244 in the OBS window.)

The pilot has now established the existence of port drift, and makes due allowance by taking up a heading of 250. (allowing 6 degrees port drift compensation, ie. set track 244 - heading 250.)

If the 'guesstimated' allowance of 6 degrees was correct, then the aircraft would track direct to the Omni on an inbound track of 244, with a heading of 250.

If however the drift allowance was incorrect, then the resultant track deviation would become immediately apparent to the pilot by the subsequent deviation of the indicator needle.

If this did occur, then once again the needle would be centred by rotating the OBS, and the pilot again, would 'set out' to maintain this displayed track, with his 'amended guesstimate' of drift compensation.

GENERAL SUMMARY....... VOR.

In the summary on ADF, we concluded that,- if a pilot was competent at orientation and track interception, he was 'on top of radio navigation'.

The same logic of course applies with VOR.

If one is desirous of 'getting on top of VOR', then one must become competent at orientation and track interception using VOR.

To assist in this regard, the following 'sequence of events' is tabulated. As mentioned previously,- learn these sequences and commit them to memory.

To orientate an aircraft to an Omni and form a mental picture, three factors are required.

(i) The radial that the aircraft is on.
(ii) The radial required.
(iii) The aircraft heading.

or,

(i) The inbound track that the aircraft is on.
(ii) The inbound track required.
(iii) The aircraft heading.

Track Interception: (VOR)

Outbound to Outbound, and Inbound to Outbound.

(i) Which radial am I on ?
(ii) Which radial do I require ?
(iii) Form mental picture.

(iv) Set required track with the OBS.
(v) What heading to intercept ?
(vi) Which way is the most expedient turn onto intercept heading ?
(vii) Turn onto intercept heading.

Outbound to Inbound.

(i) Which radial am I on ?
(ii) Which radial do I require ?
(iii) Form mental picture, noting angular displacement between the two radials concerned.

(iv) Set required track with the OBS.
(v) Calculate intercept angle,- then intercept heading.

(vi) Which way is the most expedient turn onto intercept heading ?
(vii) Turn onto intercept heading.

Inbound to Inbound.

(i) Which inbound track am I on ?
(ii) Which inbound track do I require ?
(iii) Form mental picture, noting angular displacement between the two inbound tracks concerned.

(iv) Set the required track with the OBS.
(v) Calculate intercept angle,- then intercept heading.
(vi) Which way is the most expedient turn onto intercept heading ?
(vii) Turn onto intercept heading.

The VOR provides for more accurate track maintenance than does ADF, and consequently the VOR indicator is more 'sensitive'. This is particularly noticeable when tracking inbound close to the Omni, as the lateral displacement between the converging radials is progressively reduced.

The VOR can in many ways, be considered a more 'refined' radio navigation aid than ADF. The VOR will provide only limited benefit to a pilot, unless he is prepared to 'learn to use the aid', and subsequently use it for track maintenance, rather than track guidance.

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