subsequently served a 35-year career in the regular Navy. Although he had no formal education beyond high school, he became an accomplished astronomical observer. I am enclosing a one-page writeup of Commander Francis Green. If the Foundation has an interest in having the complete autobiography I would be glad to try to arrange for one. It is entertaining reading.

"He includes a description of his youth, running away to join the merchant marine, service in the blockading Union Fleet during the Civil War and his post war assignments in the USN Hydrographic Office. Although he lacked any formal education in the astronomy and math fields it is obvious that he must have been a highly motivated self-teacher." — *Richard C. Gibson*

NAVIGATION NOTES

GREAT CIRCLE SLIDE RULE

By Robert M. Girder

Explanation, With Instructions And Example:

Mathematical Basis

Determination of Great Circle course and distance between two points involves the solution of a spherical triangle whose corners are North pole, Departure point, and Destination. The known values are the Latitudes of these points and the difference in longitude between them. The desired unknowns are the Initial Course and Distance (bottom line of triangle). (Except for the names of the parts, this problem is identical to the finding of the Hc and Z in the reduction of a Calculated Altitude sight to determine a Line of Position)* The Course and Distance can be readily found by spherical trig. calculations, special tables, or by graphic methods. The graphic method, used here, is by far the fastest. In addition, it provides continuous position information along the Track. In brief, this is accomplished by using the meridians and parallels of the stereographic projection to plot the position of the destination. Further rotation of the cursor places the bottom line of triangle along a meridian, thereby making possible the measurement of the desired unknowns: **Initial course** and **distance.**

Preparation

Where marking of the plastic cursor disk is called for, use either a sharp crayon, removable with dry tissue, or a suitable felt-tip pen, removable with moist tissue. After some experience the detailed instructions below can be replaced by following the **Steps**, shown on the face of the instrument.

Course and Distance

Assuming a trip from San Francisco (N38°,W122°) to Tokyo (N36° E140°). First, determine the difference in longitude by *subtracting* if the direction of the longitudes are the same, or by *adding* if the directions are different. If the sum exceeds 180°, subtract from 360°. In this case: @122°+E140°=262°, 360°-262°=98°.

*QUIK-DRI **Sight Reduction Tables for Marine Navigation, including Celestial Rule** uses the same graphic method to determine the Azimuth and verify the Altitude. Copies are available from the author.

Next, set the cursor line on the rotatable plastic disk to 90° N Lat. Then, dot the intersection of the Diff Long (98°), interpolated between the marked meridians 90° and 100°, (top horizontal row of numbers) and the destination Lat. (N36°, interpolated between the marked parallels N30 and N40, right-hand edge). Circle the dot so it can be found later.

Now, rotate the disk clockwise, to put the cursor line over the Lat. Of Departure on the calibrated right hand edge scale. The new position of the dot will show the **Initial Course**, estimated from the bracketing Meridians on the bottom horizontal row of numbers (56°). The initial course is stated in degrees East or West of North, depending upon the direction of sailing (in this case, West). The compass course, then, is 360°-56°, or 304°.

Likewise, the dot's new position will show the **Distance**, estimated from the bracketing Parallels, evaluated by the miles scale on the left hand edge (4450 N. miles).

Track

To determine the Track, proceed as follows: Without moving the cursor, draw a **meridian line** from the dot to its North Point (90°). (Note: All meridian lines are arcs of circles on this stereographic projection. It can be sketched by hand with sufficient accuracy for most purposes. Next, rotate the cursor line back to 90°N. The new position of the drawn line will represent the **Track** from the Point of Departure (on the left hand edge) to the Destination (at the Dot). Waypoints along this line can be evaluated directly from the indicated Latitudes, and the difference in Longitude successively applied to the departure Longitude. These waypoints, conveniently every 10° change in Long. Or Lat., can then be transferred to an actual chart. In doing so, remember that on the "Slide Rule" the track always goes from Left to Right, regardless of the direction of sailing.

New Courses at Waypoints

The cutting angle of the track at each marked meridian or parallel makes possible an estimate of the changing course all along the route (for planning purposes). During the actual voyage, the new course would be recalculated at each waypoint.

(3) The vessel's Longitude 18°21'East

Part B: Star Identification

(1) Time of civil twilight after sunset:

Greenwich Mean Time 1812

Zone Time 1912

(2) The star is Arcturus

HISTORY OF NAVIGATION

ON THE ASTRONOMISCHES RECHENGERAT ARG1

By David Charlwood

Introduction.

There have been many and varied attempts in the past to solve the PZX navigational triangle utilising graphical-mechanical solutions. The great majority, however, have not possessed sufficient accuracy and ease of use to make them capable of supplanting and superseding other established methods. This paper seeks to combine and present all the relevant reports and documentation pertaining to the origin, the development and the operational history of the Zeiss ARG1. Information recently declassified and released to the general public by the relevant authorities has been included.

Origins.

Perhaps the most immediate predecessor of the ARG1 was the Bastien-Morin Type 12 calculator. This instrument was originally conceived by Professor A. J. Bastien for Air France and produced by H. Morin in Paris, France in the late 1930's. This device comprises two superimposed circular concentric transparent engraved plates based on an orthographic projection. The fixed upper plate comprising a graticule of parallels and meridians with minimal divisions is used to give an idea of the measurements carried out. The lower rotating graticule is identical to the upper, but with much more detailed engraving of which the divisions are not visible to the naked eye, but only by means of three microscopes, two of which are mobile and allow complete exploration of the grid, and a third fixed microscope which enables the latitude rotation to be accomplished. It was heavy and expensive and although the accuracy of the instrument was professed to be in the order of one minute of arc, the accuracy attained was, however, reported to be insufficient.

Operational Requirements

The Luftwaffe had decided by the early 1940's that the further development of calculated altitude and azimuth tables was virtually concluded, and that use of the German copy of the Bygrave slide rule manufactured by Dennert & Pape, at Altona, and known as the HR1, possessed difficulties for the observer when used in poor light and when subjected to aeroplane vibration.

Their new requirement was for an instrument with the following properties:

- The solution of the spherical triangle must be so simplified that, by a single insertion of the three known quantities (Time Angle, Declination and Latitude), the two required quantities (Altitude and Azimuth) will be shown directly, without intermediate quantities and without rules concerning plus and minus signs, with an accuracy of about ±1' of altitude and ±1° of azimuth.
- It should be suitable for use in all latitudes and for all heavenly bodies.
- It should make the smallest possible demand on precision engineering capacity in obtaining the desired accuracy.
- There should be direct reading of all values and scales.

The method finally chosen was spherical co-ordinate transformation. Mechanical rotation is both simple and reliable, and in addition, the whole hemisphere can be represented without troublesome distortions.

Principle Of The Instrument

The basis of the ARG1 is a grid inscribed with an equatorial stereographic diagram of a hemisphere, projected on to a plane parallel to the plane of the observer's meridian.

Consider the following two diagrams:

In the polar mode (Latitude – = 90°) the grid represents the celestial equator system, and is made up of lines marking Hour Circles and Parallels of Declination.

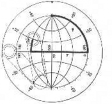


Figure 1 - ARG grid at celestial equator position in polar mode
Latitude – + (N) 90°
Time Angle = 150°
Declination = + (N) 30°

By rotating the grid from the polar mode to an angle equal to the co-latitude, the point previously marking the pole now marks the zenith, and the grid now represents the horizon system. The lines now represent Azimuth Circles and Parallels of Equal Altitude

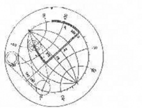


Figure 2. ARG grid at horizon system in zenith mode
Latitude = +(N) 50°
Altitude = 60°
Azimuth = 120°

Description Of The ARG1 And Accessories

The instrument (see photographs 1 & 2) has a diameter of 21.6 cm, a height of 19 cm and weighs 1.8 kgs. The front of the instrument is an alloy ring with a central plate-glass window of 10 cm diameter, through which the grid is visible. This grid is a photographic transfer on glass. The original drawing for the grid was made on a quadrant of one metre radius, and co-ordinate points were put in for intervals of 2° by means of a Zeiss stereo-comparator. Straight lines were then connected between adjacent points (the inaccuracy due to straight rather than curved lines does not exceed 0.5 minutes of arc). Intermediate lines were then interpolated and the quadrant was then photographed in four positions to form a master negative. Subsequently, over 4000 numbers were put in by hand. The declination circles are inscribed on the grid at 10 minute intervals, (as are the time angle circles) up to 60° of declination. Time angle and azimuth is figured from 0 to 180 degrees (right to left and below the equator line) and from 180 to 360 degrees (left to right and above the equator line) for the western celestial hemisphere. Near the poles the intervals of time angle become 30, at 60°, 1° at 80°, 2° at 86°, 5° at 88° and 10° at 89°. On the alloy ring is a focusing fixed microscope (1) of x14 power which enables the latitude to be set on a scale marked from +90° to -90° at intervals of 10', interpolation being possible to 1'. The latitude is set (and the grid therefore rotated) by turning a knob (4) which is set diametrically opposite the fixed microscope. Connected to the housing of the fixed microscope by an elbow joint linkage (5) is a focusing moveable microscope of x28 power (2) which can be moved to any part of the grid over the plate-glass window, and by which the grid co-ordinates are set and read after grid rotation. Fine adjustment of the moveable microscope is obtained by operation of the two knobs disposed at right-angles to it (3), in order that the cross in the field of view can be synchronised over the desired co-ordinates. The bottom of the moveable microscope has a spring-loaded cap which is covered with soft leather and which bears on the plate glass window. This tends to both keep the window free of dust and adds a little friction to maintain the moveable microscope in position once it has been set. The markings on the grid enable settings to be made accurately to 10' and by estimation to 1'. Since on moving the grid the cross in the moveable microscope will not be parallel to the lines on the grid, a rotating spring-loaded ring is provided which rotates the cross about the optical axis of the microscope thus enabling the arms of the cross to be set temporarily parallel to the grid marking for ease of reading

Shown in Figure 3 is the view through the moveable microscope with a typical reading of Hc -44° 13' and azimuth of 69° 51'.

Figure 3 - View through moveable microscope.

The rear face of the instrument is a bakelite moulding (6) provided with a circular indented handle, in the centre of which is fitted a detachable lamp-holder (covered by a red filter), and reflector, which provides 24v illumination inside the instrument. On the rear face of the instrument is a two-pin plug used for the electrical lead (7) and a rheostat (8) for controlling the brightness. On some instruments the rheostat is omitted and the lamp is connected to a 2.5v supply or to a small accumulator provided in the storage box.

Mounted on the front face of the instrument are five plaques.

Identification Plaque

Astronomisches Rechengerätl	= Astronomical Calculator
Gerät Nr..	= Part No.
Anforderz.	= Requisition No.
Werk Nr.	= Serial No.
Hersteller.	= Manufacturers code (bic = Zeiss)

Instruction Plaque

Stelle Breite auf -90°	= Set latitude to +90°
Stelle Gest. Zeitw.(..τ) und Abweichung (..δ) ein.	= Set time angle and declination
Stelle Breite des astr.	

Koppelortes ein.	= Set the altitude of the place of observation
Lies Höhe (hr) und Azimut (Az) ab.	= Read off the altitude (hr) and Azimuth (Az)

<u>Note Plaque</u>

Merke!	= Note
Nord = + Süd = -	= North = + South = -
Zahlen mit Vorzeichen δ oder hr	= Calculate with sign δ or hr
Zahlen ohne Vorzeichen τ oder Az	= Calculate without τ sign * and Azimuth (Az)

<u>Auxiliary Plaques</u>

Breite (on fixed microscope)	= latitude
Aus: Dunkel: Hell: (on rheostat)	= Off. Dim. Bright.

The storage box made of wood has fittings to enable it to be securely fixed at the navigation station and in addition provides stowage for the electrical power lead, spare bulbs, a black silk illumination hood to enable to instrument to be used in bright background light and an illustrated instruction booklet.

<u>Requisition Numbers</u>

Instrument:	Fl 23894
Storage box:	FL 23894-1
Electrical power lead:	FL 23894-2
Silk illumination hood:	FL 23894-3
Spare bulb:	FL 32777-1
Instruction booklet:	45 01 01-1

Operation Of The ARG1

1. Connect the instrument to the 24v supply and adjust the brightness.
2. Focus both the fixed and moveable microscopes.
3. Set the grid so that the value of −90° appears in the latitude scale as seen by the fixed microscope. This setting is effected by simply rotating the knob until it clicks into position and the two triangular marks are then seen to be opposite each other.
4. Move the moveable microscope until the cross in the field of view is set approximately at the time angle and declination of the heavenly body. The microscope is then rotated till arms of the cross are parallel to the lines of the chart and by means of the adjusting knobs the cross is set accurately on the required values of time angle and declination.
5. Turn the latitude knob until the latitude of the place of observation is set at the fiducial mark in the fixed microscope.
6. On the moveable microscope, the spring loaded ring is rotated to bring the arms of the cross into alignment with the chart markings, and the altitude and azimuth are read directly from the chart.

Note

The time angle (*) then used in Germany until about the middle of the 20th century, was counted from 0-360° or 0-24 hours from the lower meridian through east, south and west. M therefore differs from hour angle by 180° or 12 hours. This definition, which was introduced when astronomical time began to be reckoned from midnight to midnight, has numerous advantages and is closely related to local time. If LHA is less than 180° then time angle = LHA+180°, and if LHA is more than 180°, then time angle = LHA-180°.

Time angle and azimuth are numbered from 0-180° below, right to left, and from 180-360° above, left to right, in relation to the equator line on the grid.

If time angle is less than 180°, then azimuth is less than 180°, and if time angle is greater than 180°, then azimuth is greater than 180°. This is a simple rule according to whether the calculation is being made on the eastern or western celestial hemisphere.

Sample Sight Reduction With ARG1

Herewith the results of an observation of Altair that I made on the 6th November 1992 at DR position N 51° 17' & W 000° 27', using a Plath SKS-3D gyro-octant (#5501) with a two-minute averaging period. ARG1 (#297316) is utilised for the sight reduction.

	ASSUMED POSITION	DR POSITION
GHA Aries	326° 14'	326° 14'
GHA inc	001° 11'	001° 11'
SHA Altair	<u>062° 23'</u>	<u>062° 23'</u>
GHA Altair	029° 48'	029° 48'
Assumed Lon	<u>000° 48' W</u>	<u>000° 27' W</u>
LHA	029° 00'	029° 21'
± 180°		
τ	209° 00'	209° 21'
Dec Altair	08° 51' N	08° 51' N
Assumed Lat	51° 00' N	51° 17' N
Azimuth	219° 47'	220° 00'
Ho	41° 13'	41° 13'
Hc	41° 34'	41° 12'
A	21' A	01' T

Accuracy And Comparison With Other Methods Of Sight Reduction

Comparative trials were conducted by the German Hydrographic Institute at Hamburg in the 1940's between the ARG1 and the S-Diagrams developed by K. Schütte. On the basis of 26 calculations, errors of the ARG1 were calculated to be ± 0.74' of altitude and ± 0.83' of azimuth. A comparison of other different methods of sight reduction is as follows:

Using Assumed Position

	Hc	Δ	Az
ZEISS ARG 1	41°34'	21'A	220°
WEEMS/LINE OF POSITION BOOK	41°33'	20'A	220°
DREISONSTOCK/HO 208	41°34'	21'A	220°
HUGHES TABLES	41°34'	21'A	220°
MYERSCOUGH & HAMILTON RNT	41°34'	21'A	219°
HO 249 / AP 3270 VOL III	41°34'	21'A	219°

Using Dr Position

	Hc	Δ	Az
ZEISS ARG 1	41°12'	01'T	220°
AGETON/HO 211	41°12'	01'T	220°

Sample Great Circle Distance And Initial Course Calculation

From: N 17° 22' & W 025° 28'
To: N 40° 08' & W 073° 17'

1. Set latitude to starting position (+90°)
2. Set time angle (difference of longitude 47° 49' + 180° = 227° 49'), against declination (destination latitude N 40° 08').
3. Set departure latitude (N 17° 22')
4. Read: altitude (ZD) of 46° 55', therefore distance = 2815 nm and azimuth of 309° 10' as initial great circle course.

Note that the Log Haversine method gave 2818.2 nms and IGC of 309° 11.5'.

The Instrument Revealed

The first indication that the Luftwaffe were using a new method to solve the problem of sight reduction was the discovery of a fragment of a photograph in the wreckage of a Dornier 217 of III/KG 100 that crashed near the town of Totnes in Devon, England on the 30th April 1944. This damaged portion later proved to be from the instruction booklet on the ARG1. Less than a month later, a Junkers 290 of 1/FAG 5 was shot down into the Atlantic Ocean, some of the aircrew including the observer survived, and during their subsequent interrogation, details of the ARG1 began to emerge. In addition, U-Boats that surrendered in May 1945, were found upon inspection to be equipped with the ARG1. After the cessation of hostilities with Germany, examples of the ARG1 were sent to the Admiralty Research Laboratory at Teddington, in Middlesex, the Royal Aircraft Establishment at Farnborough in Hampshire, and a large quantity of instruments and documents were transported to Wright Field in Dayton, Ohio.

Under interrogation in England in 1946, Dr. G. Forstner stated that Zeiss had made 100 instruments, and that the total order was for 5000 of which at least 3000 had been made by other contractors. Production of the ARG1 co-incided with the cessation of long range flights by the Luftwaffe and only one bomber squadron was known to have used the ARG1. They were greatly preferred to the previous use of tables and Forstner felt that the single insertion of time angle, declination and latitude was a major advantage over the Bygrave slide rule.

Appraisal By The Allies

In July 1945, Dr. S. M. Burka, a navigation specialist at Wright Field, indicated that the ARG1 was the most worthwhile non-electric navigation aid yet picked up in Germany.

In October 1945, the British Admiralty concluded that the apparatus was simple and easy to use and was well designed and constructed. Results were in most cases correct to 1, except when badly formed triangles were attempted, but the overall accuracy was probably similar to that obtainable from five figure logarithms.

In March 1946 the Royal Aircraft Establishment at Farnborough stated that the instrument was very similar to that produced by Bastien Morin in France before the war. The ARG1 computer solved the astronomical triangle with 1' accuracy in about the same time as that required for use of the Astronomical Navigation Tables (AP 1618).

Developments

A Ue R An ARG1 training instrument, known as the A Ue R, was produced by Dennert & Pape at Altona (see photographs 3 and 4). The grid is drawn on a luminous disc of 19 cm diameter, which fits into a circular recessed plastic dish, in which it may be rotated through finger holes in the bottom of the dish. The latitude scale, engraved at 1° intervals from +90° to -90° is set against a fiduciary mark on the dish. A link arm attached to the dish holds a bulls eye magnifier, (power x2) for setting time angle and declination and reading altitude and azimith. The observer's sighting line is fixed by a cross engraved on the plane undersurface of the magnifier and a circle on its top surface. The overall diameter is 24 cm and its weight is 0.4 kgs. The overall accuracy obtained was ± 10' which was sufficient for training purposes.

ARG2

This model (see photographs 5 and 6), made largely from steel, was developed to be more suitable for mass production than the ARG1, from which it differed in the following respects

1. The overall diameter was 29 cm, and its overall height 7.3 cm.
2. The grid diameter was 20 cm (twice the diameter of the ARG1).
3. The latitude scale was set by means of a vernier knob, calibrated at 5' intervals, thus eliminating the fixed microscope.
4. The moveable microscope was replaced by a simple magnifier with a power of x14.
5. The 24v lamp holder underneath the instrument was eliminated by the substitution of overhead illumination, situated close to the viewer.
6. There is a small "dead zone" in the grid near the vernier knob which he magnifier cannot cover.

The accuracy of this variant was found under test to be in the order of ±0.86' of altitude. Only two instruments of this type were produced, one was taken to Wright Field in the USA and the other is presumed to be still in Germany.

ARG3

One of the disadvantages of the ARG 1 and 2, was that only one computation could be completed at a time. There existed an operational requirement to be able to observe two stars simultaneously. This would provide an instantaneous fix, as position lines would not have to be transferred according to the difference in time between observations. It was initially envisaged that this would necessitate two observers, but after the satisfactory development of a two-star sextant (work on which, was already in hand), only one observer would be required. The astronomical computer that would handle a simultaneous two-star observation was to have been the ARG 3. However, due to the cessation of hostilities in 1945, work on this project was discontinued and no production examples are known to exist.

Conclusion

The ARG1 was a most elegant solution to the problem of solving the astronomical triangle. A great advantage was the ability to use the DR position as easily as using the assumed position. The accuracy of the instrument was in the order of ±1' of altitude and ±1° in azimuth which is more than adequate for all practical purposes. It could be used on any heavenly body, world-wide, and therefore dispensed with the requirement to carry a number of volumes of altitude and azimuth tables. Finally, it is a pleasant and satisfying device to use.

Acknowledgments

My thanks are especially due to Dr. Gloria Clifton, Curator of Navigational Instruments at the National Maritime Museum, Greenwich, London, for her help and patience; to Lt. Cmdr. John Luykx, USN(Retd) of St. Mary's City, Maryland, USA,. For his enthusiasm and encouragement; to Dr. Stefania Riccini of Rome, Italy, for her translational skills, and finally to QinetiQ Ltd for access to the RAE photographic archives at Farnborough.

References

Admiralty Research Laboratory
Examination of German Astonomical Calculator for Converting Hour Angle and Declination into Altitude and Azimuth
(Astronomisches Rechengerat 1).
A.R.L./N1/68.05/ft.
3rd October 1945

Bastien, A.
LePoint Astronomique.
L'Aérophile
October 1937

Frieslebben, H.C.
Diagrammatic Solutions for Astronomical Navigation
Journal of the Royal Institute of Navigation.
Volume IV, Number 1.

Genty, R.
Méthode Nouvelle de Navigation Astronomique Aérienne.
Publications Scientifiques et Techniques du Ministère de L.air
Number 215, 1948.

Hughes, A.J. (1946).
History of Air Navigation
George Allen & Unwin Ltd., London

Rohnstock, Dr. Kurt.
State of Development of Astronomical Navigation in the German Luftwaffe.
Ministry of Aircraft Production, GDC Number 3E/140/7.
RTP Technical Information Bureau, 1946.

Royal Aircraft Establishment, Farnborough
Interrogation of Herr Förstner. (Dr. G. Förstner-Heidenhein)
Report Number Inst/S. 1337R/FJT/77.
January 1946

Royal Aircraft Establishment, Farnborough
German Celestial Navigation Computers, Astronomische Rechengerat.
Technical Note No. INST.947
March 1946.

Slaucitajs, S.
Vergleichende Untersuchung über die Genauigkeit der S-Diagramme und des Astronomischen Rechengeräts.
Contributions of Baltic University, Number 13, 1946.
Hamburg.

United States Strategic Air Forces in Europe
German Celestial Navigation Computers
Technical Intelligence Report No. A-482.
9th July 1945.

Williams, J.E.D.
Air Navigation Systems
Journal of the Royal Institute of Navigation
Volume 41, Number 3.

Drawings

Figure 1: ARG grid at celestial equator position in polar mode.
Figure 2: ARG grid at horizon system in zenith mode.
Figure 3: View through moveable microscope.

Photographs

Photo 1: ARG1, Negative No/ 67728, dated 8-2-1946
Photo 2: ARG1, Negative No. 67727, dated 8-2-1946

Photo 3: Training model, Negative No. 67730, dated 8-2-1946
Photo 4: Training model, Negative No. 67729, dated 8-2-1946
Photo 5: ARG2, Negative No. 68245, dated 7-3-1946
Photo 6: ARG2, Negative No. 68244, dated 7-3-1946

Symbols

φ	Greek	Latitude
λ	Greek	Longitude
τ	Greek	Time angle
δ	Greek	Declination
Δ	Greek	Delta

Photo 1: ARG 1. Used with permission of QinetiQ Ltd.

Photo 2: ARG 1. Used with permission of QinetiQ Ltd.

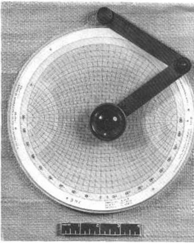


Photo 3: Training Model. Used with permission of QinetiQ Ltd.

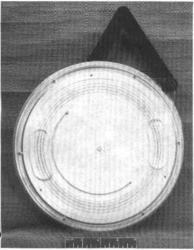


Photo 4: Training model. Used with permission of QinetiQ Ltd.

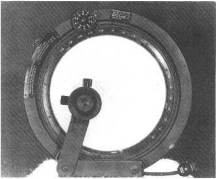


Photo 5: ARG2. Used with permission of QinetiQ Ltd.

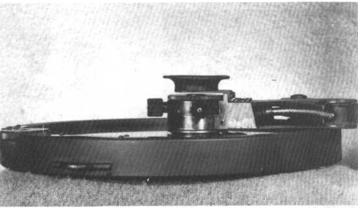
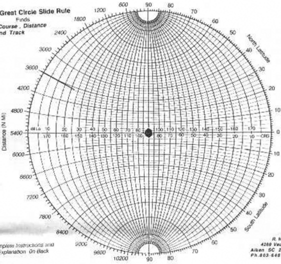


Photo 6: ARG 2. Used with permission of QinetiQ Ltd.

Great Circle Slide Rule

Finds

Course . Distance and Track

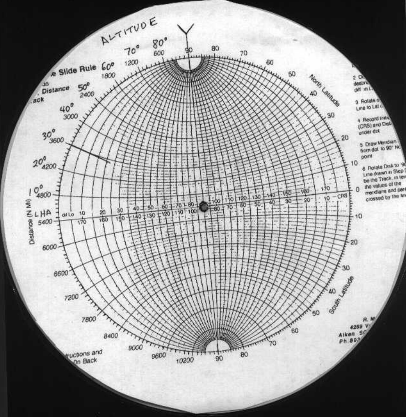


Steps

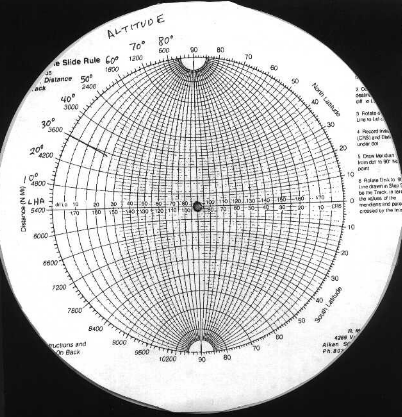
1. Rotate plastic disk to bring Line to 90° N
2. Dot intersection of destination Lat. and diff. in Long (dif Lo)
3. Rotate disk to bring Line to Lat of Departure
4. Record Initial Course (CRS) and Distance under dot.
5. Draw Meridian Line from dot to 90° North point
6. Rotate Disk to 90° N Line drawn in Step 5 will be the Track in terms of the values of the meridians and parallels crossed by the line

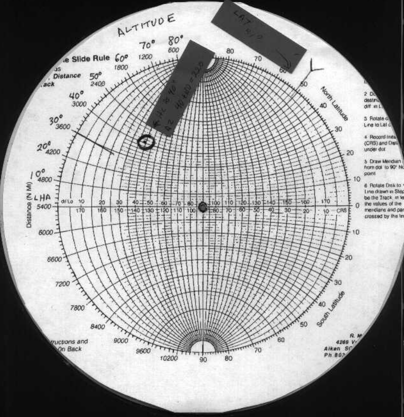
Complete Instructions and Explanation On Back

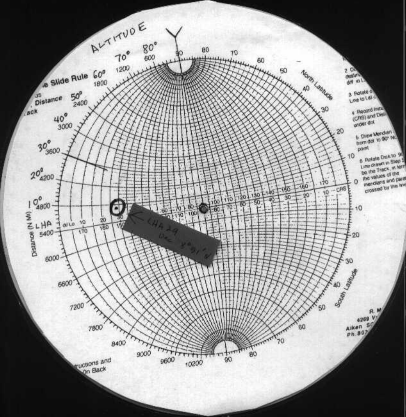
R. M. Girdler
4269 Vaucluse Rd
Aiken SC 29801-8852
Ph.803-648-1393



ALTITUDE
e Slide Rule
, Distance
ack
Distance (N Mi)
LHA
North Latitude
South Latitude
CRS
dif Lo
2 Ok
3 Rotate
4 Record
(CRS) and
under dot
5 Draw Meridian
point
6 Rotate Disk to
ructions and
On Back
Aiken


ALTITUDE
Slide Rule
Distance
Distance (N Mi)
LHA
dif Lo
CRS
North Latitude
South Latitude
2 Od
3 Rotate
4 Record
(CRS) and Dist
under dot
5 Draw Meridian
from dot to 90° No
point
6 Rotate Disk to 90
be the Track
the values of the
meridians and para
crossed by the line
ructions and
On Back
Aiken


ALTITUDE
LAT
e Slide Rule
Distance
ack
North Latitude
South Latitude
Distance (N Mi)
LHA
dif Lo
CRS
ructions and
On Back
2 Rotate Disk to
Line to Lat
4 Record Initial
(CRS) and Dist
under dot
5 Draw Meridian
from dot to 90° N
point
6 Rotate Disk to
Line drawn in Step
be the Track in
the values of the
meridians and par
crossed by the line
Aiken SC


ALTITUDE
e Slide Rule
Distance
North Latitude
South Latitude
Distance (N MI)
LHA
LHA 29
Dec
CRS
Aiken
tructions and
On Back