Martin Brenner's, Pilot Balloon Resources

Pilot Balloon Slide Rules

Pilot Balloon slide rules like this one were used by meteorologists in the weather services and military units of the United Kingdom to determine the upper wind velocities from an ascending hydrogen or helium filled Pilot Balloon (Note: use of helium was not common practice in the Met. Services in the UK). The position of the Pilot Balloon is tracked by means of one or two theodolites at one minute intervals. The Pilot Balloon slide rule is used to convert the observed azimuth and elevation readings into wind velocity and direction records. The use of slide rules and plotting boards was abandoned with the wide spread adoption of computers and programs to do the calculations, as well as the decline in the use of optical pilot balloon theodolites.

Since the angular co-ordinates of the balloon change bit little from one observation to the next, while the linear co-ordinates change considerably, it is advantageous to have the trigonometrical scales of the rule fixed and the linear scales movable. Two sine scales are required as the sine and cosine of the same angle must be indicated by cursors simultaneously. There must be three cursors at least to work on the trigonometrical scales and they must be made so that those on opposite sides of the rule may pass each other readily. These features were all introduced in the original pilot-balloon slide-rules made for the Meteorological Office in 1915. These rules were provided with double slides with which allowance could be made for variations in the assumed rate of ascent of the balloons. With the adoption of standard rates of ascent in the 1920's the extra slide became unnecessary and observers were instructed to lock the two sliders together. When the use of the "tail method" to estimate the range to the balloon became more general practice the design of the slide-rule was modified to incorporate an additional pair of scales and a fourth cursor for the calculations involved in tail ascents. The "modified" pilot balloon slide rule was annotated Mark II.

Later models MK IV, MK IV.A, MK V and MK 5 had similar features, but omitted wood and glass in their construction. Plastic laminated frames and slides with Plexiglas cursors were used. Scales were similar to the MK II with additions and changes in fiducial marks as well as the MK V and MK 5 being of wider and thicker construction.

The Met. Office of the United Kingdom designated at least 6 different Pilot Balloon slide rule models. The first model in appearing 1915 made of wood by J.J. Hicks with two slides and introduction of the final, MK 5 model in the late 1960's. Slide rules in this series starting with the MK II of 1927 have, 4 captive cursors (Glass or Plexiglas windows and brass guides) that ride in slots on the top and bottom edges. Each can be moved independently of one another. Brass knobs at both ends of the slide facilitate its movement. The rules are approximately 24.5" long.

Pilot Balloon Slide Rules (Dates are estimated from known examples)			
Mark I	1915 to 1938	J.J. Hicks	2 Slides which are lockable and three cursers
Mark II	Pre 1928 to 1943+	A.G. Thornton, W&G	W & G Units produced in Melbourne Australia differ slightly from Thorr rules.
Mark III	?	A.G. Thornton Ltd.	Dates not known, similar to Mark II in appearance
Mark IV	1952 to 1960	James Farrow & Son	Some examples labeled Hilger and Watts have also been seen.
Mark IV.A	1957 - 1964	B.R.L	
Mark V	1964-?	B.R.L & Blundell Harling Ltd.	Not Known if Mark V and 5 were in overlapping production.
Mark 5	1968-?	Blundell Harling Ltd.	

Pilot Balloon slide rules are scarce, probably because relatively few were made, and also because most were made for and used by Government agencies, and not individuals.

Slide rules like these were not used in the United States Military or Weather Services. Wind speeds and directions were solved utilizing a Plotting Board. A standard slide rule or a slightly modified 20 inch trig rule was utilized along with the plotting board. Since the speed and direction information was solved on the plotting board and the slide rule was only used for determining the horizontal distance from the observer (a trig function).

Acknowledgements: Thanks to Mr. Colin Barnes for assistance with historical information. See also M.O. 577, Handbook of Meteorological Instruments Part II pg. 34 (1961, Her Majesty's Stationery Office)

Met. Office Pilot Balloon Slide Rule Mark I

The Mark I Pilot Balloon Slide Rule was made of wood laminated with heavy white plastic with a length of 24.5-in. and width of 2.5 inches. Introduced in 1915 this rule has double slides and three cursers which can pass over each other. The double slides allow for variations in the assumed rate of ascent of pilot balloons. With the adoption of a standard weight nozzle system, ascent rates were standardized and users were advised to lock the slides together as shown in the photo below. The modified pilot balloon slide rule Mark II has a single slide and the addition two additional scales and a 4th curser which was required to use the tail method of altitude estimation.

This Mark 1 Pilot Balloon Slide Rule was produced in 1935 and examples from 1938 have been seen. Pilot balloon instructions dated 1936 only refer to the Mark II slide rule so it appears that these were still being acquired after they were no longer specified by the Met Office.

A more detailed image of the Mark 1 Pilot Balloon Slide Rule is available here.

Met. Office Pilot Balloon Slide Rule MK II

The Mark II Pilot Balloon Slide Rule was made of wood laminated with heavy white plastic with a length of 24.5-in. and width of 2.5 inches. Mark II rules were also manufactured in Australia by W & G (Melbourne). The W & G rule differs only slightly from the English A. G. Thornton LTD rule. The W & G rule uses serif fonts and has some fiducial marks that the English rule lacks. Exact dates of production are not known but the MK II is known to have started production by 1927 and I have a 1943 example. The printed scales are engraved in the plastic faces. The slide rule has 4 captive cursors (glass windows and brass guides) that ride in slots on the top and bottom edges. Each can be moved independently of one another. Brass knobs at both ends of the slide facilitate its movement. The case is fabric covered wood with felt lining.

This slide rule contains an engraved notation on the rear face

"IMPORTANT. NORMALLY NUMBER OF GRATICULE SCALE DIVISIONS PER RADIAN (K) X LENGTH OF TAIL IN FEET (I) = 12X 10^5. IN OTHER CASES MULTIPLY GRATICULE READINGS BY 1.2/KI BEFORE CALCULATION ON RULE"

The Met Office instructions for use of modified pilot balloon slide rule include directions for calculations using the tail method. These instructions date from 1927. A large image showing the scales of the Mark II slide rule is also posted

Pilot Balloon slide rules in the series were made for the British Meteorological Office by different makers, this one by A. G. Thornton LTD. Alexander George Thornton started originally in partnership with Joseph Halden in Manchester in 1878 and were a well known company making slide rules and drawing instruments.

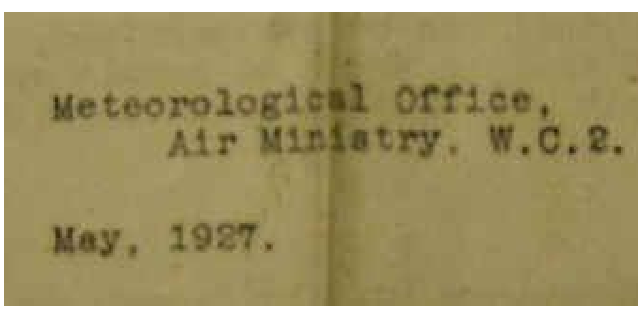
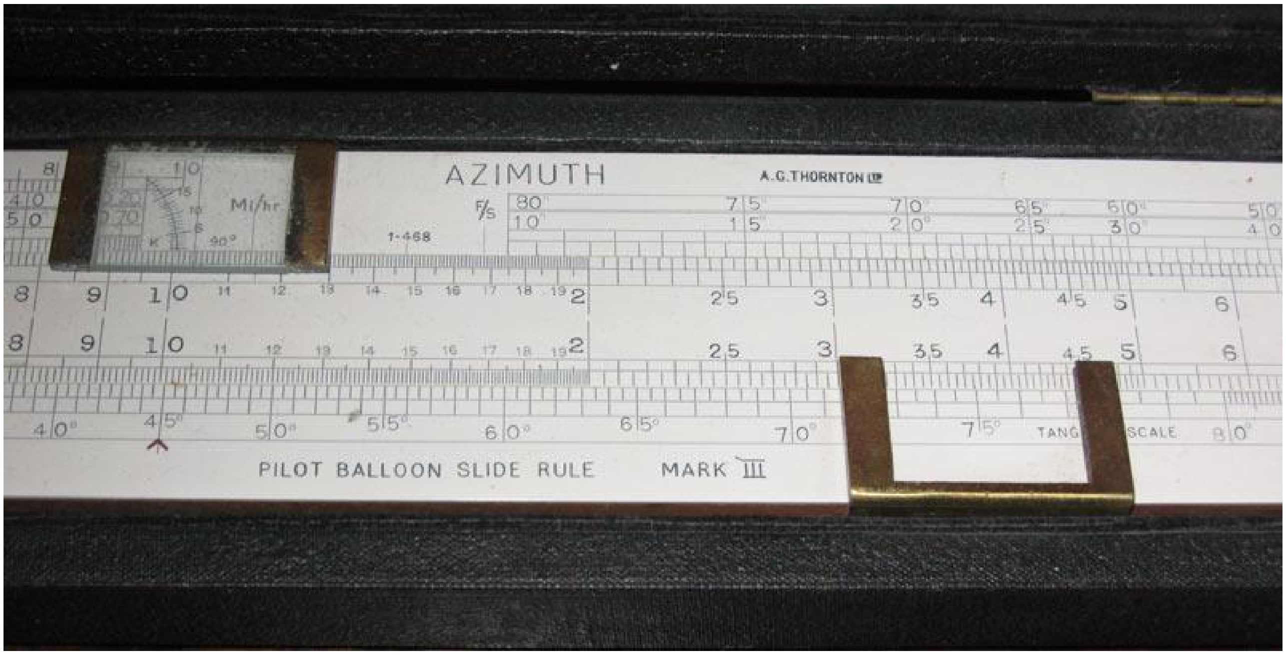


Image of an AG Thorton AG MK III Slide Rule

This image was emailed to me of a Pilot Balloon Slide Rule MK III,   Presently I have no further information about the rule other than they were in fact produced.

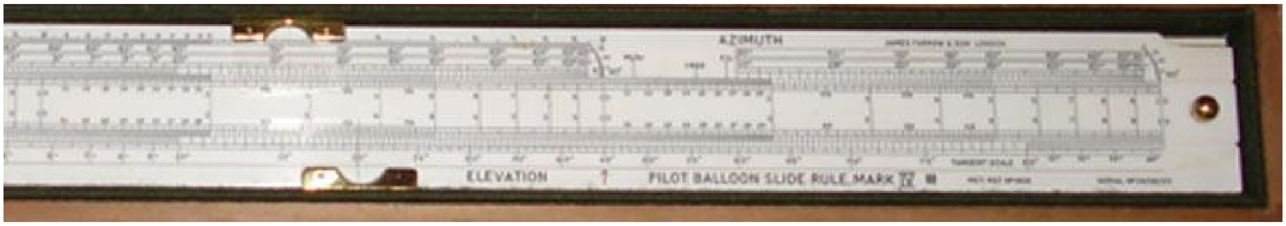


Met. Office Pilot Balloon Slide Rule MK IV

This is a Mark IV Pilot Balloon Slide Rule with a date mark of '53 (1953) It was made of a heavy white plastic with a length of 24.5-in. and width of 2.5 inches. Exact dates of production are not known but the MK IV.A is known to have been in production as early as 1952. The printed scales are engraved on the white plastic face. The slide rule has 4 captive cursors - this example is missing two that ride in slots on the top and bottom edges. Each can be moved independently of one another. Brass knobs at both ends of the slide facilitate its movement. The case wood with oiled natural wood finish. Follow this link for more detailed information on the Met. Office Mark IV Pilot Balloon slide rule

Pilot Balloon slide rules were made for the British Meteorological Office by different makers, this one was manufactured by James Farrow and Son. A later model MK IV.A was made by BRL- Blundell Rules Ltd. The MK IV and MK IV.A are functionally identical. The later MK IV.A is thicker and slightly wider. Its layout is identical to the IV.A rule except for the addition of a single reference mark ("SR. YDS" on the tangent scale at 1.85deg) on the IV.A.

Succeeding Mark IV.A, Mark V and Mark 5 Pilot Balloon slide rules were manufactured by Blundell Harling Ltd. and believed to be in production from 1964 until possibly as late as 1989. However there is no mention of a MK V rule in the "Met. Office The Measurement of Upper Winds by Means of Pilot Balloons Fourth Edition 1968 which leads to speculation that the MK V and MK 5 may have been introduced soon before or after 1968.



Details of the Mark IV pilot balloon Slide Rule

The slide rule is intended to be used with a Met. Office Pattern Pilot Balloon Theodolite (Watts Mk IIII or V). The divided graticule of the theodolite along with the scales provided on the slide rule allow for the use of the tail method for estimate the height of the balloon when strong winds are present (elevation angles of 40 degrees of less). Mark V and Mark 5 slide rules were manufactured after this model.

The Mark IV and IV.A were in general use at Meteorological Office stations in the 1960's and 1970's. The Mark IV.A is illustrated below. This model mainly differs from the Mark II in that the stock and slider, which are 24.5 in (62' 2 cm) long, are made of ivory perspex, or similar plastic material, instead of a wood laminate.

From the Met Office Text:
Meteorological Office pilot-balloon slide-rule, Mark 4 (Stores Ref., Met.868).- This slide-rule is the model in current use at Meteorological Office stations. Its main difference from the Mark 2 model is that the stock and slider, which are 24.5 in. long, are made of ivory perspex, or similar plastic material, instead of wood. From the illustration in Plate VIII it will be seen that there is a logarithmic scale, three times repeated and thus covering a range from one to 103, on both the upper and lower edges of the slide. The upper part of the stock carries two pairs of sine and cosine scales, one pair extending from 0.5 ° to 90° and the other from 10° to 90°; the degrees from 0° to 20° on each cosine scale are marked on a small arc instead of being crowded together as in an ordinary slide-rule. A logarithmic scale, twice repeated, and identical with part of the slider scales, is also provided on the upper part of the stock; this permits of the rule being used in a limited way as an ordinary slide-rule. The lower part of the stock has a tangent scale on the right extending from 3 ° to 84.30 and a scale of squares of secants from 0° to 63 ° on the left, the interval between 40° and 50° on this latter scale being twice that between 40° and 50° on either of the upper sine and cosine scales. A graticule scale, of reciprocal logarithms, replaces part of the logarithmic scale on the lower left part of the slider. Fiducial marks" K ", "Mi/hr", " 1.468" and" f ls" are engraved on the upper part of the stock, between the main trigonometrical scale and the subsidiary one, for the conversion of units as explained below.

The general relations used in operating the slide-rule to obtain the height of the balloon *h,* in feet, the total horizontal distance travelled *D,* in hundreds of feet, and the easterly and northerly components D_E and D_N of this distance from the measurements of azimuth *A,* elevation *E* and apparent length of the tail *m* in graticule units are:

$h=(kl/m)sin2E=DtanE$
$D=(kl/m)(1/sec^2E)$
$D_E = D \sin A$ and $D_N = D \cos A$,

where *k* is the number of graticule divisions per radian, *l* the length of the tail in feet, and *m* its apparent length in graticule units. Normally the product *kl* is arranged to be 1.2×10^5. If a different value is used the graticule readings must be multiplied by 1. *2/kl* before calculation on the rule.

In using the slide-rule the normal procedure is first to set the left-hand lower cursor at the observed value of the elevation *E* on the secant^2 scale and to move the slide so that the value of *m* on the graticule scale is against sec^2E. Then, after setting the right-hand lower cursor at the observed elevation on the tangent scale the height is read from the logarithmic scale on the slide. The upper cursors are now set at the observed azimuth on the sine and cosine scales and from these cursors the values of D_N and D_E are read on the logarithmic scale on the slider. If the value of D is required it can be read from the logarithmic scale opposite sin 90°. Values of the wind components are obtained from the differences of successive values of D_N and D_E. Then the larger of the components (irrespective of sign) is set at tan 45° on the tangent scale and the reading from this scale against the smaller component gives the angle (less than 45°) between the path of the balloon, in the minute interval concerned, and the nearest of the cardinal lines (W.-E. or S.-N.) bounding the quadrant in question. Finally, with this angle on the sine scale set against the smaller component on the logarithmic scale, the value opposite sin 90° gives the horizontal distance traveled by the balloon in the minute interval, and thus the wind speed in units of 100 ft./min Without further adjustment, the speed may be read off in knots (from the fiducial mark at " K "), in miles per hour (at" Mi/hr ") or in feet per second (at" f/s "). Inter-unit conversions may also be made by direct reading from these fiducial marks. The mark “1•468 " is for conversion from miles per hour to feet per second.

If the observations are made on a moving ship account must be taken of the ship's course and speed. This is most conveniently done by adding algebraically the components of the ship's velocity to the components of the relative wind velocity.

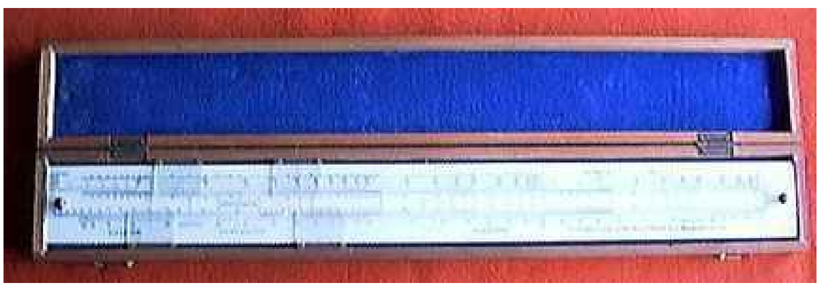
The slide-rule should always be used with care and not handled with soiled or stained fingers. If it is necessary to clean the surface warm soapy water should be used. Abrasives, petrol or solvents must never be used.

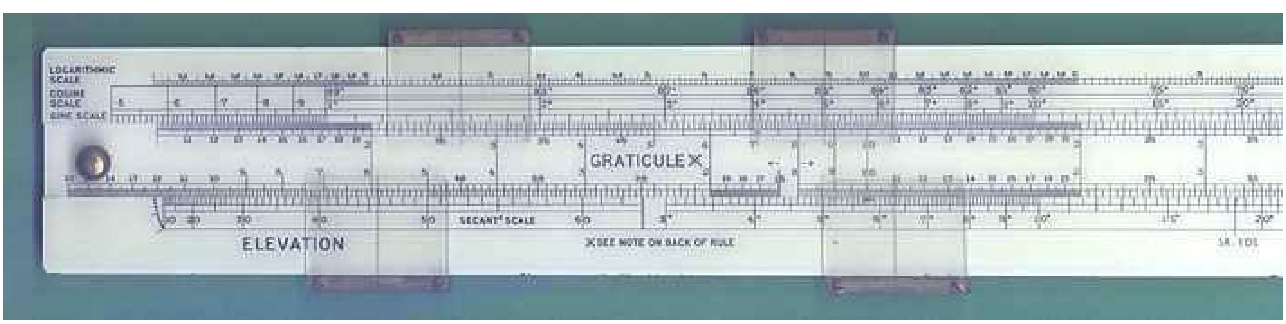
Met. Office Pilot Balloon Slide Rule MK IV.A

This is a Mark IV.A Pilot Balloon Slide Rule with a date mark of '59 (1959) A second example, from 1962 is linked on the detail page. It was made of a heavy white plastic with a length of 24.5-in. and width of 2.5 inches. Exact dates of production are not known but the MK IV.A is known to have been in production as early as 1957. The printed scales are protected with a clear Plexiglas laminate on the 1957 and 59 rules the 1962 rule is engraved on the white plastic face. The slide rule has 4 captive cursors (Plexiglas windows and brass guides) that ride in slots on the top and bottom edges. Each can be moved independently of one another. Brass knobs at both ends of the slide facilitate its movement. The case wood with oiled natural wood finish. Follow this link for more detailed information on the Met. Office Mark IV.A Pilot Balloon slide rule

Pilot Balloon slide rules were made for the British Meteorological Office by different makers, this one by BRL-Blundell Rules Ltd. a well known British slide rule maker. The Mark IV slide rule manufactured by James Farrow and Son is similar to the this rule. The layout of this rule is identical to the IV rule except for the addition of a single reference mark ("SR. YDS" on the tangent scale at 1.85deg).

Succeeding Mark V and Mark 5 Pilot Balloon slide rules were manufactured by Blundell Harling Ltd. and believed to be in production from 1964 until possibly as late as 1989. However there is no mention of a a MK V rule in the "Met. Office The Measurement of Upper Winds by Means of Pilot Balloons Fourth Edition 1968 which leads to speculation that the MK V and MK 5 may have been introduced soon before or after 1968.





Details of the Mark IV.A pilot balloon Slide Rule

The slide rule is intended to be used with a Met. Office Pattern Pilot Balloon Theodolite (Watts Mk IIII or V). The divided gradicule of the theodolite along with the scales provided on the slide rule allow for the use of the tail method for estimate the height of the balloon when strong winds are present (elevation angles of 40 degrees of less). Mark V and Mark 5 slide rules were manufactured after this model.

The Mark IV and IV.A were in general use at Meteorological Office stations in the 1960's and 1970's. The Mark IV.A is illustrated below. This model mainly differs from the Mark II in that the stock and slider, which are 24.5 in (62' 2 cm) long, are made of ivory perspex, or similar plastic material, instead of a wood laminate.

From the Met Office Texts:
"Meteorological Office pilot-balloon slide-rule, Mark 4 (Stores Ref., Met.868).- This slide-rule is the model in current use at Meteorological Office stations. Its main difference from the Mark 2 model is that the stock and slider, which are 24.5 in. long, are made of ivory perspex, or similar plastic material, instead of wood. From the illustration in Plate VIII it will be seen that there is a logarithmic scale, three times repeated and thus covering a range from one to 103, on both the upper and lower edges of the slide. The upper part of the stock carries two pairs of sine and cosine scales, one pair extending from 0.5 ° to 90° and the other from 10° to 90°; the degrees from 0° to 20° on each cosine scale are marked on a small arc instead of being crowded together as in an ordinary slide-rule. A logarithmic scale, twice repeated, and identical with part of the slider scales, is also provided on the upper part of the stock; this permits of the rule being used in a limited way as an ordinary slide-rule. The lower part of the stock has a tangent scale on the right extending from 3 ° to 84.30 and a scale of squares of secants from 0° to 63 ° on the left, the interval between 40° and 50° on this latter scale being twice that between 40° and 50° on either of the upper sine and cosine scales. A graticule scale, of reciprocal logarithms, replaces part of the logarithmic scale on the lower left part of the slider. Fiducial marks" K ", "Mi/hr", " 1.468" and" f ls" are engraved on the upper part of the stock, between the main trigonometrical scale and the subsidiary one, for the conversion of units as explained below.

The general relations used in operating the slide-rule to obtain the height of the balloon *h,* in feet, the total horizontal distance travelled *D,* in hundreds of feet, and the easterly and northerly components D_E and D_N of this distance from the measurements of azimuth *A,* elevation *E* and apparent length of the tail *m* in graticule units are:

$h=(kl/m)sin2E=DtanE$
$D=(kl/m)(1/sec^2E)$
$D_E = D \sin A$ and $D_N = D \cos A$,

where *k* is the number of graticule divisions per radian, *l* the length of the tail in feet, and *m* its apparent length in graticule units. Normally the product *kl* is arranged to be 1.2×10^5. If a different value is used the graticule readings must be multiplied by 1. *2/kl* before calculation on the rule.

In using the slide-rule the normal procedure is first to set the left-hand lower cursor at the observed value of the elevation *E* on the secant^2 scale and to move the slide so that the value of *m* on the graticule scale is against sec^2E. Then, after setting the right-hand lower cursor at the observed elevation on the tangent scale the height is read from the logarithmic scale on the slide. The upper cursors are now set at the observed azimuth on the sine and cosine scales and from these cursors the values of D_N and D_E are read on the logarithmic scale on the slider. If the value of D is required it can be read from the logarithmic scale opposite sin 90°. Values of the wind components are obtained from the differences of successive values of D_N and D_E. Then the larger of the components (irrespective of sign) is set at tan 45° on the tangent scale and the reading from this scale against the smaller component gives the angle (less than 45°) between the path of the balloon, in the minute interval concerned, and the nearest of the cardinal lines (W.-E. or S.-N.) bounding the quadrant in question. Finally, with this angle on the sine scale set against the smaller component on the logarithmic scale, the value opposite sin 90° gives the horizontal distance traveled by the balloon in the minute interval, and thus the wind speed in units of 100 ft./min Without further adjustment, the speed may be read off in knots (from the fiducial mark at " K "), in miles per hour (at" Mi/hr ") or in feet per second (at" f/s "). Inter-unit conversions may also be made by direct reading from these fiducial marks. The mark “1•468 " is for conversion from miles per hour to feet per second.

If the observations are made on a moving ship account must be taken of the ship's course and speed. This is most conveniently done by adding algebraically the components of the ship's velocity to the components of the relative wind velocity.

The slide-rule should always be used with care and not handled with soiled or stained fingers. If it is necessary to clean the surface warm soapy water should be used. Abrasives, petrol or solvents must never be used. "

Met. Office Pilot Balloon Slide Rule MK V

This is a Mark V Pilot Balloon Slide Rule The printed scales are engraved in the plastic faces. The slide rule has 4 captive cursors (Plexiglas windows and brass guides) that ride in slots on the top and bottom edges. Each can be moved independently of one another. Brass knobs at both ends of the slide facilitate its movement. This rule was used by the CBM (Commonwealth Bureau of Meteorology and does not have a Met Office Stamp and date.

This slide rule contains a engraved notation directing the user to see a not on the back of the rule however no note was engraved on the back of the rule. I believe that the annotation is a carryover from the Mark IV.A rule but the note about graticule line spacing note was not specified for this model, hence the note on back of rule label was omitted in error. The more recent Mark 5 rule includes the note on the back but not the reference to it on the front.

A large image showing the [scales of the Mark V slide rule] is also posted. This rule is very similar to the Mark IV.A rule and it is manufactured by the same manufacturer however the scales lack the horizontal lines for a cleaner look. Some changes in the fiducial marks are also incorporated.

Met. Office Pilot Balloon Slide Rule MK 5

This is a Mark 5 Pilot Balloon Slide Rule issued in 1970. The printed scales are engraved in the plastic faces. The slide rule has 4 captive cursors (Plexiglas windows and brass guides) that ride in slots on the top and bottom edges. Each can be moved independently of one another. Steel (other models had brass colored) knobs at both ends of the slide facilitate its movement. This rule was used by the Met Office and has a Met Office Stamp and date.

This slide rule does not contain a engraved notation directing the user to see a not on the back of the rule. however the note is engraved on the back of the rule as it is on the MK II, MK IV, and MK IV.A rules. The previous Mark 5 rule reference to the note on the front of the rule, but lacks the actual note on the back of the rule.

A large image showing the scales of the Mark 5 slide rule is also posted. This rule is very similar to the Mark 5 rule and it is manufactured by the same manufacturer however there are some changes in the fiducial marks and the scales are about 1CM longer.

Meteorological Office

Pilot Balloon Slide Rule, Mark 5

OBSERVERS INSTRUCTION

1. General Description

The slide rule is used for computing upper winds from readings of the azimuth and elevation of a pilot balloon at regular intervals. The theory of the method, with other details, is given in Met O 804 (Measurement of Upper Winds by means of Pilot Balloons, Fourth Edition, London, Her Majesty's Stationary Office, 1968), the quantities involved being as follows:-

E = elevation
A = azimuth
K = graticule constant
l = Length of tail
m = apparent length of tail in graticule units (See page 26 of Met O. 804)
D = total distant traveled by balloon
D_E, D_N = easterly and northerly components of this distance
V_W to E, V_S to N = easterly and northerly components of distance traveled in the one minute interval
h = height of balloon above starting point.

The general relations between these quantities, as used in operating the slide rule are:-

$h = Kl \sin 2E/2m = D \tan E$

$d = (Kl/m)(1/\sec^2 E)$

$D_N = D \cos A$ and $D_E = D \sin A$

The Following scales are incorporated:-

A logarithmic scale on numbers, three times repeated, on both the upper and lower edges of the slider.
A logarithmic scale, twice repeated, on the upper part of the stock, identical with part of the slider scales.

Sine and cosine scales, partly duplicated, on the upper part of the stock
a secant^2 scale, from 0deg to 63deg on the left part of the lower stock.
A tangent scale, from 3deg to 84.3deg on the right part of the lower stock.
A graticule scale (reciprocal logarithms), replacing part of the logarithmic scale on the lower left part of the slider.

<u>IMPORTANT</u>. The product of K, the number of graticule divisions per radian and L, the length of the tail in feet, is normally 1.2×10^5. In other cases adjust the length of the tail so that $Kl/1.2 \times 10^5 = 1$

Fiducial marks a b, c and d are engraved on the upper part of the stock, and marks E and ^ on the lower stock, for the conversion of units (see section 3).

2. Standard Procedure

The standard procedure for the computation of winds by the use of pilot balloons and theodolite are described fully in Met O 804. Three methods are described (a) winds by pilot balloon using a fixed rate of ascent (b) using a tail of known length and (c) using two theodolites.

3. Change of Units

The use of fiducial marks in reading values of wind speed directly in knots or meters per second, etc., is fully described in Met O. 804. When the slide rule is used for other purposes of in a non-standard way, care must be taken that the fiducial marks still apply e.g. when using time intervals other than one minute or when performing a radar wind ascent where the ranges are in yards. In these cases other reference points may have to be found.

Inter-unit conversions may be made using the fiducial marks on the slide rule by directly reading between the marks thus:-

A -> B	converts	kts to ft/s
B -> A	"	ft/s to kts
A -> C	"	kts to m/s
C -> A	"	m/s to kts
E -> tan 45	"	ft to m or ft/s to m/s
Tan 45 -> E	"	m to ft or m/s to ft/s

4. Multiplication and division

The additional logarithmic scale in the upper part of the stock permits the rule being used in a limited was as an ordinary slider-rule.

5. Maintenance

The rule should always be use with care and not handled with soiled or stained fingers. If it is necessary to clean the surface warm soapy water should be used. Abrasives, petrol or solvents must never be used.

Glossary of terms used in the Pilot Balloon Web Site

Ascent Rate. The rate at which a balloon will climb (gain altitude) through air free of up-drafts or down-drafts usually expressed in meters per minute.

Bent Axis Telescope. A telescope sighting device where the optical path has a 90 degree bend in it so the operator's eye position does not change when the elevation is changed through a complete 180 degrees. This is usually accomplished with the use of a three or five sided prism.

Free Lift. The total lift of the balloon minus the weight of the balloon. It does not include any attachments such as a lighting unit. The lift is caused by dense air in the altitude floating the less dense - lighter gas (helium or hydrogen) inside the balloon.

Pibal. Meteorological jargon for a Pilot-Balloon itself or the determination of upper winds by releasing and tracking a freely ascending balloon with a theodolite. (In some low altitude-short duration applications a compass and clinometer are used in place of the theodolite.)

Radiosonde. An electronics package attached to a balloon and carried aloft. It contains set of instruments that measure pressure temperature, and humidity and a radio transmitter that transmits a data stream containing the information from the onboard sensors. See also NOAA's Web site for more information.

Rawinsonde. A type of upper-air observation that determines the wind speed, direction, pressure, temperature, and relative humidity by utilizing a radiosonde tracked by a radio direction-finding device such as a radio theodolite. For more information on Rawinsondes follow this link to http://www.atirus.com/wwa_text3.html, also the NOAA's Site.

Tail Method. In a single theodolite observation the height of the balloon is approximated by multiplying an assumed rage of ascent by the duration of the ascent. This method assumes an accurate ascent rate assumption as well as a lack of up or down-drafts. A tail of a known length can be attached to the balloon, the apparent length of the tail as viewed through a divided graticule on a theodolite can be determined. The measurement of the angle subtended by the length of tail enables the distance to the balloon and hence the height of the balloon to be calculated without making any assumptions about the rate of ascent of the balloon. (This method is useful in conditions where the wind speed is great enough such that the observed elevation angle of the balloon is 40 degrees of less).

True North. The direction heading towards the geographical north pole. This is as opposed to Magnetic North, the direction that a compass indicates as north - the magnetic north pole (some place in Northern Canada). The difference between Magnetic North and True North is called magnetic declination.


Pilot Balloon Slide Rule
MARK I 607/35
J.J. HICKS
LONDON
Cosine Scales
Sine Scales
Time Scale
Tangent Scale


General
The modified slide rule is designed for the direct computation of the following quantities when the tail method is employed:
$h = \frac{K1}{2m}$ sin 2E = D tan E
$D = \frac{K1}{m}$ $\frac{1}{\sec^2 E}$
D_n = D cos A
COSINE SCALES
SINE SCALES
AZIMUTH
PILOT BALLOON SLIDE RULE
2263/43
MARK II
A. G. THORNTON Co
GRATICULE
SECANT SCALE
TANGENT SCALE
ELEVATION
ELEVATION

LOGARITHMIC SCALE
COSINE SCALE
SINE SCALE
AZIMUTH
Mi/hr
F/s
1468
GRATICULE
SECANT² SCALE
TANGENT SCALE
ELEVATION
SEE NOTE ON BACK OF RULE
SR. YDS
ELEVATION
PILOT BALLOON SLIDE RULE, MARK IVA
MET. REF. Nº 868 A


LOGARITHMIC SCALE
COSINE SCALE
SINE SCALE
AZIMUTH
C.B.M. IDENT 480
Mi/hr
GRATICULE *
ELEVATION
SECANT² SCALE
*SEE NOTE ON BACK OF RULE
ELEVATION
TANGENT SCALE
PILOT BALLOON SLIDE RULE, MARK V
BLUNDELL HARLING LTD
WEYMOUTH — ENGLAND
REF No MET. 868A
CBM 841


LOGARITHMIC SCALE
COSINE SCALE
SINE SCALE
AZIMUTH
BLUNDELL HARLING LTD · WEYMOUTH · ENGLAND
GRATICULE
ELEVATION
SECANT² SCALE
ELEVATION
TANGENT SCALE
PILOT BALLOON SLIDE RULE, MARK 5
MET. REF. № 29550
4071/70