(v) In the central area of the computer disk, concentrically about the pivot point, aircraft altitudes in the Quadrantal Height System are tabulated to recall to memory the prescribed flying heights within the ranges for L.E.R. and V.E.R. flight.

Fig. 2c Rear Face of ARISTO AVIAT 610, 615

3. Everyday Arithmetic

Scales (b) and (c) are two circular logarithmic scales, similar to the scales of the conventional type of slide rule. As such, they are used for every kind of computation involving multiplication, division, proportion and "rule of three" problem.

3.1 Reading the Scales

As in any logarithmic scale, the intervals decrease progressively in width in clockwise direction. The system of subdivision, therefore, changes between the ranges 10 — 20, 20 — 50 and 50 — 10. The user should study this system carefully. The sample settings in fig. 3 exemplify the differences in readings taken within the three ranges.

Readers not skilled in slide rule manipulations will soon be able to read the scales at sight after a little systematic practice with a number of different values.

Fig. 3

As with any conventional slide rule, the location of the decimal point cannot be determined with the computer because its scales only take account of the significant figures of a number in their correct order. When, for instance, the answer to a problem set on the computer is given as 12, this may stand for 0.12 or 1.2 or 12 or 120 . . . In practice the magnitude of the answer is usually unmistakably clear from the outset. Where doubts arise, a quick approximative computation with strongly rounded-off factors settles the question.

The initial line of the scale is called the index and is marked 10. The large numerals 20, 30 etc. divide the scale into its principal intervals and the graduations of the nūmbers give the first decimal place in the answer to a calculation. The smaller figures — or the extended graduations — within the principal intervals give the second place of decimals, whilst the smallest graduations provide the third place. This may need to be found by interpolation between graduations.

3.2 Multiplication

Identical in principle to solution by tables of logarithms, sections of the rotating inner scale are added (geometrically) to sections of the stationary outer scale. Thus, in the example 32 x 1.4, the index 10 of the inner scale is set opposite 32 on the outer scale. The answer 44.8 then appears over 14 on the outer scale. The use of the rotary hairline indicator facilitates the operation.

Fig. 4

3.3 Division

As division is the inverse of multiplication, the order of the steps described above is simply reversed. With the cursor hairline, set 14 on the inner scale to 44.8; of the outer scale. The quotient 32 then appears over the index mark 10 of the inner scale.

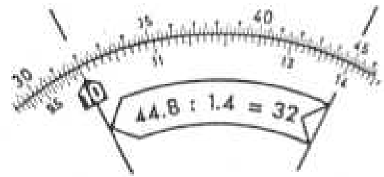

Fig. 5

3.4 Multiplication and Division Combined

In problems of the type $\frac{a \times b}{c}$ the division always comes first and the multiplication of the quotient by b follows. In the problem $\frac{44.8 \times 3.4}{1.4}$ the division $44.8 \div 1.4$ is done as just explained. Without stopping to read the answer then set the hairline to 3.4 of the inner scale and, opposite this value, read the answer 108.8 on the outer scale.

Example: $\frac{327 \times 5.22 \times 0.453}{128}$

Roughly $\frac{300 \times 5 \times 1/2}{100} = 7.5$ (approximate magnitude of the answer)

Procedure:

(1) Hairline over 327 of outer scale
(2) Turn 128 of inner scale under hairline
(3) Hairline over 5.22 of inner scale
(4) Index 10 moved under hairline
(5) Hairline moved to 0.453 of inner scale
(6) Under hairline read the answer 6.04 on the outer scale

3.5 Proportions

Many typical air navigation problems can be easily expressed in the more usable form of proportion. When the given ratio is set with the terms opposite each other on the two scales, the same ratio prevails throughout the entire range of the scales.

The example in par. 3.4, reduced to proportion form, would read

$$\frac{44.8}{1.4} = \frac{108.8}{3.4}$$

The joint between the scales may be regarded as the dividing line in a common fraction.

Example of a percentage problem:

Original tank contents 960 l
Consumption 647 l

To find: Consumption in per cent of the original contents.

The contents 960 is to 100% as the consumption is to the required percentage.

$$\frac{960}{100} = \frac{647}{x}$$

Answer: $x = 67.4\%$.

Example of a time conversion problem:

Given the flying time 0.43 hours as resulting in a time-distance-speed problem (see par. 6.2.1). To find the equivalent in minutes.

Since 1 h = 60 min, write the proportion

$$\frac{1}{60} = \frac{0.43}{x}$$

Set the Hour Mark ⚠ opposite the Index 10. Rotary index to 43 on the outer rim scale. On the adjacent rim scale read $x = 25.8$ min.

4. Conversions between Metric and British/US Standards

The index 10 on the rim scale (b) is labelled "m" "km" "Ltr" to show that all three metric units are set or read at this one mark, to obtain or convert the various non-metric units whose labels are conspicuously printed and graduated on the circumference of this scale.

Fundamentally every conversion commences by setting the value to be converted on the inner scale under the mark of the given unit. The result is then read from the rotary inner scale against the mark for the required unit. In the following figures the first setting is enclosed in a circle and arrows point out the direction of rotation of the indicator.

4.1 Conversion of Lengths and Distances

4.1.1 Given: 3 ft
Required: value in yards and m
Result: 3 ft = 1 yard = 0.915 m

Turn scale value 30 under ft mark and read result from rotatable scale under the corresponding mark for yards or meters.

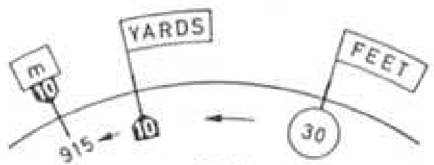

Fig. 6

4.1.2 Given: 17 m
Required: Value in yards and ft
Result: 18.59 yards, 55.8 ft

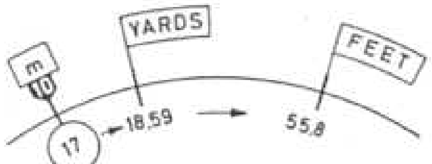

Fig. 7

4.1.3 Given: 172 stat miles
Required: naut miles and km
Result: 149.5 naut miles, 277 km

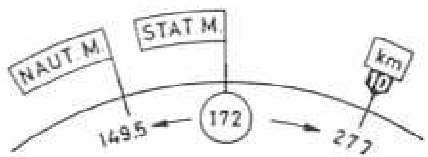

Fig. 8

4.2 Conversion of Liquid Measures

4.2.1 Given: 2350 l
Required: imp gal and US gal
Result: 517 imp gal,
621 US gal

Fig. 9

4.2.2 Given: 173 US gal
Required: imp gal and l
Result: 144 imp gal
655 l

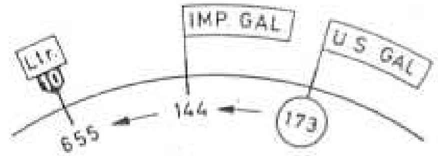

Fig. 10

4.3 Calculation of Weights from Liquid Measures

For the conversion of liquid measures of specific gravities 0.65 to 0.95 into their equivalents in weight, there are two scales along the extreme rim of the outer ring, one for conversions into kg, the other for conversions into pounds. For any given number of litres or gallons the equivalent weight in kg or lb can be determined. The arrow bearing the marks kg and lb is used in converting from one system to the other. The computer converts on the basis of British Standard:

1 imp gal = 4.546 kg = 10.0253 lb;

1 kg = 2.205 lb. As an approximation, 1 gallon is often assumed equivalent to 10 lb.

Set the fluid quantity to be converted on the rotatable inner scale (c) under the appropriate mark (l, imp gal, or US gal) on the outer scale (b) and turn the indicator over the specific gravity value of the liquid on scale (a).

Read under the indicator from the inner scale the weight corresponding to the given fuel quantity. The weight will be shown in kg if the indicator was set over the specific gravity scale labelled kg or will be shown in lb if the indicator was set over the scale labelled lb. With these marks the equivalents of weights in pounds and kilograms can be found directly as described in par. 4.1.

4.3.1 Given: 234 US gal,
spec. grav. 0.72
Required: weight in kg and lb
Result: 637 kg, 1407 lb

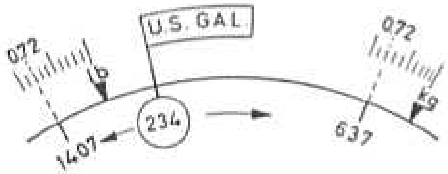

Fig. 11

4.3.2 Given: 156 imp gal,
spec. grav. 0.74
Required: Weight in lb
Result: 1157 lb

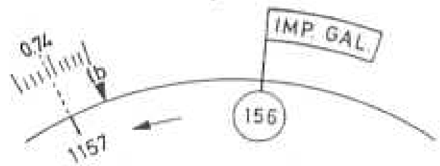

Fig. 12

5. Time and Speed Conversions

The difference between conversions of this type and those just described consists in that the time and speed marks are printed on the movable scale (c). Hence the mark labelled with the given unit is set opposite the given quantity on the stationary scale. The result can then be read opposite the mark for the other unit.

5.1 Conversion of Times

5.1.1 Reduction of Minutes to Hours

On the minute scale (c) and the hour scale (d) the respective equivalents of 1 to 10 hours are aligned to each other. On the inner rim of the black circle the hour scale is extended to 20 hours = 1200 minutes. The AVIATJET 647 has marks for two hours only — 11 and 12.

5.1.2 Reduction of Minutes to Seconds with the Marks △ and sec

Given: 17 minutes

Required: Equivalent in seconds

Result: 1020 seconds

Note that the hour mark △ is used for both hours and minutes. As fig. 13 shows, the solution is analogous when the problem is stated in reversed order.

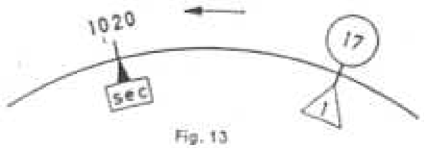

Fig. 13

5.2 Conversion of Speeds

5.2.1 Reduction of m/sec to km/h

By reason of its coincidence with the graduation line for "36", the sec mark also simplifies conversions between hours and seconds, in consideration of 1 h = 3600 sec and 1 m/sec = 3.6 km/h. When, for instance, the mark 10 of the minute scale (c) is matched with 35.8 m/s on scale (b), the mark sec supplies the answer 129 km/h.

5.2.2 Conversion with the Marks m/sec and ft/min

Given: 500 ft/min

Required: m/sec

Result: 2.54 m/sec

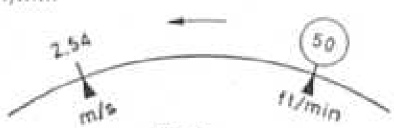

Fig. 14

6. Distance-Time-Speed Problems

Problems of this kind are usually given in rule-of-three form but can easily be changed to the more usable proportion form (see par. 3.5).

6.1 Time or Rate of Climb and Descent

6.1.1 Example: An aircraft is to climb from an altitude of 2000 ft to 11 000 ft at the rate of 700 ft/min. Required is the time to climb the altitude difference of 9000 ft.

The rate of climb 700 ft/min means that the aircraft climbs 700 ft in one minute. Hence the first ratio in the proportion is 700 : 1.

Therefore: $\frac{700}{1} = \frac{9000}{x}$

Setting: Set movable 10 under rate of climb 700.

Reading: Read duration of climb 12.85 min from the movable scale under the altitude difference 9000.

Result: Duration of climb 13 min

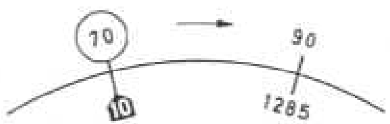

Fig. 15

6.1.2 Example: An aircraft descends 8500 ft in 14 min, required is the rate of descent.

Proportion: $\frac{8500}{14} = \frac{x}{1}$

Setting: 14 under 85

Reading: 607 over 10

Result: Rate of descent 607 ft/min

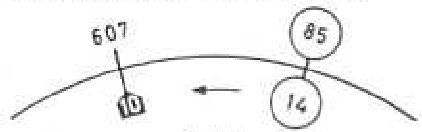

Fig. 16

6.2 Distance-Time-Speed Problems

6.2.1 Given: Ground speed 246 kt
Distance 745 NM

Required: Flying time

Approach: Knots are nautical miles per hour, accordingly:

$$\frac{246}{\triangle} = \frac{745}{x}$$

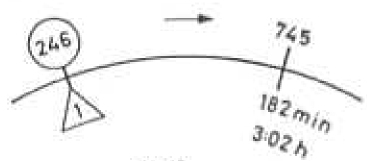

Fig. 17

Setting: Set hour mark △ of the time scale against the ground speed 246 on the outer scale (distance scale).

Reading: Read under distance 745 on the distance scale the flying time 182 min = 3 : 02 h from the time scale. White scale for minutes, black for hours.

6.2.2 Given: Distance 412 km
Flying time 1 : 28 h = 88 min

Required: Ground speed

Setting: Set flying time 88 min on the time scale under the distance 412 km on the distance scale.

Fig. 18

Reading: Read over the hour mark △ of the time scale the ground speed 281 km from the distance scale. By a lucky coincidence the logarithmic interval separating the mark ft/min from the hour mark △ is numerically approximately equal to the conversion factor between km/h and kt. Thus, opposite ft/min we can also read the speed in knots: 153 kt. The strictly correct reading would lie two division lines to the left: 152 kt.

6.2.3 Given: Ground speed 247 kt
Flying time
2 : 16 h = 136 min

Required: Distance flown

Setting: Set hour mark △ under ground speed 247 kt on distance scale.

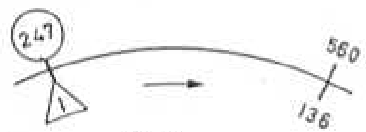

Fig. 19

Reading: Read over flying time 136 min on the time scale the distance flown 560 NM from the distance scale.

6.2.4 Point of Equal Time (Critical Point)

If for example engine trouble occurs during flight it is important for the pilot to know whether the airport of departure or the airport of destination can be reached sooner. For this purpose the Point of Equal Time (P.E.T.) or Critical Point (C.P.) is determined, i. e. the point from which the continuation of the flight to the destination would require the same time as the return flight to the point of departure. The formula used is:

$$T_{P.E.T.} = \frac{T_F \times GS_{home}}{GS_{out} + GS_{home}} \quad \text{(Time formula)}$$

Where $T_{P.E.T.}$ = Flying time to Point of Equal Time,
T_F = Time to fly from base to destination (flight plan time),
GS_{OUT} = Ground speed on flight out (ground speed out),
GS_{HOME} = Ground speed on return flight (ground speed home).

The distance from the point of departure to the Point of Equal Time (Critical Point) is calculated by means of the following formula:

$$D_{P.E.T.} = \frac{D_z \times GS_{home}}{GS_{out} + GS_{home}} \qquad \text{(Distance formula)}$$

Where $D_{P.E.T.}$ = Distance from base to P.E.T.
D_z = Distance from base to destination.

These equations may be transposed to the more convenient proportion form, as follows:

$$\frac{GS_{home}}{GS_{out} + GS_{home}} = \frac{T_{P.E.T.}}{T_F} \text{ or } \frac{D_{P.E.T.}}{D_z}$$

Example:

Given: Distance to destination D_z = 920 NM
GS_{out} = 240 kt
GS_{home} = 210 kt
Flight plan time
T_F = 3:50 h = 230 min

Required: Flying time to P.E.T. distance $D_{P.E.T.}$

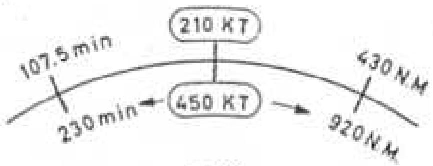

Fig. 20

Intermediate calculation:
$GS_{out} + GS_{home}$ = 450 kt

Setting: Set indicator over GS_{home} = 210 on the outer scale and set the sum $GS_{out} + GS_{home}$ = 450 on the rotatable inner scale under the index hairline. With this setting and in accordance with the above mentioned proportion the corresponding flying times T or the distances D will appear opposite each other.

Reading: 1. Turn hairline to T_F = 230 on the inner scale and read $T_{P.E.T.}$ = 107.5 min from the outer scale.
2. Turn indicator over D_z = 920 on the inner scale and read $D_{P.E.T.}$ = 430 NM from the outer scale.

Result: The P.E.T. will be reached after a flying time of 107.5 min. The distance flown will then be 430 NM.

6.2.5 Determination of the "Point of No Return"

The Point of No Return depends upon the endurance of the aircraft. After passing the Point of No Return the remaining fuel will not be sufficient for a return flight to the point of departure. The flight can only be continued to the destination or to an alternate airfield. Also the Point of Safe Return is often to be determined, the calculation of which is based upon the amount of available fuel after deducting the required reserve.

The formula for the Point of No Return is:

$$T_{P.N.R.} = \frac{E \times GS_{home}}{GS_{out} + GS_{home}} \qquad \text{(Time formula)}$$

Where $T_{P.N.R.}$ = Flying time to Point of No Return
E = Endurance

This formula is of the same type as the P.E.T.-formula so that here again the same proportion is valid:

$$\frac{T_{P.N.R.}}{E} = \frac{GS_{home}}{GS_{out} + GS_{home}}$$

Example:

Given: Endurance 6 : 30 h = 390 min
GS_{out} = 240 kt
GS_{home} = 210 kt
$GS_{out} + GS_{home}$ = 450 kt

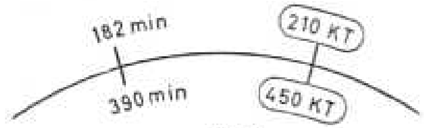

Fig. 21

Required: Point of No Return, distance

Setting: Set GS_{home} over $GS_{out} + GS_{home}$ as shown in par. 6.2.4

Reading: Read flying time to Point of No Return from the outer scale over the endurance on the inner scale.

Result: The Point of No Return will be reached after a flight of 182 min = 3 : 02 h. If the point is to be located geographically, determine the distance to the Point of No Return by means of GS_{out} according to the usual time-distance calculation (see par. 6.2.3). The distance is 728 NM.

7. Fuel Consumption

7.1 Given: Consumption 220 imp gal per hour, specific gravity of fuel 0.72 and flying time 3 : 24 h = 204 min

Required: Total consumption and weight of fuel in lb

Setting: Set hour mark ⚠ of the time scale under the hourly consumption 220 on the outer scale.

Reading: Read total consumption 748 imp gal from the outer scale over flying time 204 on the time scale.

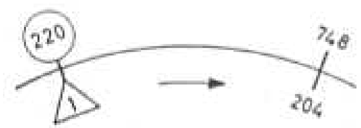

Fig. 22

Intermediate result: Total consumption 748 imp gal

Conversion to weight: (see par. 4.3.2)

Result: 5390 lb

7.2 Given: Total consumption 1470 US gal
Flying time
4 : 05 h = 245 min

Required: Consumption per hour

Result: 360 US gal

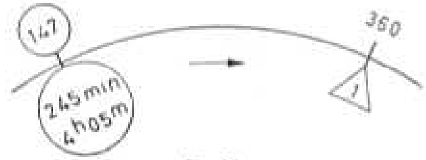

Fig. 23

7.3 Given: Hourly consumption 320 gal,
Fuel available 1460 gal

Required: Maximum flight duration

Setting: Set hour mark of the time scale under hourly consumption.

Reading: Read opposite expendable fuel on the outer scale the maximum flight duration 274 min from the time scale.

Fig. 24

8. Pressure Pattern Flying

8.1 Calculation of Cross-Wind Component V_n from Pressure Comparison

The formula for the calculation of the cross-wind component is:

$$V_n = \frac{C \times (D_2 - D_1)}{\sin\varphi \times AD}$$

where: C = constant 21.47
φ = mean latitude between points of pressure comparison
D_1 = difference value in ft for the first measurement
D_2 = difference value in ft for the second measurement
AD = air distance in NM

The latitude scale on the inner disk of the computer takes care of the term $\frac{C}{\sin\varphi}$ in the above equation, i. e. the "K-factor", which leads to the simplified equation:

$$V_n = \frac{D_2 - D_1}{AD} \times K$$

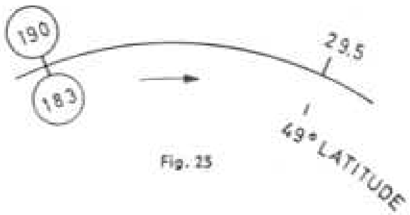

Fig. 25

Example: 10:00 h Absolute height above sea level (Radio Altimeter): .... 10240 ft
Pressure altitude: .... 10100 ft
D_1 .... +140 ft

10:50 h Absolute height above sea level: 10050 ft
Pressure altitude: .... 10100 ft
D_2 .... − 50 ft

$D_2 - D_1 = -50 - (+140) = -190$

True Air speed = 220 kt

Air Distance (in 50 minutes) = 183 NM

Mean Latitude: 49° N

The value $D_2 - D_1$ is negative. This indicates that the aircraft is flying from an area of higher pressure to one of lower pressure. Under these conditions, according to the Buys Ballot's wind law, in the northern hemisphere the wind is blowing from the left. The cross-wind component is, therefore, positive.

Setting: Set difference of D-values 190 on the outer scale (DISTANCE) opposite the air distance 183 on the edge scale (MIN) of the inner disk. Turn hairline over mean latitude 49° on LATITUDE scale.

Reading: Under hairline read cross-wind component V_n = 29.5 kt.

8.2 Calculation of Beam Displacement (Z_n)

The formula used is: $$Z_n = \frac{K \times (D_2 - D_1)}{E.T.A.S.} \qquad \frac{Z_n}{K} = \frac{D_2 - D_1}{E.T.A.S}$$

where: K = K-factor (see par. 8.1)
D_1 = Difference value in ft for first measurement
D_2 = Difference value in ft for second measurement
E.T.A.S. = Effective true air speed between measurements

The Z_n-value is used for obtaining pressure lines of position (P.L.O.P.)

Example: $D_2 - D_1 = -170$ ft
E.T.A.S. = 175 kt
Mean latitude: 38° N

Setting: Set true air speed 175 kt on rim scale of inner disk under difference of D-values 170 ft on outer scale and turn indicator over mean latitude 38° on latitude scale.

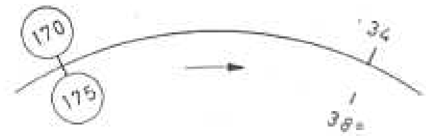

Fig. 26

Reading: Read under hairline beam displacement Z_n = 34 NM for the time elapsed between the first and second measurement.

$D_2 - D_1$ is negative, therefore, for the time of the second measurement, the beam displacement is to be plotted perpendicular to the heading 34 NM to the right of the respective air position.

8.3 Calculation of Drift from V_n or Z_n

The determination of drift from the value of the cross-wind component or of the beam displacement will be described in par. 11.1.9 dealing with the graphical solution of triangles.

9. Air Speed Calculations

9.1 With ARISTO AVIAT 610, 613, 615, 617, 618

Air speed indicators are calibrated in accordance with the International Standard Atmosphere at sea level. If the actual air density at the flight level differs from standard air density at sea level the true air speed will deviate from the indicated air speed even if the indicator is free from defects or instrument errors. The main factors governing air density are air pressure and temperature. Because of the relationship between air pressure and altitude pressure, altitude may be used in place of air pressure for the calculation of true air speed.

With the ARISTO AVIAT 610, 613, 615, 617 and 618, air speed calculations are carried out by means of the scales labelled AIR SPEED (see fig. 1, f). It should be noted that at high speeds, due to compressibility heating, the thermometer will indicate a higher than actual temperature. Therefore, the observed temperature must be corrected before being used for setting the computer. The temperature correction is read from a double scale in the central part of the AVIAT. E. g. for an air speed of 324 kt the thermometer reading must be reduced by 10 °C; for 500 kt the correction is −23 °C.

The temperature correction scale can only give estimative values, since the magnitude of the error caused through frictional heating depends on the type and position of the thermometer bulb. Closer correction values can be obtained from the table usually furnished by the manufacturers of the particular type of aircraft.

9.1.1 Calculation of True Air Speed (T.A.S.)

Given: Rectified air speed (R.A.S.)
Corrected outside air temperature (C.O.A.T.) in centigrade;
Pressure altitude in ft or km.

Required: True air speed (T.A.S.).

Setting: Set corrected temperature on the red scale (f) labelled "C.O.A.T." against PRESSURE ALTITUDE in km in the upper part of the window or against pressure altitude in ft in the lower part.

Reading: Read true air speed (T.A.S.) from outer scale (b) over rectified air speed (R.A.S.) on movable scale (c).