Comparisons of Figs. 2 and 4 with Figs. 1 and 3 show that:

(i) the total error with present procedures is larger than the instrumental error by a factor of about three for height, and a factor of about seven for vector wind at moderate ranges (60 km),

(ii) of the four sources of error discussed here (i.e. instrumental and observational errors for both radar and slide rule) the radar observational error is the biggest in its effect on height, but at short to moderate ranges the slide rule observational error, with gross mistakes included, is the biggest in effect on wind.

Any effort to reduce the present errors in computed winds should be directed to reducing both the radar observational error and the computational error. Avenues which might be explored are:

(i) to allow more time for the observations,

(ii) to improve the slide rule, or employ different computational aids, particularly those which allow more time for manipulation of the radar controls.

The following are some additional points in explanation or of interest. Absolute values of differences between the observations of range, azimuth and elevation from the two radars were plotted against range, azimuth, elevation and time, and were found to be substantially independent of them all. There is no reason to expect any dependence, except probably when the signal is weak (i.e. at very great range), or when the elevation is near 90°, or when the elevation is very low.

Table 2 shows that accuracy varied between flights. The variations in accuracy of azimuth and elevation observations, and most of the variations in range, are ascribed to variations of skill or care between the observers, although this was not evident at the time. All the observers were experienced and were judged to be competent, and there is no reason to doubt that their performance was typical.

In flights 3 and 4 there was an abrupt change in ΔR during the soundings. In flight 3 the mean value of ΔR changed from 0.16 km to a new value of 0.51 km, and in flight 4 the change was from 0.05 to 0.19 km. The change must be ascribed to an unidentified minor fault in the equipment, which is designed specifically to make very accurate measurements of range increments rather than absolute range. The scatter of ΔR about the separate means remained approximately the same in each flight, and since only increments of R affect the wind computations to any extent the two parts of each flight have been combined for this investigation.

It might be expected that the observational errors in range, azimuth and elevation would increase with their respective rates of change, because (i) errors in timing the observation would become more serious, and (ii) the observer may be forced to accept less precise settings of the controls in order to minimize the timing error. However, no apparent dependence was indicated when differences between the two radars were plotted against rates of change (up to 1.8 km min^{-1} and 4.2 deg min^{-1}).

Timing errors were not measured separately. They have been included in the standard deviations for range, azimuth and elevation.

The slide rule vector wind errors shown in Figs. 3 and 4 do not include a small additional error (+ 1.3%), which is due to the use of the approximation of 6000 ft for 1 nautical mile (6080 ft) in the slide rule computations where windspeed is in knots.

The "observational" error in slide rule operation includes a rounding-off error, which occurs when speed and direction are entered on the computation form to the nearest m sec^{-1} (or knot) and degree. The vector wind standard deviation of the rounding-off error ranges from about 0.3 m sec^{-1} at zero wind speed to about 0.6 m sec^{-1} at 100 m sec^{-1}.

There are various other sources of error outside the scope of this study; for example,

(i) Errors in height due to radar refraction:

In routine observations, a correction for refraction is made from tables based on an average profile of refractive index, but no allowance is made for day to day variations.

(ii) Errors due to averaging:

The procedures described provide winds averaged over layers about 600 metres thick, so the wind at a specified level can only be obtained approximately, with an accuracy depending on the vertical shear.

5. SUMMARY OF WF2 ACCURACY

In the operational use of upper wind reports, the errors in particular soundings cannot be found immediately from Figs. 2 and 4 because the range and ground range are not usually available. Table 3 has therefore been constructed to provide a rough indication of likely errors in individual flights, in British units. The figures in the table have been taken from Figs. 2 and 4 and rounded off, assuming normal balloon ascent rates.

Table 3. Standard deviation of errors in vector wind and height for particular wind soundings made with WF2 radar under routine observational procedures

Pressure P (mb)	Mean wind in layer (1000-P)mb (kt)	Standard deviation of error at level P	
		Vector wind (kt)	Height (ft)
700	20	3	60
500	50	8	300
200	20	8	300
200	50	14	600
10	20	14	600
200	100	18	1000
10	40	18	1000

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