TABLE 5

Minimum Dial Diameters[50]

(In inches)

Number of scale markings	Minimum dial diameter for a viewing distance of 20 inches	36 inches
38	1	1
50	1	1.28
70	1	1.79
100	1.43	2.57
150	2.14	3.86
200	2.86	5.14
300	4.29	7.71

well as speed, the numbering and division markings should be in the decimal system. If the numbers increase by 10's or 100's, there should be division marks to make the smallest division equal to 1 or 10.[51,52] If accuracy in interpolating between scale markings is important, a large number of markings would be recommended, but a great number of graduation marks produces a cluttered appearance and is likely to cause gross errors (see Figure 8). Scales with number intervals of

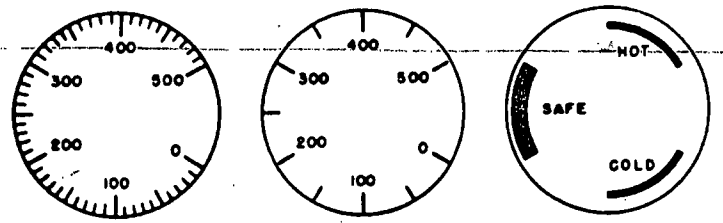

Figure 8. Scale markings. A scale should never have more markings or finer subdivisions than are needed to fulfill its function. A temperature scale such as the one at the left above could be replaced by the one in the center if only approximate quantitative readings were necessary. The scale at the right would be preferable if the safe operating range was all that was desired. As a general rule the fewest reading errors are made with dials having the fewest markings. (From Baker and Grether.[46])

five with four divisions between numbered graduation marks are poorly designed, though they can be seen on many machines. Consistency of marking and numbering should apply to all dials that must be used consecutively by the same operator. On the basis of present knowledge, at least $^1/_2$ inch linear distance between the numbered division marks is recommended for dials viewed at 30 inches. The height

[51] W. R. Garner and J. W. Gebhard, Machine dials and scales, *Machine Design*, **21**, No. 8, 98–104 (1949).

[52] M. D. Vernon, Scale and dial reading, *Rept. No. 49*, Med. Research Council Unit in Applied Psychol., Cambridge University, England, June, 1946.

of the numerals or markings at various viewing distances is shown in Table 6. The proportions, or height to width ratio of the numerals or letters, should be about 3:2 on dials and 1:1 on direct reading counters.[50]

TABLE 6

Height of Characters and Markings for Dial Design[50]

Viewing distance	Character height (in.)	Marking height (in.) Major	Intermediate	Minor
1 ft. 8 in. or less	.09	.22	.16	.09
1 ft. 8 in.–3 ft.	.17	.40	.28	.17
3–6 ft.	.34	.78	.56	.34
6–12 ft.	.68	1.57	1.12	.68
12–20 ft.	1.13	2.63	1.87	1.13

Since most people expect the values of a scale to increase in magnitude when the pointer turns clockwise, this relation should be incorporated into the original display design if feasible.[53] Otherwise, one can expect "reversal" errors to occur; for example, on a counterclockwise dial if the pointer is on the graduation 21 when graduation 20 is numbered, the worker may read 19 instead of 21.

Pointer Design. Experimental research on this topic, although limited, indicates that pointer width is a relatively unimportant consideration: in one instance a reduction from $^3/_{32}$ to $^1/_{32}$ inch caused no loss of legibility. Length, however, is important. Reading errors will increase if the tip of the pointer is more than $^1/_2$ inch from the scale markings. Nor should the tip extend beyond the edge of the outer scale. In general, the whole pointer, rather than only the pointer tip, should be of a contrasting color to the dial.[54] In those jobs in which a worker is required to move a control in co-ordination with the pointer on a visual indicator, the control movement should always be in the same direction as the pointer if possible (see the discussion of "Direction of Movement" on page 100).

Multirevolution Instruments. These displays consist of two or more pointers on a single dial face. A watch or clock would be a simple example of an instrument of this type. A single reading thus requires an understanding of the locations and interrelationships of all the pointers. One advantage of this type of instrument seems to be that a large range of values can be compressed into a small physical space. Nevertheless, the numerous reading errors found to be associated with these instruments makes their replacement desirable whenever possible.[54,55] Altimeters are a complex type of multirevolution instrument with a high incidence of reading errors.

[53] L. M. Christensen, The effect of the staircase scale on dial reading accuracy, *Memorandum Report No. MCREXD-694-1P*, Air Materiel Command, USAF, October 1, 1948.

[54] P. M. Fitts, Psychological aspects of equipment design, *Tech. Rept. No. 5829*, Air Materiel Command, USAF, August, 1949.