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Example: Assume that the minimum battery voltage for the examples above is 105 V. Then

$$\frac{105\ \text{V}}{60\ \text{cells}} = 1.75\ \text{V/cell}$$

$$\frac{105\ \text{V}}{58\ \text{cells}} = 1.81\ \text{V/cell}$$

This minimum cell voltage is then used in the sizing calculation.

6.1.2 Float voltage as limiting factor

To eliminate the need for frequent equalizing charges (refer to IEEE Std 450-1995), it may be desirable to establish a float voltage at the high end of the manufacturer's recommended range. The float voltage must, however, be consistent with the maximum system voltage (see 6.1.1). This higher float voltage may then reduce the number of cells and may increase the cell size required for a given battery duty cycle.

6.1.3 Rounding off

If the calculations shown in 6.1.1 indicate a need for a fractional cell, the result should be rounded off to a whole number of cells. The minimum cell voltage, float voltage, and equalize voltage should then be recalculated and verified for adequacy of operation.

6.2 Additional considerations

Before proceeding to calculate the cell capacity required for a particular installation, the designer should consider factors that will influence cell size but that are not included in the general equation.

6.2.1 Temperature correction factor

The available capacity of a cell is affected by its operating temperature. The standard temperature for rating cell capacity is 25 °C (77 °F). If the lowest expected electrolyte temperature is below this standard temperature, select a cell large enough to have the required capacity available at the lowest expected temperature. If the lowest expected electrolyte temperature is above 25 °C (77 °F), it is a conservative practice to select a cell size to match the required capacity at the standard temperature and to recognize the resulting increase in available capacity as part of the overall design margin. Table 1 lists cell size correction factors for various temperatures for vented lead-acid cells with nominal 1.215 specific gravity. For unlisted temperatures within the range of Table 1, interpolate between adjacent values and round off to two decimal places. For VRLA cells, check with the manufacturers for the appropriate temperature correction factors.

6.2.2 Design margin

It is prudent to provide a capacity margin to allow for unforeseen additions to the dc system and less-than-optimum operating conditions of the battery due to improper maintenance, recent discharge, or ambient temperatures lower than anticipated, or a combination of these factors. A method of providing this design margin is to add 10–15% to the cell size determined by calculations. If the various loads are expected to grow at different rates, it may be more accurate to apply the expected growth rate to each load for a given time and to develop a duty cycle from the results.

The cell size calculated for a specific application will seldom match a commercially available cell exactly, and it is normal procedure to select the next higher capacity cell. The additional capacity obtained can be considered part of the design margin.

Note that the "margins" required by 6.3.1.5 and 6.3.3 of IEEE Std 323-1983 are to be applied during "qualification" and are not related to "design margin."

Table 1—Cell size correction factors for temperature

Electrolyte temperature		Cell size correction factor
(° F)	(° C)	
25	–3.9	1.520
30	–1.1	1.430
35	1.7	1.350
40	4.4	1.300
45	7.2	1.250
50	10.0	1.190
55	12.8	1.150
60	15.6	1.110
65	18.3	1.080
66	18.9	1.072
67	19.4	1.064
68	20.0	1.056
69	20.6	1.048
70	21.1	1.040
71	21.7	1.034
72	22.2	1.029
73	22.8	1.023
74	23.4	1.017
75	23.9	1.011
76	24.5	1.006
77	25.0	1.000
78	25.6	0.994
79	26.1	0.987
80	26.7	0.980
81	27.2	0.976
82	27.8	0.972
83	28.3	0.968
84	28.9	0.964
85	29.4	0.960
86	30.0	0.956
87	30.6	0.952
88	31.1	0.948
89	31.6	0.944
90	32.2	0.940
95	35.0	0.930
100	37.8	0.910
105	40.6	0.890
110	43.3	0.880
115	46.1	0.870
120	48.9	0.860
125	51.7	0.850

NOTE—This table is based on vented lead-acid nominal 1.215 specific gravity. However, it may be used for vented cells with up to a 1.300 specific gravity. For cells of other designs, refer to the manufacturer.

6.2.3 Aging factor

As a rule, the performance of a lead-acid battery is relatively stable throughout most of its life, but begins to decline with increasing rapidity in its latter stages, with the "knee" of its life versus performance curve occurring at approximately 80% of its rated performance.

IEEE Std 450-1995 recommends that a battery be replaced when its actual performance drops to 80% of its rated performance because there is little life to be gained by allowing operation beyond this point. Therefore, to ensure that the battery is capable of meeting its design loads throughout its service life, the battery's rated capacity should be at least 125% (1.25 aging factor) of the load expected at the end of its service life.

Exceptions to this rule exist. For example, some manufacturers recommend that vented batteries with Planté, modified Planté, and round plate designs be replaced when their measured capacity drops below 100% of their rated capacity (1.00 aging factor). These designs maintain a fairly constant capacity throughout their life.

6.2.4 Initial capacity

Batteries may have less than rated capacity when delivered. Unless 100% capacity upon delivery is specified, initial capacity can be as low as 90% of rated capacity. This will rise to rated capacity in normal service after several charge-discharge cycles or after several years of float operation.

If the designer has provided a 1.25 aging factor, there is no need for the battery to have full rated capacity upon delivery because the capacity normally available from a new battery will be above the duty cycle requirement. When a 1.00 aging factor is used, the designer should ensure that the initial capacity upon delivery is at least 100%, or that there is sufficient margin in the sizing calculation to accommodate a lower initial capacity.

Example: If the cells have 90% initial capacity and the margin is greater than 11%, then no additional compensation for initial capacity is required.

6.3 Cell size

This subclause describes and explains a proven method of calculating the cell capacity necessary for satisfactory performance on a given duty cycle. The application of this method to a specific duty cycle, using an optional preprinted worksheet to simplify the calculations, is demonstrated in A.2. Instructions for the proper use of the worksheet are given in 6.4.

6.3.1 Initial calculation

Equation (1) (see 6.3.2) requires the use of a capacity rating factor C_t (6.3.3) that is based on the discharge characteristics of a particular plate type and size. Thus, the initial calculation must be based on a trial selection of positive plate type and capacity. Depending on the results of this initial calculation, it may be desirable to repeat the calculation for other types or sizes of plates to obtain the optimum cell type and size for the particular application. In addition, it may be desirable to repeat the calculation to take into account any differences in performance per plate within a given series of cells. Use the capacity from the first calculation as a guide for selecting additional types to size.

6.3.2 Sizing methodology

The cell selected for a specific duty cycle must have enough capacity to carry the combined loads during the duty cycle. To determine the required cell size, it is necessary to calculate, from an analysis of each section of the duty cycle (see Figure 2), the maximum capacity required by the combined load demands (current versus time) of the various sections. The first section analyzed is the first period of the duty cycle. Using the capacity rating factor (see 6.3.3) for the given cell type, a cell size is calculated that will supply the required current for the duration of the first period. For the second section, the capacity is calculated assuming that the current A_1, required for the first period, continued through the second period; this capacity is then adjusted for the change in current (A_2–A_1) during the second period. In the same manner, the capacity is calculated for each subsequent section of the duty cycle. This iterative process is continued until all sections of the duty cycle have been considered. The calculation of the capacity F_S required by each section S, where S can be any integer from 1 to N, is expressed mathematically in equation (1). F_S will be expressed as watt-hours, ampere-hours, or number of positive plates, depending upon which C_t is used (see 6.3.3).

$$F_S = \sum_{P=1}^{P=S} \frac{A_P - A_{(P-1)}}{C_t} \tag{1}$$