Performance Characteristics (cont.)

performance of alkaline and regular zinc-carbon cells is compared in **Figure 9**, showing the "D" size cell at 70°F (21°C) and 32°F (0°C). **Figure 9a** shows "AA" cell performance under the same conditions. The alkaline cell will maintain a higher voltage for considerably longer than the regular zinc-carbon cell, resulting in a service life at lower temperatures which is up to ten times that of the regular zinc-carbon cell.

5.5 Internal Resistance

Alkaline cells, because of their compact construction and highly conductive electrolyte, have low internal resistance, usually less than 1 ohm. The low internal resistance characteristic is a benefit in applications involving high current pulses. Unlike regular zinc-carbon cells, alkaline cells do not require rest periods between pulses and maintain their low internal resistance, increasing only at the very end of useful life.

5.6 Energy Density

Energy density is a measure of available energy in terms of weight and volume. It is the ratio of a cell's capacity to either its volume or weight and can be used to evaluate a cell's performance.

Table 1 is a summary of the major alkaline product types comparing both volumetric energy density and gravimetric energy density. Volumetric energy density is an important factor where battery size is the primary design consideration. Gravimetric energy density becomes important where weight of the battery is critical, such as in portable computers and cellular phones. The values shown in this table are typical for each cell size. Actual energy output will vary, dependent mostly on drain rates applied.

PRODUCT NUMBER	SIZE	NOMINAL VOLTAGE	RATED CAPACITY*	LOAD	WEIGHT		VOLUME		TYPICAL GRAVIMETRIC ENERGY DENSITY**		TYPICAL VOLUMETRIC ENERGY DENSITY	
		volts	ampere-hours	ohms	pounds	kilograms	cubic inches	liters	watt-hours per pound	watt-hours per kilogram	watt hours per cubic inch	watt hours per liter
MN1300	D	1.5	15.000	10	0.304	0.138	3.440	0.056	59.2	130	5.2	322
MN1400	C	1.5	7.800	20	0.143	0.065	1.640	0.027	65.5	144	5.7	347
MN1500	AA	1.5	2.850	43	0.052	0.024	0.510	0.008	65.8	143	6.7	428
MN2400	AAA	1.5	1.150	75	0.024	0.011	0.230	0.004	57.5	126	6.0	345
MN9100	N	1.5	0.800	100	0.021	0.010	0.210	0.003	45.7	96	4.6	320
7K67	J	6.0	0.580	340	0.075	0.034	0.960	0.016	37.2	82	2.9	174
MN908	Lantern	6.0	11.500	15	1.349	0.612	30.620	0.502	40.9	90	1.8	110
MN918	Lantern	6.0	24.000	9	2.800	1.270	75.880	1.243	41.1	91	1.5	93
MN1604	9V	9.0	0.580	620	0.101	0.046	1.390	0.023	41.4	91	3.0	182

* TO 0.8V per cell at 21°C (70°F).

** Based on 1.2 volt average operating voltage per cell at 21°C (70°F).

Table 1. Comparison of typical energy densities of major DURACELL® alkaline cells/batteries.

To determine the practical energy density of a cell under specific conditions of load and temperature, multiply the ampere-hour capacity that the cell delivers under those conditions by the average discharge voltage, and divide by cell volume or weight.

Gravimetric Energy Density:

$$\frac{\text{(Drain in Amperes x Service Hours) x Average Discharge Voltage}}{\text{Weight of cell in Pounds or Kilograms}} = \frac{\text{Watt-Hours}}{\text{Pound or Kilogram}}$$

Volumetric Energy Density:

$$\frac{\text{(Drain in Amperes x Service Hours) x Average Discharge Voltage}}{\text{Volume of cell in Cubic Inches or Liters}} = \frac{\text{Watt-Hours}}{\text{cubic Inch or Liter}}$$