Ample Power Company

Amp Hours and Beer

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What do Amp hours and beer have in common? More than you think. Let's review the idea of Amp hours as usually explained. One Amp of current for one hour is one Amp hour, Ah. By the same logic, 100 Amps for 1/100 of an hour is also 1 Ah. This definition of Ah is not complicated. The problem in understanding Ah arises when we speak about a battery of a given Ah capacity. If we have a battery rated at 100 Ah, that battery can supply 5 Amps of current for 20 hours. That same battery can't supply 100 Amps for 1 hour, however. In fact, it can only supply 100 Amps for about 1/2 an hour. What gives?

The true capacity of a battery is dependent on the rate of discharge. The faster the rate of discharge, the less total Ah capacity can be delivered. This phenomenon was described mathematically back in 1897 by a researcher named Peukert. He formulated the equation:

$$I^n T = C$$

In Peukert's equation, the letter I is the discharge current, letter n is a value related to battery construction, letter T is the duration of discharge, and the letter C is the capacity removed as a result of that discharge. If exponent n is equal to one, then we have the familiar circumstance where 1 Amp for 100 hours is equal to 100 Ah. (I = 1, n = 1, T = 100, so C = 100 Ah.) But, exponent n is never equal to 1, even in the best of batteries. Exponent n has normal values of 1.05 to 2, with about 1.2 being a common value. Lets use n = 1.2 in Peukert's equation with I = 100 Amps. We now find that C = 251 Ah. In other words, if we want to draw 100 Amps for 1 hour, we need a battery of 251 Ah, assuming the battery has a Peukert's exponent n = 1.2. Suppose we have an exponent of 1.1. For 100 Amps, C now equals 159 Ah considerably lower than 251 Ah. As mentioned, exponent n is related to battery construction. The lower the value, the better the battery will supply high currents.

Table 1. Exponential Amp Hours Consumed

N =	1.05	1.1	1.15	1.2	1.25
Amps	EA	EA	EA	EA	EA
2	2.1	2.1	2.2	2.3	2.4
5	5.4	5.9	6.4	6.9	7.5
10	11.2	12.6	14.1	15.8	17.8
15	17.2	19.7	22.5	25.8	29.5
20	23.2	27.0	31.4	36.4	42.3
30	35.6	42.2	50.0	59.2	70.2
40	48.1	57.9	69.6	83.7	100.6
50	60.8	73.9	89.9	109.3	133.0
75	93.1	115.5	143.3	177.9	220.7
100	125.9	158.5	199.5	251.2	316.2

In Table 1, exponential Amps are tabulated for various currents with different exponents n. For instance, 15 Amps from a battery with n = 1.2 consumes Amp hours as if 25.8 Amps is being drawn. Note that for low values of current, the value of n doesn't have much impact on capacity C. As currents increase, however, the effect of n is significant. What Table 1 demonstrates is the need to measure Ah using Peukert's equation if we really want to stop guessing about battery capacity. For a battery with an exponent of 1.2, a 2 Amp draw for an hour actually removes 2.3 Amp hours, or about 13% more than a linear measurement indicates. A 20 Amp draw for an hour results in a depletion of 36.4 Ah . . . a whopping 45% more than a linear measurement would show! How accurate is Peukert's equation? Recent tests indicate that errors are in the range of 0.5–1%. Only the Ample Power monitors actually compute Amp–hours remaining from Peukert's equation.

Now, what about beer? We've explained Peukert's equation in prior issues, yet many have expressed confusion about the effect of discharge rate on the Ah removed from a battery. Pouring a few bottles of beer will yield an intuitive feel for Peukert's equation. For this experiment you need a few bottles of beer and some glasses. For dramatic results the beer and glasses shouldn't be too cold.

For the first experiment, leave the glass upright and pour the beer quickly into the center of the glass. After pouring you'll find just a small amount of liquid in the bottom of the glass, with lots of foam on top. For the second experiment, tilt the glass and pour the beer slowly down the side. This time, you should have lots of liquid and only a small amount of foam.

In the beer experiment, the liquid in the bottom of the glass represents the capacity, C,available for use. The faster you pour, the less the capacity. If you pour slowly, there is more beer to drink.

The beer experiment also demonstrates another battery phenomena . . . recovery. A battery that has been discharged at a high rate can be rested, and additional capacity recovered. Just as beer foam will eventually settle into liquid, battery capacity recovers as electrolyte diffuses through the plates.