Ametek Prestolite Power AC power / Charger / Battery terms

Basic Values:

Voltage: The potential difference at the battery (DC) or at the charger input (AC) measured in Volts.

Current: The rate of flow of electric charge measured in Amps.

Output Power (Watts and kW): *Watts(W) = Voltage X Current*

Kilo Watts(kW) = (Voltage X Current) X .001

Note: These equations are valid only for DC. See below for more on AC power.

Efficiency: Output Power divided by <u>real power</u> input. This is typically expressed as a percentage. For a three phase charger, it is necessary for a single meter to measure all 3 phases simultaneously in order to account for the relative phase relationships and get an accurate measure of real power.

Ferro - ~80%

SCR - ~85%

HF - ~93%

AC power:

Real Power(Watts and kW):

Also called: Active Power and Actual Power

For three phase kW = Voltage$_{L-L}$ * Line Current * 1.73 *.001 * PF

For single phase: Vac x Iac x PF   Example (480 x 10 x .9)/1000 = 4.32Kw

Reactive Power (KVAR): Power that does not contribute to charging batteries. KVAR is 0 when PF = 1. Also called: Imaginary power.

Total Power (kVA): also called apparent power. kVA = $\sqrt{(kW^2 + KVAR^2)}$

Power Factor (PF): A value from zero to one that explains the amount of real power out of the total power. Perfectly pure power draw is PF = 1. Typical utilities start to add fees when the PF is less than 0.75. Power factor equation: PF = kW / kVA. This would be read as "power factor is real power over total power". Our HF chargers are > 0.95 and our SCR chargers have power factor as low as .65 depending on battery size and charger ratings
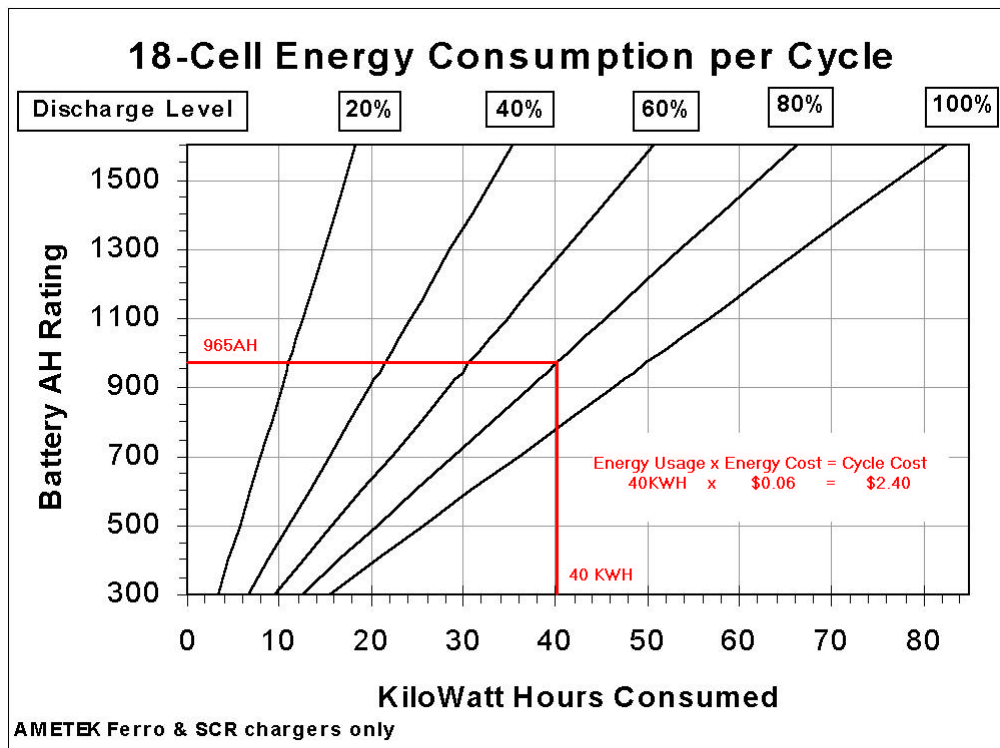
Power factor correction – An electronics module that creates a better power factor with a combination of diodes, IGBT's, and magnetics (inductors). Our Equinox product had this type of module, but all other chargers do not.

Input THD – Total Harmonic Distortion is a measure of how well the power is both used and delivered to the charger. It is measured in percentage. 0.0% is perfect and a number over a few percent is considered poor. We typically do not measure our THD since it is mostly driven by the quality of the building's AC power delivery rather than the charger itself.

Buying AC power from utilities: Most facilities buy "real power" and pay a demand charge as well as a power factor fee if their power factor is low. There are some utilities now charging for kVA.

Demand Charge (Peak Demand) The part of a bill for electric power based on the amount of power that the customer requires to be kept available to him. It is based on the highest usage over a 15-30min. period at any time during the billing cycle.

KWh: This is a measure of energy that includes time, or how much power has been delivered for how long. KWh = kW * time in hours.

18-Cell Energy Consumption per Cycle

Discharge Level: 20% 40% 60% 80% 100%

Battery AH Rating vs KiloWatt Hours Consumed

965AH

Energy Usage x Energy Cost = Cycle Cost
40KWH   x $0.06   = $2.40

40 KWH

AMETEK Ferro & SCR chargers only

Battery and Charger:

Start Rate:

Conventional: 16.3 amps / 100 amp-hour and less
Opportunity: 16.3 - 25 amps / 100 amp-hour
Fast: 25 - 40 amps / 100 amp-hour

SCR Chargers start rate

Opportunity Charge
- 100 % Charger = 25.0 amps / 100 amp-hour

Conventional Charge
- 100 % Charger = 16.3 amps / 100 amp-hour
- 80 % Charger = 14.3 amps / 100 amp-hour
- 60 % Charger = 10.5 amps / 100 amp-hour

Ferro resonant Chargers start rate

Conventional Charge

- 100 % Charger = 20 amps / 100 amp-hour
- 80 % Charger = 17 amps / 100 amp-hour
- 60 % Charger = 13 amps / 100 amp-hour
- 50 % Charger = 10 amps / 100 amp-hour

Finish Rate: For many years, finish rate was 4.5 amps per / 100 amp-hour of rated capacity, however in 2014, this was increased to 5% based on East Penn Manufacturing's most recent Application Guide.

Specific Gravity: Measured density of the electrolyte in the battery. Most batteries have a gravity of 1.280-1.295 when fully charged. (However, there are some special designs that operate at higher SG, such as 1.325.) A fully discharged battery typically has a SG of about 1.160. In order to be useful, this measurement must be temperature corrected based on temperature of the electrolyte. The temperature correction is to add ~0.001 for every 3 F° above 77.

State of Charge (SOC): 0-100% relates to the capacity available in the battery. Measure specific gravities and temperature to know for sure. Datalink estimates this by looking at voltage, current, and battery capacity. You are not supposed to discharge further than 20% SOC during normal use. And, the optimal minimum for opportunity charging is 30% in order to facilitate rapid recharge.

SOC VS. Open Circuit Voltage:
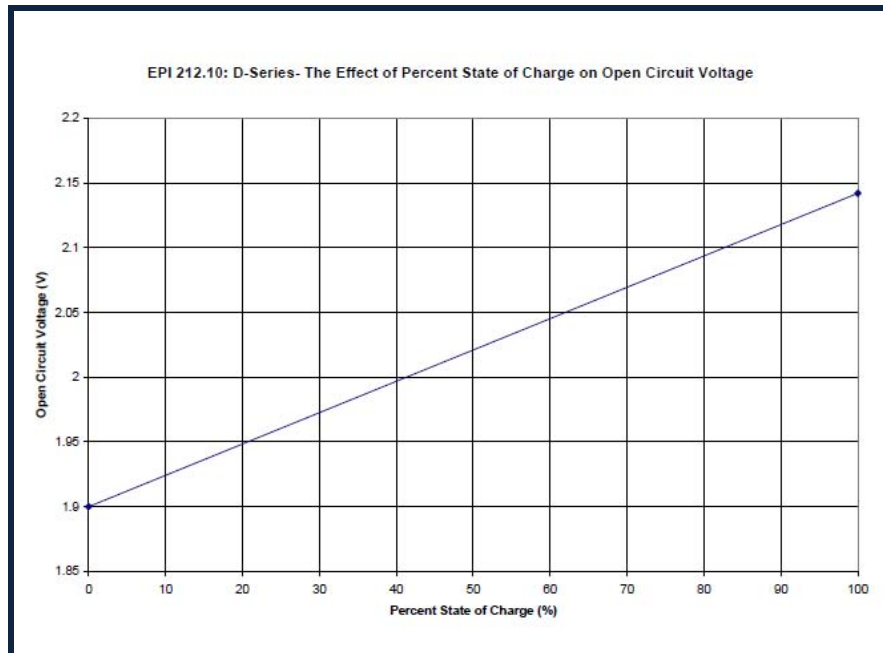
Battery Capacity (AH amp hours): Rated by the battery manufacturer.

> <u>In very general terms:</u>
> 1000 Ah could be 1 amp for 1000 hours or 10 amps for 100 hours or 100 amps for 10 hours. However, a 1000 Ah battery delivers 1000 Ah only at one particular rate of discharge. When discharged faster or slower, the Ah will vary.
> <u>As it relates to battery usage in real life:</u>
> A 1000 Ah battery can deliver 167 amps for 6 hours (known as the 6 hour rate). At lower amp draws, it will deliver more overall energy (AH) to the truck. At higher amp draws it will deliver less overall energy (AH) to the truck.

Battery Voltage: The battery voltage is estimated at 2 volts per cell nominal. Fully charged open circuit voltage is ≈ 2.13 vpc.

1.95 V/cell is common for deeply discharged battery

2.60 V/cell is common for finish voltage (on charge voltage)

2.62 V/cell is common for equalize voltage (on charge voltage)

To be meaningful, on-charge readings must be temperature corrected. To temperature correct an on charge reading, add 0.01 volts per cell for every 3° above 77°F.

Equivalent Battery Unit (EBU): One cycle of 80% of the rated battery capacity. The typical life of a battery is estimated to be 1500 EBU's.

Gassing Voltage and Temperature Compensation (lead acid): Gassing voltage is 2.4V/cell at 77degF. For every 3 degrees colder the gassing voltage is raised by 0.01V/cell. For every 3 degrees warmer the gassing voltage is lowered by 0.01V/cell. When the voltage is high enough for gassing the battery vents hydrogen gas. MAX and FLD curves are temperature compensated when the BID is used to measure battery temperature. If no BID is available, the fixed temperature parameter of the control can be set for a best estimate of temperature and the control will compensate gassing voltage based on that value. Sealed curves have different levels of compensation.

Operating Temperatures: Batteries can operate between 32degF and 150degF. Chargers can operate between 32degF and 105degF.

Charge Complete: Depending on the termination type, this will be 3 to 4 hours after the 80% point (VT) or when the on charge battery voltage is no longer increasing.

Equalize: Three hours of finish current charge after the battery reaches charge complete, 100% charged. This is a once per week cycle that helps make all the cells have equal voltage and SG's. We have day of week, cycle count, and BID cycle count types.

80% SOC: when we are at gassing voltage and the current has dropped to approximately 8 amps / 100 amp-hour

Terminations (charge complete):

> **DVDT** – charge until the charger is at finish current and the voltage is no longer rising.
> **VT** – charge for 4 hours after 80% point is reached. (3 hours on ferroresonant chargers)

No Gassing Timer: The timer begins running when the battery is connected and the charge begins. Once the charger has reached the 80% point, the charger suspends the charge cycle until the timer expires. At that point, it will continue the charge and run to completion. This prevents unwanted battery gassing during short charging cycles.

Controlled Output Chargers: Chargers that can be programmed to output a requested current and follow an exact curve. The two controlled charger types are SCR and HF. The typical current and voltage regulation is +/- 1% for both start and finish. This type of charger output maintains regulation as the input AC voltage changes.

Non Controlled Output Chargers: The Ferro charger uses only the transformer to control the current to the battery. The start current will generally go up and down as the input AC voltage changes. The finish voltage is regulated and will stay within a 1% regulation as the AC input voltage changes +/- 10%. This regulation comes from the resonant winding combined with the capacitor.

Charge Curves:

IEI: SCR and HF (controlled output chargers)
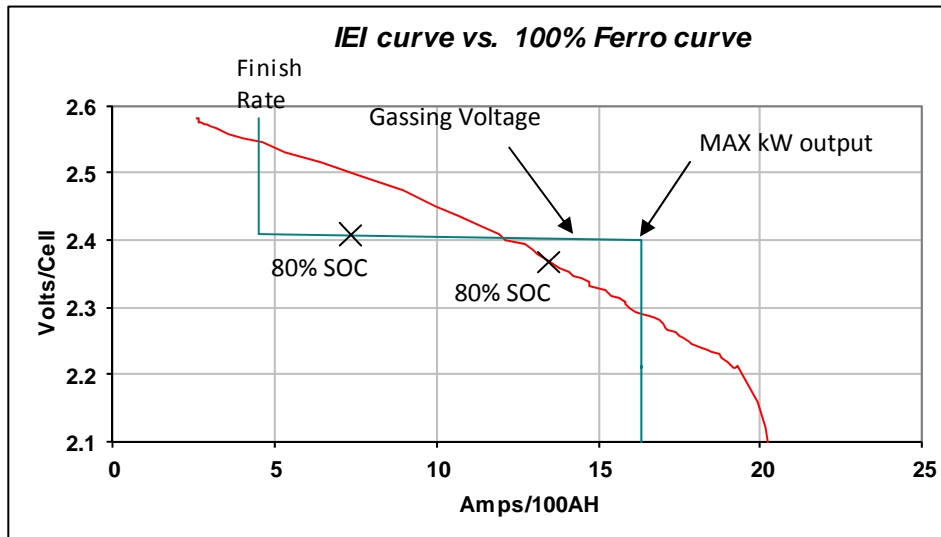Consists of 3 steps (Blue line on graph below)
1. Begin the charge at the programmed start current
2. On reaching gassing voltage, hold that voltage and allow the current to fall until reaching finish current
3. Charge at programmed finish current until end of charge conditions are satisfied. (either dV/dt or V-T)

The control will indicate 80% state of charge at 8% of capacity current in the gassing voltage portion of the curve.

Ferro:
The transformer and capacitor in the charger determine the output current for any battery voltage, gradually reducing the current as voltage rises. (Red line on graph)

Typically the control will indicate 80% at 2.37V/

IEI curve vs. 100% Ferro curve

(Chart: Volts/Cell vs. Amps/100AH. Labels: Finish Rate, Gassing Voltage, MAX kW output, 80% SOC, 80% SOC)

Charge Curve Notch:

1. The Notch was developed as a compensation for the difference in temperature between the intercell connector (where the BID measures) and the battery electrolyte temperature when operating at relatively high start rates in opportunity or fast charge at the beginning of the cycle. In other words, to prevent cutting back too quickly. It applies only when operating with the MAX curve.

2. Charging at the start current, as we reach gassing voltage (2.40VPC) we continue at start current until reaching 2.45VPC.

3. We then hold at 2.45VPC until the current has dropped to ~75% of programmed start current.

4. We then drop down to regulate at 2.40VPC and complete the charge in the normal fashion.

Note: all VPC numbers are corrected for temperature if a BID is in use. Eclipse II, Ultra Maxx, and Equinox have the same notch as described above. There are some Equinox and Eclipse units that have modified code that push the batteries harder.

Curve Error:

1. The purpose of the Curve Error check is to verify that the charger is doing what it is programmed to do. Within tolerances, the current and voltage should match the requested output. If they do not, a Curve Error results and the charge terminates.
2. This function is sampling every 10 min when everything is normal with the charge.
3. When there is a problem, the sampling interval is decreased to 2 min.
4. If we accumulate 6 samples that are outside of the valid current/voltage windows, the control will shut off in a curve error fault.
5. Any good sample returns the count to 0 and the sample period back to 10min.
6. In current mode (start and finish) there is a +/- 10 A window about the calculated output.
7. In voltage mode (Vgas and Vlid) there is a +/- 0.09VPC window about the calculated output

Potential causes:
1. New, under formed battery
2. Very low water level battery
3. Damaged battery / thermal run away
4. Broken charger