



Battery Selection and Considerations for UPS Applications

J. Allen Byrne

Interstate PowerCare

Critical Services



Battery Selection and Considerations for UPS Applications

Almost all Power Engineers consider the Battery to be the weakest link of any battery backed power system, including a UPS.

The humble Battery is also the Roger Dangerfield of the industry ... it gets no respect!

My goal is to ensure that you recognize this Achilles heel and gain some respect.

I also want you to recognize some of the limitations, pit-falls and safety aspects of batteries in UPS applications.

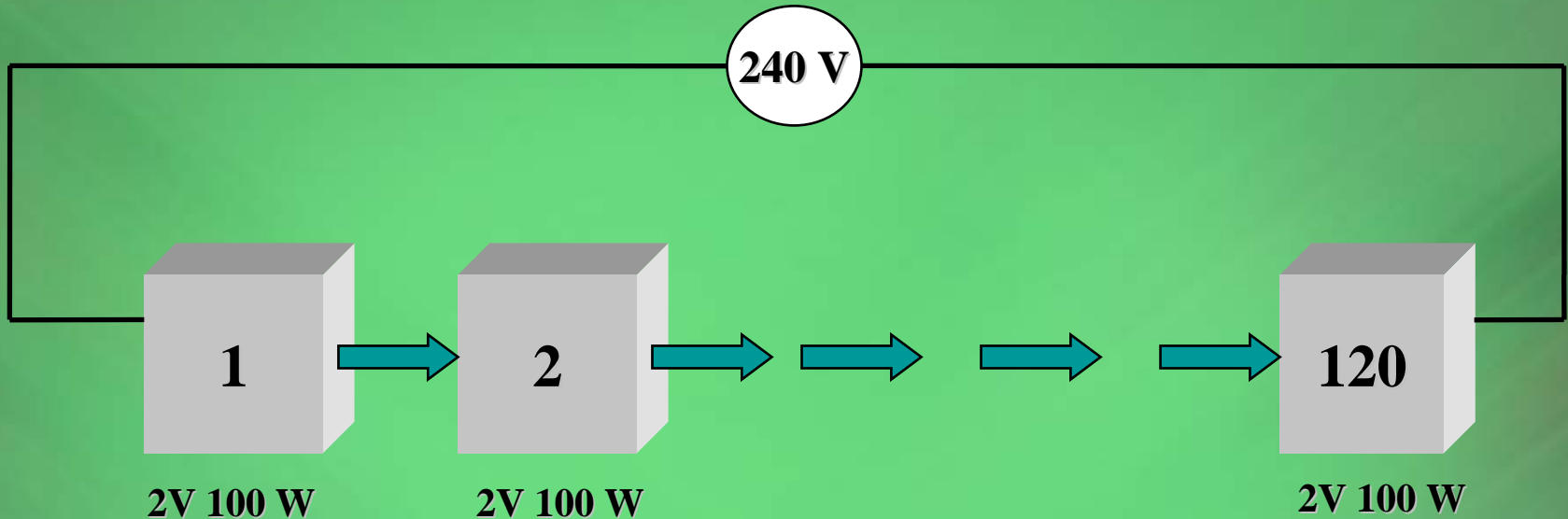


Battery Selection and Considerations for UPS Applications.

Presentation Outline

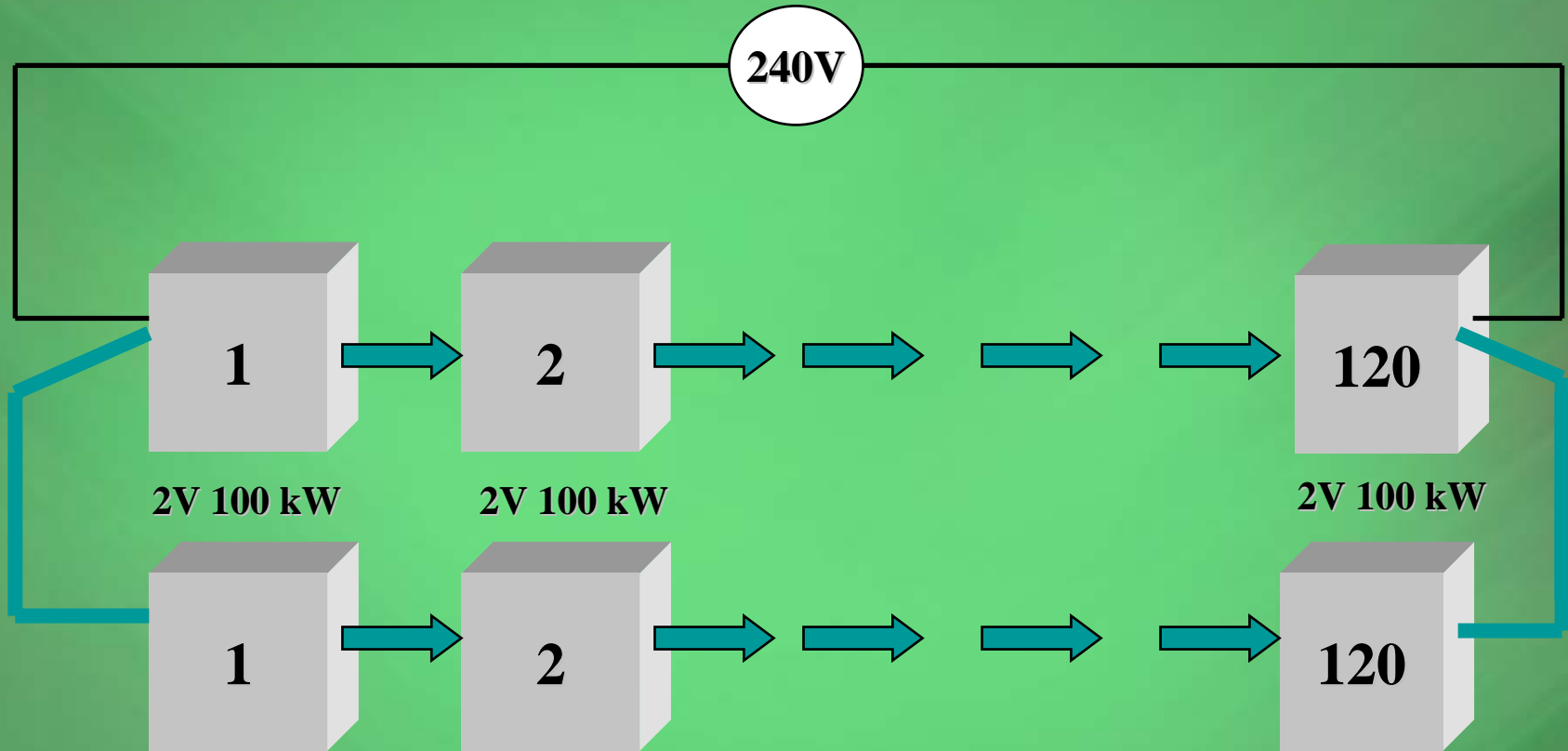
- What makes up a UPS battery?
- Calculating battery reserve time.
- Battery types.
- Which battery for which application?
- Code compliant battery installation.
- Battery maintenance.
- Battery monitoring and testing.
- Battery safety.
- Battery warranty

Battery Selection and Considerations for UPS Applications.



Battery Cells in Series -- Total Capacity 12 kW

Battery Selection and Considerations for UPS Applications.



Battery Cells in Series/Parallel – Total Capacity 24 kW

Battery Selection and Considerations for UPS Applications.

Understanding Volt Amps (VA), Watts and Battery Sizing

In an ac circuit, the product of the measured rms value of the current (Amps) and the measured rms value of the Voltage equals the Volt Amps (VA) of the circuit. However, this calculation does not reflect the reactance in the circuit.

Because of this, the VA product is only the Apparent Power of the circuit.

In order to calculate the Real Power (Watts) the Power Factor (PF) of the circuit needs to be known.

$$\text{Watts} = \text{VA} \times \text{PF}$$

In order to calculate the battery Watts required, the efficiency of the UPS Inverter also needs to be considered.

$$\text{Battery Watts} = \text{VA} \times \text{PF} \div \text{Inverter Efficiency}$$

Battery Selection and Considerations for UPS Applications.

Calculating Battery Watts

Battery Watts (BW) = VA x PF ÷ Inverter Efficiency

Some other things one might want to consider in determining Total Battery Watts.

- Voltage drop between Battery and UPS Inverter.
 - Multiply BW by percentage of voltage drop.
- Operating temperature of Battery.
 - Apply a Correction Factor of 0.006 of total BW for each °F above or below 77°F.
- Allow for system growth.
 - Multiply BW by anticipated growth percentage.
- Allow for the aging factor of the battery.
 - Multiply BW by 25% if it is required to keep battery at 100% at end of life.

Battery Selection and Considerations for UPS Applications.

Calculating Watts per Battery Cell

Having calculated the total battery Watts:

Calculate the number of cells required from the nominal dc voltage of the UPS as supplied by the manufacturer. e.g. 240 Volts = 120 two Volt cells.

Calculate the Watts per cell required by dividing the total battery Watts by the number of cells. e.g. 250 kWatts ÷ 120 cells = 2083.4 Watts per Cell.

Consult the manufacturer's data for Watts per cell, at the discharge time desired, to the end voltage per cell, at the operating temperature specified.

Select the cell with the next highest watts per cell rating.

Battery Selection and Considerations for UPS Applications.

| Constant Power Discharge Data Watts per cell at 77°F – Discharge Time (minutes) | | | | | | | | | | | | | | | | | | |
|---|-----|-----|-----|-----|-----|-----|-----|-----|------|------|------|------|------|------|------|------|------|------|
| EODV (Vpc) | 5 | 10 | 15 | 20 | 25 | 30 | 45 | 60 | 90 | 120 | 180 | 240 | 300 | 360 | 480 | 600 | 720 | 1200 |
| 1.60 | 703 | 519 | 411 | 331 | 276 | 237 | 170 | 132 | 89.4 | 69.2 | 49.1 | 38.4 | 32.1 | 27.6 | 21.8 | 18.2 | 15.6 | 9.80 |
| 1.65 | 684 | 506 | 406 | 324 | 272 | 233 | 167 | 131 | 88.6 | 68.9 | 48.8 | 38.2 | 32.0 | 27.4 | 21.7 | 18.1 | 15.5 | 9.79 |
| 1.67 | 675 | 499 | 400 | 322 | 270 | 231 | 166 | 130 | 88.3 | 68.8 | 48.7 | 38.1 | 31.9 | 27.4 | 21.7 | 18.1 | 15.5 | 9.79 |
| 1.70 | 662 | 489 | 392 | 318 | 266 | 229 | 165 | 129 | 87.9 | 68.6 | 48.5 | 38.0 | 31.9 | 27.4 | 21.7 | 18.1 | 15.5 | 9.78 |
| 1.75 | 592 | 456 | 366 | 298 | 253 | 219 | 159 | 125 | 86.6 | 68.3 | 48.2 | 37.8 | 31.7 | 27.2 | 21.5 | 17.9 | 15.3 | 9.69 |
| 1.80 | 501 | 397 | 329 | 274 | 239 | 210 | 154 | 122 | 85.0 | 67.7 | 47.7 | 37.4 | 31.3 | 27.0 | 21.3 | 17.8 | 15.2 | 9.52 |
| 1.85 | 443 | 357 | 303 | 257 | 223 | 198 | 148 | 117 | 82.0 | 65.5 | 46.1 | 36.2 | 30.4 | 26.2 | 20.7 | 17.3 | 14.8 | 9.14 |
| 1.90 | 373 | 306 | 260 | 225 | 198 | 176 | 134 | 107 | 75.6 | 60.8 | 42.8 | 33.5 | 28.1 | 24.3 | 19.4 | 16.3 | 13.9 | 8.45 |

| Constant Current Discharge Data Amperes at 77°F – Discharge Time (minutes) | | | | | | | | | | | | | | | | | | |
|--|-----|-----|-----|-----|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|
| EODV (Vpc) | 5 | 10 | 15 | 20 | 25 | 30 | 45 | 60 | 90 | 120 | 180 | 240 | 300 | 360 | 480 | 600 | 720 | 1200 |
| 1.60 | 402 | 291 | 228 | 182 | 151 | 129 | 91.9 | 71.2 | 47.8 | 36.8 | 26.0 | 20.2 | 16.9 | 14.5 | 11.4 | 9.51 | 8.14 | 5.09 |
| 1.65 | 383 | 279 | 222 | 176 | 147 | 125 | 89.4 | 69.5 | 46.9 | 36.3 | 25.6 | 20.0 | 16.7 | 14.3 | 11.3 | 9.43 | 8.04 | 5.08 |
| 1.67 | 372 | 270 | 215 | 172 | 144 | 123 | 87.9 | 68.5 | 46.4 | 36.0 | 25.4 | 19.9 | 16.6 | 14.3 | 11.3 | 9.38 | 8.01 | 5.06 |
| 1.70 | 364 | 265 | 211 | 170 | 142 | 122 | 87.0 | 67.9 | 46.1 | 35.9 | 25.3 | 19.8 | 16.5 | 14.2 | 11.2 | 9.34 | 7.99 | 5.04 |
| 1.75 | 319 | 243 | 193 | 157 | 133 | 115 | 83.0 | 65.2 | 44.8 | 35.3 | 24.8 | 19.4 | 16.3 | 14.0 | 11.0 | 9.19 | 7.85 | 4.96 |
| 1.80 | 265 | 207 | 171 | 142 | 123 | 108 | 78.9 | 62.4 | 43.4 | 34.5 | 24.3 | 19.0 | 15.9 | 13.7 | 10.8 | 9.04 | 7.71 | 4.83 |
| 1.85 | 229 | 183 | 155 | 131 | 113 | 101 | 74.8 | 59.2 | 41.4 | 33.0 | 23.2 | 18.2 | 15.2 | 13.1 | 10.4 | 8.65 | 7.39 | 4.57 |
| 1.90 | 193 | 157 | 133 | 115 | 101 | 89.4 | 67.9 | 54.1 | 38.1 | 30.6 | 21.5 | 16.8 | 14.1 | 12.2 | 9.71 | 8.14 | 6.94 | 4.23 |

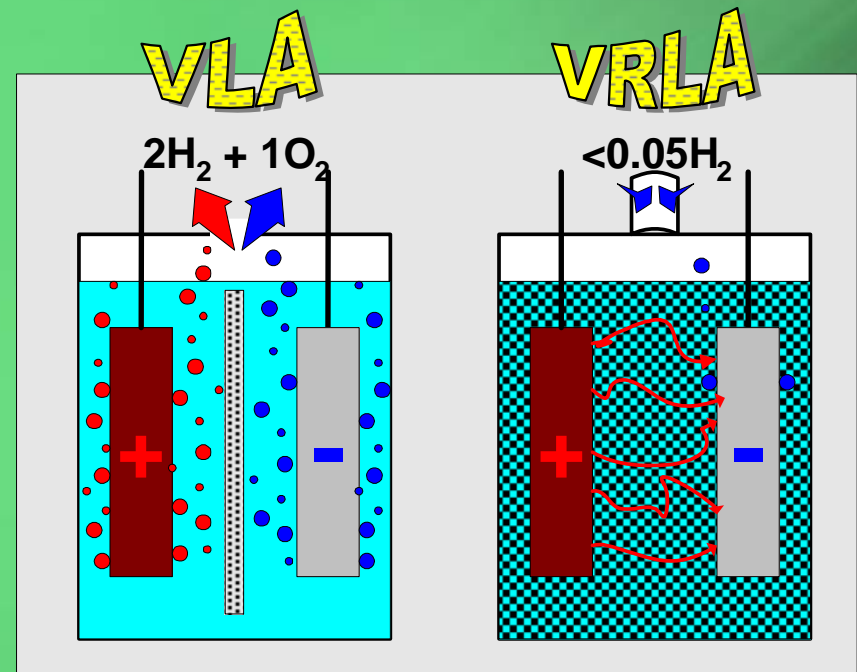
Note: Batteries to be mounted with 0.5 in. (1.25 cm) spacing minimum and free air ventilation. Specifications subject to change without notification.

Typical Manufacturer's Battery Discharge Data

Battery Selection and Considerations for UPS Applications.

Basic Types of Lead-Acid Batteries

- Vented Lead-Acid (Flooded) VLA.
- Valve-Regulated Lead-Acid VRLA (so-called sealed)
 - Absorbed Electrolyte
 - Gelled Electrolyte



Battery Selection and Considerations for UPS Applications.

Valve-Regulated Lead-Acid.

These so-called “sealed, maintenance free” batteries are neither!

- They are not Sealed!
- They are not Maintenance Free!
- Almost all are of a lead-acid, calcium plate design.

Two Types

- Absorbed Glass Mat (AGM).
- Gelled Electrolyte.

Battery Selection and Considerations for UPS Applications.

Basic Types of Plate Construction

- Planté / Pure Lead
- Pasted
- Tubular

Basic Types of Plate Material

- Pure Lead
- Lead Selenium
- Lead Calcium
- Lead Antimony

Battery Selection and Considerations for UPS Applications.

Comparison of Two Main Chemistries

| | Lead-Acid VLA | Lead-Acid VRLA | Ni-Cad |
|-------------|------------------|-------------------|------------------|
| Cost | Moderate | Moderate | High |
| Reliability | Moderate to High | Low to Moderate | Moderate to High |
| Maintenance | Moderate to High | Moderate | Low to Moderate |
| Life | Moderate to High | Low to Moderate | Moderate to High |
| Safety | Low to Moderate | Moderate to High | Low to Moderate |
| Ruggedness | Low | Moderate to High | Moderate to High |
| Disposal | Moderate | Relatively Simple | Can be Difficult |

Battery Selection and Considerations for UPS Applications.

Plate Material Summary.

| | Pure Lead | Lead Selenium | Lead Calcium | Lead Antimony |
|-------------|-----------------------|-----------------------|--------------------|---------------------------|
| Life | Long | Long | Low - Medium | Medium |
| Maintenance | Moderate | Moderate | Moderate | High |
| Cycling | Very Good | Very Good | Poor | Good |
| Temperature | Medium | Good | Poor | Poor |
| Comments | Used mainly in Europe | Used mainly in Europe | Used mainly in USA | Used in USA but declining |

Battery Selection and Considerations for UPS Applications.

Plate Type Summary.

| | Planté | Flat Pasted | Tubular | Round |
|-----------------|-----------|-------------|------------|-----------|
| Plate | Pure Lead | Lead Alloy | Lead Alloy | Pure Lead |
| Life | Long | Medium | Long | V Long |
| Maintenance | Low | High | Medium | Low |
| Energy /density | High | High | Medium | Low |
| Cycling | Good | Poor - Good | High | Poor |
| High Temp. | Average | Average | Good | Average |
| Initial Cost | High | Low | High | High |
| | | | | |

Battery Selection and Considerations for UPS Applications.

Valve-Regulated Lead-Acid.

These so-called “sealed, maintenance free” batteries are neither!

- They are not Sealed!
- They are not Maintenance Free!
- Almost all are of a lead-acid, calcium plate design.

Two Types

- Absorbed Glass Mat (AGM).
- Gelled Electrolyte.

Battery Selection and Considerations for UPS Applications.

Reliability Problems with VRLA

- **Low reliability had given industry cause for concern.**
- **Extensive studies carried out in USA and Sweden in 1990's.**
 - **More than 50,000 cells tested.**
 - **Nine plus manufacturers.**
 - **Sizes from 20 – 1,000 Ampere hour.**
 - **Both AGM and Gel tested.**

Results ? ? ?

Battery Selection and Considerations for UPS Applications.

Results (20 Year Product)

- Insufficient capacity accounted for 90% of failures.
- 80% premature cell failures.
- 41% of cells degraded to less than 50% capacity within 6 years.
- 60 plus % string failures within 7 years.
- 20 year cell life really 5 – 8 years.

But things are getting better.

Most of the failure mechanisms have been identified and either rectified or addressed.

Battery Selection and Considerations for UPS Applications.

Which Battery is Best?

Short duration, high rate discharge such as UPS.

Batteries designed for general purpose or low rate discharge are really not suitable for UPS applications.

UPS batteries need to be able to deliver a lot of current over a relatively short period of time.

Very specific cell design criteria should be considered such as:

Thin-Plate (high surface area) design to allow for high rate discharge.

Radial plate grids.

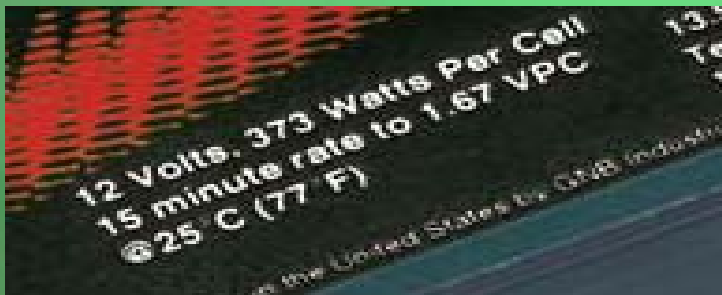
Thick internal plate bus bar and large, heavy duty, cell posts to handle high currents.

Low internal resistance

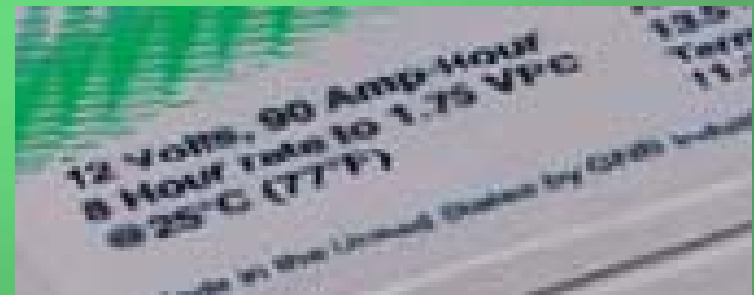
Battery Selection and Considerations for UPS Applications.



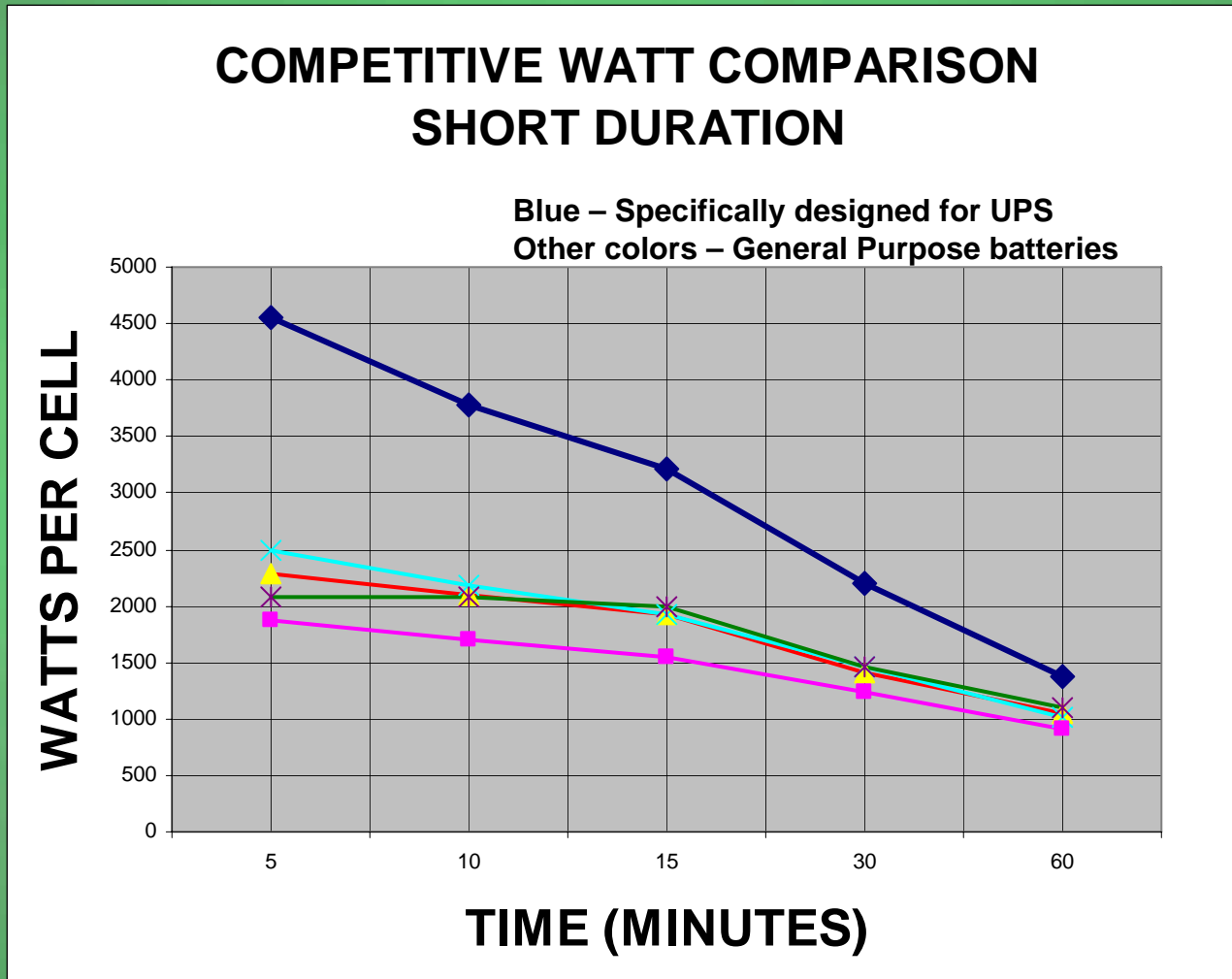
Short Duration Battery for UPS



Long Duration for Telecom



Battery Selection and Considerations for UPS Applications.



Battery Selection and Considerations for UPS Applications.

Equipment Cost Comparison. 750 KVA UPS Battery

| Item | VLA | VRLA UPS | VRLA Gen. Purpose |
|----------------------|-----------|-------------|----------------------|
| Battery | \$115,700 | \$126,100 | \$208,000 |
| Zone 4 Rack | \$5,500 | NR | NR |
| Spill Containment | \$6,200 | NR | NR |
| Flame Retardant Jars | \$7,700 | NR | NR |
| 5 Year Warranty | \$10,800 | NR | \$19,200 |
| Special Ventilation | \$1,500 | NR | NR |
| Eye Wash | \$550 | \$50 | \$50 |
| Hydrogen Detection | \$530 | NR | NR |
| | \$148,480 | \$126,150 | \$227,250 |

Battery Selection and Considerations for UPS Applications.

Additional Cost Comparisons. 750 KVA UPS Battery.

| Item | VLA | VRLA UPS | VRLA Gen. Purpose |
|----------------------------|------------------|------------------|----------------------|
| Carried Forward | \$148,480 | \$126,150 | \$227,250 |
| Freight etc. | \$10,300 | \$8,800 | \$15,000 |
| Installation | \$9,000 | \$7,200 | \$13,000 |
| 10 Year Maintenance | \$62,000 | \$28,000 | \$52,000 |
| Real Estate @ \$100 sq/ft. | \$11,616 | \$5,160 | \$10,058 |
| Total | \$241,396 | \$175,310 | \$317,308 |
| | 138% | 100% | 181% |

Battery Selection and Considerations for UPS Applications.

Battery Installation.

Install in accordance with IEEE 484 (VLA) and IEEE 1187 (VRLA).

Use knowledgeable personnel.

Key is Ventilation and Maintainability

Avoid battery cabinets where possible

Ventilation is difficult

Maintenance is seriously restricted.

Be aware of Code Requirements.

Spill Containment.

Ventilation.

OSHA requirements.

National Electric Code.

Building and Fire Codes.

Local Codes.

Battery Selection and Considerations for UPS Applications.

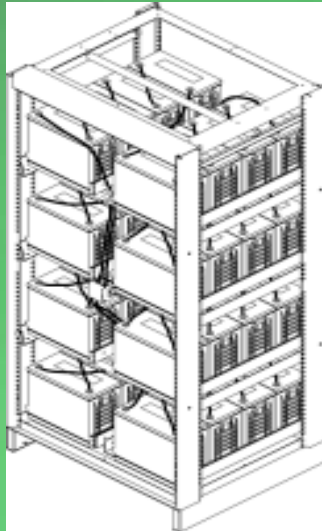
Battery Safety

This needs to be taken seriously

Don't be the target of legal action



Battery Selection and Considerations for UPS Applications.



**Battery Cabinets.
Are they safe?**



Battery Selection and Considerations for UPS Applications.

The problems with batteries in cabinets.

Access for installation.

Difficult to make and inspect connections and check torque

Access for maintenance.

Difficult to access terminals to take periodic readings.

Visual inspection is impossible.

Replacing defective battery blocks can be extremely difficult.

Heat.

Heat generated nearby equipment.

Heat build up because of restricted air-flow

Heat generated within the battery because of charging current

Personnel safety.

It can be plain dangerous

Battery Selection and Considerations for UPS Applications.

Top Terminal or Front Terminal?



Battery Selection and Considerations for UPS Applications.



20 Year Modular VRLA



**10 Year Equip.
Rack Mount**



10 Year Battery Rack Mount VRLA

Battery Selection and Considerations for UPS Applications.

Battery Selection.

Application is Important!

Is the battery suitable for
the Application?

Refer to:

IEEE 484

IEEE 1184

IEEE 1189



Battery Selection and Considerations for UPS Applications.

Battery Selection. What Should We Consider?

- Voltage
- Discharge Time
- Recharge Time
- Charging Regime
- Cycle or Standby Service
- Life Span
- End of Life Criteria
- Parallel (multiple) Strings
- Battery Type
- Battery Chemistry

Battery Selection and Considerations for UPS Applications.

Battery Selection. What Else Should We Consider?

Location

Environment (climate)

Code Requirements

Spill Containment

Physical Protection

Ancillary Equipment

Racking/Cabinets

Installation

Maintenance

External Factors

Support Systems

Other?

Battery Selection and Considerations for UPS Applications.

Which Battery is Best?

Large UPS

| | |
|------|---------------------------------|
| VLA | Pasted Flat Plate. |
| VRLA | Lead Calcium with added alloys. |

Medium UPS

| | |
|------|---------------------------------|
| VRLA | Lead Calcium with added alloys. |
|------|---------------------------------|

Small UPS

| | |
|------|---------------------------------|
| VRLA | Lead Calcium with added alloys. |
|------|---------------------------------|

Battery Selection and Considerations for UPS Applications.

- **Institute of Electrical Engineers, Power Engineering Society – Stationary Battery Committee (IEEE PES SBC)**
- The IEEE PES SBC writes codes and standards for batteries used in stationary (fixed) application such as Telecommunications, UPS and Utility applications. Some of these Codes and Standards that are applicable are as follows:
 -
 - **Number** **Subject.**
 - IEEE 450. Maintenance and Testing of VLA Batteries.
 - IEEE 484 Installation of VLA Batteries.
 - IEEE 485 Testing of VLA Batteries.
 - IEEE 1184 Guide for batteries for UPS.
 - IEEE 1187 Installation of VRLA Batteries.
 - IEEE 1188 Maintenance and Testing of VRLA Batteries.
 - IEEE 1189 Selection of VRLA Batteries.
 - IEEE 1491 Guide to Battery Monitoring.
 - IEEE 1578 Battery Spill Containment. (Not yet released).
 - IEEE 1635 Battery Ventilation and Thermal Management. (Not yet released).
 - IEEE P1635 Battery Ventilation and Thermal Management.
 - IEEE P1657 Battery Technician Training

Battery Selection and Considerations for UPS Applications.

Spill Containment



Spill Containment Barrier



Spill Absorption Pillows



Battery Selection and Considerations for UPS Applications.

Large VLA Battery System with Room Spill Containment



Battery Selection and Considerations for UPS Applications.

**Large VRLA
Battery System
with no Spill Containment.**

**In most jurisdictions it's not
required.**



Battery Selection and Considerations for UPS Applications.

Battery Management.

If the load is critical, install some sort of battery monitoring.

Refer to IEEE 1491.

Obtain baseline data on completion of battery installation.

Initiate a meaningful maintenance program. There is no such thing as a “maintenance free” battery.

Examine the battery maintenance records and act accordingly. Be proactive.

Test the battery as recommended by IEEE 450 (VLA) and IEEE 1188 (VRLA).

Battery Selection and Considerations for UPS Applications.

Battery Warranty

- Warranty is a “numbers game.”
- Understand what you are getting. Replacement? Freight? Labor?
- All similar warranties may not be equal.
- Warranty may be reduced for UPS applications.
- Know what you have to do to validate warranty.
- Know what you have to do to keep warranty valid.
- Negotiate Warranty. Full plus pro rata? Full and out?

Battery Selection and Considerations for UPS Applications.

Battery Warranty – A Numbers Game – Can You Collect?

ABC Battery Mfg. Co. warrants that Type X batteries for service life according to the terms of the limited warranty and the warranty schedule (Table 1) or the specific number or combination of cycles in Table 2, whichever occurs first.

Table 1-UPS Warranty Schedule
(Float Service)

| |
|------------------|
| Full Replacement |
| 3 Years |

Table 2- Warranted Life Cycle

| Discharge Duration* | Cycles | Discharge Duration** | Cycles |
|---------------------|--------|----------------------|--------|
| 5 min. | 650 | 1 hour | 280 |
| 10 min. | 460 | 4 hours | 230 |
| 15 min. | 400 | 8 hours | 220 |
| 30 min. | 330 | | |

*Based on an end-voltage of 1.67 Vpc at 77° F(25°C)

**Based on an end-voltage of 1.75 Vpc At 77° F(25°C)

If the battery fails to deliver 80% of its rated capacity prior to 36 months from the date of shipment and prior to the warranted cycle life, ABC Battery Mfg. Co. agrees to repair or replace the battery FOB its factory. The user may apply the unused warranty life towards the purchase of a replacement battery of equal or greater ampere-hour capacity. Freight and labor charges shall be the sole responsibility of the user.

Battery Selection and Considerations for UPS Applications.

Summary

- **Proper battery selection is essential.**
- **Know the Codes, Standards and Practices.**
- **Particular attention needs to be paid to operating conditions.**
- **A meaningful maintenance program must be put in place.**
- **There is no such thing as a sealed, maintenance free battery.**
- **The battery is going to fail, the objective should be to make that later rather than sooner.**

Battery Selection and Considerations for UPS Applications.

Questions?



Battery Selection and Considerations for UPS Applications.

Thank You

J. Allen Byrne

Office. 301 696 9669
Mobile. 240 344 5445
e-mail. allen.byrne@ibsa.com

