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Battery Sizing

Scope

- **Battery selection criteria**
- **Electrochemistry**
- **Comparison of Lead Acid vs Nickel Cadmium**
- **Battery Sizing – Understanding load profiles**
  - Where and how you can save money

The Basics – Build a Load Profile

- **WHERE TO BEGIN**
  - When will the battery discharge
- **LOADS TO CONSIDER**
  - Continuous
  - Non-Continuous
  - Momentary
- **WHAT HAPPENS FIRST**
  - Followed by?
  - For how long?
- **MARGINS**
  - Design
  - Aging
  - Effects of temperature
  - Fluff

NORMAL OPERATION
AC Available
No Faults

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2 amps for indicating lights, relays etc.

4.160KV

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–

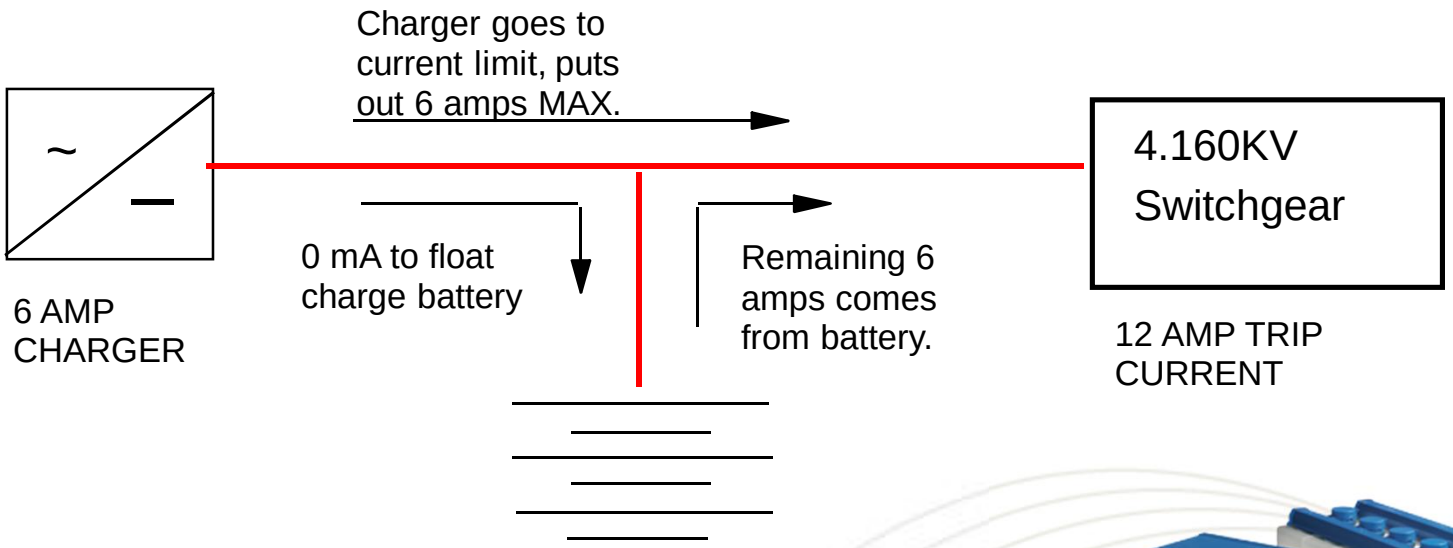
6 AMP CHARGER

30 mA to float charge battery

Switchgear

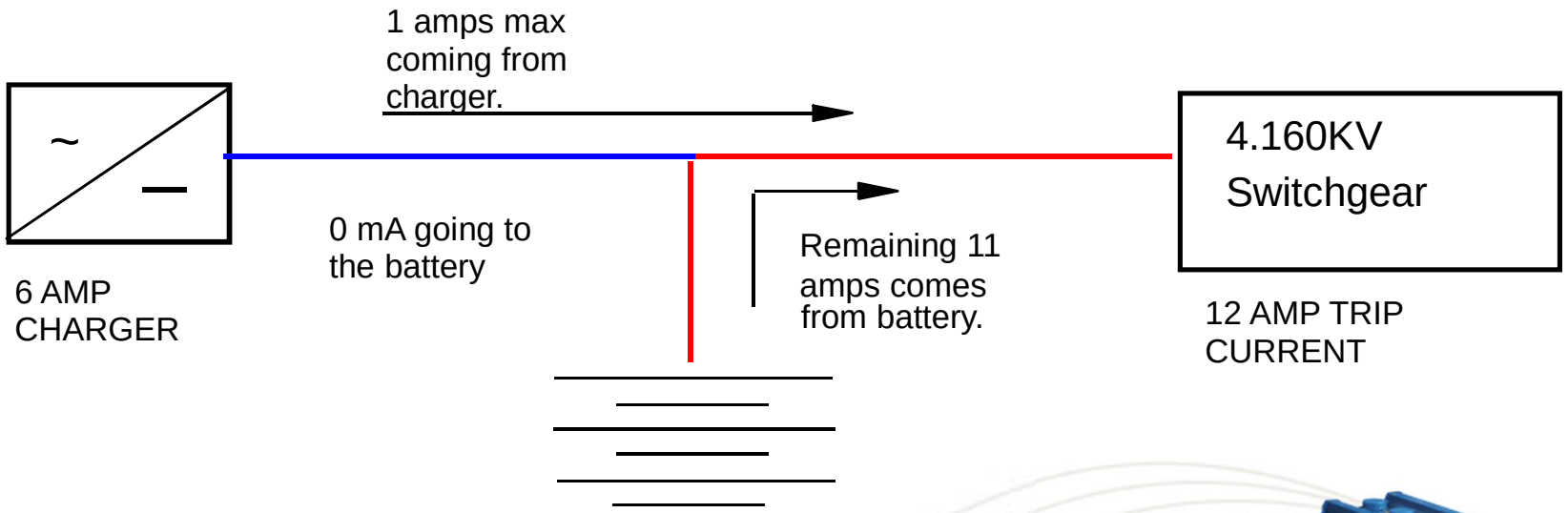
12 AMP TRIP CURRENT

Basics



Load requirements exceed maximum charger output

ABNORMAL CONDITION
Charger Output Limited
Breaker Operating



Charger output is limited in some way.

ABNORMAL CONDITION
AC Failure
Charger Output @ Zero

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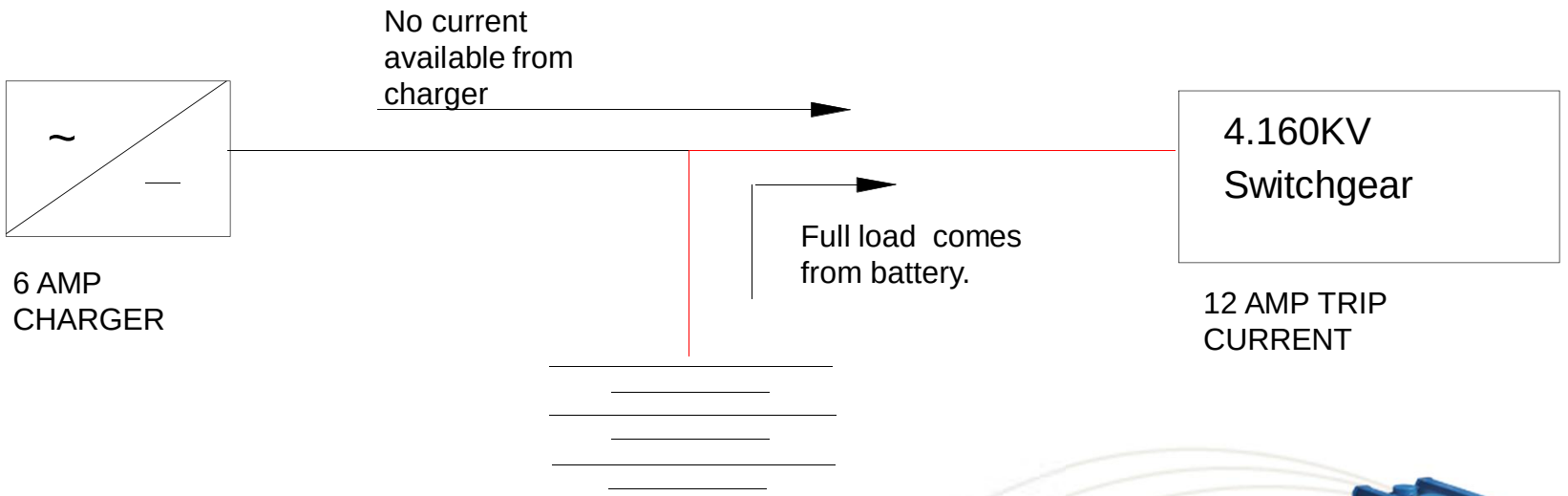


Charger output is lost completely, due to rectifier or AC failure.

Continuous Loads

- **Loads that are energized for the duration of the duty cycle**
- **Are normally supplied by the charger**
- **Can have a big effect on battery capacity**
- **Examples**
  - Continuously operating motors / pumps
  - Relay coils
  - Indicating lights

Non-Continuous Loads

- **Energized for only a portion of the duty cycle**
- **Can be turned on or off automatically or by operator action**
- **Special considerations:**
  - If inception is known, but end is not, run to end of duty cycle
  - If end is known, and inception is not, consider the load from the beginning of the duty cycle.
- **Examples**
  - Emergency lighting
  - Lube oil pumps
  - Communication

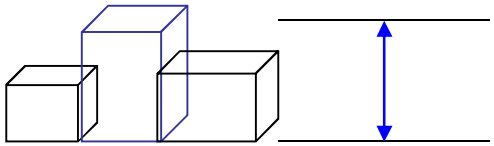
Momentary Loads

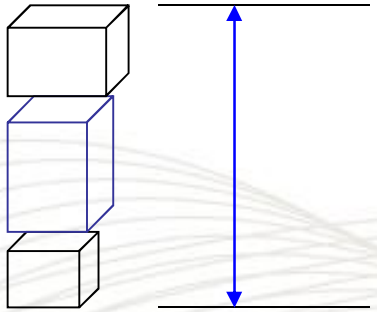
- **Very short in duration, can be fraction of a second**

- **Lead Acid - IEEE 485**
  - Even though the load may last for only a few cycles, you must treat it as lasting one full minute
- **Nickel Cadmium - IEEE 1115**
  - Even though the load may last for only a few cycles, you must treat it as lasting one full second
- **Examples**
  - Switchgear operation
  - Engine starting
  - Field flashing

Dealing with Multiple Momentary Loads

- **Discrete Sequence Known**
  - Load is maximum current at any instant





- **Sequence Unknown**
  - Load is sum of all loads in that period
  - Usually a greater demand on battery

Dealing with Multiple Momentary Loads

IEEE States:

- **If a discrete sequence can be established, the load for the period shall be assumed to be the maximum current at any instant**

Example:

		Duration
1 Trip - 3 breakers	45 amps	0.5 sec
2 Trip - 5 breakers	75 amps	1 sec
3 Trip - 4 breakers	60 amps	1 sec

Since we can determine the sequence, the load for the period would be 75 amps for one minute (for lead acid)
Nicad can be broken into 3 distinct loads, or, 75A for 3 seconds

Dealing with Multiple Momentary Loads

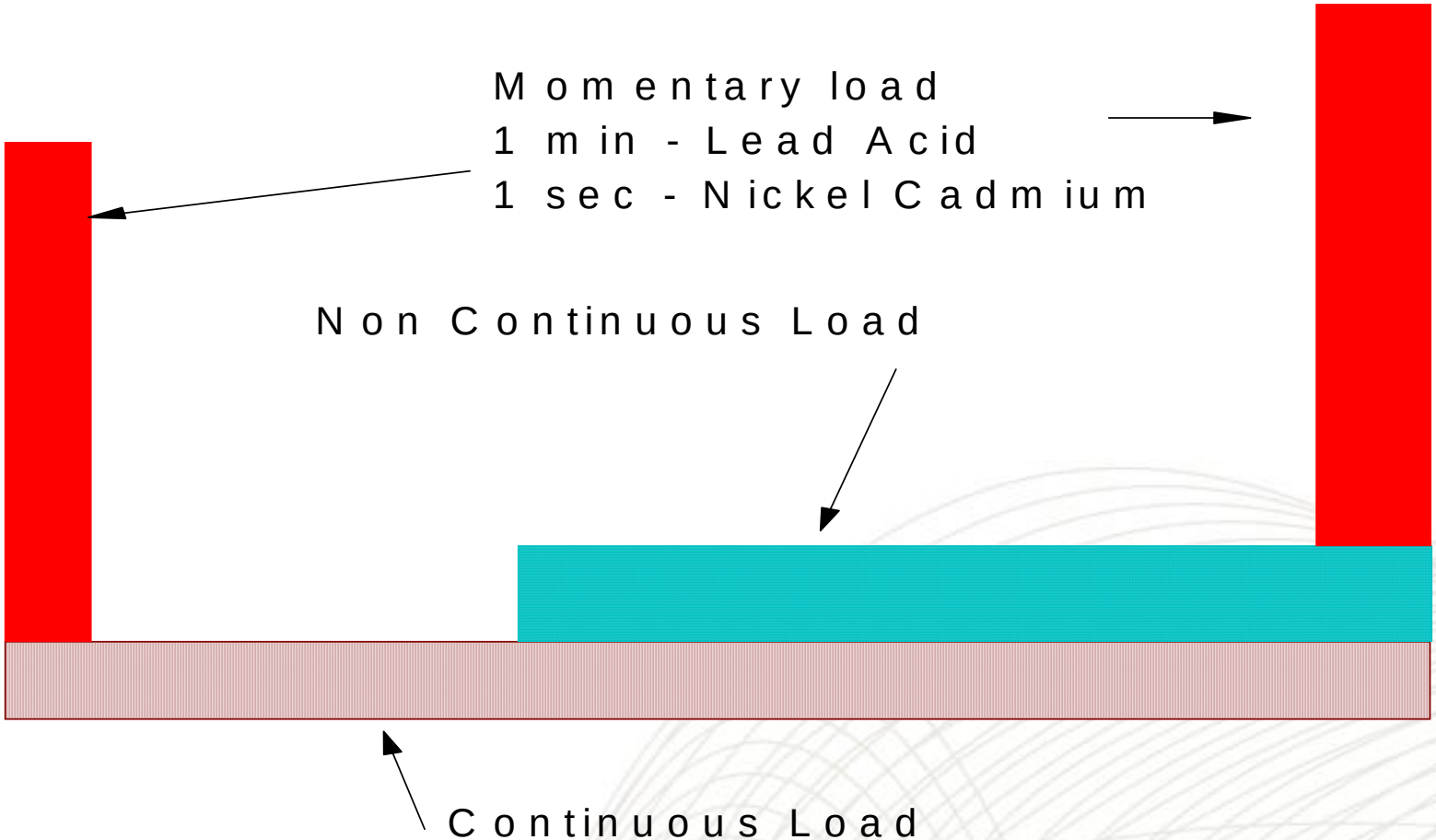
- **IEEE States:**
  - If a discrete sequence cannot be established, the load for the period shall be assumed to be the sum of all the loads occurring within that period

Example:

			Duration
Trip	- 3 breakers	45 amps	0.5 sec
Trip	- 5 breakers	75 amps	1 sec
Trip	- 4 breakers	60 amps	1 sec

Since we cannot determine the sequence, you must treat the load as occurring all at once
180A for 1 minute - Lead
180A for 1 second - Ni-Cd

The Duty Cycle



Sizing Margins or Making Batteries Bigger

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- **Aging Factor**
  - 25% Recommended

- **Applicable to:**
- **All types of flooded lead acid**
- **VRLA**
- **Nickel Cadmium**

- **Exception is Plante`**

Sizing Margins or Making Batteries Bigger

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- **Low Temperature Correction**
  - For operation below rated temperature
- **High Temperature**
  - Improves performance slightly
  - Not normally used in sizing calc's.
  - Design margin for maximum life

Sizing Margins or Making Batteries Bigger

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- **Design Margin**
  - Normally considered for future equipment or load growth
  - Allows for operation at lower than expected temperature
  - Can cover for less than adequate maintenance
- **Almost every sizing has one!**

Sizing Margins or Making Batteries Bigger

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- **If the calculation requires a 220 Ah battery, and the next cell size up is 250 Ah - -**
- **The 30 Ah difference is a 13% margin, “designed” in**
- An additional margin of 10% might not be required

It's Money

- **Develop load profile using worst case**
- **Try to determine sequences**
  - Not knowing requires conservatism
  - Conservatism can increase required capacity
  - Increased capacity - More $
- **Closely review various sizing factors**
  - Low temperature increases battery size
  - Aging factors are good ideas - ensure long reliable life
  - Evaluate design margins, especially after sizing a battery

Have we lost anyone

So far we've covered...

- **Various discharge scenarios**
  - Pick the worst case
- **Various load types**
  - Continuous
  - Non-Continuous
  - Momentary
- **Sizing margins / factors**
  - Temperature correction
  - Aging factor
  - Design margins

Sizing - What's needed

- **Load profile**
  - Include all prudent margins
- **Voltage**
  - Maximum
  - Minimum
- **Manufacturers data**
  - Yes, you do need us
- **Capacity rating - Kt factors**
  - Amps per positive plate - Rt factors
- **Battery type**
  - Flooded lead acid
  - Nickel cadmium
  - VRLA

The load profile

15 BREAKERS

TRIP	- 10A, 5 CYCLES	Sim./Brkr
CLOSE	- 7A, 5 CYCLES	Seq./Brkr
SP. CHG	- 4A, 6 SECONDS	Seq./Brkr

TWO OPERATIONS,

Beginning and end of 8 hr duty cycle

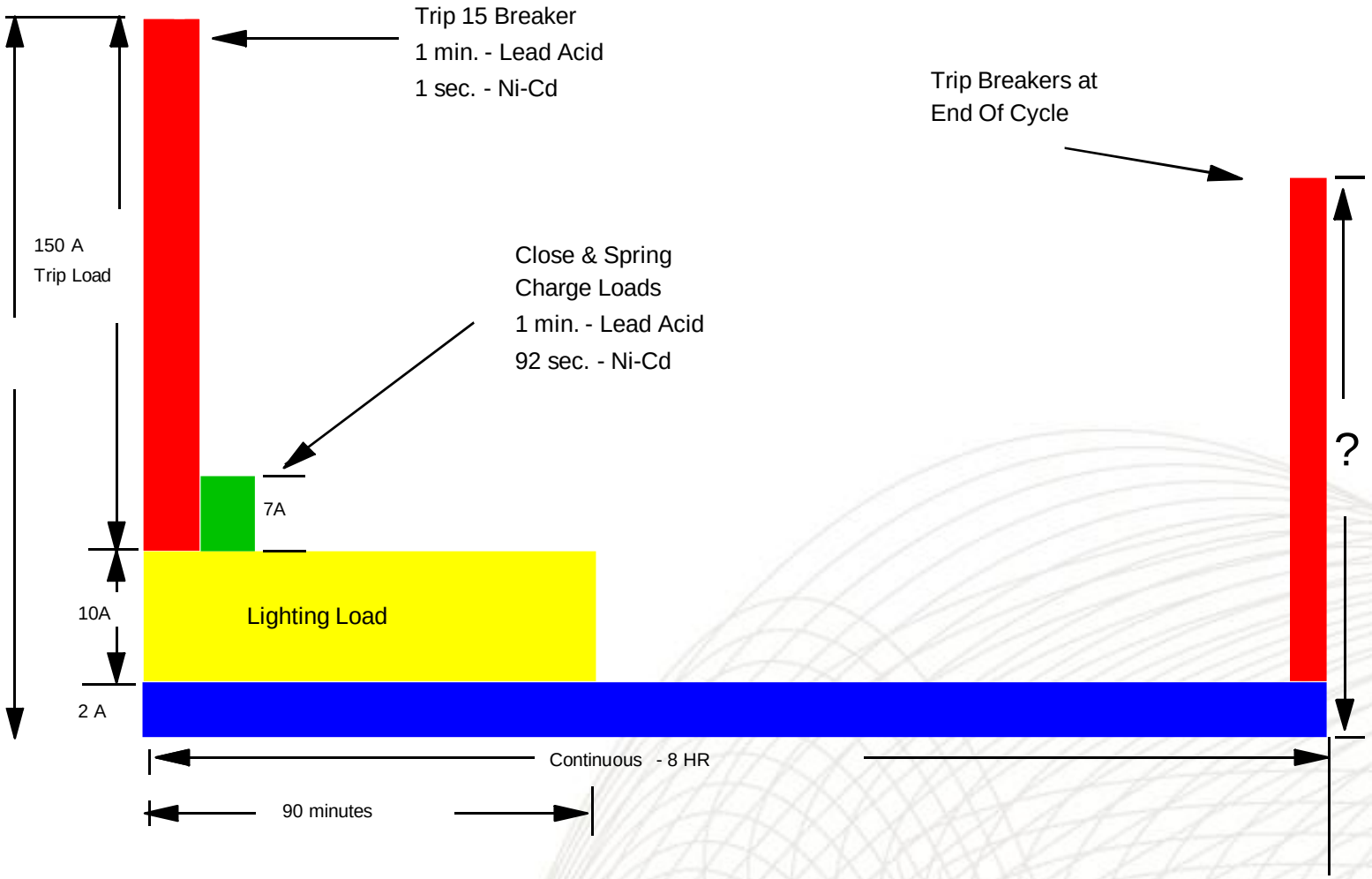
2A CONTINUOUS LOAD

EMERGENCY LIGHTING LOAD

1200 Watts - 90 minutes

Starts at outage

The load profile



Load profile defined

- **Nickel Cadmium**
  - 162A 1 second
  - 19A 92 seconds
  - 12A 88.45 minutes
  - 2A 390 minutes
  - 152A 1 second
- **Lead Acid**
  - 162A 1 minute
  - 19A 1 minutes
  - 12A 88 minutes
  - 2A 389 minutes
  - 152A 1 minute

Voltage window

- **Maximum and Minimum values**
  - Determined by DC powered equipment
- **Allow widest possible range**
  - Uses maximum number of cells
- **More cells = lower end of discharge voltage**
- **More efficient capacity utilization**
- **Least expensive battery**

Impact of voltage window

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- **IEEE 485 Example:**
  - 140V - 105V window
  - 60 cells, to 1.75 VPC - 1,010.4 Ah req'd
- **Wider voltage window**
  - 62 cells, to 1.69 VPC - 944 Ah req'd
  - 3% increase cell qty, 7% capacity reduction
- **Narrower voltage window**
  - 58 cells, to 1.81 VPC - 1,186 Ah req'd
  - 3% decrease cell qty, 17% increase in capacity
- **100Ah High rate ni-cd cell**
  - One minute rate To 1.14 VPC 243 amps
  - One minute to 1.05 VPC 406 amps

No. of cells calculation

Max. Volts - Determines number of cells that can be adequately charged.

Equalize value is normally used as determining cell voltage

Ex $\frac{140V\ max}{2.33VPC} = 60$ cells (lead acid)

or

$\frac{140V\ max}{1.46VPC} = 96$ cells (nickel cadmium)

End of discharge calculation

Min. Voltage - Lowest value system designed to operate at

$$\frac{\text{Min. Volts}}{\text{\# of cells}} = \text{End of discharge voltage / cell}$$

Ex. $\frac{105 \text{ VDC}}{60 \text{ cells}} = 1.75 \text{ VPC}$ Lead Acid

Ex. $\frac{105 \text{ VDC}}{96 \text{ cells}} = 1.09 \text{ VPC}$ Nickel Cadmium

Sizing factors

- **Kt factors**
  - Based on performance per rated ampere hour
  - Kt factor = $\frac{\text{Rated ampere hours}}{\text{Amps available for time t}}$
- **Rt factors**
  - Based on performance per positive plate
  - Used primarily with lead acid cells
  - Rt factor = Amps available for time t per positive plate

Capacity rating factors

- **Kt factors**
  - Determined from tabular data
- **Examples**
  - 160 Ah rated cell
  - 8 hr discharge rate - 20 amperes
  - Kt = 160 Ah / 20 amps
  - 8 Hr rate Kt = 8
- **One minute discharge rate - 320 amperes**
  - Kt = 160 Ah / 320 amps
  - One minute Kt = 0.5
- **Kt factors are multipliers in IEEE worksheets**

Capacity rating factors

- **Rt Factors**
  - Found in plate performance curves
  - Not all manufacturers publish them
  - When not available, use Kt
- **Rt factors are divisors in IEEE worksheets**

Did you know this?

- **Most lead acid model numbers indicate number of plates per cell**
  - 3CC7 = Seven plates per cell
  - 4JC11= Eleven plates per cell
- **One more negative plate than positive**
  - Seven plates = 4 Neg - 3 Pos
  - Eleven plates = 6 Neg - 5 Pos
- **50Ah / positive plate**
  - 150Ah cell from above example (3 pos x 50Ah)
  - 250Ah cell for eleven plate cell (5 pos. x 50Ah)
- **Positive plates are same for the range**

More things you should know

- **Ampere hour nomenclatures**
  - Most nickel cadmium
  - Some VRLA
- **Pos. plates are not identical thru range**
- **Wider or taller plate = higher capacity**
- **More plates per cell = higher capacity**

Real life

- Create a duty cycle

- **Periods**
  - Amps_____ Duration_____
  - Amps_____ Duration_____
  - Amps_____ Duration_____
- **Voltage window**
  - Max_____ MIn_____
- **Calculated No. of cells**
  - Lead acid___ Nickel cadmium___
- **Environment**
  - High Temp_____ Lowest Temp_____
- **Aging factor _____ (not for Plante')**
- **Design margins _____**

Summing up

- Battery Sizing is a science
- Building the load profile is an art
- Electro-chemistries vary greatly
- You have more control over your battery selection than you think

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Thank you for your attention