

# Battery Council International



## Optimizing the Acceptance of Electric Trucks In the Existing Plant Environment

by

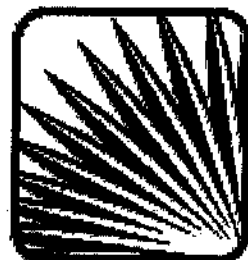
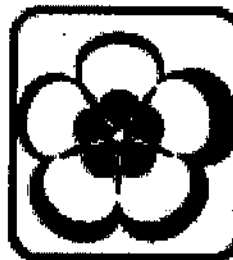
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Crystal Ballroom A-F, Terrace Level  
Renaissance Esmeralda Resort & Spa – Indian Wells, California  
1:50 – 2:10 p.m.  
Monday, May 3, 2004

*116th Convention*

**May 2-5, 2004**



## **Battery Council International**

**Renaissance Esmeralda Resort and Spa • Indian Wells, California**

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# **Battery Council International**

## **116<sup>th</sup> Convention**

**May 2-5, 2004**

### ***Presentation***

#### **OPTIMIZING THE ACCEPTANCE OF ELECTRIC TRUCKS IN THE EXISTING PLANT ENVIRONMENT**

We all have a common purpose of increasing the applications for battery-powered equipment. With limited growth expected in some markets, increasing the desirability of battery powered lift trucks is a key to motive power battery growth.

Our goal as an industry must be to make available improved utilization methods for electric trucks, and make it applicable for the broadest range of potential users. That would lead us to consider solutions, which could be applied to existing facilities and equipment.

#### **Factors Impacting Preference**

There are key factors, which impact the application of improved charging methods in existing plant applications.

- User requirements for their truck daily utilization
- Limits on existing connectors, cables, and batteries in present service
- Battery charging technology and the capability to meet user requirements
- Availability and location of existing plant electrical service

If we can discover a way to understand these factors and gain additional acceptance of battery powered material handling equipment, it will benefit the lead acid motive power market.

## **ITA data**

We will first review how we are doing replacing internal combustion lift trucks with battery-powered models. This data on lift trucks sold is available on the public domain web site of the International Truck Association and shown with their approval. We are reviewing the percentage of all trucks shipped that are battery powered. As we add a linear trend line it is apparent our progress is positive. We have made significant inroads since 1983.

The ability to eliminate charging delays is a key factor in positioning the electric motive powered vehicle as nearly a continuous duty service vehicle to rival the continuous service of Internal Combustion models.

## **Battery Daily Requirements**

This chart defines the number of "full battery equivalents" needed during a user application day.

While some users may well not utilize the truck sufficiently to require a second battery daily, many applications will require more power than one battery daily can provide.

We have added a highlight of the applications where higher power opportunity charging would increase utilization. We have represented that as the rapid charging application zone. Users operating in this range could reduce the number of required battery changes. Any reduction of battery change out is clearly an opportunity to improve utilization and make electric trucks a more desirable option.

## **Amp Hour Law**

This presentation will introduce data using a typical 1000 Amp Hour 12 cell battery. Power usages can be easily extrapolated for other battery sizes.

In order to understand the theoretical limits of re-charging a battery we would refer to a text written by George Wood Vinal who gave us mathematical limitations of battery recharge known as the Amp Hour Law. David Linden in his text expanded that explanation. We can input into the battery the number of amps that are equivalent to the amp hours remaining to be returned. Every time we transform active material to a fully charged state there is chemically less active material to attack.

This chart shows that a fully discharged 1000 Amp Hour battery could initially accept 1000 amps of recharge current. As the battery is progressively charged it can accept less current in direct proportion to the capacity to be restored. Customarily batteries are returned for charge when they are 80% discharged and at that point they could theoretically accept 800 amps of charge current.

## **Conventional Start Rates**

This chart shows the theoretical limit and now shows the conventional start rate of 200 amps. This will allow recharge of a fully discharged battery in 8 hours. That rate is consistent with the present BCI specification BCI I-4 (8/96). Other conventional chargers are available that provide lower start rates and are customarily referred to as 80% or 60% units.

## **Rapid Charge Rates**

Rapid Charge products have been produced that deliver approximately 600 to 700 amps as applied to an 80% discharged 1000 amp hour battery. This is generally the highest start rates being presently provided.

## **Rapid or Fast Charging**

Any charge current exceeding the conventional 200 Amp and below the theoretical maximum of 1000 Amps, or the application maximum of 700 amps, I would consider Rapid Charging. I shall use the terms rapid charging and fast charging to be synonymous. Various sources have used each term to have different connotations, but I am not aware of any standards body that has assigned definitions to these terms.

On occasion I am asked about "Rapid Charging" as if it were one very specific single process or event.

I hope this chart helps us to understand the dramatically wide range of charge currents, anywhere from 200 to 700 amps, which have been described by the term, "Rapid Charge".

The objective now is to explore the attributes of various charge rates and how they can be applied.

## **Heat Generated**

We can review the heat generated by the respective currents. The basic law of electricity that power equals the square of current times resistance does reveal a very important impact of increasing current. The heating of all components (connectors, cables, and batteries) is dramatically increased with added current from the charger. With heat being undesirable for batteries, utilizing the lowest charge current the application will allow is very significant.

Let's now review the current limitations of typical existing trucks and installations.

## **Connectors Ratings**

We observe that there are available connectors to comply with the entire range of currents including the 700-amp range we previously reviewed.

Typical 1000 amp hour batteries in existing service are out fitted with connectors rated for 320 to 350-amp maximum and cables that comply with those connector rating.

The basic SB(?) 350 or Euro Din 320 connector series are used in nearly all conventional 1000 amp hour 24 volt batteries and trucks in service today. The 175 and 160 series are used on 80 volt applications and smaller battery sizes. These basic connector capacities have been in service since the 1970's and represent nearly all-existing users. Any broad range solution for existing operations would need to work with those connectors.

In addition, batteries that are to be charged at currents greater than 350 amps they must be specially constructed, modifications include but are not limited to dual cable and connectors and various other modifications that lower the overall battery resistance.

### **AC Input Service Required**

Each AC service drop can support different levels of output from the charger. A 100 Amp service can support up to 875 Amps of charger output. Dropping to a typical 30 amp 480 VAC service, we see that 250 amps are available from the charger. If we were targeting on replacing existing plant equipment we would need to stay in 30 Amp input service range. Installing new electrical service can be exceptionally costly and in some cases impossible.

### **Charge returned in 30 minutes**

In a typical opportunity charging application the user would charge the battery during a 30-minute lunch break We will review a summary of the amp hours returned to the battery during "lunch".

This chart shows us the amp hours added by chargers with various start rates.

It is interesting to see that the lower currents have exactly the same return as the highest power for batteries that are 80 % charged, and provide over 60% of the return at 50% when starting state of charge. This reflects the constraints of the amp hour law that limits the amount of capacity that can be returned as the battery approaches full charge.

### **Charge returned compared to maximum rapid charge rates**

We are comparing the capacity returned by 250 amp or 400 amp chargers as a percentage of the capacity returned by the maximum 700 amp units. This gives a visual perspective to the conclusion that lower rates can provide significant user benefits. Keep in mind that the 250 amp rate can be utilized with existing connectors, batteries, and AC service.

### **Application Guide**

We can summarize the data with a chart that shows how various conventional and rapid chargers can be utilized in existing plant applications. The middle ground where a 250 amp unit could be utilized, covers a significant percentage of user requirements. Manufacturers of industrial batteries for motive power are providing application specific warranty coverage. Limitations are consistent with the adverse conditions of higher current, heating and the consequential effects.

### **New Technology**

The ability to give users customized solutions and allow them to enjoy the new benefits of battery powered, pollution free service is within our grasp. It will clearly benefit existing users and accelerate replacement of IC trucks.

Rapid charging has opened a very broad range of new possibilities, but it does not need to be beyond the grasp of existing users. It is exciting to discover that we can implement rapid charging in existing plants utilizing conventional batteries, connectors, and existing input electrical service. The opportunity to grow our customer base with this knowledge is a welcome opportunity.

In addition we must work rapidly to provide technical guidance to the user community. I happen to chair the BCI group that is working to update BCI I-4 to include standards for rapid

charging. I would close with an invitation to anyone who is not presently active in the group, and would be willing to contribute to let me, or a BCI Staff member, know. We would sincerely appreciate your help, and will insure you are actively included.

I will be available to answer any questions that you may have now or later during the meetings.

#### References

1. George Wood Vinal, Storage Batteries, Great Britain, 1924, pp. 244-245
2. David Linden, Handbook of Batteries and Fuel Cells, McGraw-Hill Book Company, New York 1984, pp Chapter 14 -82,14-85

***Optimizing The Acceptance Of  
Electric Trucks  
In The Existing Plant Environment***

**AMETEK®**  
PRESTOLITE POWER

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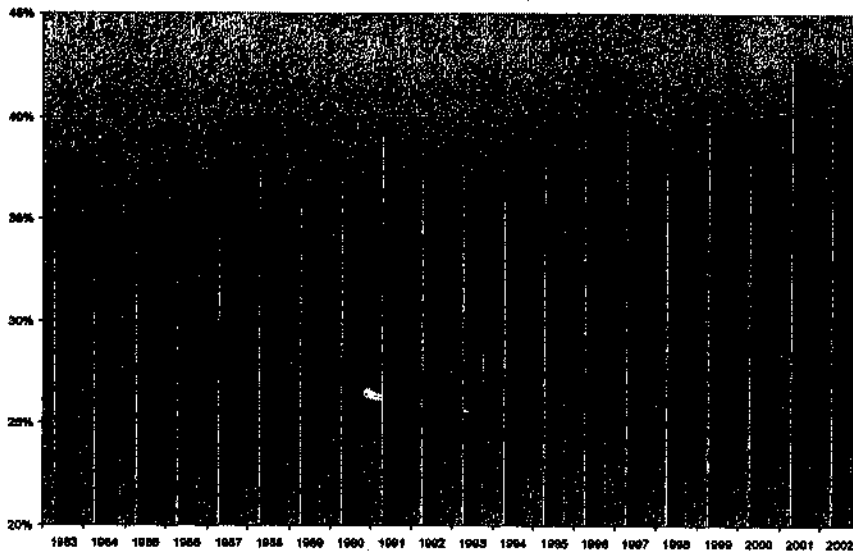
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**Factors Impacting Electric Truck Preference  
Improvements**

- User requirements for daily Truck Utilization
- Limits on existing Connectors, Cables and Batteries in present service
- Capability of battery chargers to meet the application requirements
- Availability & location of existing plant electrical service

OPTIMIZING THE ACCEPTANCE OF ELECTRIC TRUCKS IN THE EXISTING PLANT ENVIRONMENT

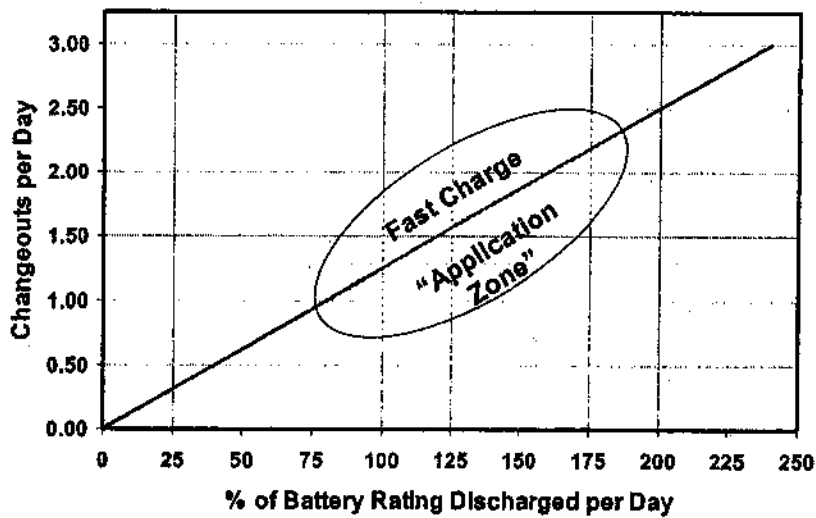
## Electric Riders as % of Electric + Gas



\*Used with permission of Industrial Truck Association [www.indtira.org](http://www.indtira.org)

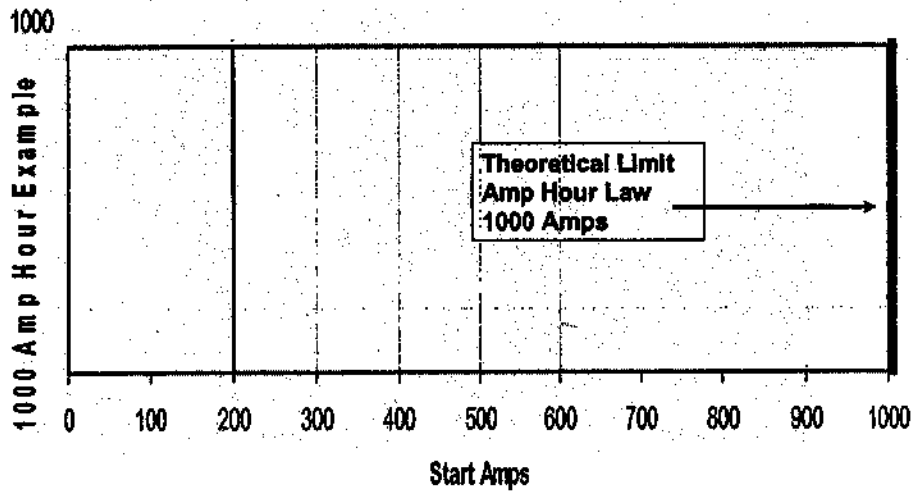
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## Daily Battery Power Required Per Truck



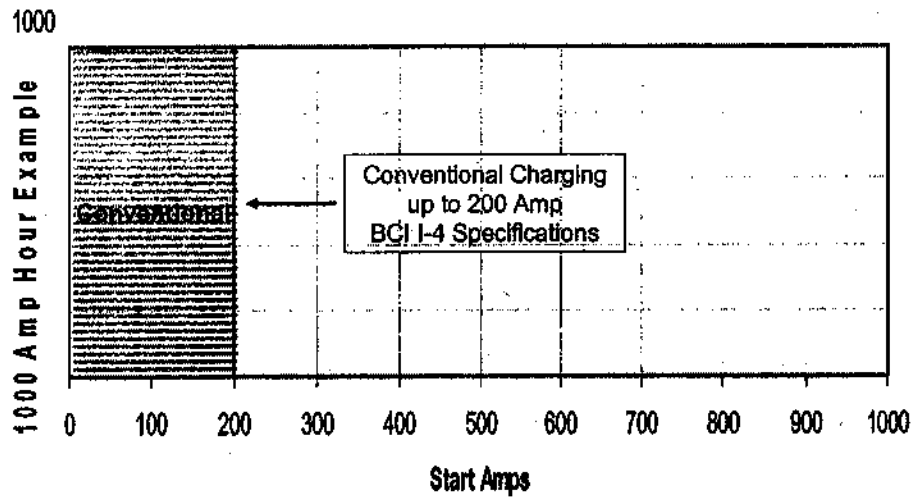
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## Charging Start Rates



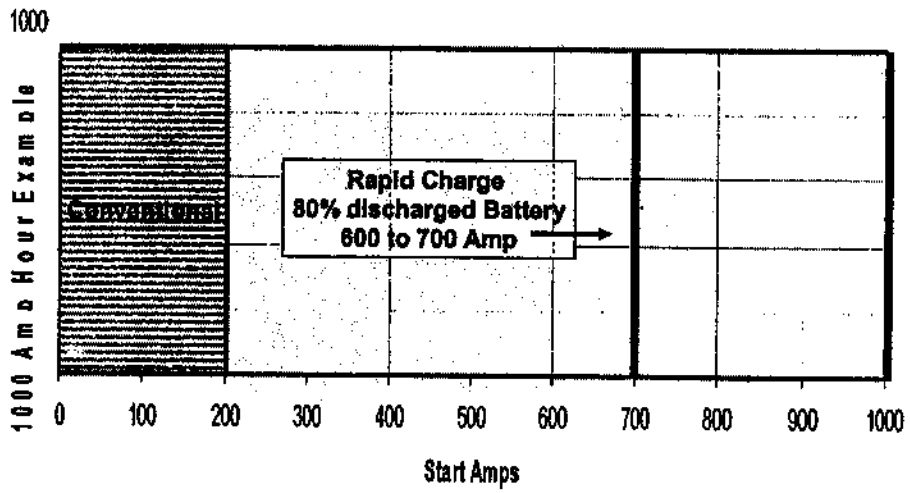
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## Charging Start Rates



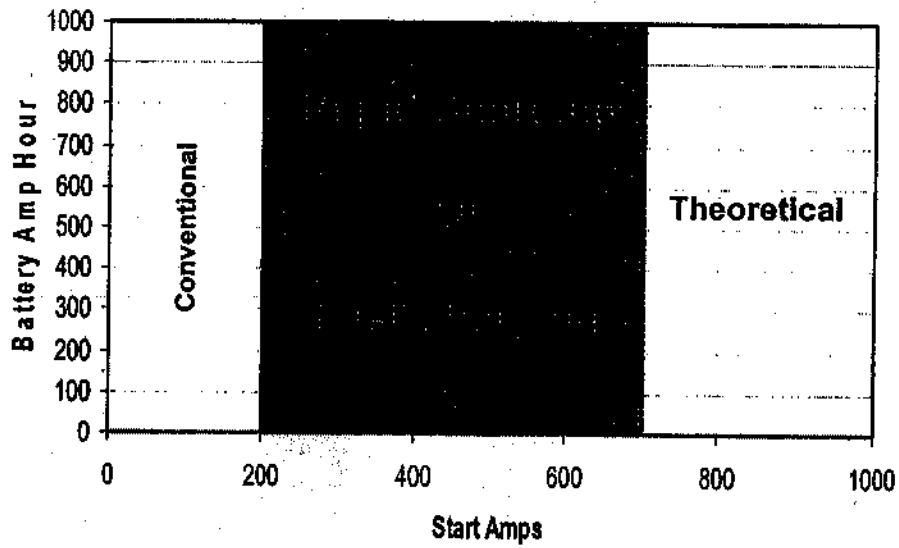
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## Charging Start Rates



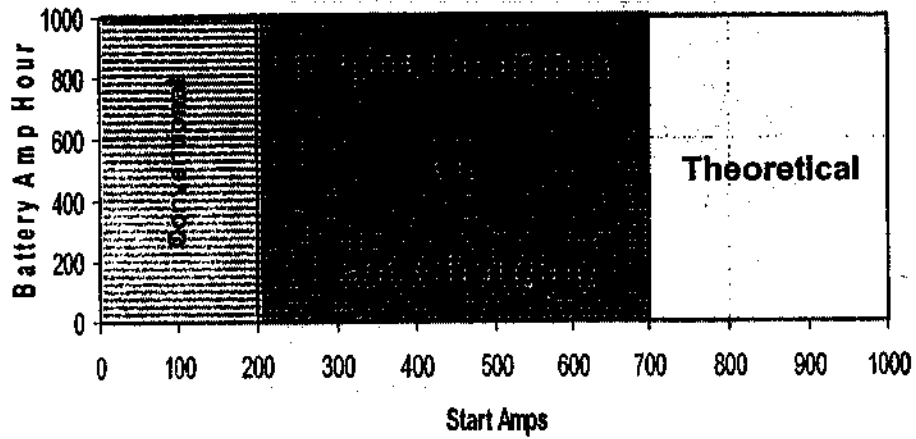
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## Charging Start Rates



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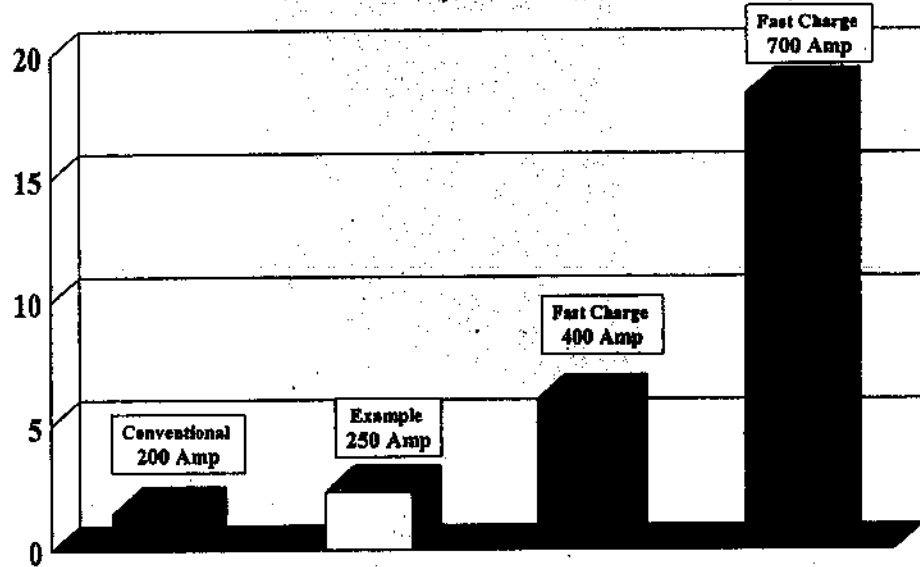
## Charging Start Rates



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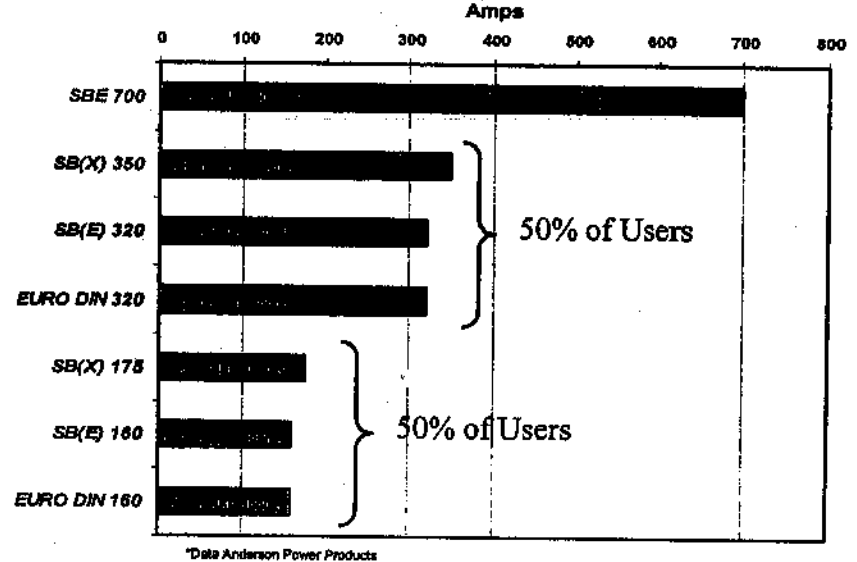
## Heat Generated

Relative Resistive Battery, Cable & Connector Heating



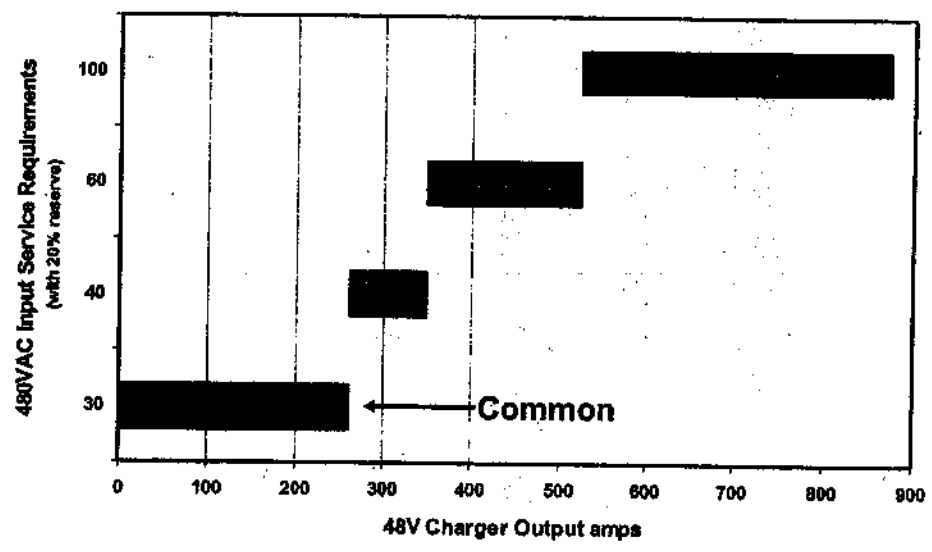
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# Generic Battery Connector Current Ratings



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# Charger Output vs Plant AC Service



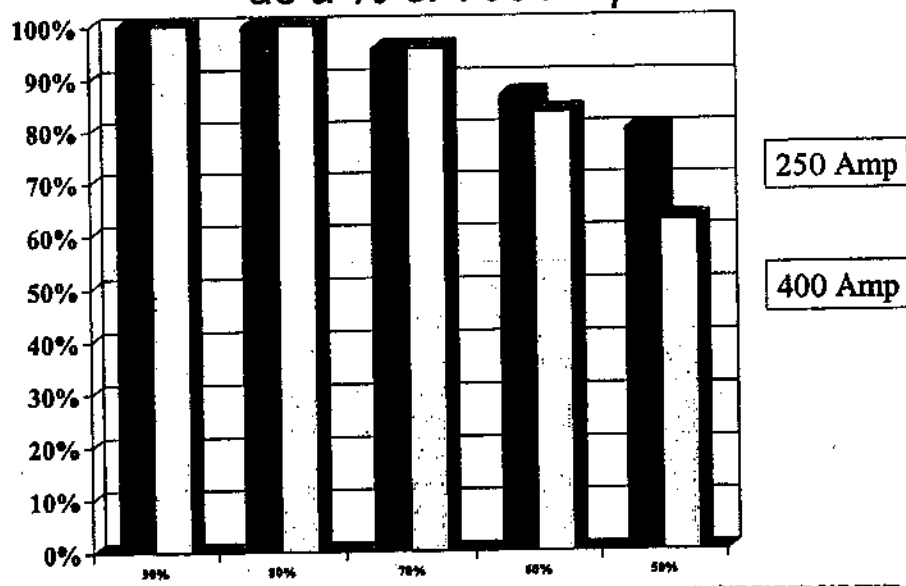
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## Amp Hours Returned in 30 minutes

Battery State of Charge	700 Amp Unit	400 Amp Unit	250 Amp Unit
90%	60	60	60
80%	90	90	90
70%	115	110	110
60%	150	130	125
50%	200	160	125

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## Charge return in 30 mins as a % of 700 Amp



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## Application Guide for Fast Charging

	<b>Light Duty</b> (0-2 Hrs Run Time per Shift)	<b>Medium Duty</b> (2.1 -4 Hrs Run Time per Shift)	<b>Heavy Duty</b> (4.1-6 Hrs Run Time per Shift)
<b>Single Shift</b>	200 Amp Conventional	200 Amp Conventional	250 Amp Rapid Charge
<b>Two Shift</b>	200 Amp Conventional	250 Amp Rapid Charge	250 Amp Rapid Charge
<b>Three Shift</b>	250 Amp Rapid Charge	400 Amp and Up Rapid Charge	400 Amp and Up Rapid Charge

OPTIMIZING THE ACCEPTANCE OF ELECTRIC TRUCKS IN THE EXISTING PLANT ENVIRONMENT

### *New Technology can accelerate IC Truck Replacement*

- Achieve virtual Continuous Duty Service with the least cost solution
- Reduce productivity impact of Battery Changeout
- Obtain full battery warranty coverage
- Operate within the existing plant environment
- Develop enthusiastic operator acceptance

OPTIMIZING THE ACCEPTANCE OF ELECTRIC TRUCKS IN THE EXISTING PLANT ENVIRONMENT

***Optimizing The Acceptance Of  
Electric Trucks  
In The Existing Plant Environment***

***Thank you for your time and attention!***

*Larry Henry  
Division Vice President  
AMETEK Prestolite Power  
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**OPTIMIZING THE ACCEPTANCE OF ELECTRIC TRUCKS IN THE EXISTING PLANT ENVIRONMENT**