SOLVE FOR X.

“Turbo-charging” Your Forklift Fleet: The Power of Industrial Lithium Forklift Batteries

Presented by:

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McCormick Place | Chicago
April 3-6, 2017
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NAVITAS SYSTEMS

Agenda

- Navitas Introduction
- Market Review / Segmentation
- Technology Review
- NYSERDA Project Results
- Case Study Deployments
- Financial Outlook
- Additional Benefits

SOLVE FOR X. Navitas Introduction

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	Lithium Battery Solutions	System Design and Assembly	Electronics & Battery Management Systems (BMS)	Custom Cell Development	Analytical and Testing	Cell Chemistry R&D
Capability						
Scope	•12V NATO 6T Battery • 24V NATO 6T Battery • Multi-kWh motive application batteries	•In-house battery pack design development, prototyping, and manufacturing	• In-house BMS Design • In-house SMT line	•Various Li-ion chemistries developed •High power and High energy density chemistries	• 500+ MACCOR test channels •Cell tear down analysis •In-house UL/UNDOT testing	•Custom anode, cathode, and electrolyte development •Battery materials evaluation

PALLADIUM energy
Portable Batteries Div.

MicroSun
Founded 2003

MicroSun
2012

NAVITAS SYSTEMS
Large Format Div.
Electronics Div.
Founded Nov. 2012

A123 SYSTEMS
Government R&D Group
Acquired February 2013

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The Material Handling Industry is Prime to adopt Lithium

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The material handling market is poised to capitalize on cost efficiencies created by the substantial investments in cell technology made by other industries

Lithium Battery Industry Spectrum

Market Segment Categories

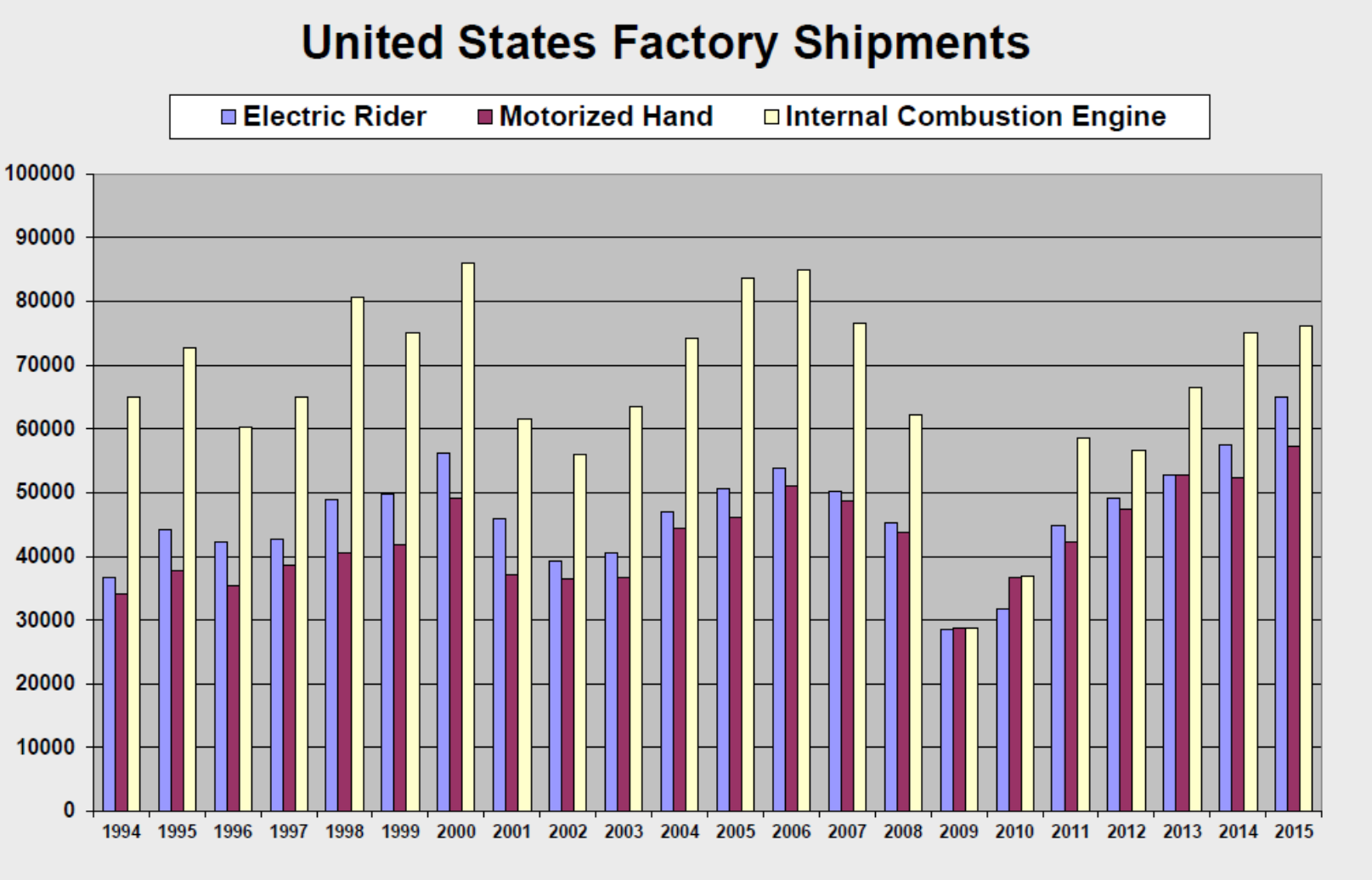
	Portable Applications	Industrial and Motive Applications	Electric Vehicle	Grid Level
Lithium Battery Products				
Energy	1 – 100 Wh	100 Wh – 1 kWh	1 kWh – 1 mWh	20 - 100 kWh
Applications	   	  	    	  	  

ITA Industry Panel Survey Indicates Lithium Optimism

9. What sources of motive power will show the most growth in electric forklift trucks in the next three years? Please rate the following on a scale of 1 to 3 (where 1=-10% to 0%, 2=>0% to 10%, 3=11% to 20%)

Motive Power Source	1 -10% to 0%	2 >0% to 10%	3 11% to 20%
Lithium Ion	1	10	4
Lead Acid Battery	5	8	2
Fuel Cells	7	8	0

# of respondents



Lithium Forklift Product Categories

Industrial Truck Association (ITA)

Class 1: Electric Counterbalance (Cushion or Pneumatic Tire)

Class 2: Electric Narrow Aisle

Class 3: Electric Pallet Jacks

Class 4: Internal Combustion, Cushion Tire Counterbalance

Class 5: Internal Combustion, Pneumatic Tire Counterbalance

Navitas Starlifter Lithium Product Overview

- ESS Battery
  - 24V, 36V, 48V Battery Packs
- Counterweight Tray
  - Weight and Footprint Replacement For Lead Acid battery packs
- UIM (User Interface Module)
  - Visual and Audio Indicator of lithium battery pack information for truck operators
  - Provides warnings for low state of charge and faults
  - Diagnostics information display

Primary Lithium Applications

Fast Opportunity Charging

Capable of Charging in 1-2 Hours; Lead Acid Charger Compatible

Superior Cold and Hot Performance

40% Increased runtime of lead acid in freezer warehouse temperature

Multi-Shift Operations

High Performance, Long Run Time, Long Life

Lithium Value Propositions

Lithium Forklift Battery Program

nyserda
Energy. Innovation. Solutions.

NAVITAS SYSTEMS

RAYMOND

NYSERDA Executive Summary

- The objectives of the project were:
  1. Demonstrate Lithium Battery is viable for lift truck applications through bench level performance and safety testing
  2. Develop and release a public interface specification to include truck, energy storage system (battery) and charger;
  3. Demonstrate a Lithium Battery's performance in real-world, in-truck application including opportunity/fast charging (enabling one battery per truck), cold temperature robustness and reduced overall fleet operating costs;
  4. Advance the technology from TRL4 (component level technology development) to TRL 6 (engineering scale technology demonstration).
- Upon completion of the project, the summary results were:
  1. Developed and published a Public Standard Interface Specification for all trucks, batteries and chargers
  2. Successfully demonstrated LIB as drop-in replacement for LAB in a Reach Truck
  3. 17% productivity improvement with LIB and opportunity/fast charging (pallet moves per operational hour) demonstrated at customer site
  4. Demonstrated ability to operate with reduced lithium nameplate capacity of 40-50% of lead acid
  5. Developed comprehensive ROI calculator to determine payback period for single truck (16 months) and full fleet (10 months) conversions from LAB to LIB. Installing a new fleet of truck with LIB over LAB results in a 9% overall savings (capital investment and labor) over a six-year period.
  6. Advanced the technology to a TRL 8 (actual system qualification)

NYSERDA Project Tasks

1. Requirements and Specification Development
    1. Standard Communication Interface between lithium battery, forklift and charger
    2. Mechanical Design Requirements (Wide Range of Battery Sizes)
    3. Truck Energy Demand Profile
    4. Charging Cycle Definition
2. Module Level Battery Evaluation and Testing
    1. Bench Testing
    2. Performance Baseline (Various Temperatures)
    3. Heavy Duty Cycle with Opportunity/Fast Charging
3. System Design (Battery to Truck and Charger)
    1. Electrical/Communication Systems
    2. Mechanical System Design
    3. FEA and Mechanical Modeling
4. Battery Integration and Qualification
    1. Battery Install, Integration and Check Out
    2. In Truck Confirmation Testing
5. Customer System Evaluation
    1. Lithium vs Lead Acid Battery Testing Summary

NYBEST Performance Parameters Validated

Parameter	Results	Notes
Actual Ah Capacity Under Real World Forklift Load vs. Manufacturers Ah Nameplate	✓	Measured 109%
Ability to Support Real World Forklift Load in Hot Ambient Temperature	✓	Measured 112%
Ability to Support Real World Forklift Load in Freezer Warehouse Ambient Temperature	✓	Measured 40% increase over Lead Acid
Ability to Support Real World Forklift Operation for 14 Continuous Shifts with No Battery Change-Outs Utilizing Opportunity Charging	✓	Completed 14 continuous shifts

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Maines Field Trial Success & UL Safety Validation

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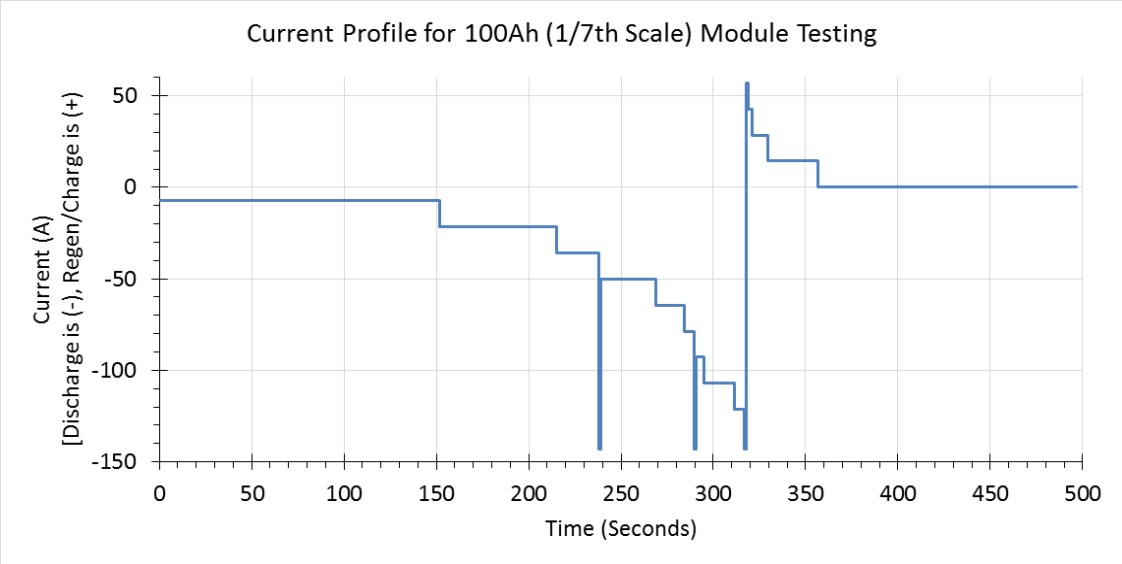
Parameter	Results	Notes
Safety Testing – Thermal Runaway	✓	Exceeded expectations with no cell propagation and 2 minute venting
MAINES FIELD TRIAL Forklift driver reaction	✓	Drivers loved the LIB
Lift Speed and Truck Acceleration	✓	Notable increase by drivers, especially at bottom of SOC vs. lead acid
Productivity vs. Lead Acid Truck	✓	17% increase in pallets/hour using LIB due to faster trucks and no battery swaps
LIB Zero-Maintenance	✓	5 weeks field operation without maintenance
Opportunity Charging	✓	700Ah LIB battery with no swap-outs did the job of a 1240Ah lead acid
Battery Efficiency	✓	50% less waste heat from LIB vs. LAB 2% more work done with 10% less Ah's with LIB

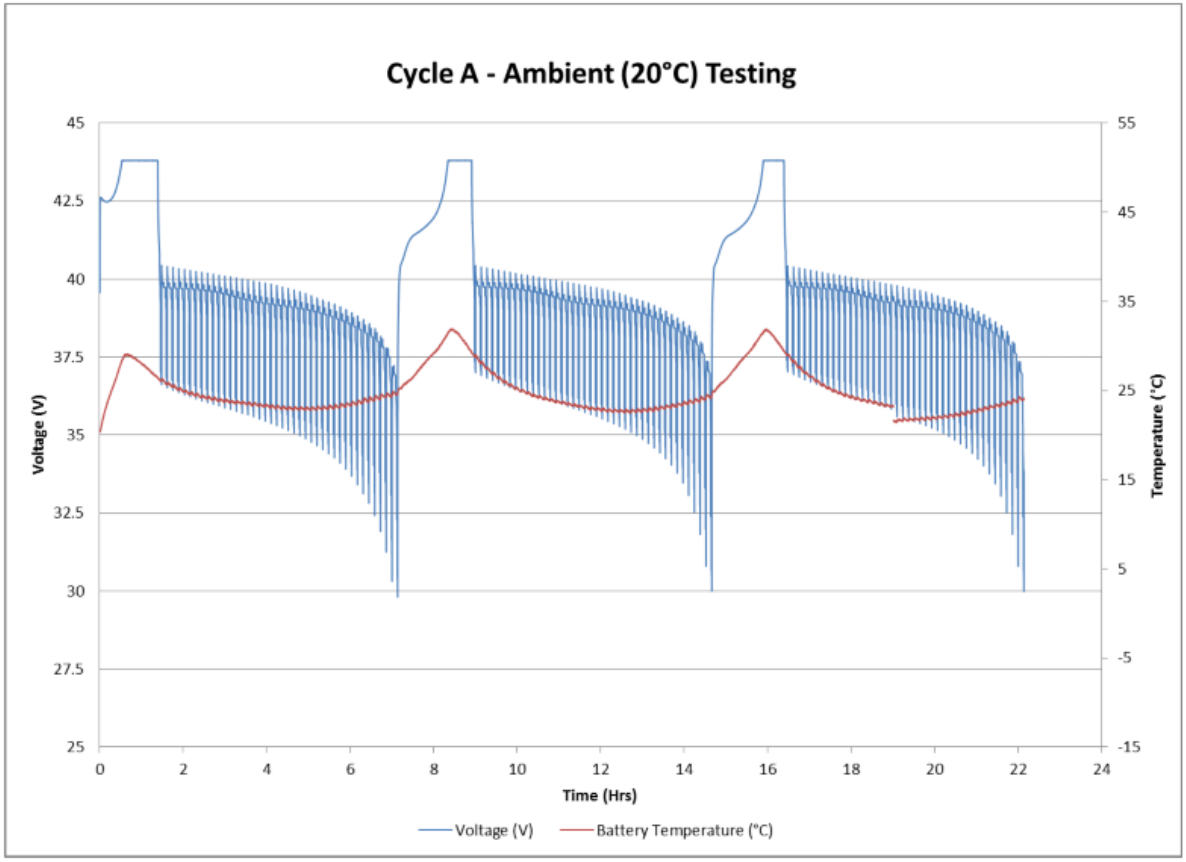
Duty Profile and Test Set Up

95% percentile user duty profile



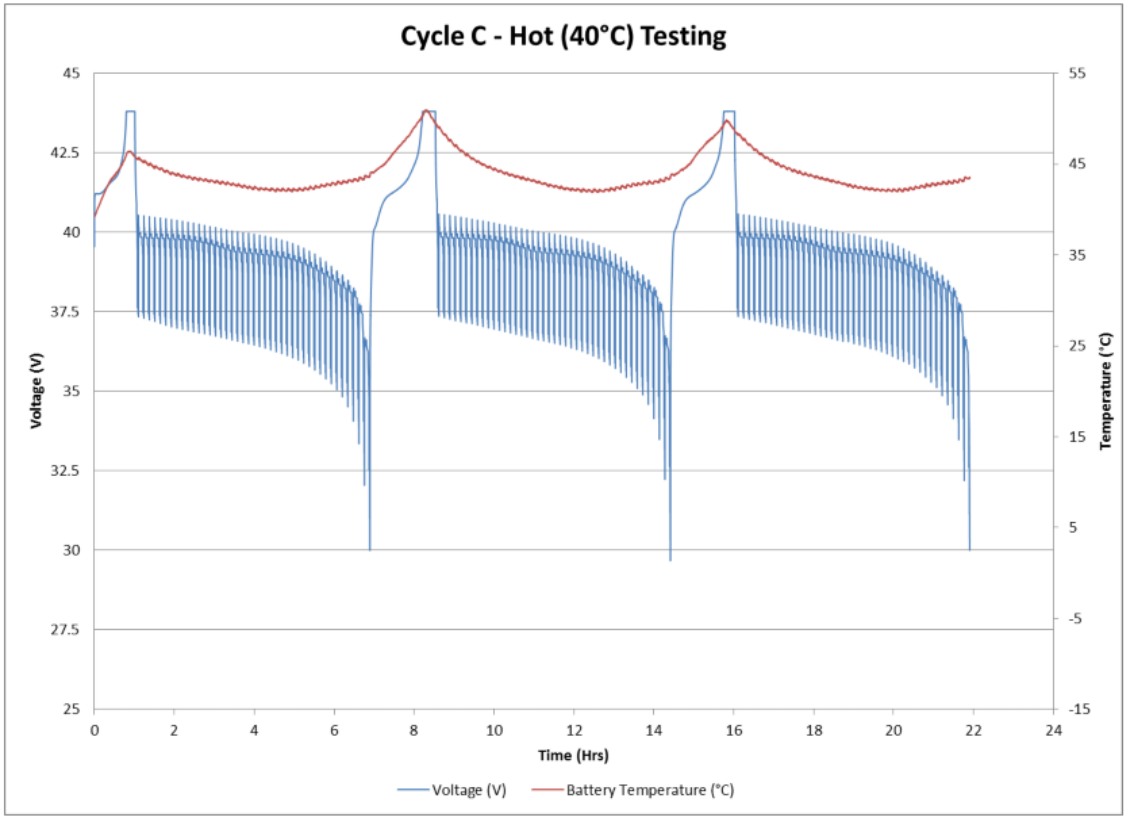
Description		Est Time
1.	Place module in environmental chamber. Soak until battery stable at 20 ±°1 C	<1 hr
2.	CC charge at 72A until Max Voltage (43.8V) reached, then CV charge at 43.8V until Current <2A	2 hrs
3.	Run sequence A (500 second drive cycle) until lower voltage limit reached (30 V). Estimated at 34 cycles	5 hrs
4.	Repeat charge and discharge (steps 2 & 3) 3x	
5.	Set chamber to 20°C, soak until stable	

Forklift Duty Cycle Validation



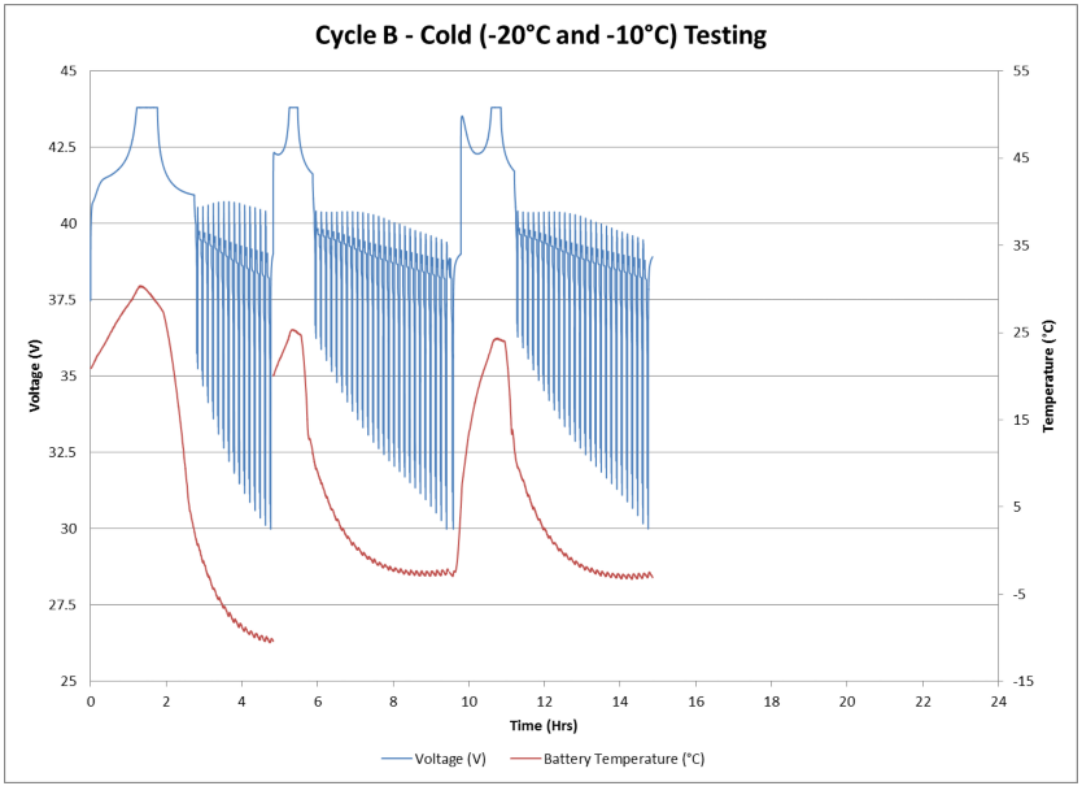
- Lithium battery maintained good temperature over forklift duty cycle
- Lithium battery discharged total **109%** of manufacturers Ah nameplate rating over forklift duty cycle

Forklift Duty Cycle – High Temperature



- Lithium battery maintained in-spec temperatures over forklift duty cycle when starting hot-soaked at 40 degrees Celsius (104 Fahrenheit)
- Lithium battery discharged total **112%** of manufacturers Ah nameplate

Forklift Duty Cycle – Cold Temperature



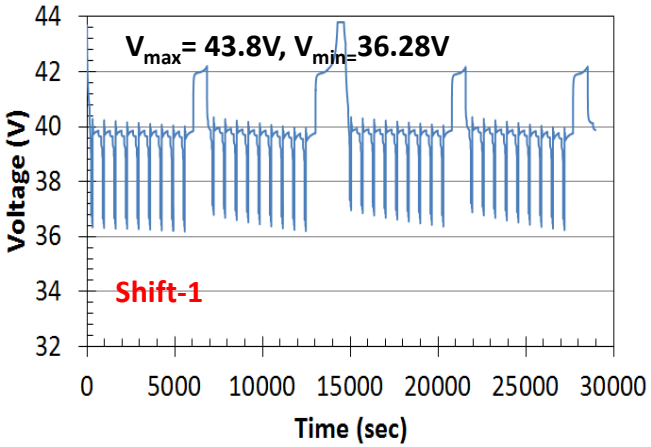
- Lithium battery provided forklift power requirements with no problems when cold soaked in -20 and -10 degree Celsius "freezer" type environments
- Lithium battery discharged total **70%** of manufacturers Ah nameplate while cold **vs. typical 50%** effective capacity with lead acid

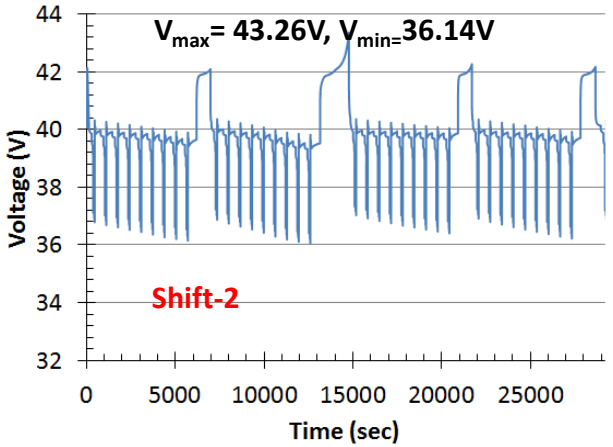
Opportunity Charging Validation

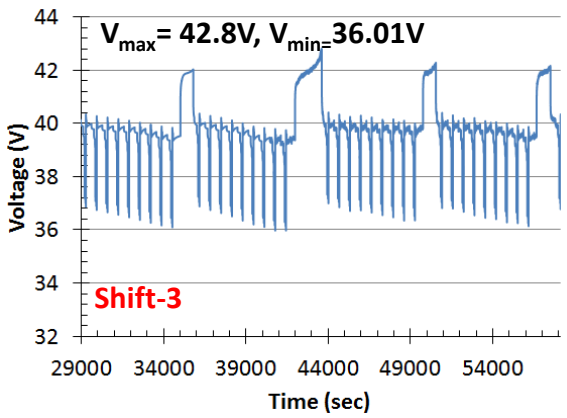
- Key value add from Navitas lithium battery is ability to utilize 1 battery per truck for 3-shift per day operation with short high-power opportunistic charging during worker breaks – **NO BATTERY CHANGES**
- Testing simulated actual forklift load and opportunity charging profile on Navitas lithium battery module
- Battery forklift load was supplied by Raymond as typical customer use case profile
- The testing results (next slide) support continuous 24-hour 3 shift per day operation using opportunity charging

Time	Load Profile Sequence
1.75 hours	Simulated forklift battery operating load profile from Raymond: typical work period
15 minutes	Opportunity charging profile for 15 min workers break 1
1.75 hours	Repeat work sequence
30 minutes	Opportunity charging profile for 30 min workers lunch
1.75 hours	Repeat work sequence
15 minutes	Opportunity charging profile for 15 min workers break 2
1.75 hours	Repeat work sequence
15 minutes	Run opportunity charging profile for 15 min at shift change
TOTAL: 8 hours	**Total work: 7 hours** **Total break + opportunistic charging: 1 hour**

Opportunity Charging Validation

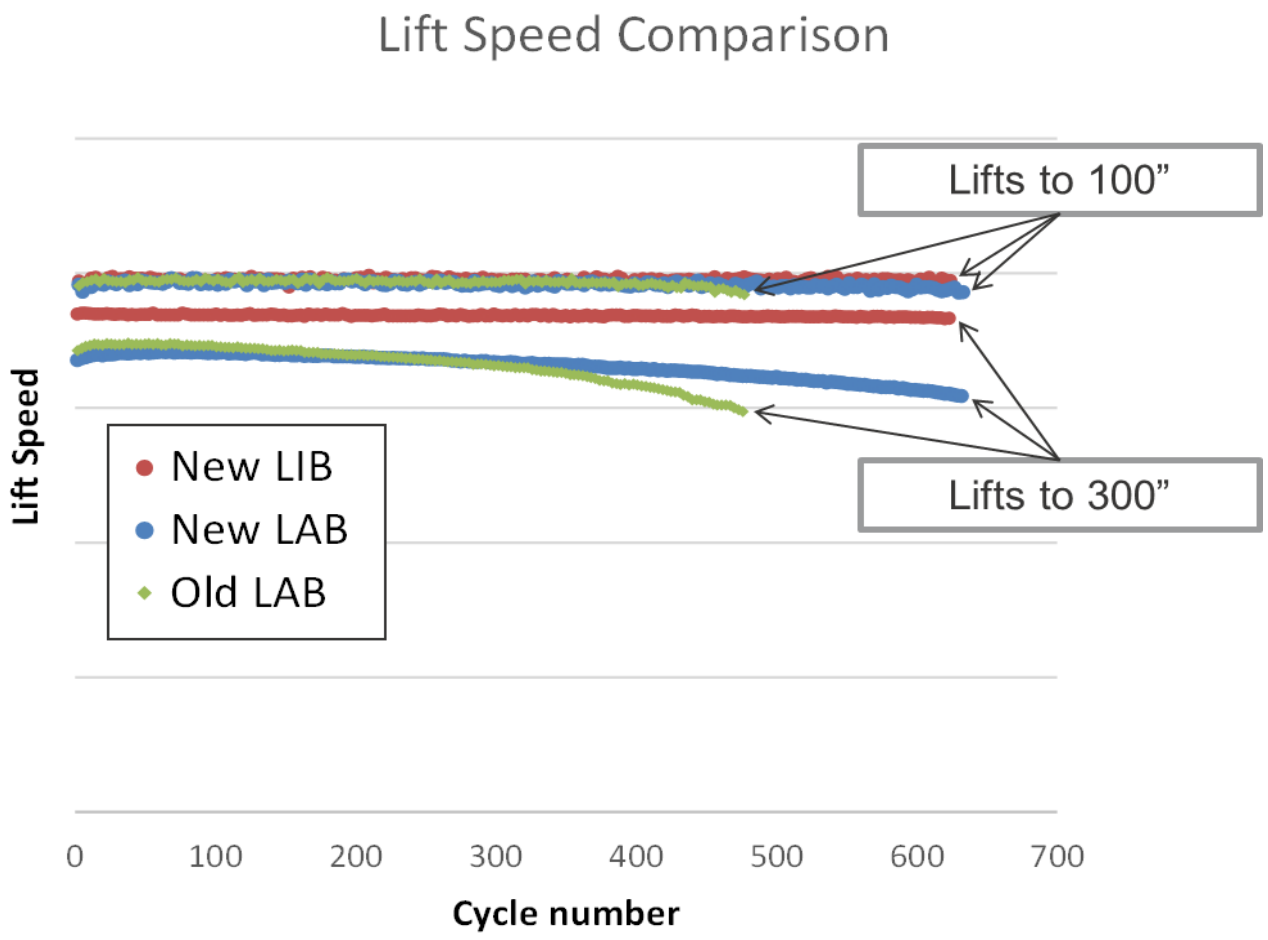




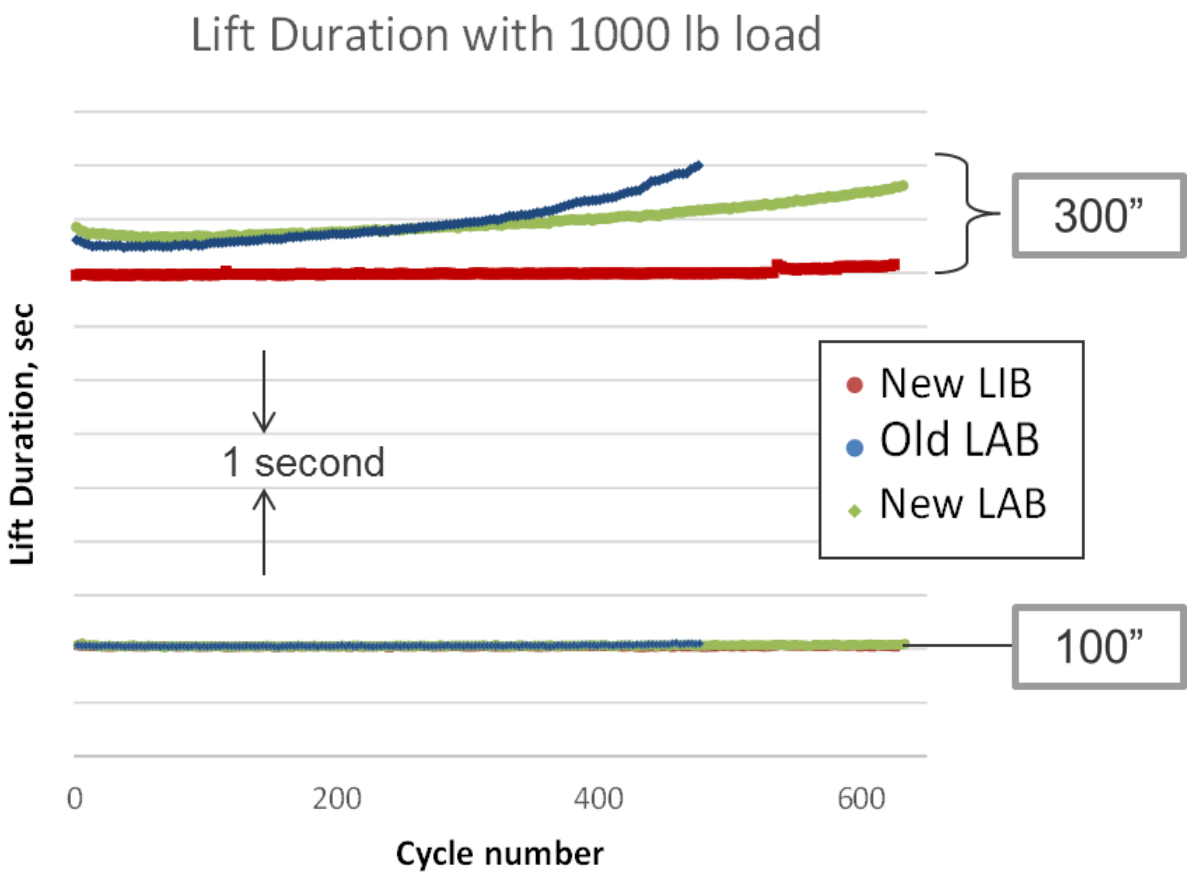


- Lithium battery completed **14 continuous shifts** using simulated forklift duty cycle and short opportunity charging during worker break periods
- Beginning battery capacity start of first shift: 100% SOC
- Ending battery capacity at 14th continuous duty shift: 7% SOC
- Test was performed on Navitas lithium cells without Navitas active balancing BMS – **Results would have been even better with active balancing turned ON**

Starlifter Lithium Power Equals Increase Productivity – Lithium Lifts Loads Consistently Faster



Starlifter Lithium Power Equals Increase Productivity – Lithium Lifts Loads Consistently Faster



EDP – Energy Demand Profile Testing

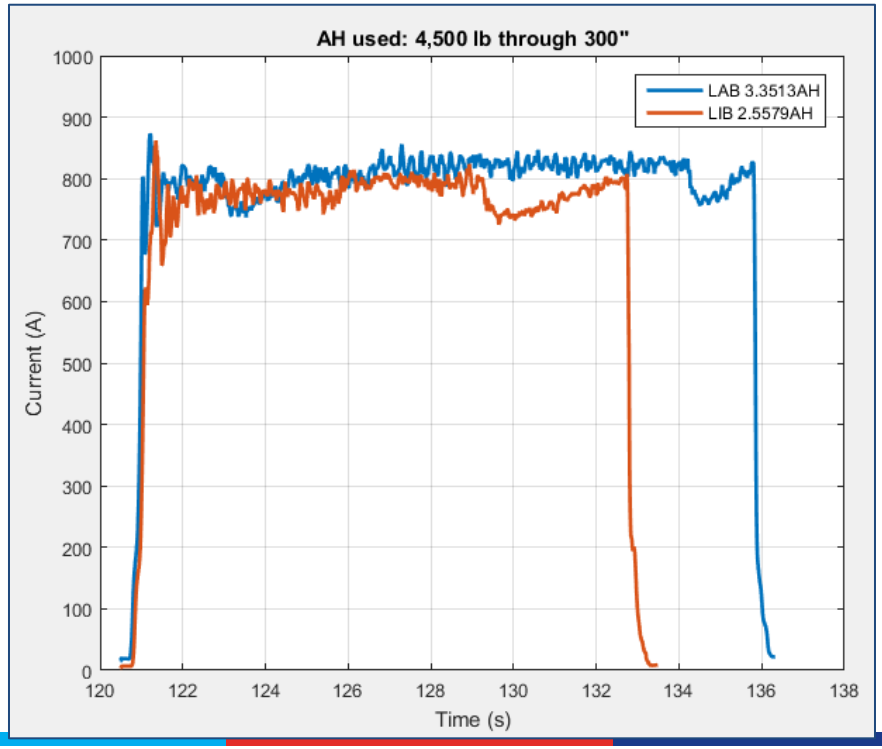
- Highest Demand Conditions Testing – lifting max load to the max height at full speed – lifting a 4500lb load to 300”

	Starlifter Lithium	Lead Acid
Peak Output current	750A	810A
Energy Consumption	2.56Ah	3.35Ah
Lift Time	12 seconds	15 seconds

7.5% Lower Internal Resistance

23% Less Energy Consumption

20% Quicker Lift Duration



Lead Acid Vs Lithium Field Lift Test

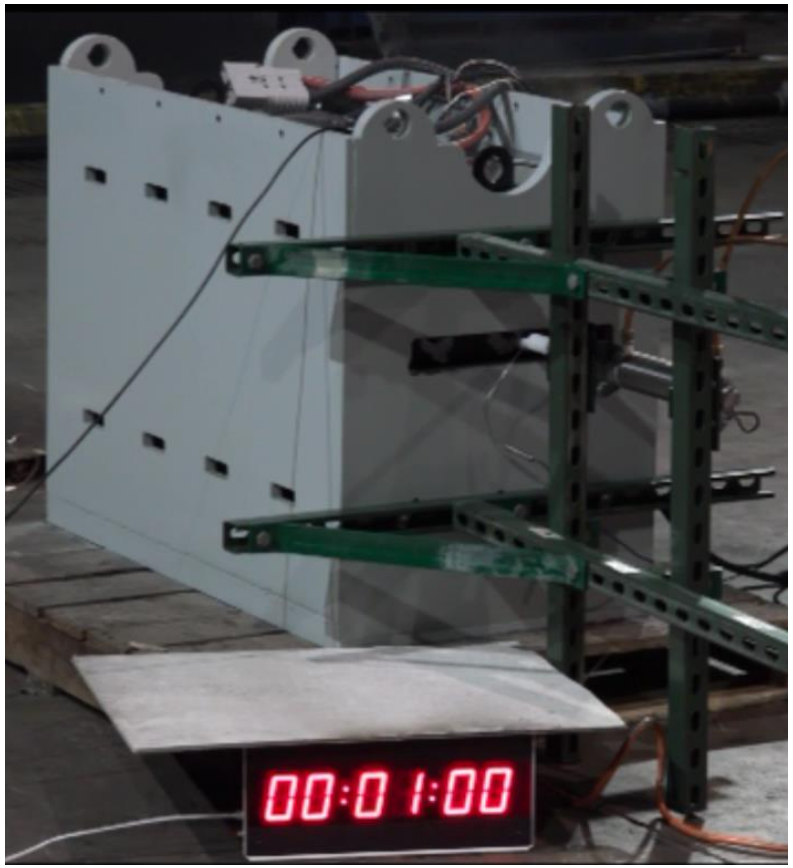
Lithium Battery – ~12 seconds to lift load to 300”

~20% Quicker Lift Duration

Lead Acid Battery – ~15 seconds to lift load to 300”

UL Safety Video

- Starlifter Passed Short Circuit Test With Flying Colors
  - Slight smoke for 1 minute then nothing



Customer Evaluation Objectives

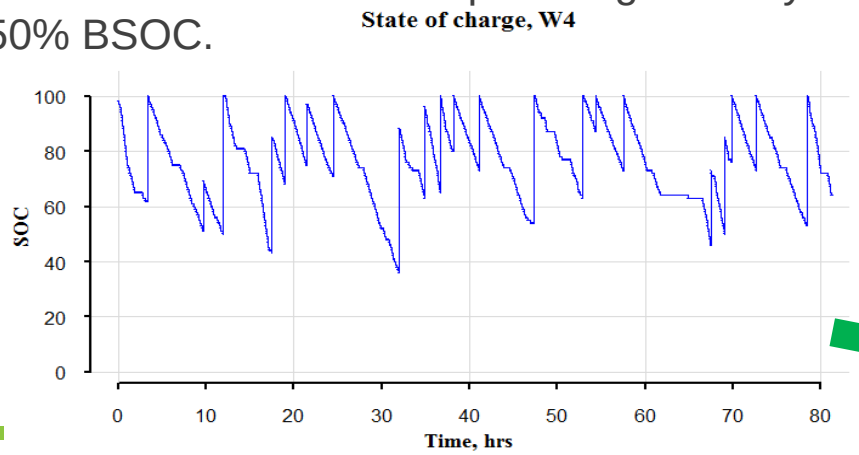
Customer Field Testing Objectives:

1. Demonstrate lithium technology with fast charging in a cold warehouse at a customer site
2. Quantify productivity improvements of LIB over LAB
3. Compare Truck and Battery Performances
4. Quantify Labor Hours Associated with Battery Changing

Successful Field Demonstration at Maines

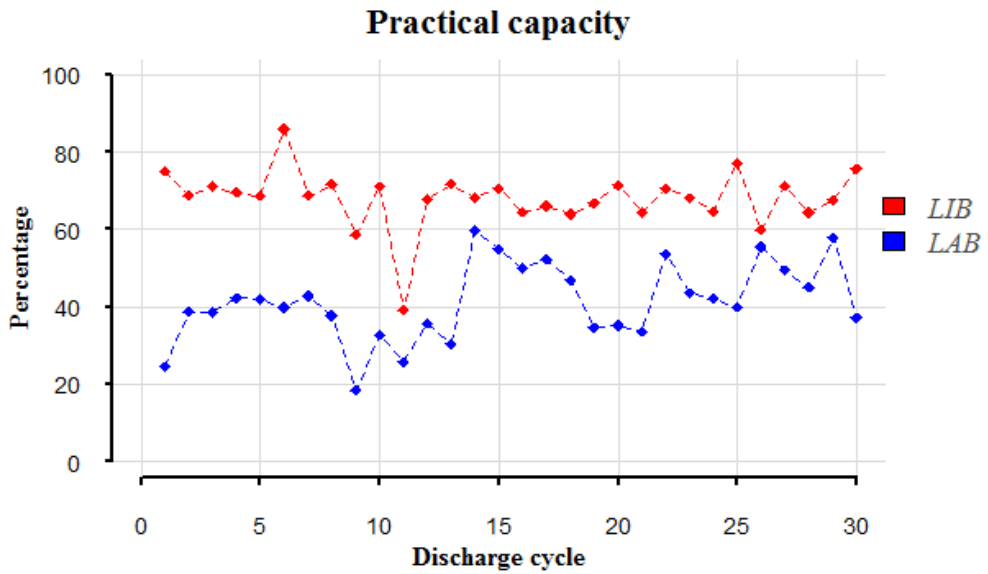
Truck #	Battery	Nameplate Capacity (Ah)	Calculated Energy (kWh)
F105	LAB	1240	44
F102	LIB	700	28

The operators enjoyed using the LIB truck (F102) and commented that it was more responsive than the LAB system (F105), and maintained consistent performance even at low BSOC, versus the LAB which drops off significantly below 50% BSOC.



Maintained a high state of charge with opportunity fast charging

Practical Capacity Comparison



- **In a cold warehouse the practical capacity percentage seen:**
  - 70% of Starlifter Lithium Nameplate
  - 40% of Lead Acid Nameplate
  - Both result in ~500Ah practical capacity
- **Lithium Cycle = 80% DOD Cycle**
- **Lead Acid Cycle = Battery Change**

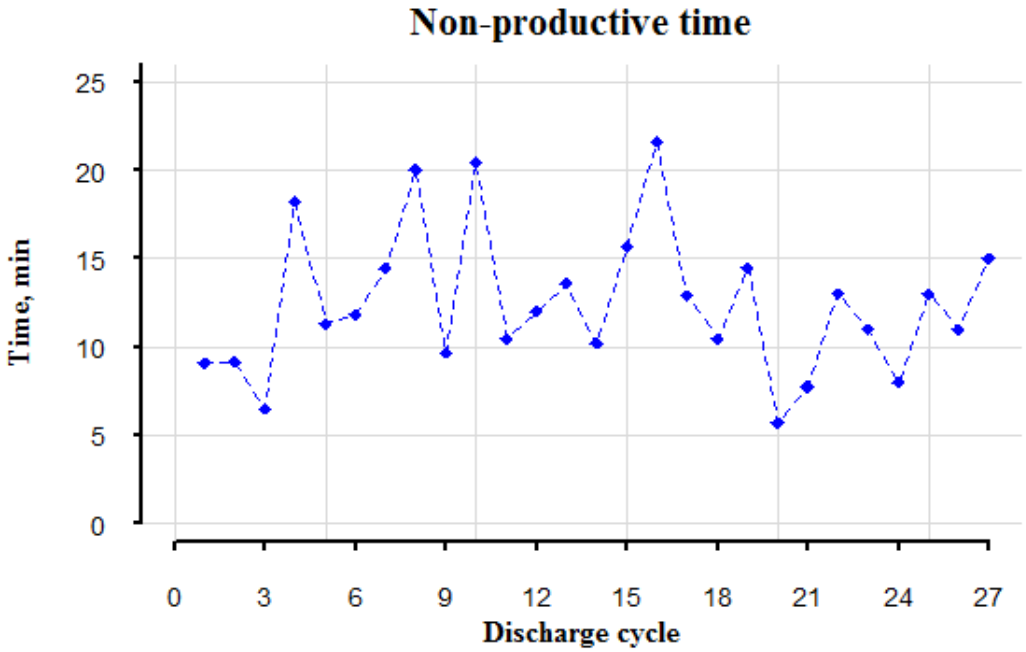
Lithium Power Means More Productivity

		Week 1	Week 2	Week 3	Week 4	Week 5	Total
F105 - LAB	pallets moved (#p)	756	707	708	1060	760	3991
	operational hours (hr)	42	37	42	53	42	216
	avg #p/hr	18	19	17	20	18	18
F102 - LIB	pallets moved (#p)	921	730	711	865	781	4008
	operational hours (hr)	43	37	36	39	37	192
	avg #p/hr	21	20	20	22	21	21

17% Increased Pallets Moved Per Hour

Lithium Batteries with Fast Charging Eliminates Non-Productive Time

- **Battery Changes occur approximately 1 time per shift**
  - Sometimes more as the lead acid batteries age and performance decreases become more noticeable
- **The *Lead Acid Truck averaged 12.6 minutes of lost time per lead acid battery changeout* over the program test period**



Maines Driver Survey Feedback – Lead Acid

2. How satisfied are you with the performance of lead acid powered forklift at the beginning of your shift or after a battery change/opportunity charge under the following categories using a scale of 1 to 5.

1 – Does not meet requirements
2 – Slightly meets requirements
3 – Moderately meets requirements
4 – Meets requirements
5 – Exceeds requirements

(circle your response)

f.	Overall performance	1	2	3	4	5
g.	Power	1	2	3	4	5
h.	Forklift Range	1	2	3	4	5
i.	Consistent speed	1	2	3	4	5
j.	Load Capacity	1	2	3	4	5

For the first 2 hours of a fully charged LAB that is in good condition. Due to lack of watering they don't stay in good condition

3. How satisfied are you with the performance of lead acid powered forklift at the end of your shift or before a battery change/opportunity charge under the following categories using a scale of 1 to 5.

(circle your response)

a.	Overall performance	1	2	3	4	5
b.	Power	1	2	3	4	5
c.	Forklift Range	1	2	3	4	5
d.	Consistent speed	1	2	3	4	5
e.	Load Capacity	1	2	3	4	5

Maines Driver Survey Feedback - Lithium

4. **How satisfied are you with the performance of the lithium battery powered forklift <u>at the beginning of your shift</u> or after a battery change/opportunity charge** under the following categories using a scale of 1 to 5.

1 – Does not meet requirements
2 – Slightly meets requirements
3 – Moderately meets requirements
4 – Meets requirements
5 – Exceeds requirements

(circle your response)

p.	Overall performance	1	2	3	4	5
q.	Power	1	2	3	4	5
r.	Forklift Range	1	2	3	4	5
s.	Consistent speed	1	2	3	4	5
t.	Load Capacity	1	2	3	4	5

5. **How satisfied are you with the performance of the lithium battery powered forklift <u>at the end of your shift</u> or before a battery change/opportunity charge** under the following categories using a scale of 1 to 5.

(circle your response)

f.	Overall performance	1	2	3	4	5
g.	Power	1	2	3	4	5
h.	Forklift Range	1	2	3	4	5
i.	Consistent speed	1	2	3	4	5
j.	Load Capacity	1	2	3	4	5

Maines Driver Survey Feedback

6. Answer the following question comparing Lead-acid battery against Lithium Ion powered forklifts using a scale of 1 to 3.

1 – Lead-acid batteries outperform Lithium Ion Batteries
2 – No difference
3 – Lithium Ion Batteries outperform Lead-acid batteries

(circle your response)

a.	Overall performance	1	2	(3)
b.	Power	1	2	(3)
c.	Forklift Range	1	(2)	3
d.	Consistent speed	1	2	(3)
e.	Load Capacity	1	2	(3)

Comments/Observations:

For this project the lithium battery was appropriately sized to match the operation for cost effectiveness, not necessarily to extend range in this application although it might be a sought-out feature by the driver

7. Did you feel overall the lithium battery improved your productivity on the job? (circle your response)

1) No, it was worse 2) Hard to tell (3) Definitely

8. After your experience with Lithium batteries, given a choice between a lead acid powered truck and lithium truck, which one would you request? (circle your response)

a. **Lead Acid**
(b.) **Lithium**

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Navitas Starlifter Installation Examples

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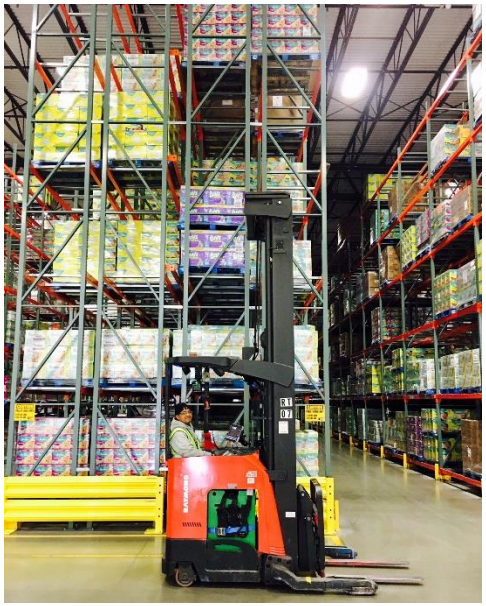

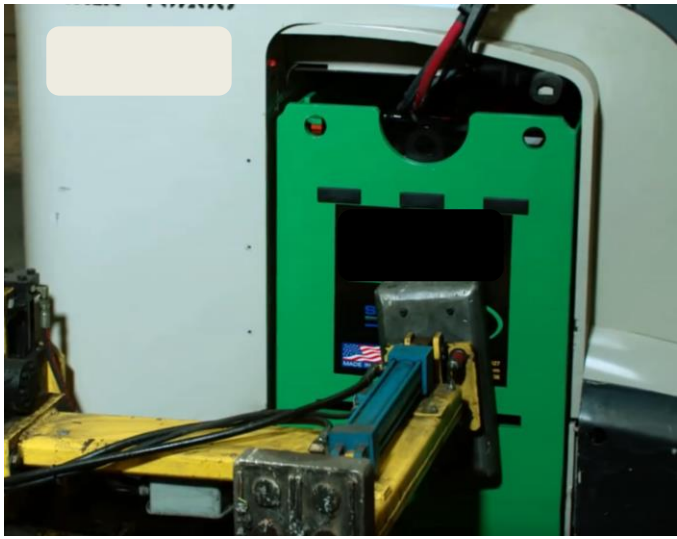

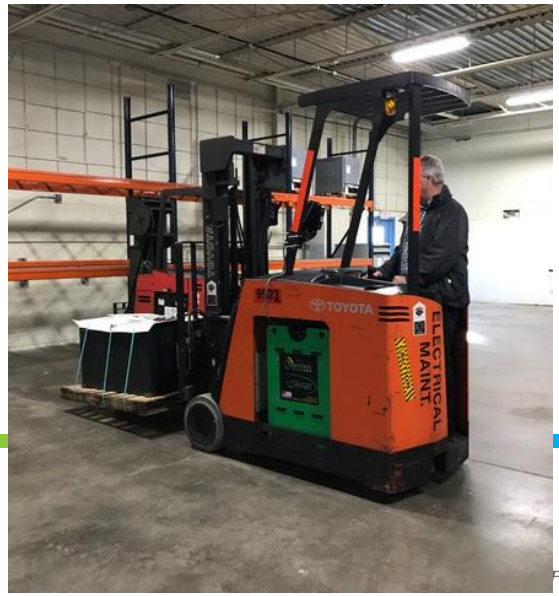

3 Shift Cold Storage Installations

- Cold Storage Distribution Facility – 24/7 Operation
  - Productivity measurement by quota % expected by baselined lead acid performance and assigned tasks then compared to historical performance data by driver
    - **“Employee’s driving the forklift saw an average 7% increase” – LMS Data Analyst**
- Trucking / Third Party Logistics “Fresh” Distribution Center – 24/7 Operation
  - Productivity measured by driver as pallets per hour
    - **211 pallets per day historical performance with lead acid, 226 pallet per day with Starlifter lithium battery = 7% productivity improvement**
    - **+3 Hours / Day increased uptime** for lithium truck, the lead acid truck wasn’t able to support the operations needed and required additional “jumper” trucks to support the operation

***Both facilities already had fast charging – the data displayed is compared to lead acid with fast charging, no battery changing operation**

Multi-Shift Heavy Duty Installations

- Consumer Goods Distribution Center – 24/7 2 Shift Operation
  - Currently performing lead acid battery changing because of the limited amount of charging time available, <3 Hours Per Day
    - **Lithium will enable them to maintain full uptime with a single battery per truck and charge during just breaks, lunches and shift change**
- Government Defense Logistics – 2 Shift Operation
  - Currently in process of transitioning from lead acid battery changing to fast charging lithium
    - **Enabling the increase of operational readiness for peak demands while maintaining or reducing fleet size and reducing overall operational costs**

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Maintenance Loves the Lithium Forklift

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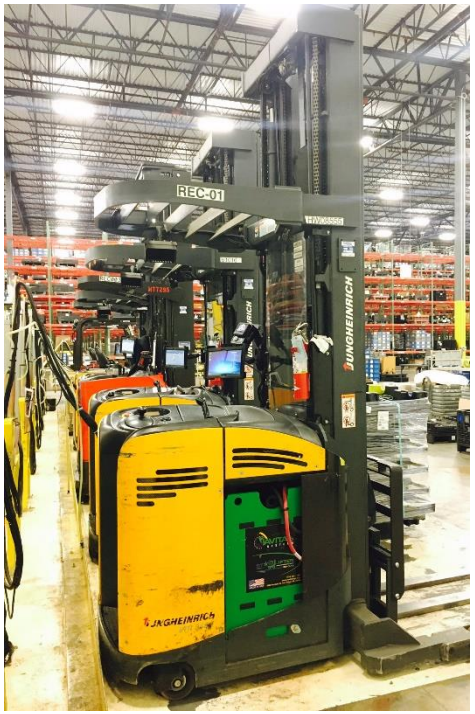
Answer the following question comparing Lead-acid battery against Lithium Ion powered forklifts using a scale of 1 to 3.

1 – Lead-acid batteries outperform Lithium Ion Batteries
2 – No difference
3 – Lithium Ion Batteries outperform Lead-acid batteries

(circle your response)

a.	Overall performance	1	2	3
b.	Power	1	2	3
c.	Forklift Range	1	2	3
d.	Consistent speed	1	2	3
e.	Load Capacity	1	2	3

Lithium



Comments/Observations:

Did you feel overall the lithium battery improved your productivity on the job? (circle your response)

1) No, it was worse 2) Hard to tell 3) Definitely

After your experience with Lithium batteries, given a choice between a lead acid powered truck and lithium truck, which one would you request? (circle your response)

a. **Lead Acid**
b. **Lithium**

Survey Completed by:
Facility Maintenance Manager

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For More Information:

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www.navitassys.com

www.lithiumforkliftpower.com

Or visit ProMat Booth #S5630

Customer Evaluation Profile Summary

Even with the variation in travel and lift distances, the LIB clearly demonstrates a productivity increase over the LAB. This is due to the higher performance of the LIB truck (faster lifts and faster acceleration), and the performance drop off seen in a LAB at lower BSOC.