Lima eBus
Safety Implications

Naeem Farooqi, Principal Consultant
WSP Canada Inc.
Workshop Agenda

1. Hazards of eBus Maintenance & Operations
2. Personal Protective Equipment (PPE)
3. Arc Flash Hazard
   1. What is Arc Flash?
   2. Required PPE
   3. Procedures and Maintenance Practices
   4. Training Requirements
4. Shop Floor Safety Standard Operating Procedures (SOPs), Equipment & Tooling
5. Emergency Response Protocol
   1. Stakeholder Involvement (OEM, First Responders, Transit Agency)
   2. Protocol Development & Communication
6. Session Wrap & Questions

Session 6
Safety Implications
13:30pm to 15:00pm

Lima eBus to be maintained by BYD
Safety for general purpose information
eBus Safety Hazards
eBus Safety Hazards

- High Voltage components (i.e. battery, power cables)
  - Electrocution
  - Arc Flash (Thermal and Flash)
  - Burn Risk (Hot Surfaces)

- Working at Heights (i.e. roof mounted battery packs)

- Pinch points (i.e. access panels, doors, latches)

- Crush hazard
  - Lifting heavy components (i.e. hoists, lifting cranes)
High Voltage Mitigation Guidelines

1. Know the system, components you are working on
2. Possess the necessary High Voltage training and qualifications
3. Have a second qualified and trained person act as a safety observer
4. Wear your own Personal Protective Equipment (PPE)
5. Develop Standard Operating Procedures (SOPs) for lock-out tag-out and establishing a safe work zone
6. Always verify High Voltage system is de-energized before work is started “Test before you touch”
7. Apply your own “Lock-out Tag” when performing work
Battery Access

- Always follow OEM requirements and training for maintenance of High Voltage components
- Some OEMs may void warranty for access to battery
Arc Flash & PPE
Arc Flash

- Arc Flash results from high voltage electrical discharge between conductors bridged by an air gap

- Current jump creates a large burst of thermal energy and light flash
  - Jump from battery to conductive tools/equipment

- Risk of igniting airborne dust and particulate matter

- Potential for severe injury if proper PPE and training are not in place for workers
  - Intense burst of Light (UV) and Temperature
  - Potential for Shrapnel
  - Release of Toxic Vapour
Arc Flash

- Voltage level mandates High Voltage training, PPE rating and safe work zone requirements
  - Canada 30V threshold
  - USA 50V threshold
  - Peru threshold (Enel X)

- National Fire Protection Association (NFPA) 70E Standard for Electrical Safety in the Workplace

- Thermal energy of 1.2 cal/cm² can cause a 2nd degree burn
Arc Flash

Minimum PPE Category 2 (8 cal/cm²)

- Fire Rated Coveralls
- Fire Rated Balaclava
- Face Shield
- Hard Hat
- Safety Glasses
- Ear Plugs
- High Voltage Rated Gloves
- Electrical Hazard (EH) Rated Boots (Insulated up to 600V)
Arc Flash PPE Requirement per Person

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Est. Unit Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arc Flash Protective Clothing Kit</td>
<td>$ 850</td>
</tr>
<tr>
<td>Black Electrical Glove Kit</td>
<td>$ 130</td>
</tr>
<tr>
<td>Leather Protector - For Rubber Gloves</td>
<td>$ 27</td>
</tr>
<tr>
<td>Over Boots</td>
<td>$ 150</td>
</tr>
<tr>
<td>Balaclava Head Cover (one size fits all)</td>
<td>$ 32</td>
</tr>
<tr>
<td>Hard Hat and Face Shield (one size fits all)</td>
<td>$ 206</td>
</tr>
<tr>
<td>Fall Safety Harness 425LBS</td>
<td>$ 163</td>
</tr>
<tr>
<td>Brady Personnel Lockout Pouch Kit</td>
<td>$ 92</td>
</tr>
<tr>
<td>Steel Lock Hasp with Tab</td>
<td>$ 12</td>
</tr>
<tr>
<td>American lock A1106RED</td>
<td>$ 17</td>
</tr>
<tr>
<td>Lock Out Tag</td>
<td>$ 24</td>
</tr>
<tr>
<td><strong>Grand Total (PPE) per Person:</strong></td>
<td><strong>$ 1,704</strong></td>
</tr>
</tbody>
</table>

*Cost estimates only. Consult eBus OEM for specific requirements

Recommendation two (2) sets per person
  - One PPE set
  - One spare set
General PPE Requirements

• Reference for appropriate PPE:
  • Warning Labels
  • OEM Specifications
  • Work Instructions (SOPs)
  • Local Legislation

• Regular inspection of all PPE equipment, certification and renewal responsibility of employer

• Proper PPE usage responsibility of employee
**High Voltage Gloves**

- Reference ASTM requirements for appropriate insulating gloves
- Visual inspection and air tested for cuts, holes, tears or other defects which may impact insulation
- Blow & Fold test on gloves prior to use
- Third party glove inspection and electrical testing every 6 months
- Always test gloves prior to use
Static Free Toolkits

- Wrenches, Socket Sets, Screwdrivers, Pliers and Calipers

Electro Static Discharge (ESD) safe tools required to safely dissipate natural build up of static electricity charge
  - ESD can be released through contact with conductors (i.e. metallic vehicle frame)
  - Risk of electrocution
  - Risk of damage to electrical components (i.e. logic controllers, circuits)

- Follow Toolkit OEM requirements for recertification (typically 3 years)

- Keep all certification records on-site

- Regularly inspect toolkits for any damage to protective coating (i.e. scratches, chips)

- Clearly separate (certified vs. certification required toolkits) and lock access to tooling to prevent tampering

Wiha Insulated Tools
<table>
<thead>
<tr>
<th>Item Description</th>
<th>Est. Unit Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluke Multimeter - CAT 111 c/w Test Leads</td>
<td>$ 835</td>
</tr>
<tr>
<td>Wiha Insulated Master Electrician’s Tool Kit</td>
<td>$ 3,760</td>
</tr>
<tr>
<td>Wiha 1/4 in ratchet set insulated SAE</td>
<td>$ 506</td>
</tr>
<tr>
<td>Wiha 1/4 in ratchet set insulated Metric</td>
<td>$ 510</td>
</tr>
<tr>
<td>Wiha open end wrench insulated metric</td>
<td>$ 572</td>
</tr>
<tr>
<td>Wiha open end wrench insulated SAE</td>
<td>$ 574</td>
</tr>
<tr>
<td>Wiha insulated Serrated Tweezers Straight</td>
<td>$ 61</td>
</tr>
<tr>
<td>Wiha insulated Serrated Tweezers Angled</td>
<td>$ 86</td>
</tr>
<tr>
<td>Insulated Torque Wrench 1/4&quot;</td>
<td>$ 612</td>
</tr>
<tr>
<td>Insulated Torque Wrench 3/8&quot;</td>
<td>$ 683</td>
</tr>
<tr>
<td>Insulated Torque Wrench 1/2&quot;</td>
<td>$ 737</td>
</tr>
<tr>
<td>Torque screwdriver set</td>
<td>$ 418</td>
</tr>
<tr>
<td>Insulated crimper 30 - 6 Awg 7&quot;</td>
<td>$ 62</td>
</tr>
<tr>
<td>Insulated hex key set 10pc metric</td>
<td>$ 333</td>
</tr>
<tr>
<td>Long SAE Natural insulated hex key set 12 pc</td>
<td>$ 295</td>
</tr>
<tr>
<td>Wiha Insulated &quot;bitFlip&quot; Set</td>
<td>$ 126</td>
</tr>
<tr>
<td>Phase tester</td>
<td>$ 206</td>
</tr>
<tr>
<td>Pulse width meter</td>
<td>$ 492</td>
</tr>
<tr>
<td>Fluke meter</td>
<td>$ 364</td>
</tr>
<tr>
<td>Modular test lead kit</td>
<td>$ 166</td>
</tr>
<tr>
<td>Test probe flat blade</td>
<td>$ 20</td>
</tr>
<tr>
<td>Test probe back probe</td>
<td>$ 20</td>
</tr>
<tr>
<td><strong>Total PPE Cost (Set per Person):</strong></td>
<td><strong>$ 11,440</strong></td>
</tr>
</tbody>
</table>

*Cost estimates only. Consult eBus OEM for specific requirements and recommended toolkits

- Recommendation one (1) set per person
- Approx. $11,500 USD per person
Shop Safety & Equipment
Working at Heights

- eBuses can have roof mounted battery packs and/or power electronics

- Need for working at heights safety training and use of fall arrest equipment

- Regular inspection of all fall arrest equipment (legislative requirements)
Lock Out / Tag Out (LOTO) Procedure

• Warning labels, OEM training and SOPs developed govern Lock Out requirements

• All work only conducted by qualified and trained persons with appropriate PPE

• Before re-energizing ensure:
  1. All tools are removed, replace any access covers that may have been removed
  2. Notify all workers equipment will be re-energized
  3. Remove Lock Out/Tag Out Devices
  4. Verify all workers are clear
  5. Re-energize the equipment
High Voltage Checks

- High Impedance Multimeters used to measure Voltage (V) and Current (A) across conductors
- Used to troubleshoot electrical circuits
- Identify power supply is safely disconnected for further work
- Typical Resistance greater than 1 megaohm (MΩ) price point $1,000 USD
- If Voltage exceeds 10V follow Lock Out procedure
Arc Flash

- Perimeter barrier around the High Voltage Junction Box and/or Battery Compartment area

- Create a “Safe Zone” that is at least 4 ft (1.2 m) away from the High Voltage components (follow OEM recommendation)
  - Safety Barrier (Light/Thermal Shields)
  - Insulated Safety Rescue Hook

- Anyone in this area must have their own lock placed on the bus

- Arc Flash warning labels on High Voltage Components determine PPE requirements

**WARNING**: You must be training and qualified to be inside of the barrier
Charging Safety

- Follow OEM Standard Operating Procedures (SOPs) for vehicle charging
- Ensure appropriate PPE is worn
- Training on Power Supply Disconnect Switch
- Visual inspection of all cables and connectors for damage, kinks and cuts
- Safety stow charging connector when not in use
- On-site first aid and medical response SOP posted in case of emergency
Charging Safety

1. Power off and apply parking brake

2. Open charging compartment door with key

3. Plug in charging guns

4. Swipe card or press “Start charging” to charge
Charging Safety

• Make sure charging port and charging gun have no corrosion and damage or other problems that may cause short circuit, which can cause serious accident while charging
• Do not disconnect charging gun if your hand is wet, it could cause electric shock and harm body safety
• Do not use or store charging equipment if ambient temperature exceeds 50°C
• The High Voltage distribution box may produce the sound of clatter while the charging gun is connected which is normal
• Stop the charging box first and then pull out charging gun
• Make sure charging gun is disconnected and charging compartment door is closed before driving
• If ambient temperature is lower than 0°C charging time can take longer than normal due to charging efficiency
• If eBus is not used for a long period, driving and charging batteries every 3 months is recommended to extend service life
Emergency Response Protocol
Emergency Response Plan

- Medical response plan posted in vehicle maintenance, servicing and charging areas
- Staff to receive regular training on emergency response
- On-site staff identified with CPR training
- Emergency first aid kits located in accessible and easily visible areas
- Call Local Emergency Services Number 105
- Assess accident scene for hazards before reacting
- Insulated Rescue Hook can be used to pull someone away from electrocution incident
eBus Accident Response Plan

- Stakeholder involvement in vehicle training:
  - Drivers
  - Local First Responders
  - Vehicle OEM

- Covers layout of High Voltage systems and potential hazards

- Response protocol in the event of an accident

- Location of Emergency Power Disconnect for vehicle battery
  - Inside Driver’s Area
  - Secondary Disconnect Outside Access Panel
BYD eBus High Voltage Disconnect

- High Voltage disconnect contactors
- High Voltage electrical conduit in orange
eBus Accident Response Plan Sample
eBus Accident Response Plan Sample

**Proterra Catalyst® E2 Electric Transit Bus - Manual Shutdown**

Important: The following actions will shut down the electrical systems on the bus.

1. Set the Parking Brake by pulling the **yellow knob** on the driver's lower left panel:

2. Turn the **Master Switch** at the Driver's Left Console to the OFF position, which controls the electrical systems:

3. Open the curbside rear access panel and turn the **Vehicle Master Disconnect** switch to the OFF position:
Safety Summary

- Ratio of workplace safety incidents to fatalities:
  - Mechanical Incident = 300:1
  - Electrical Incident = 10:1

- Risk Mitigation through:
  - Proper use of PPE
  - Staff Training & Risk Identification
Thank you! Stay Safe!

Naeem Farooqi  
Principal Consultant  
Toronto, Canada  

416-644-0580  
Naeem.Farooqi@wsp.com  

Twitter: naeemfarooqi11  
Linkedin: Naeem Farooqi  

wsp.com