APTA STREETCAR SUBCOMMITTEE
BOMBARDIER FLEXITY FLEET

Sunday June 23, 2019
Agenda

1. LEGACY FLEET
2. FLEXITY VEHICLE
   • Design Features
   • Design Challenges
   • Maintenance Challenges
3. INFRASTRUCTURE
   • Infrastructure Changes
   • Pole To Pantograph
   • Challenges
4. OPERATIONS
   • Changes To Operations
5. LESSONS LEARNED
LEGACY FLEET

Canadian Light Rail Vehicle (CLRV)
- Commissioned: 1979
- Manufacturer: UTDC
- Total Purchased: 196
- Total Length: 40 Ft
- Total Capacity: 102 Passengers
- Mid-Life Overhaul: None
- Motorized Trucks: 2/2

Articulated Light Rail Vehicle (ALRV)
- Commissioned: 1988
- Manufacturer: UTDC
- Total Purchased: 52
- Total Length: 75 Ft
- Total Capacity: 155 Passengers
- Mid-Life Overhaul: None
- Motorized Trucks: 2/3
FLEXITY VEHICLE
BOMBARDIER FLEXITY LFLRV

- Commissioned: 2014
- Manufacturer: Bombardier Transportation
- Total Purchased: 204
- Total On Property: 154 (June 1, 2019)
- Total Length: 100 Ft
- Total Capacity: 251 Passengers
- Total Articulation: 4
- Motorized Trucks: 3/3
VEHICLE NETWORK INTEGRATION

- Minimum horizontal curves: 11.1m inside rail radius
- Maximum Gradients: 8%
- Interoperability with Legacy fleet
- Mix traffic
ACCESSIBILITY

**AODA Regulation** (Accessibility for Ontarians with Disabilities Act)

- Public Announcements
- 2-stage Ramp
PASSENGER & OPERATOR COMFORT

Passenger comfort
• HVAC
• Wide windows, bright lighting
• Bicycle rack

Operator’s Features
• Transition from pedals to hand Master Controller
• HVAC
• Door cameras & Rear view cameras
IMPROVED PERFORMANCE

• Propulsion & Hydraulic Braking
  • Redundancy (3 motorized/braking bogies)
  • Spin slide correction
• Reduced noise and vibration
• Reduced loading & off-loading time
RELIABILITY CHALLENGES

Braking equipment
Traditionally electric-pneumatics
LFLRV – Hydraulic system
• Oil Leakages
• Loose hardware
• Premature component failures

Door System
Traditionally pneumatic activated
LFLRV - Belt pulley activated
• Wire damages due to fatigue
• Grease flushed out
• Adjustment parameters at installation
ENVIRONMENT

• Snow, Salt, Slush, Dirt
  ➢ Articulation bearings
  ➢ Ramp mobile part

• Corrosion
  ➢ Bogie mounted equipment
  ➢ Roof mounted
MAINTENANCE CHALLENGES

Design modifications (6th MOD program)
- Maintenance Instructions, troubleshooting procedures
- Training material
- Logistics: Parts, space, availability of cars

New technology
- Fault logs
- Signal/Event logs
CHANGES TO INFRASTRUCTURE

2018 – 2020 Modifications:
• Building Extension
• Addition of Roof Access Platforms
• Addition of Pressurized Sanding System & Silo
• Reconfiguration of Track Layout

Total Capacity:
• Maintenance – 16 LFLRV
• Storage – 39 LFLRV

2021 – 2023 Modifications:
• Building Extension
• Addition of Roof Access Platforms
• Addition of Pressurized Sanding System & Silo
• Reconfiguration of Track Layout

Total Capacity:
• Maintenance – 14 LFLRV
• Storage – 52 LFLRV

• Passenger Platforms
• 177 KM Overhead Catenary

Commissioned 2016
Total Capacity:
• Maintenance – 20 LFLRV
• Storage – 100 LFLRV
POLE TO PANTOGRAPH CONVERSION
POLE TO PANTOGRAPH CONVERSION

• Conversion scheduled in 3 stages
  ➢ Stage 1: LFLRV Pole Operation Only
  ➢ Stage 2: LFLRV Pole & Pantograph Operation (Allows For Legacy Vehicle Operation)
  ➢ Stage 3: LFLRV Pantograph Operation Only

• Conversion Strategy
  • Smallest to Largest Route (According to Fleet Requirements)
  • Least to Most Complex (According to no. of Intersections)
  • Opportunity to couple conversion with planned city projects

• Network is currently 50% in Hybrid mode & is expected to be 100% Hybrid by Q1 2022
• Full pantograph conversion is expected by 2025
POLE TO PANTOGRAPH CONVERSION SCHEDULE

512 St. Clair - Panto 2020
511 Bathurst – Hybrid 2018.
510 Spadina – Hybrid 2018
506 Carlton – Panto 2020
505 Dundas – Panto 2019
504 King – Panto 2022
501 Queen – Panto 2022
501 Queen – Hybrid 2021
504 King – Hybrid 2019
509 Harbourfront – Panto 2019
HYBRID CATEHERY

FROGS

Glider Added To Traditional Frog Allows Pantograph Bar to Slide Below Shoe Guideway

4.5 Kg added weight

Hybrid Frog Pole & Pantograph Operation

Traditional Frog Pole Operation
HYBRID CATERNARY

CROSSOVERS

<table>
<thead>
<tr>
<th>Pole Operation</th>
<th>Pole &amp; Pantograph Hybrid Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional 90 deg. fixed X-over</td>
<td>New dual operation 90 deg. Fixed X-over</td>
</tr>
<tr>
<td>Fixed 90 Degree Crossovers</td>
<td>1.0 Kg added weight</td>
</tr>
<tr>
<td>Traditional 30-90 deg. adjustable X-over</td>
<td>Depression pan bolted to traditional adjustable X-over</td>
</tr>
<tr>
<td>Adjustable Crossovers</td>
<td>7.9 Kg added weight</td>
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</table>
Section Insulators

- Insulation is achieved via fiberglass gap
- Gap creates a dead zone for poles but is too short allowing for a pantograph to bridge sections
- Light weight and compact
- Minimal spanning

Pole Only Operation

- Insulation is achieved via 3 air gaps
- Sections between air gaps are powered to allow for continuous operation and long enough to prevent pantograph from bridging sections
- Additional spanning required to support section blocking diodes and heavy/long insulators

Pole & Pantograph Operation
POLE TO PANTOGRAPH CONVERSION CHALLENGES

Challenges:

• Weight of hardware – increased risk of sag
• Pole, pantograph and wire interface – increased risk of interference
  ➢ Pole and Pantograph snags & damage
  ➢ Down overhead
• Increased maintenance efforts of hybrid system
• Accelerated wear of pantograph carbon strip without full stagger
• Conversion of network while trying to maintain service levels

Lessons Learned:

• Installation of anti-trap deflector bars required to mitigate snagging of de-wired poles
• Installation of constant tension devices to mitigate sag
• Earlier conversion of routes to full stagger to mitigate localized carbon wear
OPERATIONS
CHANGES TO OPERATIONS

PRE-SERVICE

Manual Sand Fill System

Pressurized Sand Fill System

Challenges:

• Increased Yard Movements
• Pinch Point
• Balancing Service Requirements with Realistic Throughput
• Reliability of Sand Pump

Benefits:

• Elimination of Moisture
• Reduced Sand Consumption
CHANGES TO OPERATIONS

YARD CONTROL

Manual Switch System

Automated Switch System

Challenges:

• Switch & Software Reliability
• Operator Pick Up vs Hostler Delivery
CHANGES TO OPERATIONS

ASSET MANAGEMENT AND TRAINING

- ‘Fix On Fail’
- In-House Maintenance Work Order System (SMS)
- In-House Technical & Vehicle Training & Qualification

- Predictive Maintenance
- Enterprise Asset Maintenance Work Order System (MAXIMO)
- Technical Degree from College/University with In-House Vehicle Familiarization, Training and Qualification
LESSONS LEARNED
LESSONS LEARNED

1. Program vs Project Management Oversight

2. Catenary Conversion Plan
   • Bus Substitution & Closures
Q&A?
APPENDIX
CHANGES TO OPERATIONS

MAINTENANCE – YARD VS FACILITY PRE-SERVICING

Manual Sand Fill System

Pros:
✓ Flexibility of Pre-Servicing
✓ Minimizes Yard Movements
✓ Faster Pre-Servicing

Cons:
× Exposure To Inclement Weather
× Susceptible To Slip, Trips, Fall & Strains
× Open System – Subject To Moisture
× Cleanliness & Wastage

Pressurized Sand Fill System

Pros:
✓ Eliminates Exposure To Inclement Weather
✓ Reduces Slips, Trips, Falls & Strains
✓ Improves Cleanliness & Reduces Wastage
✓ Enclosed System – Eliminates Moisture
✓ Frees Up Resources

Cons:
× Increases Yard Movement
× Sand System – Pinch Point
CHANGES TO OPERATIONS
MAINTENANCE – MANUAL VS AUTOMATED SWITCH SYSTEM

Manual System

Pros:
✓ More Robust Switches

Cons:
× Exposure To Inclement Weather
× Susceptible To Slip, Trips, Fall & Strains

Automated System

Pros:
✓ Eliminates Exposure To Inclement Weather
✓ Reduces Slips, Trips, Falls & Strains

Cons:
× Increased Maintenance – Electrical & Software System
MAINTENANCE

- Pre-Service
  - Sanding Inside (no longer can do outside)
  - Panto – Cut Power and Roof Access Inside
  - Longer Pre-Servicing Time 15min x 3 ppl
  - More Yard Movements & Through Put in the Carhouse
  - Re-railing – more difficult but front/back trucks – pull back on fast

PD Inspection – move from 30 to 60 days
More Diagnostic tooling required
On Board Health Monitoring System
No more pneumatics – hydraulics contract out repairs/overhaul
Introduction of ramp and HVAC systems
Modular composite panels vs large steel plates – faster turn around
Redundancy – less RCCO
No Ice Cutters but Slider Prototype and Glycol Spray
CHANGES TO OPERATIONS

TRANSPORTATION

King Street Pilot
Pole To Panto
POLE TO PANTOGRAPH CONVERSION

CHRONOLOGY

2009 – Bombardier Flexity Vehicle order placed to replace existing fleet of CLRV and ALRV streetcars
   – New vehicles to be outfitted with both pole and pantograph current collection systems
2010 – Hybrid parts prototyping and test installations begin on St Clair, Fleet Street and Roncesvalles
2013 – Testing with pantograph begins on Queen and St. Clair
2014 – First revenue service vehicle operates on Spadina with pole operation
   – First deployment of pantograph operation in Hillcrest Yard exclusively
   – Pantograph testing continues on St. Clair, Fleet and Queens Quay
2015 – Pantograph snags OCS on St Clair during testing resulting in delayed revenue service deployment
2016 – Pantograph operation begins in Leslie Barns
2017 – Hybrid Pole/Pantograph operation begins on the 509 Harbourfront route
2018 – Hybrid Pole/Pantograph operation begins on the 510 Spadina route
2019 – Pantograph only operation begins on 512 St. Clair route
POLE TO PANTOGRAPH CONVERSION

Lower Spadina & Queens Quay

Pole Only Operation

- High number of segments in curves with compact hardware
- Hardware straddles wire conflicting with pantograph interface
- Trolley wire in curves goes from centerline of track to apex of curve close to inside rail back to centerline of track
- All facing pans are no more than a 60 degree angle to the trolley wire preventing de-wired poles from becoming lodged in spanning

Pole & Pantograph Operation

- 1/3 less segments in curves with heavier hardware
- Longer hardware to extend outside pantograph envelope
- Trolley wire in curves must stay within the pantograph envelope and causing greater ware to panto carbons and wire
- Anti-trap deflectors installed to keep de-wired poles from getting lodged in spanning
POLE TO PANTOGRAPH CONVERSION

Hybrid Auto Tensioning

- Compact design allows for installation on shared poles
- Tensioning device location is out of reach of the public
- 500m tension length with 2000 lbs. of constant tension from -40°C to +40°C
- Specialized component to allow for auto tensioning with pole and pantograph operation
- Anchors one side of the trolley wire and allows the auto tensioned wire to slide through clamp
- Unit is unidirectional (i.e. no reverse operation through clamp)

Cam/Spiral – Constant Tensioning Device

Pole & Pantograph Compatible
Overlap Transition Clamp
CHANGES TO OPERATIONS

New facility - Design and delivery of new Assets

- Wheel lathe
- Lifting units - Hoist
- Sanding Units
- Automatic wheel profiling
- Flushing carts
# CHANGES TO OPERATIONS

## MAINTENANCE – POLE VS PANTOGRAPH SYSTEM

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<td>✓ 2 Month Frequency – Carbon Replacement</td>
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<tr>
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<td>× Increases Servicing Time – Power Cut</td>
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<tr>
<td>× 1-2 Day Frequency – Carbon Replacement</td>
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CHANGES TO OPERATIONS

Sand Consumption

2016 - AUGUST 2018 MONTHLY SAND USAGE RELATIVE TO STREETCAR VEHICLES REQUIRED FOR PASSENGER SERVICE

METRIC TONES

DATE
CHANGES TO OPERATIONS

POLE VS PANTOGRAPH

Challenges:
- Maintenance of 2 Systems
- Pole/Panto/Overhead Interface
- Panto Drops Damage & Inventory Supply

Benefits After Conversion:
- 2-month inspection vs. daily
OPERATIONS CHALLENGES

Challenges

• Customer Education
  ➢ Passenger Activated Doors

• Operator Discipline
  ➢ All Doors Boarding
  ➢ Pole & Pantograph Areas
  ➢ Operating Speeds At Intersections and Under Passes