



Center Axle Wheel Lock

NFIL Review

November 9, 2006

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Agenda

- State problem
- 5 Whys
- 8D process
- 8D summary
- Root Cause supporting data
- Options

Problem Statement

- Center axle wheel(s) locks
- Effects handling stability and control if not detected.

5 Whys

- Consequence: Effects handling stability and control if not detected.
- 5 WHY's
- Issue: Center axle wheel is locked
 - Wheels not rotating
 - Brakes not released
 - Lack of clearance between drum and lining
 - Reference factors below

8D Problem Solving

- Problem Statement - The center axle wheel is locked
- Performed Is / Is-Not analysis to gather facts on What, Where, When and How Big of problem
 - What
 - ARM "W" and Cast Plus brakes on NF buses (issue not with other OEM's using same product on same application)
 - Smaller notch (#2) factor in NF (Different notch on other OEM's)
 - Brake shoe does not fully release from the drum on NF buses (not other OEM)
 - Where
 - Center axle wheels
 - 60ft Articulated
 - NYCTA, Minneapolis, Ottawa, Des Moines
 - Colder climates

8D Problem Solving Continued...

- Is / Is-Not analysis to gather facts on What, Where, When and How Big of problem
 - When
 - Approx. Jan 1999
 - During initial pullout after parking brake engagement overnight
 - Pullout in forward direction
 - All brake life cycle (new buses and buses that have been in service)
 - How Big
 - Latest information unavailable – no recent reports of incident
 - Initial data:
 - 37 NYCTA reported incidents
 - 10.6% of NYC bus fleet, or .0686% of total daily pullouts

8D Problem Solving Continued...

- Obtained **facts** to identify “Is-Not” conditions for the “Is” statements
- Developed **facts on** “Differences” and “Changes” for each “Is and Is-Not statement” pairs
- Developed hypothesis based on the following rule:
Differences / Changes (facts) + Engineering Rationale = Problem Statement
 - Developed 11 theories based on above rule – no exceptions
- Tested (paper trial) probability of hypothesis being true for each “Is” statement (**facts**)
 - If the hypothesis “A” is the true root cause THEN how does it explain why we see the problem in the “Is” condition
 - Tested 198 trial runs

8D Problem Solving Continued...

- Trial run of hypothesis resulted in the following leading theories:

Issue Root Cause (s)	8D Ranking
Consequence: Effects handling stability and control if not detected.	n/a
Cause 1 Tighter lining to drum clearance requires higher air pressure to fully release parking spring causing center axle wheel to lock	18
Cause 2 Reduced lining to drum clearance from thermal expansion & contraction of drum and auto slack adjustment from an already tighter clearance on notch #2 slack adjuster causes center axle wheel to lock	16
Cause 3 Climate (winter, road slush), road de-icers and cleaning chemicals (wash solution) increases the risk of corrosion of drum and subsequent increase in friction between shoe and drum causing center axle wheel to lock	16
Cause 4 Insufficient time to charge parking brake air system leaves parking brakes potentially engaged during pullout and causes center axle wheel to lock	17

- Leading theories confirmed as causes via experiments (lab and field)

Root Cause Supporting Data

Cause 1 (Theory C) - Tighter lining to drum clearance requires higher air pressure to fully release parking spring causing center axle wheel to lock.

- Results from the ABA specification Notch #2 -- as confirmed by field measurements showing minimal clearance.
- Over adjusted ABA during maintenance – seen on NYC vehicle
- Requires higher air pressure to release spring brake – as confirmed from release time measurements
- Results in higher service (brake drum) temperatures -- as confirmed by field measurements showing zero clearance.

Root Cause Supporting Data

Cause 2 (Theory D) - Reduced lining to drum clearance from thermal expansion & contraction of drum and auto slack adjustment from an already tighter clearance on notch #2 slack adjuster causes center axle wheel to lock.

- Tight clearance leads to drum expansion causing ABA to further adjust during service -- as confirmed by field measurements showing zero clearance measured when reaching ambient temperature.
 - It has also been witnessed at NYC facilities that when the bus is lifted on a hoist, that the wheel would not rotate freely due to zero clearance.

Root Cause Supporting Data

Cause 3 (Theory F) - Climate (winter, road slush), road de-icers and cleaning chemicals (wash solution) increases the risk of corrosion of drum and subsequent increase in friction between shoe and drum causing center axle wheel to lock

- Brake output torque for a given amount of residual brake application pressure can be higher when contaminants enter the friction surfaces
 - – lining to drum coefficient of friction has been demonstrated to be as high as double.

Root Cause Supporting Data

Cause 4 (Theory K) - Insufficient time to charge parking brake air system leaves parking brakes potentially engaged during pullout and causes center axle wheel to lock.

- Driving the bus with insufficiently charged air system has been witnessed at NYC facilities.
- The time to charge the air system depends, in part, on how much the air system has leaked down while out of service.
 - Recorded pre-start-up pressures on 50 NYCTA buses, resulted in full range of leak down occurrences.
- Wheel lock due to partially applied brakes depends on the tire to road friction coefficient and the normal force on the tire (axle load).
- Tire to road friction coefficient is dependent upon the weather conditions; hard tire rubber due to cold temperatures, slippery ice, snow wedges built up under the tire, etc.
- Air systems may tend to leak down more during cold temperatures.
- Measured release times can exceed start up to drive away time.
 - Recorded side to side wheel release time differences
- Low air tank alarm turns off at 75 psi, whereas parking brake chamber fully releases at 80 psi.
 - A pressure drop from the reservoir to the brake chamber compounds this issue.

Options

Issue Root Cause (s)	8D Ranking	% Contribution to ranking	Option 1 Integrated detection module	Option 2 Integrated detection module + ASA + Air Chamber	Option 3 Drum + Dust Shield + ASA + Air Chamber + shoes + hardware + wedges
Consequence: Effects handling stability and control if not detected.	n/a	n/a	Addresses	Addresses + some improvement in causal	Does not address
Cause 1 Tighter lining to drum clearance requires higher air pressure to fully release parking spring causing center axle wheel to lock	18	27%	Does not address	Improvement in causal + Detection	Improvement in causal
Cause 2 Reduced lining to drum clearance from thermal expansion & contraction of drum and auto slack adjustment from an already tighter clearance on notch #2 slack adjuster causes center axle wheel to lock	16	24%	Does not address	Improvement in causal + Detection	Improvement in causal
Cause 3 Climate (winter, road slush), road de-icers and cleaning chemicals (wash solution) increases the risk of corrosion of drum and subsequent increase in friction between shoe and drum causing center axle wheel to lock	16	24%	Does not address	Improvement in causal + Detection	Improvement in causal
Cause 4 Insufficient time to charge parking brake air system leaves parking brakes potentially engaged during pullout and causes center axle wheel to lock	17	25%	Does not address	Improvement in causal + Detection	Improvement in causal

NFIL May 8th 2006 Letter to NHSTA

- This letter shows general agreement to root cause understanding between ARM and NFIL.
- NFIL does not view ARM upgrade kit 100% reliable
 - ARM agrees
- NFIL's letter to NHSTA indicates further action required beyond the brake upgrade.
 - ARM agrees..
- Based on the above, a detection system is required for 100% reliability to assure vehicle control.



060408 - Person -
Progress Rep...

Next Steps

- Integrated detection system is required to prevent vehicle loss of control incidents (consequence).
 - ARM believes that brake upgrade kit (option 3) is not 100% reliable to prevent wheel lock.
 - Complete evaluation of ARM upgrade kit in NYC
- ARM recommendation is to move forward with option 2
 - ABA notch #4 plus long stroke chambers
 - Integrated detection system
- ARM suggests joint meeting with NHSTA to review final field action.