National Transportation Safety Board

Train Braking Simulation Study

Conventional Pneumatic, Trailing Distributed Power Pneumatic, and Electronically-Controlled Pneumatic Brake System Performance

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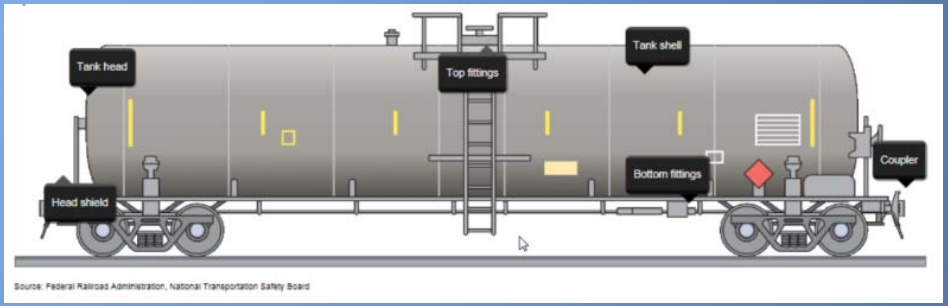
Methods to Improve Tank Car Safety

- Operational speed constraints (lower energy)
- Build a better product wrapper
  - Increase tank car shell thickness
  - Full height head shields
  - Protect inflow/outflow valves
  - Improve pressure release valves
  - Add thermal insulation and jacket



- Improve track and car inspection and maintenance
- Advanced brake systems

Advanced Brake Systems

Goal: Dissipate train kinetic energy (as heat)

Method 1: Improve brake signal propagation rate

- Increase the number of paths
- Change the type of path (pneumatic or electronic)

Method 2: Increase car wheel brake force

$$\text{Car } NBR = \frac{car\ net\ brake\ shoe\ force}{car\ gross\ rail\ load}$$

Emergency Brake Signal Propagation

Brake System	Brake Signal Path	Brake Signal Speed	Car Brake Application
Conventional Pneumatic (CONV)	Train Brake Pipe	~950 ft/sec (from head-end)	Sequential; Front-to-rear
Distributed Power Pneumatic (Trailing DP)	Train Brake Pipe	~950 ft/sec (from each end)	Sequential; Front-to-rear; Rear-to-front
Electronically-Controlled Pneumatic (ECP)	Train Electrical Cable	Nearly Instantaneous	Parallel; Nearly Simultaneous

Increase Car Wheel Brake Force

Methods

- Change brake shoe mechanical lever ratio
- Increase target brake cylinder pressure
- Shorten time to fully pressurize the brake cylinder

Yields higher brake shoe force and increased car NBR

- Brake shoe and wheel thermal loads increase
- Loads on track structure change

Air Brake Schematic (Apply Brake)

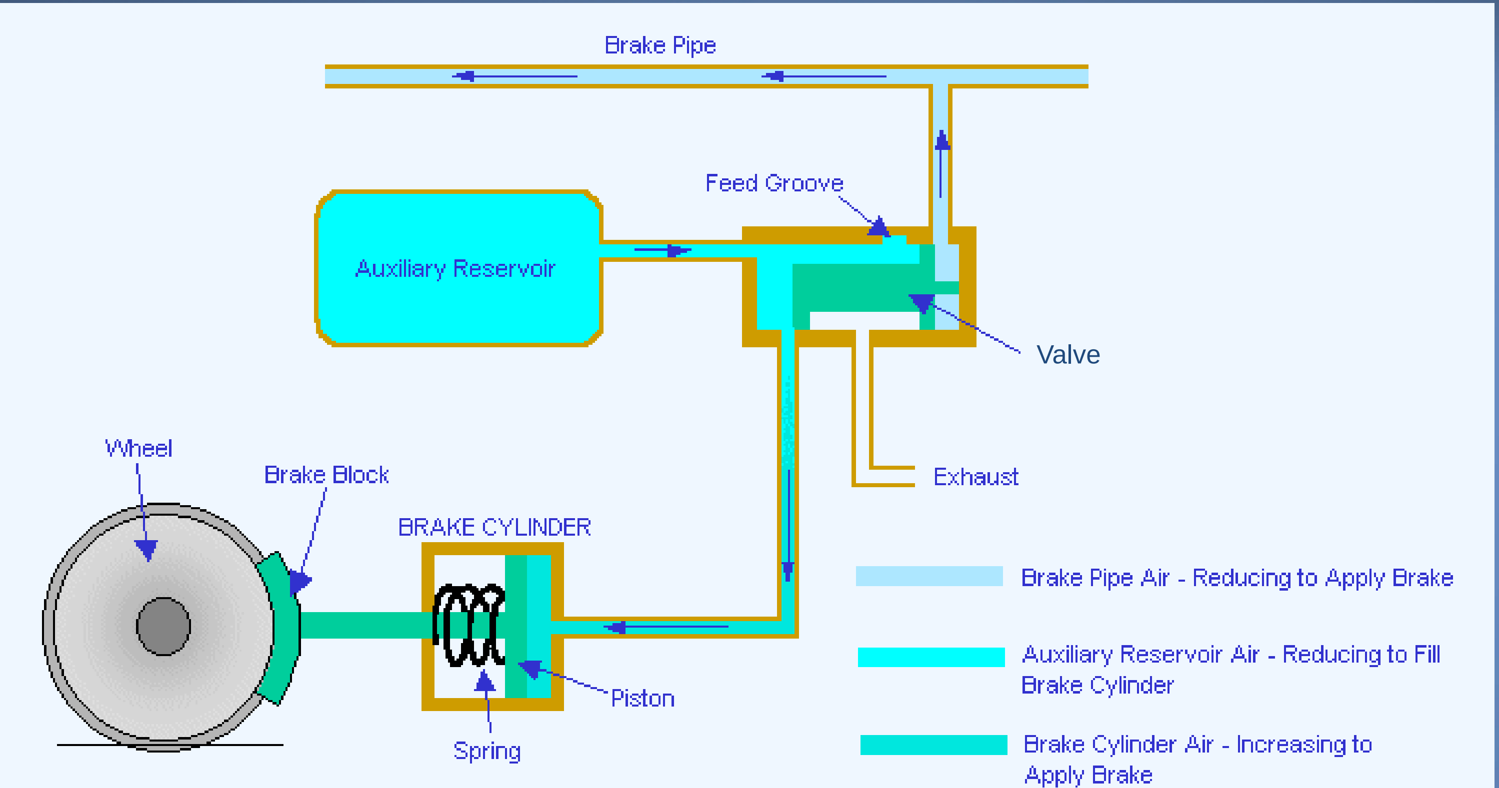
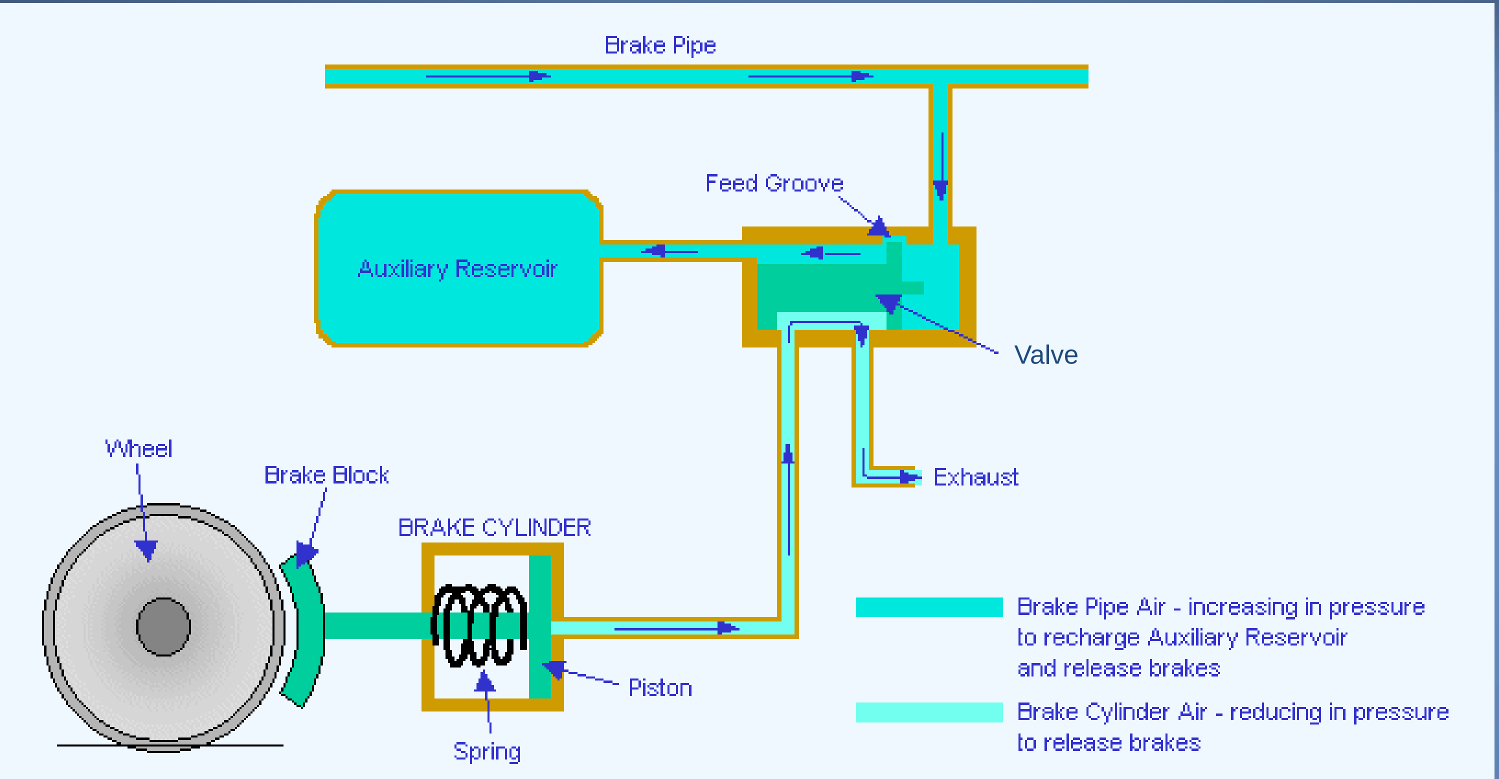


Image adapted from https://www.quora.com/How-do-trains-stop, available on 2/6/2017

Air Brake Schematic (Release Brake)



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Study Goals

1. Quantify train stopping performance capability for each brake system
2. Assess quality of the stop by comparing in-train force profiles
3. Evaluate kinetic energy dissipation benefits
   – Reduced stopping distance
   – Increased engineer/conductor response time margin

Simulation Study Scope

- Train/track properties
  - Mass/length (52, 78, 104, 130, 156 tank cars)
  - Track grade (-2 to +2 percent)
  - Initial speed (20 to 70 mph)
- Brake configuration (CONV, DP, ECP)
- Net braking ratio (10, 12.8, 14 percent)
- Emergency or full service braking
- Locomotive brakes applied or bailed off
- 3,790 simulation scenarios

Assumptions

- Clean, dry rail
- No inoperative brakes
- Head-end, engineer-induced brake application
- No derailment, collisions among cars, or collisions with other obstacles
- No loss of communications

Simulation Tool

- Train Energy and Dynamics Simulator (TEDS)
- Longitudinal train handling and performance applications
- Funded by Federal Railroad Administration
- Developed by Sharma & Associates, Inc.
- Validated against publicly available laboratory, field, and train empirical data

Faster Brake Signal Propagation Results

Relative to CONV 10% NBR baseline, bailed off		Stopping Distance Reduction, Percent	
Braking Configuration	**Speed, mph**	**DP**	**ECP**
Emergency	**20**	4 to 17	5 to 26
	30	4 to 11	5 to 19
	40	[illegible] to 9	4 to 15
	50	3 to 8	4 to 13
Full Service	**20**	7 to 46	37 to 75
	30	11 to 49	37 to 68
	40	10 to 39	30 to 64
	50	9 to 37	25 to 60

3 to 17

4 to 26

7 to 46

25 to 75

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Emergency Braking, Increased Car NBR

Relative to respective 10% NBR baseline, bailed off, level grade		Stopping Distance Reduction, Percent					
		12.8% NBR			14% NBR		
Braking Configuration	**Speed, mph**	**CONV**	**DP**	**ECP**	**CONV**	**DP**	**ECP**
Emergency	**20**	12	14	15	16	18	19
	40	15	17	17	20	22	23
	60	17	18	19	22	24	24

For a given speed and NBR, each brake system provides comparable emergency stopping distance benefits

Combined Effects, ECP and Increased NBR

Relative to CONV 10% NBR baseline, bailed off		Stopping Distance Reduction, Percent		
Braking Configuration	Speed, mph	ECP 10% NBR	**ECP 12.8% NBR**	ECP 14% NBR
Emergency	20	5 to 26	**13 to 39**	16 to 43
	30	5 to 19	**17 to 33**	21 to 38
	40	4 to 15	**17 to 31**	22 to 36
	50	4 to 13	**19 to 30**	24 to 36

13 to 39

10% NBR – representative of legacy tank car fleet
12.8% NBR – default ECP target, subject to car rigging and HEU setting
14% NBR – maximum acceptable loaded car NBR

Combined Effects, ECP and Increased NBR

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Emergency	20	5 to 26	**13 to 39**	16 to 43
	30	5 to 19	**17 to 33**	21 to 38
	40	4 to 15	**17 to 31**	22 to 36
	50	4 to 13	**19 to 30**	24 to 36
Full Service	20	37 to 75	**42 to 80**	45 to 82
	30	37 to 68	**45 to 73**	48 to 76
	40	30 to 64	**41 to 71**	44 to 73
	50	25 to 60	**40 to 68**	44 to 71

13 to 39

40 to 80

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In-Train Forces and Energy Dissipation

- Lower car-to-car buff forces (75 to 250 thousand lb.) for trailing DP and ECP emergency brake application
- ECP 12.8% NBR, full stop, level grade from speed of 50 mph, relative to CONV 10% NBR baseline
  - Stopping distance reduced 500 – 550 feet (about 8 to 9 tank cars)
  - Time margin for engineer/conductor corrective or mitigating action increased about 13 seconds
  - Vehicle kinetic energy decrease of 50% or more equates to distance reduction of 850 feet (14 tank cars) and time margin of 27 seconds

Summary

- Due to faster brake signal propagation rates, ECP out-performed DP, which in turn out-performed CONV
- Increasing the NBR for a given brake system yields substantial and comparable emergency stopping benefits
- Stopping distance reduction, ECP 12.8% NBR, 50 mph
  - About 22 to 28% for emergency braking
  - About 43 to 66% for full service braking

Additional Work

- Follow-on NTSB study quantified advanced brake system performance for in-train derailment scenarios
  - Number of cars that stop short of point of derailment
  - Energy dissipated by the brake system for each car
- Train energy dissipation study was peer-reviewed
- Lower and more uniform in-train force benefits of DP and ECP braking remain to be quantified

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