The Impact of Air Leakage on Locomotive Efficiency and Decarbonization

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Chris Stoos

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SwRI Locomotive Technology Center

- A group within the Powertrain Engineering Division of Southwest Research Institute
  - SwRI is a 501(c)(3) non-profit with 2,700 employees
  - 1700+ Acre facility in San Antonio, TX
  - 8 technical divisions – "From Deep Sea to Deep Space"
- Locomotive Technology Center Established in 1990 for the AAR
- Hundreds of locomotives tested to date
- Projects for EPA, CARB, FRA, CaDOT, DOE, AAR, RR's, and OEM's

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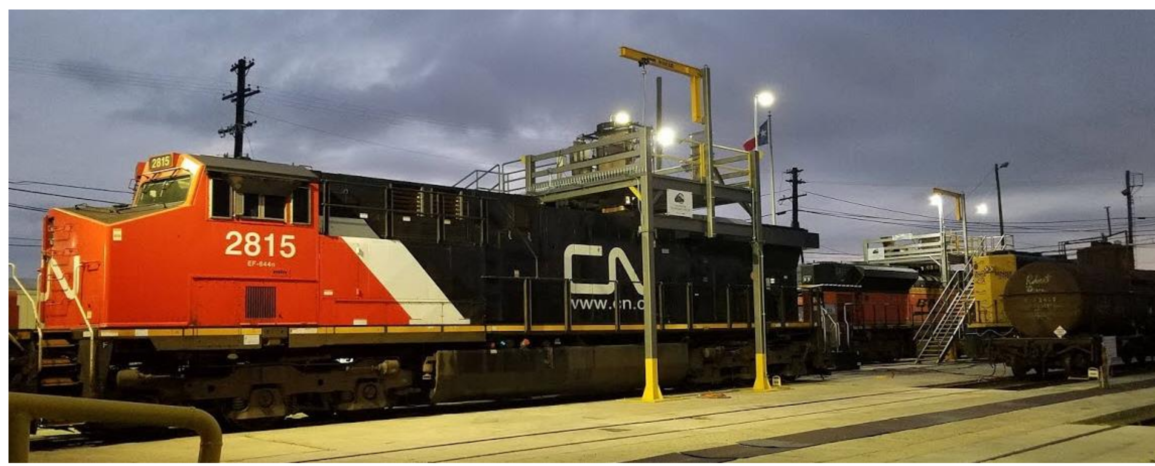
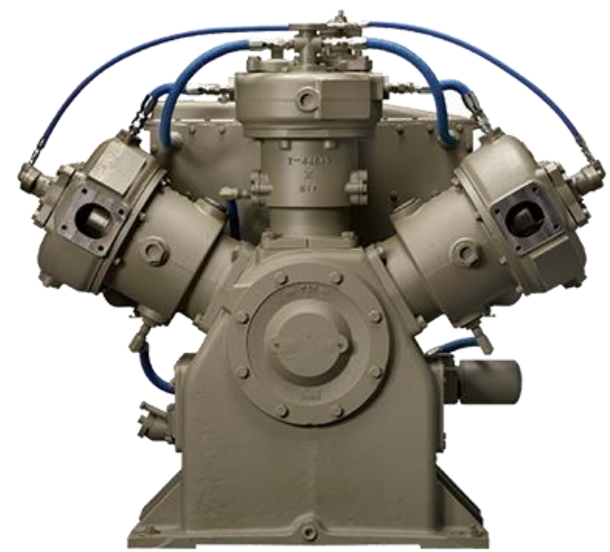
Association of American Railroads

Locomotive Technology Center
203 Milam Street

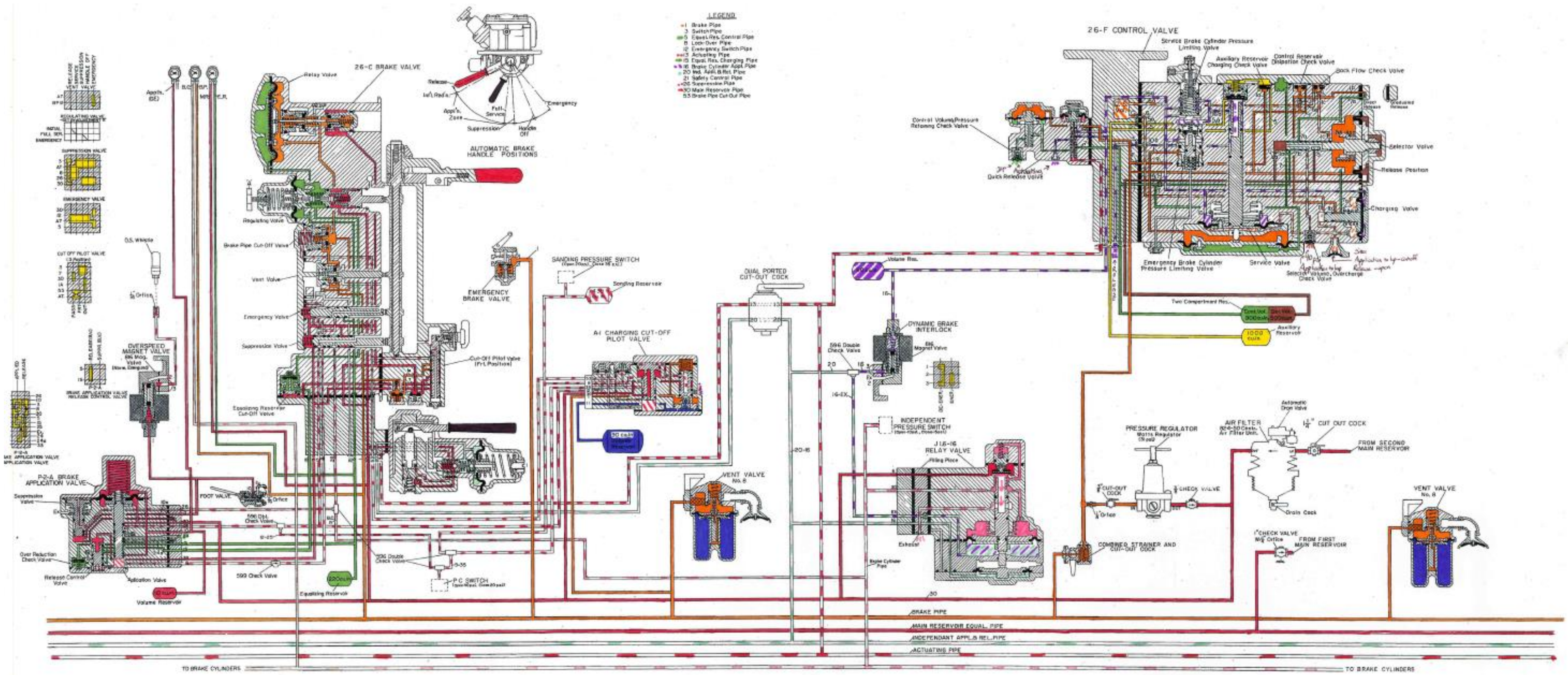


Locomotive Compressed Air Overview

- Every locomotive has an air compressor
- Those compressors are driven by the engine
  - Electric or shaft driven
- Power needed for the compressor depends on many things
  - Compressor design
  - Compressor setpoint
  - Ambient conditions
- Air used for various functions
  - Brakes, Horn, Shutters, Valve Actuation, etc.



Leaks are difficult to find.



- Trains have miles of air piping on them, including locomotives and railcars
- Air leaks are invisible and hard to detect in noisy environments with PPE
- While there are limits on some leaks, many leaks have gone ignored over the years

- Difficulty of detection and extent of the issue can make it appear insurmountable

Fuel Consumption = GHG Emissions

Railroad	SBTi Goal	% GHG from Locomotives
BNSF Railway	30% Absolute	94%
Union Pacific	26% Absolute	97.6%
CN	43% Intensity	85%*
CSX	37% Intensity	96%
NS	42% Intensity	90%
CP	38% Intensity	96%
Kansas City Southern	42% Intensity	95%

- Locomotive fuel consumption is the primary source of GHG emissions for all railroads
- Reducing fuel consumption is necessary to meet stated SBTi goals
- Fuel consumption gains can be made in many areas
  - Operational efficiency improvements
  - Locomotive efficiency improvements
  - Engine efficiency improvements

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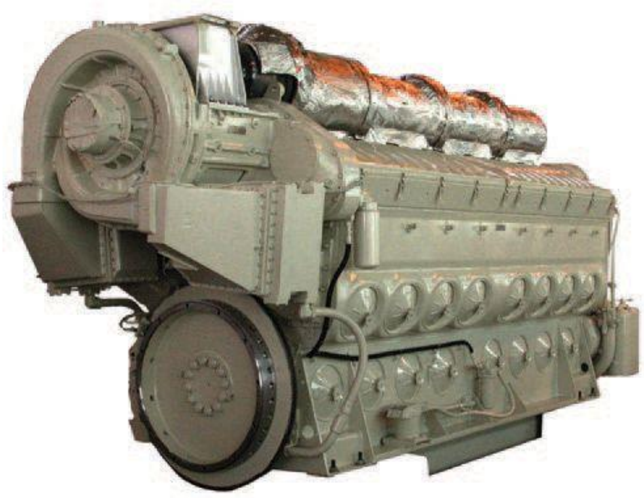
Air leaks fall in this category

Locomotive Fuel Consumption

Brake Specific Fuel Consumption

- Mass of Fuel per unit of brake horsepower
- Measure of Engine Efficiency
- Good to compare different engine models/types



Traction Specific Fuel Consumption

- Mass of Fuel per unit of traction horsepower
- Measure of Vehicle Efficiency
- Good to compare different locomotive models

How much does it matter?

Test Locomotive	Baseline LH NTSFC - Air Compressor Cut Out [lb/THP-hr]	Change in LH NSTFC - Compressor Cut In [%]	Change in LH NTSFC - 30 SCFM Brake Pipe Leak [%]	Change in LH NTSFC - 60 SCFM Brake Pipe Leak [%]
Locomotive 1	0.389	1.3%	1.6%	-
Locomotive 2	0.366	-	1.2%	-
Locomotive 3	0.352	-	2.2%	-
Locomotive 4	0.444	-	2.3%	-
Locomotive 5	0.409	1.1%	2.1%	-
Locomotive 6	0.399	-	2.2%	-
Locomotive 7	0.403	-	2.1%	5.2%
Locomotive 8	0.393	-	-	5.8%
	Average NSTFC Increase:	*1.2%*	*2.0%*	*5.5%*

Test Locomotive	Baseline SW NTSFC - Air Compressor Cut Out [lb/THP-hr]	Change in SW NSTFC - Compressor Cut In [%]	Change in SW NTSFC - 30 SCFM Brake Pipe Leak [%]	Change in SW NTSFC - 60 SCFM Brake Pipe Leak [%]
Locomotive 1	0.416	2.9%	4.1%	-
Locomotive 2	0.404	-	3.1%	-
Locomotive 3	0.398	-	4.7%	-
Locomotive 4	0.491	-	2.6%	-
Locomotive 5	0.505	2.56%	5.4%	-
Locomotive 6	0.445	-	4.9%	-
Locomotive 7	0.445	-	5.2%	14.1%
Locomotive 8	0.434	-	-	14.1%
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Most railroads operate their locomotive fleet somewhere between these two duty cycles.

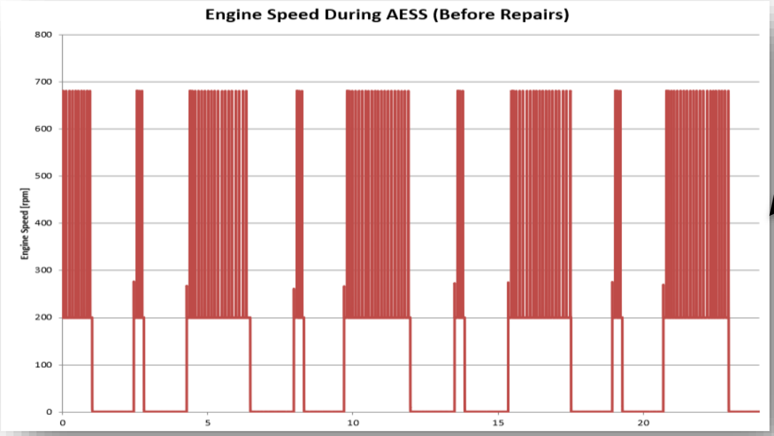
These values DO NOT include losses due to train delays, AESS restarts, etc.

Total fuel consumption penalties are likely higher.

AESS – Great, when it works

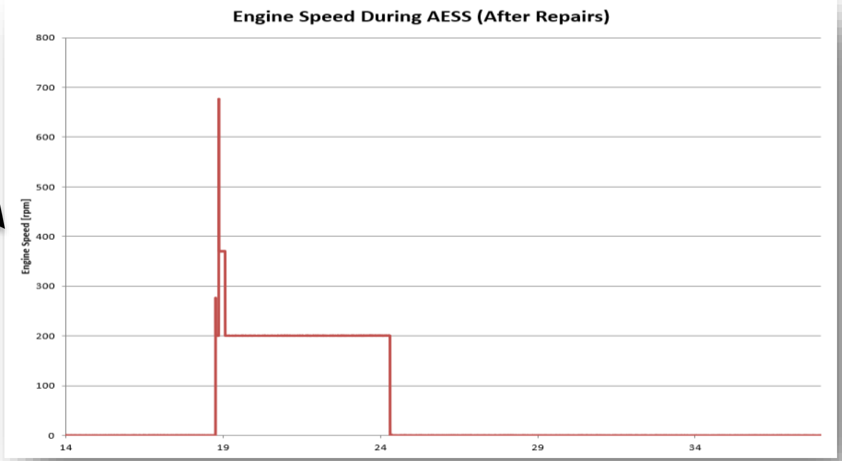
	Average Run Time Per Start [min]	Average Time Between Restarts [min]	% On Time [%]	Est. Fuel Burned (per 24hrs) [gal]	Emissions (per 24hrs) [kg CO_2]
Before Repairs	79.3	82.9	48.9%	69.6	777.6
After Repairs	260.7	1,072.3	19.6%	26.4	294.9
% change	*228.7%*	*1194.1%*	*-60.0%*	*-62.1%*	*-62.1%*

CN 8862 Before Repairs



Each graph represents 24 hours.

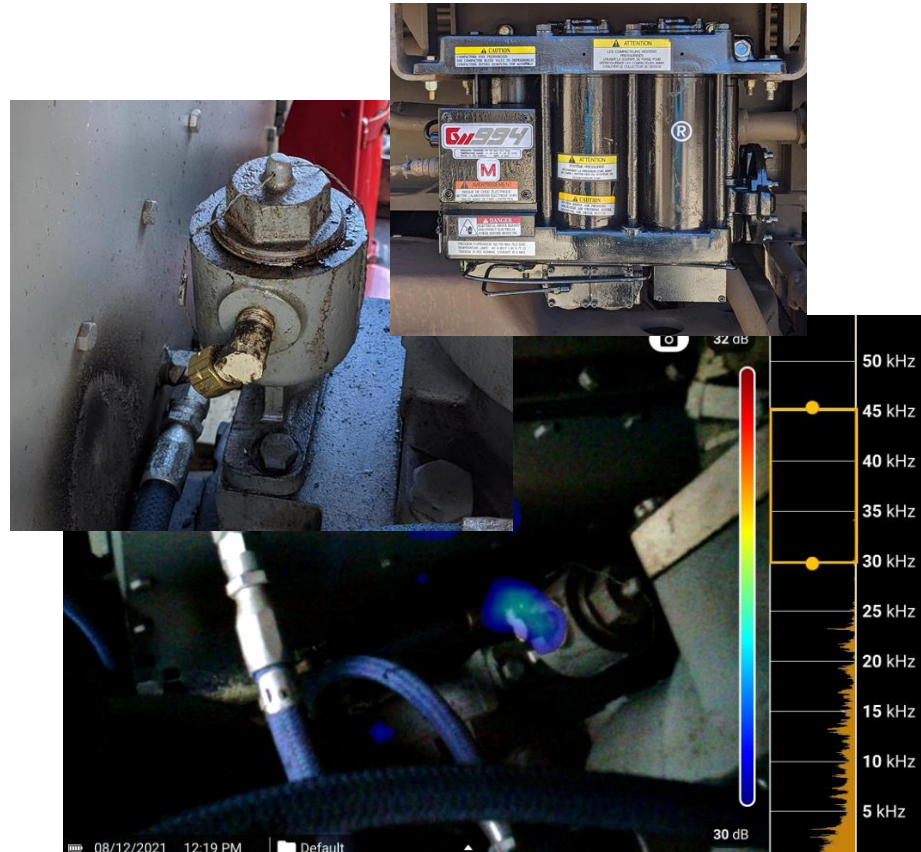
CN 8862 After Repairs



43.2 gal/day difference

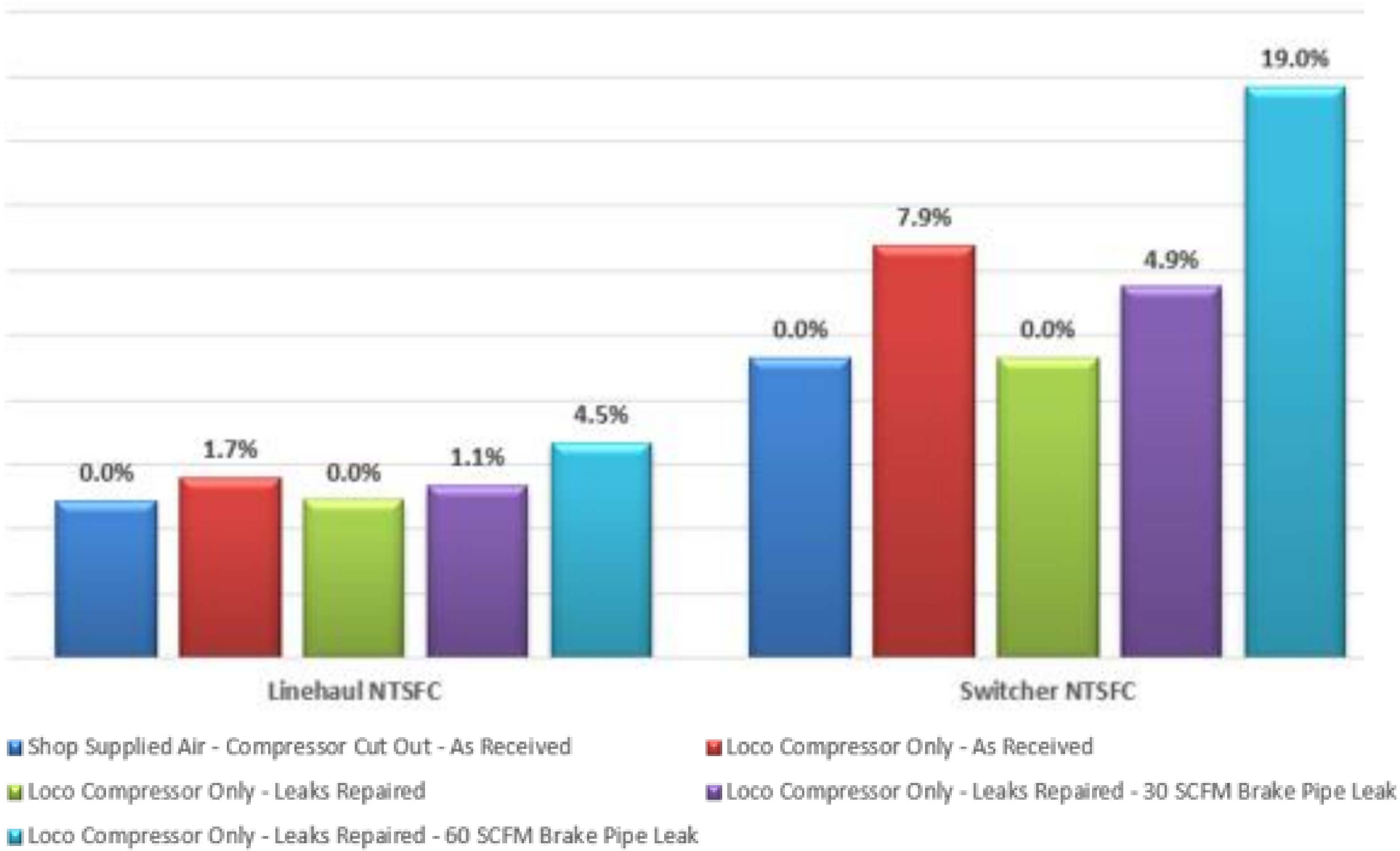
CN 8862 – Air Leaks (with approx. repair time)

1. Air Dryer – Replaced (20 min)
2. RB-MV – Fixed (10 min)
3. MR2 Pressure Sensor – Fixed (1 min)
4. MR Filter Housing – Fixed (20 min)
5. Union threads near sump – Fixed (5 min)
6. Compressor – Not Fixed
7. Shutter Mag Valve – Fixed (5 min)
8. Unloader Mag Valve – Fixed (20 min)
9. MR2 Check Valve – Replaced (2 hrs)
10. Piping on supply to Air Brake Cabinet - Fixed (60 min)



Times listed do not include time spent finding leaks

GHG Impact of Leaks



Air Leaks are Independent of Fuel Type

- Whether Biodiesel, Renewable, Natural Gas, Hydrogen, or Battery Electric…air leaks will reduce the efficiency of ALL of them.

- Overall Vehicle Efficiency needs to be a focus point for railroads moving forward on new and rebuilt locomotives
  - Even with the same engine, it can be better.

What can be done

- Mechanical requirements need to change
  - FRA leak limits are set for safety, not efficiency
  - Railroad requirements need to become more stringent
- Advanced tools and autonomous inspections
- Mechanical personnel need the time and support to start chipping away at the problem
  - It is not an issue that can be fixed in a day

- There is opportunity to work with suppliers to optimize air usage of components
  - Air Dryers
  - Mag Valves
  - Anything that uses air should be on the table.

Conclusions

- Air leaks are a significant contributor of greenhouse gas and criteria emissions for railroads
- The issue needs to be addressed and mechanical will need time and resources
- ROI of fixing air leaks is favorable due to reduction in fuel consumption
- Air leaks and other vehicle efficiency improvements are independent of fuel source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