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Cold Weather Leak Audits of Air Brake Systems

Scott Cummings and Steve Belport

Summary

Audits of leaks in the air brake systems of five trains were conducted recently in a cooperative effort of the Association of American Railroads' (AAR) Strategic Research Initiatives Program to improve brake performance and the Cold Weather Brake Technical Advisory Group (TAG) of the AAR's Brake Systems Committee. The Alaska Railroad (AKRR) hosted members of the Cold Weather Brake TAG for leak audits of three trains in sub-zero temperatures in late January 2011, and Transportation Technology Center, Inc. (TTCI) personnel conducted two audits of the Facility for Accelerated Service Testing (FAST) train at different temperatures.

The leak audits showed that careful air brake system maintenance by AKRR enables rail operations to continue safely and efficiently in cold weather. Cold temperatures seemed to have the largest effect on leakage from the valve portions and valve gaskets. Other significant sources of leaks at a variety of temperatures included glad hands and flange gaskets at the connections between the pipe bracket and reservoirs. TTCI's train leak audits at FAST showed that the quantity and severity of leaks decreases with increasing ambient air temperature. The valve portions and valve gaskets are the largest source of severe leaks in temperatures below 0°F.

Thermal contraction of steel and temperature dependent properties of gasket material act to degrade the ability of an air brake system to maintain a pressurized state during cold weather. Pressure gradient and flow rate were used to assess the leakage of each train's air brake system at steady state.

The average count of leaks per car as a function of temperature was remarkably similar to relationships established in 1975 for three of the trains audited. The average severity of each leak as a function of temperature was substantially lower than the 1975 relationships. The reasons for this have not yet been investigated.

Please contact **Scott Cummings (719) 584-0739** with questions or concerns regarding this *Technology Digest.* E-mail: scott_cummings@ttci.aar.com.

INTRODUCTION

As part of the AAR's Strategic Research Initiatives Program to improve brake performance, investigations are underway to identify the sources of leaks in the air brake system during cold weather operations. This *Technology Digest* describes the results of five leak audits that were conducted in early 2011 and compares the results to relationships established in the past.

BACKGROUND

Thermal contraction of steel and temperature dependent properties of gasket material act to degrade the ability of an air brake system to maintain a pressurized state during cold weather. The ability to effectively control the pressure in the brake system is paramount to conducting safe and efficient railroad operations. Two steady state criteria are commonly used to assess the leakage of a train's air brake system: pressure gradient and flow rate. The pressure gradient is the difference in air pressure of the train brake line between the head end locomotives and the end-of-train device. The flow rate is a measurement taken at the head end locomotives of the volume of air per unit time needed to replace any air leaking from the brake system.

Palmer summarized industry efforts to investigate system leakage as far back as 1925 up to the publishing date of 1975.[1] Data reported by Palmer shows that the brake pipe leakage (includes brake pipe, hose assembly, angle cock, and branch pipe) was the driving factor in total system leakage at or above the freezing point of water. At colder temperatures, leaks in the rest of the brake system (control valve, reservoir, etc.) increased substantially. Palmer described relationships between the number of audible leaks per car and the air flow rate per car as functions of the ambient temperature.

In March 2010, a Cold Weather Brake TAG was formed to investigate brake system and component performance issues during cold weather conditions. Below are several topics that may be addressed by this TAG highlighting brake performance differences in cold and warm weather:

- Small brake applications (approximately 10 psi) applied for several minutes seem to create stuck brake conditions
- Acceptable leakage location and magnitude limits
- End hose gaskets and leaks due to hose coupling misalignment
- Crimped hose connections
- Life cycle recommendations for flanged connection gaskets
- Cold room testing at -40°F for rebuilt valves and new and reconditioned brake cylinders
- Air signal propagation characteristics in colder weather (-40°F)
- Control of air in trains equipped with distributed power

INSPECTION FORM

The Cold Weather Brake TAG created a form (available upon request) for leak auditors to complete during an audit. The purpose of the form is to ease the documentation effort required during the audit and facilitate consistent collection and analysis of audit data. Likely sources of system leaks are illustrated and numbered, as Figure 1 shows. For each leak discovered, auditors note the car number (and in some cases, the end of the car), the number corresponding to the location of the leak, and a qualitative severity rating from 1 to 5 (5 being the most severe). The severity ratings are based on the intensity of the noise generated by the leak. Table 1 provides guidelines for the severity scale with the understanding that there are dependencies on the individual auditor and the amount of background noise.

Prior to each leak audit, appropriate hand brakes were applied and the train brake line was charged with air to approximately 90 pounds per square inch (psi). The train was allowed to reach steady state conditions and then the gradient and flow rate were recorded based on readouts in the lead locomotives. The location and severity of each audible leak was then documented for every car in the train.

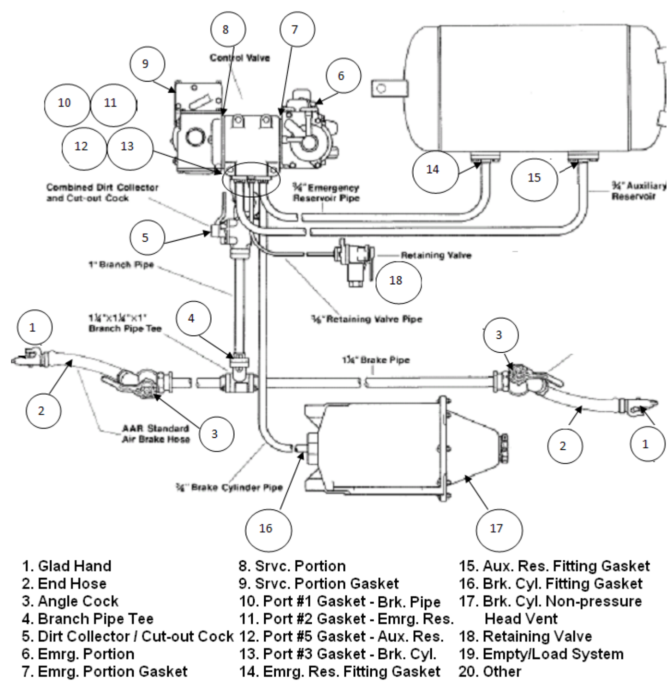

Figure 1. Inspection Locations (Graphic Courtesy of New York Air Brake)

Table 1. Leak Severity Rating Scale Used by TTCI Auditors

Leak Severity Rating	Approximate Maximum Distance at Which the Leak is Audible
1	15 ft
2	50 ft
3	100 ft
4	200 ft
5	300 ft or more

LEAK AUDIT RESULTS

AKRR hosted members of the Cold Weather Brake TAG in Fairbanks, Alaska, for leak audits of three trains in late

January 2011. At this time of year, local average daily temperatures range from -20°F to 0°F and record lows are below -60°F.[2] To illustrate the effects of cold temperatures on the brake system, AKRR provided a sample of data from 24 cars with brakes that would not apply at temperatures between -14°F and -36°F. When retested several days later at -8°F with no repairs made, the brakes applied successfully on all cars.

The Cold Weather Brake TAG conducted leak audits on three AKRR trains. Unfortunately, the weather was relatively mild (-4°F to -9°F) when the audits were conducted, and the train brake lines were not leaking substantially as evidenced by the lack of pressure gradient and flow rate.

TTCI employees conducted two additional leak audits on the train at FAST in early February 2011, to gather data that may better represent the typical condition of the air brake system of North American rolling stock. When the leak audits were conducted, the FAST train was comprised of three locomotives at the head end followed by 96 aluminum coal gondolas built in the late 1990s and equipped with truck mounted brakes. Eighteen older mixed freight cars were at the rear of the train for a total train length of approximately 6,200 feet. One of these older cars was removed from the train in the days between the two leak audits. No other changes were made to the brake system of the train between inspections. The first FAST train leak audit was conducted at -6°F during dawn hours with minimal radiant heating from the sun. The second FAST train leak audit was conducted eight days later at 28°F in full sunshine.

Figure 2 shows the locations and severity of the leaks found on the three AKRR trains. Seven of the eight leaks with severity greater than 2 were found on train number 1. Figures 3 and 4 show the severity and locations of the leaks in the first and second FAST train leak audits, respectively. The leak locations were grouped according to several main categories as follows. The first four main categories correspond to Palmer's definition of brake pipe, and the last three categories correspond to Palmer's definition of the rest of the brake system:

- Glad Hand (Location No. 1, Figure 1)
- End Hose (Location No. 2, Figure 1)
- Angle Cock (Location No. 3, Figure 1)
- Other – Brake Pipe (Locations Nos. 4-5, Figure 1)
- Valve Portions / Gaskets (Locations Nos. 6-9, Figure 1)
- Flange Gasket (Locations Nos. 10-15, Figure 1)
- Other – Brake System (Locations Nos. 16-20, Figure 1)

The brake pipe (and in particular the glad hands) account for many of the minor leaks while the remainder of the brake system accounts for a large share of the more severe leaks. Below 0°F, the majority of the severe leaks were found on the valve portions and the valve gaskets. During the warmer leak audit on the FAST train, only minor leaks were found in these locations while the most severe leaks were found at the flange gaskets between the pipe bracket and the reservoirs.

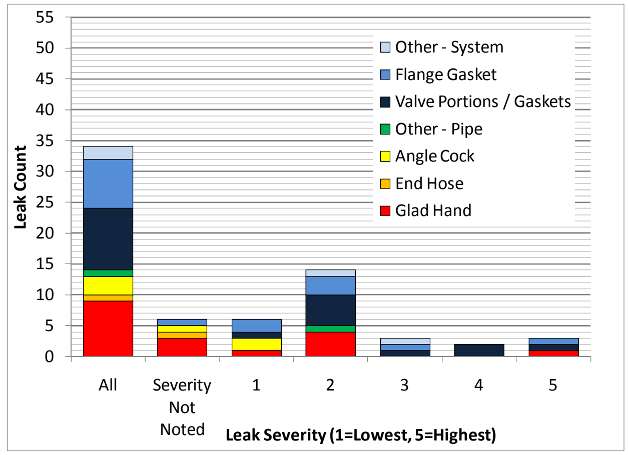

Figure 2. Leak Audit Results from Three AKRR Trains at Temperatures between -4°F and -8°F

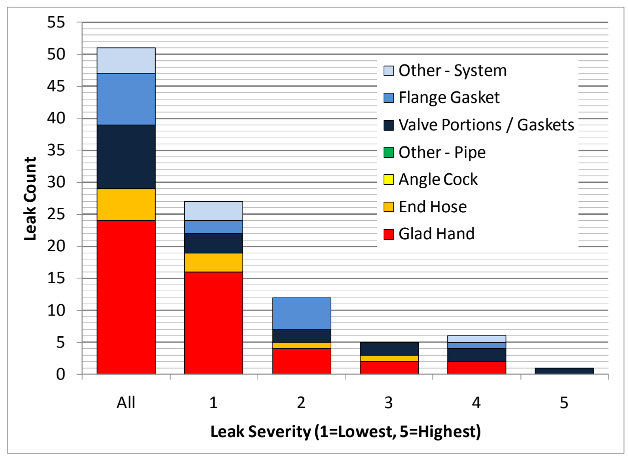

Figure 3. Results of the First FAST Train Leak Audit at -6°F

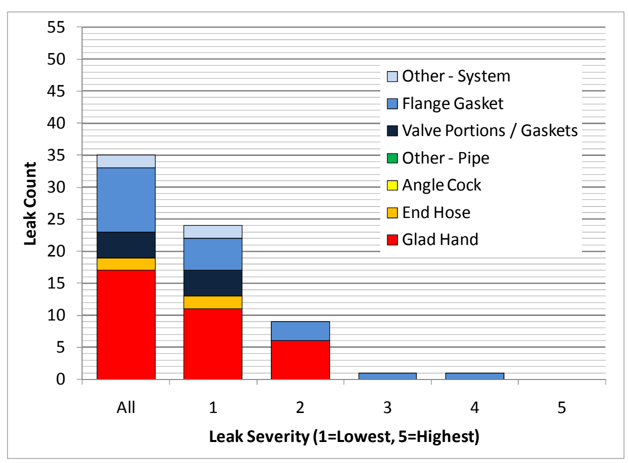

Figure 4. Results of the Second FAST Train Leak Audit at 28°F

Table 2 lists relevant details about the three AKRR trains audited and the cold and relatively warmer audits on the train at FAST.

Table 2. Train Details and Leak Results

Train Number	1	2	3	4	5
Location	AKRR	AKRR	AKRR	TTC	TTC
Car Count	51	83	66	114	113
Approximate Train Length (ft)	2,900	4,900	5,200	6,200	6,100
Air Temperature	-8°F	-4°F	-9°F	-6°F	28°F
Steady State Pressure Gradient	3 psi	2 psi	0 psi	8 psi	1 psi
Flow Rate (ft^3/min)	No Appreciable Flow Rate			65	16
Number of Leaks	22	6	7	51	35
Average Leaks / Car	0.43	0.07	0.11	0.45	0.31
Average Flow Rate per Leak (ft^3/min)	0.0	0.0	0.0	1.27	0.46
Average Flow Rate per Car (ft^3/min)	0.0	0.0	0.0	0.57	0.14

ANALYSIS

Palmer described the average number of leaks per car as a linear function of the air temperature. Figure 5 shows an approximation of this relationship and the data from these five leak audits. The first AKRR train and the FAST train are in good agreement with the Palmer brake system leakage relationship. AKRR trains 2 and 3 had far fewer leaks than expected based on the temperature. This reinforces the notion that AKRR trains 2 and 3 may not be representative of typical North American freight trains. Though exact build dates of the cars in the AKRR trains was not recorded, trains 2 and 3 were generally comprised of newer cars compared to train 1 and the FAST train.

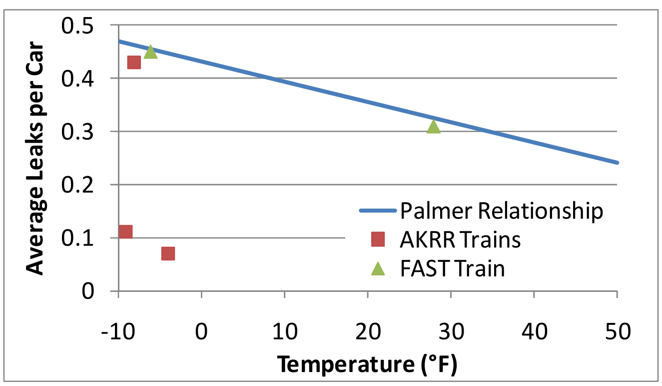

Figure 5. Leaks per Car as a Function of Temperature

Although Palmer does not specify a curve for the average flow rate per leak as a function of temperature, he does provide the information needed to generate such a curve: average leaks per car and average flow rate per car. Figure 6 shows an approximation of this relationship and the data from the five recent leak audits. Interestingly, the Palmer curve implies that on average, leaks reach a minimum severity at 20°F and are more severe at temperatures below and above this level. This is not explained in the paper and may not have been intended by Palmer. The FAST train data shows a more logical relationship of decreasing average leak flow rate as a function of increasing temperature. As temperature rises, the FAST train data shows that both the number of leaks and the average severity of each leak are reduced. The presence of audible leaks combined with a lack of an appreciable reported flow rate in all three AKRR trains does not seem to correspond well with either the Palmer relationships or the data from the FAST train.

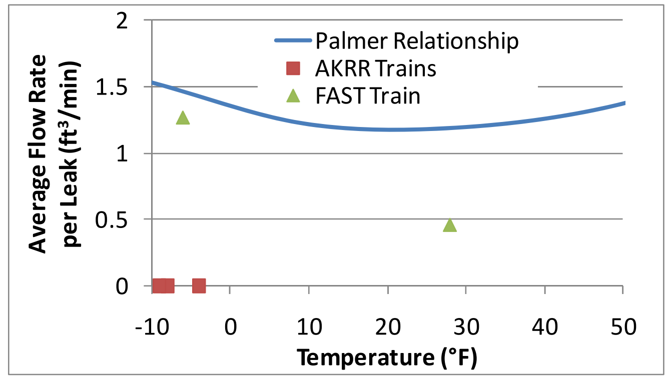

Figure 6. Flow Rate per Leak as a Function of Temperature

CONCLUSIONS

Data from five air brake system leak audits shows the following:

- The valve portions and valve gaskets are the largest source of severe leaks in temperatures below 0°F
- Glad hands are the source of many minor leaks, regardless of temperature
- Flange gaskets at the connections between the pipe bracket and reservoirs are another significant source of leaks
- The quantity and severity of leaks decreases with increasing ambient air temperature

FUTURE WORK

TTCI and the Cold Weather Brake TAG plan to conduct additional leak audits during the winter of 2011-2012 to increase the quantity of data. TTCI plans to further investigate the effects of pressure gradient and ambient temperature on individual brake valve performance.

ACKNOWLEDGEMENTS

TTCI expresses its gratitude to the AKRR for providing trains and hosting the leak auditors. The Alaskan leak audits were conducted by members of the AAR Cold Weather Brake TAG and TTCI.

REFERENCES

1. Palmer, D. E., "Brake System Leakage," *Proceedings of 67th Annual Air Brake Assoc. Meeting*, pp 38-46, 1975.
2. Based on graphical temperature data for Fairbanks International Airport from www.wunderground.com.