

APPENDIX Q
RAILROAD CARS





Modern-day locomotive



Corroded locomotive



Reconditioned railroad cars

RAILROAD CARS

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SUMMARY AND ANALYSIS OF RESULTS

Corrosion Control and Prevention

Railroad cars typically suffer from both external and internal corrosion. While external corrosion, which is primarily due to atmospheric exposure, is a concern, car appearance takes precedence. External corrosion is controlled by the application of coating systems (epoxies with or without a urethane coat) directly to metal. Certain categories of cars, particularly tank cars, are almost all leased by the shippers; therefore, the lessees often choose to apply only an exterior paint system to address aesthetics.

Internal corrosion is caused by an aggressive cargo, such as coal, sodium chloride, or various acids. The rate of corrosion has to be controlled, not only for the obvious reasons of prolonging the service life of a car, but also to prevent contamination of the transported product (e.g., food products or high-purity chemicals). Protection from internal corrosion is achieved by using coating systems or rubber linings. As an alternative, cars for certain corrosive cargo services are manufactured from corrosion-resistant materials, such as aluminum or stainless steel (raising the price of a car twofold), or undergo component upgrades (such as valves made from stainless steel rather than from carbon steel).

When it comes to corrosion, there are a limited number of regulations imposed on the industry. Tank cars are required to be periodically inspected for corrosion damage to the shell and the heads. The time frame of these inspections, the test techniques, and the acceptance criteria are left to the discretion of the owner. The most common inspection intervals for the cars transporting benign commodities are 10 years, and the cars used in an aggressive commodity service are typically inspected once every 5 years.

Based on the limited corrosion cost information, it is estimated that the total annual corrosion-related maintenance costs amount to approximately \$504 million (broken down into \$258 million for external coatings and 246 million for internal coatings and liners).

Opportunities for Improvement and Barriers to Progress

It seems that the current corrosion control practices in the industry are fairly uniform in that they are limited to replacing the exterior/interior coatings and linings as they degrade in service. Despite the availability of the more expensive and longer-lasting coating systems, which would yield lower life-cycle costs, the savings are apparently not high enough to justify the diligent care. On the other hand, the annual industry cost for new railcars is between \$1.2 billion and \$2.4 billion (although it is impossible to determine how many are bought as replacements); therefore, even a modest extension of a car's service life could result in considerable savings.

Interviews with the industry experts suggest that partially due to the perceived limited impact of the problem on revenue (less than 1 percent of revenue) and partially due to the complex ownership structure, the railroad companies and shippers do not track corrosion-related costs.

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Recommendations and Implementation Strategy

Considering that there are almost 1.5 million railroad cars in service today, there is a significant opportunity for the reduction of corrosion-related costs in the railroad car industry. In order to reduce the costs, however, the industry should first make an attempt to estimate the magnitude of the problem, which means that the costs of the exterior and interior protective systems must be documented.

Summary of Issues

Increase consciousness of corrosion costs and potential savings.	It appears that the industry is not particularly concerned with the corrosion-related costs, apparently because of the perceived insignificance in terms of cost (estimated to be less than 1 percent of the revenue). The complex ownership structure (many cars are not owned by the railroads) further complicates the tracking of the costs. Data on corrosion costs can be obtained from the protective systems manufacturers.
Change perception that nothing can be done about corrosion.	The general attitude with respect to corrosion is that it is a “nuisance”. Investments in the protective systems are regarded as a “necessary evil” and are made without giving much consideration to the life-cycle costs. If corrosion costs were tracked with more accuracy, the industry would be in a position to acknowledge the scope of the issue and would be able to realize significant savings through utilizing effective and efficient corrosion control solutions. The corrosion issues are not heavily regulated by the government.
Advance design practices for better corrosion management.	The primary focus of government regulations are on the safety of the railroad cars in the event of an accident and the cars are designed to have specific containment features (such as an outer shell for the tank cars). Corrosion is commonly addressed by constructing cars with a built-in corrosion allowance (extra thickness). The coating systems currently used for the cars are not necessarily developed for this application. Through cooperation with the coatings suppliers, the industry could explore the issue of developing protective coatings and linings specifically for the railroad cars.
Change technical practices to realize corrosion cost-savings.	To reduce the corrosion-related costs, it will be beneficial to increase the frequency of the car inspections. The potential cost-savings through early corrosion detection and prevention should, of course, be balanced with the increased expenditures of the more frequent inspections, which, as mentioned above, require the tracking of corrosion costs.
Change policies and management practices to realize corrosion cost-savings.	
Advance life prediction and performance assessment methods.	No data available.
Advance technology (research, development, and implementation).	The industry acts as the end-user of the corrosion control technology developed elsewhere (coating manufacturers). It may be beneficial to enter into closer cooperation with the protective coating producers to develop coatings specifically for the railroad cars.
Improve education and training for corrosion control.	The first step should be to assess the magnitude of the problem in the industry through accounting for the corrosion-related costs.

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SECTOR DESCRIPTION

The Class I railroads in the United States consist of freight railroads with average operating revenues of \$256.4 million or more. Class I railroad volume in 1998 was 2.21 trillion ton-km (1.38 trillion ton-mi). The U.S. railroads transported nearly 26 million carloads, including nearly 8.8 million intermodal trailers and containers. Class I railroads operated 20,261 locomotives, which hauled a fleet of 1,315,667 cars with an aggregate capacity of 127.8 million tons (140.9 million short tons). U.S. railroads owned and maintained more than 211,200 route km (132,000 route mi) in 1998. Class I railroads owned and operated 191,701 km (119,813 mi) and 156,691 km (97,932 mi), respectively.⁽¹⁾

The Association of American Railroads (AAR) has estimated that, while making up only 2 percent of American railroads, Class I railroads employed more than 89 percent of the industry workforce, operated 70 percent of the track, and generated 91 percent of the revenue in 1998.⁽¹⁾ Table 1 and table 2 summarize the make-up and use of the railroad car fleet.

Table 1. Railroad car fleet statistics (number of cars).

TYPE	TOTAL ALL OWNERS	CLASS I RAILROADS	OTHER RAILROADS	CAR COMPANIES AND SHIPPERS
Covered hoppers	382,313	151,879	21,447	208,990
Tank cars	232,425	914	37	231,474
Gondolas	197,972	114,675	17,628	65,669
Hoppers	164,506	98,014	16,598	49,894
Box cars	156,633	92,983	47,276	16,374
Plain box	26,594	1,324	11,441	13,829
Equipped box	130,039	91,659	35,835	2,545
Flat cars	143,758	89,171	13,229	41,358
Refrigerator cars	29,645	23,574	3,766	2,305
Others	8,412	4,394	1,678	2,340
TOTAL	1,472,297	668,587	168,935	634,778

Table 2. Aggregate railroad car use data (in freight car-miles).

CAR TYPE	FREIGHT CAR-MILES (x thousand)
Hopper (covered)	5,091,536
Flat	3,577,710
Box (equipped)	2,507,341
Gondola (plain)	2,374,349
Hopper (open top, general service)	2,052,092
Flat (multi-level)	2,000,852
Gondola (equipped)	1,239,295
Tank (under 22,000 gal)	1,236,102
Hopper (open top, special service)	1,222,205

Table 2. Aggregate railroad car use data (in freight car-miles) (continued).

CAR TYPE	FREIGHT CAR-MILES (x thousand)
Tank (22,000 gal and over)	1,112,346
Flat (all other)	954,520
Box (plain 50 ft and longer)	460,390
Refrigerator (non-mechanical)	378,455
All other car types (total)	373,977
Refrigerator (mechanical)	212,776
Flat (general service)	17,558
Box (plain, 40 ft)	247
TOTAL	24,811,751

1 gal = 3.96L, 1 ft = 0.305 m, 1 mi = 1.61 km

Covered hoppers make up the greatest proportion of the car fleet (28 percent) and transport the most total freight. Tank cars are the second largest segment of the railroad car fleet (18 percent), but transport a disproportionately smaller amount of the load; however, on a per car basis, both of these car types are at the bottom of the group (see table 3). Table 1 suggests that railroads own very few of the tank cars (99.6 percent are owned by the leasing companies or the shippers).

Table 3. Average annual miles per railroad car.

TYPE	MILES PER CAR (x thousand)
Flat cars	31.5
Refrigerator cars	19.9
Hoppers	19.9
Equipped box	19.3
Gondolas	18.3
Plain box	17.3
Covered hoppers	13.3
Tank cars	10.1

1 mi = 1.61 km

The types of commodities transported by the railroads are shown in table 4. Coal has traditionally been the most frequently transported commodity. In fact, it makes up approximately 27 percent of the carloads. A distant second is the chemicals and allied products category (6.5 percent).

Table 4. Volume of transported commodities.⁽¹⁾

COMMODITY GROUP	CAR LOADS (x thousand)
Coal	7,027
Chemicals and allied products	1,680
Motor vehicles and equipment	1,546
Farm products	1,404
Food and kindred products	1,282
Non-metallic minerals	1,256
Metals and products	671
Lumber and wood products	645
Waste and scrap material	581
Pulp, paper and allied products	547
Petroleum and coke	483
Stone, clay and glass products	475
Forwarder and shipper association traffic	376
Metallic ores	311
Other carloads	7,421
TOTAL CARLOADS ORIGINATED	25,705

AREAS OF MAJOR CORROSION IMPACT

The largest costs to the industry are due to corrosion of the exterior and interior of the railroad cars.

External Corrosion

External corrosion of the cars is primarily due to atmospheric exposure. While corrosion damage is still a concern, car appearance takes precedence; therefore, the car manufacturers/lessees often choose to apply an exterior paint system to address the issue of aesthetics. The paint systems are typically “direct-to-metal” (DTM) epoxy or epoxy with a urethane coat. This epoxy substrate adds protection against ultraviolet radiation.

Internal Corrosion

The most common method of internal corrosion prevention is the use of coating systems and rubber linings for internal surfaces. The use of linings and interior coatings is aimed not only at prolonging the service life of the car fleet, but also at precluding the contamination of the transported commodity by corroding metal substrate. Considering that certain types of commodities may be rather corrosive (e.g., chemicals), these corrosion prevention measures are an absolute necessity. While the largest segment of the freight has historically been coal, chemicals and allied products amount to the second largest group of transported goods, while food and kindred products make up 5 percent of transported goods (see table 4). The latter two groups of commodities are either corrosive or sensitive to contamination. Approximately 130,000 of the covered hopper cars are used for transporting plastic pellets, which require liners to preserve product purity. The liner life is 8 to 10 years.⁽²⁾

Transportation of coal presents a problem because, when mixed with moisture, it becomes highly acidic and corrosive to the carbon steel. There are indications that a large number of cars can be significantly affected by this problem.⁽²⁾ Corrosion is likely to be further advanced by the use of the thawing sheds during the winter months in

cold climates, in which the cars are heated to thaw the coal. By some estimates, there are about 100,000 cars used for coal service; therefore, the problem may be quite extensive.⁽²⁾

Another type of aggressive commodity is sodium chloride (rock salt). The cars used for transporting rock salt suffer from advanced corrosion attack and last for approximately only 3 years.⁽²⁾ The high cost of rehabilitation of salt cars (see the Corrosion Control Costs section below) created a trend toward using unlined, covered hopper cars previously utilized to transport grain for rock salt service. When corrosion becomes considerable, the cars are scrapped. Since such a process cannot continue indefinitely, more and more rock salt is expected to be hauled by trucks and barges, as the revenue seems to be insufficient to justify the corrosion-related replacement/rehabilitation costs.

In order to accommodate the properties of the cargo, in addition to the use of coatings and linings, certain components of the cars, such as valves, undergo an upgrade from the lower corrosion-resistant carbon steel to the higher resistant steel grades, such as stainless steel.

As mentioned above, rubber linings are often used for strong acids (concentrated hydrochloric, phosphoric). In cases of extremely aggressive cargoes, such as nitric acid, the entire tank car body is manufactured from stainless steel (Type 316L).

CORROSION CONTROL COSTS

The cost of external coating was estimated from the data collected through the railroad car manufacturers and leasing companies (the data is summarized in table 5). The most commonly used types of coatings are DTM epoxy and epoxy/urethane, the former being the cheaper alternative and the latter being the more expensive alternative. The cost of exterior coatings also varies for different types of cars, with an average of about \$2,500 per car. According to industry sources, the exterior coatings are typically alkyd- or epoxy-based and the expected service life is approximately 8 to 16 years.

Interior coatings can typically be found on covered hoppers and tank cars, as these tend to be used for the transporting of chemicals and other purity-sensitive products or chemically aggressive commodities. One type of internal coating is spray-applied vinyl esters, used for most types of acidic services (certain strong organic and inorganic acids), caustic commodities, salts, and oxidizers. Spray-applied, modified, cold-set epoxy coatings are typically used for preserving the product purity of such chemicals as solvents (such as benzene, alcohol, and toluene), oil products, and food. High-temperature baked epoxy coatings, due to the process through which they are applied, require that if the internal coating is to be replaced at some point, the external coating would have to be replaced as well (on the cars without external insulation).

Table 5. Corrosion-related maintenance costs for railroad cars.

RAILROAD CAR TYPE	TOTAL (ALL OWNERS)	EXTERNAL COATINGS REPAIRS, EVERY X YEARS	COST PER CAR	INTERNAL COATING/LINER REPAIRS, EVERY X YEARS	COST PER CAR
Covered hoppers	382,313	8-10 (pellet cars)	\$2,800	8-10	\$3,500
Tank cars*	232,425 sulfuric acid service	8-10	\$2,200-\$2,600	8-10	\$3,400
				4-8	\$4,300 (non-insulated)
	~10,000 rubber-lined		\$2,600	10	\$15,000

Table 5. Corrosion-related maintenance costs for railroad cars.

RAILROAD CAR TYPE	TOTAL (ALL OWNERS)	EXTERNAL COATINGS REPAIRS, EVERY X YEARS	COST PER CAR	INTERNAL COATING/LINER REPAIRS, EVERY X YEARS	COST PER CAR
Gondolas*	197,972				
Hoppers*	164,506	10 (coal service)	\$10,000 (steel replacement)		
	~50,000 lined	15-20 (food service)	\$2,000	10	\$2,500-\$3,000
		10-15 (chemical service)	\$3,000	5-10	\$2,500-\$3,500
Box cars*	156,633				
Plain box	26,594	15-20	\$2,200	15-20	\$750-\$1,000
Equipped box	130,039	10-15	\$2,500	10-15	\$1,500
Flat cars*	143,758	10-15 (auto rack)	\$6,000		
		15-20 (articulated)			
Refrigerator Cars*	29,645	8-10	\$2,500	wood interior	
Others*	8,412				

*Some information was not available.

The Code of Federal Regulations (CFR) 180.509(d) mandates that tank cars undergo periodic internal and external inspection to check for corrosion damage to the shell and the heads. Paragraph 180.509(c) dictates that the inspection intervals are determined by the next commodity to be transported by the car. The frequency of inspections, the test techniques, and the acceptance criteria are at the owner's discretion. Such intervals for the unlined/uncoated or lined/coated cars transporting benign commodities are typically 10 years. If the next transported commodity is hazardous (as defined by listing in Appendix B of DOT-E 12905), the operator/owner of an unlined/uncoated tank car has to adjust the selected inspection interval, depending on the inspection results (5-year intervals if less than half of the shell thickness reduction allowance remains). Cars can be condemned due to general or localized corrosion attack.

It is estimated that about 40 percent of the tank cars have an interior coating and 10 percent have a rubber lining.⁽³⁾ The cost of an interior coating (such as phenolic resin) is estimated to be about \$3,500 per car, with a service life ranging between 2 and 15 years before a complete overhaul is required. The cost of a rubber lining is much higher (about \$14,000 per car), with a service life of 8 to 20 years.

The cars used to transport aggressive commodities (such as the rock salt mentioned above) may require rehabilitation of the car body, which may cost between \$10,000 and \$15,000. When coupled with an additional \$6,000 for the lining and a short service life of 2 years, such rehabilitation may be considered uneconomical. The type of purchased/leased cars is dictated by the type of cargo. Regulations significantly restrict shippers from using the same car for transporting different types of commodities without cleaning the car interior (e.g., one cannot transport chemicals and food products back-to-back).

The cost of car component upgrading (such as valves and fixtures) from carbon to stainless steel is approximately \$3,000 per car. The cost of an all-stainless steel tank car increases the new car price nearly twofold, from approximately \$60,000 to approximately \$120,000.

Given the lifetime of coatings (see table 5), it was assumed that every year, on average, approximately 7 percent (once every 15 years) of the total fleet undergoes exterior coating replacement at an average cost of \$2,500 per car and 10 percent (once every 10 years) of the internally coated fleet undergoes interior coating/lining replacement at a cost of \$3,000 per car. This study estimated the annual cost of corrosion-related maintenance to be \$504 million (see table 6).

Table 6. Estimated internal and external coating costs for railroad cars.

	ALL OWNERS	FREQUENCY	COST	TOTAL COST
	quantity	% / year	\$ / application	\$ x million / year
External Coating	1,472,297	7	2,500	258
Internal Coating	821,371	10	3,000	246
TOTAL				\$504

To contrast this number with the capital expenditures on the new car fleet, some approximate estimates can be made (only for the cars owned by the Class I railroads, which effectively excludes the tank cars). With an average car cost of approximately \$30,000 and the number of purchased cars varying between 40,000 and 80,000 for the past 3 years, buying new cars costs \$1.2 billion to \$2.4 billion annually (4.3 to 8.6 percent of the operating expenses for all Class I railroads). As the cost of maintenance of the existing car fleet is small in comparison to the new car purchases, the benefits of extending the service life of an average car could be considerable.

Information regarding specific company practices with respect to corrosion control is very scarce and not easily obtainable for a variety of reasons, including lack of tracking or reluctance to release information regarded as proprietary. The data obtained suggest that current corrosion maintenance practices in the industry are fairly uniform in that they are limited to replacing the exterior/interior coatings and linings as they degrade in service. Since many of the cars are leased (almost all tank cars are), at times, the lessors replace the coatings due to aesthetic considerations. More expensive (and longer-lasting) coatings could ostensibly yield lower life-cycle costs; however, the savings are apparently not high enough to justify the diligent care, or railroad companies are simply not motivated to spend any time looking into the issue.

REFERENCES

1. Association of American Railroads data, 2000.
2. Coating industry expert, Personal Communication, June 2000.
3. Tank car leasing company executive, Personal Communication, June 2000.