DCT 251

Determination of the Impact of Heavy Axel Loads on Short Lines

By

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INTRODUCTION

Railways, to include short line and regional railroads, are coming under increasing pressure to reduce operating costs to permit them to compete more effectively and increase their level of profitability. Since the mid-1990s, Class 1 railroads have addressed this need by increasing car capacity (and weight). By increasing the capacity of the freight cars, with little or no corresponding increase in the empty or "tare" weight, it is possible to increase train capacity by 10 to 20%. In addition, the reduction in the number of cars needed to carry a fixed amount of commodity, results in a measurable decrease in the capital costs associated with car (and in many cases locomotive) acquisition, as well as reductions in operating and equipment maintenance costs, due to the reduced number of cars and trains. This led to the introduction of 36 ton axle load cars (with a gross weight on rail of 286,000 lb.) for bulk commodity traffic in the mid-1990s, with the corresponding adoption of the 286,000 lb. car limit by the Association of American Railroads (AAR) for free interchange in North America.

This trend to heavier cars was accompanied by considerable research into the costs and benefits of larger cars and heavier trains. This includes both the issues of increasing car size, through the introduction of new equipment, and the issue of increasing the loading of existing cars. Recent economic benefit studies have shown that significant operating savings exist for Class 1 railroads and shippers [1, 2, 3, and 4]. This overall benefit is in spite of increases in track and structure maintenance costs due to the increased axle loads. Experience over the past decade plus has shown that well maintained main line track with heavy rail, sound ties, and good ballast sections can support these higher axle loads, though with an increase in the "annual" maintenance costs due to greater track component damage and shortened component lives.

However, this trend to heavier cars, particularly heavy axle load cars, has serious potential impact for short lines and regional railroads. This is because short lines often operate track with light rail sections and marginal tie and ballast condition. The effect of these increased axle loads can be very significant for this type of track and railway operation. Yet many short lines are facing the requirement to accept these heavier cars from their main line connecting partners as well as from customers who want to take advantage of the economies of scale afforded by these heavier cars. The implications of this to the short line operators can be potentially very significant. This includes impact in the area of safety (and the potential for increasing number of derailments) as well as the impact of increased maintenance of way and structures costs, both operating and capital.

Overview

While Class 1 railroads have moved to 286,000-pound heavy axle load cars, to the point that it is now accepted in free interchange, the American shortline industry has been playing catch up. While the current level of track and structures on shortlines is generally adequate for traditional 263,000-pound railroad cars with 33-ton axles, it is often marginal or even inadequate for the new generation 286,000-pound cars with 36-ton axle loads. This is clearly the case in the state of Delaware where several of the major short lines, Maryland and Delaware and the Delaware Coast Line have large segments of track with light rail (e.g. 85 lb. rail) that is generally inadequate for the heavy axle load operations (this will be discussed further, later in this report). Because of customer demand, as well as pressure from the Class 1 railroads which initiate much of the traffic that ends up in Delaware, the Maryland and Delaware re-laid several of their busier line segments with heavy rail sections (130 to 136 lb./yard rail) which allowed them, in conjunction with tie and ballast work, to operate these heavier cars. However, many portions of the railroad still has light 85 lb. rail and as such operation of these heavier cars is not permitted on these line segments, despite requests from customers.

Operation of heavy axle load cars on short lines with light rail and poor tie and/or ballast conditions represents first and foremost a safety problem. This is primarily due to their increased vertical and lateral loading of the track, Thus for example, the very light 85 lb. rail experiences significant numbers of broken rails (on MD & DE the railroad reported on several of their lines 20 rail defects in 37 miles of track) with virtually no broken rails on their heavy rail segments. Likewise poor tie conditions result in wide gage conditions and poor ballast support results in track geometry deterioration all of which can result in derailments, even at the low operating speeds associated with these short lines.

From an engineering standpoint, there is no question that heavy axle loads shorten track component lives, increase the rate of degradation of the track structure, and increase the risk of derailments. However, the operating savings that can be achieved by operating fewer but larger cars, offer several benefits including;

- Need for fewer cars to transport the same volume of commodity
  - Reduced equipment capital costs
  - Possible reduction in overall car maintenance costs
- Need for fewer trains
  - Possible reduction in locomotives required
- Improved net to tare ratio (ratio of goods carried to empty car weight- see *Table 1*)
  - Reduced fuel consumption per net ton
  - Reduced train weight per ton of goods carried
- Reduction in car and locomotive miles operated
- Fewer crew starts

Whether these operating savings do, in fact, off-set the increased track and equipment costs arising out of increasing axle loads, represents the key question in any evaluation on the overall benefits (and costs) of heavy axle load equipment. The answer to this question is both service-specific and route-specific because many of the key variables that can affect the outcome are both service and route specific. Track maintenance and derailments costs are determined by the weight and type of rail, the age and condition of the ties, ballast quality, and other track parameters. Conclusions reached regarding the optimum train weight, car weight, and train length for one route are not necessarily applicable to another.

While studies have shown a net benefit of the order of 3 to 8% of total cost for heavy axle loads on Class 1 railroads, short lines, with their more marginal track and structure conditions and their lower traffic densities, may not see this net benefit. In addition to increased maintenance costs, short lines and regional railroads may incur increased capital costs associated with upgrading of marginal bridges, replacement of lighter bolted rail with heavier rail, and significant increase in ties inserted (beyond routine maintenance). There is also the potential for increase in derailments, again due to the higher level of loading associated with HAL equipment on marginal track. However, because of the significant benefits that accrue to Class 1 railroads, short lines may be required to accept these heavy axle load cars, even if overall economics of HAL equipment is not as favorable for the short lines themselves. This likewise is the case when faced with shipper pressure to allow these heavier cars.

TABLE 1

HAL Benefits

- Improved net/tare

Gross Weight on Rails (lb.)	Net to Tare Ratio
263,000	3.1
286,000	3.5
315,000	3.7

- Fewer cars needed
- Fewer car miles
- Fewer locomotives
- Fewer crew starts
- Less Fuel

Effects of Heavy Axle Load Traffic

In the area of track and structures maintenance and failure, heavy axle loads (HAL) most strongly effect MoW and Structures costs for the key track component areas to include;

- Rail and joints
- Ties and fastenings
- Ballast and surfacing
- Turnouts and special trackwork
- Bridges

This is particularly true for track with light rail sections, moderate to poor tie conditions, poor ballast, and similar conditions as common in short line railroad track. This is illustrated in Figure 1.

Figure 1: Overview of short line track condition

While the effects of HAL traffic on Class 1 railroads has been well documented in earlier studies (1, 2, 3, and 4), the effects on short lines and regional railroads has not been as well addressed. However, the following effects of HAL traffic are expected to be most important on Short Lines and Regional Railways.

Increased rail defects

Increased axle loads, particularly on lighter rail sections can result in an increased occurrence of rail defects, particularly fatigue defects as well as joint defects. The two short lines discussed here-in both have experienced rail problems on their light rail sections (85 lb. rail) under 286,000 lb. loading. This will increase with heavy axle load operations. The broken rail defects include vertical split head defects (Figure 2) , head and web separations (Figure 3) , and broken bolt holes (Figure 4) as well as broken joint bar failures (Figure 5). Note the vertical split head in 85 lb. rail shown in Figure 2 represents one of the largest classes of rail failure on the light rail sections. Thus Maryland and Delaware reported 9 broken rails requiring replacement on the Centerville Line in 2013, 12 on that line in 2012, and 14 in 2011. On their Chestertown line they reported 14 in 2012 and 16 in 2011. Maryland and Delaware Railroad also reported reports rail joint problems to include numerous broken joint bars (1 per week). In 2013 on one 16 mile long Segment, they replaced 17 rails – all 85 lb. rail and 25 bars. Joints are major problem with batter, loose bolts, surface degradation etc. Delaware Coast Line also reports 6 to 7 broken rails a year, many of which are joint related.

Figure 2: Vertical Split Head on 85 lb. rail.

Figure 3; Head and Web separation

Figure 4: Bolt Hole failure

Figure 5 Broken Joint Bar

Replacement with heavier rail represents a major capital upgrade costs that is often beyond the reach of short lines without external financial help.

Compounding the problem is the need for multiple sets of compromise joint bars due to the frequent changes in rail section. (see Figure 6)

Figure 6: Compromise Joint Bar Between two different rail sections

Increase in surface degradation

Increased axle loads can result in increased rate of track geometry degradation to include surface. Line, cross-level, warp/twist, etc. This is especially true in conjunction with poor ballast and degraded joints. Poor joints (and underlying tie condition) can increase dynamic loading and result in increased loss pf track geometry as illustrated in Figures 7 and 8.

Figure 7: Surface degradation on 85 lb. rail track


Figure 8: Surface and alignment degradation on 85 lb. rail track.

Increase in tie degradation

Tie represents still another major area of impact of heavy axle loads, with the need for good tie condition considered to be a key factor in operating heavy axle load track. Poor tie condition, to included decayed and/or missing ties, as illustrated in Figure 9, also represents a major maintenance cost area for short lines. In many cases, inadequate tie/fastener condition, particularly on curves, necessitates to the use of gage rods in lieu of good ties (often referred to as the poor man fix of weak tie/fastener condition)

Figure 9: Poor tie conditions

Increased degradation at turnouts.

Turnouts represent another major maintenance area, particularly under increasing axle loads. Turnouts with small rail sections, poor tie and ballast conditions, generally require high levels of maintenance and can be a source of major problems under heavy axle load conditions.

Bridge Upgrade or replacement

Bridges have the potential for being a major axle load liming factor on short lines, particularly bridges that are already marginal at 263,000 lb. These bridges will restrict the introduction of 286,000 lb. cars until they are upgraded to withstand the increased axle load levels. This can be a major capital cost. However, it was noted that in general, bridge condition was good on the observed short line railroads in Delaware.

Technical Discussion

The issues associated with track related heavy axle loads include two major components: capital (component) upgrade and annual maintenance costs. For the capital upgrades key decision factors include track condition and composition and traffic volume, make-up, and speed; often on segment by segment basis. They also include any bridge upgrade issues. For the maintenance costs, analysis the analysis focuses on the increase in maintenance cost as a function of axle load effect. This will be discussed later in this section. The detailed analysis methodology for both capital upgrade and maintenance cost are discussed in References 1 through 4 for main line track and 5 through 8 for short lines.

Capital Upgrade

Track

The decisions as to if and what type of capital upgrades are required usually depend on the current structure of the track and the level of heavy axle load traffic expected. Based on the user defined parameters for track characteristics and condition, a series of logic tables have been developed as discussed in references 5 and 6 in which each category of track component (rail, ties, ballast, and turnouts) is rated as to its suitability to carry 286K loads in service as well as the interaction between these components.

Each track component on each rail line is defined as:

- OK (adequate for 286K loadings)
- Marginal (replacement determined by condition of other track components or by condition of component as defined by rate of defects or failures)
- Replace (in need of replacement or improvement, regardless of condition of other components)

Thus OK, refers to the fact that the component is adequate for use under 286,000 lb. cars, though it still requires that all of the components; rails, ties and ballast be defined as OK.

Marginal refers to the fact that the component may be adequate provided the other components are all OK and that there is not a high rate of degradation/failure of the component. Thus for example, small rail section may adequate if ties and ballast are all OK and there is not a high level of defects being encountered under conventional 263,000 lb. car traffic. However, as in the case of the Maryland and Delaware Railroad, where the current 85 lb. rail is experiencing significant numbers of rail and joint defects under 263,000 car loading, use of this section would not be considered adequate even if tie and ballast condition are both OK. (Note, since MD and DE operates at between 15 and 20 mph, the rail must be replaced in any case.)

Replace, when used with respect to rail, means complete replacement. When the term “replace” is used for ties and ballast, it does not mean replacement of each component in its entirety, but rather installation of sufficient ties and/or sufficient ballast to bring track up to the minimum level appropriate for its traffic volume and operating speed.

The associated decision matrices for rails ties and ballast are presented in Tables 2, 3 and 4 respectively.

TABLE 2 Rail Matrices

Operating Speed ≤ 10 MPH

	---------------- **Traffic Density** ----------------			
Rail Size	**< 1 MGT**	**1 – 5 MGT**	**5 – 10 MGT**	**> 10 MGT**
≥ 115 lb.	OK	OK	OK	OK
100 - 114	OK	OK	OK	OK
90 - 99	OK	Marginal	Marginal	Replace rail
< 90 lb.	Marginal	Marginal	Replace rail	Replace rail

Operating Speed > 10 MPH, ≤ 25 MPH

	---------------- **Traffic Density** ----------------			
Rail Size	**< 1 MGT**	**1 – 5 MGT**	**5 – 10 MGT**	**> 10 MGT**
≥ 115 lb.	OK	OK	OK	OK
100 – 114	OK	OK	Marginal	Marginal
90 – 99	Marginal	Marginal	Replace rail	Replace rail
< 90 lb.	Replace	Replace	Replace rail	Replace rail

Operating Speed > 25 MPH

	---------------- **Traffic Density** ----------------			
Rail Size	**< 1 MGT**	**1 – 5 MGT**	**5 – 10 MGT**	**> 10 MGT**
≥ 115 lb.	OK	OK	OK	OK
100 – 114	OK	Marginal	Marginal	Replace
90 - 99	Replace	Replace	Replace	Replace rail
< 90 lb.	Replace	Replace	Replace rail	Replace rail

TABLE 3 Tie Matrices

Operating Speed ≤ 10 MPH

# Good Ties/Rail	---------------- Traffic Density ----------------			
	< 1 MGT	1 – 5 MGT	5 – 10 MGT	> 10 MGT
20	OK	OK	OK	OK
15	OK	OK	OK	OK
10	OK	Marginal	Marginal	Renew
5	Renew	Renew	Renew	Renew

Operating Speed > 10 MPH, ≤ 25 MPH

# Good Ties/Rail	---------------- Traffic Density ----------------			
	< 1 MGT	1 – 5 MGT	5 – 10 MGT	> 10 MGT
20	OK	OK	OK	OK
15	OK	OK	Marginal	Marginal
10	Marginal	Marginal	Renew	Renew
5	Renew	Renew	Renew	Renew

Operating Speed > 25 MPH

# Good Ties/Rail	---------------- Traffic Density ----------------			
	< 1 MGT	1 – 5 MGT	5 – 10 MGT	> 10 MGT
20	OK	OK	OK	OK
15	OK	Marginal	Marginal	Renew
10	Marginal	Renew	Renew	Renew
5	Renew	Renew	Renew	Renew

TABLE 4 Ballast Matrices

Operating Speed ≤ 10 MPH

Ballast Depth (Under Tie)		**---------------- Traffic Density ----------------**			
Good	**Poor**	**< 1 MGT**	**1 – 5 MGT**	**5 – 10 MGT**	**> 10 MGT**
6”	8”	OK	OK	OK	OK
4”	6”	OK	OK	OK	OK
2”	4”	OK	Marginal	Renew	Renew
None		Renew	Renew	Renew	Renew

Operating Speed > 10 MPH, ≤ 25 MPH

Ballast Depth (Under Tie)		**---------------- Traffic Density ----------------**			
Good	**Poor**	**< 1 MGT**	**1 – 5 MGT**	**5 – 10 MGT**	**> 10 MGT**
6”	8”	OK	OK	OK	OK
4”	6”	OK	OK	Marginal	Renew
2”	4”	Marginal	Renew	Renew	Renew
None		Renew	Renew	Renew	Renew

Operating Speed > 25 MPH

Ballast Depth (Under Tie)		**---------------- Traffic Density ----------------**			
Good	**Poor**	**< 1 MGT**	**1 – 5 MGT**	**5 – 10 MGT**	**> 10 MGT**
6”	8”	OK	OK	OK	OK
4”	6”	Renew	Marginal	Renewal	Renew
2”	4”	Renew	Renew	Renew	Renew
None		Renew	Renew	Renew	Renew

As a general rule, rail of less than 90 lbs. per yard is not considered adequate for 286K loads, even with good support conditions. A minimum of 10 good ties per rail length (39 feet), and at least two inches of clean, good quality ballast are the minimum support conditions required. Total tie renewal required to upgrade to 286,000lb. cars is calculated as the difference between this number and the actual number of good ties per rail length, from the input data.

For ballast, a similar process is used. A minimum of two inches of good clean ballast under the ties is required even for operations at 10 mph on the lightest-density lines, if 286K cars are to be operated. For railroads with poor ballast or no ballast, at a minimum two inches of ballast must be added. More may be required, depending on tonnage, operating speed, and ballast condition (defined as good, fair, or poor in the surveys).

Increase in Maintenance due to HAL

As noted in the previous section, even after upgrade of components to allow for increased axle loads, the can be an expected increase in track maintenance costs associated with these heavier axle loadings. This is discussed in detail in references 1 through 6 and the results summarized in Table 5 and Figure 10. Note the difference in the per axle and per MGT increases is due to the fact that under 286,000 car operation, there are fewer axles carried per MGT (due to the higher per axle loading) and as a result the actual maintenance cost increase effect is reduced because of this. Thus the per MGT column is the proper column to use in assessing the impact of increased axle loads (going from 263,000 lb. cars with 33 ton axle loads to 286,000 lb. cars with 36 ton axle loads).

TABLE 5
Heavy Axle Load Damage Factors

	Damage* (per axle)	Damage* (per MGT)
Rail Wear	+9%	0%
Rail Fatigue (internal)	+29%	+19%
Rail Fatigue (surface)	+16%	+ 7%
Rail Joints	+32%	+21%
Ties	+13%	+ 4%
Good Ballast	+9%	0%
Poor Ballast	+60%	+47%
Turnouts	+29%	+19%

*Based on 286,000 lb. car.

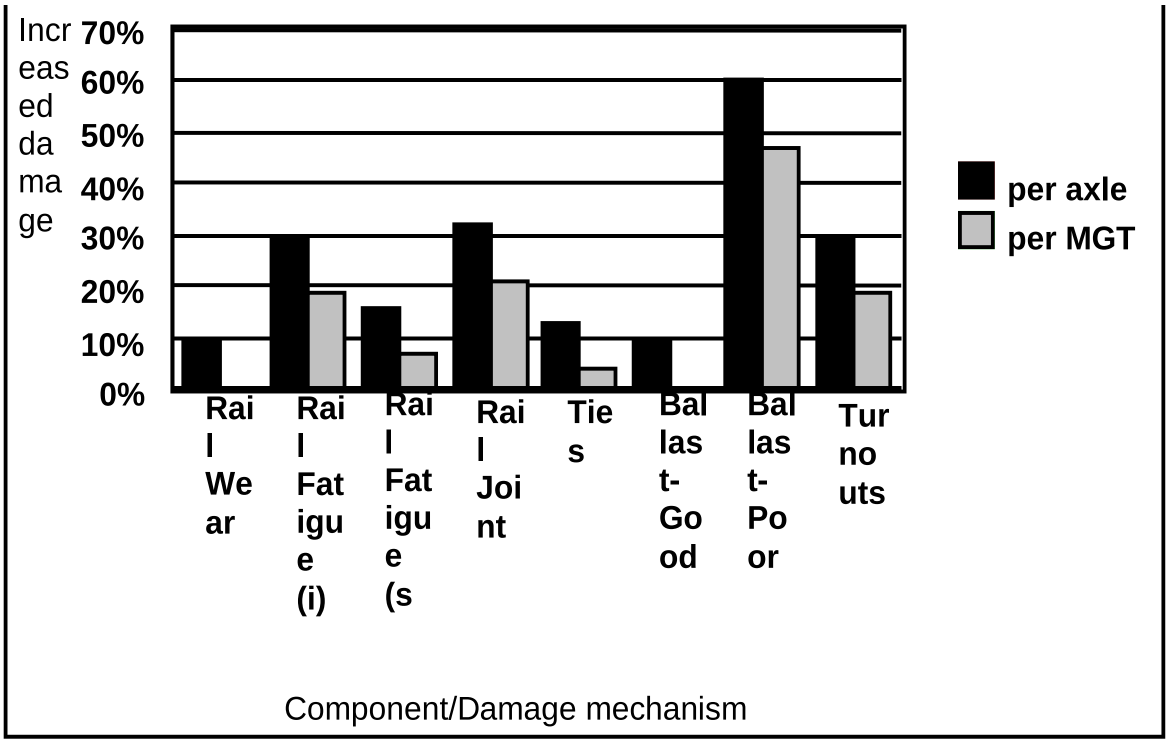

Figure 10: Heavy Axle Load damage Increases by Track Component

State of Delaware Examples

Two short lines operating in the state of Delaware were examined in detail to include field inspections and discussions with senior management. In discussions with Delaware Coast Line it was determined that the railway does not currently carry any 286,000 lb. cars and that there is no current demand from its shippers to operate these heavier cars. The Maryland and Delaware railroad however does currently operate 286,000 lb. cars on their line segments with heavier rail (130-136 lb. /yard) but does not allow operation of these heavier cars on the remaining track which is mostly 85 lb. rail. MD & DE also noted that they have received requests from shippers for operation of 286,000 lb. cars on track currently laid with 85 lb. rail, but they do not have the capital resources to upgrade the rail for this track.

The following is a summary of operating information for the two short line railroads.

Maryland & Delaware Railroad

Maryland and Delaware operates 3 route segments; all interchange with NS. Primarily Class 2 (20 mph) - on heavy rail segments or Class 1 (10 mph) on light rail segments.

Segment I- Townsend DE to Massey MD with branches continuing to Chestertown and Centerville. This segments carries approximately 1000 cars/year to include 100 heavy axle load (286K) covered hopper cars to Massey. Segment is owned by Maryland MTA but operated by MD&DE

The Townsend to Massey segment was relaid with 130-131 rail and 286K cars are allowed to operate approximately 9 miles. The rest of this segment is light 85 lb. PR/PS rail and load limit is 263K cars. About 32 miles on both branches.

They are getting shipper requests for 286K cars from shippers which include Eastman Chemical which moves about 300 tank cars/year to Chestertown (current in 263K cars) and Purdue which moves grain (covered hopper cars) and propane cars to Centertown.

Segment II- Seaford DE to Cambridge MD; carries approximately 1000 cars/year with 286K cars allowed from Seaford to Hurlock – 16 miles (130-131 rail) and 263K the rest of the way (85 lb. rail). Cars include covered hopper cars, propane tanks (mostly 263K) and box cars carrying pulp paper (500/year) to include both 286 and 263K cars. (DART paper cup company is big producer on this line). Currently about 450/year 286K cars operate on this line.

Segment III goes from Frankford DE to Snow Hill MD. Primarily 100 lb. rail, and limited to 263K cars. Currently most traffic is on the northern one mile within DE, about 100 cars/year.

Overall; carry about 2000 cars/year of which about 500 to 600 are 286K limited to heavy rail (130-131) segments

Products are agricultural products related to chicken producers (grain, corn, fertilizer, propane) plus chemicals to Eastman.

Major problems include:

Joint problems; numerous broken joint bars (1 per week). In 2013 on Segment I, replaced 17 rails – all 85 lb. (33 feet length- difficulty in getting replacement 85 rail) and 25 bars. Joints are major problem with batter, loose bolts, surface degradation etc.

This is key issues for not allowing 286K cars on 85 lb. rail segments.

They were scheduled to do their first Ultrasonic Test for rail defects (UT) test - they have history of broken rails due to those found by track inspector – but it was cancelled due to lack of funding.
Field inspection of Chestertown line from Massey MD MP 0 through MP 16 performed on 5-20-2014 with Eric Calloway and Scott Harris of MD & DE, AMZ and Ni Attoh-Okine by hy-rail truck and walking inspection

Line carries 400 to 600 cars/year on 85 rail section; weight restricted to 263,000 lb. cars (286K cars were observed on line, was told that they were light loaded to 263K. Usually 5 to 12 cars trains though up to 20 car trains.

MD&DE system power

3 RS-3 with EMD 12 cylinder engines 1200 HP
1 SW 8 cylinder 900 HP
2 CF7 16 cylinder 1500 HP

RR owns 3 Hy-rail vehicles
Rode in new MoW truck (used by track inspector/maintainer)

Line has a small amount of 130-136 rail at start, then transitions to 85 lb. rail for approximately 12 miles, and then goes to 100 lb. rail. 130-85 transition is stepped via one rail length of 100 lb. rail.

Line is mostly 85 lb. rail (100 at west end from about MP 12 on) with 6x8 wood ties ; mostly in good condition but some bad patches of ties and small size ballast; well consolidated and full cribs 6”+ shoulders. Plates are small single shoulder plates (many failing in bending) and no rail anchors. Numerous types of joint bars including large number of 65 lb. rail joint bars installed on 85 lb. rail (with gap under rail head)

Track appears to be OK maintained to the level; it is Class 2 (max speed 20 mph) but drops to Class 1 on some locations)

Primary rail defect appears to be vertical Split Head (VSH); many observed in stockpiles and on right of way; due primarily to small head of 85 lb. rail. Some broken bases also observed as well as failure from bolt hole crack. One head and Wed Separation (H&W) observed on rail with VSH as well.

Numerous joint bar conditions including cracked joint bar, loose bolts, large gaps, and a wide assortment of different joint bars on the 85 lb. rail. In some location square (opposite) joints observed instead of usual stagger).

Numerous locations of surface bent rail (at joints); with some surface defects at or approaching FRA limits, particularly approaching road or farm crossings.

Track tamped 3 times in 30 years.

Overall RR seems to make good use of limited resources.

Key issues with HAL

1. Impact at joints
2. Poor subgrade
3. Wheel/rail contact

As noted previously, there is pressure from customers to use 286,000 lb. cars.

Portion of lines upgraded to 130-136 lb. rail and currently allows HAL operations

Remainder of line either 85 lb. rail or 100 lb. rail. In both cases weight limit is 263,000 lb. cars, 286,000 lb. cars not allowed

A second track inspection was performed on June 24 2014 on the Maryland and Delaware RR Snow Hill line near Selbyville, DE.

Only the northern 4 miles of line is active, from the interchange with NS at Frankford, DE south to one customer- Pep- Up, a propane customer receiving approximately 120 cars/year (and down to the engine house in Selbyville). The customer recently upgraded their facility and built new siding and unloading facility (they can unload up to 8 cars at a time). Traffic is currently 263,000 lb. tank cars, with a 263,000 weight restriction because of rail size. The rail is 100 lb. /yd. PS or PR rail. The old customer Tyson Foods at Snow Hill is no longer using rail service (using trucks exclusively) so the rest of the line is inactive.

General condition of track:

FRA Class 1 operating at 10 mph
Rail seems to be in generally reasonable condition, not as many rail breaks as reported on the 95 lb. rail segments. The team observed one fractured rail, one broken rail base and one cracked joint bar.)
Tie condition was poor but generally within Class 1 limits.
Ballast condition had poor quality ballast and numerous line, surface cross-level and gage defects were observed but again generally within Class 1

There was an observed problem with movement of rails in direction of loaded traffic (south) and reports of sun-kinking of track due to tight joints (observed- see Figure 11). Note, tight joints, such as due to running of the rails (as observed here) creates an ‘equivalent” CWR condition that can result in track buckling or sun-kinks.


Figure 11: Observed Tight Joints

Some locations have anchors every 2 or 3 ties in direction of loaded movement. However, in the areas where significant tie movement was observed (see Figure 12), no anchors were observed. It is strongly recommended that anchors be used on this line and should be carried through the entire line. Note only need anchors on one side (North side) to prevent rail running south.


Figure 12: Significant Tie Movement Due to Running of Unanchored Rails

It was noted both on this line and on the previous inspection that bridge condition was good (though it was not clear from simple visual inspection that they are rated for 286,000 cars).

Delaware Coast Line

The Delaware Coast Line is a 21 mile short line in Southern DE with HQ in Milford DE. They operate two lines, a 15 mile line from Georgetown DE (and the NS interchange) to Lewes DE and the 6 miles Milton Industrial line to Ellendale DE where it interchange with NS.

The Georgetown-Lewes line carries approximately 470 to 540 cars per year divided between:
75-100 263,000 lb. propane tank cars
40 to 50 263,000 lb. caustic soda tank cars
330 to 400 286,000 grain covered hopper cars.

The Milton - Ellendale line carries approximately 30 263,000 lb. propane tank cars per year to one customer at the end of the line.

The major propane traffic is into the into Airport Industrial park near Georgetown while the grain traffic is to a grain transfer pit approximately two miles past the Airport Industrial park switch. The caustic soda traffic goes to the end of the line at Lewes.

Delaware Coast Line is an ICC Class 3 Railroad and is designated as and maintained to FRA Class 1 standards with a speed limit of 10 mph on the entire line. The lines are owned by the State of Delaware and DCLR railroad is contracted to operate and maintain the lines.

There have been no recent derailments on the line.

The railroad has 3 locomotives on the Georgetown-Lewes line and one switcher on the Milton Industrial line.

The entire railroad was originally 85 lb. bolted rail with some 100 lb. rail. In recent years, the segment from Georgetown to the Airport Industrial Park has been relaid with 132 RE rail. Approximately 1500 feet remains to be upgraded to 132 RE rail, of which 1000 feet is already on the right of way awaiting installation this fall and the remainder scheduled for next year.

There is a new 119 RE rail switch at the entrance to the industrial park and a new switch was also added at Milton to accommodate the propane traffic to Wilson Baker.

A field inspection of sections of both lines of the Delaware Coast Line was conducted on August 11 2014 by Dr. Zarembski of the University of Delaware, Mr. Dan Herholdt, President DCLR and David Campbell, DelDoT.

The Georgetown to Lewes line inspected from Airport Road Georgetown [NS] to Airport Industrial Park Siding switch plus an additional several hundred feet past the switch. The line is FRA Class 1 with 10 mph speed limit

As noted above, most of the line from the NS interchange at Georgetown to the Airport Industrial Park siding was upgraded from 85 lb. rail to 132 RE jointed rail. Of the remaining 1500 feet to the industrial park siding switch, 1000 out of last 1500 feet is being upgraded this fall with the rail already on right of way, as seen in Figure 13. The last 500 feet is scheduled for upgrade next year. The switch is a Number 10 119 RE switch that was in excellent condition. A new Derail was recently installed just ahead of the switch (at the recommendation of the FRA).

Overall, the track was in excellent condition In 132 RE rail section; rail, tie, and ballast were in excellent condition (Figure 13) with some limited batter at joints observed. In the 85 RE Rail Sections, to include the 1500 feet leading up to the switch and several hundred feet past the switch, the track was also good condition with good ties and ballast (Figure 14). The rail was primarily 4 hole bars but some 6 hole 85 lb. rail bars were observed. Of these six hole bars, 2 were observed with cracks in the joint bars, which will require replacement, particularly since 286,000 lb. cars operate on this segment. Note 6-hole joint bars for 85 lb. rail are subject to excessive flexure and cracking. The ties are 6x8 industrial ties, with an ongoing program of approximately 500 new ties installed per year. The fasteners are cut spikes with single shoulder tie plates. Ballast on the observed track on this line was good, with large ballast particles and minimum fines and gravel. Track geometry was very good for a Class 1 track. It was noted, that an FRA inspector recently went over the line and found no reportable defects.

Maintenance of geometry is currently performed using hand tools; all maintenance work is done by DCLR personnel.

Figure 13: Delaware Coast Line Track near Airport Industrial park with new 132 RE rail awaiting installation.

Figure 14: Segment of Track past Industrial Park Switch

DCLR indicated that they have about 6-7 broken rails year, including broken rail from bolt holes, transverse breaks, etc. All defect are on 85 lb. rail. This does not include cracked joint bars. This represents approximately 0.4 defects per mile year.

It is noted that the line currently is carrying 286,000 lb. covered hopper grain cars from NS interchange in Georgetown to a grain transfer pit approximately 2 miles past the Airport Industrial Park Switch. Approximately 330 to 400 cars per year representing approximately 0.05 to 0.1 MGT per year. All other traffic is 263,000 lb. cars.

Milton Industrial line to Ellendale [NS] is not in as good condition. The track is again 85 lb. rail with 6x8 industrial ties and poor ballast. Since there had been no traffic on this line for many years, prior to the recent opening of the Wilson Baker facility in Milton, no ties had been installed. Thus tie condition is not as good as on the Georgetown-Lewes line. Ballast condition is likewise not as good, with gravel and dirt predominating as shown in Figure 15. Tie and Ballast problems also include some locations where ties are covered with pine needles and earth (see Figure 16). However, the track does meet FRA Class 1 standards as verified by the recent FRA track inspection.

Figure 15: Segment of Milton- Ellendale line

Figure 16: Segment of Milton- Ellendale line covered with Pine Needles

Broken Rail Risk and Rail Resting

As noted in this report, broken rails, to include rails and joint bars, represent a significant problem on the lighter rail section track on both the Maryland and Delaware and the Delaware Coast Line. Neither use ultrasonic rail testing (UT) to detect defects but rather rely on inspectors, which requires the defect to be visible to the inspector, usually when it fails or breaks (through the track inspectors on both railroads have shown the ability to locate rail defects before they break and cause a derailment).

Research studies encompassing over more than two decades have shown a relationship between rail defect occurrence and broken rail derailments [9, 10]. The corresponding derailment rate was found to be one broken rail derailment for every 826 defects (based on all mainline defects), which corresponded to a derailment per defect rate of 0.0012. However, when total rail defects are examined based on how they were detected or found, i.e. between detected defects (those defects located by non-destructive inspection processes such as ultrasonic testing) and service defects (those defects located by visual inspection, observation of breaks, etc.), then the data starts to show some significant behavior.

In general on railroads that use ultrasonic testing, the distribution of defects in the two categories, ultrasonic test detected and service (detected by visual inspection) varies from 85 to 90% detected and 10 to 15% service. However, on the two Delaware short lines, the defects are 100% service (no ultrasonic testing is used) Examination of the relationship between derailments and service defects shows a well-defined linear relationship with a derailment every 120 service defects for a derailment per service defect rate of 0.0084.

Analysis of North American defect data, on primarily freight lines, indicates that the North American industry average for service defects is approximately 0.1 broken rails per mile per year. Thus guidelines for setting risk factors indicates that for general freight routes, which includes the two Delaware short lines, a service defect rate of the order of 0.09 to 0.10 defects/mile/year is the maximum that should be allowed. However, this is also based on an overall defect rate (service plus detected by UT) of 1 defect per mile per year per test. (i.e. if a line is tested once a year, it should not have more than 1 defect/mile, if it is tested every 2 years, it should have not more than 0.5 defects per mile per year).

Noting that the reported defect rate for the Delaware Coast Line is of the order of 0.4 defects/mile/year (6 to 7 defects/year over 16 miles) and for the Chestertown Line of the Maryland and Delaware is of the order of 0.85 defects/mile/year (14 defects over 16 miles), and that neither line uses ultrasonic testing, both lines have rail defect rates that are above the recommended level of service defects alone (0.1 defects/mile/year). Thus both the DCLR and the MD and DE are approaching the recommended level of total defects based on a UT test every one to two years. Note however that all of the reported defects are on the lighter rail sections, primarily 85 lb. rail.

Thus both the MD & DE and the DCLR should add ultrasonic rail testing to their rail program on a once every two year basis, under current operations. This is particularly true for the segments of 85 lb. rail that carry 286,000 cars on the DCLR. Given the high cost of bringing in an Ultrasonic Test vehicle for the limited mileage involved, it may be worthwhile for the railroads (or the states of MD and/or Delaware) to purchase a hand held walking stick rail inspection system. This will be discussed further under recommendations. In addition, a semi-annual dedicated visual walking inspection of rail and joint bars should be conducted on any segments of 85 lb. rail that carry 286,000 cars on the DCLR. This inspection should follow the recommendation of FRA 213.119 (h).

For heavy axle load operations, the use of 85 lb. rail should be avoided unless the ties and ballast are in excellent condition and the traffic level is very low. Thus, the short segment of the DCLR carrying a very low volume of 286,000 cars can operate at 10 mph speed, provided the tie, ballast and joint condition is maintained in very good condition (FRA Class 2 or better) and the recommended rail and joint bar inspections performed. Furthermore the rail defect rate must be less than 0.5 defects/mile/year. In general, for any significant level of traffic, 85 lb. rail should be replaced with heavier rail sections for 286,000 car operations, as was the case for MD & DE lines that currently allow 286,000 cars. Note again, there have been no reported rail defects on the line segments with 130 to 136 lb. rail.

Recommendations

Based on the results of the noted above, the use of light rail sections, particularly 85 lb. rail, under 286,000 car operations should be avoided for any significant level of traffic, e.g. 500 to 1000 cars a year or more. The risk of increased rail breaks and associated derailments is high based on the current level of observed rail and joint defects. Thus, in general, for any significant level of traffic, 286,000 lb. car heavy axle load operations, the current 85 lb. rail sections should be relaid with heavy rail sections. Likewise the current 100 lb. rail sections should be carefully inspected as to their current condition, and the tie and ballast condition brought up to acceptable standards, before any decision to allow heavier axle load operations be considered.

For low levels of traffic, such as currently operating on the DCLR, 286,000 cars can operate at 10 mph on 85 lb. rail provided the tie, ballast and joint condition is maintained in very good condition, comparable to the levels currently in place and the recommended rail and joint bar inspections performed. Tie, ballast and joint condition should be maintained to no less than FRA Class 2 track standards. Rail defect rate should be maintained at 0.5 defects/mile/year or less. Ultrasonic rail testing should be performed once every two years on the segments of 85 lb. rail that carry 286,000 cars. In addition, a semi-annual dedicated visual walking inspection of rail and joint bars should be conducted on any segments of 85 lb. rail that carry 286,000 cars. This inspection should follow the recommendation of FRA 213.119 (h).

Based on previous industry studies, with the upgrade to heavier rail, with good tie and ballast support, as defined in tables 2 through 4, it can be expected that an increase in maintenance costs of the order of 10 to 25% will occur, with the advent of a significant amount of HAL (286,000 lb. car) traffic. Note this increased level of maintenance will be higher with lighter rail sections. The exact increase is dependent on the percentage of traffic moving in HAL cars.

Prior to the initiation of significant levels of HAL (286,000 lb. car) operations the following actions should be taken:

- Perform a dedicated rail and joint bar walking inspection to identify any rail or joint bar defects or cracks. Replace any such identified defect or cracked joint bar.
- Upgrade joint bars and joint support (to include joint ties and ballast under joints) to match the upgraded rail sections. In addition, significant battered joints (e.g. deeper than 0.125") should be weld repaired with proper grinding and slotting of joints.
- Perform a full system rail test to include ultrasonic testing of all rails, joints, etc. with a state of the art commercial rail testing service for all line segments scheduled to see HAL operations (note this can be done via ultrasonic test vehicle or walking stick as discussed below). This includes all section relaid with heavy rail.
- Perform a full system track geometry inspection using contractor based hy-rail track geometry vehicle.
- Perform a detailed inspection of ties and fasteners, *particularly in all curves*, from the point of view of lateral track strength (resistance to rail overturning and gage widening). Special emphasis should be placed on curves with lighter rail sections and single shoulder tie plates. If locations are of questionable strength, consider testing with hi-rail track strength/track geometry test car such as currently commercially available. Sufficient ties/fasteners should be present to avoid gage widening under the operation of heavy axle load cars.

After the start of HAL operations, specific actions identified for ongoing maintenance include:

- Performance of ongoing rail testing with the frequency of testing based on number of defects found and annual tonnage levels. This is necessary because of the increased risk of rail fatigue defects associated with the HAL traffic.
    - A walking stick ultrasonic test system that can be used by one man walking along the track may be appropriate for these operations (see Figure 17).

Figure 17: Hand Pushed Walking Stick for Rail Ultrasonic Testing

- Monitor tie condition under joints carefully.
- Perform a periodic track geometry inspections of track. This is of particular importance in view of potential for joint and geometry degradation and should be performed as a minimum every second year. More frequent inspections may be necessary for higher density lines.
- Use high quality ballast for all surfacing and ballast applications. This is to reduce the rate of ballast degradation, fouling, and loss of surface, alignment and cross-level.
- Inspect and maintain joints to include adequate bolts in joint bar and maintenance of joint rail surface by weld repair with proper grinding and slotting of joints. This is of particular importance on jointed rail where HAL traffic will increase the rate of surface batter at the joints. Make sure that welding repair practice is appropriate for HAL operations, in light of the high stresses placed on the welds by the HAL equipment.
- Inspect switch points and frogs on an ongoing basis with a particular emphasis on surface condition (e.g. frog and switch point batter) geometry, and fracture of key components. Repair as necessary to include weld repair of batter. Make sure that welding repair practice is appropriate for HAL operations, in light of the high stresses placed on the welds by the HAL equipment.
- Monitor rail head surface condition to include plastic flow, spalling, shelling, micro cracking, corrugations and other surface defects.
- Consider lubrication of curves greater than four degrees to reduce rail wear.

For HAL operations on track with 85 lb. rail

- Limit maximum speed should be 10 mph
- Limit HAL traffic to less than 1000 cars per year

- Maintain tie, ballast and joint condition in very good condition, corresponding to no less than FRA Class 2 track.
- Maintain rail defect rate at 0.5 defects/mile/year or less.
- Perform ultrasonic rail testing once every two years.
- Perform a semi-annual dedicated visual walking inspection of rail and joint bars following the recommendation of FRA 213.119 (h).

REFERENCES:

1. Newman, R. R., Zarembski, A. M., Resor, R., "Burlington Northern's Economic Assessment of High Capacity/Heavy Axle Load Cars", Bulletin of the American Railway Engineering Association, Bulletin 726, Vol. 91, May 1990

2. Newman, R. R., Zarembski, A. M., Resor, R., "The Effect of Increased Axle Loads on Maintenance of Way and Train Operations on the Burlington Northern Railroad", International Heavy Haul Railways Association/Transportation Research Board Workshop", Vancouver BC June 1991.

3. Hargrove, M., "Economics of Heavy Axle Loads", Proceedings of the Workshop on Heavy Axle Loads, Pueblo, CO, October 1990.

4. Newman, R. R., Zarembski, A. M., Resor, R., "Economic Implications of Heavy Axle Loads on Equipment Design, Operations, and Maintenance", American Society of Mechanical Engineers, WAM RTD-Volume 4, Rail Transportation, December 1991.

5. Zarembski, A.M., "The Implications of Heavy Axle Load Operations for Track Maintenance on Short Lines". **American Railway Engineering Maintenance Association Annual Technical Conference, September** 2000.

6. Resor, R.R., Zarembski, A.M., & Patel, P.K., "An Estimation of the Investment in Track and Structures Needed to Handle 286,000 lb. Rail Cars on Short Line Railroads", **Transportation Research Board,** 2000.

7. Zarembski, A.M., Turner, F., "Funding Infrastructure Upgrade Needs on Short Lines", **Railway Age Magazine**, December 2001.

8. Turner, R., Zarembski, A.M., "Helping Shortlines Meet the Challenges of HAL", published **Railway Track & Structures Magazine,** November 2001.

9. Palese, Joseph W., Wright Thomas W., "Risk-Based Ultrasonic Rail Test Scheduling on Burlington Northern Santa Fe", American Railway Engineering Maintenance Association Annual Technical Conference, 2000.

10. Zarembski, A.M., Palese, J.W., "Risk Based Ultrasonic Rail Test Scheduling: Practical Applications in Europe and North America, Conference Contact Mechanics and Wear of Rail/Wheel Systems (CM2003), Gothenberg, Sweden, June 2003.

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