Anatomy of the U.S. Railway Industry – Past, Present, and Future

By

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March 10-12, 2015

Presented during Session 211 at the 2015 Purdue Road School Transportation Conference & Exposition
Early Modes of Transportation in the U.S.

- Waterways
- Crude Roads
- Rivers/Canals 1700’s
- Railroads 1830
- Better Roads
  Trucks/Automobiles early 1920’s
- Air – Passengers 1950’s
- Interstates
  Trucks/Automobiles early 1960’s
- Railroads 2000’s!!!
Common Goals & Functions of the Railroad Industry

• The movement of Freight and People in the most efficient manner possible

• Principal Function in U.S.
  • Hauling Freight (~ 45 %)

• Characteristics
  • Fast
  • Reliable
  • Convenient
  • Economical
  • Safe/Secure
  • Fuel Efficient
  • Environmentally Friendly

• Renewed Interest in Passenger Rail in the U.S. ?
Distribution of Intercity Revenue Freight Ton-Miles by Different Modes

Source: AAR from Eno Foundation for Transportation

42%
In general, railroads tend to transport high mass, low value commodities traveling a long distance.

But, increasingly high-value freight being moved via rail intermodal.

Source: 1998 data from US DOT FHWA.
Projected growth in US freight shipments

- Domestic and international freight volumes in 2020 are expected to be 67 percent and 85 percent higher, respectively, compared to 1998.

http://www.ise.msstate.edu/ncit/Research/ncitdec04/TrustworthyData.htm
Growth in US Railroad Freight Traffic 1920-2010

- US railroad freight traffic has grown steadily since the mid-20th century, and this trend has continued into the 21st century.
The Fundamental Principle of Rail Transport - EFFICIENCY

Implications for Economics, Energy & Environment
or
Why Rail Transport is More Important Than Ever!

“Must Overcome Resistance”
Rail uniquely combines speed and energy efficiency

*Plus environmentally Friendly
Rail is the principal means of economically moving large, heavy freight long distances overland.
Energy Efficiency: Truck vs. Rail

• How far can each mode transport a given amount of freight for a given amount of energy?
• Specifically, how far can we transport one ton of freight with one gallon of diesel fuel?

Rail is over 3 times more efficient than truck

(AAR & FRA data)
How many miles can one ton be transported with one gallon of fuel?

- GM Hummer: 3 miles
- Toyota Prius hybrid: 33 miles
- Semi-trailer: 130 miles
- Railroad freight train: 480 miles
Increased Public Interest in Rail

- Increased awareness of rail as a solution to congestion, pollution, and fuel inefficiency
- Increased motivation to invest public money in rail infrastructure
  - Heartland
  - CREATE
  - Green Power (Locomotives)
  - Crescent (PIP)
In the last 20 years...

- Vehicle travel increased 78%
- Road miles increased only 1%

Traffic congestion costs the U.S. $67 billion annually
Intermodal growth has been entirely in containers since the mid-1990s.

Trailer on flatcar (TOFC) traffic peaked in 1994 and has generally declined since then.
Intermodal Definition

• Intermodal Shipment: a freight shipment that moves between origin and destination using two or more modes of transportation using efficiently connected and coordinated exchanges

• Two Types of Intermodalism:
  • Bulk
  • Unitized

• Growth of Unitized Intermodal Shipments has been a spectacular trend in transportation

• Containers have Domestic and Internationally Standardized Designs
Intermodal Freight involves Multimodal Movements

Intermodal: Transportation by more than one means of conveyance (multimodal), as by truck, ship and/or rail with efficiently connected and coordinated exchanges.
Basic Types of Unitized Intermodal Equipment & Service

- Railroad intermodal transportation is typically described as either:
  - Trailer on flatcar (TOFC)
  - Container on flatcar (COFC)
- Although the early railcars used to transport these were flatcars, intermodal rolling stock has become highly specialized
- Also “RoadRailer”, is a system in which a container can ride directly on either highway or railroad wheel assembly, without any car at all
Passenger Rail Service

- **Intercity Passenger Rail**
  - Trains that move passengers between cities
  - Long distances, high speeds

- **High Speed Passenger Rail**
  - Short to medium distance intercity rail

- **Urban Rail Transit**
  - Trains that move passengers within a city/urban area OR between the suburbs and the central city
  - Several types of urban rail transit modes
Summary

• Rail Industry is growing
• Rail has become a viable alternative to truck
• Spike in Public Interest due to
  • Highway congestion issues
  • Population growth issues
  • Environmental issues
  • Fuel conservation issues
• Significant investment required to accommodate expansion of the infrastructure to increase freight and passenger growth
Summary (cont.)

- Railroads’ unique ability to provide, low-cost, high capacity rail freight is essential to a thriving economy
- Deregulation has had a significant positive effect on railroad operations – efficiency, economics, & safety
- Consolidation of resources on fewer rail lines and fewer railroads, has led to greater economies of scale and consequent better performance and more efficient freight rail transportation
- Railroads are able to extract greater value from their infrastructure by increasing railcar size, capacity and corresponding axle loads
- Intermodal has begun to eclipse certain traditional bulk freight, notably coal, that has been the basis of rail traffic for over a century
- Intermodalism, especially use of containers, has experienced dramatic growth as the US participates more and more in the global economy
Summary (cont.)

- Railroads provide sustainable mobility because of their inherent efficiency compared to highway transport.
- Strength and rigidity of steel wheel on steel rail supported by robust infrastructure enables much larger, heavier railcars and locomotives, and consequent economies of scale.
- Low rolling resistance enables very low power to move very large loads.
- Fixed guideway system enables trains, which further enhance potential economies of scale.
- These efficiencies lead to compelling economic, energy and environmental benefits.
- Ironically, rail efficiency also poses certain challenges to railroads – congestion on high tonnage mainlines.
Overview of Railway Operations
By
John K. Secor

The 30,000 Foot View
For years the railroads have made a point to remove themselves from public view.

Consequently there is little public understanding of how they work and their importance in the transportation network of the United States.
• Railroads were America’s First Large Corporations
• Had a Monopoly on Transportation
• Heavily Regulated thru 1970s until the Staggers Act of 1980
• U.S. Railroads Privately Owned (vs. government owned)
• U.S. Railroads are Primarily Freight
• U.S. Rail Passenger Service is Heavily Subsidized by the Public
Early Regulation

Land Grants (1850-1870)
- Railroad Acts of 1862 & 1864
- Development of Central and Western U.S.
- Emphasis on a Transcontinental Railroad

Interstate Commerce Commission (1887)

Surface Transportation Board (1995)
Recent Legislation

Passenger
• 1971 Amtrak

Freight
• 1973 3R Act
• 1976 4R Act
• 1980 Staggers (Deregulation)

Multi-Modal
• 1992 ISTEA
• 1998 T21
• 2004 SAFETEA-LU
• 2008 Safety Improvements
• 2010 Surface Transportation Assistance Act (MAP 21 – Moving Ahead Progress)
## Classification of Railroad Companies

<table>
<thead>
<tr>
<th>Class I</th>
<th>Greater than $470 Million Gross Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class II or Regional Railroad</td>
<td>Greater than $38 Million but less than $470 Million Gross Revenue or more than 350 Track Miles</td>
</tr>
<tr>
<td>Class III or Shortline</td>
<td>Less than $38 Million Gross Revenue</td>
</tr>
</tbody>
</table>

*Class of Railroad not to be confused with Class of Track*
The Changing Face of the Railroad Industry – Through the Years

From Railroad Facts 2013, Association of American Railroads

1929 to 2012
- Revenue Ton-Miles Increased 3.8 Times
- Length of Haul Increased 2.9 Times
- Net Ton-Miles/Train Hours Increased 6.7 Times
- Revenue Ton-Miles/Employee Increased 35 Times

2012 to 1929
- Only 12.5% of Employees Today (180,000 vs 1.4 Million)
- Only 42% as many Miles of Track Today (233,000 vs 550,000)
- Only 43% as many Locomotives Today (21,000 vs 48,000)
- Only 50% as Many Freight Cars Today (1.5 vs 3 Million)
## Decline of the Large Railroads

<table>
<thead>
<tr>
<th>Timeline</th>
<th>No. of Class I’s</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950-59</td>
<td>127</td>
</tr>
<tr>
<td>1960-69</td>
<td>102</td>
</tr>
<tr>
<td>1970-79</td>
<td>58</td>
</tr>
<tr>
<td>1980-89</td>
<td>15</td>
</tr>
<tr>
<td>1990-2000</td>
<td>11</td>
</tr>
<tr>
<td>2000-Present</td>
<td>7</td>
</tr>
</tbody>
</table>
Railroad Companies by Class

Class I  7

BNSF Railway  CSX Transportation  Norfolk Southern  Union Pacific

Class II (or Regionals)  30

Class III (or Shortline, Terminal or Switching)  500+
Organizational Structure

General Survey Act of 1824

War Department Engineers Survey B&O Railroad 1827

Manpower Needs of Building a Railroad Created a Need for Chain of Command

Military Type Divisional Structure Adopted
Operating Department

Over Half of Railroad Employees are in the Operating Department

- Run Trains - Over the Road, Yards/Terminals, and Local
- Mechanical – Locomotive and Freight Car Maintenance
- Responsible for the safe operation of trains

Conductors- Brakemen-Switchmen-Engineers-Hostlers-Carmen-Mechanics
<table>
<thead>
<tr>
<th>Document</th>
<th>Example of Content</th>
<th>Addressee</th>
<th>Effective Time Span</th>
<th>Authority Of</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train Order or Track Warrant</td>
<td>Extra 221 North take siding and Meet Extra 4703 South at Fred</td>
<td>Conductor and Engineer of Affected Train</td>
<td>From Issue Until Fulfilled</td>
<td>Dispatcher/Operator</td>
</tr>
<tr>
<td>General Order or Bulletin Order</td>
<td>Temporary Slow Orders/ Schedule Modifications</td>
<td>All Train Service Employees</td>
<td>From Issue until Termination or Incorporation into Timetable</td>
<td>Superintendent/Train master</td>
</tr>
<tr>
<td>Timetable</td>
<td>Schedules, Special Instructions, Speed Restrictions, Signal Indications, Class and Superiority of Trains</td>
<td>All Employees Concerned with Train Operations</td>
<td>From Effective Date &amp; Time Until Next Timetable Issuance</td>
<td>Superintendent/General Manager</td>
</tr>
<tr>
<td>Book of Rules</td>
<td>General Rules, Operating Rules, Timetable, Signal Aspects, Hand &amp; Whistle Signals, Duties of Employees</td>
<td>All Operating Department Employees</td>
<td>Until Modified</td>
<td>VP/Manager of Operations</td>
</tr>
</tbody>
</table>
Engineers Operate the Train

Conductors are in Charge of the Train
The Evolution of the Train Crew

**The Five Man Crew**
Conductor, Engineer, Fireman, Head Brakeman & Rear Brakeman

**The Four Man Crew**
Conductor, Engineer, Head Brakeman & Rear Brakeman (Elimination of Steam Engines ’50-60’s)

**The Three Man Crew**
Conductor, Engineer & Brakeman (Introduction of radios 70’s)

**The Two Man Crew**
Conductor & Engineer (Rear-end devices 80’s)

**The One Man Crew**
Engineer/Remote Control Operator (Currently)
Rail Yards & Facilities

- Industry Yards
- Flat Yards
- Hump Yards
- Depots
- Towers
- Engine Facilities
- Dispatch Centers
- Administration
Right Equipment at the Right Place
Owner’s Rights vs. User’s Rights

Return on Investment
Car Hire Deprescription vs. Prescription

Repairs
Owner’s Responsibility vs. User’s Obligation

Car Hire Settlements
Honor System for Usage
Multiple Unit Control

- Nearly all modern locomotives (electric and diesel electric powered) are capable of "multiple unit" control
- The control circuits can be electrically connected so that a single operator can control multiple locomotives
- This allows power to be matched to the requirements of any size train to maximize either efficiency or speed
- This concept has been extended through the use of radio-controlled "slave" units distributed through the train.
- "Distributed power" is particularly useful for heavy freight trains because it enables longer trains and better control, particularly on grades.
Distributed Power
Remote Control Operation
Train Control

Track Warrant Control – Dark Territory
Direct Traffic Control – DTC
Automatic Block System – ABS
Centralized Traffic Control – CTC
Yard Limits

Automatic Train Control – ATC
Cab Signals
Automatic Block System Signals (ABS)
Centralized Traffic Control (CTC)

- One or more main tracks signaled for traffic in both directions
- Movement authority is conveyed by signal system not train orders
- Train dispatcher controls switches and signals from distant location
Automatic Train Control (ATC) Operation

• All wayside signal indications are displayed in the locomotive cab

• When locomotive passes a flashing yellow signal, an alarm sounds and the engineer has six (6) seconds to acknowledge or the brakes will be applied.

• The engineer then has seventy (70) seconds to reduce to 20mph or less, or the brakes will be applied.

• Once the train is under 20mph no further enforcement is applied

• Train separation provided by train crew and signal system assisted by speed control
Cab Signals

View from inside locomotive cab
Recent Legislation

Passenger
• 1971 Amtrak

Freight
• 1973 3R Act (Penn Central)
• 1976 4R Act (Conrail)
• 1980 Staggers (Deregulation)

Multi-Modal
• 1992 ISTEA
• 1998 T21
• 2004 SAFETEA-LU
• **2008 Safety Improvements**
• 2010 Surface Transportation Assistance Act
  (MAP 21 – Moving Ahead Progress)
Rail Safety Improvement Act of 2008 mandates installation of positive train control (PTC) on:

- All mainlines over which operate regularly-scheduled commuter or intercity passenger trains
- Mainlines of Class I freight carriers over which Toxic Inhalation Hazardous (TIH) materials are handled
- Such other lines as designated by the Secretary of Transportation
Positive Train Control

PTC is Designed to Prevent:

- Train to Train Collisions
- Over Speed Derailments
- Incursions into Established Work Zone Limits
- Movement of Train through a Switch Left in the Wrong Position
- Preventing Human Error (Accountable for 40% of all Accidents)

Railroad Investment

$4.5 BILLION Thru Mid 2014

$9.0 BILLION Estimated to Complete
Looking Forward

Mergers
Crude by Rail
High Speed Rail
Re-Regulation
Industry Turnover
Crude By Rail
High Speed Rail

US High Speed Rail Association

220-mph HSR Lines
110-mph Rail Lines

2015
2020
2025
2030
Re-Regulation of the Rail Industry

- Repeal Railroads’ Antitrust Immunity
- Require Railroads to Provide Transportation Rates
- Eliminate Competition Barriers between Class I, II & III Carriers
- Improve Rate Reasonableness Standard
- Required Arbitration of Railroad Disputes
- Authorize STB to Investigate & Suspend Certain Railroad Actions
Industry Turnover

Aging Workforce - Baby Boomer Bombshell
30% or Higher Attrition Level in Next Five Years (80,000 of 180,000)

Millennials
Different Expectations of Workplace Norms (No 24/7/365)

Regulation
Workforce Hours of Service & Rest Periods (Continued Legislation)

Technology
Requires a Different Type of Workforce (Computer Skills)

Skilled Workers
Inventory of Skilled Replacement Workers Low (Electricians, etc)
Overview of Railway Engineering (Infrastructure)

Jerry G. Rose, PE
University of Kentucky
Department of Civil Engineering

- Roadway and Track
- Drainage Structures
  - Bridges
  - Culverts and Pipes
- Tunnels
- Terminals/Yards and Ports
- Buildings
- Environmental Facilities
- Signal Structures and Detectors
- Communications Structures
Major Rail-Related Agencies/Groups

**AREMA** – American Railway Engineering and Maintenance-of-Way Association
  - Technical society, individual professional members, primarily publishes Recommended Practices and other technical literature

**AAR** – Association of American Railroads
  - Composed primarily of Railroad Companies that represent the industry in many ways, mainly large Class I railroads

**ASLRRA** – American Short Line and Regional Railroad Association
  - Similar to AAR for Short Line and Regional RR Companies

**FRA** – Federal Railroad Administration
  - Part of USDOT, mainly promulgates and enforces railway safety regulations

**STB** – Surface Transportation Board
  - Part of USDOT, mainly and economic regulatory agency
MANUAL FOR RAILWAY ENGINEERING

Volume 1
Track
- Ch. 1 - Roadway & Ballast
- Ch. 4 - Rail
- Ch. 5 - Track
- Ch. 30 - Ties

Volume 2
Structures
- Ch. 7 - Timber Structures
- Ch. 8 - Concrete Structures & Foundations
- Ch. 9 - Seismic Design for Railway Structures
- Ch. 15 - Steel Structures

Volume 3
Infrastructure and Passenger
- Commuter, Transit & High Speed Rail
- Ch. 6 - Buildings & Support Facilities
- Ch. 11 - Commuter and Intercity Rail Systems
- Ch. 12 - Rail Transit
- Ch. 14 - Yards and Terminals
- Ch. 17 - High Speed Rail Systems
- Ch. 18 - Light Density and Short Line Railways
- Ch. 27 - Maintenance-of-Way Work Equipment
- Ch. 33 - Electrical Energy Utilization

Volume 4
Systems Management
- Ch. 2 - Track Measuring Systems
- Ch. 13 - Environmental
- Ch. 16 - Economics of Railway Engineering and Operations
- Ch. 28 - Clearances
- AAR Scale Handbook

www.arema.org
Engineering Department’s 4 Sub Departments

- Engineering Cost & Systems (EC&S)
- Design & Construction (D&C)
- Communications & Signals (C&S)
- Maintenance of Way & Structures (MW&S)
I. Roadway and Track
Track Functions

- Guide vehicles

- Provide a high vehicle ride quality

- Withstand and distribute loadings
  - Static (36 tons/axle)
  - Dynamic (Impact)
Railroad track is designed to be economical and easy to maintain. Constantly evaluating Alternatives. Benefits compared to Additional Costs.
### FRA Classes of Track

**Part 213 -- Subparts A to F for Class 1-5, Subpart G for Class 6-9**

<table>
<thead>
<tr>
<th>Over track that meets all of the requirements prescribed in this part for—</th>
<th>The maximum allowable operating speed for freight trains is—</th>
<th>The maximum allowable operating speed for passenger—trains is—</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excepted track.</td>
<td>10</td>
<td>N/A</td>
</tr>
<tr>
<td>Class 1 track.</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Class 2 track.</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>Class 3 track.</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>Class 4 track</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>Class 5 track</td>
<td>80</td>
<td>90</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Over track that meets all of the requirements prescribed in this subpart for—</th>
<th>The maximum allowable operating speed for trains¹ is—</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 6 track</td>
<td>110 m.p.h.</td>
</tr>
<tr>
<td>Class 7 track</td>
<td>125 m.p.h.</td>
</tr>
<tr>
<td>Class 8 track</td>
<td>160 m.p.h.²</td>
</tr>
<tr>
<td>Class 9 track</td>
<td>200 m.p.h.</td>
</tr>
</tbody>
</table>

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¹ The maximum allowable operating speed for trains is the speed at which trains may operate without exceeding the maximum limits specified in the subparts of this part.

² The maximum allowable operating speed for Class 8 and Class 9 tracks is subject to additional safety considerations.
The contact “patch” is about the size of a dime

= 0.50 in²
Static Wheel Loads

(Wheel Load)(# of wheels) = Gross Weight of Car

<table>
<thead>
<tr>
<th>Axle Load (tons)</th>
<th>Gross weight of cars (lbs)</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>80,000</td>
<td>Light rail transit</td>
</tr>
<tr>
<td>15</td>
<td>120,000</td>
<td>Heavy rail transit</td>
</tr>
<tr>
<td>25</td>
<td>200,000</td>
<td>Passenger Cars</td>
</tr>
<tr>
<td>25</td>
<td>200,000</td>
<td>Common European freight limit</td>
</tr>
<tr>
<td>27.5</td>
<td>220,000</td>
<td>U.K. and Select European limit</td>
</tr>
<tr>
<td>33</td>
<td>263,000</td>
<td>North American free interchange limit</td>
</tr>
<tr>
<td>36</td>
<td>286,000</td>
<td>Current Heavy Axle load weight for North American Class 1</td>
</tr>
<tr>
<td>39</td>
<td>315,000</td>
<td>Very limited use; research phase</td>
</tr>
</tbody>
</table>

Heavy Tonnage Freight
Track

Track is a dynamic system of interacting components that distributes the loads and provides a smooth, stable running surface for rail vehicles.

System must provide **vertical, lateral and longitudinal stability**.
Track Design and Construction

Desirable Attributes:

- ✓ Balance Stiffness and Resiliency
- ✓ Resistance to Permanent Deformation
- ✓ Stability
- ✓ Adjustability
Clearing, Site Preparation, and Installation of Erosion/Sediment Control

Grades

0% Ideal
<0.25% Gentle
0.25-0.75% Moderate
0.75-1.5% Heavy
>1.5% Severe
Mass Excavation and Installation of Drainage Structures

Curves

- $D < 2^\circ$
- $2^\circ \leq D < 8^\circ$
- $8^\circ \leq D < 12^\circ$
- $D \geq 12^\circ$

Mild
Medium
Sharp
Extreme
Roadbed (Subgrade) Fine Grading and Sub-ballast Placement
Track Construction
Unloading Ballast

Skeleton Track
Ready for Ballast
Tamper Pulling Track
Complete – Ready for Service
Trackbed/Roadbed Layers

Function as a System

- Ballast --
- Subballast --
- Subgrade --

Support the Track and the Imposed Loadings
**Ballast**
- Supports the Track
- Distributes the Loadings to the Subballast
- Protects the Subballast*
- Provides Resilience
- Anchors the Track
- Provides Adjustability
- Drains the Track

**Subballast**
- Supports the Ballast
- Distributes the Loadings to the Subgrade
- Protects the Subgrade*
- Separates the Ballast from the Subgrade
- Waterproofs the Subgrade

**Subgrade**
- Supports the Subballast
- Distributes the Loadings to the Roadbed
- Assists in Drainage

*Indicates a supporting role in the structure of the railway track.
Track Settlement and Pumping

Surface Problem (Cross level)
Profile Trouble Spots
Fouled, Muddy, Pumping Track
Types of Ties (Sleepers)

- Timber (Wood)
- Prestressed Concrete
- Composite (Polymeric)
- Steel
Wood (common)
Concrete (gaining popularity and use)
Wood Railroad Ties

Common Size
- 9 in. wide
- 7 in. thick
- 8.5 – 9 ft. long

Purpose
- Hold the 2 rails transversely secure to correct gage
- Bear and transmit axle loads with decreased pressure
- Anchor the track
Protections Against Mechanical Wear

- Tie plates
- Anti-Splitting devices
- Keep tie dry (rail seat)
- Use plate holding spikes or premium fasteners
Wood Tie Replacement Process

- Ties first marked for replacement
- Automated
- Accomplished by a "tie gang"

Production

- 800 per mile
- 4 miles per day
• ~ 3 times heavier than wood ties,
• More expensive than wood ties
• Pre-cast, Pre-Stressed, fastenings embedded
Alternate Concrete Tie

Two-Block or Bi-Block

Figure 23.4. Two-block (RS-type) tie.
Concrete Slab Track – Direct Fixation
Bolted Rail /Joints versus Continuously Welded Rail (CWR)  
~ $250,000/mile
Rail specifications are maintained by AREMA
Rail size is measured in lbs./yard of length
Most common new rail is 115 lb., 136 lb.*, & 141 lb.
Type – Standard, Intermediate*, Premium
Types of Steel Rail

- Standard Medium Carbon
- Head Hardened
- Fully Heat Treated
- Also Hi Si, CHRO/MOLY and Bainitic
133-lb rail, meeting AREMA specs, head hardened, vacuum treated, NKK Company, rolled in 1996–Mar

stamped heat number, etc.
Continuously Welded Rail (CWR)

- 1440 ft. sections
- Advantages
  - Many
- Disadvantages
  - Few
Largest and Premium Rail for:

- Heaviest Volumes
- Heaviest Loadings
- Highest Speeds
- High Degree Curves & Steep Grades
- Where Safety is a Priority
CWR Maintenance

- Need Adequate Ballast Restraint
- Should Anchor Slightly Above Mean Annual Temperature
- Don’t Disturb in Hot Temp.
- Broken Rail in Cold Temp.
- Buckled Track in Hot Temp.
No more “clickety clack”
Most North American mainline track is now made of “continuously welded rail” (CWR)
Eliminates dynamic loads at joints
Improves ride, reduces maintenance requirements and extends roadbed and other track component life
Improving the Life of Rail

- Curve Reduction
- Rail Lubrication
  - Top of Rail
  - Gage Face
- Rail Grinding
- Improved Rail Quality
- Defect Detection
Rail Testing

- Magnetic Induction
- Ultrasonic
Rail Defects and Failure

<table>
<thead>
<tr>
<th>Kind of Defect</th>
<th>Per Cent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head / Web Separation</td>
<td>43 %</td>
</tr>
<tr>
<td>Bolt Hole Break</td>
<td>29 %</td>
</tr>
<tr>
<td>Vertical Split Head</td>
<td>21 %</td>
</tr>
<tr>
<td>Base Break</td>
<td>4 %</td>
</tr>
<tr>
<td>Split Web</td>
<td>1 %</td>
</tr>
<tr>
<td>Sudden Rupture</td>
<td>1 %</td>
</tr>
<tr>
<td>Horizontal Split Head, Detail Fracture, Other Misc.</td>
<td>1 %</td>
</tr>
<tr>
<td></td>
<td>100 %</td>
</tr>
</tbody>
</table>
Rail Grinding
Preventative or Corrective

Severely Corrugated Rail
Welds

Thermite Weld

Electric Flash Butt Weld
Representative Rail Fasteners
Special Trackworks

Crossing Diamond

Turnout
The Turnout

Typical Turnout Proportions

<table>
<thead>
<tr>
<th>Frog No.</th>
<th>Turnout Lead Ft.</th>
<th>Sharpness of Curve</th>
<th>Max Speed on Diverging Route</th>
<th>Typical Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>48</td>
<td>21°</td>
<td>10 mph</td>
<td>Industry tracks</td>
</tr>
<tr>
<td>8</td>
<td>67</td>
<td>12°</td>
<td>15</td>
<td>Yards</td>
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<tr>
<td>12</td>
<td>97</td>
<td>5°</td>
<td>25</td>
<td>Low speed crossovers</td>
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<tr>
<td>16</td>
<td>131</td>
<td>3°</td>
<td>30</td>
<td>Passing tracks</td>
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<tr>
<td>20</td>
<td>152</td>
<td>1.75°</td>
<td>45</td>
<td>Junctions, end of double track</td>
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No. 24 Turnouts being used for high speed
Switch Machines

Hand Throw

Switch Heater

Remote Electric Throw
Permit the wheel flange to cross over opposing rail in turnouts & crossings.
Crossover -- 4 turnouts
Rail Crossing Diamonds

90°

Skew
Frog Maintenance

Restore using welding
Provide Access to Yard Tracks, mainly a series of Turnouts
Confusing Railroad “Crossing” Terminology

Crossing:
Two tracks crossing each other, Sometimes referred to as a “railroad crossing at grade”.
The combined hardware is also called a “diamond”.

Crossover:
Two turnouts on parallel tracks that allow trains to cross over from one track to the other.

Grade Crossing:
Where a railroad and highway cross at grade
Sometimes called a “Highway/Rail Intersection”
Renewing a 4-Diamond Crossing
Design and Research
Track Geometry
Measuring Track Geometry

Need Some Measure of Track Conditions

- **Track Inspection**
  - On the Ground
  - Detector Cars
    - TLV (Track Loading Vehicle)
    - TG (Track Geometry)
  - Rail (Sperry Cars)

- **Use TG/TLV Data**
  - Adherence to FRA & RR standards (Safety)
  - Plan maintenance activities (Budget)
  - Evaluate the performance of the teams/roadmasters (Quality)
The Three Primary Track Geometry Terms

Gage
56 ½ inches (standard)

Line
Horizontal
Alignment

Surface
Vertical
Alignment
Track Geometry

Gage

Cross-level (tangent)
Elevation (curve)

Design centerline

Alignment (horizontal)
Profile (vertical)
Track Geometry

Geometry measurement
- Rail spacing (gage)
- Rail vertical position (runoff, profile, cross-level)
- Rail horizontal position (alignment)

Measurements may be
- At a point (deviation)
- Along a section (difference)

Values are critical to safe, reliable operation
Track Geometry

curvature  superelevation  gage  rail cant  surface  cross-level
<table>
<thead>
<tr>
<th>EX#</th>
<th>TRACK</th>
<th>FROM--</th>
<th>TO--</th>
<th>LENGTH</th>
<th>FEET PARAMETER</th>
<th>MAXIMUM VALUE</th>
<th>MAXIMUM LIMIT</th>
<th>SUB EVENT</th>
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<td>79</td>
<td>1</td>
<td>470,2262</td>
<td>470,2285</td>
<td>7,50 FT AVG LEFT CANT</td>
<td>-3.23</td>
<td>470,2260 NS2</td>
<td>25</td>
<td>PRI TURN</td>
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<tr>
<td>80</td>
<td>1</td>
<td>470,2262</td>
<td>470,2284</td>
<td>13,50 FT AVG COMB CANT</td>
<td>-5.66</td>
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<tr>
<td>81</td>
<td>1</td>
<td>470,620</td>
<td>470,814</td>
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<td>-3.04</td>
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Exception Report

FILE 6000_62 N_1_03072012_1014_01.DAT
DIVISION 62 SEGMENT 6000 SEQUENCE DOWN
Date 03/07/2012 Stations
TRACK 1

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<tr>
<td>93</td>
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<td>469,4531</td>
<td>1,000 FT GAGE</td>
<td>1.03</td>
<td>469,4532 NS2</td>
<td>25</td>
<td>PRI SIGN</td>
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<tr>
<td>84</td>
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<td>469,4532</td>
<td>469,4532</td>
<td>10,50 FT AVG COMB CANT</td>
<td>-5.15</td>
<td>469,4530 NS2</td>
<td>25</td>
<td>PRI SIGN</td>
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</table>
| 85  | 1     | 469,4393 | 469,4373 | 20 Variation in X-Level | 1.79           | 469,4379 NS2 NS1 | 25 | RED TURN | 1212 |}

470.0

Page 15
Hi-Rail Vehicle – Visual Track Inspection
Track Geometry (Deviations from Ideal) Dictates Safe Speed

### FRA Track Safety Manual

<table>
<thead>
<tr>
<th>Over track that meets all of the requirements prescribed in this part for—</th>
<th>The maximum allowable operating speed for freight trains is—</th>
<th>The maximum allowable operating speed for passenger trains is—</th>
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<tr>
<td>Excepted track</td>
<td>10</td>
<td>N/A</td>
</tr>
<tr>
<td>Class 1 track</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Class 2 track</td>
<td>25</td>
<td>30</td>
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<tr>
<td>Class 3 track</td>
<td>40</td>
<td>60</td>
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<tr>
<td>Class 4 track</td>
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<td>80</td>
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<td>Class 5 track</td>
<td>80</td>
<td>90</td>
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</table>

<table>
<thead>
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<th>Over track that meets all of the requirements prescribed in this subpart for—</th>
<th>The maximum allowable operating speed for trains¹ is—</th>
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<tbody>
<tr>
<td>Class 6 track</td>
<td>110 m.p.h.</td>
</tr>
<tr>
<td>Class 7 track</td>
<td>125 m.p.h.</td>
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<tr>
<td>Class 8 track</td>
<td>160 m.p.h.²</td>
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<tr>
<td>Class 9 track</td>
<td>200 m.p.h.</td>
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Track Quality Issues

FRA Safety Standards

Railroad Maintenance Standards
(All Features are Related to Milepost Locations)
Options for Track NOT in Geometric Compliance

- Slow order track to complying class (lower class)
- Repair defect
- Operate under authority of qualified and experienced maintenance supervisor
- Take track out of service (least desirable)
Track Maintenance

Capitalized/Production and Line/Day-To-Day
Early Days

- Section gangs (cheap labor)
- Maintained small sections of track
- The RR’s provided housing
Maintain Long Sections of Track

Fewer People

Stress Safety

Mechanized

Production Oriented
Small Production Teams
Large Production Teams

Rail Change Out*

Tie Change Out*

Surface Track*

Ditching

Brush Cutting

Curve Rail Change Out

Track Undercutting

Rail Grinding

* Primary activities
Ballast Maintenance

- Fill in voids
- Restore Cross-Section
- Raise Track
- Adjust Geometry
Purpose: Adjust Geometry --- horizontally (line) and vertically (surface and crosslevel)
Tamper

- The tamper adjusts the track alignment and surface
- Tamper heads compact ballast beneath the ties
Ballast Regulator
Regulator

- The regulator distributes and shapes ballast
- The operate has a number of movable blades to accomplish this
- Most regulators have a broom for cleaning track
Compaction (Tamping)

- Can be
  - Hand (spot) or
  - Mechanized

- Performed under bearing areas (outer 2/3 of tie)

- Used to adjust geometry
  - Smooth
  - Smooth and Surface
Ballast Compactor/Stabilizer

Restores Track Stiffness quickly after ballast has been disturbed
Undercutting

Removes Fouled Ballast
Process includes removal of fouled ballast and replacement with clean ballast
Tie Removal/Installation
Ditching, Drainage Improvement and Drift Removal
Rail Grinding

- Restores rail profile for improved life cycle
At-Grade Road Crossings
Rail Lubrication Systems
(Friction Management)

SOLAR PANEL
RESERVOIR & PUMP
BARS
WHEEL SENSOR

Gage Side and Top-of-Rail
Brush Cutting and Spraying to Clear Right-of-Way
Slide Repair and Earth Retention

Geotechnical Engineering
Stabilizing Slopes
Warrant special activity
- Floods
- Snow & Ice
- Derailment
II. Drainage Structures

Bridges

Culverts and Pipes
Bridge Types

Fixed

Movable
Bridge Component Descriptions

• Type of Substructure Foundation and Support
• Type of Superstructure --- Truss or Girder or Beam
• Type of Deck --- Open or Ballasted
• Location of Track --- Deck(top) or Through
• Material --- Steel or Concrete or Timber or Stone

(Loadings and Span Length and Clearance Requirements)
Concrete Beams or Steel Girders with Ballasted Concrete Decks
Open Deck Timber Trestles and Viaducts

Combination Bridge

Open Deck Timber Trestle

Open Deck Through Steel Girder
Stone and Brick Masonry
and
Concrete
Arches
Modern Design – Concrete Ballasted Deck with Steel Girders or Truss or Concrete Girders/Beams

Combination – Open Deck Steel Girders for shorter spans and Open Deck Thru Trusses for longer spans across river
Conversion of Wooden Trestle to Concrete Ballast Deck Under Traffic

East Approach Mt Carmel, IL - Before

Common Practice Today for Modernizing U.S. Railroad Lines

After with Concrete Caps and Steel Support
Conversion Under Traffic
Track Realignment for New Bridge

Convert open deck thru truss to ballast deck concrete
Developed by Theodore Cooper around 1900.
Cooper Ratings are expressed as an E-"value". The value is the weight on the drivers in 1,000 lbs.
All of the axles are proportional to the drivers
Design vs. Rating

**Design Process**
- Live Load
- Trial Section Properties
- Other Loads
  - Dead Load
  - Impact
- Total Loads
- Allowable Stress
- Final Section Properties

**Rating Process**
- Section Properties
- Allowable Stresses
- Total Allowable Load
- Constant Loads
  - Dead Load
  - Wind
- Loads that vary with speed
  - Impact
  - Centrifugal Force
- Live Load
Bridge Inspection
Bridge Maintenance
Very Expensive
Ongoing Maintenance

Drainage Pipe
Culverts
III. Tunnels

Concrete

Rock -- Unlined

Masonry

Cut & Fill
Tunnels

Drainage

Cleaning

Drainage

Bypass
Track Lowering for Double Stacks
Notching or Raising/Replaces the Crown for Double Stack Clearance
IV. Terminals, Yards, and Ports
Terminal or Yards

Types -- Flat & Gravity (hump)

Flat

- World’s Largest:
  Bailey Rail Yard in North Platte, NE
Flat Yard

East-West System – J 77th St. Yard

(Condensed & shortened)
Tracks 1-4 "Forwarding" yard – Traffic from J-T RR to west.
Tracks 10-15 "Main yard" – Principal J classification yard.

Car cleaning Tracks
Rip Tracks
West end switching leads

E-W 77th St. Intermodal Terminal

*Forwarder Ramp* Tracks
East end switching leads

To E-W Westside Industrial Park
"Downtown" to J-T RR
EW-J Terminal RR Interchange yard
Gravity (Hump) Yard

Four sets of retarders control car speed at Burlington Northern Santa Fe’s Kansas City, Kan., Argentine Yard.
Hump Yard

Flow of Traffic

Decelerating grade
(less than 0.25%)

Accelerating grade

Hump

Profile

Classification Tracks

Skates or inert retarders at clearance points

To additional classification track groups

Group retarders

Duck-under track (to engine terminal)

Weigh-in-motion scale

Hump signal

Inspection pit

Hump bypass track

Control tower

Yard office

Caboose tracks

Receiving yard

Departure & forwarding yard

Main tracks

Trimmer leads

Through-train service & inspection tracks

Railroad Engineering Education Symposium

2014 AREMA
Large Hump Yard

BNSF Argentine Yard - Kansas City, Kansas
Small Flat Yard
Ports
Intermodal Terminals
V. Buildings
VI. Environmental Facilities

- Storage
- Transfer
- Treatment
Above ground petroleum storage tanks are required to have an impervious secondary containment structure that is capable of holding the entire contents of the largest tank inside the area plus storm water from a significant rain event.

An unlined earthen secondary containment dike in a rail yard prior to upgrades

The secondary containment dike upgraded with a new geosynthetic clay liner (GCL)
Concrete loading / unloading pads are designed to capture leaks and drips that may occur during petroleum transfer operations. Material collected by the loading / unloading pads can be routed to an on-site WWTP or removed and disposed of off site at a permitted facility.

Here is railcar loading / unloading pad that will route collected material to an on-site WWTP

Here a locomotive fueling tanker truck using a loading / unloading pad to collect material that must be inspected prior to discharge or disposal
Spill containment pans are designed to capture leaks and drips from locomotives and railcars. Material collected in spill containment pans can be routed to an on-site WWTP or removed and disposed of off site at a permitted facility.

A locomotive fueling area equipped with metal containment pans

An in-track spill containment pan that is strategically positioned in a rail yard to collect material from a leaking railcar
Equipment Wash Pads

- Equipment wash pads collect runoff from washing operations and route it to an on-site WWTP and/or POTW. The wash pads are designed to prevent wash water from co-mingling with storm water runoff.

A wash pad for large railcar loading equipment being constructed at a Railroad Intermodal facility

This operational wash pad at an Intermodal Facility collects wash water in a trench drain and routes it to an adjacent OWS prior to discharge
A wastewater treatment plant (WWTP) protects the environment by removing pollutants from potentially impacted water. A WWTP utilizes various physical and chemical treatment processes to ensure that discharged effluent meets the permitted requirements.

This WWTP was the first “green” building constructed on the NS system. It incorporated sustainable design elements and materials.

The WWTP consists of an equalization basin, OWS, chemical feed building, DAF unit, settling pond, and sludge drying beds.
VII. Signal Structures and Detectors
Intermediate Signal: A block signal equipped with either a number plate, a “G” marker, or “P” marker. It conveys Proceed at Restricted Speed as its most restrictive indication.
Centralized Traffic Control

Train Dispatcher “Routes” Trains through Turnouts and Crossovers

Wheel Impact Load Detector
VIII. Communications Structures
Overview of Railway Signals and Communications and Railway/Highway Crossings

By

John K. Secor
Figure 8D-1. Composite Drawing of Active Traffic Control Devices for Highway-Rail Grade Crossings Showing Clearances

Where gates are located in the median, additional median width may be required to provide the minimum clearance for the counterweight supports.

*For locating this reference line at other than curb section installation, see Section 8B.02.
Decision Factors for Flashing a Crossing

Accident Prediction Ratio
Flashers Only

Average Vehicle Count per Day
Flashers and Gates

Public Funds (STP 130)
Gates and Cantilevers

Private Funds
Detection Type

Preemption
Preemption vs. Preemption

Railroad Crossing Preemption - a system that allows the normal operation of a highway traffic signal to be preempted by the approach of a train which normally includes halting conflicting non-rail traffic and allowing vehicles potentially trapped upon the rail crossing to exit the crossing prior to the arrival of the train.

Federal Preemption - When railroad crossing improvements are federally funded, federal regulations specify what warning devices must be used, and the United States Supreme Court has held that section 20106 of the Federal Railroad Safety Act of 1970 expressly preempts state tort law actions challenging the adequacy of those devices.
False Activations/Activation Failures

Reporting

Causes

Remedies

Reaction
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