Improving Hot Weather Speed Restrictions: When Do We Need Them?

Kandrew Consulting Services

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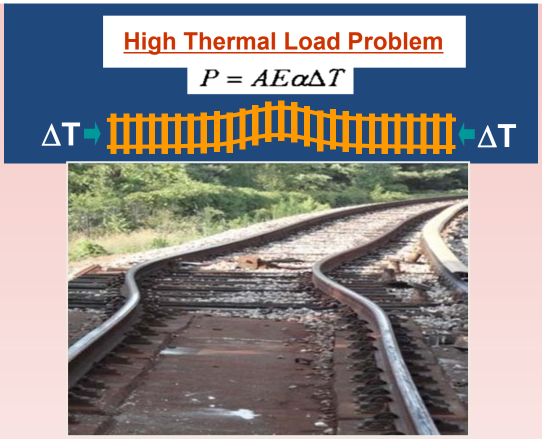
Talking Points

- What problems are addressed by HWSRs?
- What are current HWSRs and why need to improve?
- Why are SRs required and how they reduce risk?
- When and where to impose?
- What is the new *"science-based" formula for* HWSRs?
- How to manage and apply?
- What examples for application?
- What recommendations to incorporate into practice?

What Problem is Addressed?

Track Buckling Prevention



- Why need to more effectively manage?

- To reduce the risk of derailments
- To improve network put-through capacity

❑ **Question:** why is track buckling a serious industry concern?

FRA Track Failure Caused Derailment Statistics

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ACCIDENTS IN DESCENDING FREQUENCY BY CAUSE
ALL US MAINLINE TRACK (2010-2013Nov.)

	Accident Cause [T-Codes: 65 Total]	No. of Accs.	% Total	2010	2011	2012	2013
#1	**T109 Track alignment irreg. (buckled/sunkink)**	**105**	**14.7**	**29**	**37**	**27**	**12**
	T110 Wide gage (defective/missing crossties)	61	8.5	18	11	16	16
	T207 Detail fracture - shelling/head check	59	8.2	14	19	17	9
	T220 Transverse/compound fissure	55	7.7	21	14	13	7
	T001 Roadbed settled or soft	44	6.1	16	12	7	9
	T221 Vertical split head	42	5.9	9	13	7	13
	T102 Cross level track irreg. (not at joints)	34	4.7	5	14	8	7
	T314 Switch point worn or broken	27	3.8	11	8	6	2
	T210 Head and web sep. (outside of bar limit)	23	3.2	9	5	5	4
	T202 Broken base of rail	22	3.1	5	4	7	6
	T101 Cross level of track irregular (joints)	21	2.9	6	10	3	2
	T108 Track alignment irreg. (not buckled/sunkink)	19	2.7	4	3	5	7
	T111 Wide gage (spikes/other rail fasteners)	15	2.1	1	9	2	3
	T299 Other rail and joint bar defects	15	2.1	2	5	3	5
	T002 Washout/rain/slide/etc. dmg - track	14	2.0	5	6	.	3

- Track buckling also ranks **#1** in the $$$ damage/derailment ⟹ a high-priority industry goal to improve!

How to Prevent?

KEYS TO BUCKLING PREVENTION

- **Keep thermal forces within "safe" levels**
  (manage neutral temperature)
- ***Ensure "good"*** **track conditions**
  (maintain alignment and ballast condition)
- ***Control*** **train loads and dynamics**
  (apply speed restrictions when/where required)

Why Improve?

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What rationale/motivation to improve HWSRs?

- Current HWSRs are NOT based on science but on “good-feel” tradition, hence can be highly conservative; their improvement would promote higher capacity/revenue/velocity - without compromising safety
- There is no “metric” on current HWSR benefits (i.e. do they prevent derailments?)
- New “science” exists fueled by 25 years of R&D improve current HWSRs
- Although a key impediment to buckling safety and HWSRs is the lack of knowledge of rail neutral temperature (RNT), more data on RNT is becoming available which help the improvement of HWSRs

Why Apply Speed Restrictions?

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Why Speed Restrictions?

ANSWER: to reduce the risk of track buckling caused derailments

- After track maintenance (weakened ballast)

Approach: apply slow orders while restoring track lateral resistance to "safer" levels thereby increasing buckling strength thus reducing risk

- If dynamic track stabilization (DTS): no or limited slow orders.
- If no DTS: slow order traffic* for 0.1 MGTs (100,000 tons) or more.

SRs as per RR's CWR Policy

- At elevated temperatures (high thermal force conditions)

Approach: apply slow orders to reduce train dynamics/loads thereby reducing derailment risk.

- When (at what temperatures) to impose speed restrictions?
- Where (localized or blanket)?

localized → where "weaker" RNT conditions exist

blanket → territory/subdivision wide

Hot Weather Speed Restrictions (HWSRs)

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Speed restrictions at elevated temperatures (localized)

Localized SRs: where "weaker" RNT conditions exist

Current US CWR Procedures:

- Require timely repairs and readjustments of reduced RNT after rail breaks, defect removals and pull-aparts; BUT also require localized SRs at designated temperatures if RNT adjustments have NOT been made.

Rail Break/Cut Temperature (ºF)	Rail Temperature (ºF) at Which to Readjust or Apply Slow Orders*
60	135
50	130
40	125
30	120
20	115
10	110
0	105
-10	100
-20	95
-30	90
-40	85

* 25mph with NO daily inspections; or 40 mph WITH daily inspections

Hot Weather Speed Restrictions (HWSRs)

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Speed restrictions at elevated temperatures
(blanket/territory as prescribed by each RR)

- Typical HWSRs applied when the *ambient temperatures are* forecasted to reach/exceed a threshold, typically: RLT – 10ºF[some at: -15, some at - 5]

  Example: if RLT=100ºF, SR at 90ºF ambient (or rail temp = 120ºF i.e. at T_{RAIL}=RLT+20)

- BUCKLING THEORY → such HWSR temperatures can be conservative by:

  30 to 60°F (or more)

  depending on track's buckling strength and its neutral temperature!

How to Improve?

- REMOVE conservatism through a new SR formula based on buckling risk, track buckling strength, and neutral temperature estimates

Speed Restrictions and Buckling Risk

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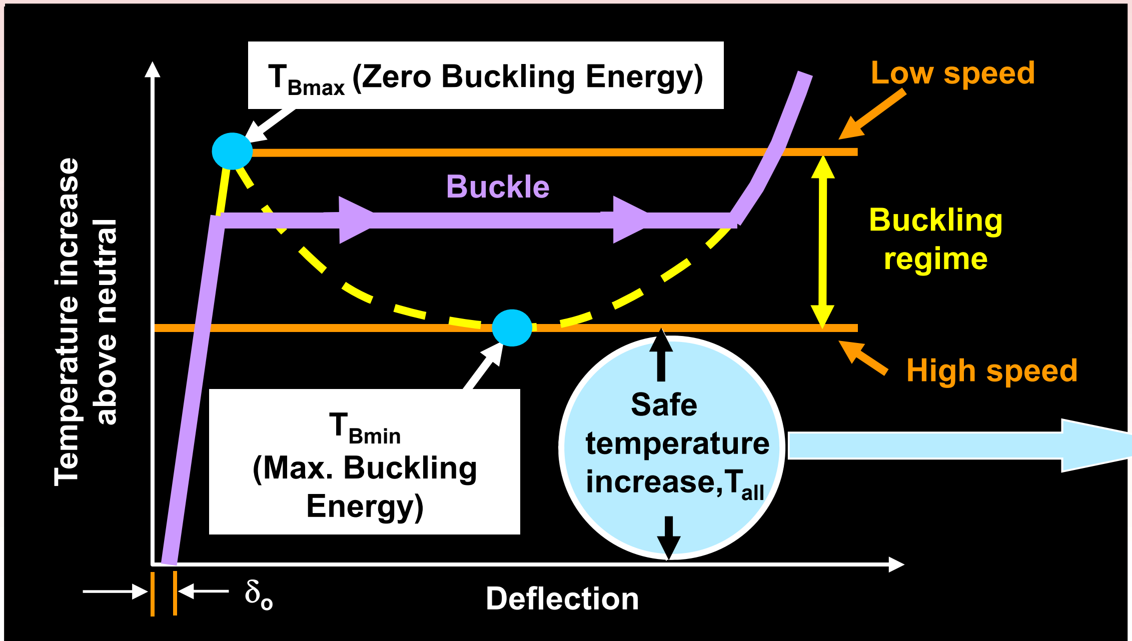
How Do Speed Restrictions Reduce the Buckling Risk?

RISK = (PROBABILITY OF OCCURRENCE) X (CONSEQUENCE)

- Theory suggests lower speeds (less train energy) reduces buckling probability by increasing buckling temperatures

- Speed restrictions reduce the consequence of a buckled track derailment i.e. less damage severity.



Determines Slow-Order Temperatures (together with RNT)

- Slower speeds (i.e. reduced energy input into track) raises the track's buckling temperature

Speed Restriction Criteria

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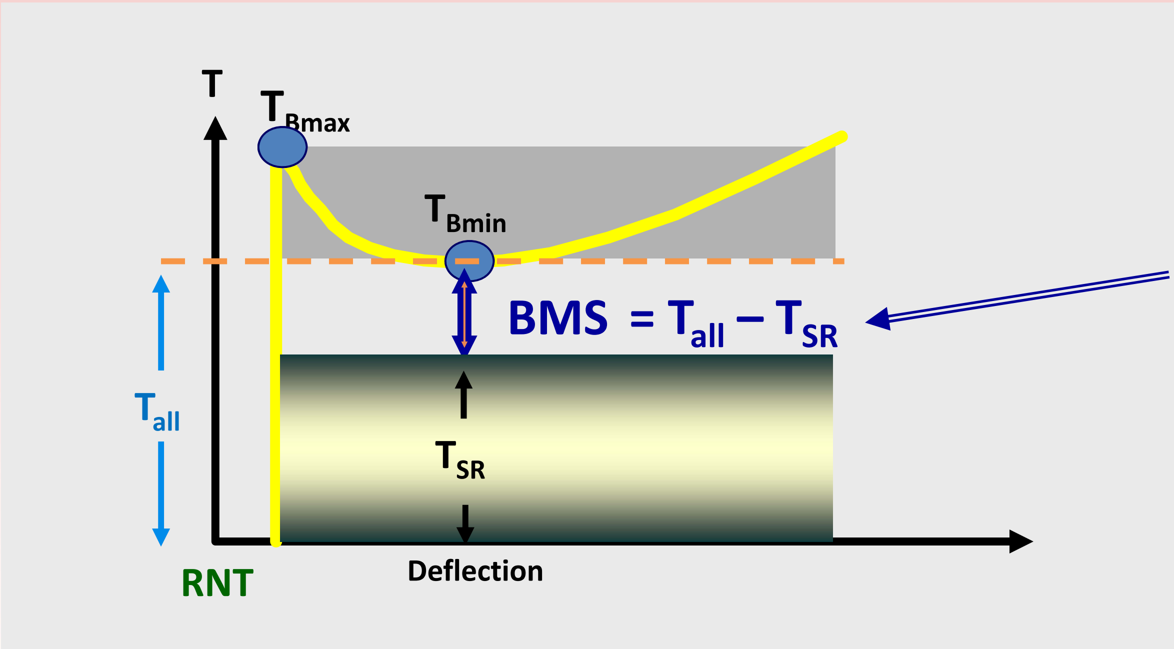
BMS "Risk Acceptance" (Safety Factor) for Speed Restrictions



- **BMS** is the reserve "buckling strength" in terms of additional temperature increase to cause a buckling risk

T_{all}, RNT, and BMS determine speed restriction temperatures, T_{SR}!

T_{all} = track buckling strength; "safe" temperature increase; buckling temperature

Speed Restriction Criteria

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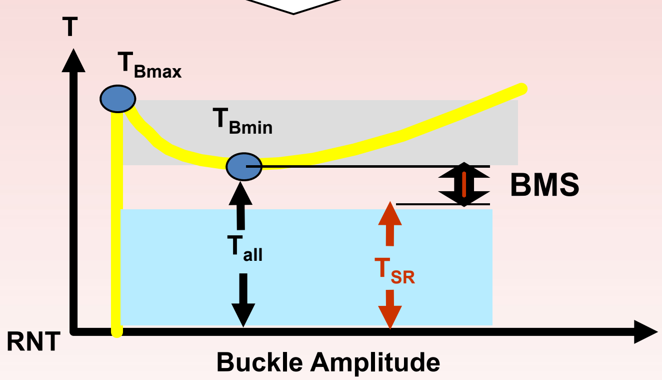
Question: when (at what temperatures) to impose slow orders?

Answer: At a temperature at which the buckling potential is "acceptably" small.

Determined by T_{all} and RNT

Determined by BMS risk acceptance



BMS	ACTION
Larger than 20ºF	OK; no action
Less than 20ºF	Advisory on slow orders

T_{SR} Equation

$$T_{SR} = T_{all} - BMS_{min} + RNT$$

Example: 130ºF = 80ºF – 20ºF + 70ºF

❑ **ISSUE:** how to apply formula i.e. what are T_{all}'s and RNTs??

Track Buckling Safety Concept

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Tall (Buckling Strength) Determination for SR Equation

Definition: T_{all} (or Track Buckling Strength) is the *"lowest" or "safest"* rail temperature increase above neutral to prevent buckling

- It is analytically determined
- It is track type/condition dependent
- Governs maintenance and safety requirements

TRACK QUALITY BASED SAFETY CRITERION

Tall RULE OF THUMB: 60°F : 80°F : 100°F above neutral

weak | average | strong

Example: if track buckling strength is "average"= 80ºF, and RNT=70ºF → T_{BUCKLE}= 150ºF

QUESTION: What is "weak", "average" or "strong"?

Track Buckling Safety Concept

Buckling Strength "Rule of Thumb" Descriptors

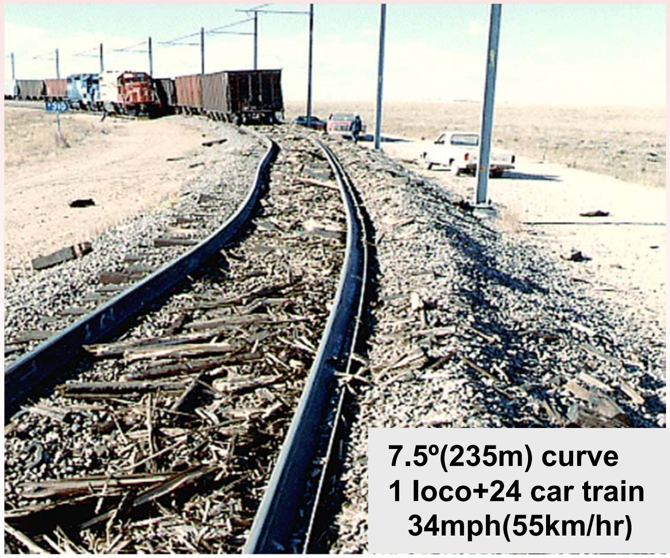
Weak (60ºF)	Higher degree curves (> 3 deg); typically Class 3-4 line defects; recently maintained to partially consolidated ballast
Average (80ºF)	Tangent to 3 deg curves; Class 4-5 line defects; "standard" ballast lateral resistance
Strong (100ºF)	Tangent, well consolidated high quality track; Class 4-6 line defects

Examples:

(1) a full scale dynamic buckling test representing "weak" track conditions [7.5º curve; 136# rail; tamped ballast; Class 4 alignment defects; buckled under the train at: 62ºF above neutral]

(2) RSAC/FRA assumed 70ºF as "weak" buckling strength in developing the new CWR standards under CFR 49 § 213.119 (October, 2009)

(3) Conducted over 1000 buckling calculations for parametric influences to enable "weak", "average" and "strong" characterizations



7.5º(235m) curve
1 loco+24 car train
34mph(55km/hr)

Note: for details on buckling strength characteristics and parametric studies, refer to Kish & Samavedam: *"Track Buckling Prevention: Theory, Safety Concept and Applications"* [DOT/FRA/ORD-13/16]

How to Determine Neutral Temperatures (RNT)?

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RNT Determination for SR Equation

$$T_{SR} = T_{all} - BMS + RNT$$

Estimate

Industry Experience and Test Data on RNT

RNT Reduction Factor: 30ºF from RLT

Example: rail installed at 100ºF, it's effective RNT is 70ºF!

Exception: rail breaks, defect removals, and "large" curve movements

Calculate

Industry CWR Req'mts on RNT Recording

CWR rules require recording RNTs when rail breaks or is cut for defect removal

Such data could be used to evaluate subdivision's RNT for slow orders

Measure

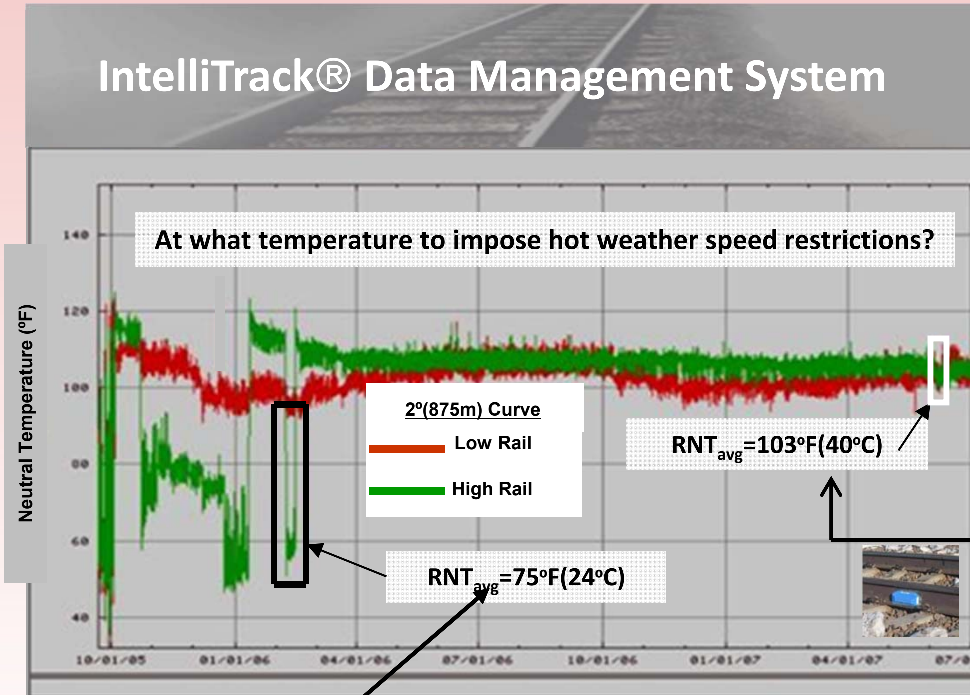
Direct RNT Monitoring via RSM Technology

Install RSMs either localized or territory wide

Use actual measured RNT data in T_{SR} equation to dictate slow orders

Illustrative Example 1: US Railroad Case Study

When RNT Is Measured by Rail Stress Modules (RSMs)



Slow Order Equation

$$T_{SR} = T_{all} – BMS_{min} + RNT$$

High Quality Track: assume buckling strength @ least AVERAGE i.e.

T_{all} = 80°F

BMS_{min} = 20°F

T_{SR} = 80°F – 20°F + 103°F = 163°F

(Conservative by 63°F)

T_{SR} = 80°F – 20°F + 75°F = 135°F

(Conservative by 35°F)

Note: current hot weather speed restriction is at 90°F ambient, hence are **CONSERVATVE** based on above case study

Illustrative Example 2: US Railroad Case Study

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When RNT is Calculated from Rail Break/ Defect Removal Data

Month	# of Service Defects	T_{BR} (ºF)	RNT_{PB} (ºF)	ΔT Causing Break (ºF)	RNT Change (from install)
January	22	19	60	41	40
February	7	19	67	48	33
M					
A					
Au					
Sep					
October	11	37	84	47	19
November	15	27	77	50	23
December	20	19	74	55	26
TOTAL	**86**	**26**	**72**	**46**	**28**

$$T_{SR} = 80°F – 20°F + 72°F = 132°F$$

(Conservative by: 32°F)

Note - for determining RNT from rail break/defect removal data refer to: Kish, *"Best Practice Guidelines for CWR Neutral Temperature Management"*, AREMA/Railway Interchange Conference, October 2013, Indianapolis USA

Avg Rail Break Temp

Avg Subdivision RNT

Avg Temp Difference Causing Break

Avg RNT Decrease From RLT

Hot Weather Speed Restriction Summary

☑ **Methodology is in place to determine "when/where" to impose hot weather speed restrictions**

Risk Based and Track Quality Based T_{SR} Equation

$$T_{SR} = T_{all} - BMS + RNT$$

- **Track Buckling Strength**
- **Rail Operator Defined "Risk Acceptance"**
- **Track Neutral Temperature**

Have Better Ways to Estimate/Determine!

"YES" on Speed Restriction Improvement

- Current HWSRs can be conservative depending on track's buckling strength and RNT; their improvement would promote higher capacity and increased revenue (with minimal impact on safety)
- "Science" exists to enable the improvement of HWSRs through better knowledge of buckling strengths and RNTs

QUESTION: when do we need HWSRs?

ANSWER: at temperatures dictated by → $T_{SR} = T_{all} - BMS + RNT$

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Talking Points Recap/Summary

- **How do HWSRs reduce risk?**

ANSWER: risk mitigation is through (a) through reduced damage severity, and (2) increased buckling temps due to reduced train energy into the track structure

- **What are current HWSRs and why need to improve?**

ANSWER: typically at T_{amb} = RLT - 10ºF (some at RLT - 5 or -15); approach tends to be conservative depending on track's buckling strength and neutral temperature → conservatism can be removed/improved!

Talking Points Recap/Summary

- **When (at what temperatures) to impose?**

ANSWER: **at temperatures at which buckling risk is acceptably small as defined by the new risk based/track quality based SR formula**

$$T_{SR} = T_{all} - BMS + RNT$$

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Talking Points Recap/Summary

- **How to manage/apply formula?**

ANSWER: track's buckling strength can be estimated by the 60:80:100 rule; RNT can be estimated, calculated, or measured; and for additional safety require:

(1) a "risk acceptance" safety factor (BMS)
(2) special measures against "severe" conditions:
(such as early heat or extreme high heat)

- **What examples for application?**

ANSWER: (1) several UP case studies, and (2) AMTRAK study (AREMA2009, Trosino/Chrismer) "small" increase in T_{SR} ⇒ large impact on system velocity

Talking Points Recap/Summary

- What recommendations for improving HWSRs?

ANSWER: conduct demonstration tests to evaluate new approach's impact/benefits on system safety and performance

EXPECTED BENEFITS

Increased velocity, revenue and put-through capacity without compromising safety!

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Thank You!

For more details refer to KISH & CLARK: *"Improving Hot Weather Speed Restrictions for Track Buckling Derailment Prevention"*, International Heavy Haul Association (IHHA) Technical Conference, June 2015, Perth, Australia

Questions?

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