Track Buckling Prevention and Improved Rail Stress Management (Module 2)

U.S. Department of Transportation
Federal Railroad Administration

July 31, 2026

Track Buckling Prevention and Improved Rail Stress Management

AGENDA

Module 1

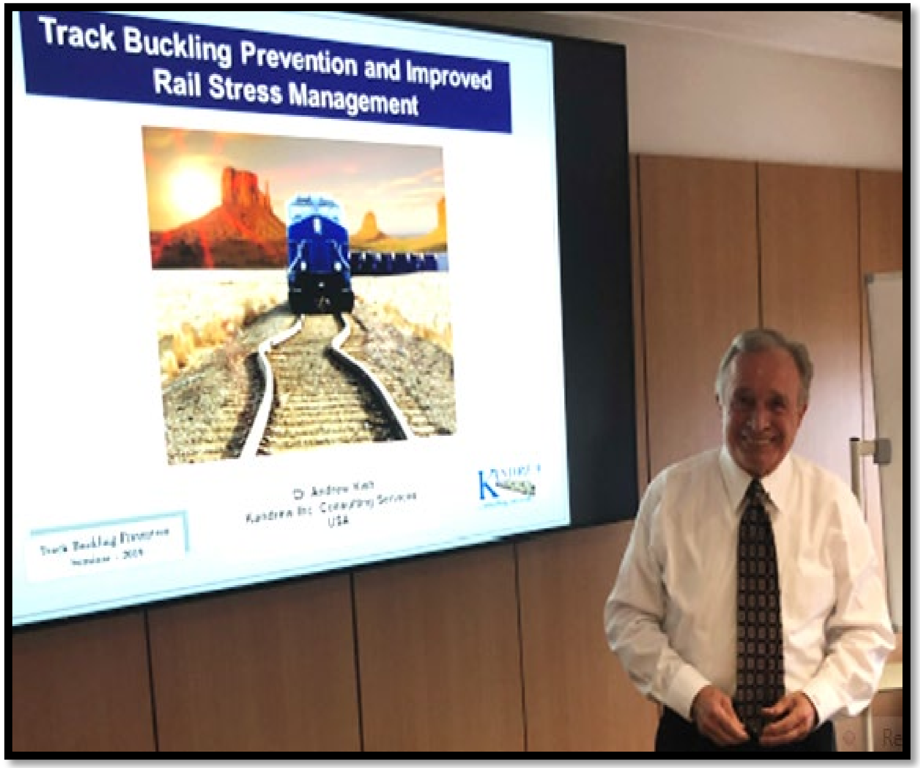
- ❑ CWR Fundamentals
  - Problem definition/track buckling basics
  - CWR Plans/Procedures
- ❑ Key Governing Parameters
  - Track lateral resistance
  - Track curvature/line defects
  - Train loads/dynamics
  - Rail neutral temperature (RNT)
- ❑ Safety Concepts/Best Practice Guidelines
  - Safety concepts and buckling prevention formula
  - Best Practice Guidelines for CWR Management

Module 2

- ❑ Improved CWR Maintenance Practices
  - The RNT problem and readjustment issues
  - RNT readjustment after rail break/defect repairs
  - Current best practice guidelines and applications: RNT-RESTORE
  - Destressing of CWR
- ❑ Review and Summary
- ❑ Q&A, Discussion, and Closing Remarks

Acknowledgement

This training course was developed by Dr. Andrew Kish of Kandrew Inc. Consulting Services. The material is based on over 30 years of Dr. Kish's US DOT/FRA/Volpe Center research, and on over 30 industry CWR briefings, training seminars, and workshops on track buckling prevention conducted both domestically and internationally.



Kandrew Consulting Services

Dr. Kish is an internationally recognized expert in rail and track mechanics with over 45 years of experience. His background includes research and testing in both the federal and private sectors including over 30 years at the US DOT's Volpe Center and 16 years as a technical consultant with US railroads, AAR, FRA, industry rail suppliers, and international agencies.

Dr. Kish was a member of the Rail Safety Advisory Committee (RSAC) which developed the new CWR safety standards enacted in 2009.

Acknowledgement

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MODULE 2 CONTENTS

Section 1: The RNT problem and its readjustment after rail break/defect repairs

Section 2: Current best practice guidelines/applications: RNT-RESTORE

Section 3: Destressing CWR: when, where, why, and how, and including curve stability management

Section 4: Review and Summary (both Modules 1 & 2)

Section 5: Closing Remarks, Discussion and Q&A

Industry/FRA/Generic CWR Plan

Procedures for the Installation, Adjustment, Maintenance, and Inspection of CWR As Required by 49 CFR §213.118 & 119: RSAC/FRA GENERIC CWR PLAN

Chapter 1 CWR Installation Procedures
- 1.1 Neutral Temperature
- 1.2 Temperature Differential
- 1.3 Installing CWR

Chapter 2 Rail Anchoring Requirements When Installing CWR
- 2.1 Standard Box Pattern
- 2.2 Solid Box Pattern
- 2.3 Bridge Pattern
- 2.4 Legacy Patterns
- 2.5 Anchor Pattern After Repair

Chapter 3 Preventive Maintenance on Existing CWR Track
- 3.1 Maintaining Desired Rail Installation Temperature Range
- 3.2 De-Stressing Rail

Chapter 4 Monitoring Curve Movement Following Surfacing and Lining
- 4.1 Staking of Curves
- 4.2 Inspecting for Curve Movement

Chapter 5 Placing Temporary Speed Restrictions Account Work
- 5.1 General Requirements
- 5.2 Responsibility for Placing Speed Restrictions
- 5.3 Speed Restriction Length
- 5.4 Speed Restrictions for Track Work

Chapter 6 Rail Joint Inspections
- 6.1 Class of Track
- 6.2 Frequency of Inspections
- 6.3 Identification of Joints
- 6.4 Switches, turnouts, track crossings, or other
- 6.5
- 6.6

Chapte
- 7.1
- 7.2

Chapter 8 Training

Chapter 9 Recor
- 9.1 Repor
- 9.2 Report Maintenance Work in CWR

REQUIREMENT: rail that has broken or cut for defect removal must be readjusted to the subdivision's desired rail neutral temperature (DRNT) minus a safe range (usually between 0 – 20°F) within the time/temperature specified by the RSAC readjustment TABLE

ISSUE

WHAT METHODOLOGY?

Section 1

The RNT problem and its readjustment after rail break/defect repairs

What is Rail Neutral Temperature?

Rail Neutral Temperature (RNT) is the rail temperature at which the net longitudinal force in the rail is zero. It is often associated with the rail "installation" or "fastening" temperature. It has a relationship to the force (P) in the rail as:

$$P = EA\alpha(T_{RAIL} - RNT)$$

E is rail steel modulus of elasticity; A is rail cross section area; α is rail steel coefficient of thermal expansion

$EA\alpha$ (lbs/ºF)
$2185_{115\#}$
$2600_{136\#}$

$$\boxed{RNT = T_i - RF_k - RF_m}$$

Installation temperature

DRNT vs. actual laying temp

Reduction factor due to rail kinematics

Rail/track movement longitudinally, curve shifting laterally, and track vertical settlement

Reduction factor due to rail maintenance

Relay, realignment, broken/defective rail repair, incorrect destressing

DRNT vs RNT_{actual}

HOW TO IMPROVE?

RSAC AND FRA GENERIC CWR PLAN*
Procedures for the Installation, Adjustment, Maintenance and Inspection of CWR
As Required by 49 CFR §213.118 & 119

Chapter 1 CWR Installation Procedures
- 1.1 Neutral Temperature
- 1.2 Temperature Differential
- 1.3 Installing CWR

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- 6.4 Switches, turnouts, track crossings, or other transition devices on moveable bridges
- 6.5 Rail Joint Conditions
- 6.6 Embedded Joints
- 6.7 Inspection Records

Chapter 7 Extreme Weather Inspections
- 7.1 Hot Weather Inspections
- 7.2 Cold Weather Inspections

Chapter 8 Training

Chapter 9 Recordkeeping
- 9.1 Report of CWR Installations
- 9.2 Report Maintenance Work in CWR

CWR Installation Temperatures Issues

- Installing CWR in “cold” temps can be difficult and problematic due to uneven rail heating, especially with large temperature differentials.

- The problem of localized installation temperature changes when joint welding is deferred to a later time frame (see 2009 FRA/RSAC Generic Plan on installing CWR with joints).

- Test data suggests that installation RNTs can end up 20–30°F lower than Desired Rail Neutral Temperature (DRNT).

❖ Takeaway: **CWR installation temperatures are often below the desired RNT.**

What is Rail Neutral Temperature?

Rail Neutral Temperature (RNT) is the rail temperature at which the net longitudinal force in the rail is zero. It is often associated with the rail "installation" or "fastening" temperature. It has a relationship to the force (P) in the rail:

$$P = EA\alpha(T_{RAIL} - RNT)$$

E is rail steel modulus of elasticity; A is rail cross section area; α is rail steel coefficient of thermal expansion

$EA\alpha$ (lbs/ºF)
$2185_{115\#}$
$2600_{136\#}$

$$RNT = T_i - RF_k - RF_m$$

- T_i: Installation Temperature → DRNT vs RNT_{actual}
- RF_k: Reduction Factor due to Rail Kinematics → Rail/track movement longitudinally, curve shifting laterally, and track vertical settlement
- RF_m: Reduction Factor due to Rail Maintenance → Relay, realignment, broken/defective rail repair, incorrect destressing

RAIL BREAK/DEFECT CUT PROBLEM

The Rail Break Problem

Issue: Welded rail (CWR) can experience rail fractures under cold temperature/tensile force conditions

- There are over an estimated 10,000 rail breaks and 100,000 internal defects annually on U.S. railroads (as per railroad sources).
- Rail break caused derailments encompass over 1/3 of ALL track failure caused derailments (FRA accident statistics: ~ 50 derailments/yr. on U.S. mainline tracks).

Relevant RNT Problem:

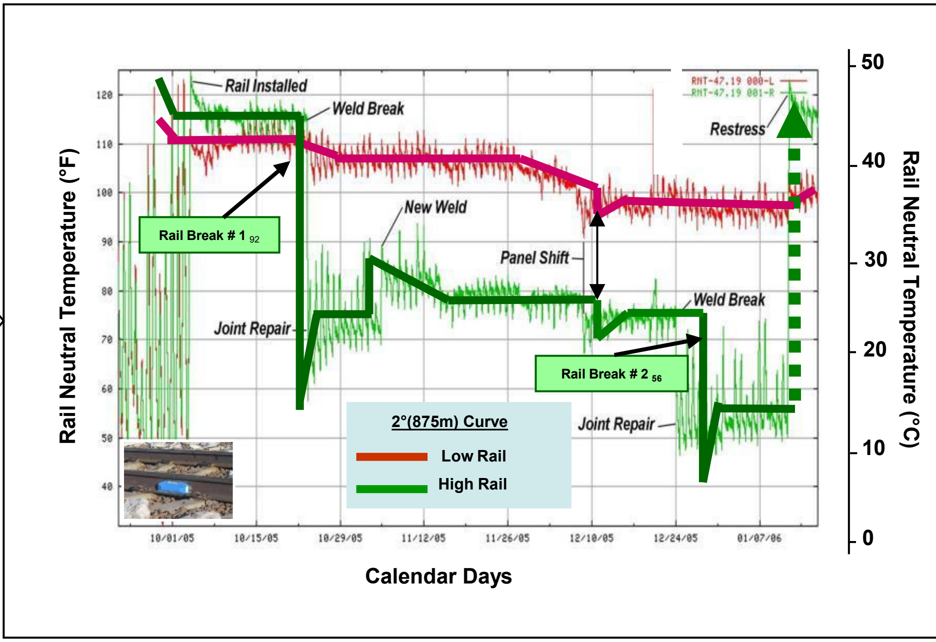
- When rail breaks or is cut for defect removal the rail's RNT is substantially reduced — requires readjustment.
- If the reduced RNT is NOT readjusted prior to the onset of "warm" temperatures, the track can become buckling-prone.
- RNT readjustments after rail breaks/defect removals are difficult due to NOT knowing what reduced stress/RNT condition is being adjusted.

Challenge

- ❑ How to effectively manage/adjust the reduced RNT conditions to minimize the track's buckling potential?

The Rail Break Problem

Problem: At rail breaks/defect removals RNT is substantially reduced



- If reduced RNT is not readjusted to the desired value before onset of warm temperatures, track can become buckling prone

CHALLENGE

How/When to Readjust RNT?

CWR Procedures

RSAC AND FRA GENERIC CWR PLAN

Procedures for the Installation, Adjustment, Maintenance and Inspection of CWR

As Required by 49 CFR §213.118 & 119

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Rail Break RNT Readjustment Issues

Why "Conventional (Old)" Readjustment Methods Need Improvement

METHOD 1: When rail is added as an interim (plug) repair for broken/cut rail, remove the added rail later at a *warmer* temperature. (Procedure often referred to as "rail-in/rail-out.")

Issue: Removing just the added rail often is not enough; also, the "warm" temperature to readjust requires specification.

METHOD 2: When the rail break/cut gap is "small," close the gap by pulling or heating the rail without any anchor/fastener removal.

Issue: RNT may be restored, but only to the *pre-break or cut value* and NOT necessarily to the desired RNT.

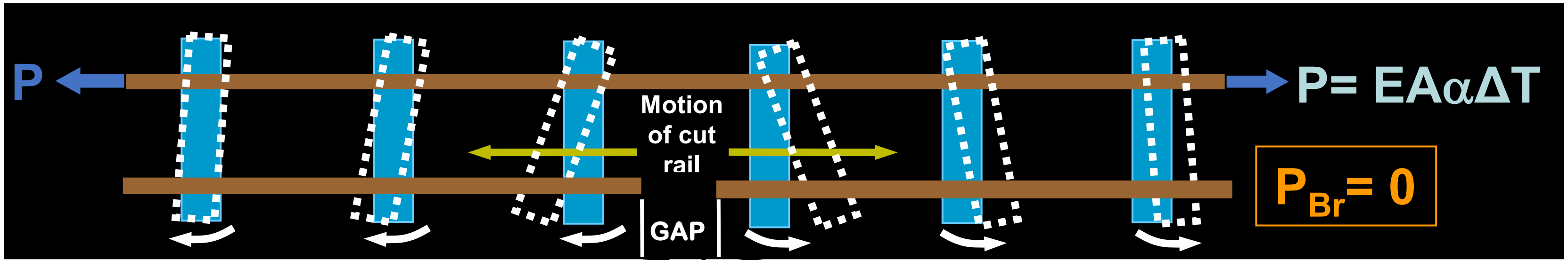
METHOD 3: When rail is added as an interim (plug) repair for broken/cut rail, return later at a warmer temperature and adjust via destressing rail by unfastening 195 ft on both sides of the cut.

Issue: Rail break/cut INFLUENCE ZONES are typically much longer than 195 ft on either side.

Takeaway: Need new CWR procedures addressing the improvement of rail break and cut RNT readjustment practices.

Rail Break Mechanics

Cold Temperature Rail Break/Defect Repair RNT Issues



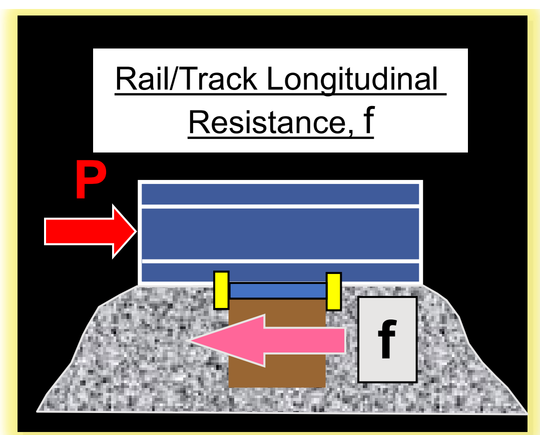
Temperature Difference, ΔT [RNT–T_{Br}]

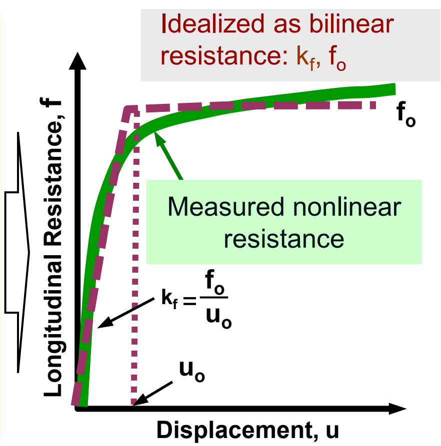
Rail/Track Longitudinal Resistance (RTLR)

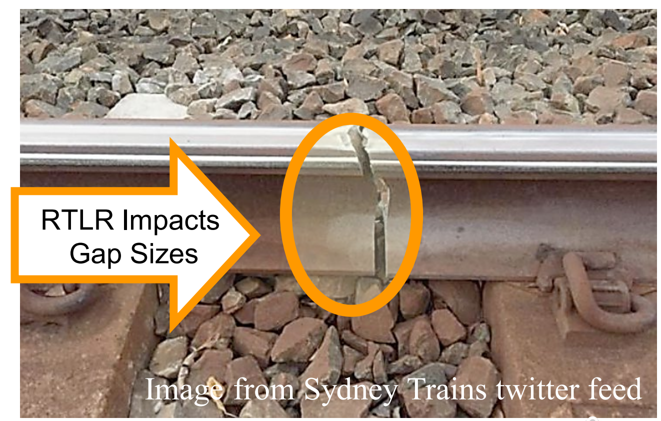
Rail Size

P = longitudinal force
P_{Br} = Zero longitudinal force at break

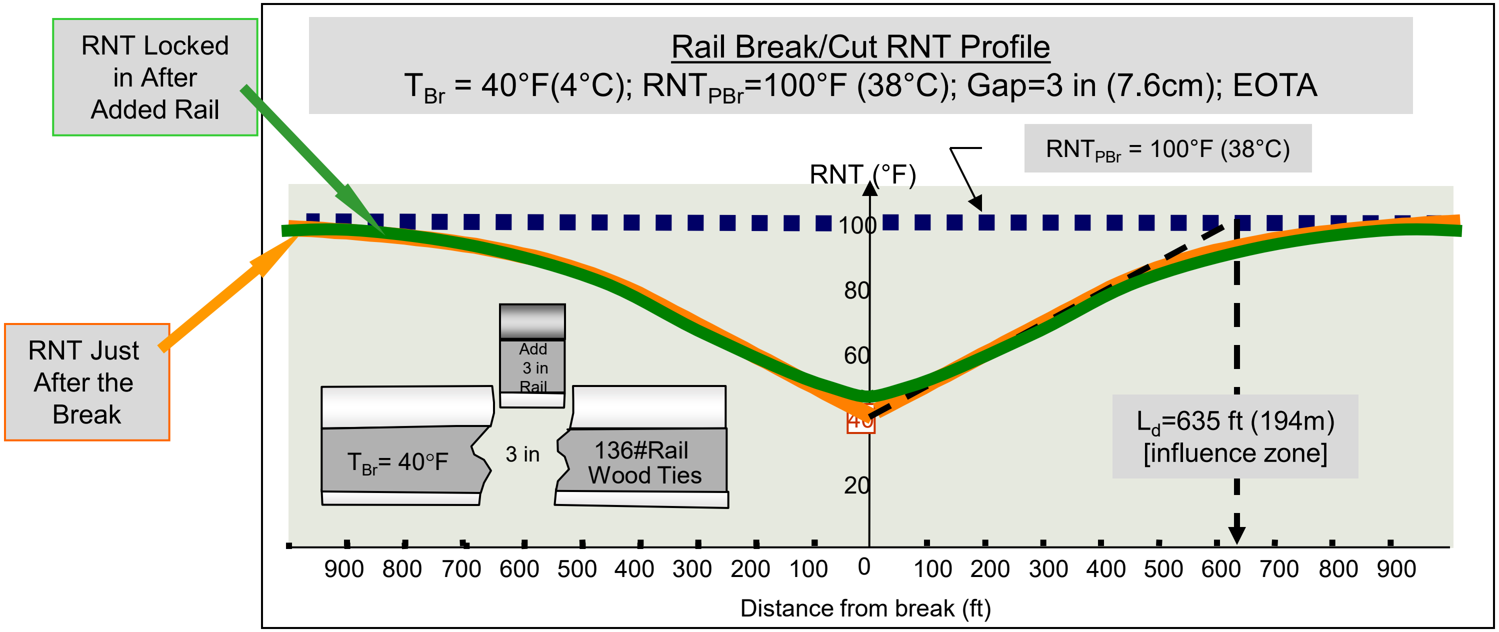
- RTLR is the restraint offered by the rail/tie structure against longitudinal movement by: *(1) ties moving through the ballast, and (2) rails moving through anchors/fasteners. The composite behavior is a non-linear interaction of the two movement's "mechanics."*







What Happens to RNT in a Rail Break/Cut Scenario?



Key RNT Readjustment Issues:

(1) When to come back to readjust.

(2) How to readjust (how much rail to cut out and what length to unfasten).

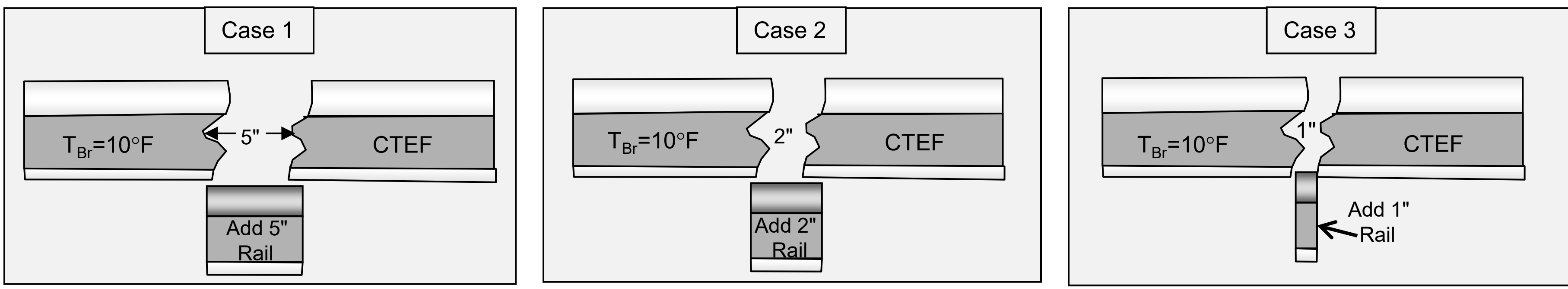
The Fallacy of the "Rail-In/Rail-Out" Doctrine

METHOD 1: When rail is added via an interim (plug) repair for broken/cut rail, remove the added rail later at a *warmer* temperature (procedure often referred to as "rail-in/rail-out").

Issue: Removing just the added rail often is not enough; also, the *warm** temperature to readjust is not specified.

(*Note: for the "warm" temperature definition, refer to the Generic Plan's RSAC Table)

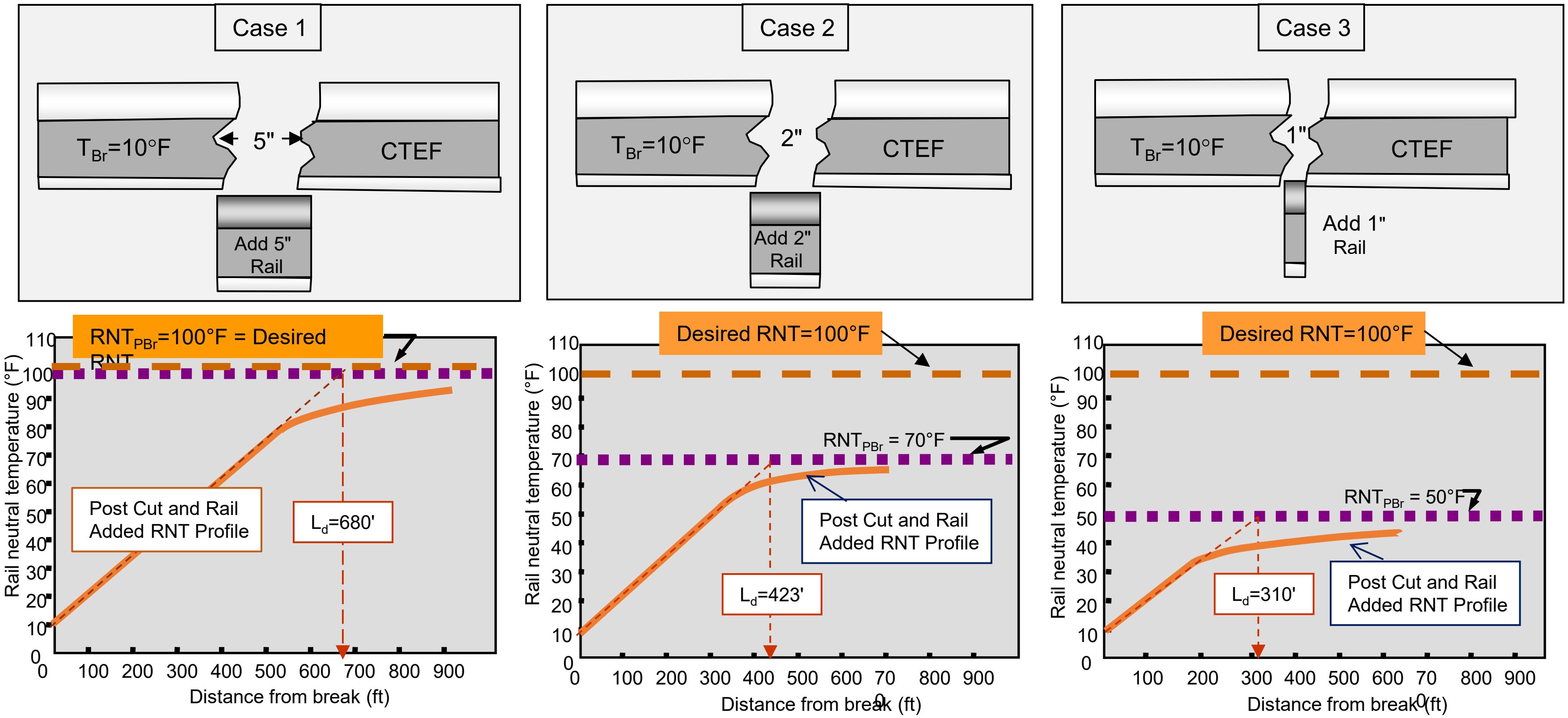
Example: Consider 3 rail break or defect cut scenarios all occurring at a rail temperature of 10°F in identical rail/track conditions on concrete ties with elastic fasteners (CTEF), BUT with different gap size/rail added scenarios. In all 3 cases the desired RNT is 100°F. The rail gang performs the "rail-in/rail-out" readjustment at a later date.



Question: Has the rail been readjusted to the desired RNT = 100°F by removing the added rail?

The Fallacy of the "Rail-In/Rail-Out" Doctrine

QUESTION: Has the rail been readjusted to the DRNT = 100°F?



- Removing the added rail restores RNT to the RNT_{PBr}, so for Case 1 it works, but for Cases 2 and 3 it does not.

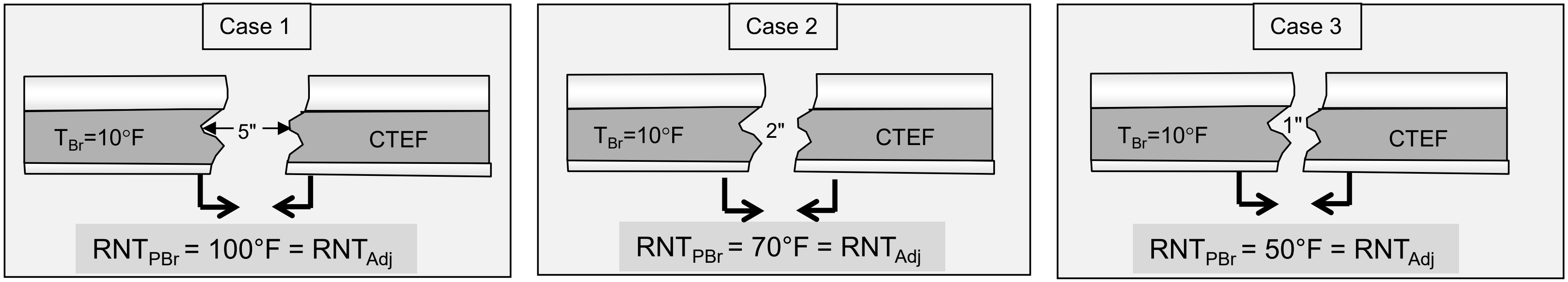
TAKEAWAY: "Rail-in/rail-out" readjusts to pre-break/cut RNTs, hence works only in cases when the pre-break or cut RNT is at or near the desired RNT.

The "Pulling Gaps Together" Issue

METHOD 2: When the rail break/cut gap is *small**, close the gap by pulling or heating the rail without any anchor/fastener removal.

Issue: RNT may be restored, but only to the *pre-break or cut value* and NOT necessarily to the desired RNT.

Example: Consider the 3 rail break or defect cut scenarios as before, but instead of adding rail as an interim repair, the railroad elects to readjust by pulling rail together through the fasteners just after the break/cut and securing with a bolted joint. What is the readjusted RNT in all three cases?



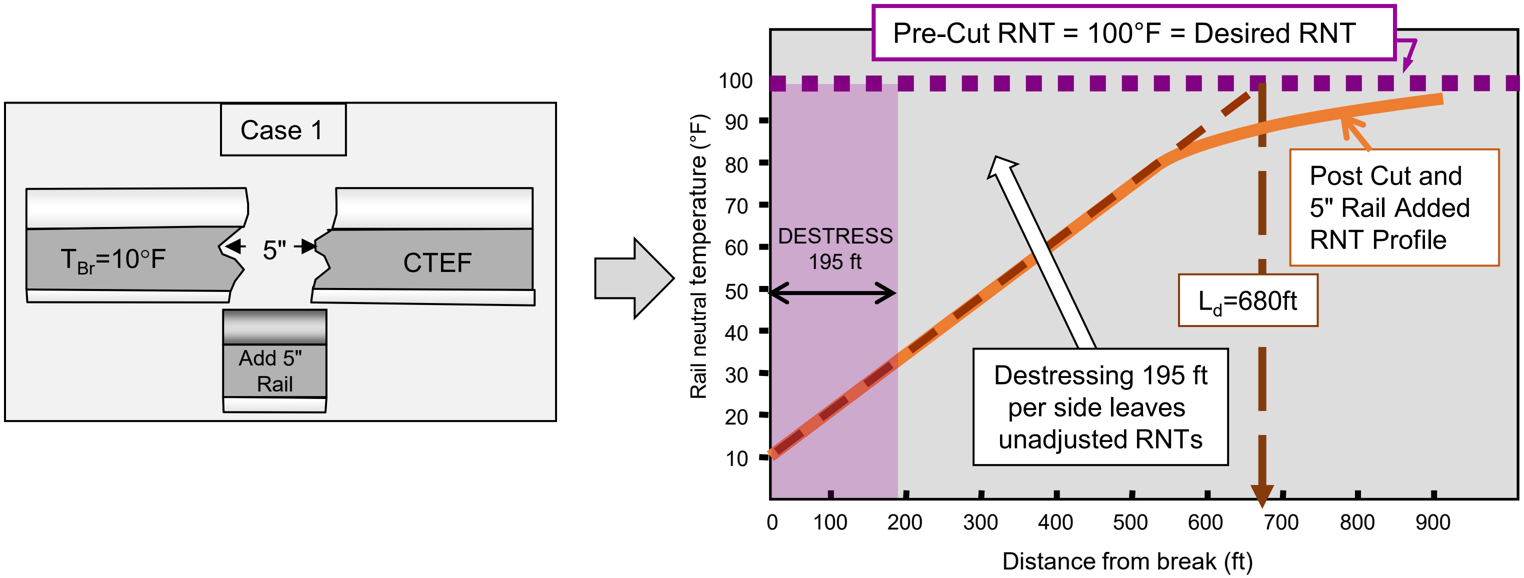
- Pulling rail together through the anchors/fasteners (i.e., with NO rail unfastening) restores RNT to the pre-break or cut value

*Notes: (1) The Cases 2 and 3 gaps may be closable by rail pullers (i.e., deemed "small"), but in Case 1 it is not.
(2) Most railroads have CWR Policy prescriptions on gap sizes deemed *"pullable."*
(3) Anchors/fasteners may need to be re-positioned.
(4) For curves in excess of 3° pulling rail together is not advisable.

Consequence of Unfastening the Currently Required 195 ft on Either Side

METHOD 3: When rail is added as an interim (plug) repair for broken or cut rail, return later at warmer temperature and adjust via destressing rail by unfastening 195 ft on both sides of the cut.

Issue: Rail break or cut INFLUENCE ZONES are typically much longer than 195 ft on either side.

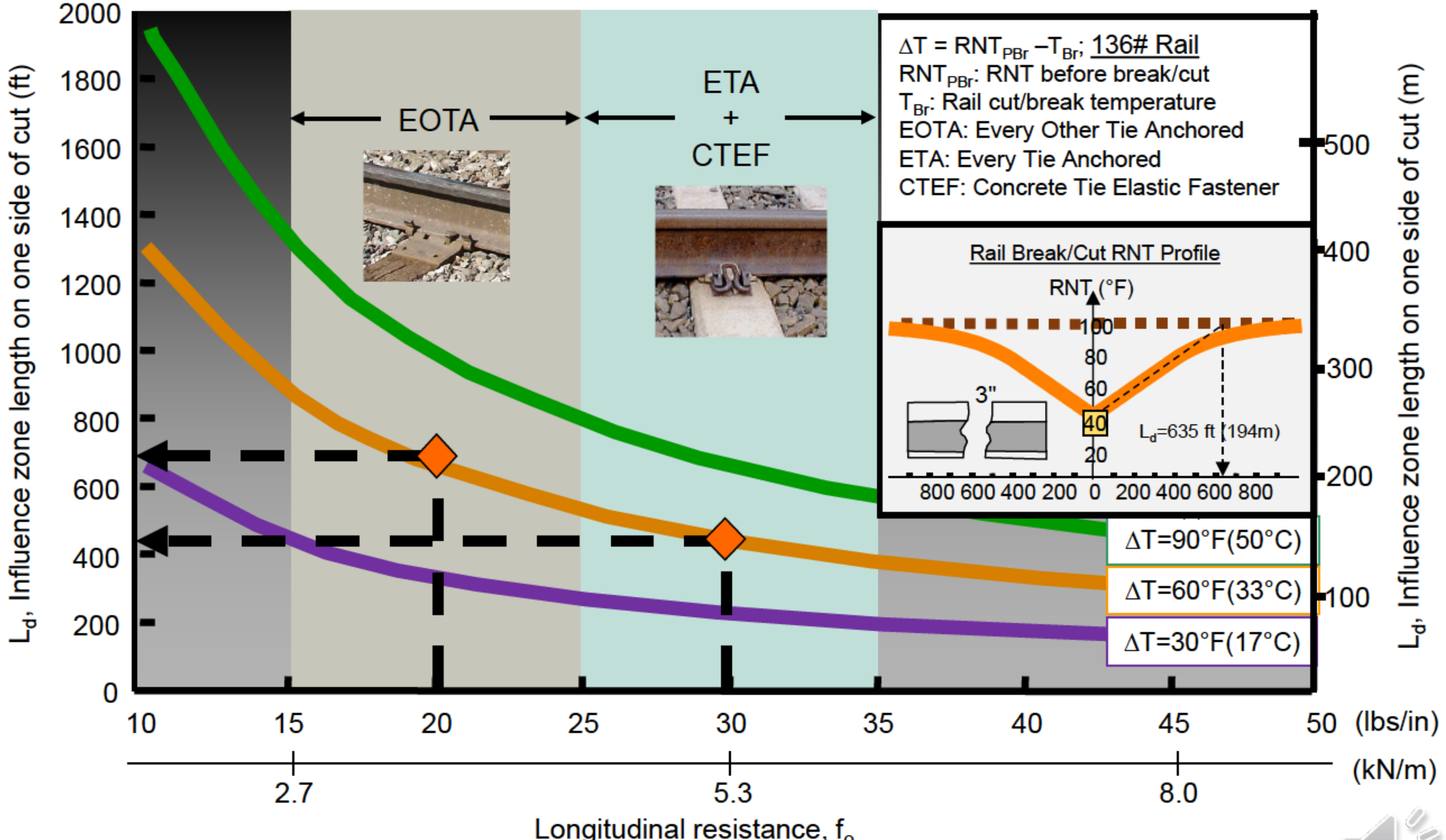


TAKEAWAY: Post break and cut RNT profiles can have large influences on the required destressing lengths; the current 195 ft in most cases may be inadequate.

QUESTION: How long are the rail break and cut influence zones?

How Long Are the Influence Zones?

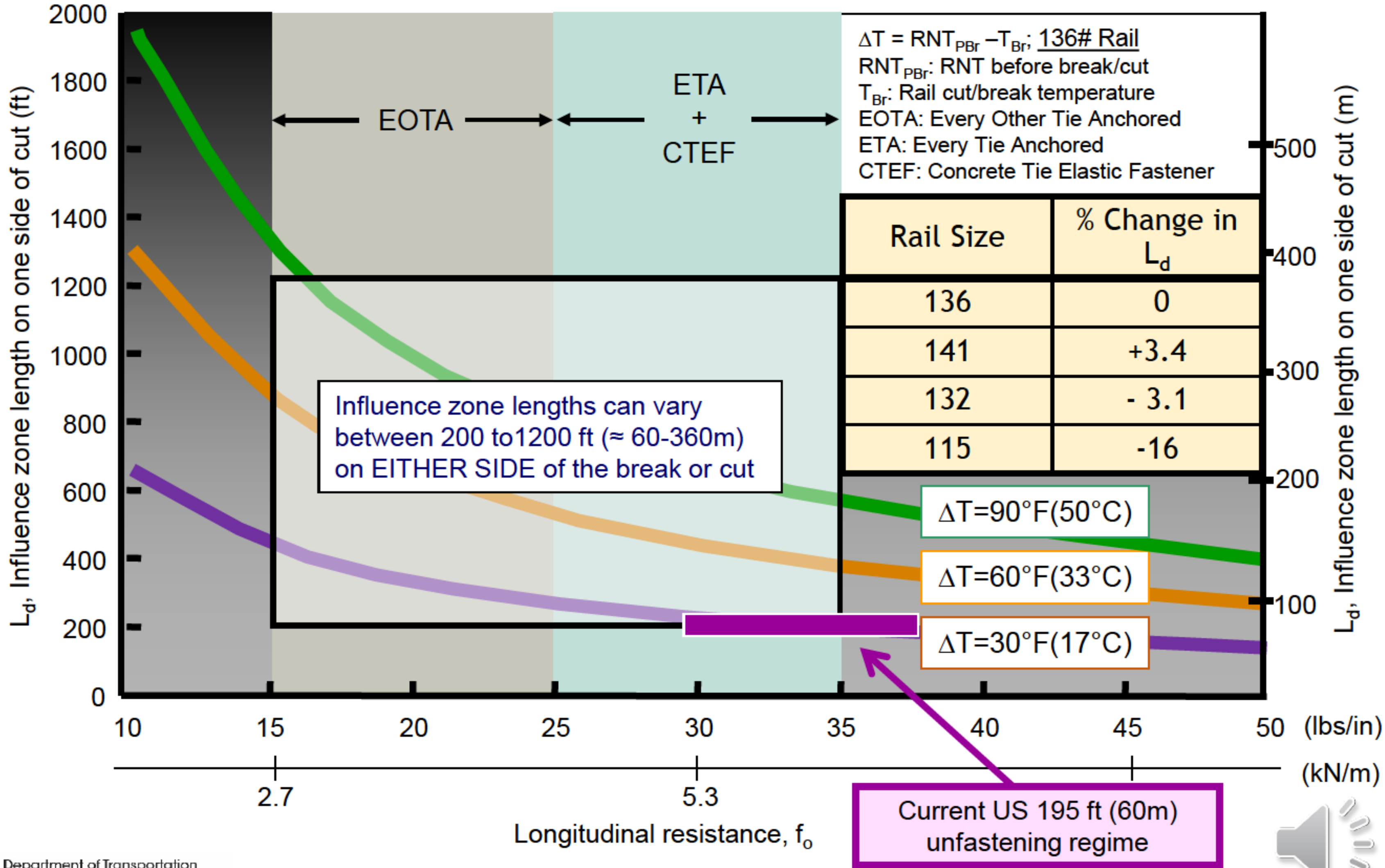
Influence Zone (L_d) Depends on Thermal Load (ΔT), Longitudinal Resistance, and Rail Size



Rail Break Mechanics

How Long Are the Influence Zones?

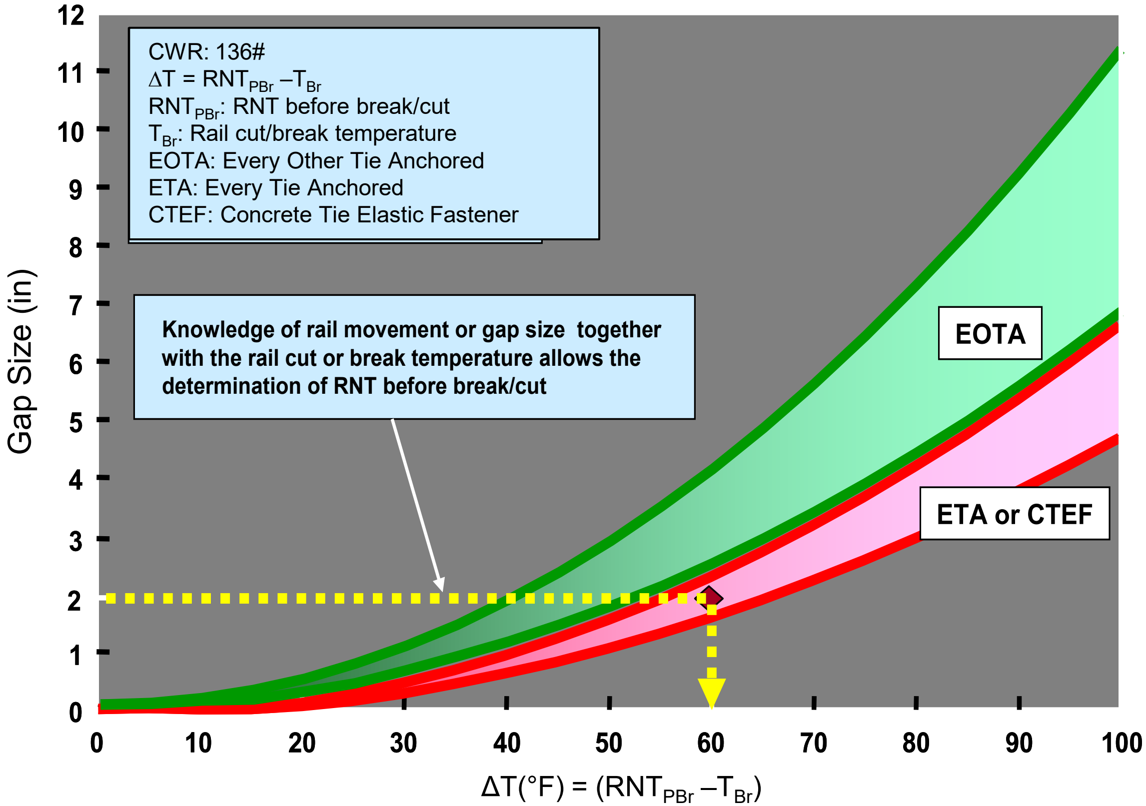
Influence Zone (L_d) Depends on Thermal Load (ΔT), Longitudinal Resistance, and Rail Size



Rail Size	% Change in L_d
136	0
141	+3.4
132	- 3.1
115	-16

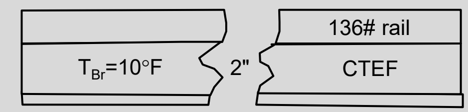
What Do Rail Break and Cut Gap Sizes Depend On?

[Answer: Thermal Load (ΔT), Longitudinal Resistance, and Rail Size]



NEW METHODOLOGY

Key Rail Break Mechanics Parameters



Gap size
Break/cut temp
Rail size/curvature
Fastener/ballast type/condition

Pre-break/cut RNT
Break/cut influence zone

READJUSTMENT PROCEDURE

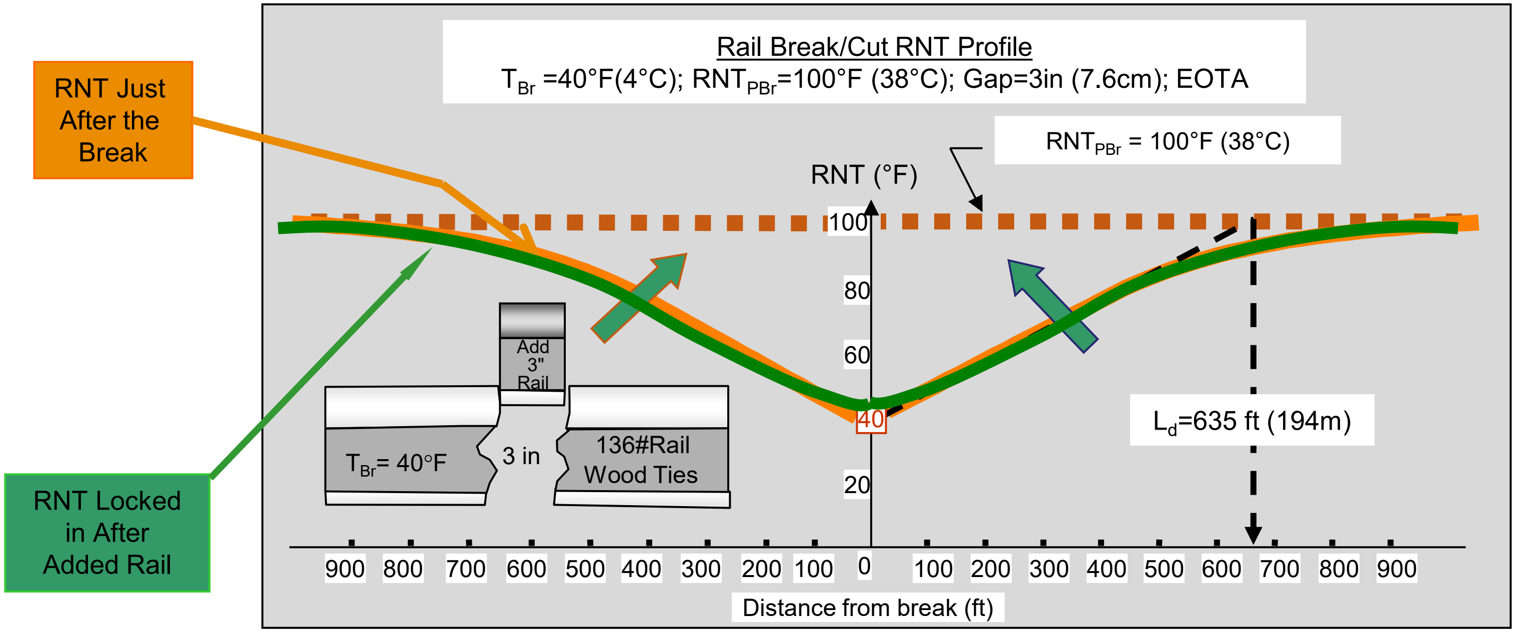
How much rail to cut out
and
what length rail to unfasten
to achieve a target RNT

NEW METHODOLOGY: Knowing gap size and T_{Br} enables the determination of Pre-Break and Cut RNTs.

Example: If ΔT=60°F and rail break temp T_{Br}=10°F, then the pre-break RNT=70°F
[Note: this is how most CWR Policy Tables provide pre-break RNTs.]

Rail Break Mechanics

How to Readjust: When and What Procedure?



Key RNT Readjustment Issues:

(1) When to come back to readjust

(2) How to readjust (how much rail to cut out and what length to unfasten)

Key RNT Readjustment Issues

When to come back and readjust?

(At temperatures before track becomes bucking prone)

How to readjust (i.e., how much rail to cut out and what length to unfasten)?

(Must know the reduced RNT profile)

As per RSAC/FRA Generic Plan

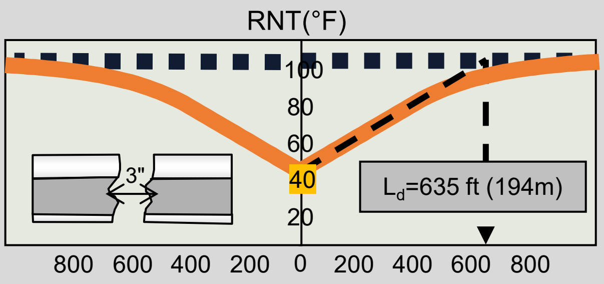
Rail Break/Cut Temperature T_{Br} (°F)	Rail Temperature (°F) at Which to Readjust or Apply Slow Orders
60	135
50	130
40	125
30	120
20	115
10	110
0	105
-10	100
-20	95
-30	90
-40	85

Question: Table prescribes rail temps; railroads typically use ambient; how to convert?

Note: Table does not apply to special case when both rails break/cut in *"close"* vicinity.

Rail Break Theory and Tests

Rail Break/Cut RNT Profile



Requires Software to Provide Applications and Procedures

RNT-RESTORE

Section 2

Current best practice guidelines/applications: RNT-RESTORE

Guidelines for Managing RNT After Cold Temperature Breaks, Cuts, and Pull-Aparts

REQUIREMENT: Rail that has broken or cut for defect removal must be readjusted to within the subdivision's DRNT) minus a safe range (usually between 0 – 20°F) within the time and temperature specified by the RSAC readjustment table.

[RSAC/FRA Generic CWR Plan – Sect. 3.1]

Rail Break/Cut Temperature (°F)	Return Rail Temperature (°F)
60	135
50	130
40	125
30	120
20	115
10	110
0	105
-10	100
-20	95
-30	90
-40	85

Question: What if NOT readjusted by the table's temps?

TOOLS REQUIRED TO IMPLEMENT

1. RNT-RESTORE (or CWR-Adjust) software (or equivalent charts and tables) to provide the pre-break or cut RNTs, and the "how's" to adjust (including the recommended unfastening lengths and of rail cut-outs/removals).

2. The railroad's data management system to record and store gap sizes, the calculated pre-break/cut RNTs, unfastening lengths, rail removals, and T_{RETURN}.

3. Procedures on how to apply — 6 APPLICATION SCENARIOS

What Charts and Tables?

Question: *A 136# rail is cut for a defect removal at a rail temperature of 10°F in a concrete tie territory, resulting in a rail gap of 2 inches. How to determine the pre-cut RNT?*

Answer: Apply RSAC developed tables currently in use by several railroads' CWR policies.

EXAMPLE

6 in. rail base (concrete ties [CTEF])

Rail Break Temp (°F)	Gap Size (inches)									
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
60	90	102	111	119	126	133	138	144	149	154
55	85	97	106	114	121	128	133	139	144	149
50	80	92	101	109	116	123	128	134	139	144
45	75	87	96	104	111	118	123	129	134	139
40	70	82	91	99	106	113	118	124	129	134
35	65	77	86	94	101	108	113	119	124	129
30	60	72	81	89	96	103	108	114	119	124
25	55	67	76	84	91	98	103	109	114	119
20	50	62	71	79	86	93	98	104	109	114
15	45	57	66	74	81	88	93	99	104	109
10	40	52	61	$\boxed{69}$	76	83	88	94	99	104
5	35	47	56	64	71	78	83	89	94	99
0	30	42	51	59	66	73	78	84	89	94
-5	25	37	46	54	61	68	73	79	84	89
-10	20	32	41	49	56	63	68	74	79	84
-15	15	27	36	44	51	58	63	69	74	79
-20	10	22	31	39	46	53	58	64	69	74

- Note: Tables are based on several restrictive assumptions; better option is to use RNT-RESTORE (or CWR-Adjust).

The RNT-RESTORE Program

RNT-RESTORE is an automated procedure to provide the rail industry with a user-friendly, science- and current best practice-based maintenance tool for more effectively managing RNT when cutting out rail defects and repairing broken rail.

APPROACH

- Apply rail break theory, test results and validation studies, CWR-Adjust experience, in-situ rail break/cut data, and current industry guidelines, practices and procedures.

INDUSTRY BENEFITS

- Improved RNT management/procedures
- Improved rail safety and performance

The RNT-RESTORE Program

RNT-RESTORE SOFTWARE ALGORITHM AND APPLICATIONS	
Module	DESCRIPTION
1	Evaluation of rail break/defect cut influence zone lengths and pre-break/cut RNTs based on theory and field measurements. Results are required inputs to Modules 2, 3, and 4, and are also required by most CWR policies.
2	RNT adjustment procedure when repairing broken/defect cut rail when performed at the time of break/cut, and when pre-break/cut RNTs (from Module 1) indicate rails can be pulled together for target RNT restoration.
3	Same as 2, but when additional rail removal is required for readjustment, and when rail is pullable through anchors/fasteners. This Module 3 provides the additional rail removal required.
4	Procedure for readjusting RNT after rail break/defect cut when interim repairs (IRs) are required (such as rail addition via a plug) and when RNT readjustment is deferred for a later time, in line with prescribed temperature limits.
5	Readjustment procedure for special cases when Module #1 (and therefore Modules 2, 3, & 4) are NOT applicable. These include: ▪ Multiple breaks on same rail within close proximity of each other ▪ Breaks/cuts at or near fixed points (bridges, tunnels, crossings, switches/turnouts, etc.) ▪ Extremely stiff, frozen rail/ballast conditions
6	Procedure for readjusting RNT after defect cut/repairs performed in warm temps (i.e., when rail in compression). NOTE: Locations under Modules 2-4 scenarios being deferred to later warm temp readjustments are NOT covered.

The RNT-RESTORE Program

- Formulation, methodology, road-map, algorithm, and step-by-step procedures are based on:

Kish: "Best Practice Guidelines for CWR Neutral Temperature Management" (AREMA 2013 paper)	Read & Kish: "Guidelines for Managing Thermal Forces and RNT in CWR" (AAR Research Report R–1003 December 2012)
Kish: "Theoretical Formulation for Equations to Evaluate Rail Break Forces, RNTs, and Gap Sizes" (Technical Monograph – 3/30/20)	Kish: "RNT-RESTORE" – An Automated Procedure for RNT Management When Repairing Rail Defects and Broken Rail" (Technical Report – 1/30/20)

- RNT-RESTORE software package is an FRA product developed by ENSCO/Kandrew Inc., under FRA sponsorship.

Improved RNT Management through RNT-RESTORE

The RNT-RESTORE Program

RNT-RESTORE SOFTWARE ALGORITHM AND APPLICATIONS	
Module	DESCRIPTION
1	Evaluation of rail break and defect cut influence zone lengths and pre-break and cut RNTs based on theory and field measurements. Results are required inputs to Modules 2, 3, and 4, and are also required by most CWR policies.

Input Parameters

- Location description
- Rail size and curvature
- Anchor/fastener/ballast type/condition
- Rail cut or break temperature
- Measured rail gap size
- IR method

Software Algorithm (Module # 1) →

Output

- Precut/break RNT_{PBr} *
- RNT influence zone length
- RNT after IR
- Recommended Module for application

* *Required by RSAC/FRA CWR Generic Plans, and by most railroads CWR policies*

How to Chose Anchor/Fastener Condition?

(“Weak,” “Average,” and “Strong”)

Input Parameters

- Location description
- Rail size and curvature
- Anchor/fastener/ballast type/condition
- Rail cut/break temperature
- Measured rail gap size
- Interim repair (IR) method

Weak: missing anchors; the majority are not tight against the ties; evidence of rail slipping through the anchors/clips; ballast crib more than 2 inches below top of ties; poor tie condition; more than half of the insulators are cracked, broken, or not seated in the shoulder; tie pads are slipping or deteriorated; evidence of rail seat abrasion.

Average: anchors are in place and tight against the ties; no evidence of rail creep; tie condition is good; full ballast section; most insulators are sound and seated correctly; tie pads are not worn or moving in the rail seat; no evidence of rail seat abrasion.

Strong: new construction or rail relay with new anchors or fasteners; full ballast section and well consolidated, and which do not exhibit any of the “weak” or “average” characteristics.

NOTE: When in doubt, the “weak” strength assumption provides the “safest” choice.
(“weak” to “strong” error range → 10 to 15°F in pre-break and cut RNTs)

The RNT-RESTORE Program

RNT-RESTORE SOFTWARE ALGORITHM AND APPLICATIONS	
Module	DESCRIPTION
2	RNT adjustment procedure when repairing broken and defect cut rail when performed at the time of break or cut, and when pre-break and cut RNTs (from Module 1) indicate rails can be pulled together for desired RNT restoration.

STEP 1: From Module 1 determine rail segment's pre-break/cut RNT.

STEP 2: From railroad's CWR Policy determine territory's desired RNT for readjustment (including any special DRNT-20 criterion/requirement) and compare with STEP 1's pre-break or cut RNT. If within range, go to STEP 3; if not, go to Module #3.

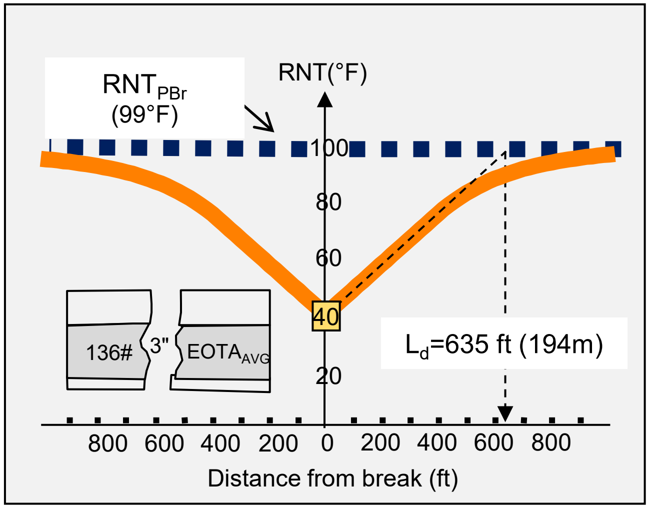
STEP 3: Determine if the existing rail gap can be closed by pulling rail together (WITHOUT ANY ANCHOR OR FASTENER REMOVAL). If pullable, proceed to STEP 4, if not go to STEP 5. *(This is an on-site/in-situ field evaluation task by the railroad maintenance personnel and is typically based on the measured gap size, labor, track time, and equipment availability.)*

STEP 4: If rail is closable by rail puller, cut an extra 1" for the weld allowance, apply puller to close the gap to 1" and make the weld. After repositioning any displaced anchors, document all pertinent information, including measured gap size, pre-break or cut RNT, the restored RNT, and rail break or cut influence zone.

STEP 5: If rail is NOT closable by puller, make any expedient IR, record all pertinent information, and proceed to Module #4 for later readjustment.

Module 2 Illustrative Example

Consider a rail break or defect removal on wood tie, every other tie anchored ($EOTA_{AVG}$), 136# rail segment, when the rail broke or was cut at 40°F, and the resulting gap size is 3 inches. How to make the repair and readjustment at the time of break or cut when the territory's desired RNT=105°F and if the railroad's readjustment prescription is to an RNT within an DRNT-10 safe range?



ANSWER: *From Module 1 the pre-break or cut RNT is 99°F. This is within territory's DRNT-10 safe range, hence a candidate for Module 2. After cutting an extra 1" for the weld allowance, close the gap to the 1" weld gap via rail puller (without any anchor removal), and proceed to make the weld. Record all pertinent data and be sure to reposition any moved anchors displaced by rail pulling. Then the readjusted RNT here is 99°F.*

Note: If for any reason the rail could not be pulled together, proceed to make an IR via a plug rail requiring adding 3" of rail, and then apply Module 4 to readjust before rail temperature exceeds 125°F (see Module 4 – Table 1).

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The RNT-RESTORE Program

RNT-RESTORE SOFTWARE ALGORITHM AND APPLICATIONS	
Module	DESCRIPTION
3	Same as 2, but when additional rail removal is required for readjustment, and when rail is pullable through anchors/fasteners. Module 3 provides the additional rail removal required at the time of the break or cut.

STEP 1: From Module 1's pre-break or cut RNT and the railroad's prescribed DRNT-X readjustment requirement, evaluate what additional rail cut is required to get within the desired RNT safe range.

(This is done within Module 3's algorithm which calculates the additional rail-cut required to produce the stipulated restored RNT [i.e., the prescribed DRNT- X].)

STEP 2: Proceed to cut out STEP 1's additional rail + the 1" weld allowance, and pull rail together without any de-anchoring/unfastening to the 1" weld gap and proceed to make the weld.

STEP 3: Record all pertinent data within this Module and in the railroad's data management system. At a minimum this data should include break or cut temperature, RNT_{PBr}, measured gap size, additional rail cut-out, and RNT_{Adj}.

NOTE 1: If rail is deemed NOT closable by puller for any reason, make plug IR before STEP 2's additional rail cut; record all pertinent information, and proceed to Module 4 for a later readjustment.

NOTE 2: This method *does not* produce a uniform readjusted RNT profile but may be acceptable in practice.

Module 3 Illustrative Example

Consider a 136# rail being cut for a defect removal at a rail temperature of 20°F in concrete tie ($CTEF_{avg}$) territory resulting in a rail gap of 2 inches. The territory's desired rail neutral temperature is 105°F. How to make readjustment at the time of defect cut in line with a DRNT-10 criterion?

ANSWER: From Module #1 the pre-cut RNT for this example is 79°F, which is NOT within the DRNT-10 safe range. Module #3 shows that an additional <u>*1" cut*</u> *would bring RNT within the DRNT-10 safe range. At this point, field personnel should decide if the additional cut of 1" (plus the 1" weld allowance) (i.e., leaving a total gap of 4") is pullable by 3" to close to the 1" gap required for welding (without any fastener removal). If so, proceed to close the gap to the 1" weld gap size, and make the weld.*

NOTE: *If the gap is NOT pullable to the weld gap size, proceed to make an IR via a plug insertion (prior to cutting any extra rail) thereby adding 2" of rail. Then proceed to Module 4 for a later readjustment prior to T_{RAIL} exceeding 115°F.*

Module 3 Illustrative Example (Continued)

Consider a 136# rail being cut for a defect removal at a rail temperature of 20°F in concrete tie ($CTEF_{avg}$) territory resulting in a rail gap of 2 inches. The territory's DRNT is 105°F. How to make readjustment at the time of defect cut in line with a DRNT-10 criterion?

NOTE: if the gap is NOT pullable to the weld gap size, proceed to make an IR via a plug insertion (prior to cutting any extra rail) thereby adding 2" of rail. Then proceed to Module #4 for a later readjustment prior to T_{RAIL} exceeding 115°F.

BETTER IR OPTION

Consider an optional IR of pulling the rail together by 2" through the fasteners and securing with a bolted joint. In this example that would produce a *"partial"* RNT adjustment to 79°F. This is still below the territory's DRNT-10 requiring a later adjustment but offers interim safety benefits (i.e., increasing the 20°F post-cut RNT to a partially restored 79°F in this example).

BENEFITS

- Added safety [79°F RNT vs 20°F]
- Less stringent return temps (see RSAC Table)
- One weld vs two (easier maintenance)

The RNT-RESTORE Program

RNT-RESTORE SOFTWARE ALGORITHM AND APPLICATIONS	
Module	DESCRIPTION
4	Procedure for readjusting RNT after rail break or defect cut when interim repairs (IRs) are required (such as rail addition via a plug) and when RNT readjustment is deferred for a later time in line with prescribed temperature limits.

Module 4 is typically employed when Module 2 (or 3) dictate an IR, and thus deferring final repair/adjustment to a later time consistent with the return time (temperature) as per RSAC or FRA CWR Policy Table:

Rail Break/Cut Temperature (°F)	Return Rail Temperature (°F)
60	135
50	130
40	125
30	120
20	115
10	110
0	105
-10	100
-20	95
-30	90
-40	85

SPECIAL NOTES FOR IRs:

- *Table's prescriptions are fully valid when IR is via a rail plug.*
- *When IR is via pulling rail together and securing with a bolted joint, table applies only when the pulled/bolted rail's partially restored RNT is BELOW the table's maximum value of 60°F.*

The RNT-RESTORE Program

RNT-RESTORE SOFTWARE ALGORITHM AND APPLICATIONS	
Module	DESCRIPTION
4	Procedure for readjusting RNT after rail break or defect cut when interim repairs (IRs) are required (such as rail addition via a plug) and when RNT readjustment is deferred for a later time in line with prescribed temperature limits.

When Knowing Reduced RNT Profile

Module 4 – Scenario 1a or 1b: Procedure for Later Readjustment Either by Method of Mechanical Rail Tensioning or Destressing

Uses information from Modules *1, 2 or 3 to evaluate rail cut required for DRNT-X where: 1a DOES NOT require unfastening* rail (but requires pulling rail through anchors/fasteners), and 1b *DOES* require unfastening rail as part of a destressing procedure.

When NOT Knowing Reduced RNT Profile

Module 4 – Scenario 2: Procedure for Later Readjustment by *"Blind"* Destressing

When Scenario 1 is NOT adoptable for any reason (such as when a railroad elects not to use, or when Module #1 is not applicable). This Scenario 2 *DOES* require unfastening a pre-determined length of rail for destressing which determines the amount of rail cut-outs.

Improved RNT Management through RNT-RESTORE

RNT Readjustment: Restressing versus Destressing

Rails in Tension: Rail Breaks and Defect Removals

Rails in Compression: *"Kinky"* Rail or Deferred Restressing

Readjustments for "Cold" Temp Repairs

RESTRESSING

(1) Adjust at time of break or defect cut (Modules 2 & 3), or:

(2) Perform interim repairs and readjust later (Modules 4 & 5)

HOW?: in accordance with railroad's CWR procedures

Key Issues: record keeping, and following applicable CWR procedures (RNT-RESTORE)

Readjustments in "Warm" Temps

DESTRESSING

Can require immediate action, or as dictated by delayed restressing requirements

HOW?: in accordance with railroad's CWR procedures

Key Issues: what lengths of rail to destress (i.e., (what lengths to unfasten, how much rail to cut out)

Module 4 – Scenario 1a – Illustrative Example

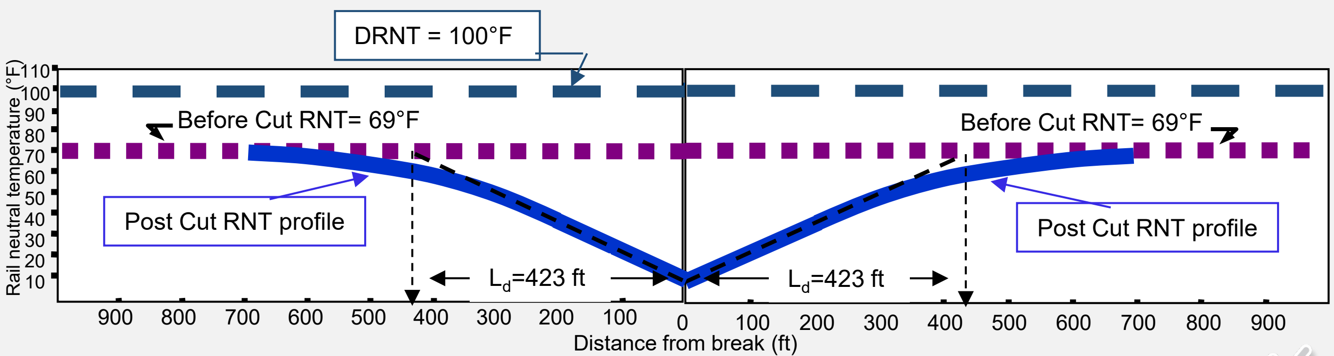
A 136# rail is cut for a defect removal at a rail temperature of 10°F in a concrete tie ($CTEF_{AVG}$) territory resulting in a rail gap of 2 inches. The territory's DRNT is 100°F. How to make adjustment when returning later after an IR?

- Use Module 1 to determine RNT_{PBr} (here 69°F) and L_D (here 423 ft), and based on IR method determine when (i.e., at what temps) to return for readjustment:
  - IR Method 1: when 2" gap is closed via puller and secured with a bolted joint, or:
  - IR Method 2: when gap is closed via rail plug (adding 2" of rail)

NOTE: For IR Method 2 return for readjustment before T_{RAIL} exceeds 110°F, and then follow Module #4

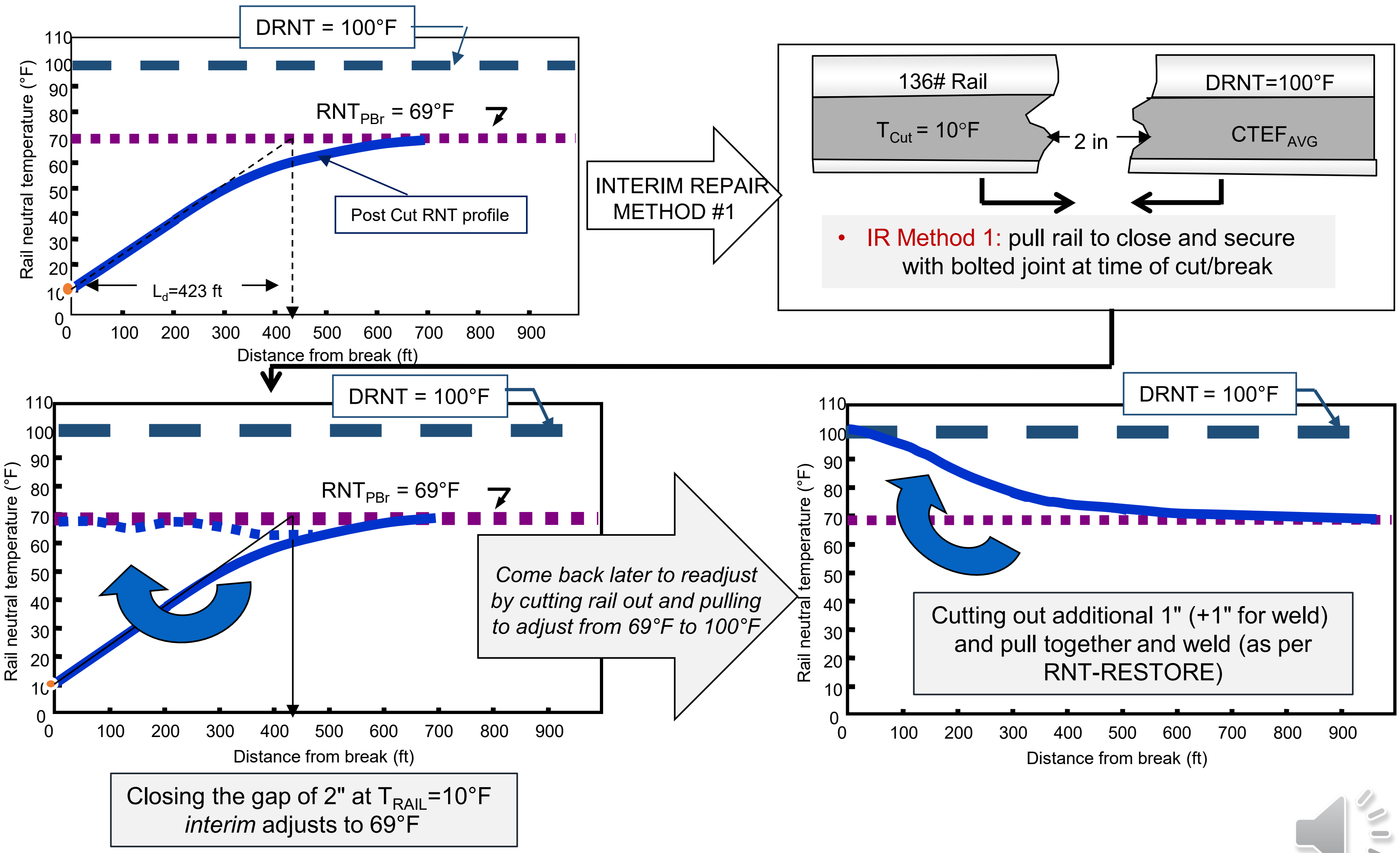
Rail Break/Cut Temperature (°F)	Return Rail Temperature (°F)
60	135
50	130
40	125
30	120
20	115
10	110
0	105
-10	100
-20	95
-30	90
-40	85

What RNT profile is being adjusted?

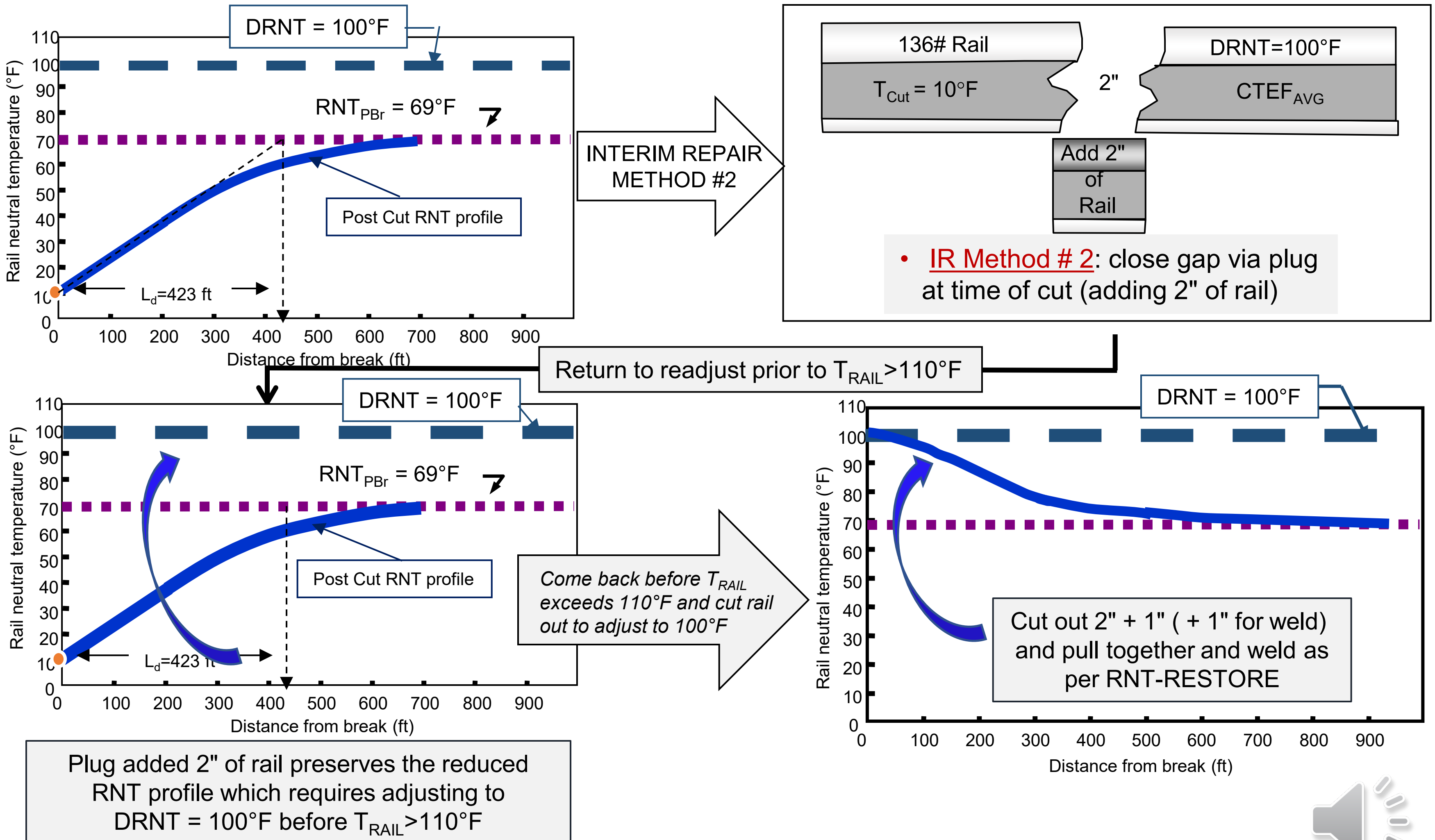


NOTE: above example assumes non-frozen ballast.

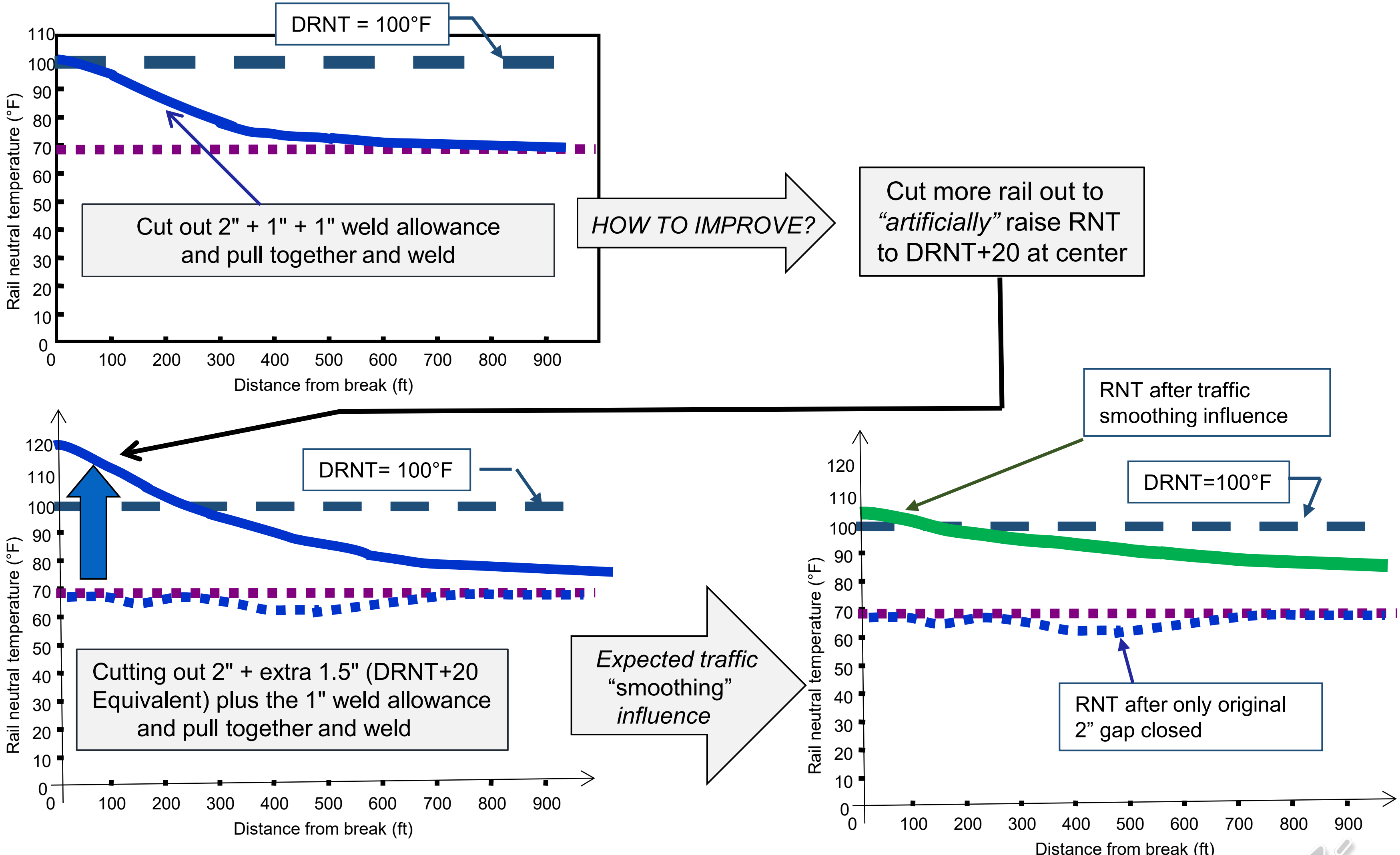
Module 4 – Scenario 1a Illustrative Example (Continued)



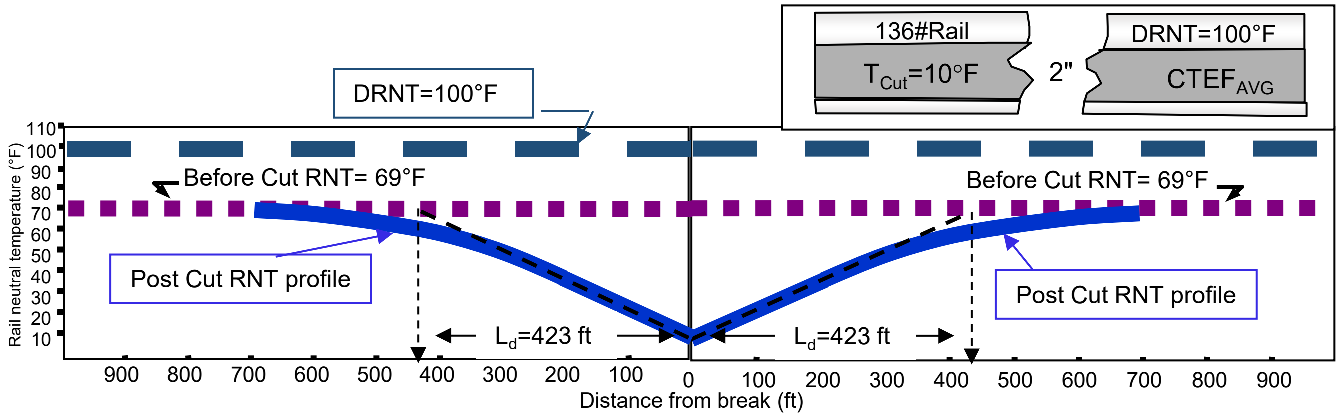
Module 4 – Scenario 1a Illustrative Example (Continued)



How to Improve the Restored "Uneven" RNT Profile?



Module 4 – Scenario 1b or 2 Illustrative Example (Destress Cases)



Destress Method/Procedure Depends On:

Scenario 1b

Knowing the RNT Profile Requiring Adjustment (“SMART Destressing”)

Scenario 2

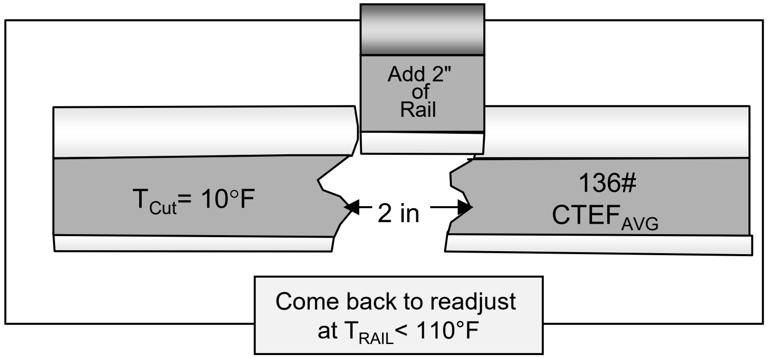
NOT Knowing the RNT Profile Requiring Adjustment (“BLIND Destressing”)

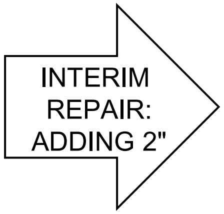
NEED TO KNOW

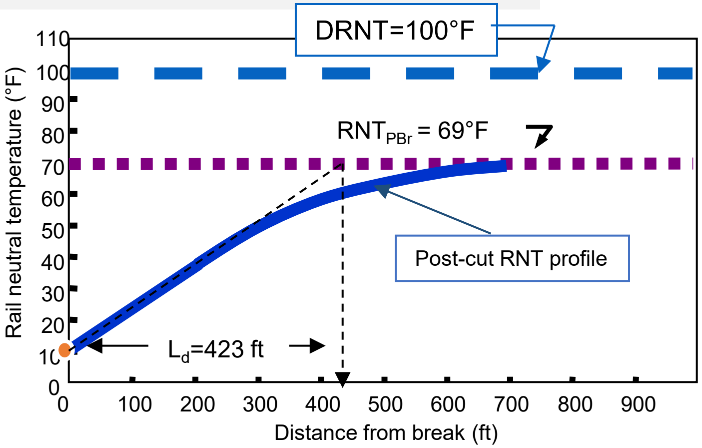
- What is a minimally acceptable adjustment length ($2L_u$) for an effective RNT restoration?
- What is the required rail cut for the chosen $2L_u$ and desired RNT?

Improved RNT Management through RNT-RESTORE

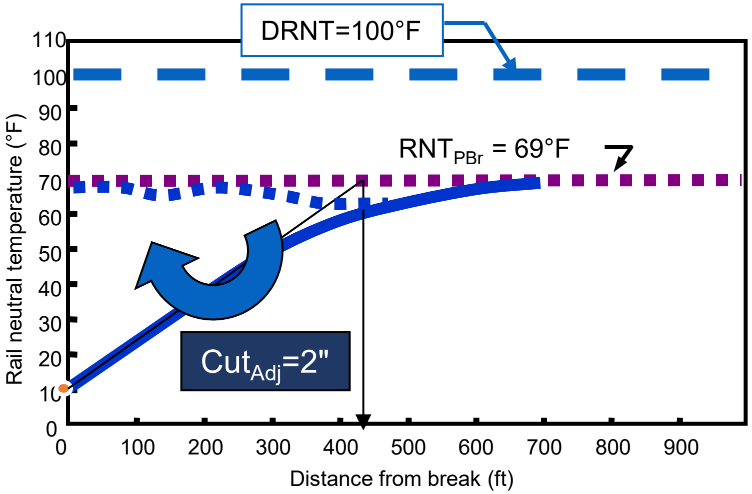
When Knowing the RNT Profile Requiring Adjustment

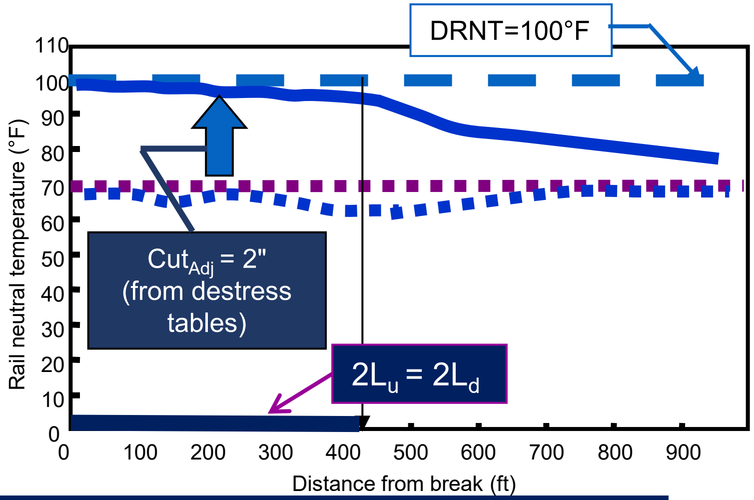






Module 4 – Scenario 1b: Destress Length = $2L_d$ = 846 ft; total rail cut-out (RC) = 4" + weld allowance

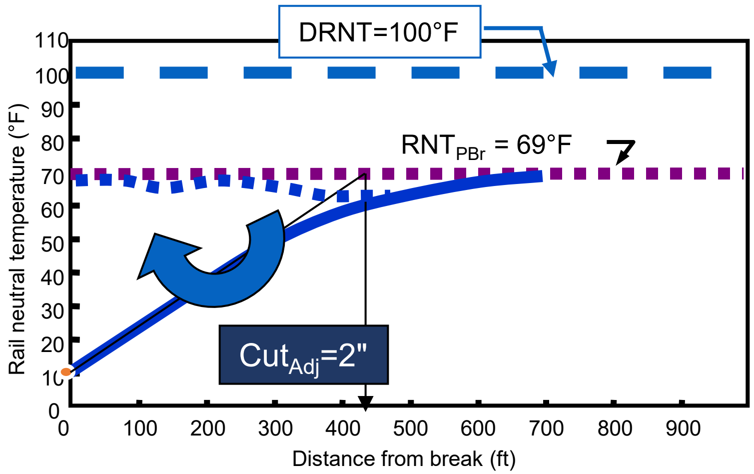


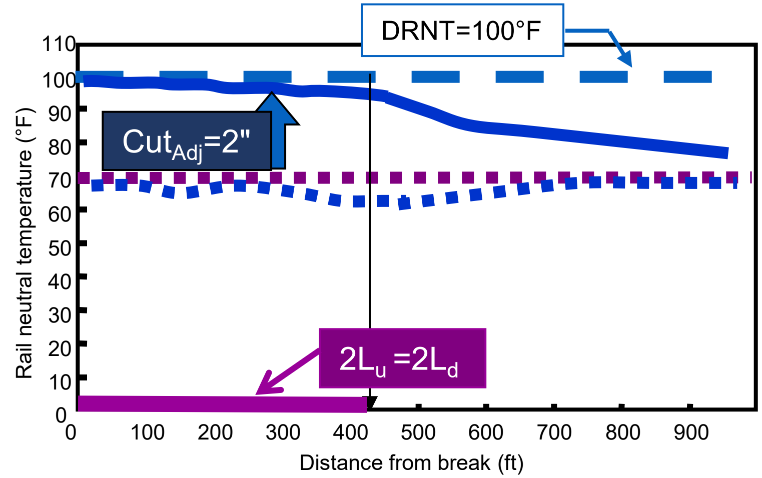


APPLICATIONAL CONUNDRUM: RAILROADS DON'T WANT TO UNFASTEN 846 ft of RAIL

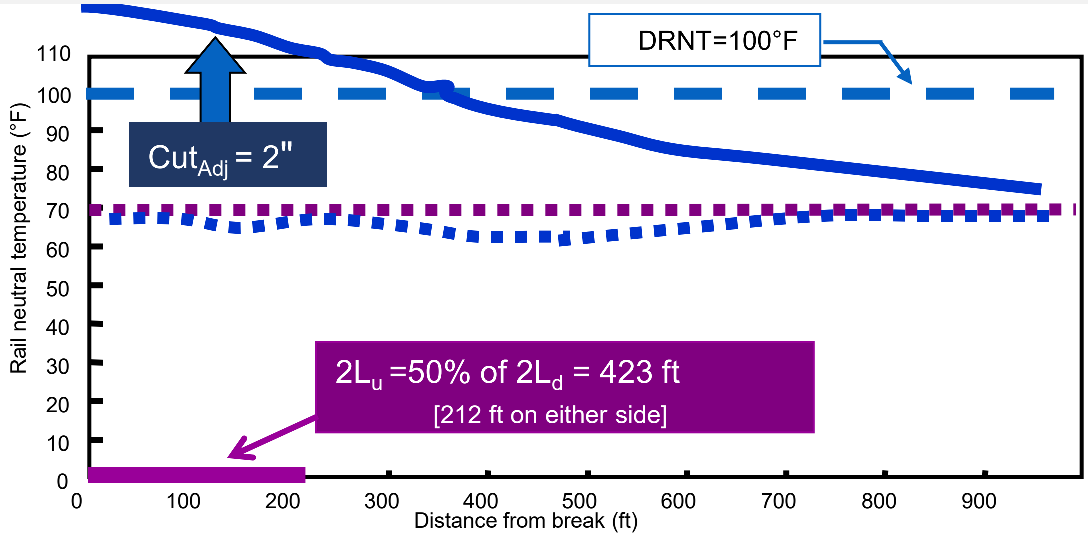
Improved RNT Management through *RNT-RESTORE*

HOW TO MAKE SCENARIO 1b DESTRESS PROCEDURE MORE RAILROAD-ACCEPTABLE?





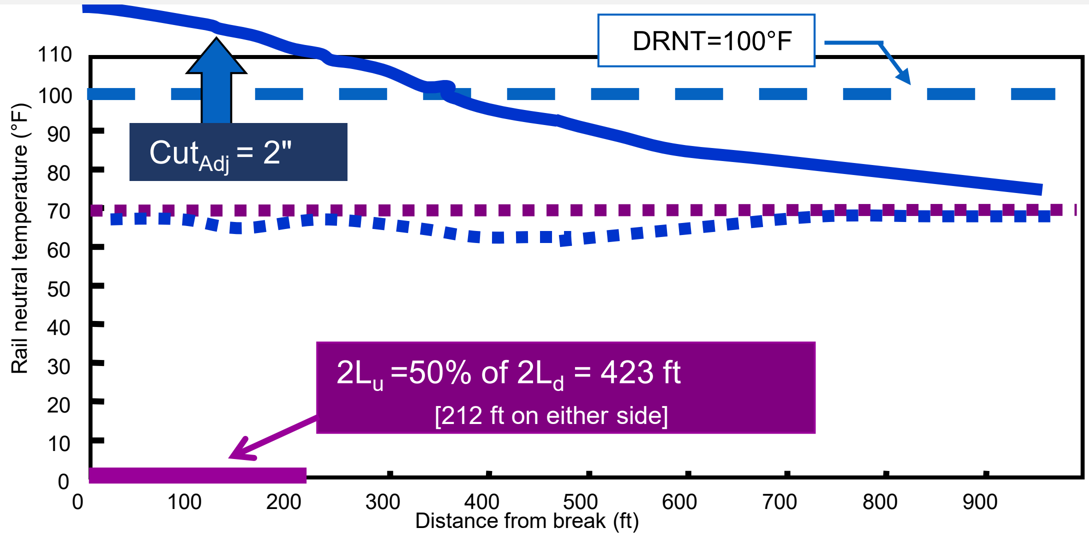
SUGGESTED METHODOLOGY: The 50% 2L$_u$ CRITERION
(BUT still cut rail out as per original 2L$_d$ requirement)



Improved RNT Management through RNT-RESTORE

HOW TO MAKE SCENARIO 1b DESTRESS PROCEDURE MORE RAILROAD-ACCEPTABLE?

SUGGESTED METHODOLOGY: The 50% $2L_u$ CRITERION
(BUT still cut rail out as per original $2L_D$ requirement)



CONUNDRUM:

IS THIS OVERSTRESSING/UNDERSTRESSING APPROACH ACCEPTABLE TO INDUSTRY?

The RNT-RESTORE Program

RNT-RESTORE SOFTWARE ALGORITHM AND APPLICATIONS	
Module	DESCRIPTION
4	Procedure for readjusting RNT after rail break or defect cut when interim repairs (IRs) are required (such as rail addition via a plug) and when RNT readjustment is deferred for a later time in line with prescribed temperature limits.

Module 4 – Scenario 1a or 1b: Procedure for Later Readjustment Either by Method of Mechanical Rail Tensioning or Destressing

Uses information from Modules *1, 2 or 3 to evaluate rail cut required for DRNT where: 1a DOES NOT require unfastening* rail (but requires pulling rail through anchors/fasteners), and 1b DOES require unfastening rail as part of a destressing procedure.

Module 4 – Scenario 2: Procedure for Later Readjustment by "Blind" Destressing Procedure

When Scenario 1 is NOT adoptable for any reason (such as when a railroad elects not to use, or when Module 1 is not available or applicable). *DOES* require unfastening "long" lengths of rail for destressing.

QUESTION

How to destress, i.e., what lengths?

Module #4 – Scenario 1b & 2 Destress Lengths

Current Best Practice Guideline on Destress Lengths

Knowing the RNT Profile Requiring Adjustment ("SMART" *Destressing)*

$2L_u$ = 50% of $2L_d$ influence zone (i.e., L_d)
BUT
cut more rail out to compensate for the 50% reduced unfastening length either by calculating:

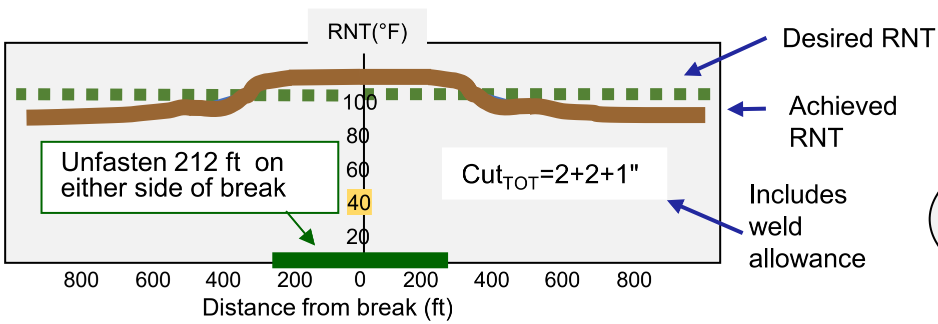
(a) Cut_{Adj} by the full $2L_d$ for DRNT
or
(b) Cut_{Adj} for L_d for DRNT + 20°F

NOT Knowing the RNT Profile Requiring Adjustment ("BLIND" *Destressing)*

CURRENT "BEST PRACTICE" COMPROMISE:

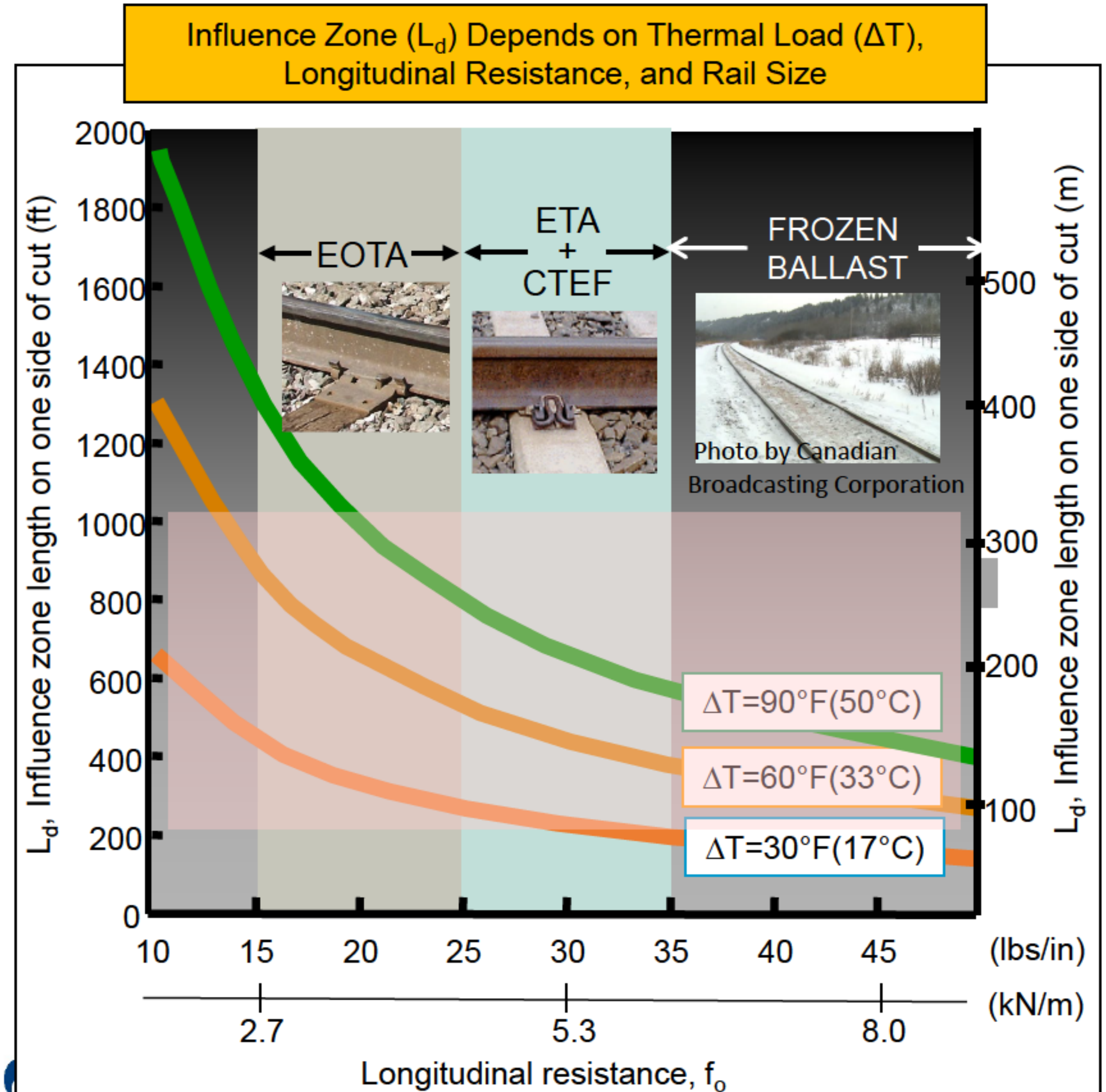
390 ft on either side (780 ft) total ("one length fit for all criterion")

ALSO BECOMES MODULE 5 FOR "SPECIAL CASES"



NOTE: RNT-RESTORE "overstresses" to compensate for the reduced $2L_u$, but with expected traffic "equalization" benefits.

MODULE 4 – Scenario 2: L_D vs Destress Lengths



INFLUENCE ZONES can vary from 200 ft to over 1000 ft on either side of break/cut; so is the "one length fit for all" ±390ft criterion OK?

If not, how to choose a destress length ($2L_u$) for "blind" destress adjustment that is more science-based?

The RNT-RESTORE Program

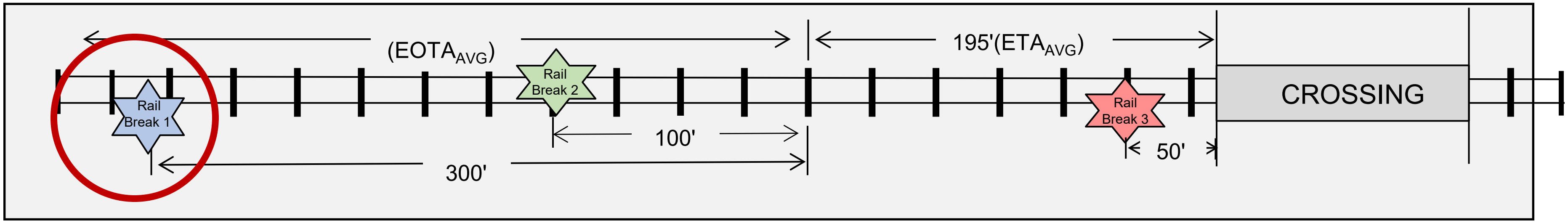
RNT-RESTORE SOFTWARE ALGORITHM AND APPLICATIONS	
Module	DESCRIPTION
5	Readjustment procedure for special cases when Module 1 (and therefore Modules 2, 3, & 4) are *NOT* applicable. These include: ▪ Multiple breaks on same rail within close proximity of each other (800 ft) ▪ Breaks and cuts at or near fixed points (bridges, tunnels, crossings, switches/turnouts, etc.) [400 ft] ▪ Extremely stiff, frozen rail/ballast conditions

Module 5: "Blind Destress" Procedure

390 ft on either side (780 ft) total
AND
readjust to DRNT
(i.e., NOT to DRNT-20)

Module 5 Illustrative Example 1a – Readjustment Near Fixed Structures

A rail break occurs at <u>one</u> of the locations shown on a 136# rail on wood ties with $EOTA_{avg}$ and ETA_{avg} at T_{RAIL}= 31°F near a crossing resulting in a gap of 2 inches. The territory's DRNT=95°F. How to make the repair/adjustment for each case for a DRNT = 95°F?



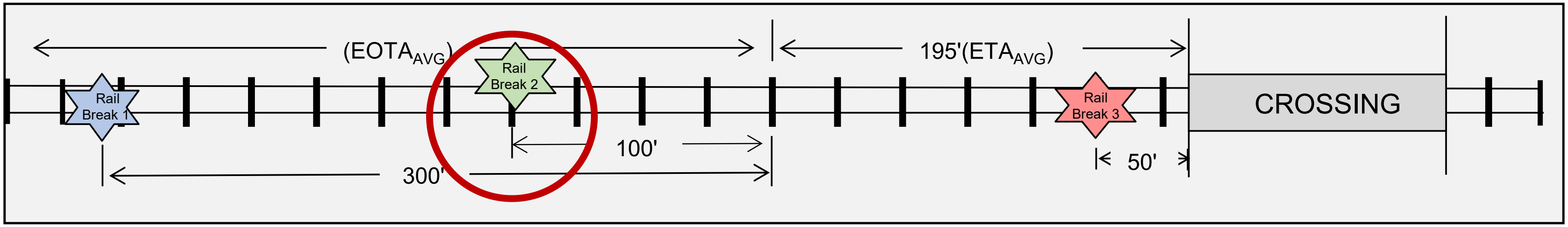
- For Rail Break 1: Module #1 applies (since Rail Break 1 is more than 400 ft away so no need for Module 5). Module #1 gives RNT_{PBr} = 80°F which is 15°F below target, so apply Module 3 at the time of the break to cut an extra 0.75" (as per Module #3) plus the weld allowance. Pull rail together by 2.75" (thru anchors) and weld.

Question 1: Suppose railroad's CWR Policy calls for a DRNT-20 restoration – what to do?

Question 2: Suppose railroad elects an IR at T_{RAIL}=31°F by plug rail (adding 2" of rail) – what to do?

Module #5 Illustrative Example #1b – Readjustment Near Fixed Structures

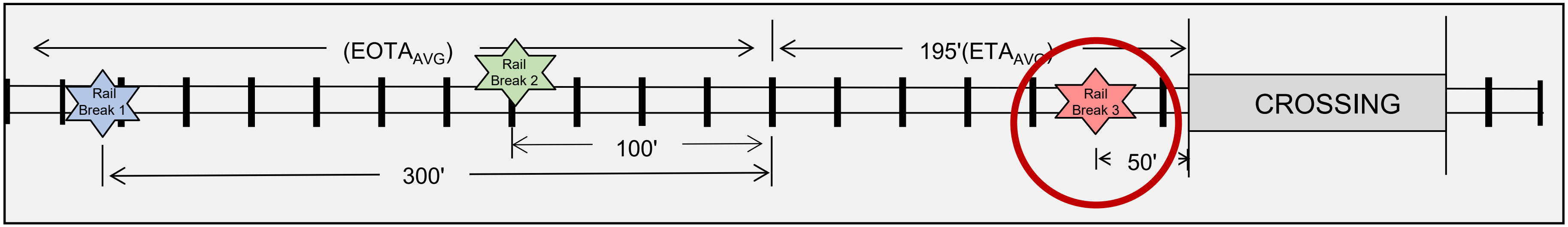
A rail break occurs at <u>one</u> of the locations shown on a 136# rail on wood ties with $EOTA_{avg}$ and ETA_{avg} at T_{RAIL}= 31°F near a crossing resulting in a gap of 2 inches. The territory's DRNT=95°F. How to make the repair/adjustment for each case for a DRNT = 95°F?



- For Rail Break 2: use Module 5 (since break 2 is within 400 ft of a fixed point). Make any IR, return by T_{RAIL}<120°F, and apply Module 5 to destress/readjust ±390 ft (realizing that only 295 ft is available toward the crossing in this case, but that's OK).

Module 5 Illustrative Example 1c – Readjustment Near Fixed Structures

A rail break occurs at <u>one</u> of the locations shown on a 136# rail on wood ties with $EOTA_{avg}$ and ETA_{avg} at T_{RAIL}= 31°F near a crossing resulting in a gap of 2 inches. The territory's DRNT=95°F. How to make the repair/adjustment for each case for a DRNT= 95°F?



- **For Rail Break 3:** Same as break 2 (i.e., Module 5 blind destress option) but apply destress cuts "sufficiently away" from break 3 location to avoid pulling "short rail" against the crossing (i.e., upon returning first weld up the rail break 3 IR joint(s) and then proceed to make destress cut ≈ 390 ft away from crossing).

Module 5 Illustrative Example 2 – Frozen Ballast Conditions

A 136# rail is cut for a defect removal at a rail temperature of 11°F in a wood tie ($EOTA_{AVG}$) territory resulting in a rail gap of 2 inches. Track was clean of snow and ice, but ballast was considered to be frozen. The territory's DRNT is 100°F. How to make repair/readjustment?

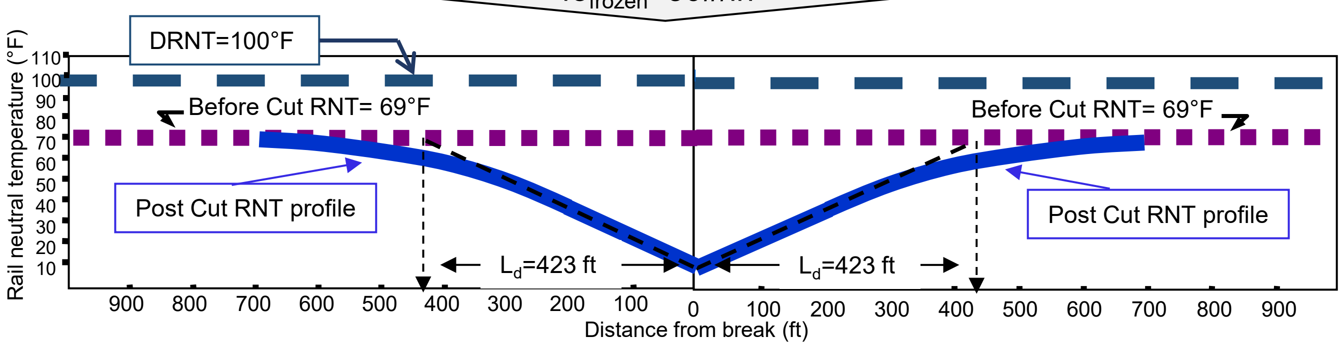
Module 1 Accounts for Frozen Ballast (Provisional)*

Fastener	f_o
$EOTA_{wk}$	15
$EOTA_{avg}$	20
$EOTA_{str}$	25
$CTEF_{wk}$	25
$CTEF_{avg}$	30
$CTEF_{str}$	35
Note: ETA=CTEF=elastic fasteners on wood ties	

T_{Br} (°F)	f_o multiplier
$T_{Br} > 30$	1
$30 \le T_{Br} < 10$	1.5
$10 \le T_{Br} < -10$	2.0
$T_{Br} \le -10$	2.5

* subject to new R&D

fo_{frozen}=30#/in



- ANSWER: Follow Module 3 if adjusting at the time of the defect cut, or Module 4 if IR defers adjustment to a later time, or Module 5 "blind-destress" option (if provisional frozen ballast f_o criteria is not acceptable).

Extra Special Case Example: Both Rails Experiencing Breaks and Cuts in "Close" Vicinity

A 136# rail beaks at a rail temp of 30°F in a wood tie ($EOTA_{AVG}$) territory resulting in a rail gap of 3". The railroad performs a plug IR, adding 3" of rail and plans on a later readjustment. A short time later the opposite rail has a rail break 100 ft away at 10°F with a gap of 2", where a 2" rail is added as a plug IR with plans to readjust later. The territory's DRNT is 100°F. How to make the readjustment?

- Question #1: Why is this a more dangerous condition?

Answer: Because BOTH rails have substantially reduced RNT (i.e., one rail at 30°F, the other at 10°F), or an effective "*track RNT*" of 20°F. According to the buckling prevention formula, this track would be potentially buckling prone at:

$$T_{RAIL} \geq 90°F$$

- Question #2: When to come back to readjust?

Answer: Both rails experiencing rail breaks or cuts in a vicinity of 200 ft of each other is an EXCEPTION to the RSAC Table. Here the return temp is before rail temps exceed 90°F in accordance with the formula:

$$T_{RETURN} = [T_{Br1} + T_{Br2}]/2 + 70°F$$

Special Case Example: Both Rails Experiencing Breaks and Cuts in "Close" Vicinity (cont.)

RSAC Return Table

Rail Break/Cut Temperature (°F)	Rail Temperature (°F) 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

Note: table does not apply to special case when both rails break/cut in *"close"* vicinity

BOTH rails experiencing breaks or cuts within 200 ft of each other (i.e., ± 200 ft in either direction) is an EXCEPTION to the RSAC Table. For such cases, the return temperature is as per:

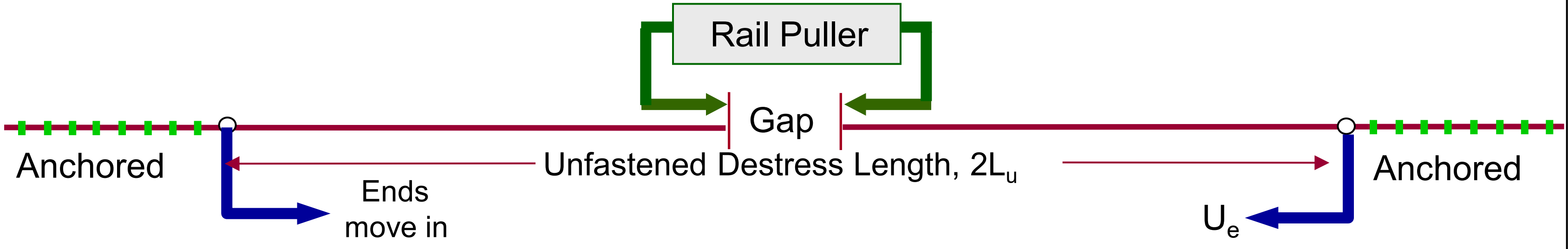
$$T_{RETURN} = [T_{Br1} + T_{Br2}]/2 + 70°F$$

- Question 3: In the previous example, when returning prior T_{RAIL} exceeding 90°F, how to readjust?

Answer: Follow RNT-RESTORE for each rail independently. Module #1 shows that for BR1 (3" gap) the RNT_{PBr} = 90°F, so apply Module #2 to cut out the 3" rail added at IR (plus the weld allowance) and pull rail together for welding, thus restoring RNT to DRNT-20.

For BR2 the RNT_{PBr} = 60°F, so apply Module 4 SMART or BLIND destress option.

How to More Correctly Destress CWR by Accounting for "End-Movements"



❖ The $2U_e$ end movements must be included in total rail cut-out when applying rail pullers or with ambient heating.

WHY IMPORTANT?

- If end movements ($2U_e$) are NOT included in the total gap size calculation, the result will be under-stressing (i.e., NOT achieving desired RNT, but lower).

HOW TO INCLUDE IN CWR PROCEDURES?

RNT-RESTORE can calculate based on rail break theory (but requires assumptions on end-condition's longitudinal stiffness)

OR

Incorporate into destress procedures to require the measurement of end movements and add to the gap setting calculation
Note: If destress procedures require the "1/4 point methodology," this should be automatic

The RNT-RESTORE Program

Module 6	Procedure for readjusting RNT after defect cut or repairs performed in warm temps (i.e., when rail is in compression). NOTE: does not include locations covered by Modules 2-4 scenarios being deferred to later warm temperature readjustments.

Question: How to handle defect cuts in compression, i.e., “negative” gaps?

Module 6

Knowing Pre-Cut RNT from “Reverse” Rail Break Theory

Correctly measure “negative” gaps (rail moving together) to provide pre-cut RNT profiles which dictate “smart” destress adjustments

More R&D required to evaluate “rail in compression” mechanics

NOT Knowing Pre-Cut RNT

Follow “Blind Destress” option, but needs further evaluations of optimum destress lengths (since cut influence zones are expected to be shorter)

More R&D required to evaluate “optimum destress lengths”

Section 3

Destressing CWR: When, where, why, and how, and including curve stability management

CWR Procedures

RSAC AND FRA GENERIC CWR PLAN
Procedures for the Installation, Adjustment, Maintenance and Inspection of CWR
as Required by 49 CFR §213.118 & 119

Chapter 1	**CWR Installation Procedures**
1.1	Neutral Temperature
1.2	Temperature Differential
1.3	Installing CWR → **PRLT**
Chapter 2	**Rail Anchoring Requirements When Installing CWR**
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2.4	Legacy Patterns
2.5	Anchor Pattern After Repair
Chapter 3	**Preventive Maintenance on Existing CWR Track**
3.1	Maintaining Desired Rail Installation Temperature Range
3.2	De-Stressing Rail → **DRNT-20**
Chapter 4	**Monitoring Curve Movement Following Surfacing and Lining**
4.1	Staking of Curves
4.2	Inspecting for Curve Movement
Chapter 5	**Placing Temporary Speed Restrictions Account Work**
5.1	General Requirements
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6.1	Class of Track
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6.7	Inspection Records
Chapter 7	**Extreme Weather Inspections**
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Chapter 9	**Recordkeeping**
9.1	Report of CWR Installations
9.2	Report Maintenance Work in CWR

What Is Destressing and Why Is It Often Difficult?

Definition: Destressing is a procedure by which the rail's RNT is readjusted to a desired value. It typically consists of cutting the rail and removing rail anchors and fasteners to provide the necessary expansion/contraction, cutting rail out as required, and re-assembling the rail (FRA Compliance Manual).

Issue: The amount of rail to cut out depends on the length of rail being adjusted and the *temperature differential* to adjust.

Rail Cut (inches) = Rail Length (inches) x Temperature Differential (°F) x 0.0000065 → Used in CWR Destress Tables

Principal Difficulty: Often the length of rail requiring adjustment is not known, thus the amount of rail removals are also not known.

CONSEQUENCE

Substandard Destressing

Destressing CWR

Types of Destressing

Programmed

Programmed destressing is when a section of rail is deemed to be sufficiently below DRNT to warrant RNT adjustment.

(typically "long" rail sections)

Reactive

Reactive destressing is an imminent action addressing tight, wavy, kinky rail.

(usually "shorter" rails sections)

Curves

Curve destressing is adjusting RNT due to cold temperature chording-in or due to maintenance-caused curve movements.

(difficult especially in tight curves)

<u>Challenge</u>:

- How to know RNT's reduced condition that dictates destressing, and what reduced RNTs requires destressing?
- What length of rail to destress?

<u>Challenge</u>:

- What length rail to destress and how?
- How much rail to cut out (especially in curves)?

Training Exercise on RNT Readjustment via Destressing

Question:

Suppose there is a section of CWR exhibiting a wavy, kinky condition on a hot summer day. The wavy length is estimated to be 260 ft. The territory's DRNT is 115°F. The next loaded coal train is scheduled within the hour. How do we address this condition?

Photo by Andy Kish

Destressing CWR

What to Do?

1) Notify track supervisor/dispatcher/roadmaster of problem and a possible emergency

2) Determine action to be taken:

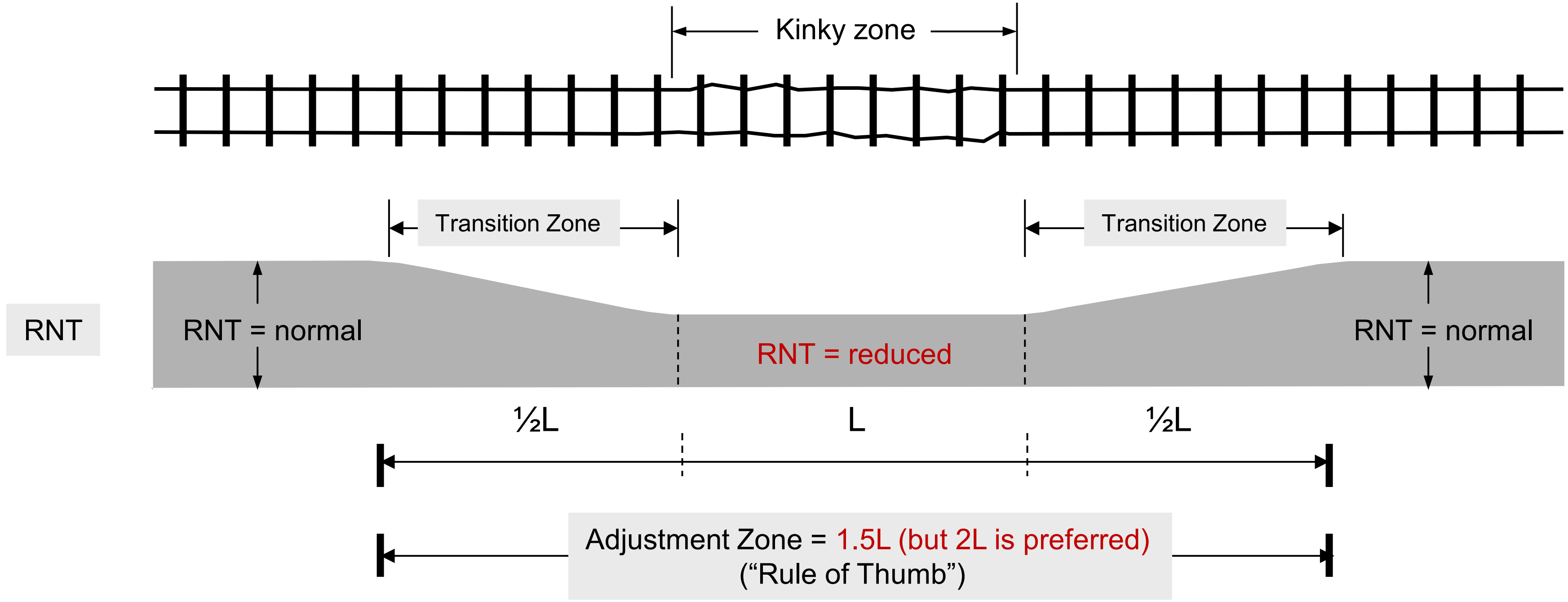
- *Take track out-of-service/destress?*
- *Make "emergency" (quick/temporary) fix?*
- *If track not taken out of service, what slow-orders to implement?*
  [see RSAC Generic Policy 7.1: @ 25mph]

3) Destressing issues: how much length of rail to adjust (unfasten), and what procedure to use (i.e., how much rail should be cut out)?

- *How long is the "kinky" zone, i.e., what length to destress?*
- *What is the desired readjusted RNT?*
- *Is this a winter rail break/defect "interim repair" location?*
- *What about the OTHER rail?*

Refer to railroad's CWR Procedures

Why is a "Kinky Rail" Condition Dangerous?

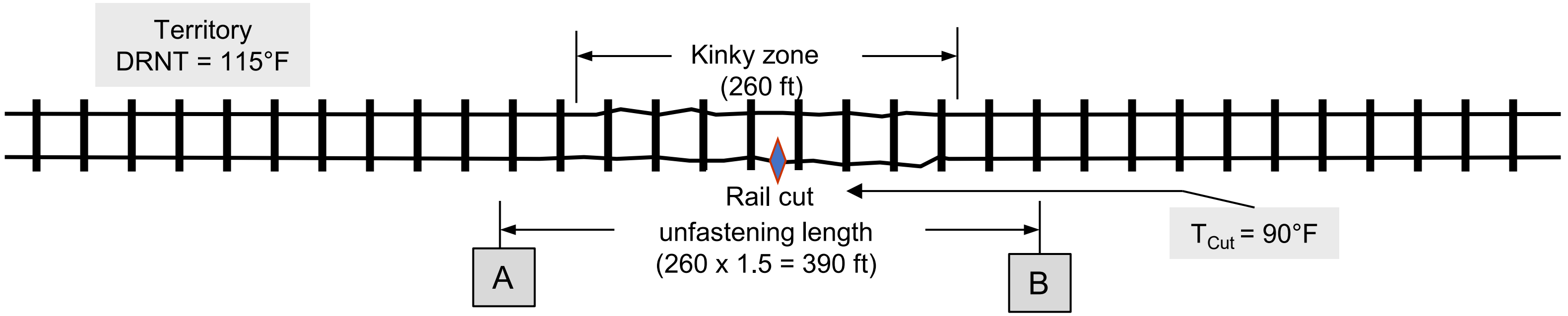


WHY DANGEROUS? Wavy/kinky rail indicates "micro-buckling," a condition of incipient buckling.

Destressing CWR

Suppose there is a section of CWR exhibiting a wavy, kinky condition on a hot summer day. The wavy length is estimated to be 260 ft. The territory's DRNT is 115°F. The rail is cut for destressing at 90°F. How should we proceed with the destressing?

<u>Illustrative Example 1 (also answer to Training Exercise)</u>



1. Kinky length is 260 ft; destress length is 390 ft [260 x 1.5, (the AB length)]; cut rail at midpoint.*
2. Unfasten minimum distance of 390 ft (i.e., 195 ft on either side of cut); keep cutting rail until no more movement.
3. Calculate the temperature differential by subtracting the rail temperature from the DRNT; in this case 115 – 90 = 25°F.
4. Here rail temp is *<u>lower</u>* than laying temperature therefore more rail must be removed.
5. Proceed to "Rail Removal Tables" for additional rail to cut for a 25°F temp differential for the 390 ft length; <u>this is ¾ inches.</u>
6. Cut out additional ¾ inches plus the required weld allowance; pull/heat rail for gap closure, and make the weld.
7. Record destress temp (90°F); DRNT (115°F); destress length (390 ft), and ¾" rail cut-out.
8. Proceed to destress the other rail.

Question: **Why should you <u>NOT</u> cut rail at either "A" or "B" end to destress (i.e., why is cutting rail in the middle preferred)?**

Tables for Additional Rail to Remove When Destress Temperature Is Lower than Territory's DRNT

Temperature Differential, TD (°F)	Amount of Adjustment Required (Inches) for a Length of Unfastened CWR — TOTAL DESTRESS LENGTH						
	390 ft	450 ft	500 ft	550 ft	600 ft	650 ft	700 ft
5	1/4	1/4	1/4	1/4	1/4	1/4	1/4
10	1/4	1/4	1/4	1/2	1/2	1/2	1/2
15	1/2	1/2	1/2	1/2	3/4	3/4	3/4
20	1/2	3/4	3/4	3/4	1	1	1
25	3/4	1	1	1	1-1/4	1-1/4	1-1/4
30	1	1	1-1/4	1-1/4	1-1/2	1-1/2	1-1/2
35	1	1-1/4	1-1/2	1-1/2	1-1/2	1-3/4	2
40	1-1/4	1-1/2	1-1/2	1-3/4	2	2	2-1/4
45	1-1/2	1-1/2	1-3/4	2	2	2-1/4	2-1/2
50	1-1/2	1-3/4	2	2-1/4	2-1/4	2-1/2	2-3/4
55	1-3/4	2	2	2-1/2	2-1/2	2-3/4	3
60	1-3/4	2	2-1/4	2-1/2	2-3/4	3	3-1/4
65	2	2-1/4	2-1/2	2-3/4	3	3-1/4	3-1/2
70	2-1/4	2-1/2	2-3/4	3	3-1/4	3-1/2	3-3/4

Rail Removal (inches) = Total Rail Unfastened Length (inches) x Temperature Differential (°F) x 0.0000065

Destressing Issues and Challenges

- Challenge 1: How to best estimate destress zone, i.e., “kinky” length?
- Challenge 2: What to do if there is no “kinky” zone evident but must destress anyway?

Answer: Follow railroad’s CWR procedures, but be aware of rail cutting temperatures:

- Determine length of rail being destressed and cut rail at center.
- Unfasten the length of rail being destressed and keep cutting until there is no more movement (may need to bypass rail ends to facilitate movement).
- Lift, tap, or vibrate rail to encourage the free expansion (especially on curves).
- Apply Destress Table (or equation) to cut out any additional rail as dictated by the temperature differential, TD.
- Reapply anchors and fasteners and weld.
- Record amount of rail cut, rail temperature, length destressed, and the restored RNT.

QUESTION: Suppose rail is cut at 60°F and moves apart by 1". WHAT to DO?

Programmed Destressing Example

Illustrative Example 2: It is suspected that a 1000 ft section of rail on wood ties was laid "cold" (well below the territory's DRNT), and it needs to be destressed to readjust DRNT to 100°F. The rail is being cut for destressing at a rail temperature of 70°F. How to proceed?

ANSWER:

Step 1: Mark the rail at midpoint (2 marks to indicate rail movement); measure rail temp (70ºF).
(NOTE: some procedures may also require "end-marks")

Step 2: Cut rail at mid-point; here the rail is likely in compression so torch cutting may be required with bypassing the rail (this means that the rail had a neutral temperature below 70°F).

Step 3: Unfasten 500' in both directions and allow the rail to keep moving together; lift, vibrate, put on rollers, tap, etc., to encourage movement; when rail stopped moving measure and record the total movement.

Step 4: Cut out the excess rail moved together, leaving rail ends just touching. At this point this unfastened rail has a neutral temperature of 70°F which needs to be raised to DRNT=100°F. Re-measure the rail temp to be sure it is not different from 70°F. Go to tables or equation to calculate the cut required for the temperature differential of 30°F for the 1000 ft length (here 2-3/8 inches).

Step 5: Cut out the 2-3/8" + weld allowance; pull the rail together to the weld allowance gap, reapply anchors, and weld. (NOTE: If "end-marks" indicate inward movement, add to cut-out.)

Step 6: Record total amount of rail removed, destressing temperature, temperature differential, and the readjusted neutral temperature.

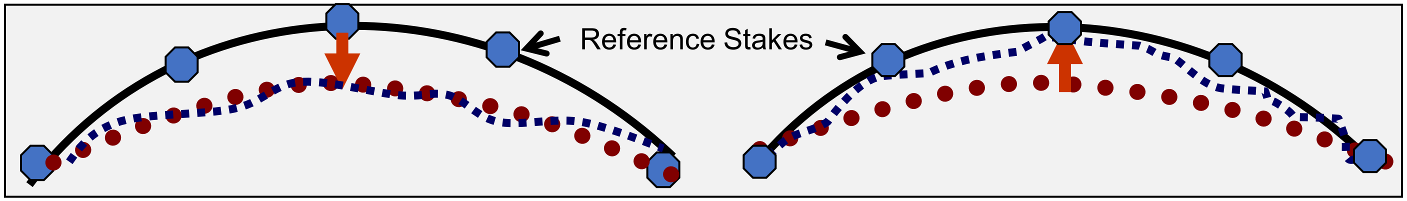
Step 7: Proceed to destress the other rail.

Destressing Issues and Challenges (cont.)

- Challenge 3: How to destress and readjust curves after pull-ins?

Answer: By relining or cutting rail out (as per the railroad's CWR procedures)

- Lining curves back is the easier (and often the preferred) approach, but:
  - Key issue is *uniformity* in restoring curve to original alignment



Note: Relining curves to pre-movement geometry restores RNT to what it was before.

- Destressing curves by cutting rail out can be problematic because:
  - How much rail to cut out? (Depends on knowing or measuring curve pull-in; *therefore* requires effective curve staking.)
  - Once rail cut, pulling/heating rail can create alignment non-uniformity.
  - Both rails must be destressed.

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What Is the Curve Stability Problem?

Curve movement ⇒ reduced RNT + reduced lateral resistance + increased line defects ⇒ Buckle-prone track

Effective management of curve movement is critical to maintaining curve stability.

How to Manage Curve Stress/RNT Condition?

Key Curve RNT Change Causes

Curve "breathing" due to temperature change

Curve "lining-in" due to maintenance when rail in tension

Rail breaks and defect removals

Readjust reduced RNT by destressing

Question: How to destress when RNT is not known?

- Answer 1 (preferred): Monitor curves with rail stress modules (RSMs)
- Answer 2 (if no RSM monitoring): MUST have reliable curve movement data to enable any destressing

Question: How much rail should be cut out per curve length and movement?

Readjust by restressing

Apply *best practice* guidelines:

- RNT-RESTORE (or CWR- Adjust)
- Railroad's CWR Policies and Procedures
- Kish/AREMA 2013 paper
- Read Kish – AAR R-1003 report

How Much Rail to Cut Out When Destressing Curves?

- Answer: Depends on curve radius, curve movement, and length of curve.
  - When a curve pulls in, the effect is "adding rail" (i.e., reducing RNT).
  - Curve pull-in can be related to rail length change, meaning the effective amount of rail added.
  - It is this "effective rail added" that must be removed for readjustment.
- Key Requirement:
  - Must know or measure curve movement, which requires effective curve staking and data acquisition

- How to apply curve movement data to rail removal?
  - See tables, charts, equation.

❖ Most important aspect of curve movement management and its destressing, BUT to date curve staking is used only on a limited basis.

How to Manage Curve Stress/RNT Condition?

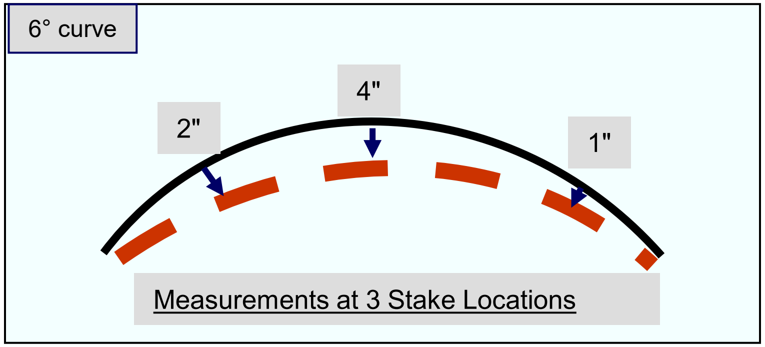
CWR Requirement on Curve Staking [RSAC/FRA CWR Plan 3.2, 4.1, & 4.2]

When surfacing and lining a curve 3° or higher when the rail temperature is 50ºF or more below the DRNT, the curve must be staked* and the curve movement monitored. If more than 3" of curve movement occurs, then a 40 mph or less slow order must be placed if the curve is not lined out or destressed prior to ambient temperatures exceeding: "X" (Note most railroads use 85°F ambient or T_{RAIL} exceeding DRNT).

*a minimum of 3 reference points at 200 feet apart or less

CWR Training Course Exercise:

A 500 ft long 6° curve is staked and surfaced in the morning at 50°F. After surfacing the stake measurements indicate the curve pulled in 4" at the center. The 136# rail was laid three years ago at the territory's DRNT of 105°F. The next loaded coal train is scheduled within the hour, and the afternoon ambient temperature is forecasted to be 85°F. How to address this condition?



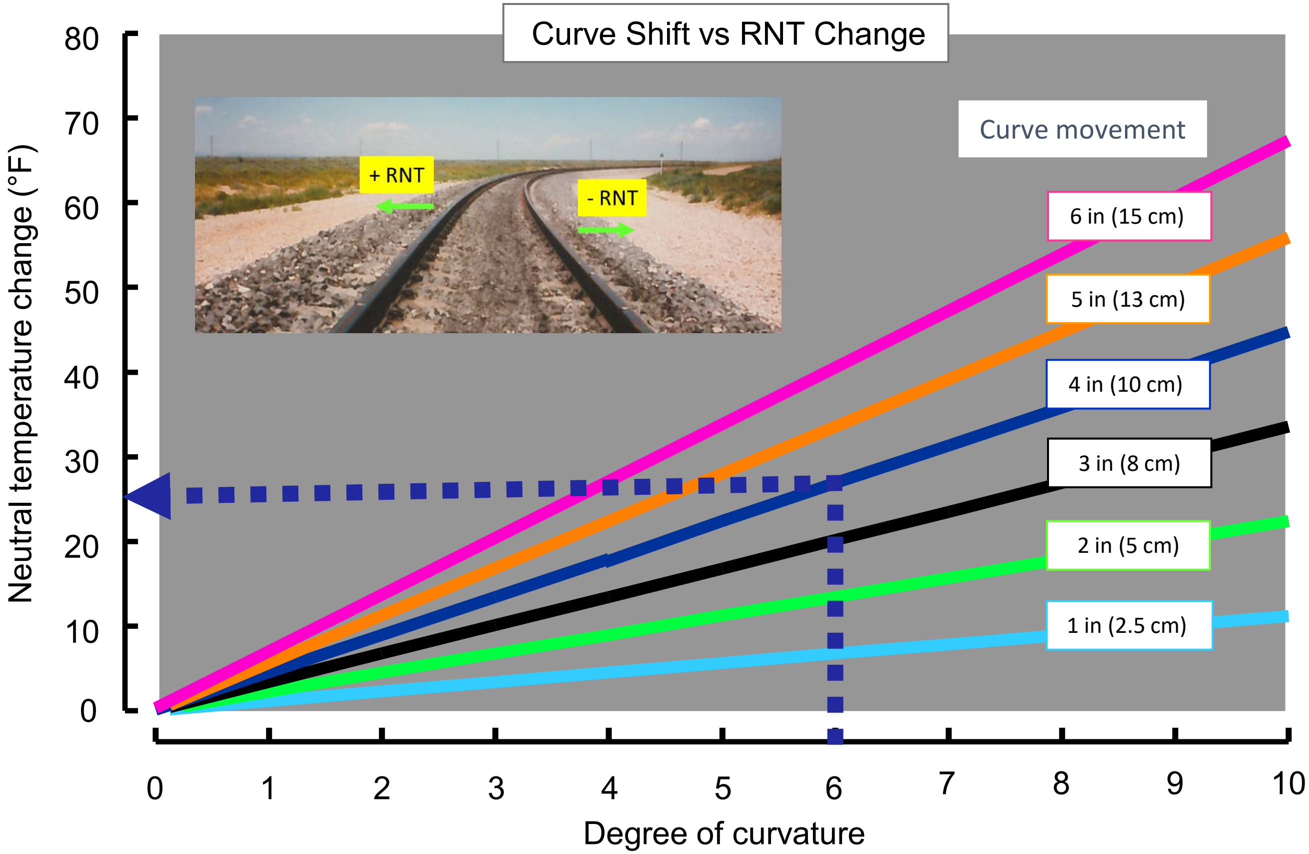
Questions:

(1) Is this track potentially buckling prone at the expected 85°F ambient?

(2) What should be done? i.e., what CWR requirements/rules govern this situation?

Curve Movement and RNT

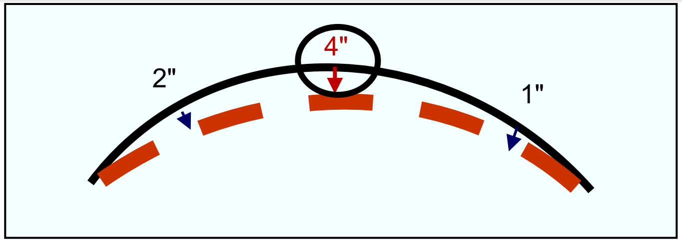
What is the RNT change on a 6° curve when it pulls in by 4"?



- A 6° curve pulling in by 4” reduces RNT by 25°F

How to Manage Curve Stress/RNT Condition

Training Exercise on Curve Staking and Destressing Procedures



Technical Aspects
(Is track buckling likely at 85°F ambient?)

- A 4" pull-in results in an approximate 25ºF RNT reduction.
- Surfacing reduces ballast resistance by 40-60%; therefore, track is considered weak.
- Weak track buckling strength is 60ºF above neutral

RNT safety factor

- Assume curve RNT before surfacing was 105-30 = 75ºF
- Surfaced track RNT=50ºF after pull-in (i.e., 75-25).
- Hence track's buckling temperature is: 110ºF (i.e., 50+60).
- At afternoon's ambient of 85ºF the rail temp is: 115ºF.

Track is potentially buckling prone at ambient 80°F (rail temp of 110°F)

(1) Know Track Buckling Fundamentals

CWR Policy Aspects
(What provisions are applicable?)

Speed Restrictions After Work

Staking of Curves and Inspecting for Curve Movement

- RSAC CWR Policy 5.4 Speed Restrictions for Track Work: Apply 30 mph for 8 trains (or as otherwise prescribed by the railroad's CWR Procedures)

- RSAC CWR Policy 4.2: When a curve has been surfaced and staked and shifted more then 3", the curve must be lined-out or destressed prior to the ambient temperature exceeding 85°F*. If the curve is not lined-out or destressed, a speed restriction of 40 MPH or less must be placed.

*Note: Aaries with railroads (some use 85°F amb or T_{RAIL}=DRNT)

(2) Know CWR Procedures and How to Apply

QUESTION: If destressing by cutting rail out, how much rail to remove?

Rail Removal for Curve Destressing

		EFFECTIVE RAIL LENGTH ADDED TO CURVE PER 1000 FT. OF CURVE											
		DISTANCE CURVE HAS CHORDED INWARD (INCHES)											
		1/2	1	1-1/2	2	2-1/2	3	3-1/2	4	4-1/2	5	5-1/2	6
DEGREE OF CURVE	5-30	1/2	1	1-1/2	1-7/8	2-3/8	2-7/8	3-3/8	3-[illegible]/8	4-1/4	4-3/4	5-1/4	5-3/4
	6-00	1/2	1	1-5/8	2-1/8	2-5/8	3-1/8	3-5/8	4-1/8	4-5/8	5-1/4	5-3/4	6-1/4
	6-30	5/8	1-1/8	1-3/4	2-1/4	2-7/8	3-3/8	4	4-1/2	5	5-5/8	6-1/4	6-3/4
	7-00	5/8	1-1/4	1-7/8	2-1/2	3	3-5/8	4-1/4	4-7/8	5-1/2	6-1/8	6-3/4	7-3/8
	7-30	5/8	1-1/4	2	2-5/8	3-1/4	3-7/8	4-5/8	5-1/4	5-7/8	6-1/2	7-1/4	7-7/8
	8-00	3/4	1-3/8	2-1/8	2-3/4	3-1/2	4-1/4	4-7/8	5-5/8	6-1/4	7	7-5/8	8-3/8
	8-30	3/4	1-1/2	2-1/4	3	3-3/4	4-1/2	5-1/4	5-7/8	6-5/8	7-3/8	8-1/8	8-7/8
	9-00	3/4	1-1/2	2-3/8	3-1/8	3-7/8	4-3/4	5-1/2	6-1/4	7	7-7/8	8-5/8	9-3/8
	9-30	7/8	1-5/8	2-1/2	3-3/8	4-1/8	5	5-3/4	6-5/8	7-3/8	8-1/4	9-1/8	10
	10-00	7/8	1-3/4	2-5/8	3-1/2	4-3/8	5-1/4	6-1/8	7	7-3/4	8-3/4	9-5/8	10-1/2

EXAMPLE: A 500 ft 6° curve pulling in by 4” requires cutting out 2-1/16”.

NOTE: For in-between TABLE values interpolate or use the equation below:

$$\text{ERA (in)} = \text{CM (in)} \times D \times \text{CL (ft)} \times 0.000175$$

- ERA: Effective rail added (inches)
- CM: Max central curve movement (inches)
- D: Degree of curve (deg)
- CL: Curve length (feet)

How to Manage Curve Stress/RNT Condition

Managing Stress/RNT after Curve Movement SUMMARY

Curve "breathing" due to temperature change

Curve "lining-in" due to maintenance when rail in tension

Readjust reduced RNT by destressing

Method 1

Destress by lining curve back to original position

- Restores RNT to what it was before the pull-in
- Might need alignment correction

Method 2

Destress by cutting rail out

- Amount given by *Curve Movement Tables*
- Both rails need destressing
- Restores RNT to what it was before the pull-in
- Might need alignment correction

MUST have reliable curve movement data

Section 4
Review and Summary

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Chapter 4 Monitoring Curve Movement Following Surfacing and Lining
- 4.1 Staking of Curves
- 4.2 Inspecting for Curve Movement

$RNT = T_i - RF_k - RF_m$

Must have effective install procedures

❑ How Much Below/Above DRNT?

RSAC: If rail is laid at a temperature more than 40°F below DRNT, rail must be adjusted prior to T_{RAIL}>DRNT, or a speed restriction of 40 mph must be placed.

❑ Installing CWR with Joints

Bolted joint installed during CWR installation	Within 60 days: • Weld joint, OR • Install joint with 6 bolts, OR • ETA 195' both directions

❑ Other CWR Installation Issues/Impacts

- RNT's RF_k=30°F reduction *"rule-of-thumb"* and its impact on installation temps
- Readjustment of broken/defective rail is to DRNT-20 (ARE WE SAFE ENOUGH?)
- How to install CWR in cold temps, i.e., how to ensure achieving DRNT? (must have ¼ point heat/pull records as quality control)

CWR Requirements/Procedures

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3.1 REQUIREMENT

Rail that has pulled apart, broken, or been cut must be readjusted to within the subdivision DRNT minus 20° (DRNT-20°) safe range. If the rail has not been readjusted to at least DRNT-20° before rail temperatures exceed the values in the table provided, a speed restriction of 25 mph will be placed, or a speed restriction of 40 mph with a required daily inspection during the heat of the day.

- Record rail gaps, rail temps, rail size, and fastener type/condition when rail breaks or is cut. Use this data to determine RNT before break/cut. (See RNT-RESTORE or CWR-Adjust or railroad's tables.)

Note: Such pre-break/cut RNT's will be approximate for frozen ballast, at/near fixed points, and with multiple breaks close to each other on the same rail.

- Readjust RNT prior T_{RAIL} exceeding CWR Policy TABLE; use RNT-RESTORE or railroad's prescribed procedures.

CWR Requirements/Procedures

Procedures for the Installation, Adjustment, Maintenance and Inspection of CWR as Required by 49 CFR §213.118 & 119 and RSAC/FRA GENERIC CWR PLAN

Chapter 1 CWR Installation Procedures
- 1.1 Neutral Temperature
- 1.2 Temperature Differential
- 1.3 Installing CWR

Chapter 2 Rail Anchoring Requirements When Installing CWR
- 2.1 Standard Box Pattern
- 2.2 Solid Box Pattern
- 2.3 Bridge Pattern
- 2.4 Legacy Patterns
- 2.5 Anchor Pattern After Repair

Chapter 3 Preventive Maintenance on Existing CWR Track
- 3.1 Maintaining Desired Rail Installation Temperature Range
- 3.2 De-Stressing Rail

Chapter 4 Monitoring Curve Movement Following Surfacing and Lining
- 4.1 Staking of Curves
- 4.2 Inspecting for Curve Movement

Types of Destressing

Programmed | Reactive | Curves

Programmed / Reactive:
- Know what length rail to destress?
- Know temperature differential table or rail cut-out formula

Curves:
- Realign or cut rail out
- Curve staking is essential
- Know curve length and inward movement
- Cut rail out as per formula (or tables)

Know and Follow Procedures in CWR Plans

Caution: (1) Destressing in cold (rail in tension) temperatures is inadvisable and not recommended, and (2) be aware of importance of end-movement monitoring when destressing.

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How to Manage Curve Movements?

Curve staking is required for curves 3° or higher when surfacing/lining at 50°F below DRNT

If curve has shifted inward more than 3 inches, the curve must be lined out or destressed prior to ambient temperatures exceeding: X *. If curve is not lined out or destressed, a speed restriction of 40 MPH or less will be placed.

*X: varies with railroads. Some use 85°F or T_{RAIL} exceeding DRNT (Note: caution if using ambient exceeding DRNT)

QUESTION: Would there be a benefit of staking all curves > 3°?

CHALLENGE: How to effectively destress curves without curve-movement data?

MORE R&D REQUIRED FOR IMPROVED CURVE STRESS MANAGEMENT

CWR Requirements/Procedures

Procedures for the Installation, Adjustment, Maintenance and Inspection of CWR as Required by 49 CFR §213.118 & 119 and RSAC/FRA GENERIC CWR PLAN

Chapter 5 Placing Temporary Speed Restrictions Account Work

5.1 General Requirements
5.2 Responsibility for Placing Speed Restrictions
5.3 Speed Restriction Length
5.4 Speed Restrictions for Track Work

Chapter 6 Rail Joint Inspections

6.1 Class of Track
6.2 Frequency of Inspections
6.3 Identification of Joints
6.4 Switches, turnouts, track crossings, or other transition devices on moveable bridges
6.5 Rail Joint Conditions
6.6 Embedded Joints
6.7 Inspection Records

Chapter 7 Extreme Weather Inspections

7.1 Hot Weather Inspections
7.2 Cold Weather Inspections

Chapter 8 Training

Chapter 9 Recordkeeping

9.1 Report of CWR Installations
9.2 Report Maintenance Work in CWR

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 decrease buckling risk.

- If dynamic track stabilization (DTS): no slow orders (or 1 train @ 30mph).
- If no dynamic track stabilization: slow order traffic for 0.1 MGTs or more.

- KEY ISSUE: At what temps to impose, what speed reductions, how many trains, and with/without DTS?

MORE R&D REQUIRED

CWR Requirements/Procedures

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Report Maintenance Work in CWR

- Rail that is added for any reason, including repair of broken or defective rail, pull-aparts, and welding of rail joints.
- Where curve has been staked and has shifted inward more than a maximum of 3".
- CWR installation or maintenance work that DOES NOT conform to written procedures.
- A record of rail neutral temperature will be maintained where rail has pulled apart, broken, or been cut for defect removal.

QUESTION: Which RNT, where stored, and how managed?

Section 5

Closing Remarks, Discussion, and Q&A

Summary of 5 Key "Rules of Thumb" on CWR

1. Ambient vs Rail Temperature: $T_{RAIL}=T_{AMB}+30°F$ (in sun); or $T_{RAIL}=T_{AMB}$ (in cold weather conditions)

2. Track quality-based buckling strength criterion: The 60:80:100 rule.
   When not sure, assume: 60 – 70°F. (Note: these are temperature increases above track neutral, and are the TBS value in the buckling preventions safety formula.)

$$T_{SO} = TBS + RNT - BMS$$

3. RNT reduction safety factor: 30°F decrease from rail laying temp (RLT).

   NOTE: Applies for *"normal"* conditions, i.e., no breaks/cuts, added rail, or excessive curve movement, and is the assumed RF_k factor in the RNT formula: $RNT = DRNT - RF_k - RF_m$

Closing Remarks

Summary of 5 Key "Rules of Thumb" on CWR (cont.)

4. Rail break/cut RNT adjustment length: 390 ft on either side of break/cut as part of *Blind Destressing.* (Note: The 780 ft is a best-practice compromise *a*nd may not apply to frozen ballast, breaks with influence zones much exceeding 780 ft, when rail is adjusted at time of the break or cut by mechanical pulling, or when superseded by RNT-RESTORE.)

5. Rail break/cut RNT adjustment temperatures: Before rail temperatures exceed values in readjustment Table [as per CWR Generic Plan]

Rail Break/Cut Temperature (°F)	Rail Temperature (°F) 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

EXCEPTION: When RNT adjustments are made at time of break/cut, or when both rails experience breaks/cuts within 200 ft

Closing Questions

1. What is the one single principal cause of buckled track?
2. Can cold temperatures (tensile forces) cause buckled track?
3. CFR 49 § 213.118/119 applies to Class 1–5 tracks. What about adequacy of Subpart G provisions under § 213.343 for Classes 6–9?
4. What can industry do to improve track buckling prevention?

Closing Remarks

Process Driven Track Buckling Prevention Program Key Elements

Have Sound CWR Procedures + **Have Sound CWR Training Program**

Follow CWR Procedures

+

Update/improve procedures with new technology developments and research results

Closing Remarks

Key R&D Questions/Needs in CWR Mechanics for Buckling Prevention

1. How to improve rail break/defect removal RNT management?

   Issue: The current methods/procedures (RNT-RESTORE, CWR-Adjust, railroad tables) could benefit from a data driven “smart” systems tool/approach, with special emphasis on fixed points.

2. How to more effectively manage curve movement and stability?

   Issue: Current requirements for curve staking to manage RNT are limited and highly labor intensive, hence require autonomous curve movement monitoring coupled with an RNT correlation capability.

3. Must develop an accurate, reliable RNT measurement technique

   Issue: RNT cannot be managed effectively without being able to measure it. This requires accurate, non-destructive, continuous, real-time, cost-effective measurement technology.

4. What is the mechanics of ballast compaction under traffic loads?

   Issue: The currently accepted industry practice of 0.1 MGT traffic for consolidation may not be adequate. If NOT, what is?

5. What are the limiting L/V conditions for heavy freight/long train/distributed power applications?

   Issue: Long train/ distributed power dynamics cause high net axle L/Vs in curves resulting in excessive track shift. Its management requires an industry driven R&D program to develop limits on allowable L/Vs and/or on ballast lateral strength requirements.

THANK YOU, AND SAFE RAILROADING!!

Questions??

Bibliography

- Kish, "*Ballast and Track Lateral Stability,*" AREMA Roadway and Ballast Symposium, February 10-12, 2020, Kansas City, USA.
- Kish, *"Fundamentals of Track Buckling Prevention and Rail Stress Management,"* 2017 International Heavy Haul Association (IHHA) Technical Conference, September 2-6, 2017, Cape Town, South Africa.
- Kish and Clark, *"Improving Hot-Weather Speed Restrictions for Track Buckling Derailment Prevention,"* 2015 International Heavy Haul Association (IHHA) Technical Conference, June 21-23, 2015, Perth, Australia.
- Kish and Samavedam, *"Track Buckling Prevention: Theory, Safety Concepts and Applications,"* DOT/FRA/ORD-13/16, Final Report, March 2013.
- Kish, *"Best Practice Guidelines for CWR Neutral Temperature Management,"* presented at 2013 AREMA/Railway Interchange Conference, September 29-October 2, Indianapolis, USA.
- Kish and Aten, *"A Smart-Systems Approach for Better Managing CWR Thermal Forces at Extreme Temperatures,"* presented at 2012 CORE, September 10-12, Brisbane, Australia.
- Kish and Clark, *"Heat Impact on CWR: Track Buckling Prevention Through Risk Based Remedial Actions,"* 2011 International Heavy Haul Association (IHHA) Technical Conference, June 19-22, 2011, Calgary, Canada.
- Kish, McWilliams and Harrison, *"Track Buckling Hazard Detection and Rail Stress Management,"* presented at the World Congress for Railway Research (WCRR), May 22-25, 2011, Lille, France.
- Kish and Clark, ***"Track Buckling Derailment Prevention Through Risk-Based Train Speed Reductions,"*** 2009 AREMA Annual Conference, Chicago, September 2009.
- Kish, *"Track Lateral Stability,"* in "Guidelines to Best Practices for Heavy Haul Railway Operations: Track," International Heavy Haul Association publication, 2009.
- Kish, *"Destressing/Restressing for Improved CWR Neutral Temperature Management,"* in "Guidelines to Best Practices for Heavy Haul Railway Operations: Track," IHHA, 2009.

Abbreviations

BMS	Buckling margin of safety
CFR	Code of Federal Regulations
CL	Curve length
CM	Curve movement
CTEF	Concrete ties, elastic fasteners
CWR	Continuous welded rail
D	Degree of curvature
DRNT	Desired rail neutral temperature
DTS	Dynamic track stabilizer
EOTA	Every other tie anchored
ERA	Effective rail added
ETA	Every tie anchored
FRA	Federal Railroad Administration
IR	Interim repair
L	Length

L/V	Lateral to vertical force ratio
MGT	Million gross tons
P	Force in rail
PRLT	Preferred rail installation temperature
RNT	Rail neutral temperature
RF	Reduction factor
RLT	Rail laying temperature
RSAC	Rail Safety Advisory Committee
RSM	Rail stress module
RTLR	Rail-track longitudinal resistance
STPT	Single tie push test
T	Temperature
TBS	Track buckling strength
TLR	Track lateral resistance
USP	Under sleeper pad

Glossary of Railroad Terms

Adjusting neutral temperature	The procedure by which a rail's RNT is re-adjusted to the desired value. It typically consists of cutting rail out and removing rail anchoring devices to allow for necessary expansion and contraction (stress-relief). The procedure is also referred to as destressing and/or restressing.
Buckling incident	The formation of lateral misalignment sufficient in magnitude to constitute a deviation from the Class 1 alignment requirement.
Coefficient of thermal expansion	A multiplier based on the physical properties if rail steel is used to calculate the change in rail length with change in temperature. For rail it is 0.0000065 in/in/°F.
Compressive force	Longitudinal force developed in the rail when its temperature is higher than the RNT.
Continuous welded rail	Rail that has been welded together into lengths exceeding 400 feet.
Preferred rail installation temperature	The rail temperature at which CWR is laid; it is typically in the range of 90 to 110ºF. Above this temperature longitudinal forces in CWR should not cause a buckling in extreme heat, nor pull-aparts below this temperature during extreme cold weather.
Disturbed track	The disturbance of the roadbed or ballast section because of track maintenance or any other event, which reduces the lateral or longitudinal resistance of the track or both.
Desired rail neutral temperature	The target RNT set by the railroad to address the requirements of a particular location.
Mechanical stabilization	A type of procedure used to restore track resistance to disturbed track following certain maintenance operations. This procedure may incorporate dynamic track stabilizers (DTS) or traffic and train passage.
Rail neutral temperature	The temperature at which rail is in a stress-free condition having neither compression nor tension, i.e., when the net longitudinal force is zero.
Neutral temperature management	Maintaining the condition of the track structure so that the neutral temperature of the rail remains near its installed neutral temperature.

Glossary of Railroad Terms

Rail anchor movement	Anchors separating from the ties usually due to “running rail.” This condition often can result in “bunched rail” and RNT change.
Rail temperature	The temperature of the rail, measured with a rail thermometer (usually at the web on both sides, and averaged).
Tensile forces	Longitudinal forces produced when rail temperature is below the RNT. High tensile forces can cause rail breaks and pull-aparts.
Tight/kinky rail	CWR which exhibits minute alignment irregularities which indicate that the rail is in considerable amount of compression and close to a buckling prone condition.
Thermal load/stress	Longitudinal forces/stresses generated in the rail due to temperature difference.
Track (curve) breathing	Curve movement in and out (sometimes referred to as “stringlining”) due to high tensile forces (causing curve pulling-in) and high compressive forces (causing curve to push-out).
Track lateral resistance	The reaction offered by the ballast to the rail/crosstie structure against lateral movement.
Track longitudinal resistance	The reaction provided by the rail anchors/rail fasteners and the ballast against longitudinal movement.
Track buckling	The sudden formation of large lateral misalignments caused by high compressive forces (usually in combination with reduced lateral resistance, lateral alignment deviations, and train loads/dynamics).
Track buckling countermeasures	The performance of installation and maintenance of CWR track in accordance with accepted procedures that maintain the stability of the track structure throughout the range of operating temperatures/conditions.
Train-induced forces	The vertical, longitudinal, and lateral dynamic forces on the rail generated by train movement.

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