TECHNOLOGY DIGEST

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De-anchoring Guidelines for the Readjustment of Rail Neutral Temperature

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Summary

To optimize rail neutral temperature (RNT) maintenance practices, Transportation Technology Center, Inc. (TTCI), Pueblo, Colorado, is developing guidelines based on research into the behavior of RNT in continuous welded rail (CWR). A key issue that TTCI investigated was the minimum length of rail to be de-anchored for effective RNT readjustment. The recommended approach is to de-anchor half the RNT influence zone that is created when a rail breaks or is cut at temperatures below the RNT. This method potentially creates a pocket of decreased or under-adjusted RNT, which is compensated for by increased or over-adjusted RNT, near the break/cut location. It is expected that train traffic will partially equalize the uneven RNT profile and alleviate the under-adjusted RNT condition.

Railroad track standards require that CWR be installed and maintained within a designated, or target, RNT range to minimize development of excessive longitudinal thermal forces. Rail maintenance activities carried out when the rail temperature is below the target RNT — specifically the repair of broken rails, repair of CWR joints that have pulled apart, or removal of rail defects — can cause significant reductions of the RNT that should be readjusted prior to hot weather.

Readjustment of the RNT is accomplished by restoring the tension lost when the rail broke, was cut, or when a joint pulled apart. The loss of tension is evident by the rail or joint gap and influences the rail over some distance on each side of the gap. Ideally, the rail in this influence zone would be unfastened/de-anchored during the readjustment process and the RNT returned to a desired condition across the entire rail length. However, influence zone lengths can be long, depending on the tension in the rail at the time of the break, and may require substantial time and resources to be fully de-anchored.

Test data indicates the force or heat applied to readjust the RNT with anchors removed from half the influence zone tends to over-tension the unanchored rail and under-tension the anchored rail, leaving a pocket of reduced RNT. The pocket will be less severe if the rail is pulled with a tensor, if the entire influence zone is heated or if the rail temperature at the time of readjustment is near the pre-break RNT.

There is also evidence from controlled tests at the Facility for Accelerated Service Testing (FAST) at the Transportation Technology Center, Pueblo, Colorado, and from RNT monitoring in revenue service that an uneven readjusted RNT tends to be equalized with traffic. RNT data being monitored on the Union Pacific South Morrill subdivision quantified the effects of a broken rail, the uneven RNT profile following readjustment, and subsequent equalization with traffic.

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INTRODUCTION AND BACKGROUND

Thermal forces are generated in CWR when rail expansion is constrained by rail anchors, rail fasteners, and the ballast section. These forces may be potentially significant and can damage the rail and track if not managed effectively. The theoretical thermal force is calculated as:

$$P=AE\alpha(\Delta T) \qquad (1)$$

where:

P is the thermal force, A is the cross sectional area, E is the rail steel modulus of elasticity, α is the rail thermal expansion coefficient and ΔT is the difference between the rail neutral temperature (RNT) and the existing rail temperature (T_m).

Rail temperatures above the RNT produce compressive forces that can cause the track to buckle and temperatures below RNT produce tensile forces that may cause rail tension failures.[1]

As the E and α terms in Equation 1 are the same for all rail sections, the force magnitude is determined by the area (115 RE rail produces about 20 percent less force/ºF than 141 RE rail) and, most importantly, the ΔT. Rail temperatures cannot be controlled; therefore, RNT maintenance is critical for effective management of thermal forces. For this reason, railroads install CWR and the RNT at temperatures generally 70 to 85 percent of the expected annual maximum. The bias of the RNT toward higher rail temperatures is intended to limit compressive forces and the potential for track buckling at the expense of higher tensile forces.

Although installed at a designated or target value, the RNT is known to change over time. Of the various influences on RNT behavior, rail that is added during cold weather to repair broken or defective rails or joints that have pulled apart, has the greatest potential for lowering the RNT. Track maintenance best practices would have the RNT at these locations readjusted prior to the onset of hot weather to avoid track instability from high compressive forces.

RNT READJUSTMENT

The RNT may be readjusted as part of the cold weather broken/defective rail repair process if conditions permit or some time following the repair when conditions are more favorable. In either case, the objective is to restore tension that was lost when the rail separated and increase the RNT by elongating the rail mechanically or thermally. As will be discussed, the length over which the longitudinal restraint of the rail is removed (de-anchored) is critical to the readjustment process and guidelines for the developed optimal lengths.

RNT RESPONSE TO A BROKEN/CUT RAIL

The first step in defining de-anchoring guidelines is to understand how the RNT responds when the rail breaks or is cut at temperatures below the RNT. Figure 1 shows an example in which pre- and post-rail break RNT profiles for concrete tie track with a 100ºF pre-break RNT and a rail break at 40ºF are plotted against distance from the break. The rail tension released when the rail breaks produces a gap and causes the existing (pre-break) RNT to drop to the rail break temperature at the gap.

The difference between the pre- and post-break RNT diminishes with distance away from the gap by the incremental longitudinal resistance of the anchors/clips and ballast section. At some distance from the gap, the cumulative resisting force exceeds the pre-break tensile force and change to the RNT is nonexistent. This distance each side of the gap over which the RNT has been affected is referred to as the influence zone (L_D) and is a function of the ΔT and longitudinal resistance.

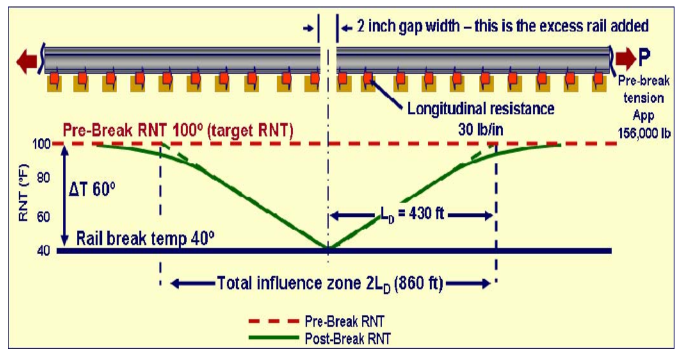

Figure 1. Example of RNT Response to a Cold Weather Rail Break

DE-ANCHORING ISSUES

Ideally, rail being readjusted would be de-anchored to allow full and uniform movement. Tests have shown that readjusting an anchored rail tends to produce an uneven and low RNT profile, even when the excess rail is removed.[2] The American Railway Engineering and Maintenance-of-Way Association recommends, as a general guideline, the length of rail that should be de-anchored should be 195 feet each side of gaps that are 3 inches or less.[3] However, based on the RNT response shown in Figure 1, de-anchoring the L_D appears to be the most ideal procedure. But, there are two practicality issues that may discourage this practice: (1) the L_D is not a set distance, but is a function of the ΔT and longitudinal resistance, which are generally unknown and (2) the L_D may be long and de-anchoring can be resource or track-time prohibitive.

RNT maintenance methodology has been developed that allows the unknown L_D and ΔT parameters to be estimated from the gap width and assumed longitudinal resistance values.[4,5,6] Software is being developed to automate this process and make it as user friendly as possible for field personnel. The issue of limiting de-anchored distances has also been investigated resulting in the recommendation to de-anchor half the L_D.

EFFECTS OF DE-ANCHORING HALF THE L_D

Test data indicates the force or heat applied to remove excess rail with anchors removed from half the L_D tends to over-tension the unanchored rail and under-tension the anchored rail, leaving a pocket of reduced RNT.

Figure 2 shows a re-adjusted RNT profile with half of the L_D de-anchored. The reduced RNT will be most severe if heat is used only on the unanchored rail and the rail temperature at the time of readjustment is low. The pocket will be less severe if the rail is pulled with a tensor, if the entire L_D is heated (anchored rail and unanchored rail) or if the rail temperature at the time of readjustment is near the pre-break RNT. Under these conditions, tension is induced into the anchored rail, in addition to the unanchored rail, and anchored rail movement contributes to the total elongation and RNT increase.

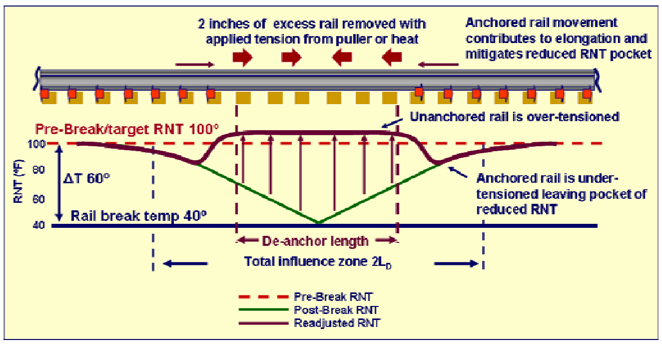

Figure 2. Readjusted RNT Profile with Half the L_D De-anchored

There is also evidence from FAST and revenue service that the unevenly readjusted RNT profile in Figure 2 can be equalized with traffic.[7] Figure 3 shows this tendency where RNT being monitored on the Union Pacific South Morrill subdivision quantified the RNT effects of a broken rail, the uneven RNT profile following readjustment and subsequent equalization after 37 million gross tons of traffic. The data in Figure 3 was collected on concrete tie track that carries predominately single direction 36-ton axle-load coal traffic. It is not clear at this point how consistent traffic equalization is under all track conditions and will continue to be investigated.

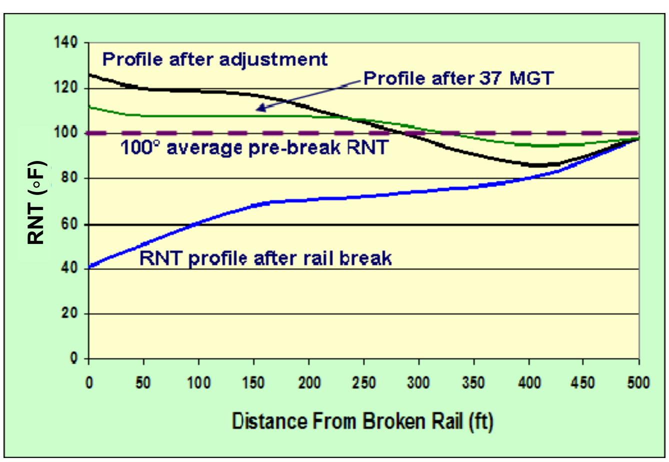

Figure 3. Effect of Traffic on Adjusted RNT Behavior

DE-ANCHORING GUIDELINES

The following de-anchoring guidelines for readjustment of the RNT following a cold weather rail break or rail defect removal require the gap width and rail temperature be measured as near the time of the break as possible and assume an average longitudinal resistance values:

1. From Figure 4, the relationship of the ΔT value at the time of the rail break to the measured gap width is given for 6- and 5.5-inch rail base sections with every tie anchored or clipped (ETA) or every other tie anchored (EOTA).

   The estimated pre-break RNT is determined by adding the rail break temperature to the ΔT value. For example, the ΔT for 136-pound rail on concrete ties with a 2-inch gap width is 60ºF and is 50ºF for 136-pound rail on wood ties with every other tie anchored and the same 2-inch gap. If the rail break temperature was 30ºF in both cases, the estimated pre-break RNT would be 90ºF for the concrete tie condition and 80ºF for the wood tie EOTA condition.

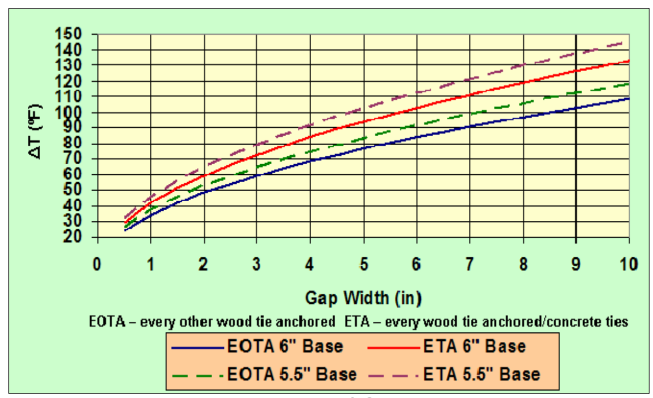

Figure 4. ΔT as a Function of Gap Width Based on Average Longitudinal Resistance

2. If the pre-break RNT is not more than 20ºF below the designated rail laying temperature (DRLT) or target RNT, the de-anchoring distance can be based on Figure 5.

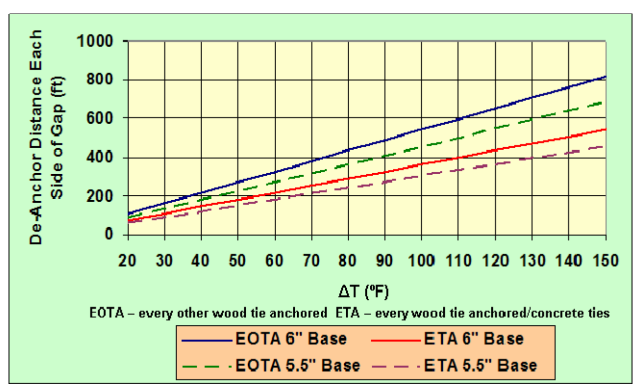

Figure 5. De-anchored Distance Each Side of Gap versus ΔT Based on Average Longitudinal Resistance

3. If the pre-break RNT is more than 20ºF below the DRLT, the de-anchored length should reflect the higher ΔT needed to increase the pre-break RNT value. For example, if the gap width in Figure 1 was 0.5 inches, the estimated ΔT from Figure 4 would be 30ºF; therefore, the pre-break RNT would be 70ºF. If the DRLT at this location happens to be 100ºF, the pre-break RNT of 70ºF is more than 20ºF lower than the DRLT and an additional 10ºF should then be added to the ΔT to push the readjusted RNT to the DRLT minus 20ºF. The de-anchored distance should also be based on a ΔT of 40ºF rather than 30ºF. Software is being developed to automate this process.
4. Mobilize as much movement from the anchored rail as possible by using a rail puller, heating the entire L_D or performing the readjustment as close to the target RNT as possible without compromising the buckling strength of the track.

FUTURE WORK

Future work by TTCI is anticipated to address the following:

- The effect of frozen ballast on longitudinal resistance, the L_D, and the ΔT °F (relationships that Figures 4 and 5 illustrate)
- Tests to better understand the effects of traffic equalization of uneven RNT
- Continued development and refinement of software to automate calculate the pre-break RNT, ΔT, L_D, and de-anchor distance based on measured gap width and rail break temperature
- Guidelines for hot weather rail de-stressing

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