Heat Order Issues
Technical Memorandum

December 15, 2008

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Table of Contents

Executive Summary

Purpose of the Report

The purpose of this technical memorandum is to identify the causes of heat delays on railroad corridors within the Commonwealth and to identify practices that are anticipated to minimize delays on these corridors in the future. This technical memorandum identifies the causes of heat delays generally, and the specific causes of heat delays along the CSX Transportation (CSX) I-95 Rail Corridor between Washington, DC and Richmond that occurred within the 2002 and 2007 timeframe.

Background

The I-95 Rail Corridor is constructed with Continuously Welded Rail (CWR) which is installed from segments approximately one-quarter mile in length and welded together. During periods of hot weather, the CWR can buckle or form a “sun kink” due to the expansion of the rail. Under these conditions the railroad may impose a “heat order” in the corridor to reduce speeds and prevent derailments. Between 2005 and 2007, CSX undertook a $29.5 million major maintenance program in the corridor to improve the physical condition of the track and roadbed and, ultimately, the safety and reliability of the rail line. During this same time period numerous heat orders were issued in the corridor as the construction temporarily weakened the track structure. Virginia Railway Express (VRE) commuter services experienced numerous delays related to heat orders in this timeframe, but the number of heat order delays dropped substantially starting in 2007 when the major maintenance program was completed. Completion of the program and significant Virginia-funded capacity enhancements also allowed CSX inspectors to move more efficiently through the corridor when inspecting the tracks for sun kinks. Changes in CSX operational policies were also instituted that target heat orders by milepost rather than broader subdivision level restrictions.

Within the Commonwealth, commuter and intercity passenger rail services operate on railroad corridors owned by Norfolk Southern (NS) and CSX. These railroads have different policies regarding heat orders. NS does not issue blanket heat orders. CSX may issue heat orders when the ambient temperature fluctuates significantly and/or reaches 90 degrees Fahrenheit.

Conclusion

In January 2008, the Virginia Department of Rail and Public Transportation (DRPT) and CSX signed an Operations Agreement to work cooperatively on the issue of heat orders. CSX has revised certain operational policies to further minimize heat order delays as follows: 1) heat orders are now issued on a milepost basis, 2) changes in the track designation policy allow a heat order to be imposed on only a single affected track in a multi-track corridor to further limit impacts, and 3) CSX adjusts the times of day when track maintenance is performed to minimize delays to passenger services. Furthermore, DRPT expects CSX to apply any new or innovative techniques to track design to alleviate potential heat orders in the future.

Actions for Heat Order Mitigation

DRPT will require that the agency be notified in advance if current railroad policies and practices for heat orders are changed by the railroad. DRPT may also require periodic reports from railroads receiving state funding for capital projects on measures to reduce or avoid heat orders. Similarly, DRPT may require periodic reports from passenger rail operators regarding the number of heat orders affecting their services, with clear documentation of heat order events and impacts on passenger rail service.

I. Purpose of the Report

The General Assembly has directed the Virginia Department of Rail and Public Transportation (DRPT) to develop a rail revenue and expenditure plan upon completion of the Draft Statewide Rail Plan, including provisions for the improvement of rail service in hot weather conditions. Specifically, Item 450 B.1-3 of Chapter 879 of the 2008 Acts of the Assembly states:

> *"1. It is the intent of the Governor and the General Assembly that immediately upon the completion of the Statewide Rail Plan in July 2008, a process for determining the appropriate balance of resource allocation between the movement of freight and passengers on Virginia's rail system, particularly between Richmond and Washington, shall be determined based on the principles outlined in Chapter 896 of the 2007 Session of the General Assembly and § 33.1-221.1:1.1 of the Code of Virginia. Such process recommendations, which shall be completed and reported no later than September 30, 2008, shall be recommended to the Governor, General Assembly, and Commonwealth Transportation Board by the Director, Department of Rail and Public Transportation.*
>
> *2. In accordance with the intent of the General Assembly, the Statewide Rail Plan shall include specific provisions for the improvement of passenger and freight train performance brought about* ***by track concerns that typically arise during extreme hot weather conditions.****" [emphasis added]*

The purpose of this technical memorandum is to identify the causes of heat delays on railroad corridors within the Commonwealth and to identify practices that are anticipated to minimize delays on these corridors in the future. This technical memorandum identifies the causes of heat delays generally, and the specific causes of heat delays along the CSX I-95 Rail Corridor between Washington, DC and Richmond that occurred within the 2002 and 2007 timeframe.

II. Background

A. Definition of Problem– What Is a Heat Order?

Virginia Railway Express (VRE), the commuter rail operator in the Washington, DC region, defines a heat restriction or "heat order" as "an order given to railroad engineers to reduce their speed over a given section of track".[1] The Federal Railroad Administration (FRA) designates a Train Accident Cause Code for sun kinks/buckling related to accidents caused under the category of track geometry. The specific FRA Code is referred to as Code: T109 Track alignment irregular (buckled/sun kink).

[1] Virginia Railway Express, http://www.vre.org/feedback/frequently_asked_questions/faq_heat_orders.htm

CSX reports that heat orders are issued if “daily highs in the summer are predicted to reach 90 degrees Fahrenheit or more; or if during other parts of the year the ambient temperature is expected to swing significantly, and especially if the predicted high will exceed 85 degrees Fahrenheit.” CSX notes that the issuance of a heat order is sometimes more complex than simply a rise in temperature; it may be issued for track disturbances, maintenance work and other rail repairs which may temporarily weaken the track structure. Such activities, if unprotected, can cause rail buckling, which is discussed in more detail later in this document.

CSX reports that heat orders typically occur on track in the afternoon and early evening between the hours of 1 p.m. and 7 p.m. Morning train traffic is not normally affected by heat orders as the ambient temperature required to produce significant rail stresses is not present.

Under extreme heat or heat fluctuations, rail expansion can cause rail buckling or a sun kink. The buckling occurs due to the expansion as a result of high rail temperatures. Buckling causes the track to shift laterally and sometimes vertically, resulting in a deformation that deviates from the normal track alignment. Buckling usually occurs in the afternoon and early evening hours, over the course of a hot day when rail stresses are highest. CSX reports that heat orders are lifted on CSX corridors after 7 p.m. as sunlight diminishes and rail stresses drop, eliminating heat-related delays for all trains.

On the CSX I-95 Rail Corridor between Richmond and Washington, DC, the freight train maximum speed limit is 60 mph, and the passenger train maximum speed limit is 70 mph. When heat orders are in place, passenger train crews are required to operate their trains at less than 40 mph. Freight train crews are required to reduce the speed of freight trains by 10 mph, but are not required to operate their freight trains at less than 30 mph.

B. Continuously Welded Rail

Modern railroad corridors throughout the world are constructed with Continuously Welded Rail (CWR). CWR is fabricated in segments that are approximately one-quarter mile long. The segments are laid in the track and welded together, creating a continuous rail surface that results in a smoother ride, safer track and less maintenance requirements.

Steel rails expand and contract as temperatures rise and fall. An 1,800-foot length of rail will expand almost one foot in length with an 80-degree change in ambient temperature. The compression and tension of CWR is constrained by properly securing the rail to the ties at the appropriate temperature for the geographic region. Before CWR was in wide use, jointed rail with gaps every 39 feet mitigated some rail forces.

The rail laying temperature for installation of CWR should be as close to the desired Rail Neutral Temperature as possible. Rail installed in this manner can withstand rail expansion and contraction as the temperature rises and falls. It is important to note that the Rail Neutral Temperature refers to the temperature of the rail at the time it is installed, and not the ambient temperature.

The Journal of Wheel/Rail Interaction provides a definition of the Rail Neutral Temperature in which CWR should be installed:

> **"Rail Neutral Temperature"**
> CWR is laid in a stress-free state at a given temperature. This becomes the Rail Neutral Temperature, or RNT. In most of the Midwest and Upper Plains of the U.S., rail is laid at a RNT of anywhere from 95 to 100 degrees. This means simply that the rail is stress free when the rail temperature is around 100 degrees. If it gets colder, the rail goes into tension and shrinks, causing potential pull aparts. If it gets hotter than 100 degrees, the rail goes into compression and expansion, causing a potential buckle or kink.[2]

CSX states that rail in Virginia is laid at a minimum rail temperature of 95 degrees Fahrenheit.

C. Heat Orders on the CSX I-95 Rail Corridor 2005-2008

From 2005 through 2007, CSX undertook an extensive $29.5 million track resurfacing and tie replacement program on the I-95 Rail Corridor between Richmond and Washington, DC. During that time period, CSX replaced approximately 224,000 ties on 182 track miles, and replaced the rail on approximately 24 track miles (there is a total of 225 track miles in the I-95 Rail Corridor between Richmond and Washington). CSX attempts to schedule these activities during the summer for two primary reasons:

1. CSX coordinates with VRE to minimize interruptions to commuter services and ridership is lighter during the summer;
2. Continuously Welded Rail (CWR) must be installed at as close as possible to the desired Rail Neutral Temperature[3] to prevent rail buckling. The ambient temperature conditions are closest to the desired Rail Neutral Temperature in the summer months during the day.

During major maintenance and construction programs, the track must be stabilized before full-speed train operations can resume in the affected portions of the corridor. This stabilization period extends over several days until track stability is restored by trains operating over the track.

A contributing factor to the magnitude of heat order impacts was the CSX policy of implementing subdivision-wide heat orders on the length of the I-95 Rail Corridor during the recent, extensive construction work from Washington, DC to Richmond. The policy has since been revised by CSX, which is discussed later in this document.

[2] Interface-The Journal of Wheel/Rail Interaction, *Preventing Track Buckles*, March 10, 2005 pg. 1.
[3] *Rail Neutral Temperature* is defined as the temperature at which the rail is neither in tension or compression.

D. Delays for VRE Commuter Services 2005-2008

For the purpose of this analysis, delays on the VRE Fredericksburg and Manassas Lines were used as measures of on-time performance impacts from heat orders, as well as trends in heat delays on the I-95 Rail Corridor. VRE data are most useful in identifying trends on the I-95 Rail Corridor for several reasons. Although Amtrak also operates numerous intercity passenger rail services along the I-95 Rail Corridor, Amtrak does not record delay information that it specifically attributes to heat delays. Also, the travel times and distances for Amtrak services differ significantly as compared to VRE services. Finally, passenger delays for Amtrak services may be attributable to events outside of the Commonwealth.

VRE provides daily and monthly on-time performance and delay statistics on its website for the period from July 2006 to August 2008. VRE also provided delay and on-time performance data for 2005. The VRE performance statistics were analyzed for the summer months from 2005 to 2008. The months analyzed include June, July and August, when heat delays historically occurred most often. **Figure 1** illustrates the results of the analysis with a clear downward trend in the number of heat delays on the VRE Fredericksburg line from 2005 through 2008. Heat orders were at their peak in August 2006 on the VRE Fredericksburg Line.

By comparison, the VRE Manassas Line, operated on a Norfolk Southern (NS) rail corridor, had only one heat order that impacted VRE services during the same, approximately three year timeframe. It should be noted that the I-95 Rail Corridor experiences a significantly higher volume of freight and passenger rail traffic overall than the Manassas Line. In addition to being a high volume freight and commuter rail corridor for the Washington, D.C. region, the CSX I-95 Rail Corridor is also a corridor utilized by Amtrak for its Florida, Carolina and Northeast regional services.

III. Discussion

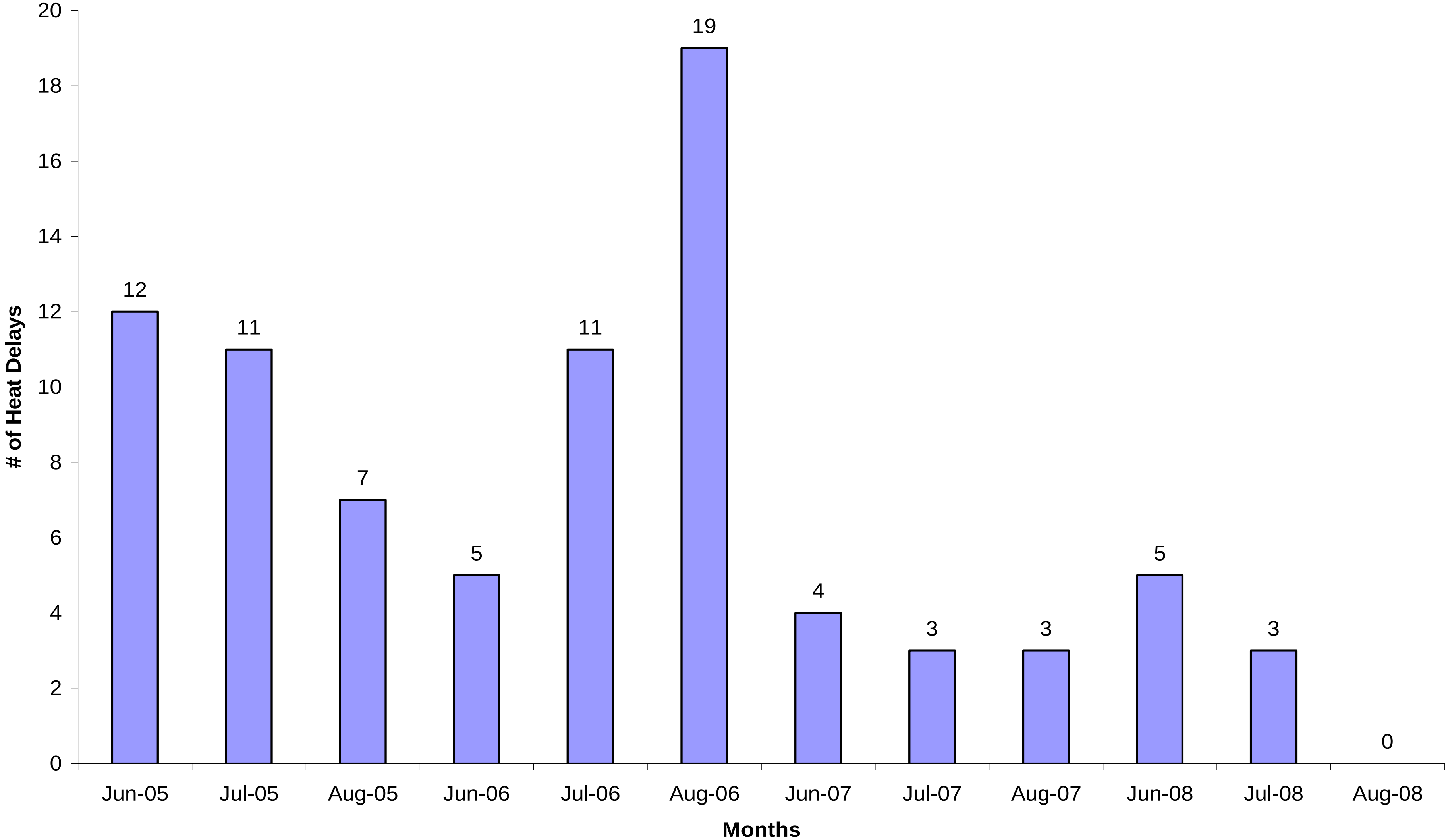
A. Heat Orders in Virginia

Heat order protocols are determined by the railroad owner/operator, “the host railroad” on whose tracks Amtrak and VRE services operate. Within Virginia, Amtrak and VRE services operate on CSX and NS tracks.

1. CSX

CSX provided a general policy statement on heat orders to VRE, which is made available on the VRE website (see Appendix A). The CSX policy on heat orders is that the orders are issued when the forecast is for temperatures to be near 90 degrees or higher. The effect is to reduce speeds of freight trains by 10 mph, but not lower than an operating speed of 30 mph, and to reduce the speed of passenger trains by 20 mph, but not lower than an operating speed of 40 mph.

Figure 1: Number of Days of Heat Delays on the I-95 Rail Corridor (Summer Months 2005-2008)



The intent is to increase safety during operations in hot weather that might cause continuous welded rail to bend or kink as a way of relieving pressure.[4] CSX issues heat orders along the railroad's entire system, including track from New England to Florida.

2. Norfolk Southern

Norfolk Southern (NS) provided to VRE a general policy on the placement of heat orders on their rail corridors (see Appendix A). On the VRE Manassas line which operates on NS track, NS states that the railroad's policy is not to issue blanket heat orders. NS inspects the track with sufficient frequency in hot weather that if problems are detected, NS orders trains to run more slowly through the affected area until the problem is corrected.[5]

B. Future Conditions and Actions

A gradual and long term rise in ambient temperatures (particularly in the summer months) will place additional stress on track structure. If the average temperature increases in Virginia in the coming decades, it seems reasonable to conclude that continuously welded rail would be in an expansion state for longer periods and more frequently. These climatic changes, in the long term, may require adjustments in rail construction and maintenance practices.

A general consensus has been reached among scientists throughout the world that more frequent and extreme heat conditions can be anticipated in the next several decades as a result of global warming caused by carbon emissions. A rise in the average ambient and rail temperature could directly impact track construction and maintenance.

Numerous studies have been conducted by a United Nations (UN) Intergovernmental Panel on Climate Change. The most recent study, *Climate Change 2007, Synthesis Report* forecasts that the average world temperature could increase by 2.0 to 4.0 degrees Celsius (3.6 to 7.2 degrees Fahrenheit) by 2100. The UN study indicates that these changes may not be limited to average temperature increases. The reports states that there will be more frequent and longer lasting heat waves in North America.

The U.S. Transportation Research Board (TRB), National Oceanic and Atmospheric Administration (NOAA), National Climatic Data Center, and National Weather Service, in coordination with the U.S. Department of Energy Lawrence Berkeley National Laboratory, have also been studying[6] the climate change issue and its impact on the nation's transportation infrastructure. The study states that track structures are typically designed to withstand a maximum of 60 degrees Fahrenheit above the Rail Neutral Temperature. The study also provides ambient temperature ranges that are potential indicators for rail buckling between 76 degrees and 90 degrees Fahrenheit, depending on

[4] Virginia Railway Express, http://www.vre.org/feedback/faq.htm#heatorders
[5] Ibid.
[6] Transportation Research Board, *Climate Variability and Change with Implications for Transportation, 2008. pg.*

the strength of the track. These values are consistent with CSX temperature thresholds for heat orders. The study also has more specific temperature and precipitation projection data for the United States forecasted to 2100 that are consistent with the findings of the UN study. Conclusions found in this study support other findings, in that CWR is typically laid at a desired Rail Neutral Temperature 40 degrees Fahrenheit, less than the maximum expected *rail temperature* for a given region of the U.S.

IV. Conclusion

For future rail projects in the Commonwealth, CSX has identified two operational policies which will reduce the number of heat delays on its rail corridors. These policies were in effect for all of 2008 and have significantly reduced the impact of heat orders:

1. Heat orders are no longer required to be placed across an entire subdivision when more than three locations require heat orders. Rather, CSX inspection and maintenance personnel are authorized to place orders on more than three locations within a subdivision at the milepost and even sub-milepost level.
2. The track designation policy has been changed as it relates to heat orders, so that in two-track or three-track corridors a heat order may be placed on a single track within the same segment of a multi-track corridor.

Passenger rail service running schedules benefit when heat orders are placed at the milepost or sub-milepost level. Passenger trains can decelerate and accelerate at certain locations when heat orders are placed at spot locations and then resume normal speed operations. Prior to 2007, passenger trains were forced to reduce speed for the entire length of the Washington, DC to Richmond corridor whenever more than three locations within the corridor required heat orders. Designating a single track of the double track rail line for a heat order also allows for increased operational flexibility and schedule adherence. CSX anticipates that these policies will continue to be in place in the long term. CSX also anticipates that the next major tie replacement cycle on the I-95 Rail Corridor will occur in the 2013-2014 timeframe. This timeframe is consistent with the six to ten-year program established by CSX. Additionally, track surfacing or smoothing will occur every two to three years as needed to ensure a high quality, safe railroad. Rail will also be replaced as required, especially in curves where rail wear occurs more quickly than along tangent sections of track.

Regarding CSX inspection practices, CSX maintains the Washington, DC to Richmond corridor to Class 4 track standards and meets the Federal Railroad Administration's required inspection standards for that class of track. CSX works cooperatively with VRE, and VRE has verified that good coordination exists between both parties in the inspection activities to minimize disruptions to passenger rail services. The eventual addition of a third track on the I-95 Rail Corridor will allow more flexibility in performing track inspection and maintenance, while maintaining train traffic and minimizing delays.

Constructed and programmed improvements in the corridor can, and will, improve the fluidity of passenger and freight train movements, as well as the inspections of the track for rail buckling during the summer months. Both CSX and VRE reported significant improvements in train movements on the corridor with the addition of a second track and the opening of the new bridge over Quantico Creek. The long-term goal for the corridor is to add a third track for the length of the corridor from Richmond to Washington, DC. A third track will add much needed capacity that will significantly enhance service reliability, increase flexibility and result in a higher average speed for trains moving through the corridor. There are currently two third-track projects in the final engineering and construction stages, AF-RW (6.4 miles through Fairfax County and Alexandria) and FB-HA (3.3 miles through Fredericksburg and Spotsylvania County).

V. Actions for Heat Order Mitigation

This analysis will serve as a component of the Statewide Rail Plan. DRPT has identified practices which will reduce the number of heat delays on railroads in the Commonwealth, including projects funded by the Rail Enhancement Fund. In addition, DRPT and CSX signed an *Improved and Reliable Passenger and Freight Rail Operations Agreement for the I-95, "S" Line, and Related Rail Corridors Agreement* (Operating Agreement) on January 4, 2008. The Operating Agreement specifically commits both parties to cooperatively develop the means and methods to address heat orders, including the development of a *Basis of Design Requirements* document. The *Basis of Design Requirements* document will provide engineering principles to guide the design and construction process. All projects contemplated by the Commonwealth will be designed and constructed to take into consideration the reduction or prevention of track related conditions that could lead to rail buckling.

In summary, DRPT will implement two actions to minimize the potential future impacts of heat delays on rail service in the I-95 Rail Corridor:

1. DRPT will require that the agency be notified in advance if current railroad policies and practices for heat orders are changed by the railroad. DRPT may also require periodic reports from railroads receiving state funding for capital projects on measures to reduce or avoid heat orders. Similarly, DRPT may require periodic reports from passenger rail operators regarding the number of heat orders affecting their services, with clear documentation of heat order events and impacts on passenger rail service.
2. Major studies funded by the United Nations and the U.S. Transportation Research Board forecast average temperature increases for North America that may range from 3.6 to 7.2 degrees Fahrenheit by the turn of the next century. Climatic changes, in the long term, may require adjustments in rail construction and maintenance practices, and both the railroads and the Commonwealth should take this under consideration in their long-term planning.

Appendix A

CSX and NS Heat Order Policies
Excerpt from VRE Website

Virginia Railway Express

Heat Orders FAQ

What Is a Heat Order?
It is an order given to railroad engineers to reduce their speed over a given section of track. As automobiles are sometimes requested to lower speeds for various road and weather conditions, trains are subject to the same thing.

Why Is a Heat Order Necessary?
The trackage that VRE trains operate on consists of continuous welded rail. Rails come from the welding plant in strings one-quarter mile long. Once the quarter-mile rails are laid in the track, the ends are welded to each other to create strings of rail that are truly continuous. This eliminates the “clickety-clack” of traditional 39-foot rails. Welded rail results in a smoother ride with less maintenance. Steel rails slowly expand and contract as temperatures rise and fall. In fact, an 1800-foot length of rail will expand almost one foot with an 80-degree change in temperature! Before welded rail, expansion was absorbed by a small gap (joints) between the rails every 39 feet. With welded rail the normal tendency to expand must be constrained internally by securing the rail. Careful engineering measures, including heating the rail, are taken when rail is installed to account for rail expansion and contraction. The ties, rock ballast, and rail anchors, which hold the rail longitudinally, must be strong enough to keep the rail solidly in place instead of expanding or contracting. Under extreme heat, the rail, on rare occasions, wins the expansion battle and a “sun kink” results. A sun kink causes the track to shift laterally causing a curve in what is otherwise a straight pair of rails. Normally these stresses are contained by the ability of both the railroad spikes, tie plates and cross ties, supported by the ballast (the stone under the rail and cross ties), to resist the side-to-side movement that causes buckling in the rails. A substantial ballast shoulder at the edge of the ties, and a “full crib” between the ties, are extremely important in overcoming the lateral forces. Additionally, railroads apply anchors at most cross ties to grip the rail and hold it in check, and thus keep the entire track structure in line. However, in some cases these measures cannot hold the extreme amount of force that high temperatures can create. A sudden release of these stresses may occur, resulting in the rapid (and often audible) development of a “kink,” or sideways movement in the track.

That is where the heat inspectors come in. To add an extra measure of safety, track inspectors are sent out when the temperature rises quickly from night to day or when the daytime temperatures become extreme and the rail attempts to rapidly expand. These inspectors look for signs the track is under extreme compression and in danger of kinking out to the side. Signs include wrinkles in the track and disturbances of the ballast. If warranted by the inspection, speeds are lowered for trains, whose heavy weight can set the steel molecules in motion. As an added safety measure, passenger train speeds that VRE must follow are lowered as well. When a “kink” or high tension is found in the track, the track is taken out of service, repaired, and then put back in service. That is why there are times that we are limited to one track during the summer as repairs are made.

Why Can Freight Trains Go Faster Than Passenger Trains during heat restrictions?
Simply, they can't and don't. Freight trains maximum speed limit is 60mph, passenger trains maximum speed limit is 70mph. During heat restrictions passenger trains must travel 20mph lower than the speed limit and freight trains 10mph lower than the posted speed limit. This effectively makes freight trains and passenger trains travel the same speed. However, as passenger trains slow as they stop and start for station stops, the freight trains do not. Hence why they seem to be moving faster.

How Is it Determined If Heat Orders Are Necessary?
The need for Heat Restrictions is determined by our host railroads. See below for their statements on heat orders.

Statements from CSX and Norfolk Southern:

CSX (from CSX)
Heat orders are issued when the forecast is for temperatures to be around 90 degrees. The effect is to reduce speeds of freight trains by 10 mph, but not lower than 30 mph, and to reduce the speed of passenger trains by 20 mph, but not lower than 40 mph. The intent is to increase the measure of safety in hot weather that might cause continuous welded rail to bend or kink as a way of relieving pressure.

Norfolk Southern (from NS)
Norfolk Southern does not issue blanket heat restrictions or heat orders. NS inspects the track with sufficient frequency in hot weather that if problems are detected, NS orders trains to run more slowly through the affected area until the problem is corrected.

Why do Norfolk Southern and CSX have different policies?
The short answer is that each railroad operates efficient and safe. Railroading is an inexact science and many challenges faced are met in different, but equally effective, ways. The approach to track restrictions in hot weather is one of those challenges.