13. APTA PR-M-RP-013-06 Recommended Practice for Selection of Wheels for Passenger Applications

Approved February 15, 2007
APTA PRESS Task Force

Authorized February 15, 2007
APTA Commuter Rail Executive Committee

Abstract: This Recommended Practice (RP) has been created for the purpose of helping to ensure compliance with 49CFR 238.231(f), 49CFR238.231(j)(4) and 49CFR 238.303(e)(8)(x) which state (in part) that "the operating railroad shall require that the design and operation of the brake system results in wheels that are free of condemnable cracks." While the rule specifically addresses the brake system, this RP suggests a method by which a wheel design, appropriate for the envisioned operation, can be chosen to minimize the risk of cracking due to service brake loading. Application of this RP is also suggested when a railroad is considering changes to its operation (such as maximum authorized speed, deceleration rate, stopping profile, or station spacing).

Keywords: wheel design, thermal cracking, transit, commuter

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Introduction

This Recommended Practice (RP) has been developed to assist APTA member railroads in the selection process of wheels appropriate for particular service applications. The RP has no predecessor and has not been adapted from any other standard. The RP establishes a performance-based approach to the selection of wheels to preclude their development of condemnable cracks. The RP can be envisioned as a filter which discriminates between combinations of wheel design and operating parameters which are likely to result in poor wheel performance and those which are not. The railroad needs to further consider the requirements of 49CFR238.231(k) during the evaluation of the appropriate wheel type to be utilized.

The RP has been developed using results of research conducted by several analysts from the private sector and the federal government. The Federal Railroad Administration (FRA) has sponsored a significant amount of this research and testing, the results of which appear in the reports listed in Annex B.

The RP considers the thermal loading imposed at the wheel tread resulting from friction braking. Much of the research noted above has focused on understanding the phenomenon of rim stress reversal[1] due to thermal loading and its relationship to thermal cracking. The essence of this research has been distilled into this RP. Using relatively few operating parameters, which are well-known and understood by railroad personnel, the RP helps to identify wheel designs which are not likely to experience thermal cracks in normal revenue service.

This RP is evolving. The limits prescribed in the RP are subject to change as experience is gained through its application in actual railroad practice. Periodic inputs from users of this RP are welcomed. If the operating agency has had satisfactory experience with an existing wheel design, this does not prohibit the purchase of wheels of the same design even though they are not recommended by this RP,. This assumes operating conditions remain the same (vehicle design, maximum speed, braking rate, maintenance practices).

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1 Rim stress reversal refers to the situation in which the as-manufactured residual circumferential (hoop) compression in the vicinity of the wheel tread is reversed to tension as a result of severe heating during on-tread friction braking. The as-manufactured residual compression assists in preventing the formation and growth of cracks which may form at the wheel tread. Reversal to tension increases the likelihood of crack formation and growth.

Participants

The American Public Transit Association (APTA) greatly appreciates the contributions of the following individual(s), who provided the primary effort in the drafting of the *Recommended Practice for Selection of Wheels for Passenger Applications*:

Al Bieber, *Chair*
Jeff Gordon
Paul Jamieson
Cameron Lonsdale
Peter Mathern
James Pilch
Thomas Rusin
Daniel H. Stone
Phil Strong

At the time that this recommended practice was completed, the Passenger Rail Equipment Safety Standards (PRESS) Mechanical Committee included the following members:

Dave Carter, *Chair*

Steven Abramopaulos
M. Andriani
Gordon Bachinsky
Jack Barnas
Ken Barnish
Al Bieber
George Binns
Brad Black
Rick Brilz
Chris Brockhoff
Dick Bruss
Dave Brooks
Mark Campbell
Gary Carr
John Casale
Al Cheren
George A. Chipko
Steve Chrismer
Roger Collen
Richard Conway
Steve Costanzo
Jack Coughlin
Tim Cumbie
Erik Curtis
Graham Curtis
Richard Curtis
Steve Dedmon
John M. Dermody
Greg Dvorchak
Ed Deitt
Magdy El-Sabaie
John Elkins
Dave Elliott
Owen Evans
Gary Fairbanks
Ronald L. Farrell
Andrew F. Farilla
Benoit Filion
Chuck Florian
Greg Gagarin
John Goliber
Jeff Gordon
Thomas Grant
Harry Haber
Kevin Heidrich
Francois Henri
Ken Hesser
Christopher Holliday
Paul E. Jamieson
James Jewell
Richard Johnson
Joe Kalousek
Joe Kahr
Bob Kells
Larry Kelterborn
Kevin Kesler
Paul Kezmarsky
Peter Klauser
Sunil Kondapalli
John P. Konrad
Susan Kristoff
Rick Laue
Nicolas Lessard
Jason Lipscomb
Cameron Lonsdale
Ben Lue
William Lydon
Susan Madigan
Dan Magnus
Eric Magel
Frank Maldari
George Manessis
Jean Major
John Mardente
James Martin
Brian Marquis
Keith McCarrick
Don Minini
Heiner Moehren
Donald Morrissey
Dak Murthy
Larry Niemond
Thomas O'Brien
Frank Orioles
George Payne
Fernando Pascual
Tom Peacock
John Pearson, Jr.
Jim Pilch
Ian Pirie
Richard Polley
John Posterino
Anand Prabhakaran
Chuck Prehm
John Punwani
Russ Quimby
James G. Rees
Al Roman
Carol Rose
Tom Rowbottom
Daniel Ruppert
John Rutkowski
Tom Rusin
Michele Salvatore
Radovan Sarunac
Fred Schaerr
Hans-Dieter Schaller
David Schanoes
Peter Schumacher
Bill Sears
Rebecca Sidelinger
Kevin Simms
Tom Simpson
Albert C. Song
Carlos Sosa
Rex Springston
Mark Stewart
Monique Stewart
Philip M. Strong
Chris Studcart
Dick Swaney
Bob Swearingen
Ali Tajaddini
KI. Takeshita
Joe Talafous
Clive Thornes
Richard Trail
Mike Trosino
Tom Tsai
Bob Tuzik
Richard Vadnal
Arun Virginkar
John Wagner
David Warner
Douglas Warner
Charles Whalen

Brian Whitten
Gary Widell
James Wilson
Bruce Wigod
Werner H. Wodtke
Clifford Woodbury
Bob Wright
P. Yablonsky
H. Yamamori
Greg Yovich
Allan Zarembski
John Zolock
Steve Zuiderveen

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APTA RP-M-013-06
Recommended Practice for Selection of Wheels for Passenger Applications

1. Overview

The purpose of this Recommended Practice (RP) is to reduce the risk to APTA member agencies of the occurrence of condemnable tread surface cracks in service. The proposed approach seeks to identify maximum loading conditions for particular wheel designs and AAR material classes above which wheel cracking may be expected to occur. Such a performance standard helps accomplish this purpose. Improved economics may also be realized in that reduced wheel reprofiling (truing) to remove wheel tread thermal cracks will prolong wheel life.

The RP comprises a simplified method to estimate the braking demand on a wheel resulting from a given set of operating conditions. The method uses basic characteristics of the railroad operation to estimate limiting brake power above which thermal cracking may be expected to occur.

1.1 Scope

This Recommended Practice (RP) may be applied to all equipment operated in passenger service.

1.2 Purpose

The purpose of this RP is to provide a rational basis for assessing whether a given wheel design will perform satisfactorily under normal railroad operating service conditions. The objective is to satisfy the design criteria set forth in 49CFR238.231(f), 49CFR238.231(j)(4) and 49CFR238.303(e)(8)(x)[2]. The methodology is designed to suggest wheel designs which will not likely experience wheel tread thermal cracking under normal operating conditions. This method requires specification of particular vehicle and operating parameters.

1.3 Practical considerations and limitations

This RP is applicable to situations representative of nominal (routine, day-to-day) operating conditions. Potentially extreme conditions which may occur in the event of equipment malfunctions or other unusual operational scenarios may exceed the limits of applicability of the technique described here. Heavy-grade (drag braking) operations are not addressed in this RP.

2 Other relevant federal regulations include 238.431(d), (e)(4) and 238.501(b)(1) which pertain to Tier II rail equipment operating at speeds above 125 mph.

AAR Standard S-660 should also be applied to these situations.

In addition to being able to obtain suggestions for appropriate wheel designs for a particular type of service, the potential impact of changes to the operation can also be evaluated. This may be particularly relevant to operating environments with relatively benign braking demand. These operations may be able to tolerate greater brake horsepower per wheel than might be suggested by this approach. These environments might include exclusively express service with limited station stops and civil restrictions, resulting in relatively few (or widely-spaced) braking cycles. Future plans (such as the potential for changing maximum authorized speed, deceleration rate, stopping profile, or station spacing) should be considered before considering a less conservative approach.

This RP is intended neither to prohibit nor endorse continued operation of wheel designs and operating conditions that exhibit satisfactory performance. It is also not the intent to endorse continued operation under circumstances where condemnable thermal cracking exists.

Due to minimal railway operational data available to APTA to develop this RP, the RP spreadsheet tool results may not accurately reflect the wheel service performance experienced on the many different railway properties of APTA. The RP and spreadsheet tool must be validated against real-world service operating characteristics (loads, speeds, operating parameters, wheel truing operations, etc.) and the actual wheel service experience of each individual railroad. If wheels are performing successfully on equipment in actual service, this fact should be given important consideration when evaluating results obtained using the spreadsheet tool. Conversely, if application of the tool results in condemnable thermal cracking in service, this must be brought to APTA's attention.

It is essential that APTA receive feedback from operating railroads on the application of the RP document in such areas as, 1) how the tool is used, 2) how results from the spreadsheet tool are evaluated, 3) how results compare to actual service experience. It is anticipated that a trial period of implementation will be necessary to evaluate the RP, given the complex and theoretical nature of the calculations upon which it is based.

2. References

This Recommended Practice shall be used in conjunction with the following publications. Should any of the following references be superseded by an approved revision, the most recent revision shall apply.

49 CFR 238.231(f), July 3, 2000

49 CFR 238.231(j)(4) , July 3, 2000

49 CFR 238.231(k), July 3, 2000

49 CFR 238.303(e)(8)(x), July 3, 2000

49 CFR 238.431(d), April 23, 2002

49 CFR 238.431(e)(4), April 23, 2002

Procedure for the Analytic Evaluation of Locomotive and Freight Car Wheel Designs, Association of American Railroads Standard S-660-83, Adopted 1981, Revised 2004.

3. Definitions, abbreviations, and acronyms

For the purposes of this Recommended Practice, the following definitions, abbreviations and acronyms apply.

3.1 Definitions

3.1.1 braking, disc: a means of retardation used on some rail vehicles that utilizes flat metal discs as a braking surface. The disc is clamped by brake pads through a caliper arrangement.

3.1.2 braking, dynamic: a means of train braking whereby the kinetic energy of a moving rail vehicle(s) is used to generate a current at the traction motor, which is then dissipated through banks of resistor grids (resistive brake) or back into the catenary or third rail system (regenerative brake). In a hydraulic transmission arrangement, a hydrostatic brake is the dynamic brake.

3.1.3 braking, tread: a means of retardation used on some rail vehicles that utilizes brake shoe that is pressed against the wheel tread.

3.1.4 cracking, thermal: a heat-induced crack at the braking surface caused by frictional heating during braking. Thermal cracking may occur in wheel tread and brake discs at the interface between the brake pad/disc and the brake shoe/wheel tread.

3.1.5 deceleration rate: instantaneous rate of change of speed with respect to time during a brake application. The unit of measure is usually expressed as miles per hour per second (mphps). The deceleration rate may be speed-dependent.

3.2 Abbreviations and acronyms

AAR	Association of American Railroads
APTA	American Public Transportation Association
CFR	Code of Federal Regulations
FRA	Federal Railroad Administration
PRESS	Passenger Rail Equipment Safety Standards
RP	Recommended Practice

4. Wheel selection for tread thermal crack avoidance

4.1 Contextual background

Wrought (forged) wheels for passenger applications are typically heat-treated during manufacture to induce beneficial grain structure and compressive circumferential residual stresses in the rim. The heat treatment consists of application of a water spray (quench) at the tread surface when the wheel is at high temperature near the end of the manufacturing process. The water spray causes rapid cooling of the quenched region, which results in a fine-grained microstructure that is more wear-resistant. A second benefit of the quenching process is the creation of compressive residual stress in the wheel rim at the tread surface. This compressive stress helps to prevent the formation of cracks and retards their growth if they manage to form. New wheels, therefore, have improved wear resistance at the tread surface and an internal stress distribution that is unfavorable to crack propagation.

Wheel tread thermal cracking is caused by severe heating of the wheel tread during on-tread friction braking in service. Excessive friction brake heating has two distinct adverse effects on wheels.

Locally, immediately under the brake shoe, a shallow layer of tread material is rapidly heated, causing it to expand. At the same time, the mechanical properties (strength) of the heated layer are reduced due to the high temperatures. The expansion is resisted by the bulk of the significantly cooler rim and plate material. Depending on the temperature gradient attained during the brake application, local compressive yielding can occur in the thin layer due to the reduced yield strength of the material. When the wheel is allowed to cool, the material shrinks, the converse of thermal expansion. If the heat-affected layer had yielded during heating, it will now be in a state of circumferential (hoop) tension. That is, the residual compression that was present following manufacture is reversed to tension at the tread surface. This is commonly referred to as stress reversal.

The presence of condemnable thermal cracks is undesirable, and in violation of FRA regulation 49CFR238.321(f), 49CFR238.231(j)(4) and 49CFR238.303(e)(8)(x). Several brake system design concepts are available to reduce the thermal loading imposed by tread brakes.

Disc brakes, which comprise either an axle-mounted, wheel-hub mounted or wheel-cheek mounted disc (or discs), that is engaged by a caliper fitted with brake pads, represent an efficient means of reducing thermal loads on the wheel tread. Disc brake-equipped rail vehicles often also have conventional tread brakes as well, since moderate tread braking helps to condition the wheel tread, remove built-up contaminants which may adversely affect axle shunting and maintain wheel to rail adhesion. Disc brake systems are generally designed to provide a specified fraction of the total braking effort of a single vehicle.

Dynamic braking, in which the electric motors are reconfigured as generators to dissipate braking energy as heat through resistor grids, is one option. However, dynamic brakes may fail without warning en route. Also, dynamic brakes are not available on a particular axle if the traction motor is inoperative or cut-out for any reason. Therefore, for the purposes of this RP, dynamic braking, if available on the equipment under consideration, is assumed to provide no brake effort. Retarding force is therefore provided by the friction braking system (tread and/or disc) alone.

4.2 Application to normal service braking operations

As discussed in the Introduction, the results of a body of research have been distilled into this RP. The outcome, for the purposes of this RP is a simple, spreadsheet-based tool[3] that can be used to distinguish wheel design/operating condition combinations which may be prone to thermal cracking (due to the reasons described above) from those which are less likely.

To download the tools, follow these instructions:

a) Go to www.apta.com.

b) From the menu on the left of the screen select "Standards Program."

c) A new Home Page will open.

d) From the menu on the left select "Published Standards."

e) From the drop down menu that appears select "PRESS."

f) From here you can download any PRESS Document.

The tool is available directly from the APTA website at the following URL: http://www.aptastandards.com/PublishedStandards/PRESS/tabid/85/Default.aspx. From the list of published standards, select APTA PR-M-RP-013-06, Recommended Practice for Selection of Wheels for Passenger Applications.

The tool allows selection of two consist arrangements:

- locomotive-hauled consists (coaches and cab cars)
- self-propelled consists (EMUs, DMUs).

The blank spreadsheet is shown in Figure 1. The input parameters required to implement the tool are described in the order in which they are presented.

A checkbox is provided to reflect the user's desire to evaluate a locomotive-hauled consist.

3 The current version of the tool (version 12, 02/15/2007) is implemented in Microsoft® Excel 2003 SP2. In order to provide required functionality, macros have been embedded in the workbook. Depending on the security settings of your computer, a dialog box asking whether to enable or disable macros may appear when loading the spreadsheet. Users should select "Enable Macros."

The status of the checkbox determines the input requirements and the user is required to enter some number of the following parameters:

- Maximum operating speed (mph)

LOCOMOTIVE PARAMETERS

- Maximum fully-fueled locomotive weight (lb)
- Number of locomotive axles
- If disc/tread combination, disc fraction (%)
- Brake shoe width (in)
- Locomotive/car deceleration rate (mph/s)
- Locomotive/car brake shoe width (in)

CAR PARAMETERS

- Car weight (lb) [4]
- Check if car is self-propelled (checkbox available only if locomotive-hauled consist is not checked)
- If disc/tread combination, disc fraction (%)
- Brake shoe width (in)

  The service deceleration rate may be characterized in two ways. If the operation employs a constant deceleration rate, the next check box should be cleared and the brake rate (in mph/sec) entered in the appropriate cell. If the operation is defined by a variable deceleration rate, the corresponding box should be checked and the variable deceleration rate is defined as a series of speed-brake rate pairs beginning at maximum speed and ending at zero. Up to five speed-brake rate pairs may be defined.

- Checkbox for variable deceleration rate (speed taper) (if selected input table appears to enter speed-dependent deceleration rate)
- Maximum service deceleration rate (mph/s) (available only if variable deceleration rate checkbox is not checked)

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4 This corresponds to the AW3 crush load for passenger equipment. The spreadsheet includes a factor to account for the effective increase in mass due to rotary inertia effects, which is 10% for EMUs and DMUs and 5% for coaches.

Car/consist performance data is displayed below the input data. The car/consist stop time, the maximum and average brake power and the brake power and deceleration rate plots are calculated and displayed automatically. The average brake power (expressed in hp) is the result of interest.

This result is compared to a table of nominal values calculated automatically for each wheel design/AAR material class combination shown in the CAR|WHEEL DESIGN table.

Currently six[5] wheel designs are represented for each of the four AAR material classes. Wheel designs that are not represented in the table require that additional calculations be performed to develop the appropriate brake power limits. APTA should be informed of this so that these designs may be included in future revisions of the RP.

Combinations (individual cells) in the CAR|WHEEL DESIGN table change colors depending on the relationship between the average brake power calculated for the specific set of input conditions and the nominal values. The colors indicate whether these designs and material grade combinations are expected to provide satisfactory performance in service:

- Combinations likely to preclude wheel tread thermal cracking turn green.
- Marginal combinations turn yellow indicating that these combinations may be suitable, but are not recommended.
- Combinations which should not be considered appear orange.

In order to avoid confusion in interpreting the indicator colors chosen for the table, the letter G (green), Y (yellow) or O (orange) also appears in each cell. Other colors used in the spreadsheet are purely aesthetic. The user is reminded that the results presented in the spreadsheet are subject to the limitations described in Section 1.3.

4.2.1 Example: self-propelled consist

Figure 2 presents an example application (example 1) using the following parameters:

- Maximum operating speed (mph) — Example: 90 mph
- Car weight (lb) — Example: 140,000 lb
- Check if car is self-propelled — Example: checked
- If disc/tread combination, disc fraction (%) — Example: 0%
- Brake shoe width (in) — Example: 2.875

5 As of 02/15/2007, the table data for the E42 locomotive wheel has not been determined. Interim placeholder data is used in these examples until the actual calculations are completed.

In this example, a variable deceleration rate is considered which tapers from 1.60 mph/s at 90 mph to 1.85 mph/s at 60 mph and is constant 1.85 mph/s from 60 mph to 0 mph.

For the operating parameters specified in the spreadsheet, the average brake power is 190 hp. Three wheel designs spanning all AAR material classes are suggested as suitable candidate wheels for the envisioned service. Three design/material combinations are identified as marginal.

4.2.2 Example: locomotive-hauled consist

Figure 3 contains another example (example 2). In this case, a locomotive-hauled consist is chosen (by checking the appropriate box). The maximum operating speed remains at 90 mph.

Additional input is required to describe the locomotive-hauled consist:

- Maximum fully-fueled locomotive weight[6] (lb) Example: 300,000 lb
- Number of locomotive axles[6] Example: 4
- If disc/tread combination, disc fraction (%) Example: 0%
- Brake shoe width (in) Example: 2.875 in
- Locomotive deceleration rate (mph/s) Example: 1.25 mph/sec

Additional input is required to describe the cars entrained:

- Number of cars in consist: Example: 8

All parameters used to describe the car are the same as in example 1. Note that the locomotive deceleration rate in this example is lower than that for the eight cars in the consist, although the same brake rates for both cars and locomotive(s) can be used. In this example, as in the previous one, car/consist performance data is calculated and displayed below the input data area. However, in this case, the calculated stop time is greater by about 4 seconds. This is due to the fact that the locomotive brake rate (deceleration rate) is lower than that of the cars.

The maximum and average brake horsepower values are now calculated and presented for the car and locomotive wheels. A new table (the LOCO|WHEEL DESIGN TABLE) is created in addition to the CAR|WHEEL DESIGN TABLE. The two tables represent the same information described above for example 1, however all table entries are recalculated based on the revised consist description.

The results for the new set of conditions are more restrictive, suggesting only three green (recommended) and one yellow (marginal) candidate wheel design/material class combinations for the cars. The locomotive wheel design table indicates a wide variety of appropriate combinations, with one combination identified as not recommended.

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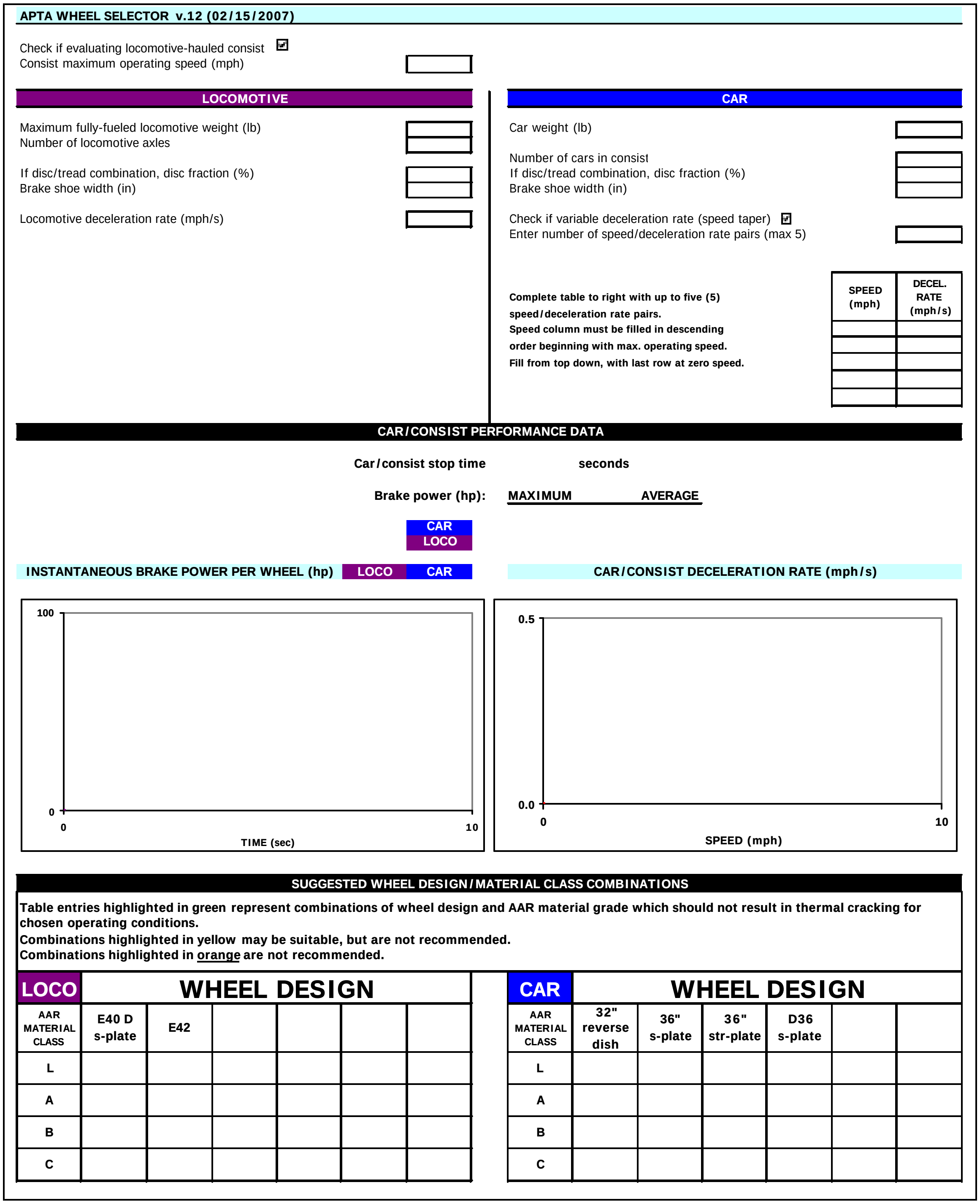
6 If more than one locomotive is included in the consist, the total weight and the total number of axles of all locomotives should be entered.

4.2.3 Example: service braking of locomotive-hauled consist with locomotive brake rate equal to coach brake rate

Figure 4 contains a final example (example 3). In this case, a locomotive-hauled consist is evaluated with the locomotive deceleration rate equal to that of the cars entrained. This is accomplished by unchecking the speed taper checkbox, which in turn, removes the variable deceleration rate table option. The locomotive deceleration rate (in this case 1.25 mph/sec) is entered as the maximum service deceleration rate for the cars. The maximum operating speed remains at 90 mph. The remaining parameters describing the car are identical to those in example 1 for the self-propelled consist. No additional input is required.

The performance data is recalculated. In this example, the average brake power applied to the car wheels is 126 hp. This is lower than what is estimated in the previous examples (190 and 196 hp, respectively) which considered a locomotive-hauled consist and self-propelled equipment. The average locomotive brake power is 282 hp, siginificantly greater than was found in Example 2 (168 hp) in which the deceleration rate of the cars exceeds that of the locomotive.

The results for these conditions are less restrictive for the cars, suggesting six green (recommended) and two yellow (marginal) candidate wheel design/material class combinations. The results are more restrictive for the locomotive wheels since no combinations are recommended.



APTA WHEEL SELECTOR v.12 (02/15/2007)

Check if evaluating locomotive-hauled consist ☑
Consist maximum operating speed (mph)

LOCOMOTIVE

Maximum fully-fueled locomotive weight (lb)
Number of locomotive axles

If disc/tread combination, disc fraction (%)
Brake shoe width (in)

Locomotive deceleration rate (mph/s)

CAR

Car weight (lb)

Number of cars in consist
If disc/tread combination, disc fraction (%)
Brake shoe width (in)

Check if variable deceleration rate (speed taper) ☑
Enter number of speed/deceleration rate pairs (max 5)

Complete table to right with up to five (5) speed/deceleration rate pairs.
Speed column must be filled in descending order beginning with max. operating speed.
Fill from top down, with last row at zero speed.

SPEED (mph)	DECEL. RATE (mph/s)

CAR/CONSIST PERFORMANCE DATA

Car/consist stop time seconds

Brake power (hp): MAXIMUM AVERAGE

CAR
LOCO

INSTANTANEOUS BRAKE POWER PER WHEEL (hp) LOCO CAR

CAR/CONSIST DECELERATION RATE (mph/s)

SUGGESTED WHEEL DESIGN/MATERIAL CLASS COMBINATIONS

Table entries highlighted in green represent combinations of wheel design and AAR material grade which should not result in thermal cracking for chosen operating conditions.
Combinations highlighted in yellow may be suitable, but are not recommended.
Combinations highlighted in orange are not recommended.

LOCO	WHEEL DESIGN					
AAR MATERIAL CLASS	E40 D s-plate	E42				
L						
A						
B						
C						

CAR	WHEEL DESIGN					
AAR MATERIAL CLASS	32" reverse dish	36" s-plate	36" str-plate	D36 s-plate		
L						
A						
B						
C						

Figure 1. Spreadsheet-based wheel design selection tool.

APTA WHEEL SELECTOR v.12 (02/15/2007)

Check if evaluating locomotive-hauled consist ☐
Consist maximum operating speed (mph) 90

CAR

Car weight (lb) 140,000
Check if car is self-propelled ☑

If disc/tread combination, disc fraction (%) 0%
Brake shoe width (in) 2.875

Check if variable deceleration rate (speed taper) ☑
Enter number of speed/deceleration rate pairs (max 5) 5

Complete table to right with up to five (5) speed/deceleration rate pairs.
Speed column must be filled in descending order beginning with max. operating speed.
Fill from top down, with last row at zero speed.

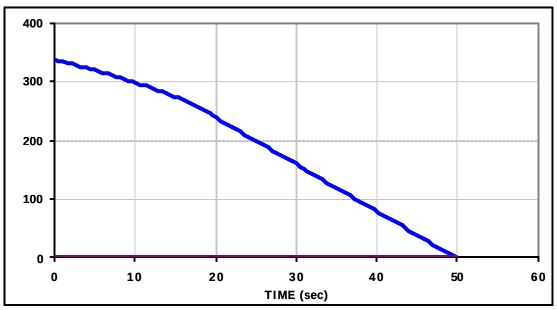
SPEED (mph)	DECEL. RATE (mph/s)
90	1.60
60	1.85
40	1.85
20	1.85
0	1.85

CAR/CONSIST PERFORMANCE DATA

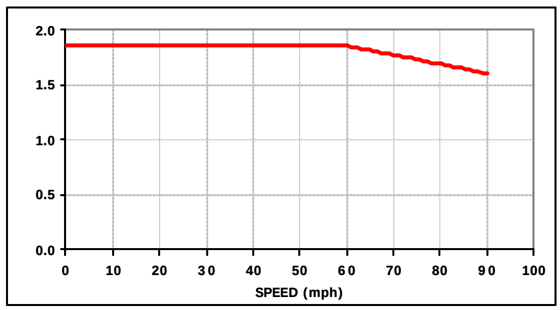
Car/consist stop time **49.89 seconds**

Brake power (hp):	**MAXIMUM**	**AVERAGE**
CAR	**337**	**190**

INSTANTANEOUS BRAKE POWER PER WHEEL (hp) LOCO **CAR**



CAR/CONSIST DECELERATION RATE (mph/s)



SUGGESTED WHEEL DESIGN/MATERIAL CLASS COMBINATIONS

Table entries highlighted in green represent combinations of wheel design and AAR material grade which should not result in thermal cracking for chosen operating conditions.
Combinations highlighted in yellow may be suitable, but are not recommended.
Combinations highlighted in orange are not recommended.

CAR	**WHEEL DESIGN**					
AAR MATERIAL CLASS	**32" reverse dish**	**36" s-plate**	**36" str-plate**	**D36 s-plate**		
L	**O**	**G**	**G**	**Y**		
A	**O**	**G**	**Y**	**O**		
B	**O**	**Y**	**O**	**O**		
C	**O**	**O**	**O**	**O**		

Figure 2. Spreadsheet-based wheel design selection tool (example 1).

APTA WHEEL SELECTOR v.12 (02/15/2007)

Check if evaluating locomotive-hauled consist	☑
Consist maximum operating speed (mph)	90

LOCOMOTIVE

Maximum fully-fueled locomotive weight (lb)	300,000
Number of locomotive axles	4
If disc/tread combination, disc fraction (%)	0%
Brake shoe width (in)	2.875
Locomotive deceleration rate (mph/s)	1.25

CAR

Car weight (lb)	140,000
Number of cars in consist	8
If disc/tread combination, disc fraction (%)	0%
Brake shoe width (in)	2.875
Check if variable deceleration rate (speed taper)	☑
Enter number of speed/deceleration rate pairs (max 5)	5

Complete table to right with up to five (5) speed/deceleration rate pairs. Speed column must be filled in descending order beginning with max. operating speed. Fill from top down, with last row at zero speed.

SPEED (mph)	DECEL. RATE (mph/s)
90	1.60
60	1.85
40	1.85
20	1.85
0	1.85

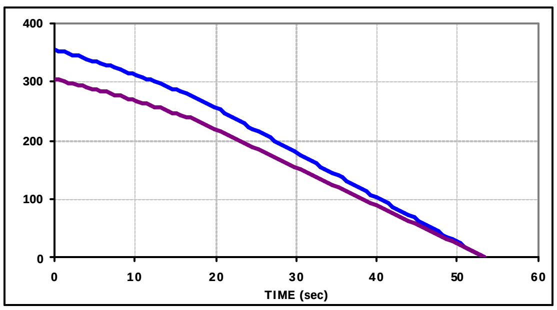
CAR/CONSIST PERFORMANCE DATA

Car/consist stop time 53.48 seconds

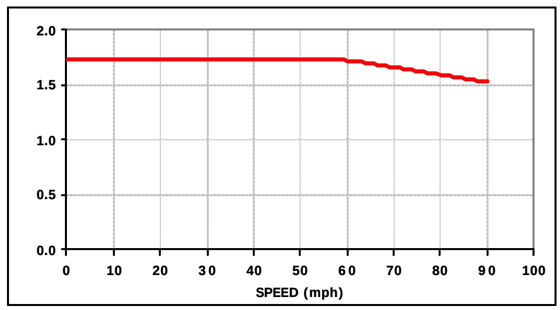
Brake power (hp):

	MAXIMUM	AVERAGE
CAR	354	196
LOCO	304	168

INSTANTANEOUS BRAKE POWER PER WHEEL (hp) LOCO CAR



CAR/CONSIST DECELERATION RATE (mph/s)



SUGGESTED WHEEL DESIGN/MATERIAL CLASS COMBINATIONS

Table entries highlighted in green represent combinations of wheel design and AAR material grade which should not result in thermal cracking for chosen operating conditions.
Combinations highlighted in yellow may be suitable, but are not recommended.
Combinations highlighted in orange are not recommended.

LOCO — WHEEL DESIGN

AAR MATERIAL CLASS	E40 D s-plate	E42				
L	G	G				
A	G	G				
B	Y	G				
C	O	Y				

CAR — WHEEL DESIGN

AAR MATERIAL CLASS	32" reverse dish	36" s-plate	36" str-plate	D36 s-plate		
L	O	G	G	O		
A	O	G	Y	O		
B	O	O	O	O		
C	O	O	O	O		

Figure 3. Spreadsheet-based wheel design selection tool (example 2).

APTA WHEEL SELECTOR v.12 (02/15/2007)

Check if evaluating locomotive-hauled consist ☑
Consist maximum operating speed (mph) 90

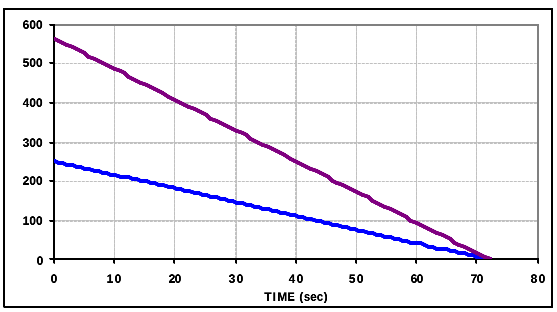
LOCOMOTIVE		CAR	
Maximum fully-fueled locomotive weight (lb)	300,000	Car weight (lb)	140,000
Number of locomotive axles	4	Number of cars in consist	8
If disc/tread combination, disc fraction (%)	0%	If disc/tread combination, disc fraction (%)	0%
Brake shoe width (in)	2.875	Brake shoe width (in)	2.875
Locomotive deceleration rate (mph/s)	1.25	Check if variable deceleration rate (speed taper)	☐
		Maximum service deceleration rate (mph/s)	1.25

CAR/CONSIST PERFORMANCE DATA

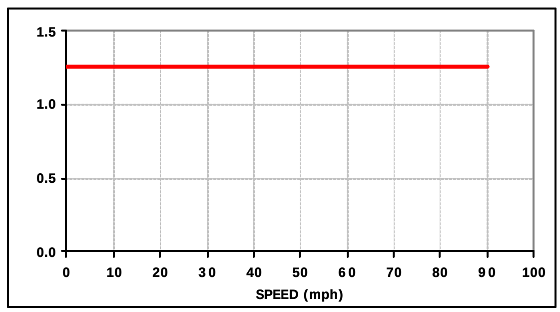
Car/consist stop time 72.00 seconds

Brake power (hp):	MAXIMUM	AVERAGE
CAR	251	126
LOCO	564	282

INSTANTANEOUS BRAKE POWER PER WHEEL (hp) LOCO CAR



CAR/CONSIST DECELERATION RATE (mph/s)



SUGGESTED WHEEL DESIGN/MATERIAL CLASS COMBINATIONS

Table entries highlighted in green represent combinations of wheel design and AAR material grade which should not result in thermal cracking for chosen operating conditions.
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Combinations highlighted in orange are not recommended.

LOCO	WHEEL DESIGN					
AAR MATERIAL CLASS	E40 D s-plate	E42				
L	O	O				
A	O	O				
B	O	O				
C	O	O				

CAR	WHEEL DESIGN					
AAR MATERIAL CLASS	32" reverse dish	36" s-plate	36" str-plate	D36 s-plate		
L	O	G	G	G		
A	O	G	G	Y		
B	O	G	Y	O		
C	O	O	O	O		

Figure 4. Spreadsheet-based wheel design selection tool (example 3).

Annex A Supporting Research (informative)

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