15. APTA PR-M-S-015-06
Standard for Wheel Flange Angle for Passenger Equipment

Approved May 18, 2007
APTA PRESS Task Force

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APTA Commuter Rail Executive Committee

Abstract: This standard defines the minimum flange angle and the minimum length of surface on the flange, over which the angle must be maintained. These wheel flange parameters are important in reducing the risk of low speed wheel climb derailments. The standard also provides drawings of wheel profiles that are compliant with the requirements of this standard.

Key Words: railroad wheel, flange angle, low speed wheel climb derailment, wheel profile, rail profile, Nadal.

Introduction

(This introduction is not part of APTA PR-M-S-015-06, Standard for Wheel Flange Angle for Passenger Equipment.)

In November 1998, APTA issued Technical Bulletin 1998-1, on Commuter Car Safety Regarding: Wheel Running Surface Manufacture and Reprofiling Contour. The bulletin recommended a minimum flange angle of 72° (suggested tolerance +3° and -2°) be achieved at the gage point, 3/8 inch above the standard base line.

The 1998-1 Technical Bulletin is superseded by this standard which requires that on all new and reprofiled wheels, a flange angle of no less than 72˚ shall exist over a continuous length of at least 0.1 inches along the surface of the flange where it will contact the rail.

The standard also provides drawings of narrow flange wheel profiles that are compliant with the requirements of this standard. Some wheel profiles currently in use such as the AAR S-621-79 can produce flange angles less than that required in this standard due to variation in tolerances. Railroads choosing to continue the use of the AAR S-621-79 wheel profile, should observe strict adherence to the railroad's quality assurance plan to confirm that tolerance stack-ups do not cause non-compliance with the flange angle requirements of this standard.

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Standard for Wheel Flange Angle for Passenger Equipment

1. Overview

1.1 Scope

This wheel flange angle standard applies to all new and reprofiled wheels used on railroad passenger equipment of all types, including non-passenger carrying cars and locomotives that are intended for use in passenger service on the general railway system of the United States. Other wheel parameters including tread taper are outside the scope of this standard.

The passenger rail industry will phase this standard into practice over the 36 month period from June 30, 2007 to July 1, 2010.

1.2 Purpose

The purpose of this document is to provide minimum requirements for the wheel flange angle to reduce the risk of wheel climb derailments. See Annex A.

This standard supersedes APTA Technical Bulletin 1998-1, on Commuter Car Safety Regarding: Wheel Running Surface Manufacture and Reprofiling Contour. The bulletin recommended a minimum flange angle of 72° (suggested tolerance +3° and -2°) be achieved at the gage point, 3/8 inch above the standard base line.

2. References

This standard, where applicable, shall be used in conjunction with the following publications. If the following publications are superseded by an approved revision, the approved revision shall apply.

AAR Manual of Standards and Recommended Practices, Section G-II, Figure 4.37 (Concluded), Narrow Flange Tapered Tread Contour – Locomotive and Amtrak (former Standard S-621-79)

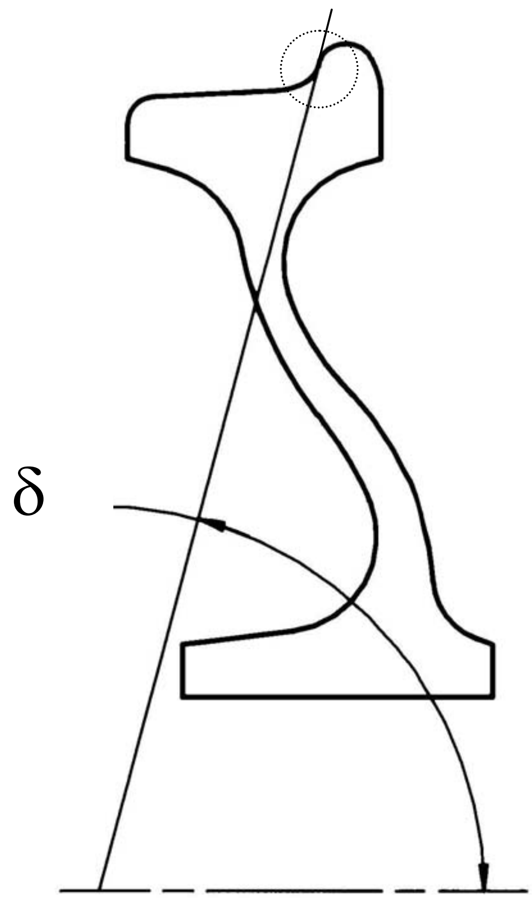
AAR Manual of Standards and Recommended Practices, Section G, Figure B.12, AAR-1B Narrow Flange Contour for Freight Car Wheels (Standard S-669)

3. Definitions, abbreviations, and acronyms

3.1 Definitions

3.1.1 flange angle: The flange angle (δ) is the maximum angle found on the surface of the wheel flange, measured with respect to the axis of the wheel set as shown in Figure 1.

Figure 1 - Flange Angle Definition



3.2 Abbreviations and acronyms

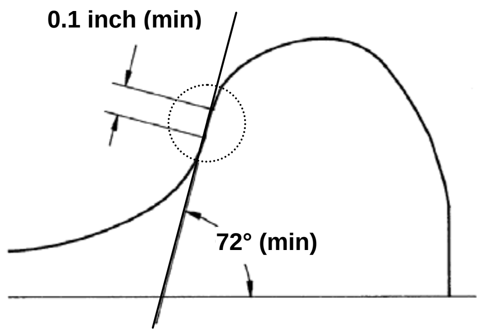
AAR	Association of American Railroads
APTA	American Public Transportation Association
CSTT	Centre for Surface Transportation Technology (division of National Research Council Canada)
FRA	Federal Railroad Administration
NRCC	National Research Council Canada
PRESS	Passenger Rail Equipment Safety Standards

4. Flange Angle Criteria

On all new and reprofiled wheels, a flange angle of no less than 72˚ shall exist over a continuous length of at least 0.1 inches along the surface of the flange, as shown in Figure 2, where it would contact the rail should the wheel climb. Annex B provides examples of wheel profiles which meet this requirement with new rail profiles[1].

The minimum flange angle of 72˚ includes manufacturing tolerances. In deciding on a flange angle to meet the minimum specified, inspectability and manufacturing tolerances shall be considered.

Figure 2 - Flange Angle Standard Criteria



5. Inspection and Maintenance

5.1 Inspection

New and reprofiled wheels shall be inspected in accordance with the railroad's quality assurance plan to confirm the acceptability of the flange angle. Acceptable inspection methods include, but are not limited to, go/no-go gauges, templates, or automated measuring tools. The quality assurance plan shall require verification of the accuracy and ability of the inspection tool to discriminate between compliant and non-compliant flange angles and to establish a test frequency that provides adequate control of wheel profiling.

5.2 Maintenance

This standard is not intended to establish guidelines for the inspection or rejection of wheel flange angles while in service. Typically, flange wear results in a steeper flange angle, so the need for verification applies more to new and reprofiled flange and tread contours. However, if a railroad has experience with flange angles that decrease with wear, APTA recommends that periodic maintenance inspections of the flange angle be established. Flange angles that decrease with wear can occur when introducing a new higher flange angle wheel on rail that has worn to the original, lower flange angle wheel.

[1] New rail profiles used – 100, 112, 115, 119, 132, 136 and 140 RE.

Annex A (informative) Wheel Flange Angle

In discussing wheel/rail interaction, an understanding of the wheel/rail interface is important. The wheel flange angle is an important part of a system that includes many variables, each of which contributes in its own way to the overall behavior of the wheel as it moves along the rail. The potential for a low speed flange climb derailment can be decreased when all of these variables, including flange angle are addressed in a comprehensive rail management program. Nadal [C9] described some of these variables in the early 1900's that include friction control in addition to the flange angle. Rail gage spreading, superelevation, rail camber, angle of attack, duration/distance traveled of excess L/V ratio and the variables that affect these parameters also play an important role in wheel climb derailments.

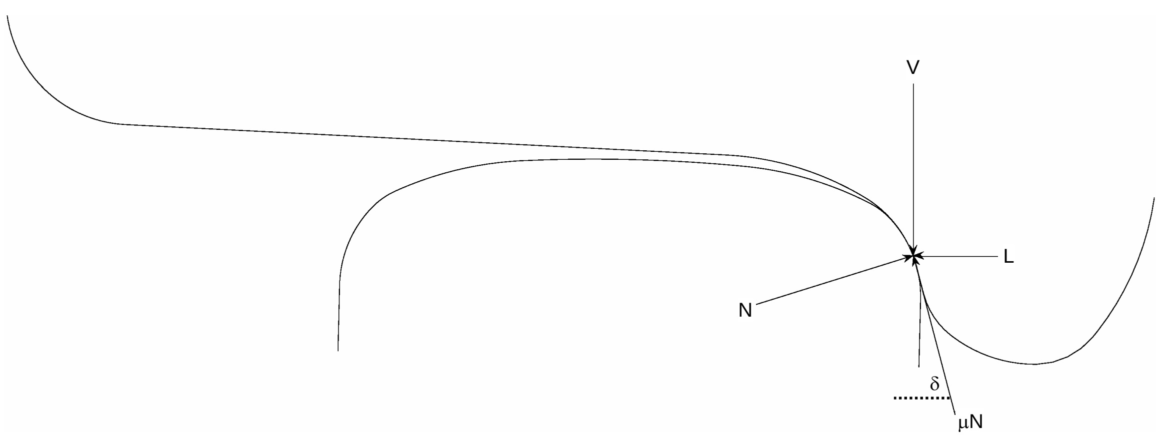
The main factors in wheel/rail interaction and their relationship are stated clearly in Nadal's formula:

$$Nadal\left(\frac{L}{V}\right)=\frac{\tan(\delta)-\mu}{1+\mu\tan(\delta)} \qquad (1)$$

where: μ = coefficient of friction between wheel and rail.

The variables in (1) are illustrated in Figure A1. The variable delta is that angle which is formed when the wheel flange surface and rail gage face surface are in contact. A worn wheel and/or rail profile can greatly affect the wheel/rail interface contact angle. Managing the contact angle as outlined in this standard is an integral part of any wheel/rail interface management strategy. The flange angle is used as an approximation of the maximum contact angle.

Figure A1 - Wheel/Rail Interaction Variables.



Nadal's formula provides an insight into the potential for wheel climb between a specific wheel and a specific rail under specific conditions. Nadal's formula is an industry accepted approach and is utilized because it is simple and straightforward, appropriate for maintaining safety and the variables can be measured.

Based on this formula, railroads have sought to optimize the wheel/rail interface by controlling the coefficient of friction through lubrication schemes, the rail gage face angle through grinding processes, and the wheel flange angle through periodic reprofiling. Some commuter railroads have adopted the AAR-1B profile (developed for freight wheels) as a wheel flange standard, because the profiled flange wears into a relatively optimal contour for maintaining a steep flange angle.

The flange angle specification outlined in this standard requires that the maximum angle be maintained over a distance, rather than at a discrete point. This will increase the probability that a high interface or contact angle between the wheel and rail is maintained despite variations in wheel and rail profiles.

Annex B (normative) Wheel Profiles

B.1 Purpose

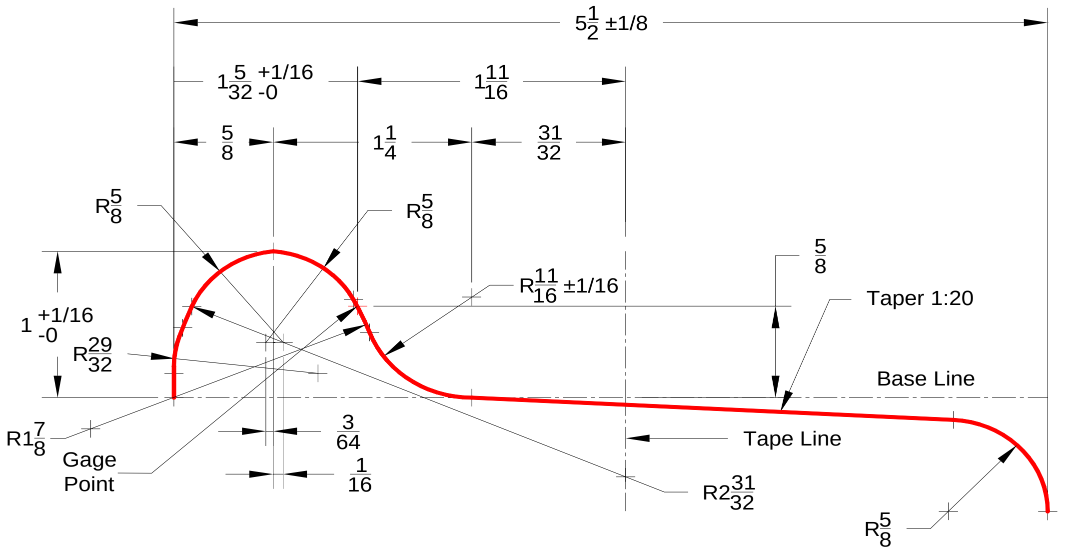
This annex provides drawings of APTA Standard wheel profiles. The narrow flange wheel profiles listed in the table below are examples that meet the requirements[2] of this standard.

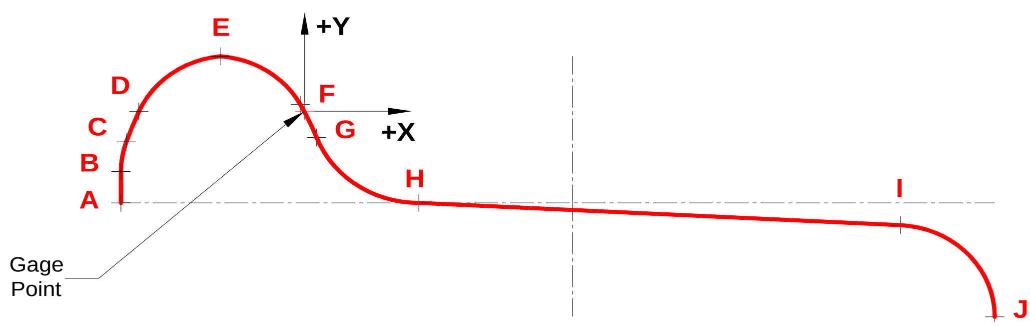
APTA Wheel Profiles			
Annex	**Series**	**Designation**	**Description**
B.2	100	120	Based on (former) AAR S-621-79, 1:20 taper
B.3		140	Based on (former) AAR S-621-79 with 1:40 taper
B.4		140M	Based on (former) AAR S-621-79 with 1:40 taper modified by NJT to provide flange angle of 72º-75º
B.5	200	220	Based on AAR-1B (AAR S-669), 1:20 taper, modified for 5.5 inch wheel width
B.6		240	Based on AAR-1B (AAR S-669) modified for 1:40 taper and 5.5 inch wheel width
B.7	300	320	NRCC-COM20 developed by CSTT [C8] and funded by FRA
B.8		340	NRCC-COM40 developed by CSTT [C8] and funded by FRA

[2] Compliance with requirements based on analysis of wheel-to-rail contact geometry using 1:40 tie plate, 56.5 inch track gage and 53-3/16 inch wheel back-to-back dimension.

B.2 APTA 120 Wheel Profile

Based on (former) AAR S-621-79, 1:20 taper.





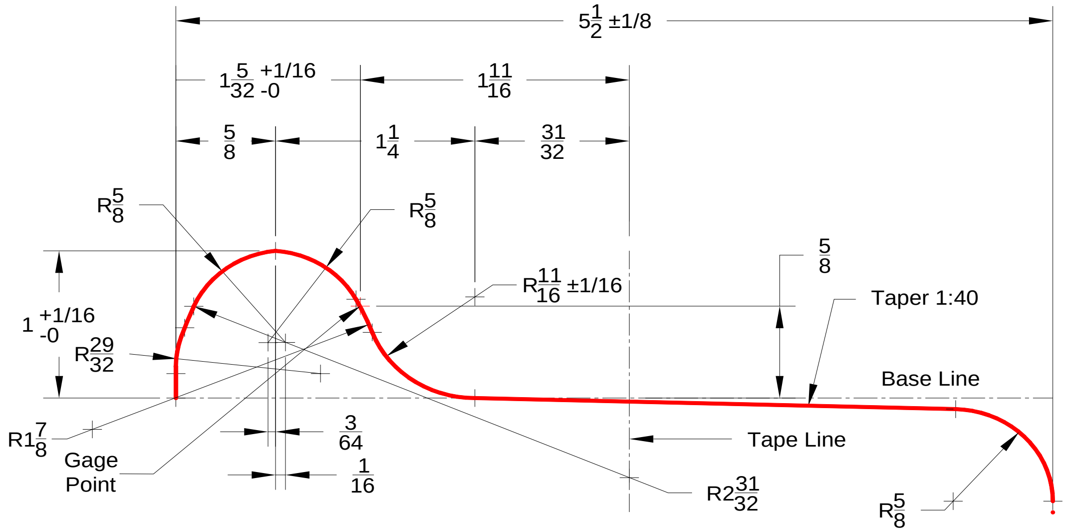
Point	Node Coordinates X	Node Coordinates Y
A	-1.1563	-0.6250
B	-1.1562	-0.4583
C	-1.1013	-0.1476
D	-1.0438	-0.0019
E	-0.5313	0.3750
F	-0.0270	0.0465
Gage Point	0.0000	0.0000
G	0.0751	-0.1790
H	0.7188	-0.6250
I	3.7500	-0.7766
J	4.3438	-1.4008

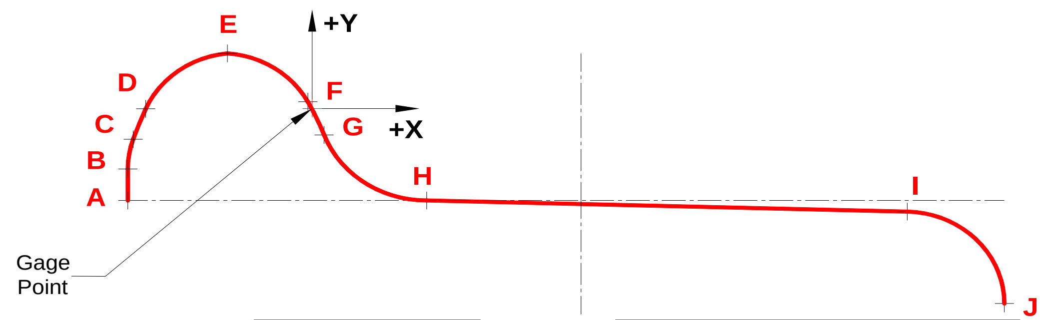
Segment	Segment Details: Radius *Line*	X - Center	Y - Center
A - B	*Line 90°*		
B - C	0.9063	-0.2500	-0.4583
C - D	2.9688	1.6875	-1.1654
D - E	0.6250	-0.4688	-0.2469
E - F	0.6250	-0.5781	-0.2482
F - G	*1.8750*	-1.6805	-0.8376
G - H	0.6875	0.7188	0.0625
H - I	*Line 1:20*		
I - J	0.6250	3.7188	-1.4008
Beyond J	*Line 90°*		

Note: All coordinates relative to 'Gage Point', and all dimensions are inches.
Flange angle must be no less than 72º over a continuous length of at least 0.1 inch.

B.3 APTA 140 Wheel Profile

Based on (former) AAR S-621-79 with 1:40 taper.





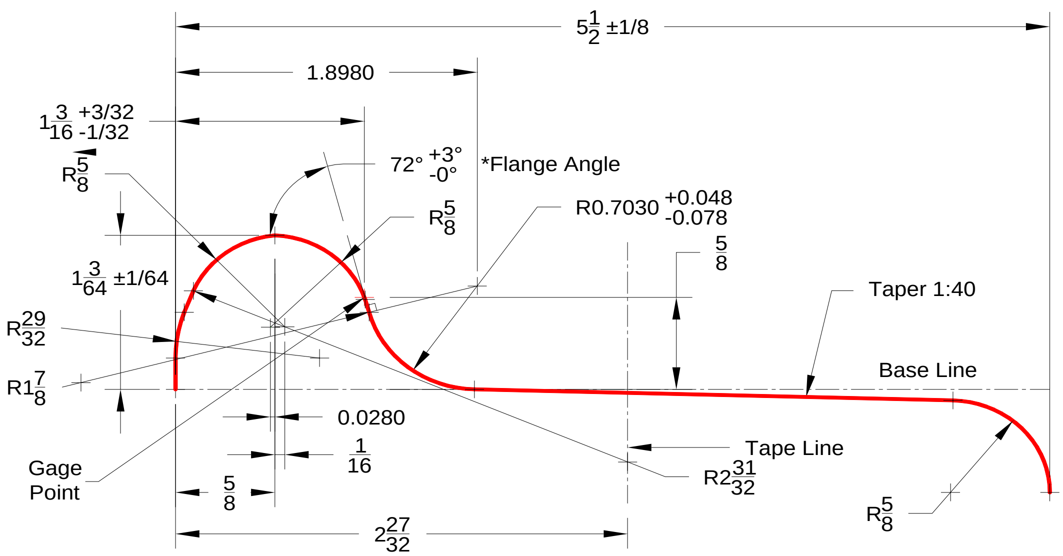
	Node Coordinates	
Point	X	Y
A	-1.1563	-0.6250
B	-1.1562	-0.4583
C	-1.1013	-0.1476
D	-1.0438	-0.0019
E	-0.5313	0.3750
F	-0.0270	0.0465
Gage Point	0.0000	0.0000
G	0.0751	-0.1790
H	0.7188	-0.6250
I	3.7344	-0.7004
J	4.3438	-1.3252

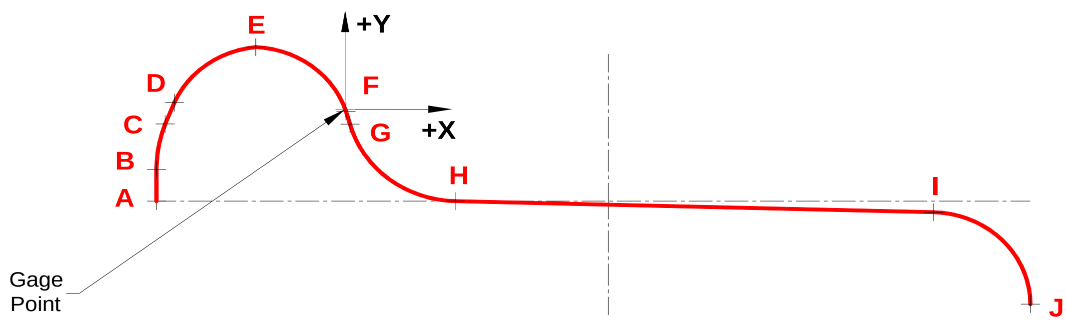
	Segment Details		
Segment	Radius *Line*	X - Center	Y - Center
A - B	*Line 90°*		
B - C	0.9063	-0.2500	-0.4583
C - D	2.9688	1.6875	-1.1654
D - E	0.6250	-0.4688	-0.2469
E - F	0.6250	-0.5781	-0.2482
F - G	*1.8750*	-1.6805	-0.8376
G - H	0.6875	0.7188	0.0625
H - I	*Line 1:40*		
I - J	0.6250	3.7188	-1.3252
Beyond J	*Line 90°*		

Note: All coordinates relative to 'Gage Point', and all dimensions are inches.
Flange angle must be no less than 72º over a continuous length of at least 0.1 inch.

B.4 APTA 140M Wheel Profile

Based on (former) AAR S-621-79 with 1:40 taper
modified by NJT to provide flange angle of 72º-75.





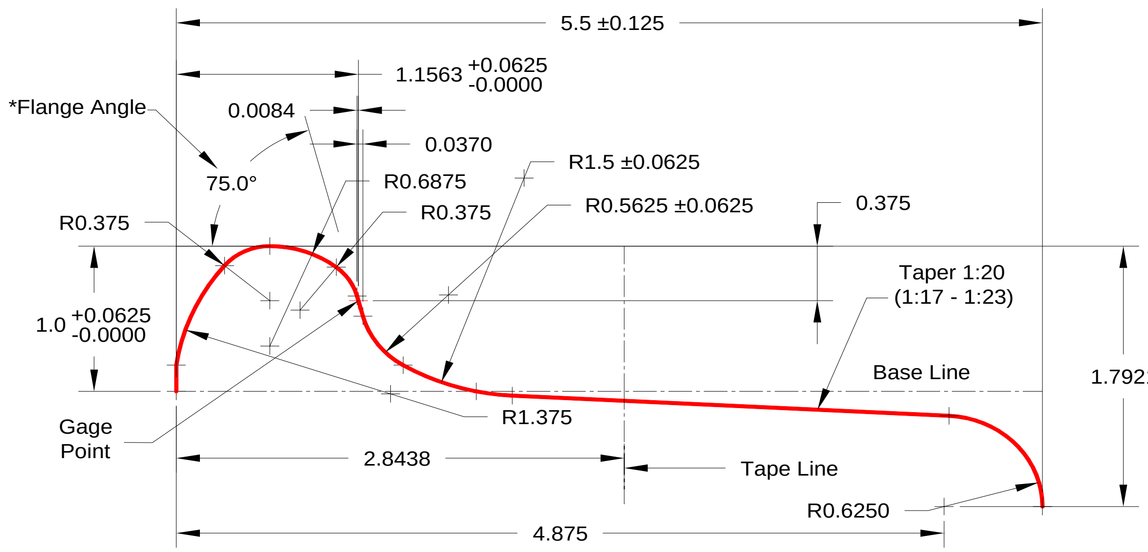
	Node Coordinates	
Point	**X**	**Y**
A	-1.1875	-0.6250
B	-1.1875	-0.4114
C	-1.1326	-0.1007
D	-1.0750	0.0450
E	-0.5625	0.4219
F	0.0054	-0.0141
Gage Point	0.0000	0.0000
G	0.0307	-0.1014
H	0.6929	-0.6250
I	3.7031	-0.7003
J	4.3125	-1.3251

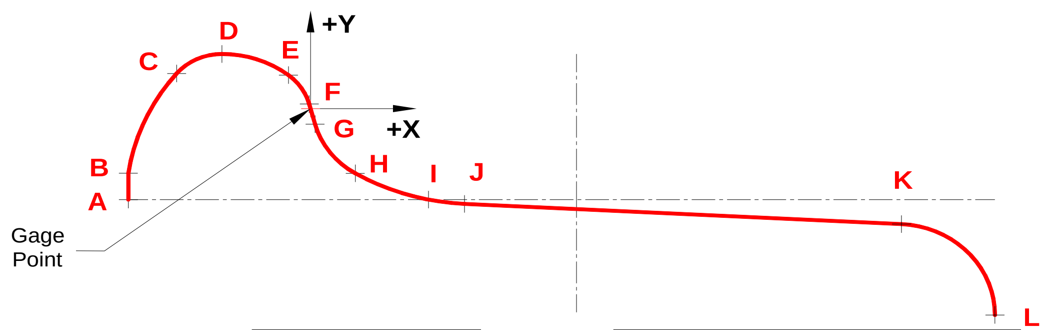
	Segment Details		
Segment	**Radius *Line***	**X - Center**	**Y - Center**
A - B	*Line 90°*		
B - C	0.9063	-0.2813	-0.4114
C - D	2.9688	1.6563	-1.1186
D - E	0.625	-0.5000	0.2000
E - F	0.625	-0.5905	-0.2025
F - G	1.875	-1.7824	-0.5793
G - H	0.703	0.7105	0.0778
H - I	*Line 1:40*		
I - J	0.625	3.6875	-1.3251
J - K	*Line 90°*		

Note: All coordinates relative to 'Gage Point', and all dimensions are inches.
*Flange angle must be no less than 72º over a continuous length of at least 0.1 inch.

B.5 APTA 220 Wheel Profile

Based on AAR-1B (AAR S-669), 1:20 taper, modified for 5.5 inch wheel width.





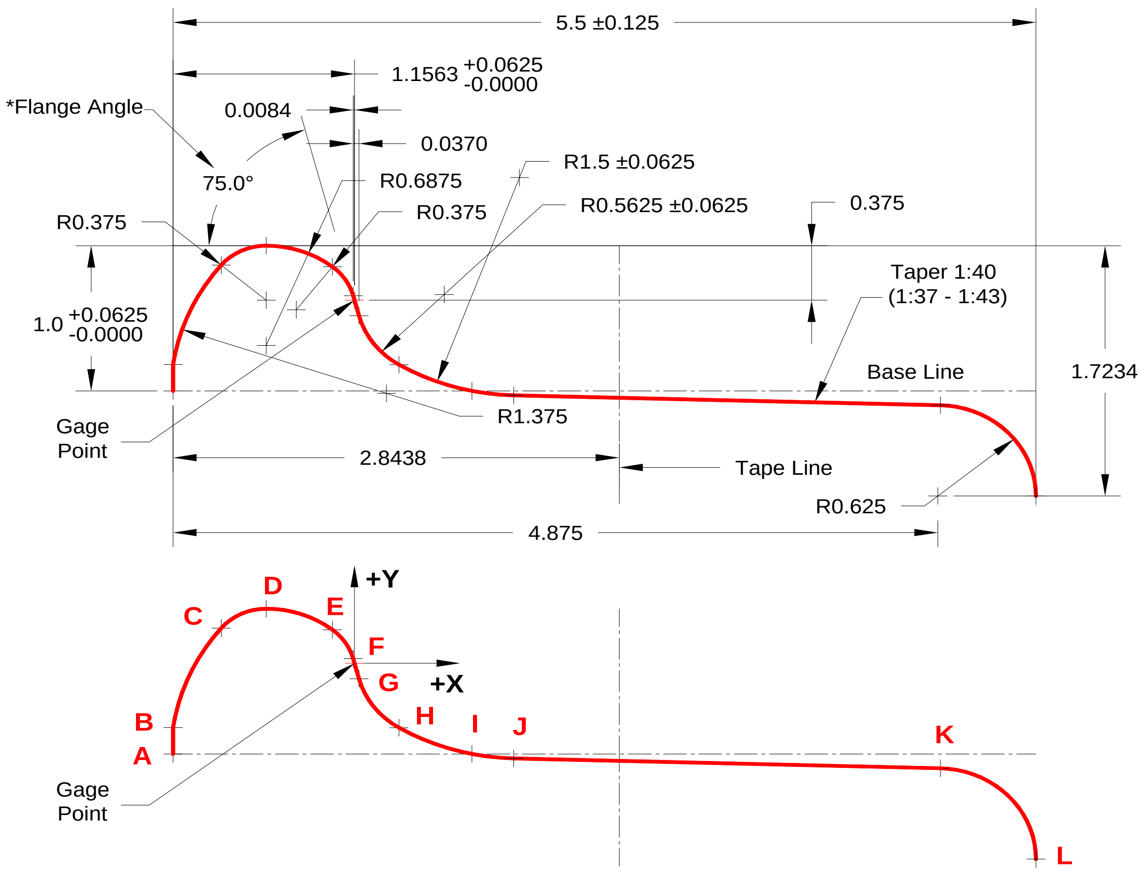
	Node Coordinates	
Point	**X**	**Y**
A	-1.1563	-0.6250
B	-1.1563	-0.4434
C	-0.8501	0.2407
D	-0.5625	0.3750
E	-0.1403	0.2301
F	-0.0084	0.0312
Gage Point	0.0000	0.0000
G	0.0286	-0.1069
H	0.2840	-0.4445
I	0.7485	-0.6250
J	0.9771	-0.6542
K	3.7499	-0.7927
L	4.3437	-1.4169

	Segment Details		
Segment	**Radius *Line***	**X - Center**	**Y - Center**
A - B	*Line 90°*		
B - C	1.375	0.2044	-0.6418
C - D	0.375	-0.5625	0.0000
D - E	0.6875	-0.5625	-0.3125
E - F	0.375	-0.3706	-0.0659
F - G	*Line 75°*		
G - H	0.5625	0.5720	0.0387
H - I	1.5	1.0520	0.8440
I - J	1.5	1.0520	0.8440
J - K	*Line 1:20*		
K - L	*0.625*	3.7187	-1.4169
Beyond L	*Line 90°*		

Note: All coordinates relative to 'Gage Point', and all dimensions are inches.
*Flange angle must be no less than 72º over a continuous length of at least 0.1 inch.

B.6 APTA 240 Wheel Profile

Based on AAR-1B (AAR S-669) modified for 1:40 taper and 5.5 inch wheel width.



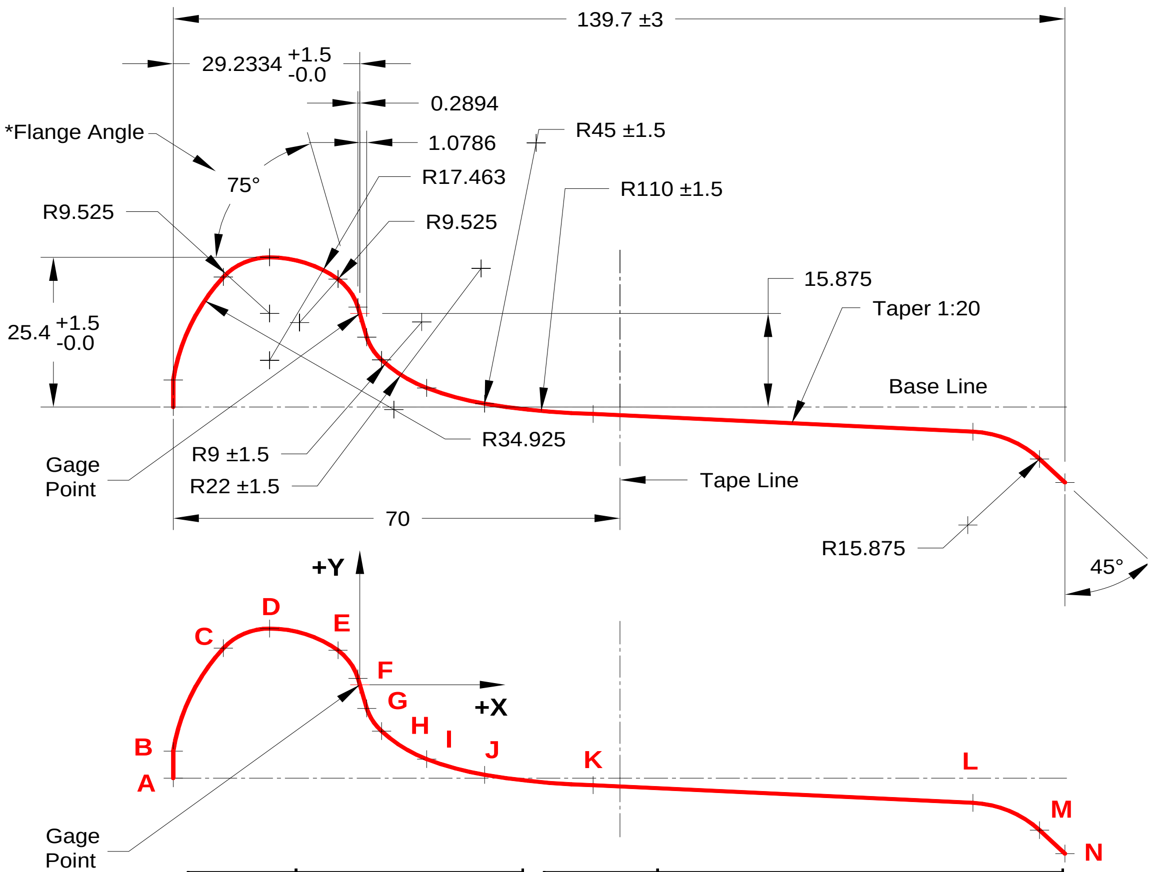
Point	Node Coordinates X	Y
A	-1.1563	-0.6250
B	-1.1563	-0.4434
C	-0.8501	0.2407
D	-0.5625	0.3750
E	-0.1403	0.2301
F	-0.0084	0.0312
Gage Point	0.0000	0.0000
G	0.0286	-0.1069
H	0.2840	-0.4445
I	0.7485	-0.6250
J	1.0148	-0.6556
K	3.7344	-0.7236
L	4.3437	-1.3483

Segment	Segment Details Radius *Line*	X - Center	Y - Center
A - B	*Line 90°*		
B - C	1.375	0.2044	-0.6418
C - D	0.375	-0.5625	0.0000
D - E	0.6875	-0.5625	-0.3125
E - F	0.375	-0.3706	-0.0659
F - G	*Line 75°*		
G - H	0.5625	0.5720	0.0387
H - I	1.5	1.0520	0.8440
I - J	1.5	1.0520	0.8440
J - K	*Line 1:40*		
K - L	*0.625*	3.7187	-1.3484
Beyond L	*Line 90°*		

Note: All coordinates relative to 'Gage Point', and all dimensions are inches.
*Flange angle must be no less than 72º over a continuous length of at least 0.1 inch.

B.7 APTA 320 Wheel Profile

NRCC-COM20 developed by CSTT and funded by FRA.



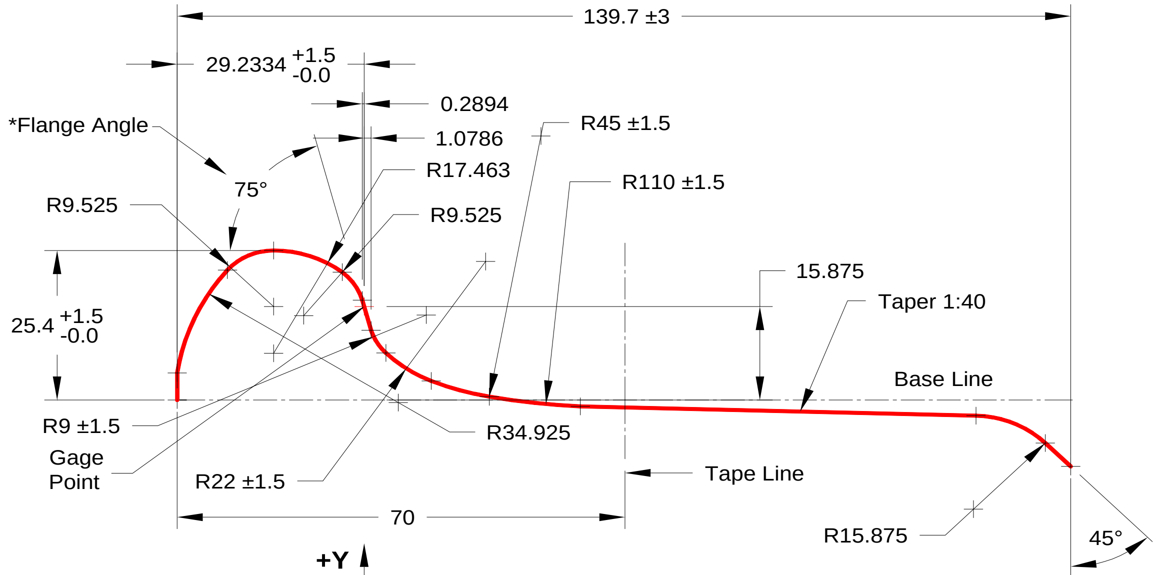
Point	X	Y
A	-29.2334	-15.8750
B	-29.2334	-11.2780
C	-21.3784	6.2040
D	-14.1504	9.5250
E	-3.4274	5.8440
F	-0.2894	1.0800
Gage Point	0.0000	0.0000
G	1.0786	-4.0250
H	3.4066	-7.8752
I	10.4796	-12.6340
J	19.5616	-15.3010
K	36.5386	-17.0500
L	96.0526	-20.0600
M	106.4856	-24.6900
N	110.4666	-28.6710

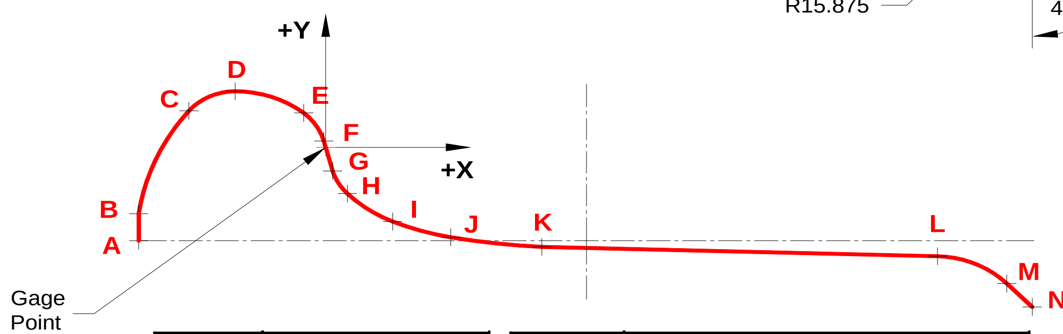
Segment	Radius *Line*	X - Center	Y - Center
A - B	*Line 90°*		
B - C	34.925		
C - D	9.525		
D - E	17.463		
E - F	9.525		
F - G	*Line 75°*		
G - H	9		
H - I	22		
I - J	45		
J - K	110		
K - L	*Line 1:20*		
L - M	15.875		
M - N	*Line 45°*		
Beyond N	*Line 90°*		

Note: All coordinates relative to 'Gage Point' and all dimensions are millimeters.
*Flange angle must be no less than 72º over a continuous length of at least 0.1 inch.

B.8 APTA 340 Wheel Profile

NRCC-COM40 developed by CSTT and funded by FRA.





Point	X	Y
A	-29.2334	-15.8750
B	-29.2334	-11.2780
C	-21.3784	6.2040
D	-14.1504	9.5250
E	-3.4274	5.8440
F	-0.2894	1.0800
Gage Point	0.0000	0.0000
G	1.0786	-4.0250
H	3.4066	-7.8752
I	10.4796	-12.6340
J	19.5616	-15.3010
K	33.7946	-16.9470
L	95.6566	-18.5280
M	106.4856	-23.1730
N	110.4666	-27.1540

Segment	Radius *Line*	X - Center	Y - Center
A - B	*Line 90°*		
B - C	34.925		
C - D	9.525		
D - E	17.463		
E - F	9.525		
F - G	*Line 75°*		
G - H	9		
H - I	22		
I - J	45		
J - K	110		
K - L	*Line 1:40*		
L - M	15.875		
M - N	*Line 45°*		
Beyond N	*Line 90°*		

Note: All coordinates relative to 'Gage Point' and all dimensions are millimeters.
*Flange angle must be no less than 72° over a continuous length of at least 0.1 inch.

Annex C (informative) Bibliography

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