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Commuter, Intercity and High-Speed Rail Mechanical Working Group

Wheel Flange Angle for Passenger Equipment

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. This standard also provides drawings of wheel profiles that are compliant with its requirements.

Keywords: flange angle, low-speed wheel-climb derailment, Nadal, rail profile, railroad wheel, wheel profile

Scope and purpose: 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. Other wheel parameters including tread taper are outside the scope of this standard. The purpose of this document is to provide minimum requirements for the wheel flange angle to reduce the risk of wheel-climb derailments. See Appendix 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 deg. (suggested tolerance +3 and −2 deg.) be achieved at the gage point, ⅜ in. above the standard baseline.

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Introduction

This introduction is not part of APTA PR-M-S-015-06, Rev. 1, "Wheel Flange Angle for Passenger Equipment."

This standard applies to all:

1. railroads that operate intercity or commuter passenger train service on the general railroad system of transportation; and
2. railroads that provide commuter or other short-haul rail passenger train service in a metropolitan or suburban area, including public authorities operating passenger train service.

This standard does not apply to:

1. rapid transit operations in an urban area that are not connected to the general railroad system of transportation;
2. tourist, scenic, historic or excursion operations, whether on or off the general railroad system of transportation;
3. operation of private cars, including business/office cars and circus trains; or
4. railroads that operate only on track inside an installation that is not part of the general railroad system of transportation.

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 deg. (suggested tolerance +3 and −2 deg.) be achieved at the gage point, ⅜ in. above the standard baseline.

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 deg. shall exist over a continuous length of at least 0.1 in. along the surface of the flange where it will contact the rail.

This standard 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 APTA 120 or APTA 140 (AAR S-621-79), may produce flange angles in compliance with this standard but as nominally defined are noncompliant.

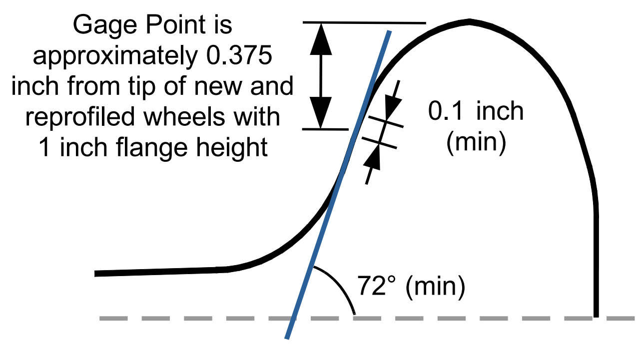
Wheel Flange Angle for Passenger Equipment

1. Flange angle criteria

On all new and reprofiled wheels, a flange angle of no less than 72 deg. shall exist over a continuous length of at least 0.1 in. along the surface of the flange at the gage point, a distance sufficiently high above the taping point where the flange would contact the rail, as shown in **Figure 1**. Appendix C provides APTA standard wheel profiles that meet this requirement, although Legacy Series wheel profiles do not meet this requirement as nominally defined.

To meet the minimum flange angle of 72 deg., inspectability and manufacturing tolerances shall be considered.

FIGURE 1
Flange Angle Standard Criteria



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

2. 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. Electronic and laser measurement methods have been found to be the most reliable for measuring flange angle as prescribed in this standard. The quality assurance plan shall require verification of the accuracy and ability of the inspection tool to discriminate between compliant and noncompliant flange angles and to establish a test frequency that provides adequate control of wheel profiling.

NOTE: This standard is not intended to establish guidelines for the inspection or rejection of wheel flange angles while in service. However, railroads should understand that low flange angles can result in increased risk of wheel climb and derailment. Typically, flange wear results in a steeper flange angle, so the need for verification applies primarily to new and reprofiled flange and tread contours. Flange angles, however, have been known to decrease in rare situations, such as when introducing a new higher flange angle wheel on rail worn to the previous lower flange angle wheel. Railroads should be cognizant of how their wheels wear and take appropriate mitigating actions.

References

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

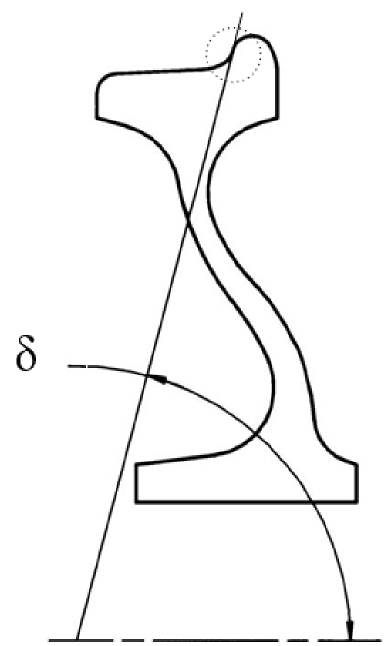
AAR Manual of Standards and Recommended Practices, Section G-II, Figure 4.37 (Concluded), Narrow Flange Tapered Tread Contour – Locomotive and Amtrak (former Standard S-621-79)

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

Definitions

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 rotation of the wheel as shown in **Figure 2**.

FIGURE 2
Flange Angle Definition



Abbreviations and acronyms

AAR Association of American Railroads
CSTT Centre for Surface Transportation Technology (division of National Research Council Canada)
FRA Federal Railroad Administration
NATSA North American Transportation Services Association
NJT New Jersey Transit

NRCC National Research Council Canada

Summary of document changes

- Document formatted to the new APTA standard format.
- Sections have been moved and renumbered.
- Scope and summary moved to the front page.
- Definitions, abbreviations, and acronyms moved to the rear of the document.
- Two new sections added: "Summary of document changes" and "Document history."
- Some global changes to section headings and numberings resulted when sections dealing with references and acronyms were moved to the end of the document, along with other changes, such as capitalization, punctuation, spelling, grammar, and general flow of text.
- Participants updated.
- Introduction updated: Applicability text added, language added indicating that some wheel profiles currently in use, such as the APTA 120 or APTA 140 (AAR S-621-79), may produce flange angles in compliance with this standard but as nominally defined are noncompliant.
- Section 1: Clarification of flange angle requirement, addition of Legacy Series wheel profile potential noncompliance, removal of references to applicable rail profiles
- Section 2: Addition of known reliable measurement methods.
- Former Section 5.2 Maintenance (would have been 2.2 by global changes to section headings) moved to note and clarified.
- Appendix A: Added New Appendix A: Flange Angle Calculation; old Appendix A moved to Appendix B.
- Appendix B: Removal of reference to AAR 1B profile.
- Appendix C.1: Potential for Legacy Series noncompliance added, note added regarding the omission of center coordinates for the APTA 320 and APTA 340 profiles depicted. Previous versions had centers which were omitted in this revision. These centers over-defined the profiles.
- Table 1: Profiles reordered to separate potentially noncompliant Legacy Series profiles, new profiles for NRCC-6 added.
- Appendix C.2: Subsections added to give historical context to the development and originally intended purpose of each profile.
- Appendices C.6 and C.7: X-Y centers omitted due to causing overconstrained conditions.
- Appendices C.8 NRCC-6 (Acela equipment) and C.9 NRCC-6 (Amtrak conventional equipment) added.
- Appendices C.10 and C.11: Potentially nominally noncompliant Legacy Series profiles relocated after compliant profiles.

Document history

Document Version	Working Group Vote	Public Comment/ Technical Oversight	Rail CEO Approval	Policy & Planning Approval	Publish Date
First published	—	—	—	May 18, 2007	June 2, 2007
First revision	April 14, 2021	Sept. 1, 2021	Oct. 22, 2021	Jan. 28, 2022	Feb. 4, 2022
Second revision	—	—	—	—	—

Appendix A: Flange angle calculation

As mentioned in Section 2, *Inspection*, a variety of sensor types are commonly used to measure wheel profile. While the concept and implementation of finding a flange angle is fairly straightforward, care must be taken to ensure that this calculation is properly performed, regardless of the measurement source. Typically, the wheel profile is measured in Cartesian coordinates, with respect to the horizontal axis (parallel with axis of rotation of the wheel) and the vertical axis of a wheel (normal to the axis of rotation of the wheel, often at a flat surface that constitutes the wheel back-of-flange). The origin of wheel profile coordinate system is often defined at the tapeline but may also be coincident with the back-of-flange or another location. It is necessary to have measurement points of sufficient accuracy such that the flange angle can be calculated within +/- 1.5 degrees.

The X-Y profile measurements must be analyzed in two ways. First, the length along the profile (distance between measurement points) must be known for determining whether the flange angle criteria is met for a sufficient distance. Second, the angle between points must be calculated. The recommended method for performing the flange angle analysis is to directly calculate the angle from the horizontal of any two points on the profile that are at least 0.1" away from one another in the profile of the flange face.

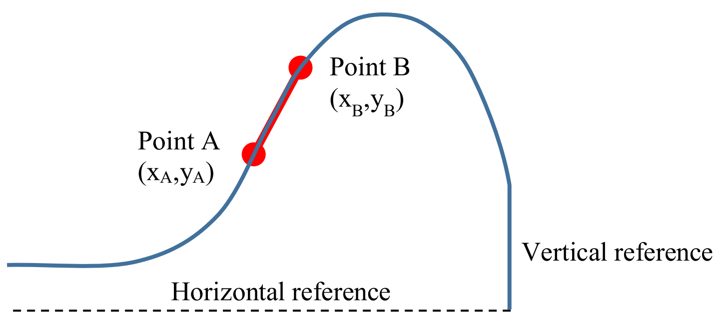


Figure 1: Flange angle must measure 72deg or more (above the horizontal axis), between any two points that are at least 0.1" from one another.

This requirement may be written:

$$\sqrt{(x_B - x_A)^2 + (y_B - y_A)^2} \geq 0.1 inch$$

And

$$\frac{(y_B - y_A)}{(x_B - x_A)} \geq \tan 72°$$

Appendix B: 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 1900s 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.

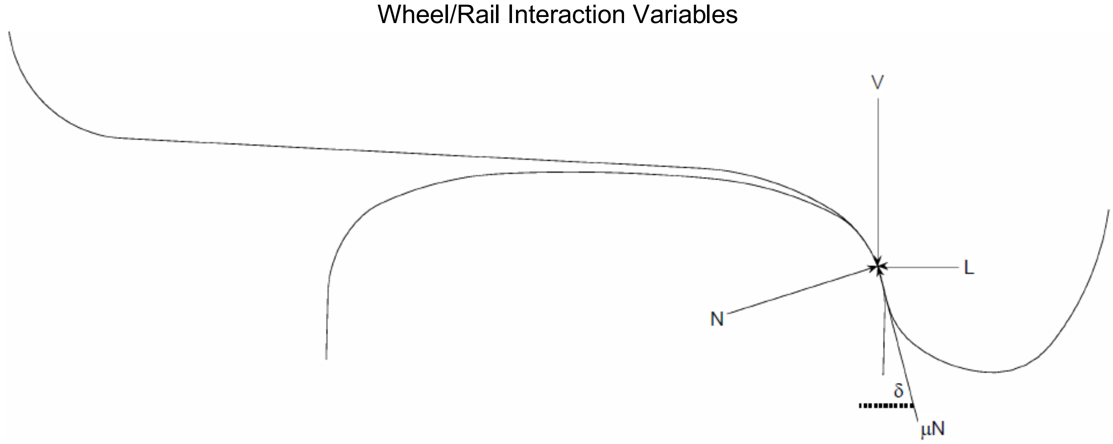
The main factors in wheel/rail interaction and their relationship are stated clearly in Nadal's formula:

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

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

The variables in Nadal's formula are illustrated in **Figure 3**. The variable delta is the angle that 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 3
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 used because it is simple and straightforward, is appropriate for maintaining safety, and has variables that 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.

Appendix C: Wheel profiles

C.1 Purpose

This appendix provides drawings of APTA standard wheel profiles. The 100, 200 and 300 Series wheel profiles listed in **Table 1** are examples that meet the requirements of this standard. The wheel profiles listed as Legacy Series can produce flange angles less than that required in this standard, and in particular are noncompliant as nominally defined.

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

TABLE 1
APTA Wheel Profiles

Annex	Series	Designation	Description
C.3	100	140M	Based on (former) AAR S-621-79 with 1:40 taper modified by New Jersey Transit to provide flange angle of 72–75 deg.
C.4	200	220	Based on AAR-1B (AAR S-669), 1:20 taper, modified for 5.5 in. wheel width
C.5		240	Based on AAR-1B (AAR S-669) modified for 1:40 taper and 5.5 in. wheel width
C.6	300	320	NEC-COM20 developed by NRC, Canada [C8] and funded by FRA
C.7		340	NEC-COM40 developed by NRC, Canada [C8] and funded by FRA
C.8 and C.9		NRCC-6	Currently used on Acela and other Amtrak equipment
C.10	Legacy	120	Based on (former) AAR S-621-79, 1:20 taper
C.11		140	Based on (former) AAR S-621-79 with 1:40 taper

NOTE: Due to the drawing precision chosen, if the drawings in Appendix B of this document are created by taking the start/end points of each segment and its radius, the coordinates for the center of each radius will never match exactly. Therefore, to avoid confusion, the center coordinates from each segment have been removed. The profiles have not been changed by the removal of these coordinates.

C.2 Wheel profile descriptions and development notes

The following section outlines basic information about each wheel profile including general usage, profile development or other historical context.

C.2.1 APTA 140M

The APTA 140M contour is a modified version of the APTA 140 profile (profile based on the AAR 1:20 narrow flange profile used for decades in North American passenger service, the AAR S-621-79) developed by NJT. The modification is specifically meant to meet the flange angle requirements of this standard.

C.2.2 APTA 220

The APTA 220 contour is a passenger version of the AAR-1B narrow flange freight car profile. This profile was, until recently, the interchange standard for North American freight service. The profile has a constant 1:20 taper tread beyond the tapeline and a flange root defined by multiple radii intended to represent a progressively increasing contact angle as typically observed in a worn wheel profile. As a result, initial wear of the profile, in comparison with the APTA 120 profile, for example, is distributed over a wider area. The profile meets and exceeds the flange angle requirements of this standard. Compared with the 1:40 version

(APTA 240), this profile is typically used for lower-speed service, as the greater tread conicity reduces high-speed stability, while providing some improvement in vehicle curving performance.

C.2.3 APTA 240

The APTA 240 contour is an adaptation of the APTA 220 profile with a 1:40 tread taper beyond the tapeline. The flange root definition is identical to the APTA 220 profile. The profile meets and exceeds the flange angle requirements of this standard. Compared with the 1:20 version (APTA 220), this profile is typically used for higher-speed service (Class 5 and above, for example). The lower tread conicity improves high-speed stability at the cost of some reduction in vehicle curving performance.

C.2.4 APTA 320

The APTA 320 contour is an adaptation of the APTA 340 profile with a 1:20 tread taper beyond the tapeline. The flange root definition is identical to the APTA 340 profile. The profile meets and exceeds the flange angle requirements of this standard. Compared with the 1:40 version (APTA 340), this profile is meant for lower-speed service (Class 4 and below, for example). The greater tread conicity reduces high-speed stability while providing some improvement in vehicle curving performance. Also known as the NEC-COM20.

C.2.5 APTA 340

The APTA 340 contour is a profile based on worn wheel profiles measured on Amtrak and commuter railcars operating on the Northeast Corridor. The profile was developed by NRCC with the support of the FRA. The flange root is defined by multiple transverse radii and is intended to represent an average worn wheel in Northeast Corridor service. The profile meets and exceeds the flange angle requirements of this standard. Compared with the 1:20 version (APTA 320), this profile is meant for higher-speed service (Class 5 and above, for example). The lower tread conicity improves high-speed stability at the cost of some reduction in vehicle curving performance. Also known as the NEC-COM40.

C.2.6 NRCC-6

The NRCC-6 profile was designed in 2002 to mimic the shape of well-worn Amtrak Acela wheels. It was developed in response to a high flange wear issue on the recently introduced Acela trains. Despite its different origin and a totally separate design effort, in shape it turned out to be very close to the APTA 340 wheel. There are two versions of this wheel profile, one for Acela equipment and one for other types of Amtrak passenger equipment, with the primary difference due to wheel width differences. Also known as the AMTK-NRCC profile.

C.2.7 APTA legacy profiles

The APTA 120 and 140 contours are legacy profiles based on the AAR narrow flange profiles used for decades in North American passenger service (see AAR S-621-79). As nominally defined, the profiles do not meet the flange angle requirements of this standard.

C.2.7.1 APTA 120

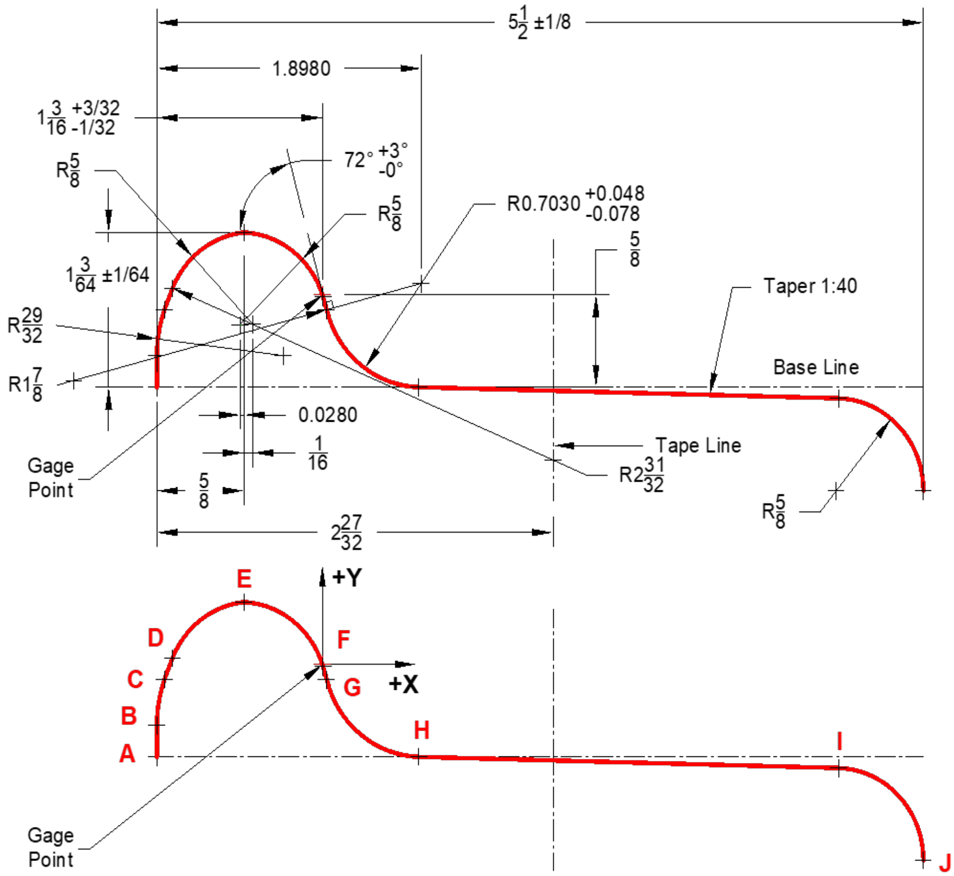
The APTA 120 contour has a constant 1:20 taper tread and a flange root defined by a single radius. This typically results in two-point contact when new. As nominally defined, the profile does not meet the flange angle requirements of this standard. Compared with the 1:40 version (APTA 140), this profile is typically used for lower-speed service (Class 4 and below, for example). The greater tread conicity reduces high-speed stability, while providing some limited improvement in vehicle curving performance.

C.2.7.2 APTA 140

The APTA 140 contour has a constant 1:40 taper tread and a flange root defined by a single radius. This typically results in two-point contact when new. As nominally defined, the profile does not meet the flange angle requirements of this standard. Compared with the 1:20 version (APTA 120), this profile is typically used for higher-speed service (Class 5 and above, for example). The lower tread conicity improves high-speed stability at the cost of some limited reduction in vehicle curving performance.

C.3 APTA 140M wheel profile

FIGURE 4
APTA 140M Wheel Profile



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

Notes:

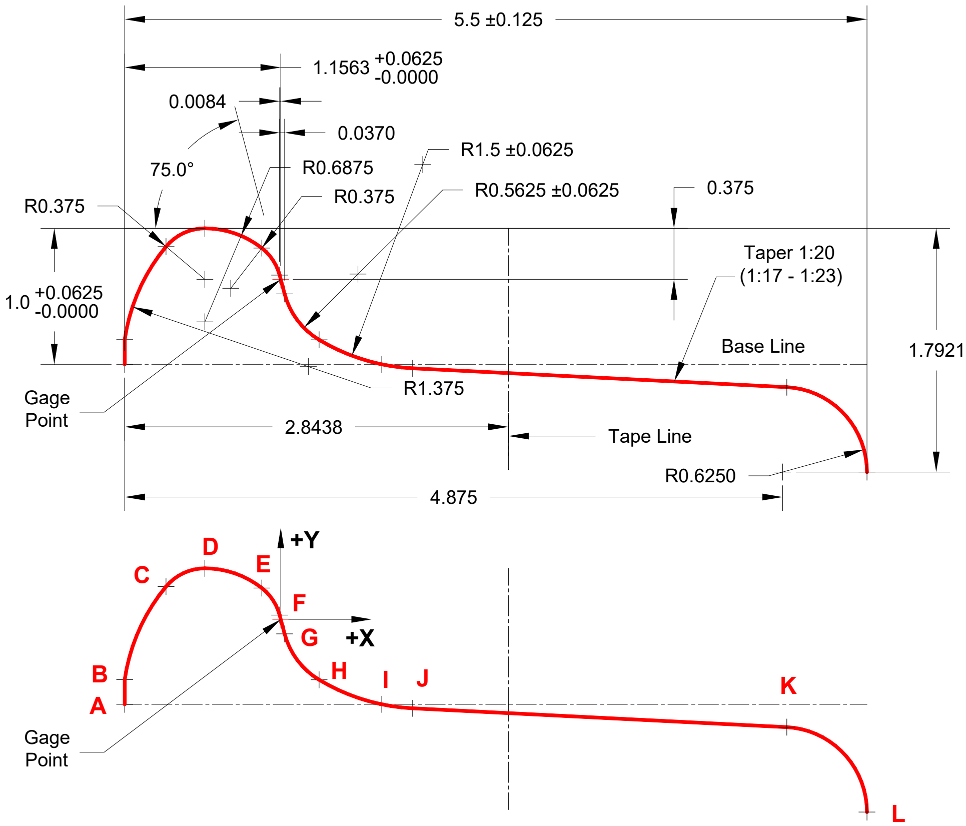
- All coordinates relative to "Gage Point."
- All dimensions are in inches.
- Flange angle must be no less than 72 deg. over a continuous length of at least 0.1 in.

	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 (ref)**	**Y Center (ref)**
A−B	Line 90 deg.		
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 deg.		

B.4 APTA 220 wheel profile

FIGURE 5
APTA 220 Wheel Profile



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

Notes:

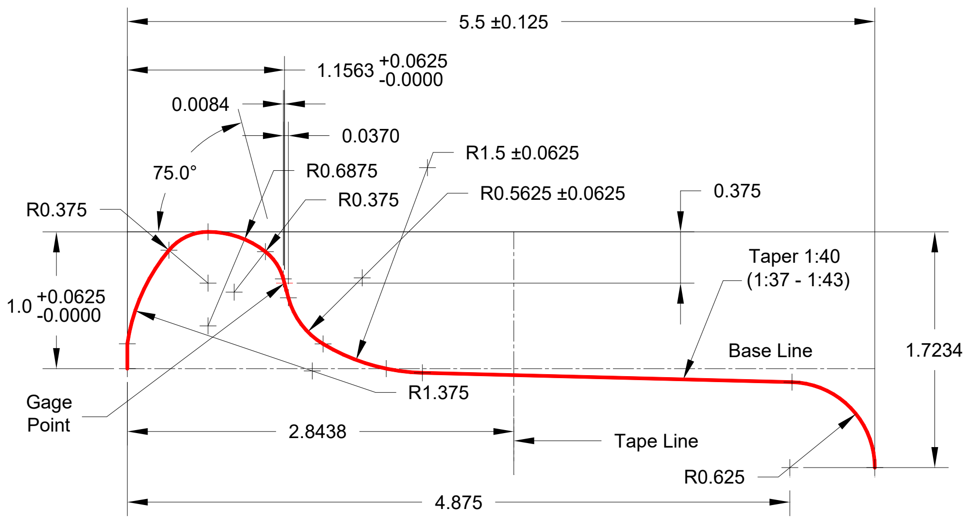
- All coordinates relative to "Gage Point."
- All dimensions are in inches.
- Flange angle must be no less than 72 deg. over a continuous length of at least 0.1 in.

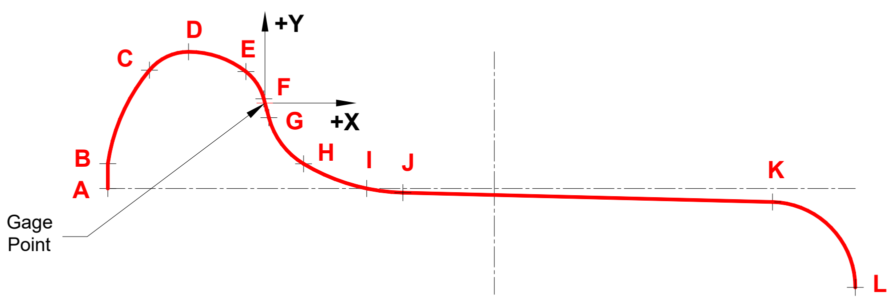
	Node Coordinates	
Point	**X**	**Y**
A	−1.1563	−0.6250
B	−1.1563	−0.4434
C	−0.8501	0.2407
D	−0.5625	0.3750
E	−0.1403	0.2301
F	−0.0084	0.0312
Gage Point	0.0000	0.0000
G	0.0286	−0.1069
H	0.2840	−0.4445
I	0.7485	−0.6250
J	0.9771	−0.6542
K	3.7499	−0.7927
L	4.3437	−1.4169

	Segment Details		
Segment	**Radius Line**	**X Center (ref)**	**Y Center (ref)**
A–B	Line 90 deg.		
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 deg.		
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 deg.		

B.5 APTA 240 wheel profile

FIGURE 6
APTA 240 Wheel Profile





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

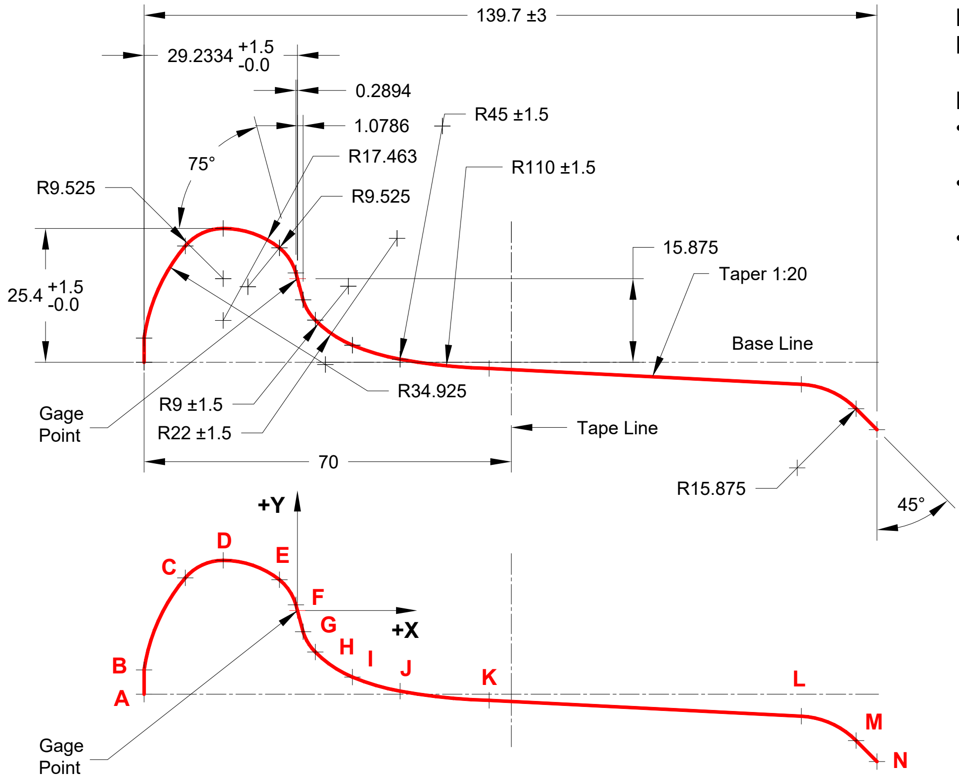
Notes:
- All coordinates relative to "Gage Point."
- All dimensions are in inches.
- Flange angle must be no less than 72 deg. over a continuous length of at least 0.1 in.

	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	1.0148	−0.6556
K	3.7344	−0.7236
L	4.3437	−1.3483

	Segment Details		
Segment	**Radius Line**	**X Center (ref)**	**Y Center (ref)**
A–B	Line 90 deg.		
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 deg.		
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 deg.		

B.6 APTA 320 wheel profile

FIGURE 7
APTA 320 Wheel Profile



NRCC-COM20 developed by NRCC and funded by FRA

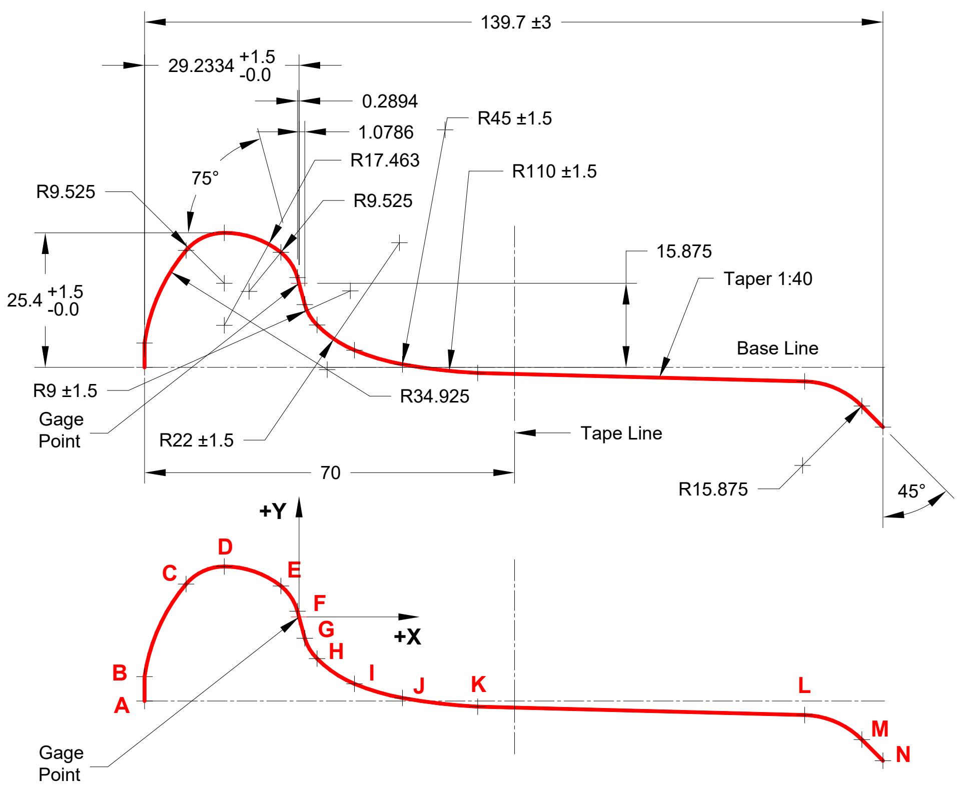
Notes:
- All coordinates relative to "Gage Point."
- All dimensions are in millimeters.
- Flange angle must be no less than 72 deg. over a continuous length of at least 0.1 in.

	Node Coordinates	
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 Details		
Segment	**Radius Line**	**X Center (ref)**	**Y Center (ref)**
A–B	Line 90 deg.		
B–C	34.925	5.3284	-16.3016
C–D	9.525	-14.1510	0.0000
D–E	17.463	-14.1518	-7.9380
E–F	9.525	-9.4478	-1.5371
F–G	Line 75 deg.		
G–H	9	9.6997	-1.4412
H–I	22	18.9913	7.6527
I–J	45	27.6295	28.9699
J–K	110	39.2888	92.9156
K–L	Line 1:20		
L–M	15.875	95.2602	-35.9152
M–N	Line 45 deg.		
Beyond N	Line 90 deg.		

B.7 APTA 340 wheel profile

FIGURE 8
APTA 340 Wheel Profile



NRCC-COM40 developed by NRCC and funded by FRA

Notes:
- All coordinates relative to "Gage Point."
- All dimensions are in millimeters.
- XY centers omitted (overconstrained).
- Flange angle must be no less than 72 deg. over a continuous length of at least 0.1 in.

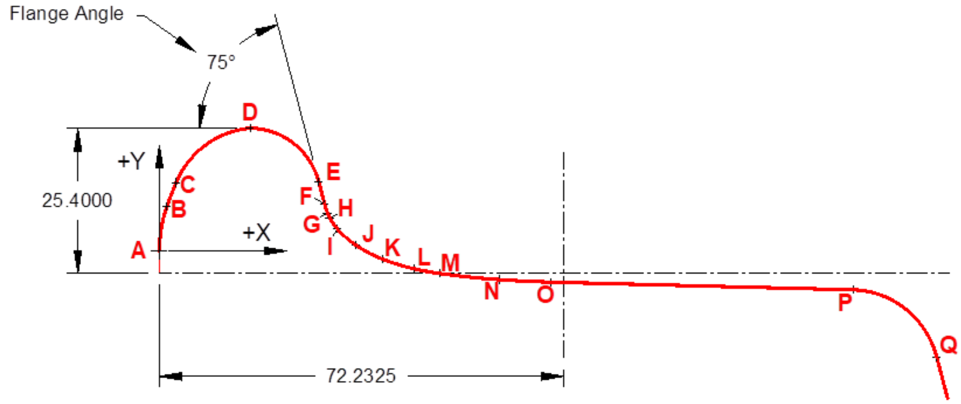
	Node Coordinates	
Point	**X**	**Y**
A	−29.2334	−15.8750
B	−29.2334	−11.2780
C	−21.3784	6.2040
D	−14.1504	9.5250
E	−3.4274	5.8440
F	−0.2894	1.0800
Gage Point	0.0000	0.0000
G	1.0786	−4.0250
H	3.4066	−7.8752
I	10.4796	−12.6340
J	19.5616	−15.3010
K	33.7946	−16.9470
L	95.6566	−18.5280
M	106.4856	−23.1730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

	Segment Details		
Segment	**Radius Line**	**X Center (ref)**	**Y Center (ref)**
A–B	Line 90 deg.		
B–C	34.925	5.3284	-16.3016
C–D	9.525	-14.1510	0.0000
D–E	17.463	-14.1518	-7.9380
E–F	9.525	-9.4478	-1.5371
F–G	Line 75 deg.		
G–H	9	9.6997	-1.4412
H–I	22	18.9913	7.6527
I–J	45	27.6295	28.9699
J–K	110	39.2882	92.9157
K–L	Line 1:40		
L–M	15.875	95.2600	34.3980
M–N	Line 45 deg.		
Beyond N	Line 90 deg.		

B.8 NRCC-6 (Acela equipment)

FIGURE 9

NRCC-6 Wheel Profile (Acela Equipment)



Notes:

- All coordinates relative to Point A.
- All dimensions are in millimeters.
- Flange angle must be no less than 72 deg. over a continuous length of at least 0.1 in.

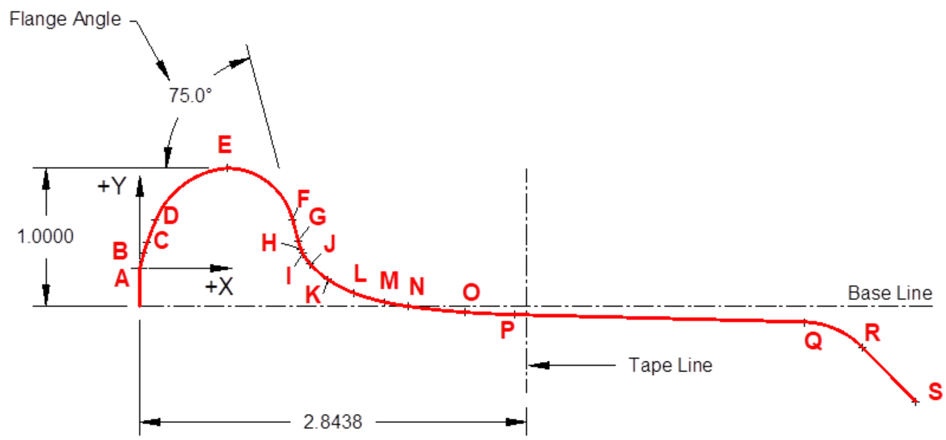
	Node Coordinates	
Point	**X**	**Y**
A	0.0000	0.0000
B	1.3444	7.7516
C	2.9708	11.9112
D	16.2334	21.4836
E	28.5007	12.0706
F	29.5482	8.1614
G	30.0896	6.5637
H	30.4495	5.7881
I	31.7913	3.8602
J	35.1141	1.0049
K	39.9088	−1.4627
L	45.5659	−3.1440
M	50.1587	−3.9615
N	60.7292	−5.0419
O	70.0403	−5.4678
P	123.9621	−6.8158
Q	138.8994	−18.5771

	Segment Details		
Segment	**Radius Line**	**X Center (ref)**	**Y Center (ref)**
A–B	23.0200	23.0200	-0.0001
B–C	75.3023	72.2587	-17.5781
C–D	15.8758	17.5756	5.6869
D–E	12.7000	16.2334	8.7836
E–F	Line 75 deg.		
F–G	13.0000	42.1052	11.5261
G–H	10.0000	39.3324	10.3809
H–I	9.0000	38.4441	9.9216
I–J	18.0000	45.0969	15.9830
J–K	24.0000	48.4245	20.9757
K–L	40.0000	54.1016	35.9347
L–M	60.0000	58.3694	55.4740
M–N	150.0000	70.6854	144.6274
N–O	225.0000	75.6635	219.4620
O–P	Line 1:40		
P–Q	15.8750	123.8250	-22.6858
Beyond Q	Line 75 deg.		

B.9 NRCC-6 (Amtrak conventional equipment)

FIGURE 10

NRCC-6 Wheel Profile (Conventional Equipment)



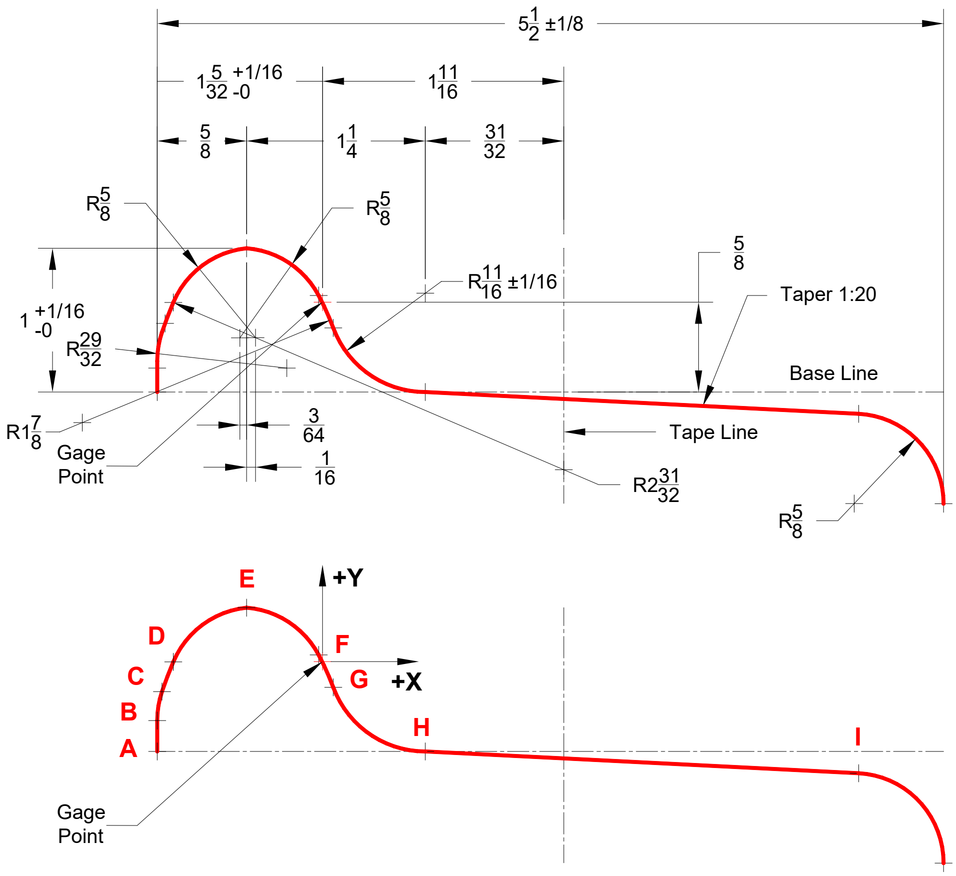
Notes:
- All coordinates relative to Point A.
- All dimensions are in inches.
- Flange angle must be no less than 72 deg. over a continuous length of at least 0.1 in.

	Node Coordinates	
Point	**X**	**Y**
A	0.0000	0.0000
B	0.0308	0.1148
C	0.0527	0.1850
D	0.1169	0.3492
E	0.6390	0.7261
F	1.1220	0.3555
G	1.1632	0.2016
H	1.1845	0.1388
I	1.1988	0.1080
J	1.2515	0.0322
K	1.3823	−0.0802
L	1.5711	−0.1773
M	1.7939	−0.2435
N	1.9746	−0.2757
O	2.3909	−0.3182
P	2.7574	−0.3350
Q	4.8803	−0.3881
R	5.3066	−0.5709
S	5.7000	−0.9643

	Segment Details		
Segment	**Radius Line**	**X Center (ref)**	**Y Center (ref)**
A–B	Line 15 deg.		
B–C	0.9063	0.9062	-0.1197
C–D	2.9647	2.8447	-0.8118
D–E	0.6250	0.6915	0.1033
E–F	0.5000	0.6390	0.2261
F–G	Line 75 deg.		
G–H	0.5118	1.6576	0.3341
H–I	0.3937	1.5484	0.2890
I–J	0.3543	1.5134	0.2709
J–K	0.7087	1.7754	0.5095
K–L	0.9449	1.9064	0.7061
L–M	1.5748	2.1299	1.2950
M–N	2.3622	2.2979	2.0643
N–O	5.9055	2.7828	5.5743
O–P	8.8583	2.9788	8.5205
P–Q	Line 1:40		
Q–R	0.6250	4.8647	-1.0129
R–S	Line 45 deg.		
Beyond S	Line 90 deg.		

B.10 APTA 120 wheel profile

FIGURE 11
APTA 120 Wheel Profile



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

Notes:

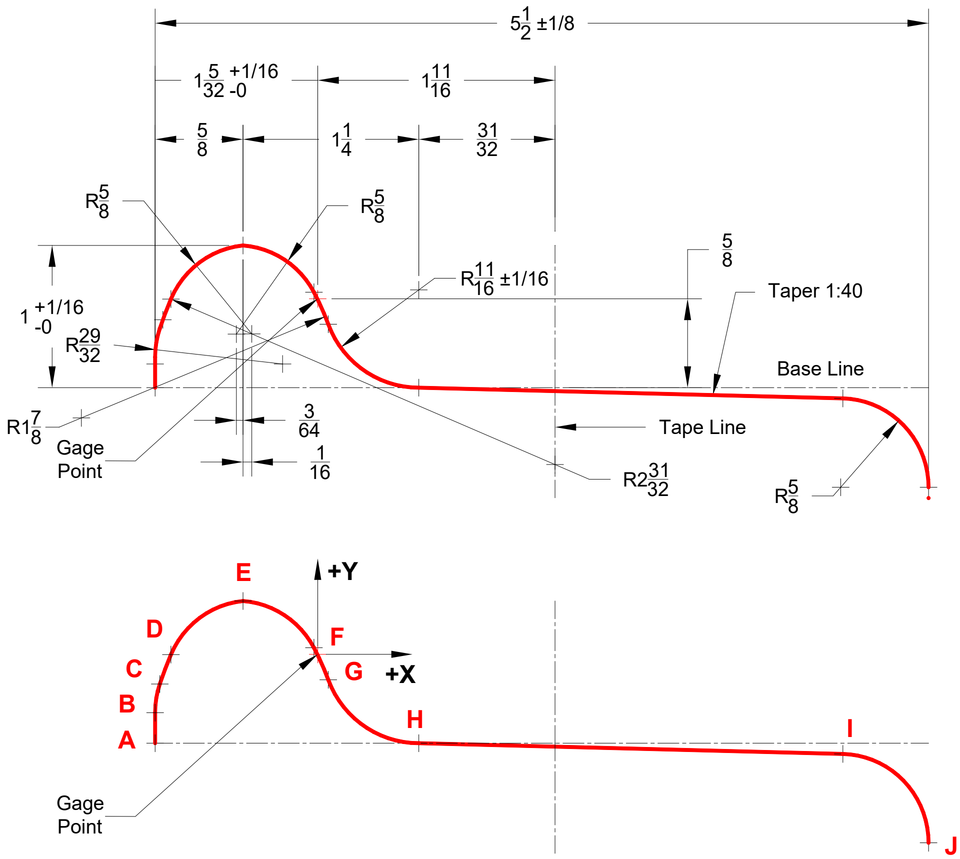
- All coordinates relative to "Gage Point."
- All dimensions are in inches.
- Flange angle must be no less than 72 deg. over a continuous length of at least 0.1 in.
- As nominally defined, this profile does not meet the flange angle requirements of this standard.

	Node Coordinates	
Point	X	Y
A	−1.1563	−0.6250
B	−1.1563	−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 Details		
Segment	Radius Line	X Center (ref)	Y Center (ref)
A–B	Line 90 deg.		
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 deg.		

B.11 APTA 140 wheel profile

FIGURE 12
APTA 140 Wheel Profile



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

Notes:

- All coordinates relative to "Gage Point."
- All dimensions are in inches.
- Flange angle must be no less than 72 deg. over a continuous length of at least 0.1 in.
- As nominally defined, this profile does not meet the flange angle requirements of this standard.

	Node Coordinates	
Point	**X**	**Y**
A	−1.1563	−0.6250
B	−1.1563	−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 (ref)**	**Y Center (ref)**
A–B	Line 90 deg.		
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 deg.		

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