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Passenger car tire road wheel removal codes

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Executive summary

As a result of the Tire Recall Enhancement, Accountability and Documentation Act, passed in 2000, the U.S. Department of Transportation's National Highway Traffic Safety Administration upgraded Federal Motor Vehicle Safety Standard No. 109 for light vehicle tires to FMVSS No. 139, which was published on June 23, 2003, and became effective on Sept. 1, 2007.

As part of their ambitious tire test development program, NHTSA used the proposed tire endurance road wheel test, which is a stepped-up load test, to study different tire aging protocols. One important document entered into the Tire Aging Docket by the NHTSA Applied Research group was a file consisting of photographs of individual tires that had exhibited different failure modes as observed upon road wheel testing of used tires taken out of service, new tires of these same models, and variously new and aged tires of different brands.

In order to increase awareness, we have summarized the road wheel removal codes established by NHTSA to categorize different failure modes. The NHTSA removal codes classified the failure based first on its location in the tire—for example: bead, innerliner, sidewall, carcass, shoulder, belt and tread regions—and next on the type of failure observed on the road wheel, for example: blister (bubble), chunking, cracking, delamination, detachment, distortion, loosening, opening, rupture, separation or splitting.

Thirty-one removal codes were established in order to provide a uniform catalog of descriptions of tire failures for future use by NHTSA and other investigators.

TECHNICAL NOTEBOOK
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In response to the Tire Recall Enhancement, Accountability and Documentation Act—commonly known as the TREAD Act[1]—passed by the U.S. Congress on Nov. 1, 2000, the Department of Transportation's National Highway Traffic Safety Administration examined the effectiveness of the tire safety standards known as the Federal Motor Vehicle Safety Standard No. 109, first established in 1968.

NHTSA embarked on an ambitious tire test development program that culminated in the upgraded standard FMVSS No. 139, "New pneumatic radial tires for light vehicles," published on June 26, 2003, to be effective on Sept. 1, 2007.

NHTSA studies began with the laboratory road wheel (dynamometer) testing of 101 on-road tires and eight full-size spare tires of varying ages and mileages that were retrieved from vehicles in use in Phoenix. Results were then compared to laboratory road wheel testing of 45 new (unused) versions of the same tire models.[2]

Removal codes for the end-of-test findings for these tires that failed as a result of road wheel testing were categorized and established in order to provide uniform descriptions for future use by NHTSA and other investigators.[3]

The pneumatic tire is a complex composite of individual rubbery components[4,5] and metal and textile reinforcements that have been rubberized so that upon vulcanization they all can react to covalently bond to adjacent components such that the tire can perform as one coherent unit.

Fig. 1 is a schematic of an example passenger car radial tire with the individual components labeled.[6] The elastomers (for example NR, SBR, SSBR, or BR), their grades (for example, NR grades of SMR 5, SMR 10 or SMR 20; percent-styrene in SBR; and percent-vinyl in SSBR), polymer blends and the ratios used make the individual tire components unique, with each serving a specific function. Along with the particulate fillers (for example carbon black, precipitated silica, clay, or calcium carbonate), types (for example, reinforcing N234 or N330 or semi-reinforcing N550 or N660 carbon black grades) and their relative amounts (phr) can contribute further to differentiating the performance of the individual components.[7-10]

Thus, these composites of individual components can make tires different between the various manufacturers as well as among their various product lines even if the same size for the same application.

Finally, the current light vehicle tire standard—FMVSS No. 139, "New pneumatic radial tires for light vehicles"—does not include a test to evaluate the risk of tire failure caused by aging during a tire's service life.[11] This is thought more important in the southern states of the U.S.: California (southern), Arizona, New Mexico, Texas, Louisiana, Mississippi, Alabama, Georgia and Florida.

Laboratory road wheel testing is an accepted method to evaluate the relative performance of light vehicle tires,[12, 13] particularly for tires that had previously been aged in an oven.[11, 14]

Removal codes established

NHTSA posted a document on its Tire Aging Docket that showed photographs of different failure modes of passenger car radial tires.[3] Failures were generated based on laboratory road wheel testing.[11]

In this file, NHTSA established removal codes to classify an individual tire failure first based on its general location in the tire and then on its failure mode. For example, the general area in the tire can be the bead, innerliner, sidewall, carcass, shoulder, belt and tread regions. The type of failure is, for example, a blister (bubble), chunking, cracking, delamination, detachment, distortion, loosening, rupture, separation and split.

Thirty-one photographs are included in the file that illustrate one example of each of the 31 different road wheel failure modes observed. A specific removal code was thus established to categorize each tire failure type.

Google or Bing searches can afford thousands of results in under one minute; however, these findings are only generally organized with limited educational value. Thus, this report is a summary showing only photographs from the NHTSA database[3] in order to increase general awareness of this important educational tire road wheel failure cataloging.

For the bead region, four removal codes have been established for failed

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Fig. 1: Example schematic of a passenger car radial tire.[6]

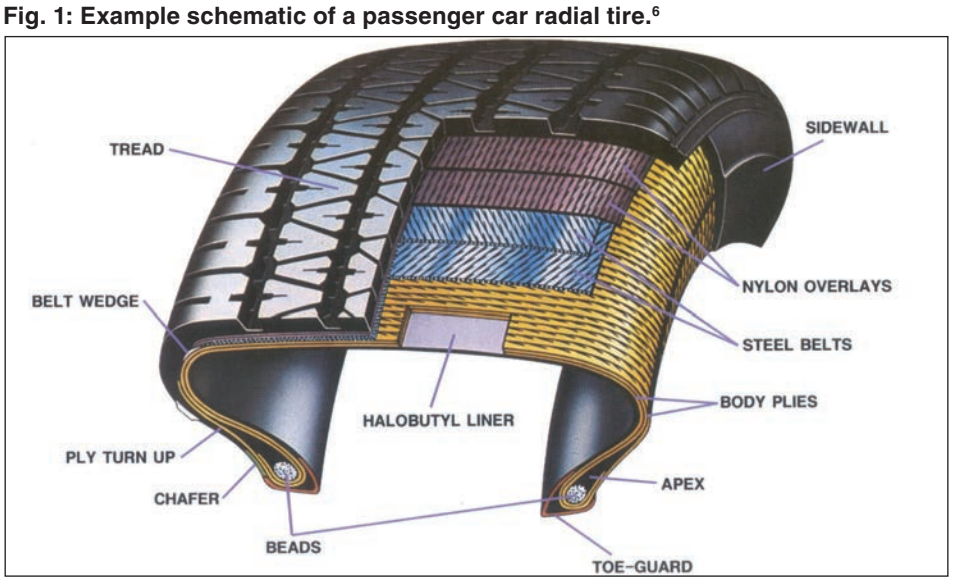

Fig. 2: Photograph of a tire displaying bead turnup cracking = BdTuCr.

Fig. 3: Photograph of a tire displaying a bead turnup rupture = BdTuR.

Fig. 4: Photograph of a tire displaying an innerliner separation = ILS.

Fig. 5: Photograph of a tire displaying an innerliner split = ILSplit.

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passenger car radial tires. In approximate order of increasing severity they are: bead damage (BdD), which can be cracks, tears or separations on the bead toe or heel areas that extend to ply material and can be caused by mounting or dismounting the tire; bead ripped (BdRi), which can be caused by a breakdown of bonding between components in the bead area; bead turnup cracking (BdTuCr), which can be cracks in the rubber in the lower sidewall area that can extend into the ply material (**Fig. 2**); and bead turnup rupture (BdTuR) of the body ply cords with radial cracking, which can lead to rapid air loss in the tire (**Fig. 3**).

For the tire innerliner region, four removal codes have been established. In approximate order of increasing severity they are: innerliner separation (ILS), which can be a parting of the innerliner from cord material in the carcass and can range from a small blister or bubble (**Fig. 4**) or can be larger separations with or without air loss; innerliner split (ILSplit), which can be cracking which can result in air loss (**Fig. 5**), or openings at the innerliner splice, or openings which can be caused by carcass cord material penetrating (striking through) into the innerliner and can lead to air loss; and innerliner damage (ILD) and innerliner failure (ILF), which can lead to rapid air loss from the tire.

For the tire sidewall region, four removal codes have been established: blister or bubble on the sidewall (SwBlister); sidewall cracking (SwCr), which can be a crack typically circumferentially in the mid (**Fig. 6**) to upper sidewall area; sidewall rupture (SwR), which can be the breaking away of pieces of the sidewall with or without loss of air; and sidewall rupture with delamination (SwR+Dl), which can be the separation or peeling of sidewall pieces (**Fig. 7**).

For the carcass region, a removal code for carcass rupture (CaR) has been established (**Fig. 8**), and two removal codes for ply coat delamination at the interface with the sidewall (PCD-I), (**Fig. 9**) and to the tire cords (PCD-TC) have been established.

For the shoulder region, removal codes have been established, including one which also shows a failure in the belt region. They are: slit on the shoulder (ShSlit), which can be a crack, typically circumferential, in the upper sidewall or tread shoulder that extends down to the ply material; shoulder rupture (ShR), which can be a circumferential separation through the innerliner and the carcass plies in tread shoulder region which can lead to rapid air loss (**Fig. 10**); tread shoulder cracking (TShCr); tread shoulder pocket cracking (TShPoCr) and tread shoulder chunking (TSHC), which can both be the breaking away of pieces of the tread at the shoulder region (**Fig. 11**); and

The authors

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Waddell

Larry Evans retired from the Transportation Research Center as a research analyst assigned to the National Highway Traffic and Safety Administration of the U.S. Department of Transportation, where his primary responsibility was analysis of NHTSA's extensive tire and vehicle testing programs.

His varied background in the tire industry starts with a post as a research chemist at Goodyear, where he worked on rubber compounding and fabric-to-rubber adhesion for tires and industrial engineered products. He was a senior research associate in silicas at PPG Industries, and then technology manager at J.M. Huber Corp. responsible for global research and implementation of silica for the rubber, plastics and coatings industries.

Evans has 12 patents, authored 60 scientific publications and presented more than 70 technical seminars around the world. He is a member of the ACS Rubber Division and chaired its Program Planning Committee and the Best Paper Committee; ASTM D11 Committee on Rubber and F09 Committee on Tires; and the Society of Automotive Engineering.

Walter Waddell has bachelor's and doctorate degrees in chemistry, and was a research associate at Columbia University and an associate professor at Carnegie-Mellon University.

His industrial experience includes: section head, research, at Goodyear; senior scientist in silicas at PPG Industries; and senior research associate at ExxonMobil Chemical Co., from where he retired.

Waddell has 37 patents, 154 publications, 170 technical presentations, and numerous recognitions and awards.

These include: Research Fellow (U.S. National Institutes of Health); Sparks-Thomas and Melvin Mooney Distinguished Technology Awards (ACS Rubber Division); Award of Appreciation (ASTM F09 Committee on Tires); International Rubber Conference Medal; and Joe Hightower and Southwest Regional Awards (American Chemical Society).

He is a member of the American Chemical Society; the ACS Rubber Division, where he served as chairman; and ASTM D11 Rubber and F09 Tire Committees.

Evans and Waddell currently are the co-chairs for the International Tire Exposition & Conference, which will be held Sept. 11-13 in Akron.

Fig. 6: Photograph of a tire displaying a sidewall crack = SwCr.

Fig. 7: Photograph of a tire displaying a sidewall rupture with delamination = SwR+Dl.

Fig. 8: Photograph of a tire displaying a carcass rupture = CaR.

Fig. 9: Photograph of a tire displaying ply coat delamination at the interface of the sidewall = PCD-I.

Fig. 10: Photograph of a tire displaying shoulder rupture = ShR.

Fig. 11: Photograph of a tire displaying tread shoulder chunking = TShC.

Fig. 12: Photograph of a tire displaying tread shoulder chunking with belts exposed = TSh+BE. Tread shoulder cracking is also visible = TShCr.

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tread shoulder chunking with belts exposed (TShC+BE) (**Fig. 12**).

Removal codes have been established representing different possible types of failures in the belt region. They include: belt edge exposed (BEE) (**Fig. 13**); belt edge loosened (BEL) (**Fig. 14**); belt edge separation (BES) (**Fig. 15**); belt No. 1 to carcass detachment (B1P1D) (**Fig. 16**); belt No. 1 to belt No. 2 separation (BBS); partial tread and belt No. 2 detachment (PT+B2D) (see **Fig. 17**); and complete tread and belt No. 2 detachment (CT+B2D) (**Fig. 18**).

Finally, for the tread region, removal codes have been established for tread groove cracking (TGCr) (**Fig. 19**); tread chunking (TC), which can be the breaking away of pieces of the tread (**Fig. 11**); and tread lug chunking (TLC), which can be a localized, partial-depth chunk-

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Fig. 13: Photograph of a tire displaying belt edge exposed = BEE.

Fig. 14: Photograph of a tire displaying belt edge loosening = BEL.

Fig. 15: Photograph of a tire displaying a belt edge separation = BES.

Fig. 16: Photograph displaying belt No. 1 to carcass detachment = B1P1D.

Fig. 17: Photograph of a tire displaying partial tread to belt No. 2 detachment = PT+B2D.

Fig. 18: Photograph of a tire displaying complete tread to belt No. 2 detachment = CT+B2D.

Table 1: Summary of NHTSA road wheel removal codes.

Region	Removal Code	Tire Failure Mode
Bead	BdD	Bead Damage
	BdRi	Bead Ripped
	BdTuCr	Bead Turn-Up Cracking
	BdTuR	Bead Turn-Up Rupture
Innerliner	ILS	Innerliner Separation
	ILSplit	Innerliner Split
	ILD	Innerliner Damage
	ILF	Innerliner Failure
Sidewall	SWBlister	Sidewall Blister
	SwCr	Sidewall Cracking
	SwR+Dl	Sidewall Rupture with Delamination
	SwR	Sidewall Rupture
	PCD-I	Ply Coat Delamination at Interface
	PCD-TC	Ply Coat Delamination to Cords
Carcass	CaR	Carcass Rupture
Shoulder	ShSlit	Slit on Shoulder
	ShR	Shoulder Rupture
	TShCr	Tread Shoulder Cracking
	TShC	Tread Shoulder Chunking
	TShPoCr	Tread Shoulder Pocket Cracking
	TShC+BE	Tread Shoulder Chunking with Belts Exposed
Belt	BEE	Belt Edge Exposed
	BEL	Belt Edge Loosened
	BES	Belt Edge Separation
	BBS	Belt-1 to Belt-2 Separation
	B1P1D	Belt-1 to Carcass Detachment
	PT+B2D	Partial Tread to Belt-2 Detachment
	CT+B2D	Complete Tread to Belt-2 Detachment
Tread	TGCr	Tread Groove Cracking
	TLC	Tread Lug Chunking