Designation: A 729/A 729M – 06

Standard Specification for Alloy Steel Axles, Heat-Treated, for Mass Transit and Electric Railway Service[1]

This standard is issued under the fixed designation A 729/A 729M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers heat-treated alloy steel axles for mass transit and commuter cars in electric and locomotive hauled railway service.

1.2 This specification is for solid design roller bearing axles with machined bodies.

1.3 Various axle designs are used for this service including motor and non-motor with either inboard or outboard journals.

1.4 Supplementary requirements including those in the general requirements of Specification A 788/A 788M are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.5 Unless the order specifies the applicable "M" specification designation, the axles shall be furnished to the inch-pound units.

1.6 The values stated in either inch-pound or SI (metric) units are to be regarded separately as standard. Within the text and tables, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 29/A 29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought, General Requirements for

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings

A 388/A 388M Practice for Ultrasonic Examination of Heavy Steel Forgings

A 788/A 788M Specification for Steel Forgings, General Requirements

E 112 Test Methods for Determining Average Grain Size

E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

E 1426 Test Method for Determining the Effective Elastic Parameter for X-Ray Diffraction Measurements of Residual Stress

3. Ordering Information

3.1 Material supplied to this specification shall conform to the requirements of Specification A 788/A 788M, which outlines ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

3.1.1 If the requirements of this specification are in conflict with the requirements of Specification A 788/A 788M, then the requirements of this specification shall prevail.

3.2 In addition to the ordering information required by Specification A 788/A 788M, the purchaser should include with the inquiry and order a detailed drawing, sketch or written description of the axle showing complete details pertaining to dimensions, tolerances if more restrictive than those contained in this specification, degree of finish, and location of stamping.

3.2.1 Unless the purchaser designates a class in the purchase order or contract, the class used shall be at the producer's discretion.

3.3 Supplementary requirements, if needed, including any that are appropriate from Specification A 788/A 788M.

4. Chemical Requirements

4.1 *Chemical Composition*—The steel shall conform to the chemical requirements specified in Table 1.

4.2 Seven classes of steel are included in Table 1. Unless otherwise specified by the purchaser, the choice of steel class to be used for any given axle grade is at the option of the producer.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.06 on Steel Forgings and Billets.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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TABLE 1 Chemical Requirements

	Composition %					
	Class A	Class B	Class C	Class D[A]	Class F	Classes G & H
Carbon	0.43-0.48	0.28-0.33	0.38-0.43	0.28-0.33	0.45-0.59	...
Manganese	0.75-1.00	0.40-0.60	0.75-1.00	0.70 0.90	0.60-0.90	0.60-0.90
Phosphorous	0.035 max	0.035 max	0.035 max	0.035 max	0.035 max	0.035 max
Sulfur	0.040 max	0.040 max	0.040 max	0.040 max	0.040 max	0.040 max
Silicon	0.15-0.35	0.15-0.35	0.15-0.35	0.15-0.35	0.15 min	0.15 min
Nickel	...	...	...	0.40-0.70	[B]	[B]
Chromium	0.20-0.35	0.80-1.10	0.80-1.10	0.40-0.60	[B]	[B]
Molybdenum	...	0.15-0.25	0.15-0.25	0.15-0.25	[B]	[B]
Vanadium	0.08 max	0.08 max	0.08 max	0.08 max	[B]	[B]
Aluminum	0.04 max	0.04 max	0.04 max	0.04 max	[B]	[B]

[A] Class D meets the requirements of SAE 8630 alloy steel.
[B] The manufacturer may add these elements as necessary to meet the specified mechanical properties after the required heat treatment. The actual chemistry shall be reported.

4.3 Unspecified element additions to Classes F, G, and H shall be reported.

4.4 The purchaser may use the requirements of Specification A 788/A 788M for a product analysis.

5. Manufacture

5.1 *Forging Practice*—The axle may be made direct from the ingot or from blooms, the total reduction in cross-sectional area from ingot or strand cast blooms to axle forging being not less than 3 to 1, unless otherwise specified.

5.2 *Cooling and Heating*:

5.2.1 Blooms shall be reheated for forging in a manner that will prevent internal bursts and overheating.

5.2.2 Axles that are heat-treated directly from forging shall be cooled below the transformation temperature to at least 1000°F [538°C] before any reheating operation.

5.3 *Heat Treatment*:

5.3.1 Axles shall be heat-treated in accordance with Table 2.

5.3.2 Grades A and F shall be heat-treated by double normalizing, followed by tempering. After heating to and holding at an appropriate temperature in the austenitic range, the axles shall be cooled in still air to under 500°F [260°C]. They shall then be reheated into the austenitic range to the same or a lower temperature and again air cooled to under 500°F [260°C]. A furnace charge thus treated is termed a double normalizing charge. After cooling, the axles are then tempered as in 5.3.4.

5.3.3 All other Grades shall be liquid quenched and tempered. After heating to and holding at an appropriate temperature in the austenitic range, the axles shall be quenched in a suitable medium. A furnace charge thus treated is termed a quenching charge. Following quenching, the axles are tempered as in 5.3.4.

5.3.3.1 Grade H axles require a normalizing cycle prior to the quenching heat treatment.

5.3.3.2 At the manufacturer's option for Grade G, a normalizing cycle may precede austenitizing for the liquid quenching operation.

5.3.4 *Tempering*—Axles shall be reheated gradually to and held at an appropriate subcritical temperature, and shall then be allowed to cool under uniform conditions. A furnace charge thus treated is termed a tempering charge.

5.3.4.1 When required by supplementary requirement S2, axles that have been rough machined after heat treatment shall be heated to and held for an appropriate time at a temperature that is less than the last tempering temperature by at least 50°F [10°C]. Then the axles shall be quenched directly into water with the axle length vertical.

TABLE 2 Heat Treatment and Tensile Requirements

Grade	Heat Treatment	Size, Solid Diameter or Thickness, in. [mm]		Tensile Strength, psi [MPa], min	Yield Strength @ 0.2 %, min	Elongation, in 2 iu. [50 mm], min	Reduction of Area %, min
		Over	Not Over				
A, F	Double Normalize and Temper	...	8 [200]	88 000 [605]	50 000 [345]	22	37
		8 [200]	12 [300]	86 000 [595]	48 000 [330]	21	35
B, C D, G	Quench and Temper	...	4 [100]	105 000 [725]	70 000 [485]	24	45
		4 [100]	7 [175]	100 000 [690]	65 000 [450]	22	45
		7 [175]	10 [250]	85 000 [585]	50 000 [345]	20	40
		10 [250]	...	82 500 [570]	48 000 [330]	19	35
H	Normalize, Quench, and Temper	...	7 [175]	115 000 [795]	75 000 [515]	20	40
		7 [175]	10 [250]	105 000 [725]	65 000 [450]	18	35
		10 [250]	...	100 000 [690]	60 000 [415]	18	35

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5.3.5 Heat treatment may be performed in either batch-type furnaces or continuous furnaces.

5.4 *Straightening*—Straightening, if necessary, shall be done before machining and preferably at a temperature not lower than 950°F [510°C]. Straightening, performed at temperatures lower than 950°F [510°C], shall be followed by stress relieving or applicable heat treatment.

6. Metallurgical Requirements

6.1 A specimen, representing each heat in each heat-treatment lot, shall be taken for the heat treated grain size determination in accordance with Test Methods E 112. This sample section may be cut from the large undistorted portion of the tension test specimen in such a way as will give a face transverse to the axis of the axle.

6.2 The entire specimen shall show a uniform, fine-grained structure of No. 5 or finer as measured in accordance with Test Methods E 112.

6.3 Alternatively, the austenitic fine grain requirements of Specification A 29/A 29M may be used in lieu of the heat-treated grain size described in 6.1. In this case, the grain refining elements used shall be included in the heat analysis results.

7. Tension Test Requirements

7.1 Tension tests shall be taken from the test prolongation or from an axle in accordance with 7.2.

7.1.1 Axles shall conform to the requirements in Table 2.

7.1.2 The diameter of the test prolongation of axle forgings shall be determined by the forged diameter of the journal.

7.1.3 Tests shall be made only after final heat treatment.

7.1.4 The longitudinal axis of the specimen shall be located at any point midway between the center and surface of the axle or full-sized prolongation and shall be parallel to the axis of the axle.

7.2 *Prolongation*:

7.2.1 To ensure that sufficient material is available for test purposes, prolongations shall be attached to at least 5 % of the axles in each heat in each heat-treating lot.

7.2.2 If axles with prolongations have been expended, then axles may be used for test procurement.

7.3 *Number of Tests*:

7.3.1 Unless otherwise specified by the purchaser, mechanical tests shall be made as covered in 7.3.2 and 7.3.3.

7.3.2 Where batch-type furnaces are used, one test per heat per size classification is required, but each test shall represent no more than 70 axles. The axles represented by this test shall be called a heat-treatment lot.

7.3.3 Where continuous heat-treating furnaces are used, one test per heat per size classification is required, but each test shall represent no more than 70 axles. The axles represented by this test shall be called a heat-treatment lot.

7.4 *Retest*:

7.4.1 If the results of the mechanical tests of any lot do not conform to the requirements specified, the axles may be retreated, but not more than three additional times and retests shall be made in accordance with Section 7.

8. Nondestructive Testing Requirements

8.1 *Ultrasonic Examination*—The purpose of this examination is to evaluate the quality of new axles *(1)* by determining end face to end face penetrability, and *(2)* by detecting discontinuities that may be harmful to axle service.

8.2 *Method*—The axle examination shall conform to Practice A 388/A 388M.

8.3 *Time of Examination*—Examination shall be made after heat treatment and after the axle end faces have been machined square, and preferably before being centered.

8.4 *Instrument Sensitivity and Scanning*:

8.4.1 *Instrument Sensitivity*:

8.4.1.1 The instrument sensitivity shall be adjusted to produce an indication of 20 % full screen height (FSH) from a reference test block manufactured from a representative heat-treated axle forging having a ⅛-in. [3.20-mm] diameter, 1 in. [25.4 mm] deep, flat-bottomed hole drilled perpendicularly to and at a distance of 15 in. [381 mm] from the test end face of the axle section. The reference blocks shall have a surface finish of 80 to 125 µin. [2.03 to 3.20 µm] and detect in reference axles a flat-bottom hole of the size and distance specified in the table below.

8.4.1.2 At the sensitivity established in 8.4.1.1, the instrument shall be capable of detecting a flat bottom hole of the size and distance specified below:

Minimum Size (Flat-Bottom Holes) Detectable at Various Distances from End Faces

Test Distance to 15 in. [381 mm]	Test Distance 15 to 30 in. [381 to 762 mm]	Test Distance over 30 in. [762 mm]
⅛ in. [3.20 mm]	¼ in. [6.35 mm]	⅜ in. [9.52 mm]

8.4.2 *Scanning*:

8.4.2.1 Scanning shall be performed from both end faces, which shall have a surface finish of 125 µin. [3.20 µm]

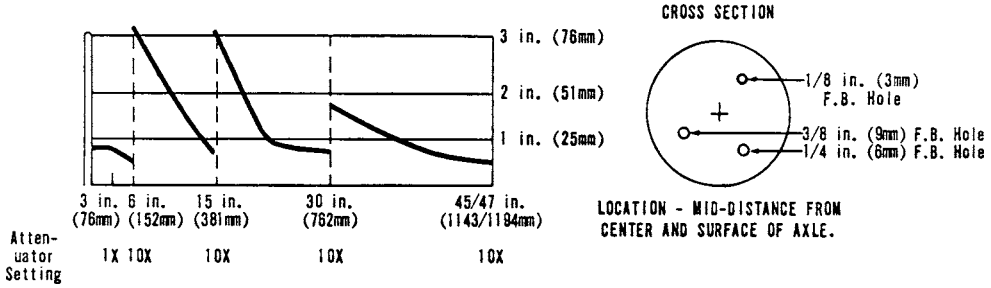

FIG. 1 Typical Distance-Amplitude Curve for a Heat-Treated Axle Using a 1⅛-in. [28.6-mm] Diameter 2.25-MHz Quartz Transducer

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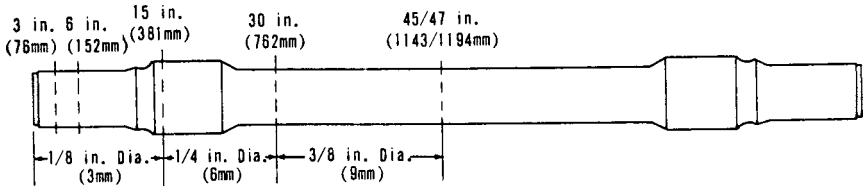

FIG. 2 Location of Reference Holes in an Axle—Flat Bottom Hole Sizes for a Heat-Treated Axle

maximum and, when specified, from the OP. The scanning shall include the maximum end face area obtainable by manual or automated inspection techniques.

8.4.2.2 During scanning the amplitude of the indication from the end face opposite the search unit shall be monitored and the amplitudes of all discontinuity indications shall be evaluated with respect to the distance from the test surface (see 8.4.3 and 8.7.2).

8.4.3 *Distance-Amplitude Correction*—The amplitude of an ultrasonic indication must be considered in relation to its distance from the testing surface to evaluate its significance. This can be accomplished by an electronic device or by distance-amplitude curves (DAC), which are described in 8.7.2.

8.4.4 In addition to the reportable conditions of Practice A 388/A 388M, indications exceeding the resulting back reflection shall be reported.

8.5 *Acceptance*:

8.5.1 *Longitudinal Penetration*—Axles that do not produce a 40 % FSH back reflection from the end of face opposite the search unit shall be rejected or made acceptable by heat treatment.

8.5.2 *Discontinuity Test*—The axle shall be rejected if the amplitude of any discontinuity indication exceeds the indication levels obtained from the flat-bottom holes listed in the table under 8.4.1.2 considering the distance-amplitude correction as described in 8.4.3.

8.5.3 *Radial Scan*—An axle forging shall be unacceptable if from the radial scan from the OP one or more reflections are present producing indications accompanied by complete loss of back reflection not attributable to geometric configuration. For this purpose, a back reflection of less than 5 % of full screen height shall be considered loss of back reflection.

8.6 *Marking*—Axles that meet the ultrasonic inspection requirements of this specification shall be stamped with the letter "T" on the end face adjacent to the heat number or serial number.

8.7 *Additional Information*:

8.7.1 *Amplitude Correction*—The amplitude of an ultrasonic indication from a given discontinuity size varies with its distance from the test surface. To compensate for this effect, a distance-amplitude relationship is employed. The relationship can be established by an electronic device or by curves. Because the distance-amplitude relationship is influenced primarily by the ultrasonic transducer and instrument, it is necessary to relate this factor to the specific equipment used. Appropriate distance-amplitude curves shall be developed. A typical example is shown in Fig. 1 as related to the axle in Fig. 2.

8.7.2 *Spurious Ultrasonic Indications from Contour Variations*—Because an axle varies in cross section it is possible to produce spurious indications, particularly at changes of cross section. These must be recognized, and are not reason for rejection. It is not practical to define these indications as responses from axle contours.

8.7.3 *Near-Field Resolution*—It should be recognized that detection of discontinuities near the test surface is limited by the ultrasonic test frequency. In the case of quenched and tempered axles, this is approximately 1 in. [25.4 mm] from the test surface.

9. Magnetic Particle Examination

9.1 Magnetic particle examination of finish machined axles shall be done in accordance with Test Method A 275/A 275M.

9.2 Acceptance shall be in accordance with Annex A1.

10. Dimensional Tolerances

10.1 *Length and Diameter*:

10.1.1 For axles ordered to finished length, the overall length shall not be less than the specified minimum length nor more than 1/16 in. [1.6 mm] over.

10.1.2 For axles ordered for finished-end facing by the purchaser, the overall length shall range from 1/8 in. [3.2 mm] to 1/4 in. [6.4 mm] over the specified minimum length.

10.1.3 For any other axles ordered to final length and not covered by the above classifications, the overall length shall not be less than the specified minimum length nor more than 1/8 in. [3.2 mm] over.

10.1.4 The specified minimum length shall be the nominal overall final length less any allowable tolerances.

10.1.5 Rough-machined areas, either the entire axle or designated parts thereof, shall be 1/8 in. [3.2 mm] to 1/4 in. [6.4 mm] over the finished diameter; in the case of motor axles having a conglomerate of diameters for the seats for wheel, gear, gear case bearing, and grounding ring the entire area shall be rough machined to a single diameter 1/8 to 1/4 in. [3.2 to 6.4 mm] over the finished diameter of the segment having the largest diameter. Longitudinally 1/8 to 1/4 in. [3.2 to 6.4 mm] of metal shall be allowed at each change of cross section for finish machining.

10.1.6 The smooth-machined body shall be to the specified size with no more than 1/8 in. [3.2 mm] over on the diameters and shall have no more than 1/8 in. [3.2 mm] allowance longitudinally at each change of cross section.

11. Workmanship and Finish

11.1 Axles shall conform to the size, shape, and finish shown on the purchaser's drawing and unless otherwise

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specified shall have center holes with clearance drilled for lathe center points and not counter bored. All machining shall be done in a workmanlike manner.

11.2 Where a smooth-machined finish on the body (10.1.6) is specified, it shall be to a maximum of 250 µin. [6.35 µm]. Rough machining shall be free of excessively rough ridges and coarse chatter marks.

11.3 Finish machined axle surfaces shall be free of injurious imperfections as defined in Annex A1.

12. Product Marking

12.1 In addition to the marking requirements of Specification A 788/A 788M, axles shall be legibly cold-stamped with letters and figures not less than ¼ in. [6.4 mm] high. This stamping shall be on the end face or under cut shoulder at the end of the journal as shown on the purchaser's drawing. It should include month and year made, manufacturer's name or trademark, heat number, and serial number.

12.2 In addition to the above required markings, bar code tags may be applied to the axles. If these tags are applied, it is recommended that Bar Code 39 be used. The size and location of the tags, as well as the information to be included, shall be agreed upon by the purchaser and the manufacturer.

13. Keywords

13.1 axles; rail applications; steel forgings

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified by the purchaser. Details shall be agreed upon by the manufacturer and the purchaser.

S1. Macroscopical Tests

S1.1 The prolongation from the largest axle in each heat shall be sawed normal to the axis of the axle and shall then be split longitudinally. The transverse and the longitudinal faces shall be etched for macro examination in accordance with Method E 381.

S1.2 Acceptance criteria shall be based on the adjuncts of Method E 381 as specified in the purchase order.

S2. Accelerated Cooling after Stress Relief

S2.1 When specified, the rough machined axle shall be given a sub-critical quench from a temperature above 900°F [480°C]. Sufficient allowance shall be left in the rough machined billet so that the axle can be machined to final dimensions after sub-critical quench.

S3. Residual Stress Measurement

S3.1 When specified, fee residual compressive stresses shall be measured in the body section of one representative axle. X-ray diffraction residual stress measurements to Test Method E 1426 shall be considered the standard method.

S3.2 The results shall be reported.

ANNEX

(Mandatory Information)

A1. INTERPRETATION OF IMPERFECTIONS CONSIDERED INJURIOUS IN AXLES

A1.1 General

A1.1.1 The conditions that have been most difficult for inspectors to evaluate are light lines visible to the normal unaided eye, variously described as actual seams, hairlines, stringers, shadow seams, ghost lines, and so forth, which appear after the axles have been finish machined and burnished or ground. It is, therefore, advisable to describe these conditions in more detail.

A1.1.2 The interpretation of injurious imperfections as enumerated below is not to be considered as precluding other unforeseen or objectionable conditions not specifically listed. The right of the purchaser is reserved to reject temporarily such axles and make final settlement on the basis of further negotiations between representatives of the manufacturer and the purchaser who are especially qualified to decide such questions.

A1.1.3 Any transverse or circumferential seams, cracks, or laps of indeterminate depth on the axle surfaces other than the discolorations listed in A1.1.4 regardless of their location, are considered to be injurious and are cause for rejection without further machining.

A1.1.4 Ghost lines, shadow marks, or other similar discolorations, visible to the normal unaided eye that are not actual separations in the metal are not considered injurious regardless of location.

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A1.1.5 Any longitudinal discontinuity, variously termed hairline, stringer, or fine seam, in machined fillets is considered to be injurious and is cause for rejection without further conditioning.

A1.2 Journals and Dust Guards

A1.2.1 Fine longitudinal discontinuities on the finished (burnished or ground) surfaces variously termed hairlines, stringers, or fine seams are not considered injurious if they meet the following conditions:

A1.2.1.1 Must not extend into fillets.

A1.2.1.2 Must not be over ¾ in. [20 mm] long individually in the journal nor ½ in. [12.7 mm] long individually in the dust-guard seat.

A1.2.1.3 Total length of such imperfections over ¼ in. [6.4 mm] long must not exceed 2 in. [50.8 mm] in any one end of the axle.

A1.3 Wheel Seats, Gear Seats, Gear Case Bearing Seat, and Grounding Ring Seats

A1.3.1 Longitudinal discontinuities on the finished-machined surface of wheel and gear seats, variously termed hairlines, stringers, fine seams, tight seams, surface imperfections, and so forth, are not considered injurious if they meet the following conditions:

A1.3.1.1 Must not extend within 1½ in. [38.1 mm] of either end of the seats covered in this section.

A1.3.1.2 Must not be over ½ in. [12.7 mm] long individually.

A1.3.1.3 Total length of such imperfections, ¼ in. [6.4 mm] to ½ in. [12.7 mm] long, must not exceed 3 in. [76.2 mm] in any one end of the axle.

A1.4 Areas Between Attachment Seats (Body) Specified to Be Smooth Machined

A1.4.1 Longitudinal discontinuities on the smooth machined body, variously termed hairlines, stringers, or fine seams, are not considered injurious if they meet the following conditions:

A1.4.1.1 Must not extend into fillets at the ends of the body,

A1.4.1.2 Must not be over ½ in. [12.7 mm] long individually,

A1.4.1.3 Total length of such imperfections, ¼ in. [6.4 mm] to ½ in. [12.7 mm] long, must not exceed 1½ in. [38.1 mm] in any 12 in. [305 mm] of body length, and

A1.4.1.4 Axles containing longitudinal discontinuities in the body in excess of those described in A1.4.1.2 and A1.4.1.3 may be reconditioned by grinding or machining provided the diameter is not reduced below the specified minimum.

APPENDIX

(Nonmandatory Information)

X1. COMPOSITIONS FOR AXLE APPLICATIONS

X1.1 For the guidance of the purchaser, typical standard compositions that cloud be used for axle applications are listed below, however the diameter of the axle at the time of heat treatment must be taken into account when selecting the forging composition.

Grade	Standard Composition Specification A 29/A 29M
B	4130
C	4140
D	8630

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 729/A 729M – 05a) that may impact the use of this standard. (Approved Sept. 1, 2006.)

(*1*) Added 3.2.1.
(*2*) Revised 7.1.1.
(*3*) Revised Phosphorous for Class F in Table 1.
(*4*) Revised Table 2.
(*5*) Deleted Table 3.

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