SAE Aerospace
An SAE International Group

AEROSPACE MATERIAL SPECIFICATION

SAE AMS 2759/7A

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Superseding AMS 2759/7

Carburizing and Heat Treatment of Carburizing Grade Steel Parts

1. SCOPE:

This specification, in conjunction with the general requirements for steel heat treatment covered in AMS 2759, establishes the requirements and procedures for three classes of gas, vacuum and liquid carburizing and related heat treatment of parts fabricated from carburizing grade steels. It does not cover pack carburizing.

1.1 Classification:

Parts to be carburized shall be processed to meet the requirements of one of the following classes:

Class 1: Case depth and case hardness shall be as specified. Subsurface case hardness shall be in accordance with Table 1. Surface carbon shall be 0.70 to 1.00%. Retained austenite shall not exceed 10%. Intergranular carbides shall be scattered and discontinuous and shall not be evident in more than 40% of the grain boundaries.

Class 2: Case depth and case hardness shall be as specified. Subsurface case hardness shall be in accordance with Table 1. Surface carbon shall be 0.75 to 1.10%. Retained austenite shall not exceed 20%. Continuous carbide network shall not be evident in more than 80% of the grain boundaries.

Class 3: Case depth and case hardness shall be as specified.

1.1.1 If no class is specified, parts shall be processed to meet the requirements of Class 2.

1.2 Types:

Type 1: Gas and vacuum carburizing
Type 2: Liquid (salt bath) carburizing

1.2.1 If no type is specified, Type 1 shall be used.

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1.3 Safety - Hazardous Materials:

While the materials, methods, applications, and processes described or referenced in this specification may involve the use of hazardous materials, this specification does not address the hazards which may be involved in such use. It is the sole responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

2. APPLICABLE DOCUMENTS:

The issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been canceled and no superseding document has been specified, the last published issue of that document shall apply.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 2418	Copper Plating
AMS 2750	Pyrometry
AMS 2759	Heat Treatment of Steel Parts, General Requirements
ARP1820	Chord Method of Evaluating Surface Characteristics
J423	Methods of Measuring Case Depth

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM E 3	Preparation of Metallographic Specimens
ASTM E 18	Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
ASTM E 384	Microindentation Hardness of Materials
ASTM E 1019	Determination of Carbon, Sulfur, Nitrogen, Oxygen, and Hydrogen in Steel and in Iron, Nickel, and Cobalt Alloys

2.3 ASM Publications:

Available from ASM International, Materials Park, OH 44073-0002.

ASM Metals Handbook, Volume 9 - Atlas of Microstructures, 9th Edition

3. TECHNICAL REQUIREMENTS:

3.1 Equipment:

Shall conform to the requirements of AMS 2759.

3.1.1 Quenching Equipment: Shall be in accordance with AMS 2759.

3.1.2 Auxiliary Equipment: Shall be in accordance with AMS 2759.

3.1.3 Thermal Processing Equipment: Pyrometry shall conform to AMS 2750.

3.1.4 Cleaning Equipment: Shall be in accordance with AMS 2759.

3.1.5 Carburizing Atmosphere Equipment: For gaseous carburizing, the atmosphere shall be provided by external endothermic gas generators, nitrogen/propane, nitrogen/methane, or nitrogen/methanol mixtures. For vacuum carburizing, suitable gases, such as but not limited to propane, methane, methanol, acetylene, ethylene, or natural gas, shall be introduced into the furnace. Circulation of the atmosphere shall provide uniform carburizing.

3.1.5.1 For Classes 1 and 2 gaseous carburizing, the carbon potential shall be controlled and recorded by automatic equipment. Manual equipment may be used to verify the automatic equipment.

3.1.5.2 For vacuum carburizing, mass flow sensors shall record the additions of carburizing medium. The carbon potential shall be determined by correlation of the additions with the results from carbon gradient test specimens.

3.1.5.3 Other carburizing media, such as molten salt bath or fluidized beds, may be used when appropriate, except pack carburizing shall not be used. The carbon potential shall be determined by correlation with the results from carbon gradient test specimens. When molten salt baths are used, the medium shall be analyzed periodically for chemical composition.

3.1.5.4 Carbon potential shall be determined in accordance with 3.11.8.

3.1.5.5 Accuracy of Atmosphere Control Instruments: The accuracy of instruments used for analyzing and controlling carbon potential of furnace atmospheres shall be checked as often as necessary to ensure that the equipment is operating properly and shall be calibrated as required.

3.2 Sequence of Operations:

Shall be (1) preparation for carburizing, (2) carburizing, (3) cooling after carburizing, (4) hardening, and (5) tempering. The hardening operation may be omitted when cooling after carburizing has incorporated a quench in accordance with 3.6.4, and when the conditions of 3.2.1, 3.2.2, or 3.2.3 are satisfied.

3.2.1 Parts were quenched from the carburizing temperature and both of the following apply:

3.2.1.1 Case depth is 0.020 inch (0.51 mm) or less.

3.2.1.2 Carburizing temperature was not higher than 1600 °F (871 °C).

3.2.2 Parts were furnace cooled to the austenitizing temperature, stabilized, and quenched in accordance with 3.6.4 and either of the following apply:

3.2.2.1 Parts were made from a low hardenability steel (e.g. 1020, 4615, 4620, 8615, or 8620).

3.2.2.2 Parts were made from a high hardenability steel (e.g. 4320, 4820, or 9310), and were carburized to meet Class 3 requirements.

3.2.3 Parts made from a low hardenability steel were quenched from the carburizing temperature and either of the following apply:

3.2.3.1 Parts were carburized to meet Class 2 or Class 3 requirements.

3.2.3.2 Parts were carburized to meet Class 1 requirements and quenching from the carburizing temperature was approved by the cognizant engineering organization.

3.3 Preparation for Carburizing:

All metallurgical operations, such as brazing or welding, or stress inducing operations, such as forming or bending, should be completed prior to carburizing. Parts shall be free from visible defects, contamination, and corrosion that may be detrimental to the appearance or performance of the finished parts.

3.3.1 Stress Relief: Parts may be stress relieved prior to carburizing or hardening by heating to a selected temperature ±25 °F (±14 °C) within the range 900 to 1200 °F (482 to 649 °C), holding at temperature for not less than 2 hours, and cooling in air. Alternatively, parts that have been extensively machined, welded, or severely formed, may be normalized before final machining before carburizing. Normalizing times and temperatures for commonly carburized steels are given in Tables 2 and 3.

3.3.2 Cleaning: All parts shall have scale, oxides, residual oil film, and any other surface contamination removed prior to carburizing or heat treatment.

3.3.3 Selective Carburizing: Selective carburizing may be accomplished by masking surfaces not to be carburized. Alternatively, parts may be carburized on all surfaces and the case removed by machining or grinding those surfaces not requiring carburizing.

3.3.3.1 It is permissible to carburized to a depth greater than the maximum specified by an amount equal to that depth removed in subsequent machining operations (See 3.11.1.2.1).

3.3.4 Masking: Masking shall be copper plate, not less than 0.0008 inch (20 µm) in thickness, applied in accordance with AMS 2418. Other masking may be used if acceptable to the cognizant engineering organization.

3.3.5 Visual Inspection: Parts shall be visually inspected prior to and after carburizing. Parts exhibiting blistering, peeling, or porosity in the masking before or after carburizing shall be subject to rejection.

3.3.6 Loading of Parts: Shall be such as to minimize distortion at temperature and to permit free circulation of the carburizing atmosphere.

3.4 Carburization:

3.4.1 Carburizing Temperature: Shall be at a selected temperature ±25 °F (±14 °C) consistent with the material to be carburized and the depth of case required. Typical carburizing ranges are as follows:

Gas Carburizing:	1450 to 1750 °F (788 to 954 °C)
Vacuum Carburizing:	1550 to 1900 °F (843 to 1038 °C)
Liquid Carburizing:	1500 to 1750 °F (815 to 954 °C)

3.4.2 Carburizing Potential: The carbon potential shall be such as to provide the required case carbon content and case depth. Alternatively, the cycle may be adjusted to provide a carburizing stage followed by a diffusion stage. The diffusion stage is accomplished with an atmosphere of lower carbon potential.

3.5 Cooling after Carburizing:

Shall be in accordance with one of the following:

3.5.1 Quenching from the carburizing temperature.

3.5.2 Cooling in a protective atmosphere to 900 °F (482 °C) or lower, followed by cooling at a rate not faster than that provided by fan circulated air or atmosphere. Fan cooling from the carburizing temperature is permitted.

3.5.3 Furnace cooling from the carburizing temperature to the austenitizing temperature in Table 2, stabilizing, and quenching.

3.6 Hardening:

Shall consist of austenitizing and quenching. It may be preceded by subcritical annealing in accordance with Tables 2 and 3, and cooling to ambient temperature.

3.6.1 Atmosphere: Atmosphere or masking or both shall be used to protect part surfaces from decarburization, carburization, intergranular oxidation, and other surface damage during sub-critical annealing or austenitizing. Parts exhibiting blistering or peeling in the prior masked areas after exposure to elevated temperature shall be subject to rejection.

3.6.2 Rate of Heating: Heating rates shall be controlled to prevent damage to the parts. Parts of complicated design, involving abrupt change of section or sharp corners, should be subcritically annealed or preheated prior to austenitizing to avoid cracking and to minimize distortion. Preheating in air atmosphere up to 1100 °F (593 °C) is permitted.

3.6.3 Austenitizing: Temperature shall be as specified in Table 2. For steels not listed in Table 2, austenitizing temperatures shall be specified by purchaser. The charge shall be held within the specified temperature range for sufficient time for necessary diffusion and transformation to take place. The holding time intervals shown in Table 3 are suggested times starting when furnace control instruments reach set temperature or when the lowest load thermocouple reaches the lower limit of the required temperature range. The proper time interval will vary with the type of steel, power input to furnace and size of charge, as well as the nominal thickness and configuration of the individual parts.

3.6.4 Quenching: Following austenitizing, parts shall be quenched in the media specified in Table 2 and as follows:

3.6.4.1 Oil Quenching: Quench in circulating oil at a temperature between 60 to 160 °F (16 to 71 °C) at the start of the quenching operation. The circulation of the oil shall be controlled so that the oil temperature does not exceed 200 °F (93 °C) at any time during the quenching operation. Parts may be quenched in a die or in an open basket, but in either case, the oil shall circulate around every part.

3.6.4.2 Molten salt or synthetic quenchants are permitted when approved by the cognizant engineering organization.

3.6.4.3 Marquenching: Parts shall be marquenched in a nitrate salt bath, oil bath, or alternate quenchant operated between 350 to 450 °F (177 to 232 °C). The parts shall be in the marquenching bath only for sufficient time to stabilize the parts at the bath temperature, but not less than two minutes, followed by cooling in still air.

3.6.4.4 For steels other than those listed in Table 2, quench media shall be as specified by the purchaser.

3.6.5 Sub-Zero Treatment: Sub-zero treatment is required for parts carburized to Class 1 and Class 2 requirements and for steels containing 2.5% or more of alloying elements when carburized to Class 3 requirements. Other parts shall be sub-zero treated when specified. Parts shall be held at -100 °F (-73 °C) or lower, for one hour per inch of thickness, but not less than one hour, and warmed in air to room temperature. The sub-zero treatment shall be initiated within two hours after removal from the quench.

3.6.5.1 When authorized by the cognizant engineering organization, a snap temper not exceeding 300 °F (149 °C) may be used after quenching and prior to the sub-zero treatment when part design and thermal stresses may result in part cracking.

3.6.6 Cleaning: Parts may be cleaned before tempering. Marquenching salts shall be removed, before tempering, by a hot water rinse.

3.7 Tempering:

Tempering shall be started within two hours after quenching or sub-zero treatment except as permitted in 3.7.1.

3.7.1 If hardened parts cannot be tempered within two hours after sub-zero cooling, they shall be snap tempered for not less than one hour at not higher than 250 °F (121 °C).

3.7.2 Unless otherwise specified, parts shall be tempered for not less than two hours at a temperature consistent with the case hardness requirements but within the range of 275 to 450 °F (135 to 232 °C). Soak time shall commence when the recording potentiometer and the furnace load reaches the prescribed temperature.

3.8 Cleaning Carburized Surfaces:

Shall be by one of the following methods; blast cleaning, detergent cleaning, vapor blast cleaning, degreasing, abrasive honing, or anodic electrolytic cleaning. Acid pickling or cathodic electrolytic cleaning is not permitted.

3.9 Removal of Masking:

Masking shall be removed from parts after the carburizing operation. If plating is used, it shall be removed by a method which is controlled to prevent etching, pitting or hydrogen embrittlement of the part.

3.10 Straightening:

Straightening carburized areas of parts is permitted only if done prior to sub-zero treatment and/or tempering and if approved by the cognizant engineering organization.

3.10.1 Warm straightening is permitted in uncarburized areas of the parts. Part temperature shall not exceed 275 °F (135 °C) during the straightening operation.

3.11 Properties:

3.11.1 Case Depth:

3.11.1.1 Measurement: Shall be determined in accordance with 3.11.1.1.1, 3.11.1.1.2, or 3.11.1.1.3.

3.11.1.1.1 Case Depth Determination by Microhardness Method: Shall be by microhardness traverse of a test specimen sectioned perpendicular to the carburized surface and prepared in accordance with ASTM E 3. Hardness shall be determined in accordance with ASTM E 384 or SAE J423, starting 0.002 inch (0.05 mm) from the carburized edge and traversing inward in increments of 0.004 inch (0.10 mm) to the depth where a hardness of 542 HK500 or 513 HV500 or less is reached. The case depth shall be the distance from the surface to the location where the hardness is equivalent to 50 HRC.

3.11.1.1.2 Case Depth Determination by Metallographic Method: Shall be by examination of a test specimen sectioned perpendicular to the carburized surface and prepared in accordance with ASTM E 3. Etch the sectioned surface with a suitable reagent to get maximum contrast between phases and constituents, then examine at 40X to 60X magnification. The case depth shall be the distance from the surface to the location where the contrast is greatest. In case of dispute, the method of 3.11.1.1.1 shall apply.

3.11.1.1.3 The method of ARP1820 may be used to determine depth of thin cases.

3.11.1.2 Case Depth:

3.11.1.2.1 The depth of the applied case on the as-carburized and hardened part shall be sufficient to assure that engineering drawing required finished case depth and surface hardness requirements are met. The case depth is defined as the depth below the surface of the finished part where the hardness is the equivalent of 50 HRC. (See also 3.11.3). This is often referred to as the “effective case depth”.

3.11.1.2.2 The drawing case depth applies to the finish machined surfaces. The effective case depth at external corners, internal corners, boundaries, internal bores and gears and splines shall be as follows:

3.11.1.2.2.1 For external edges with a radius less than two times the maximum specified case depth, the case depth may be exceeded for a distance from the corner equal to three times the minimum specified case depth.

3.11.1.2.2.2 For internal corners with a radius less than two times the maximum specified case depth, the case depth may be less than the minimum specified for a distance from the theoretical corner equal to two times the minimum specified case depth but not less than one half of the minimum specified case depth.

3.11.1.2.2.3 For boundaries between carburized and uncarburized areas, the case depth may be less than the minimum specified case depth for a distance from the boundary equal to two times the minimum specified case depth but not less than one half the minimum specified case depth at the boundary. The carburized case may extend by normal diffusion beyond the boundary by not more than twice the minimum specified case depth.

3.11.1.2.2.4 For gears and splines, the specified case depth applies to the tooth surface at the pitch diameter. Case depth at the root radius shall be not less than 0.75 times the minimum specified case depth.

3.11.1.2.2.5 For internal bores, the case depth is applicable at the entrance and midpoint depth of bores open at both ends, and at the entrance and closed end of bores open at only one end.

3.11.2 Case Surface Hardness: Shall be determined in accordance with 3.11.2.2.

3.11.2.1 The roots of splines or gear teeth may exhibit a hardness not more than 2 HRC or equivalent numbers lower than that required at the pitch line. When approved by the cognizant engineering organization, a reduction of 4 HRC or equivalent is acceptable.

3.11.2.1.1 If a suitable surface is not accessible for hardness testing, the hardness at 0.002 inch (0.05 mm) obtained as in 3.11.1.1 shall be the case hardness.

3.11.2.2 Case Hardness Determination: Shall be in accordance with ASTM E 18 on the carburized and hardened surface, of the finished part using a superficial hardness test appropriate for the depth of case specified.

3.11.3 Sub-Surface Case Hardness: For parts carburized to Class 1 and Class 2 requirements, the sub-surface hardness shall meet the requirements of Table 1, determined in accordance with 3.11.3.2. Where a different hardness is specified, the subsurface hardness shall be as specified, when applicable.

3.11.3.1 Sub-surface hardness requirements do not apply to roots of splines or gear teeth.

3.11.3.2 Sub-surface Case Hardness Determination: The hardness traverse or 3.11.1.1 shall be used to determine the sub-surface case hardness. The microhardness conversion for 58 HRC shall be 690 HK500 or 653 HV500 and for 60 HRC shall be 732 HK500 or 697 HV500.

3.11.4 Core Hardness: Shall be as specified, determined in accordance with 3.11.4.1.

3.11.4.1 Core hardness shall be determined in accordance with ASTM E 18 on a noncarburized surface of the part, or at a location not less than five times the case depth from the surface, or at the approximate center of the microstructure specimen (See 3.11.6.6).

3.11.5 The hardness of non-carburized surfaces shall be in accordance with specified core hardness.

3.11.6 Case Microstructure: Shall be predominantly tempered martensite, determined in accordance with 3.11.6.6.

3.11.6.1 Intergranular oxidation shall not exceed 0.0005 inch (0.013 mm) in depth from the unmachined surface.

3.11.6.2 For Class 1 parts, any intergranular carbides on a finish machined working surface shall be scattered and discontinuous and shall not be evident in more than 40% of the grain boundaries. Only dispersed intergranular spheroidal (secondary) carbides are permitted more than two grains below the finish machined working surface. Massive or blocky carbides are unacceptable.

3.11.6.3 For Class 2 parts, a continuous carbide network shall not be evident in more than 80% of the grain boundaries. Photomicrograph 13 on page 220 of ASM Metals Handbook, Volume 9, 9th Edition, is an illustration of the maximum acceptable continuous carbide microstructure. Photomicrographs 12 and 14 on page 220 of ASM Metals Handbook, Volume 9, 9th Edition, are illustrations of non-acceptable microstructures containing excessive carbides around the grain boundaries and massive carbides.

3.11.6.4 The microstructure of a finished Class 1 part shall not show evidence of retained austenite in excess of Figure 16 on page 220 of ASM Metals Handbook, Volume 9, 9th Edition. If interpretation of the microstructure is questionable, or if it appears to represent retained austenite in excess of this figure, x-ray diffraction shall be performed to determine the acceptability. When inspected by x-ray diffraction, retained austenite greater than 10% is unacceptable.

3.11.6.5 The microstructure of a finished Class 2 part shall not show evidence of retained austenite in excess of Figure 17 on page 221 of ASM Metals Handbook, Volume 9, 9th Edition. If interpretation of the microstructure is questionable, or if it appears to represent retained austenite in excess of this figure, x-ray diffraction shall be performed to determine the acceptability. When inspected by x-ray diffraction, retained austenite greater than 20% is unacceptable.

3.11.6.6 Case Microstructure Determination: Shall be by examination of a test specimen sectioned perpendicular to the carburized surface and prepared in accordance with ASTM E 3. Examine at 900X to 1100X magnification for retained austenite, 400X to 600X for intergranular oxidation and carbides, and 200X to 300X for core structure. For part surfaces which are to be subsequently machined, the stock to be removed in finish machining need not be evaluated.

3.11.7 Core Microstructure: The transformed microstructure of the core shall be consistent with the steel composition and the thickness of the part at the time of quenching.

3.11.8 Carbon Content of Case (Carbon Potential): Shall be 0.70 to 1.00% for parts carburized to Class 1 requirements and 0.75 to 1.10% for parts carburized to Class 2 requirements, determined in accordance with 3.11.8.1 or 3.11.8.2.

3.11.8.1 A machined specimen, not less than 0.50 inch (12.7 mm) in diameter and 6 inches (152 mm) in length shall be carburized, preferably with a furnace load, for each alloy processed. The specimen shall be carburized to a depth not less than the maximum depth normally carburized or 0.020 inch (0.51 mm), whichever is greater. The specimen shall not be hardened after carburizing. 0.005 inch (0.13 mm) shall be machined from the diameter of the carburized specimen and the chips discarded. Chips for analysis shall be taken from the next 0.005 inch (0.13 mm) machined from the diameter. The chips shall be free of oil, grease, dirt, scale, or other foreign substances. Carbon determination may be by any method acceptable to purchaser, but in case of dispute, the combustion analysis method of ASTM E 1019 shall govern.

3.11.8.2 Alternatively, a specimen, not thicker than 0.01 inch (0.25 mm), of the same material as is required to be carburized, may be tested. In this case, the entire thickness of the specimen is analyzed for carbon content.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection:

Shall be in accordance with AMS 2759. Where test specimens are required, except for specimens for case carbon determination, these shall be supplied by purchaser.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests for case depth (3.11.1), case surface hardness (3.11.2), sub-surface case hardness (3.11.3), core hardness (3.11.4), hardness of noncarburized surfaces (3.11.5), case microstructure (3.11.6), and core microstructure (3.11.7) are acceptance tests and shall be performed on each lot.

4.2.2 Periodic Tests: Tests for carbon content of the case (3.11.8) are periodic tests and shall be performed every six months unless frequency of testing is specified by purchaser.

4.2.3 Preproduction Tests: All tests specified are preproduction tests and shall be performed on specimens for each piece of carburizing equipment to be used, as applicable for the carburizing class or classes (See 1.2) to be processed, and prior to any production carburizing.

4.3 Sampling and Testing:

Shall be as specified in AMS 2759 and the following; other methods of sampling, including statistical sampling, are permitted when authorized by purchaser.

4.3.1 Lot: Shall be in accordance with AMS 2759 and the following:

4.3.2 Process Control Specimens: At least one test specimen shall accompany each lot through each carburizing cycle. One specimen shall be hardened, tempered, and tested for properties required by 4.2.1. Purchaser may request one or more additional specimens to be quenched and tempered with the production parts. Additional specimens are required for parts with two or more carburized surfaces which are of different case depths or of different shapes or sizes or materials.

4.3.2.1 Test specimens shall represent the part thickness of the heaviest cross-section carburized and shall be of the same alloy as the parts, or shall represent the part configuration such as a section of gear or spline teeth or an internal bore if the bore has a depth to diameter ratio greater than one.

4.3.2.1.1 At least one specimen per lot shall be cut perpendicular to carburized surfaces and the section metallographically prepared in accordance with ASTM E 3. The examination may be performed on a finished part or an as-hardened and tempered part.

4.3.2.1.2 Where metallographic examination is conducted before finish machining, the test procedure shall provide evidence that finished case requirements will be met after finish machining.

4.3.2.1.3 For gears and splines, the test piece shall consist of not less than four teeth of an actual gear or spline. For internal bores, the bore diameter and depth shall be the same as the actual parts.

4.3.2.1.4 Metallographic examination shall include a microhardness traverse sufficient to show the actual effective case depth and surface hardness at all required surfaces.

4.3.2.1.5 Microstructure of each metallographically prepared section shall be examined for compliance with the metallographic requirements of this specification.

4.3.2.2 Test specimens shall be uniformly distributed throughout the furnace load.

4.3.2.3 Actual parts or part sections may be used in lieu of the test specimen.

4.4 Approval:

Shall be in accordance with AMS 2759.

4.5 Furnace Log and Recorder Chart Entries:

Shall be in accordance with AMS 2759.

4.6 Records:

Shall be in accordance with AMS 2759.

4.7 Reports:

Shall be in accordance with AMS 2759.

4.8 Resampling and Retesting:

If any specimen used in the above tests fails to meet the specified requirements, disposition of the heat treated parts may be based on the results of testing three additional specimens or two actual parts for each original nonconforming specimen. Except as permitted in 4.8.1, failure of any retest specimen or part to meet the specified requirements shall be cause for rejection of the parts represented. Results of all tests shall be reported.

4.8.1 Parts that do not meet the minimum case depth or minimum hardness limits after processing as herein specified may be reprocessed by recarburizing, rehardening, or retempering as necessary to meet specified requirements except that parts may be recarburized only once. Except for retempering, reprocessing is not applicable to parts that exhibit excessive case depth. Test samples for such reprocessing shall be the remaining portions of specimens or parts used to determine the original nonconformance.