AEROSPACE MATERIAL SPECIFICATION

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Superseding AMS2762A

Carburizing
Carbon and Low-Alloy Steel Parts

RATIONALE

This document has been reaffirmed to comply with the SAE 5-year Review policy.

NONCURRENT NOTICE

This specification has been declared “NONCURRENT” by the Aerospace Materials Division, SAE, as of January 2002. Refer to AMS 2759/7 for new designs. It is recommended, therefore, that this specification not be specified for new designs.

“NONCURRENT” refers to those materials or processes which have previously been widely used and which may be required on some existing designs in the future. The Aerospace Materials Division, however, does not recommend these as standard materials for future use in new designs. Each of these “NONCURRENT” specifications is available from SAE.

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1. SCOPE:

This specification covers the procedure for carburizing and related heat treatments of carbon and low-alloy steel parts to produce case hardening and specified mechanical properties within the capability of each respective steel.

1.1 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 following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order.

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, Steel Parts, General Requirements

2.2 ASTM Publications:

Available from ASTM, 1916 Race Street, Philadelphia, PA 19103-1187.

ASTM E 3	Preparation of Metallographic Specimens
ASTM E 18	Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
ASTM E 384	Microhardness of Materials

2.3 U.S. Government Publications:

Available from Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-2073-1	DOD Materiel, Procedures for Development and Application of Packaging Requirements

3. TECHNICAL REQUIREMENTS:

3.1 Carburizing Equipment:

3.1.1 Furnaces: The design and capacity of the carburizing furnace shall be such that the temperature at any point in the working zone shall not vary from the desired heat treating temperature, after the charge has been brought up to temperature, more than ±25 °F (±14 °C). Thermocouples shall be located in the working zones and shall be adequately protected from contamination by furnace atmosphere by means of suitable protection tubes. Pyrometry shall be in accordance with AMS 2750.

3.1.2 Carburizing Media: Gaseous carburizing atmosphere provided by external endothermic gas generators are preferred. Carbon potential control may be effected by enrichment of the endothermic atmosphere prior to its admission into the furnace. Positive (fan) circulation shall be provided.

3.1.2.1 Carbon potential of the furnace atmosphere shall be controlled and/or monitored by automatic equipment of the infrared, dew point, hot-wire, or equivalent type. Manual equipment may be used when the skill of the operator has been demonstrated to be effective and checks are made at frequent intervals.

3.1.2.2 Other carburizing media, such as salt bath or volatized hydrocarbon liquids, may be used when appropriate.

3.1.2.2.1 Salt baths used for carburizing shall be of a type and grade which will not react objectionably with the steel being treated.

3.1.2.2.2 Pack carburizing methods shall not be used.

3.1.2.3 Furnaces used for carburizing shall not be used for nitriding.

3.1.3 Accuracy of Atmosphere Control Instruments: The accuracy of instruments used for analyzing and controlling the 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 Hardening Equipment:

Furnaces and related equipment used in hardening carburized parts shall conform to the requirements of AMS 2759 as applicable.

3.3 Preparation:

3.3.1 Heat Treatment: Close tolerance parts, such as gears, should be normalized or stress relieved after rough machining and prior to pre-carburizing finish machining to minimize dimensional distortion in carburizing.

3.3.2 Stopping-Off: If parts are not to be carburized all over, the surfaces not to be carburized shall be protected to prevent absorption of carbon from the furnace atmosphere. Protection may be accomplished by copper plating in accordance with AMS 2418 or by other methods acceptable to purchaser. Alternatively, parts may be carburized all over and the case machined off the surfaces required to be free of carburization.

3.3.3 Surface Condition: Parts, before carburizing, shall be clean and free from dirt, grease, oxide, scale, and other injurious foreign matter. Surfaces to be carburized should be free from decarburization.

3.4 Procedure:

3.4.1 Loading Parts: Parts shall be suitably placed and supported in the carburizing furnace to prevent distortion at the carburizing temperature and to ensure free circulation of the carburizing atmosphere to all surfaces. Test specimens of comparable material and hardness shall be included with each load of parts as required for process control.

3.4.2 Carburizing:

3.4.2.1 Case Depth: The depth of case applied is governed by drawing requirements and the amount of material to be removed by subsequent machining. Unless otherwise specified, the maximum amount of stock to be removed shall be 20% of the depth of the applied case or 0.010 inch (0.25 mm), whichever is smaller.

3.4.2.2 Gas Carburizing: Shall be accomplished at a selected temperature ±25 °F (±14 °C) within the range 1600 to 1750 °F (871 to 954 °C) for the time necessary to develop the required case depth. The furnace atmosphere shall be maintained to produce the required properties of the carburized case.

3.4.2.2.1 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.

3.4.2.2.2 Upon completion of the carburizing cycle, the parts shall be cooled in a protective atmosphere to a temperature not higher than 900 °F (482 °C), after which they may be air cooled.

3.4.2.3 Liquid Carburizing: Shall be accomplished at a selected temperature ±25 °F (±14 °C) within the range 1500 to 1750 °F (816 to 954 °C) for a length of time necessary to develop the required case depth. The cyanide content of the carburizing salt shall be appropriate for the temperature of the furnace bath to produce a case essentially of carbon dissolved in iron.

3.4.2.3.1 Upon completion of the carburizing cycle, the parts shall be cooled to room temperature in a manner that will prevent decarburization of the carburized surfaces.

3.4.2.4 Parts exhibiting high case hardness after carburizing and cooling to room temperature may be tempered at 1125 °F ± 25 (607 °C ± 14) when machining is required on carburized areas prior to final heat treatment.

3.4.3 Hardening of Carburized Parts:

3.4.3.1 Rate of Heating: Heating rates shall be suitably controlled to prevent damage to the parts. When the material, size, and design of parts, or the operating conditions are such that no cracking or excessive warpage results, parts may be charged into the heat treating furnace or bath at any temperature not exceeding the maximum temperature specified. Parts of complicated design, involving abrupt change of section or sharp corners, and parts which have been previously hardened shall be subcritically annealed or preheated prior to austenitizing to avoid cracking and minimize distortion.

3.4.3.2 Transformation Hardening: The austenitizing temperature shall be within the range shown in Table 1 for the respective steel and the size of the parts. The exact temperature is governed by the chemical composition, previous treatment, and size and shape for the piece to be hardened and the handling equipment used. In general, parts of heavy cross section should be hardened from a temperature on the high side of the specified temperature range.

3.4.3.2.1 Austenitizing Time: 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 2 are suggested times starting when furnace, control instruments reach set temperature. 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.

3.4.3.2.2 Quenching: Hardening shall be accomplished by quenching from the austenitizing temperature specified in Table 1 into an appropriate medium. Cooling rates and transformation temperature shall be controlled to produce the desired microstructure and combination of mechanical properties. Parts shall be cooled to or below the quenching bath temperature before tempering.

3.4.3.2.2.1 When post hardening dimensional requirements of the part are not obtainable by free quenching, machine or quench fixturing may be used.

3.4.3.2.3 Sub-Zero Treatment: When required to complete transformation and provide desired microstructure, parts should be cooled to a temperature within the range -90 to -150 °F (-68 to -101 °C), held at the selected temperature within ±10 °F (±6 °C) for a time commensurate with section thickness but not less than 1 hour, and warmed in air to room temperature.

3.4.3.2.3.1 Sub-zero treatment should follow the quenching operation as soon as practical. When specified, a short tempering treatment may be used after quenching and prior to sub-zero treatment when part design and thermal stresses may result in part cracking.

3.4.3.3 Tempering: Parts shall be tempered, as the final heat treat operation, for not less than 1 hour at a temperature consistent with the case hardness requirement but within the range 300 to 400 °F (149 to 204 °C).

3.5 Properties:

3.5.1 Case Depth: Shall be within the range specified on the drawing. Case depth shall be effective case depth, defined as the depth where the hardness is the equivalent of 50 HRC, determined with a Vickers or Knoop indentor using a 500 gram load in accordance with ASTM E 384.

3.5.1.1 Case depth is defined as the distance below the surface corresponding to the middle of the transition between case and core. Measurement shall be made at 100X magnification on a cross-section of the carburized and hardened case metallographically prepared in accordance with ASTM E 3.

3.5.2 Hardness:

3.5.2.1 Case hardness shall be as specified on the drawing, measured in accordance with ASTM E 18 or ASTM E 384 on the carburized and hardened surface, using scale appropriate for the depth of case specified.

3.5.2.2 When specified, core hardness shall be as specified on the drawing, measured in a representative area of part sufficiently removed from the carburized case so as to truly represent the core material.

3.5.3 Microstructure: Shall be determined on a representative cross-section metallographically prepared in accordance with ASTM E 3 and examined at 250 - 500X magnification.

3.5.3.1 Case structure shall be essentially tempered martensite.

3.5.3.1.1 Massive carbides and grain boundary carbides shall not exceed the amount illustrated by Figure 1B, examined at 500X magnification.

3.5.3.1.2 Retained austenite, untempered martensite, and coarse martensitic needles shall not exceed the amount illustrated by Figure 2B, examined at 500X magnification.

3.5.3.1.3 No evidence of surface decarburization shall be permitted.

3.5.3.2 The structure transition from case to core shall be gradual.

3.5.3.3 Core structure of low-alloy steels should be essentially tempered martensite. No grain boundary ferrite or free ferrite is permitted except that in heavy sections bainite and ferrite may be permitted to limits agreed upon by purchaser and vendor.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection:

The processing vendor shall supply all samples for vendor's tests and shall be responsible for performing all required tests. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that processing conforms to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests for case depth (3.5.1), hardness (3.5.2), and microstructure (3.5.3) are acceptance tests and shall be performed to represent each lot.

4.2.2 Preproduction Tests: Tests for all technical requirements are preproduction tests and shall be performed prior to or on the initial shipment of the product to a purchaser, when a change in material and/or processing requires reapproval as in 4.4.2, and when purchaser deems confirmatory testing to be required.

4.2.2.1 For direct U.S. Military procurement, substantiating test data and, when requested, preproduction test material shall be submitted to the cognizant agency as directed by the procuring activity, contracting officer, or request for procurement.

4.3 Sampling and Testing:

Shall be in accordance with the following; a lot shall be all parts of similar design, fabricated from the same steel, carburized and heat treated in the same furnace(s) at the same time, and presented for vendor's inspection at one time.

4.3.1 For Preproduction Tests: At least three samples representing the processing procedures and heating and cooling cycles to be used for heat treating production parts. Unless prohibited by purchaser, these samples may be selected from the first production heat treat lot.

4.3.2 For Acceptance Tests: Sufficient samples representative of the parts being heat treated shall be included with each furnace load of production parts to determine effectivity of the carburizing heating and cooling cycles.

4.4 Approval:

4.4.1 The process and control procedures, or a preproduction sample part, or both, whichever is specified, shall be approved by the cognizant engineering organization before production parts are supplied.

4.4.2 The supplier shall make no significant change to materials, processes, or controls from those on which the approval was based, unless the change is approved by the cognizant engineering organization. A significant change is one which, in the judgement of the cognizant engineering organization, could affect the properties or performance of the parts.

4.4.3 Control factors for the process shall include but not be limited to:

a) shape and size of parts as carburized and as hardened
b) carburizing furnace or salt bath
c) limits on carburizing potential of atmosphere or salt composition
d) equipment used to monitor/control atmospheres
e) carburizing temperature ±25 °F (±14 °C)
f) carburizing time ±10%
g) racking method in carburizing furnace or salt bath
h) hardening temperature and time
i) quench oil and quench temperature
j) whether sub-zero cooling is used
k) tempering temperature ±10 °F (±6 °C) and time
l) if actual parts are not used for control, size and shape of test specimens

4.5 Records:

4.5.1 Records of furnace temperature surveys, calibration of control and recording instruments, types of furnace atmospheres, and thermal processing used in carburizing and hardening specific lots of steel parts shall be maintained for such time as agreed upon by purchaser and processor and made available for review by purchaser on request.

4.5.2 Heat Treating Log: A log for each heat treat load shall be maintained for examination for not less than two years. The log shall include not less than the following information:

Shop order number
Material identification and part number
Tempering temperature
Hardness and case depth of parts
Date of heat treatment

4.6 Reports:

The vendor of heat treated parts shall furnish with each shipment a report showing the results of tests to determine conformance to the requirements of this specification. This report shall include the purchase order number, material specification number and its revision letter if any, AMS 2762B, part number, and quantity of heat treated parts.

4.7 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 for each original nonconforming specimen. Except as permitted by 4.7.1, failure of any retest specimen to meet the specified requirements shall be cause for rejection of the parts represented. Results of all tests shall be reported.

4.7.1 Parts which do not meet specified case depth or hardness limits after heat treat 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.

5. PREPARATION FOR DELIVERY:

5.1 Identification:

Heat treated parts shall be identified as agreed upon by purchaser and vendor. The markings shall have no deleterious effect on the parts or their performance and shall be sufficiently stable to withstand normal handling.

5.2 Protective Treatment:

Carburized parts shall be coated with a suitable corrosion-preventive compound prior to shipment.

5.3 Packaging:

5.3.1 Parts shall be packaged to ensure that the parts, during shipment and storage, will be protected against damage from exposure to weather or any other normal hazard.

5.3.2 Packages of parts shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to handling, packaging, and transportation of parts to ensure carrier acceptance and safe delivery.

5.3.3 For direct U.S. Military procurement, packaging shall be in accordance with MIL-STD-2073-1, Commercial Level, unless level A is specified in the request for procurement.

6. ACKNOWLEDGMENT:

A vendor shall mention this specification number and its revision letter in all quotations and when acknowledging purchase orders.

7. REJECTIONS:

Heat treated parts not conforming to this specification, or to modifications authorized by purchaser, will be subject to rejection.

8. NOTES:

8.1 A change bar (I) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this specification. An (R) symbol to the left of the document title indicates a complete revision of the specification, including technical revisions. Change bars and (R) are not used in original publications, nor in specifications that contain editorial changes only.

8.2 Table 3 shows the AMS equivalents of the steel designations shown in Table 1.

8.3 For direct U.S. Military procurement, purchase documents should specify not less than the following:

Title, number, and date of this specification
Part number of parts to be carburized
Case depth, case hardness, and core hardness, when specified, desired
Number of pieces to be carburized
Level A packaging, if required (5.3.3).

8.4 Similar Specifications:

MIL-S-6090 is listed for information only and shall not be construed as an acceptable alternate unless all requirements of this AMS are met.

8.5 Products meeting the requirements of this specification have been classified under Federal Standardization Area Symbol "MFFP".

PREPARED UNDER THE JURISDICTION OF AMS COMMITTEE "B"

TABLE 1 - Hardening of Carburized Steels

Steel Designation	Austenitizing Temperature °F	Austenitizing Temperature °C	Recommended Quenchant	Relative Core Hardness
SAE 1015 - 1020	1425 - 1475	774 - 802	Water	Low
SAE 1115 - 1118	1425 - 1475	774 - 802	Water	Low
SAE 3310 - 3312	1475 - 1525	802 - 829	Oil	High
SAE 4615 - 4620	1475 - 1550	802 - 843	Oil	Moderate to High
SAE 8615 - 8620	1525 - 1575	829 - 857	Oil	Moderate to High
SAE 9310 - 9317	1475 - 1550	802 - 843	Oil	High
SAE 43BV12	1525 - 1600	829 - 871	Oil	Moderate
SAE 94B17	1525 - 1600	829 - 871	Oil	Moderate to High

TABLE 2 - Approximate Holding Time for Austenitizing

Nominal Diameter or Distance Between Parallel Sides Inches	Nominal Diameter or Distance Between Parallel Sides Millimeters	Air or Atmosphere Furnaces Minutes	Salt Bath Furnace Minutes
Up to 0.250, incl	Up to 6.35, incl	25	18
Over 0.250 to 0.500, incl	Over 6.35 to 12.70, incl	45	35
Over 0.500 to 1.000, incl	Over 12.70 to 25.40, incl	60	40
Over 1.000 to 1.500, incl	Over 25.40 to 38.10, incl	75	45
Over 1.500 to 2.000, incl	Over 38.10 to 50.80, incl	90	50
Over 2.000 to 2.500, incl	Over 50.80 to 63.50, incl	105	55
Over 2.500 to 3.000, incl	Over 63.50 to 76.20, incl	120	60
Over 3.000 to 3.500, incl	Over 76.20 to 88.90, incl	135	65
Over 3.500 to 4.000, incl	Over 88.90 to 101.60, incl	150	70
Over 4.000 to 5.000, incl	Over 101.60 to 127.00, incl	165	80
Over 5.000 to 8.000, incl	Over 127.00 to 203.20, incl	210	100