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1.0 SCOPE

This specification covers a direct quench carburize hardening heat treatment.

2.0 APPLICATION

This heat treatment is applicable to carburized parts, which require the combination of a hard case with an intermediate degree of hardness in the core. The hardness of the core is dependent upon the hardenability of the material and section size. Core hardness will be specified on the part number drawing if required.

3.0 QUALIFYING SPECIFICATIONS

- 1E2317 Inspection - Acid Etch
- 1E2532 Microstructure Standards - Carburize Hardening Heat Treatments
- 1E2617 General Requirements - Heat Treat

4.0 DRAWING DESIGNATIONS

4.1 This is a multiple variation specification; the designations A, B, C, and D describe the temper condition, see Figure 1. Additional information concerning temper designations can be found in 1E2617.

Former Designation	Current Designation	Temper
1E2318	1E2318A	Furnace tempering required by reheating quenched parts to 150°C minimum. Drawings of parts other than gears calling for carburize hardening with no temper designation are in this classification.
	1E2318B	Furnace tempering or residual tempering at 150°C minimum permitted.
	1E2318C	Tempering is optional and is not a functional requirement of the part. Drawings of gears without a temper designation are in this classification.
	1E2318D	All tempering including preheating for subsequent assembly is prohibited. Engineering Design Control A528 approval is required to use this drawing designation.

Figure 1

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CARBURIZE AND HARDEN – DIRECT QUENCH CASE AND CORE	DATE 09 NOV 2018	CHG NO 21	NUMBER 1E2318

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5.0 PROCESSING REQUIREMENTS

5.1 Machining Operations

5.1.1 All machining operations including grinding shall be performed before carburizing and hardening, unless stock removal (1E2261) after hardening is permitted or required on the drawing.

5.1.2 If grinding of the gear tooth profile is required to meet the dimensional requirements of the print, hard finishing is allowed provided that the following conditions are met:

5.1.2.1 The hard finishing process shall be controlled to eliminate thermal damage and shall be inspected per 1E2317B (periodic acid etch inspection).

5.1.2.2 Unless otherwise specified on the print, the hard finish stock removal for gear profiles shall not exceed 0.2 mm per flank.

5.1.2.3 The specified surface carbon, surface hardness, hardened depths and microstructure shall be attained on the hard-finished surface. To ensure attainment of the required hardened depths after hard finishing, the carburize depth may be increased up to the amount of stock removal permitted, (see 5.1.2.2 and gear cutter specification).

5.1.3 Hard finishing shall not be permitted after heat treatment on gears in which the actual hardened depth is less than 0.7 mm, and cannot be used as a salvage operation without approval from Engineering Design Control P418.

5.2 Heat Treating Operations

5.2.1 Carburize to obtain the specified hardened depth at a maximum temperature of 955°C.

5.2.2 Furnace cool from the carburizing temperature to a temperature above the Ar₃ temperature of the core material commensurate with preventing excessive amounts of retained austenite.

5.2.3 The quench rate shall be commensurate with section size and hardenability of the material to meet the quality requirements of this specification and the part number drawing.

5.2.4 Unless otherwise specified on the print, deep freezing is prohibited.

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5.2.5 Ammonia additions are prohibited without Engineering Design Control P418 approval.

6.0 QUALITY REQUIREMENTS

6.1 Control of Heat Treat Special Process Characteristics

6.1.1 Special Process Requirements apply only when tighter control of heat treat process parameters beyond normal heat treat process controls are required by a 1E2966 Special

Characteristics note  on the part drawing.

6.1.2 Special Process Requirements

6.1.2.1 Temperature control throughout the furnace workspace shall be checked when furnace is placed in service, after major overhauls, or at a frequency specifically requested by the customer. Temperature uniformity throughout the furnace part workspace shall be within $\pm 5^{\circ}\text{C}$.

6.1.2.2 Thermocouples and temperature controllers shall be checked, managed and results recorded in accordance with ME1004 and MQ1010-90.

6.1.2.3 Furnaces shall be equipped with atmosphere composition- and carbon potential control systems capable of maintaining carbon potentials within ± 0.1 wt.% C in the furnace atmosphere. For control systems utilizing oxygen probe control only, accuracy should be checked with shim stocks per ME1033 at least once a week at each normal operating temperature/atmosphere setpoint. For control systems utilizing oxygen probe and infrared CO/CO₂ control, it is sufficient to check accuracy with shim stocks monthly. Records for each furnace shall be kept by Heat Treat Manufacturing. Control or supervisory system calculated atmosphere levels shall not be substituted for shim stock checking.

6.1.2.4 When new equipment is placed in service, after major overhauls, or at a frequency specifically requested by the customer, the atmosphere uniformity shall be determined by 1) running either test pieces or piece parts throughout furnace workspace, and 2) analyzing for proper surface carbon levels and microstructure.

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CARBURIZE AND HARDEN – DIRECT QUENCH
CASE AND CORE

DATE
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6.1.2.5 A hardened depth test piece, ME1019 fracture bar or piece part (which can be destructively analyzed) shall be run with each load on batch type furnaces. On continuous furnaces, test pieces shall be run at least daily or any time cycle times are changed. The depth shall be within production process limits established by Heat Treat Engineering. The use of control system 'calculated depth' shall not be a substituted for the actual test pieces, but with customer approval, the frequency of test piece checks may be modified if 'calculated depth' control systems are employed.

6.1.2.6 When new equipment is placed in service, after major overhauls, or at a frequency specifically requested by the customer, the quench uniformity and severity shall be determined by running piece parts throughout quench workspace and analyzing for proper microstructure and hardened depth.

6.1.2.7 Quench system shall be equipped with a means of proving adequate quench flow on continuous basis.

6.1.2.8 A maximum transfer time to the quench shall be established for each part number.

6.1.2.9 Parts from each load shall be file tested for as-quenched surface hardness per MH1023.

6.2 Audits

6.2.1 All production parts shall be audited regularly. The frequency of audits shall be negotiated between the Heat Treat supplier and Caterpillar Purchasing in conjunction with ITDD Heat Treat Engineering and Engineering Design Control P418.

6.2.2 The Heat Treat supplier, ITDD Heat Treat Engineering, and Engineering Design Control P418 shall agree to a written test plan for audit procedures. Changes to the audit procedure require approval by all groups. The Heat Treat Supplier and/or ITDD Heat Treat Engineering shall supply a written record of all audits to the Engineering Design Control P418.

6.3 Hardness

6.3.1 If the drawing allows more than 1/3 of the specified minimum hardened depth to be removed, hardness on the finished surfaces shall be commensurate with the remaining amount of hardened depth.

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6.3.2 Hardness required at a specified depth applies only to the location shown on the part number drawing. Hardness at other locations in the part shall be commensurate with section size, distance from the surface, and hardenability of the material. It is intended that hardness testing of the core be performed only when sample parts are sectioned for complete metallurgical evaluation.

6.4 Gear and Spline Quality Requirements

6.4.1 The surface hardness requirement specified for gears shall be met along the entire active profile and root of the gear tooth, see Figure 2.

6.4.2 Surface hardness along the active profile shall be measured via a microhardness taken at 0.10 mm below the surface.

6.4.3 For hard finished gear teeth, the specified surface carbon, surface hardness, hardened depths and microstructure shall be measured and rated on the as-heat treated part and after hard finishing. The requirements of this specification and the relevant print note shall be met in both the as-heat treated and hard finished condition.

6.4.4 When evaluated on as-heat treated parts (before hard finishing), the hardened depth in the root (Location C) shall be at least 60% of that specified for the X location, see Figure 2.

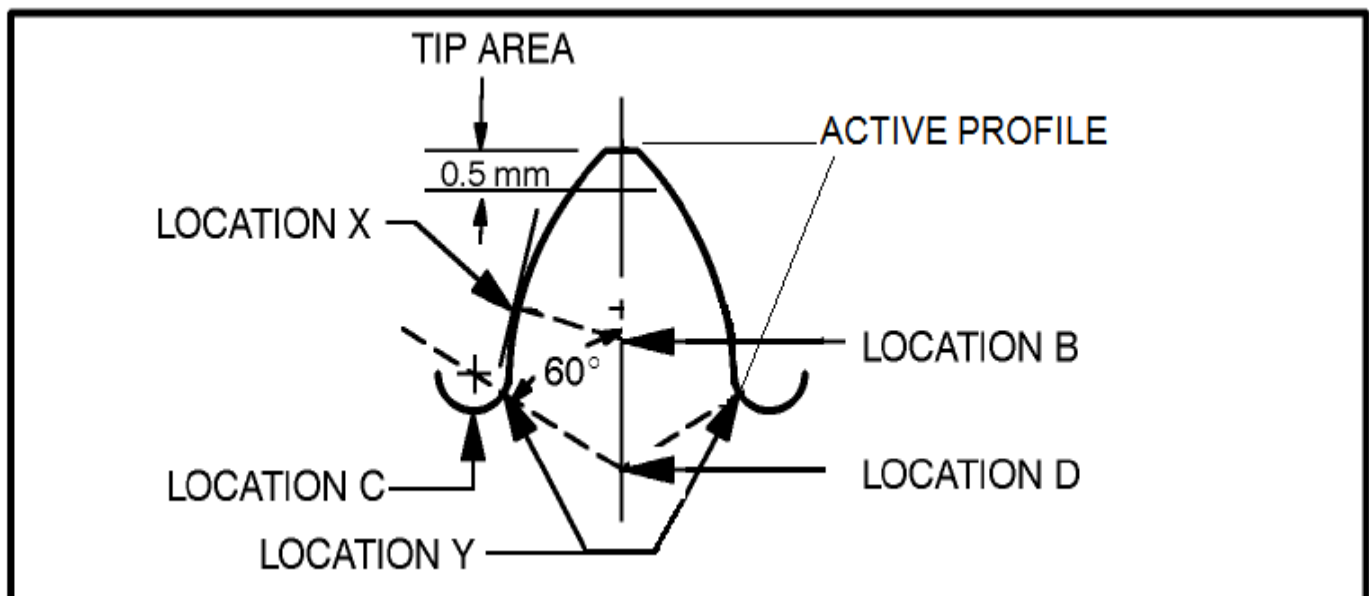


Figure 2 - Test Locations for Gears and Splines

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6.5 Microstructure on Finished Product

6.5.1 Grain size shall be 5 or finer.

6.5.2 All parts processed to this specification shall meet the minimum microstructure requirements of this specification as described below, shown in Figures 3 and 4, and rated according to 1E2532 photomicrographs. 1E2532 Quality photomicrograph copies are available through ITDD Heat Treat Engineering, Design Control A556.

6.5.2.1 All 1E2532 ratings shall be based on observation of several fields of view at the specified location. Ratings shall be made at 500x with the surface visible and located near one edge of the field of view (reference photos in 1E2532). This will include a depth of approximately 0.10-0.12 mm.

6.5.2.2 Note that **Borderline** means marginally acceptable, when rating a microstructure constituent. Continued production at this level is unacceptable. Supplier shall act to bring microstructure within acceptable range. Additional auditing by the supplier is required until process capability is proven.

6.5.3 The surface carbon shall be 0.70-1.00%. Note that an unacceptable level of retained austenite or network carbides is indicative of excessive case carbon levels.

6.5.4 The case microstructure shall consist primarily of martensite (tempered as required).

6.5.5 Oxides shall be rated on un-etched samples, bainite shall be rated on lightly etched samples, and the remaining constituents shall be rated after normal etching with nitric acid in alcohol (Nital) or equivalent etch.

6.5.6 Retained Austenite

6.5.6.1 Acceptability of piece parts shall be based on hardness and microstructure.

6.5.6.2 Hardness shall be measured at a depth of 0.1 mm below the surface using either a 500 g Knoop Hardness (HK .5) or a 1 kg Vickers Hardness (HV 1). Measurement using other hardness scales is not permitted for this requirement. The minimum hardness shall exceed 670 HK .5, or 653 HV 1.

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6.5.7 Carbides

6.5.7.1 Carbides upon Direct Quench - Parts that are fully austenitized at the carburizing temperature and subsequently direct quench hardened per 1E2318 shall be rated according to the direct quench carbide series (DC1 - DC5) in 1E2532.

Note: Direct quenched parts made of 1E4039 or other steel grades, where carbides were present in as-received base steel and remain undissolved at the carburizing temperature, can be rated according to the network carbide series (C1 - C6) in 1E2532 upon approval of ITDD Heat Treat Engineering or Engineering Design Control P418.

6.5.7.2 Carbides upon Reheat Hardening - Parts that are processed according to the allowable alternates 1E2204 - Standard Carburize and 1E2203 - Harden Carburized Case and Core shall be rated according to the network carbide series (C0 - C6) in 1E2532 and 1E2203 requirements.

6.5.8 Core Ferrite - Any evidence of undissolved ferrite (incomplete austenization) in the core shall be cause for rejection (1E2532 ratings F6 and F7).

6.5.9 Microcracks

6.5.9.1 Microcracks are sometimes observed in microstructures when retained austenite and carbon levels are near or above maximum limits. Microcracks may also be caused by metallurgical sample preparation or etching. Samples that do not exhibit microcracks immediately after etching, but exhibit delayed microcracking after etching, are not rejectable for microcracks if all other requirements of this specification are met.

6.5.9.2 Samples containing microcracks should be re-ground to remove a minimum of 0.25 mm and re-polished, lightly etched and observed immediately to determine if microcracks were caused by sample preparation.

6.5.9.3 Parts with microcracks immediately following light etching are rejectable if more than seven (7) microcracks are observed in any single field of view (0.2 mm X 0.15 mm actual size) in the region between the surface and 0.5 mm depth. No microcracks longer than 8 microns actual length are permitted.

6.5.10 Figure 3 contains the 1E2532 quality levels for gears and splines. Figure 4 contains the 1E2532 quality levels for all other carburized components.

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Microstructure Constituent	Location (refer to Figure 2)	Acceptable	Borderline	Non-Conforming
Retained Austenite (see 6.4.6)	Entire Active Profile	< A4	A4	A5
Gears -Surface Bainite/Pearlite	X, depth of 0-0.02 mm	< B2	B2	B3-B7
	C, depth of 0-0.02 mm	B0-B7	N/A	N/A
Gears -Subsurface Bainite/Pearlite	X, depth of 0.02-0.20 mm	< BB3	BB3	BB4-BB7
	C, depth of 0.02-0.20 mm	< BB5	BB5	BB6-BB7
Splines - Surface Bainite/Pearlite ⁽¹⁾	mid-flank (0-0.02 mm)	< B5	B5	B6-B7
	root (0-0.02 mm)	B0-B7	N/A	N/A
Splines - Subsurface Bainite/Pearlite ⁽¹⁾	mid-flank (0.02-0.20 mm)	< BB3	BB3	BB4-BB7
	root (0.02-0.20 mm)	< BB5	BB5	BB6-BB7
Carbides (Direct Quench) 1E2318	Entire Active Profile	< DC1	DC1	DC2-DC5
Decarburization	Entire Active Profile	D0	N/A	D1-D4
	Tip Area	< D1	D1	D2-D4
Grain Boundary Oxides	Entire Active Profile	< O3, depth of 0.018 mm MAX	O3, depth of 0.019 - 0.028 mm	O4, depth greater than 0.028 mm
Ferrite	B, D	F0-F5	N/A	F6-F7

Figure 3 - 1E2532 Quality Levels for Gears and Splines

Note (1): B7 and/or BB7 bainite are acceptable on external or internal splines provided that 85 HR15N surface hardness is attained.

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Microstructure Constituent	Location	Acceptable	Borderline	Non-Conforming
Retained Austenite (see 6.4.6)	Surface to 0.20 mm below surface	< A4	A4	A5
Surface Bainite/Pearlite ⁽¹⁾	Surface to 0.02 mm below surface	< B3	B3	B4-B7
Subsurface Bainite/Pearlite ⁽¹⁾	0.02-0.20 mm below surface	< BB4	BB4	BB5-BB7
Carbides (Direct Quench) 1E2318	Surface	< DC1	DC1	DC2-DC5
Carbides (Reheat Harden) 1E2204/1E2203	Surface	< C3	C3	C4-C6
Decarburization	Surface	< D1	D1	D2-D4
Grain Boundary Oxides	Surface	< O3, depth of 0.018 mm MAX	O3, depth of 0.019-0.028 mm	O4, depth greater than 0.028 mm
Ferrite	Core	F0-F5	N/A	F6-F7

Figure 4 - 1E2532 Quality Levels for all other 1E2318 Carburized Components

Note (1): B7 and BB7 bainite are acceptable on trunnions, trunnion bearings and trunnion caps provided surface hardness and hardened depth are attained.

7.0 ALTERNATE HEAT TREATMENTS

Where it is advantageous to the manufacture of parts, the combination of 1E2204 - Standard Carburize and 1E2203 - Harden Carburized Case and Core heat treatments may be substituted as alternates for 1E2318 - Carburize and Harden - Direct Quench Case and Core heat treatment; however, no alternate to the specified temper type is permitted.

8.0 REFERENCES

Abbreviations 1E0011
Caterpillar 1E2203, 1E2204, 1E2966, 1E4039, ME1004, ME1019, ME1033, MH1023, MQ1010-90

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