1.0 SCOPE

This specification covers interpretations and general requirements of heat treatments and related processing controls specified on Caterpillar Inc. part number drawings.

2.0 GENERAL INTERPRETATIONS

The heat treatment specified on a part number drawing applies to all areas of the part unless selected areas are excluded or qualified. For the quench hardening heat treatments, the most rapid quench shall be employed to obtain the greatest quench hardness and depth of hardening possible without quench cracking. Any post-heat treat stock removal will reduce metallurgical properties such as carburized depth, hardened depth, and surface hardness, depending on the amount of stock removed. As cast, as forged, and wrought steel surfaces exhibit poorer mechanical properties than machined surfaces heat treated to the same hardness level.

2.1 Selective Heat Treatment - Selected areas on a part required or permitted to be heat treated, or required or permitted to be soft are designated on part number drawing as follows:

2.1.1 "H" Lengths - An "H" length dimension defines the minimum area on the part that is required to be hardened to the specified minimum hardness. The "H" length at the hardened depth may be less at either or both ends by an amount equal to the minimum specified hardened depth (see Figure 1).

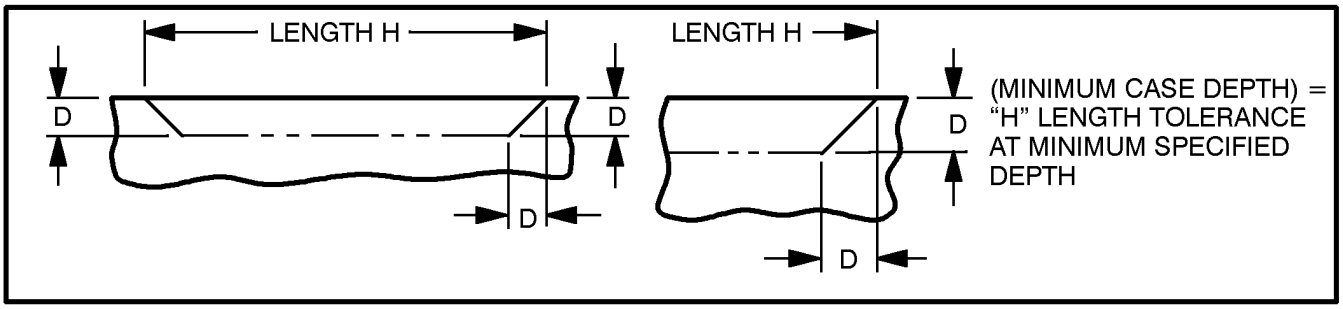

Figure 1

The maximum area allowed to be hardened may be designated on part number drawings by one of the following methods:

2.1.1.1 "H permitted" lengths are specified to designate the maximum allowable boundaries of specified "H" length.

2.1.1.2 "H" lengths are specified alone where the entire extent of a feature or clearly defined protrusion of a part must be hardened. The "H" length may be extended beyond the physical dimension of the part for hardened surfaces bounded by non-square edges. (See Figure 2).

2.1.1.3 An “H” length can be specified with a plus and minus bilateral tolerance or a unilateral plus tolerance minus zero.

2.1.1.4 “Face A, B, etc.” bounded by “H permitted” lengths may be specified where face areas are not clearly defined.

2.1.1.5 “Face A, B, etc.” may be specified alone without “H” and/or “H permitted” lengths if the boundaries of the faces are clearly defined by sharp changes in size or shape.

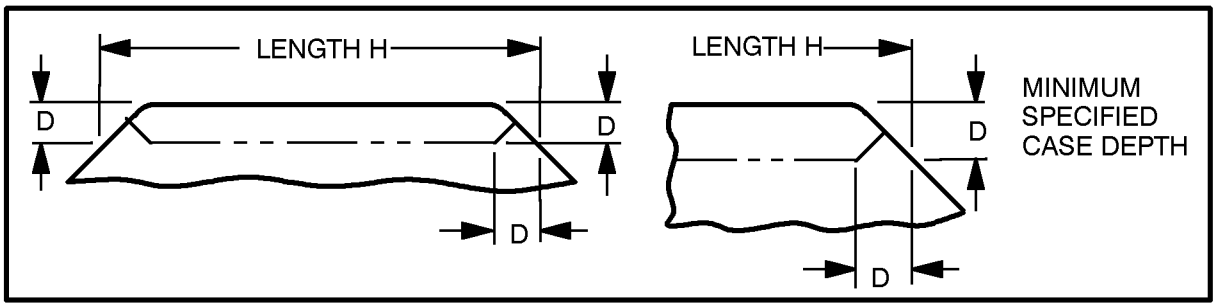

Figure 2

2.1.2 “S” Lengths - An “S” length dimension defines the minimum area on a part that is required to be soft or of a lower hardness than the balance of the heat treated area without qualification as to metallurgical structure. Unless specified otherwise “S” length hardness shall be in the machinable hardness range (normally Rockwell C30 maximum). A hardness range specified in conjunction with an “S” length is typically used to ensure machinability. “S” length requirements may be attained by selective quenching, selective austenitizing, selective tempering, or by protection during heat treat.

2.1.2.1 “S permitted” lengths are specified in conjunction with “S” lengths to designate the maximum allowable boundaries of the specified “S” length. The surface hardness in an “S permitted” length shall be no softer than the minimum allowable hardness for an adjacent “S” length and no harder than the maximum allowable hardness for an adjacent hardened area.

2.1.2.2 An “S permitted” length may be specified alone on a drawing to define a length on a part where heat treat is not required but which may be heat treated to the same requirements as the remainder of the part. Unless an “S permitted” length is qualified with a hardness requirement, such “S permitted” lengths may be left soft or heat treated at the discretion of manufacturing.

2.1.3 Multiple Length Callout - Multiple “H” lengths and “S” lengths are designated H1, H2, H3, and S1, S2, S3, etc. Drawings exist which specify H, HH, HHH, and S, SS, SSS for multiple hard and soft lengths, respectively.

2.1.4 Special notes which designate areas to be hard or soft.

2.1.4.1 Areas required to be hard may be indicated by note as follows:

"Unless otherwise specified (heat treatment, hardness, carb depth, etc.) required only on (gear teeth, Face A, Surface A, etc.)".

2.1.4.2 Areas not required to be hard:

"Unless otherwise specified (heat treatment, hardness, carb depth, etc.) not required on (Face A, Surface A, forged surfaces, etc.)"

2.2 Machine processing after heat treatment is controlled and allowed only as follows:

2.2.1 Heat Treat Specifications - The heat treatment specified qualifies the general extent and/or amount of stock removal that is permitted after heat treatment.

2.2.2 Process Notes - Processing notes and dimensions, or 1E2261 Stock Removal controls specified on the drawing further qualify the extent, amount, and dimensions on which stock removal is allowed beyond that controlled by the heat treat specification.

2.2.3 Commodity Specifications - Commodity specifications such as 1E1042 for pins and dowels may allow the source of supply to control finish stock removal provided the finished part meets all dimensional and geometric tolerances, and all heat treat requirements.

2.2.4 Gear Tooth Profiles

2.2.4.1 Hard finishing cubic boron nitride (except CBN grinding) after heat treat is permitted only where the drawing specifies "gear tooth profile finishing after heat treatment allowed. See gear cutter specification for finish stock". In these cases special gear cutters are specified on the drawing to limit grind removal, thus controlling minimum properties in the part.

2.2.4.2 Cubic boron nitride grinding is permitted after heat treatment without Engineering approval provided:

The CBN process is controlled to eliminate grinding burns, and the specified surface carbon, surface hardness, hardened depths, and microstructure are attained. To ensure attainment of the required hardened depths after grinding, the carburize depth may be increased up to the amount of stock removal permitted. See gear cutter specification.

2.2.4.3 CBN grinding is not permitted after heat treatment on gears that specify 1E0548 (Nitride HDN), and 1E0439 (Carbonitride). It is not permitted on gears in which the actual harden depth is less than 0.7 mm, and cannot be used as a salvage operation without engineering approval.

3.0 QUALITY REQUIREMENTS

Heat treat conformance shall be determined by auditing and testing piece parts. The frequency of auditing shall be determined by quality control unless otherwise qualified on the drawing or in another specification. To avoid excessive destruction of piece parts, test specimens representative of the piece part may be used for production process control. However, rejection or acceptance of piece parts shall not be based on the conformance or non-conformance of the test specimens. When alternate methods of inspection are employed, the heat treat source plant shall periodically audit specimens and piece parts to assure that heat treat quality requirements are attained. In situations where an alternate heat treatment has been used rather than that specified on the print (e.g., 1E2318 as an alternative to 1E2204/1E2203), the quality requirements of the alternate heat treatment shall be used for inspection.

3.1 Surface Hardness

3.1.1 Hardness testing shall be performed on a properly prepared surface with appropriate correction factors applied for geometry when testing on curved surfaces. Correction factors shall be in accordance with ASTM E10 for Brinell hardness testing, ASTM E18 for Rockwell hardness testing, and ASTM E384 for micro hardness testing of metallic materials.

3.1.2 A specified surface hardness applies to a smooth flat surface. If the heat treat specification allows decarburization, it should be removed prior to testing in accordance with Paragraph 3.1.4.4.

3.1.3 The hardness specified immediately following the 1EXXXX heat treat callout, e.g., 1E0106 HDNS BR 3.6-3.9, 1E0288A HDNS length H1 RKW C55 min., 1E2203C HDNS RKW C59 min., etc., applies to the surface of the part in the heat treated condition before any subsequent machining. Surface hardness of the areas requiring heat treatment shall be within the specified hardness range. (See Article 2.0 - General Interpretations on areas requiring heat treatment.)

3.1.4 Testing Methods

3.1.4.1 The hardness test scale specified on the drawing is the hardness test scale to be employed in arbitration of acceptance or rejection of heat treated piece parts, including powdered metal gears. For non P/M gears, any hardness test method must confirm the specified surface hardness. Where other hardness test scales are employed, conversion from one scale to another shall be in accordance with ASTM E140 “standard hardness conversion tables for metals” or SAE J417B “hardness tests and hardness number conversions”.

3.1.4.2 At Caterpillar, Brinell hardness is expressed as the diameter of impression made by the spherical Brinell ball in the metallic surface being tested rather than by Brinell hardness number. Brinell hardness testing shall conform to ASTM E10 standard method of test for Brinell hardness of metallic materials. Brinell hardness callouts on Caterpillar drawings shall be interpreted as being expressed in mm diameter of impression even when mm is not shown.

3.1.4.3 Hardness tests on parts that have been finish machined after heat treatment must be performed with the appropriate hardness test scale in accordance with specimen thickness or case depth remaining on the finished part. See Figure 3 - Guide for Selection of Hardness Test Scale (reference ASTM E18). Minimum specimen size for Brinell hardness tests are detailed in ASTM E10.

In general, valid Brinell hardness tests require a minimum sample size of 15 x 15 x 15 mm.

3.1.4.4 Test Location - Hardness may be measured at any location on the hardened surfaces. Where a test location is specified on the part number drawing, hardness must also be tested on the indicated surface feature and/or location.

3.1.4.5 A test location specified on a machine dimension indicates that the dimension must be processed before heat treatment to provide the specified hardness on the test location feature. Spline teeth shall be tested in the roots and on the tips of the teeth at two locations 180° apart. Where spline teeth and/or roots are either too small or too large to hardness test by an indentation hardness method, alternate methods such as file testing may be used, provided the specified degree of hardness is assured.

3.1.4.6 When inspecting gears, the quality check should insure that the active profile as well as the root meets the minimum specified surface hardness. A microhardness test taken at 0.1 mm depth is considered equivalent to surface hardness. A microhardness test taken with a knoop indenter at 0.1 mm depth will be used for arbitration. Quality checks on the active profile shall be performed by a microhardness tester when possible. Alternate methods, such as file testing, may be used when geometry prohibits the use of a microhardness tester.

SPECIMEN THICKNESS OR THICKNESS OF HARDENED CASE DEPTH IN mm	ROCKWELL SUPERFICIAL HARDNESS			ROCKWELL HARDNESS				
	15N	30N	45N	A	B	C	D	F
0.15	92	--	--	--	--	--	--	--
0.20	90	--	--	--	--	--	--	--
0.25	88	--	--	--	--	--	--	--
0.30	83	82	77	--	--	--	--	--
0.35	76	80	74	--	--	--	--	--
0.40	68	74	72	86	--	--	--	--
0.45	X	66	68	84	--	--	--	--
0.50	X	57	63	82	--	--	77	--
0.55	X	47	58	78	--	69	75	--
0.60	X	X	51	76	94	67	72	98
0.65	X	X	37	71	87	65	68	91
0.70	X	X	20	67	80	62	63	85
0.75	X	X	X	60	71	57	58	77
0.80	X	X	X	X	62	52	51	69
0.85	X	X	X	X	52	45	43	--
0.90	X	X	X	X	40	37	X	--
0.95	X	X	X	X	28	28	X	--
1.00	X	X	X	X	--	20	X	--

X = MATERIAL ORDINARILY TESTED WITH 1/16 INCH BALL (ROCKWELL B OR G)

NOTE: FOR A GIVEN THICKNESS, ANY HARDNESS GREATER THAN THAT CORRESPONDING TO THAT THICKNESS CAN BE TESTED. FOR A GIVEN HARDNESS, MATERIAL OF ANY GREATER THICKNESS THAN THAT CORRESPONDING TO THAT HARDNESS CAN BE TESTED ON THE INDICATED SCALE.

Figure 3 - Guide for Selection of Hardness Test Scale

3.1.4.7 Surface Preparation - When decarburization is permitted on the surface of heat treated parts, it must be removed from the test area to obtain a valid hardness reading. Grinding/buffing of parts to remove decarburization is permitted with the following restrictions. Amount of decarburization to be removed on heat treated parts requiring additional processing must be less than the machining allowance specified on the print. Parts that have been ground for hardness testing to the extent that they will not clean up by subsequent processing are rejectable.

3.1.4.8 Parts having areas machined prior to heat treatment may be buffed to remove tooling marks that may affect hardness readings.

Note: Surfaces of finished parts shall not contain hardness indentations detrimental to the application of the part.

3.2 Hardened Depth - Hardened depth is the depth of hardness on the as hardened (and tempered if required) part prior to any subsequent machining.

3.2.1 Testing Methods - Unless otherwise qualified by another specification, or a specific hardness and depth on the drawing, the hardened depth is the depth as measured perpendicularly from the surface to a point of hardness as follows:

3.2.1.1 Rockwell C50, when the specified minimum surface hardness is Rockwell C55 or greater.

3.2.1.2 5 points Rockwell C lower than the specified minimum surface hardness, when the specified minimum surface hardness is less than Rockwell C55.

3.2.1.3 Testing shall be performed by an appropriate microhardness tester. Conversion to RKW C hardness values shall be made in accordance with ASTM E140 “standard hardness conversion tables for metals” or SAE J417B “hardness tests and hardness number conversions.”

3.2.2 Carburize-Hardened Depth - All carburizing steels used in gears with a base carbon content between 0.18-0.23% inclusive shall have a maximum hardness after heat treat of HRC 48 at location B. See Figure 4.

3.2.3 Hardened Depth Measurements on Gears

3.2.3.1 An “X” dimension specified in conjunction with the heat treatment on drawings of gears fixes the Location “X” on the tooth profile from which hardened depth, and other related metallurgical requirements are to be measured or observed. Test specimens shall be sectioned from a part through the middle of the tooth face width.

When an “X” dimension is shown, measure down from the tip of the tooth along the tooth centerline a distance equal to Dimension “X”. Then construct a line perpendicular to the centerline extending from the “X” dimension to the point of intersection with the surface as shown in Figure 4. Requirements shall be measured along a line perpendicular to a line tangent to the tooth surface at this location.

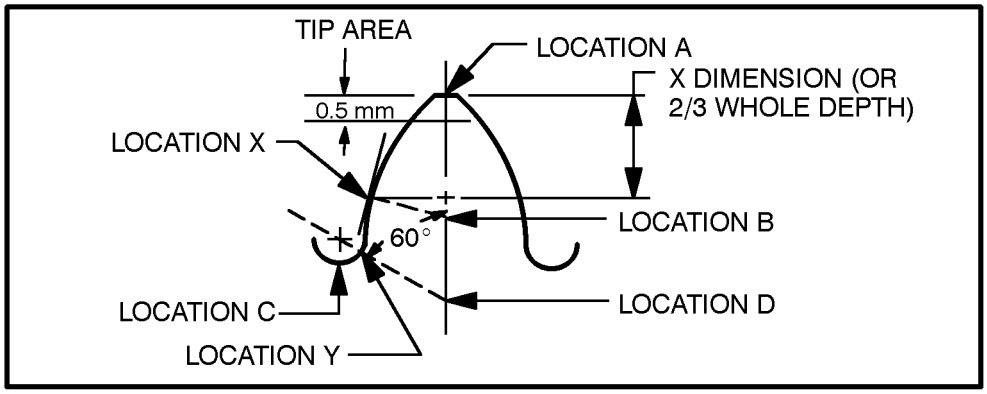

Figure 4 - X Dimension Location

When an “X” dimension is not specified, quality requirements shall be measured along a line constructed as shown in Figure 4, originating from a point two-thirds the distance measured from the tooth tip towards a line constructed tangent to the two adjacent root radii.

3.2.3.2 Core hardness shall be evaluated at Test Location B (Figure 4) using a Rockwell C indentation.

3.2.3.3 Hardness probes from Location “Y” shall be taken along a line forming a 60° included angle with the gear tooth centerline and thru the point of origin of the root radius. (See Figure 4.) Hardness depth readings shall be taken in increments as needed to construct the actual hardness depth curve from Location “Y” through Location “D”. Unless otherwise specified by the engineering drawing, the hardened depths as measured at the “Y” location shall not be used as a basis for rejection. Location “C” is defined as the root center.

3.2.3.4 Unless otherwise specified on the print, for gears where the bore serves as a bearing race, the minimum hardened depth on the bore shall be 85% of the hardened depth requirements specified for the teeth at Location X, minus the maximum allowable stock removal per 1E2261 as allowed on the print. For gears that run with sleeve bearings only, or have pressed-in bearing races, the surface hardness on the finished bore surface shall be HRC 50 minimum, unless otherwise noted on the print.

3.3 Carburizing (Applicable Only to Parts Specifying a Carburize Hardening Heat Treatment)

3.3.1 Process Restrictions - Use of ammonia in atmospheres used for carburizing or hardening of carburized parts is prohibited, unless specifically allowed in the carburizing or hardening specification.

3.3.2 Conversion of Carburized Depth Ranges to Hardened Depth - Prints that specify a standard carburized depth range can convert to a hardened depth range by the following:

3.3.2.1 Determine the required minimum hardened depth. If not available on the part print then the minimum hardened depth is equal to the minimum carburized depth for plain carbon steels, or else equal to 0.1 mm greater than the minimum carburized depth for alloy steels.

3.3.2.2 Find the maximum allowable hardened depth in the following graph or chart using the minimum hardened depth that was determined in Article 3.3.2.1.

3.3.2.3 If a “carb depth permitted” is called out on a print, then a “hardened depth permitted” must also be allowed. If the maximum hardness depth is 1.3 mm or less, the permitted hardened depth would be 0.3 mm greater. If the maximum hardened depth is more than 1.3 mm, the permitted hardened depth would be 0.4 mm greater.

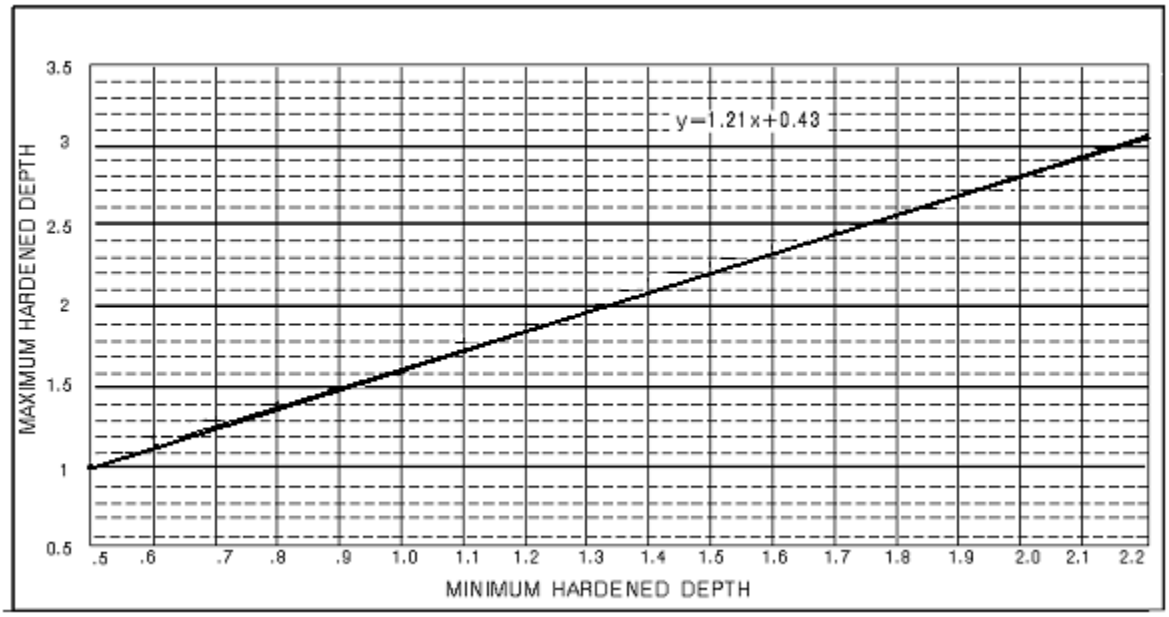

Figure 5 – MIN/MAX Hardened Depth Relationship

Minimum HDN Depth (mm)	Maximum HDN Depth (mm)	Minimum HDN Depth (mm)	Maximum HDN Depth (mm)
0.5	1.0	1.4	2.2
0.6	1.2	1.5	2.3
0.7	1.3	1.6	2.4
0.8	1.4	1.7	2.5
0.9	1.5	1.8	2.6
1.0	1.6	1.9	2.7
1.1	1.8	2.0	2.8
1.2	1.9	2.1	3.0
1.3	2.0	2.2	3.1

3.3.3 Piece part loading and the carburizing cycle shall be controlled to produce an evenly distributed hypereutectoid (0.70-1.0% carbon at the surface) case on all machined surfaces of the part. Unless otherwise qualified by another specification or the part number drawing the following apply:

3.3.3.1 Hardened and Carburized Depth - Hardened depth specified is applicable to the part in the as heat treated condition prior to any subsequent finish processing allowed by processing dimensions or 1E2261 Stock Removal Control on the part number drawing or by another specification.

3.3.3.2 Carburizing shall be accomplished by gas carburizing. The carburizing cycle (time and temperature) shall be controlled to maintain an ASTM grain size of 5 or finer in the hardened product.

3.3.3.3 The hardened depth specified applies to exposed surfaces. The hardened depth on various other features such as drilled holes, keyways, outside and inside radii, and corners may vary from the specified depth by 60%.

3.3.4 Temper Designations

3.3.4.1 For 1E0288 Induction Hardening used in conjunction with carburizing, the temper designation applies to 1E0288 only.

3.3.4.2 Letter designations A, B, C, or D following carburize hardening callouts, such as, 1E2203A, 1E2318D, etc., are interpreted as follows:

3.3.4.3 Letter “A” designation following the carburize hardening specification callout requires furnace tempering 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.

3.3.4.4 Letter “B” designation following the carburize hardening specification callout permits either furnace tempering or residual tempering at 150°C minimum.

3.3.4.5 Letter “C” designation following the carburize hardening specification callout indicates that tempering is optional and is not a functional requirement of the part. Drawings of gears without a temper designation are in this classification.

3.3.4.6 Letter “D” designation following the carburize hardening specification callout prohibits all tempering including preheating for subsequent assembly.

3.4 Surface Defects

3.4.1 Cracks and Laps - No cracks or laps are permitted on heat treated parts except where a specification or the drawing qualifies the extent to which cracks or laps are permitted.

3.4.2 Burns - Burns on heat treated surfaces which can be observed by the naked eye or which can be revealed by acid etching, such as the procedure outlined in 1E2317 for acid etch inspection of gears, are cause for rejection.

3.4.2.1 Burns caused by arcing of a high frequency current or inductor with the surface of the metal being heated will generally melt the surface and can usually be identified by visual inspection.

3.4.2.2 Burns resulting from grinding or any other type of machining can cause localized tempering, residual temper stresses at the surface, and occasionally surface cracking.

3.5 Decarburization

3.5.1 Carbon Free Depth (CFD) is defined as decarburization with sufficient carbon loss to form clearly defined surface ferrite grains under metallographic examination. CFD results from the part being heated above the A3 temperature in a decarburizing atmosphere. CFD ferrite should not be confused with other forms of ferrite resulting from the following conditions:

3.5.1.1 Incomplete solution during austenitizing (blocky ferrite).

3.5.1.2 Slack quenching or insufficient steel hardenability (acicular ferrite).

3.5.1.3 Temperature falls below the A3 temperature prior to quenching (acicular or blocky ferrite).

3.5.2 Maximum Affected Depth (MAD) is decarburization with loss of carbon sufficient to cause a lighter shade of tempered martensite when examined metallographically. An alternate method to detect MAD is to take micro hardness probes (Tukon or Vickers Diamond Pyramid) in the MAD area. A hardness 3 points or more Rockwell C lower than adjacent base metal hardness indicates the presence of MAD.

4.0 PROCESSING CONSIDERATIONS

4.1 Dimensional Stability - Any size changes or distortion to the geometry of piece parts caused by heat treatment or subsequent heating or preheating operations must be compensated for to provide an acceptable part meeting drawing requirements.

4.1.1 Heat Treat Tooling - Piece parts may require special heat treat tooling to provide the required dimensional and geometric accuracy in the finished heat treated part. Heat treat tooling may consist of various types of supports used during the heating cycle and/or universal manifolds, special fixtures, dies, plugs, and expanding locators for quenching.

4.1.2 Test Lots - On components, which prohibit finish machining after heat treat, the component dimensions apply **after heat treat**. To obtain forging dimensions, multiply by the appropriate heat treat growth factor to be provided by the heat treat facility. In addition, test lots may be needed to determine a machined size and tolerance, which will provide the finished part dimension, and geometric tolerances in the heat treated condition. Even when the drawing permits or requires finish machining after heat treatment, a test lot may be needed to assure that the actual amount of stock removed after heat treat provides piece parts meeting the dimensional, geometrical, and metallurgical requirements of the drawing. 1E0348 Test Lot is called out on many drawings as an aid to the producer to indicate that size changes which occur during heat treat may necessitate determination of a size and tolerance which will produce

acceptable piece parts after heat treat. It is impossible without considerable background data to foresee which dimensions require a test lot, i.e., a length dimension with apparent ample tolerance may require a test lot the same as a closely toleranced hole dimension. The need for test lot data is the responsibility of the producer, and is generally shared between manufacturing and planning. 1E0348 Test Lot is not specified on new drawings and the producer has full responsibility to determine the need for test lots.

4.1.3 Annealing Prior to Heat Treatment - Where necessary to relieve residual stresses, improve machinability, or minimize distortion in subsequent heat treatment, manufacturing may opt to add a preliminary subcritical anneal or 1E0579 Anneal Operation before machining or heat treat.

4.2 Post Heat Treat Considerations - Unless allowed by the piece part drawing or a higher level drawing, heating operations for hot straightening or hot assembly, performed after the heat treatment of a part, shall be performed at a temperature which does not reduce the mechanical properties of the part or material below those specified. Consideration must also be given to the effect on material properties, which may not be specified (e.g., formability, toughness, etc.).

4.2.1 Mechanical Straightening - Unless restricted by the part number drawing, mechanical straightening may be employed after heat treatment to fulfill geometric tolerances. Warm straightening (150°C) is required when hardness is equivalent to or greater than Rockwell C40.

4.2.2 Preheating For Assembly - Preheating may be employed to expand parts for assembly to reduce interference fit. A combination of cooling one part and heating another may be required when a maximum preheat temperature is specified on a drawing.

5.0 NITRIDE HARDENED PARTS

Nitride hardened parts, particularly gears require conformance to the proper machine processing sequence relative to heat treatment and to proper control of both the direct hardening and nitride hardening processes.

5.1 Machine Processing

5.1.1 Provisions in 1E0106 and 1E0107 specifications which allow processing to finished dimensions before direct hardening do not apply to parts subsequently nitride hardened.

5.1.2 Parts specifying 1E0106 Direct Harden may be rough machined before direct hardening the same as required for parts specifying 1E0107.

5.1.3 Surfaces to be nitride hardened must be finish machined after direct hardening and before nitride hardening. Finish machine stock removal must be sufficient to remove all of the carbon depleted zone (including maximum affected depth) or carbon enriched zone resulting from the furnace atmosphere during direct hardening.

5.1.4 Processing after nitride hardening is allowed only on dimensions specifying the note "gear tooth profile grinding allowed" or 1E2261 Stock Removal Control. See Paragraph 2.2.4.2.

5.2 Direct Hardening (1E0106 or 1E0107) Prior to Nitride

5.2.1 Quench Medium - Parts direct hardened prior to nitriding must conform to the requirements listed in Article 6.0 of this specification and those listed in the individual direct hardening heat treat specifications with the following exceptions:

5.2.1.1 1E0509 and 1E0681 steels shall be oil quenched.

5.2.1.2 1E1286 may be either oil or water quenched.

5.2.2 Tempering - The minimum tempering temperature after hardening is 565°C.

5.2.3 Microstructure Requirement - The direct hardened microstructure, in the area of the nitride case depth below all surfaces requiring nitriding, shall be primarily tempered martensite with little or no evidence of intermediate transformation products.

Note: Nitriding of decarburized surfaces and microstructures containing intermediate transformation products produces brittle iron nitrides which have low ductility and impact properties and are unacceptable beyond the extent of the white layer depth permitted by 1E0548 (see Paragraph 5.1.3).

6.0 DIRECT HARDENED PARTS

6.1 Quench Rate

6.1.1 Direct harden employing a quench rate, which provides the greatest quench hardness and hardened depth attainable with the specified material and section size without quench cracking.

6.1.2 To assure process control, as quenched surface hardness and tempering temperature should remain constant for a specified material and section size from batch to batch. For parts heat treated at Caterpillar Facilities, consult Caterpillar Manufacturing Practice ME4000 for relationships between material, as quenched surface hardness and tempering temperature.

6.2 Microstructure - Microstructure of direct hardened parts shall disclose evidence of being fully quenched, essentially martensitic at the surface containing no evidence of blocky ferrite resulting from incomplete austenization.

6.3 Consult the individual heat treat specifications for additional processing and quality requirements.

7.0 REFERENCES

Caterpillar Specifications	1E0106, 1E0107, 1E0288, 1E0288A, 1E0348, 1E0439, 1E0509, 1E0548, 1E0579, 1E0681, 1E1042, 1E1286, 1E2203, 1E2203A, 1E2203C, 1E2204, 1E2261, 1E2317, 1E2318, 1E2318D
Caterpillar Manufacturing Practice	ME4000, MH1023
ASTM	E10, E18, E140, E384
SAE	J417B