1.0 SCOPE

This specification establishes photomicrograph standards for guidance in maintaining acceptable microstructures in carburize hardened parts. The primary constituent in a carburize hardened microstructure shall be composed of martensite (tempered as required). This specification establishes measurements for the secondary constituents in the martensitic matrix.

2.0 APPLICATION

For metallographic rating purposes, only printed copies from Design Control A556 are to be used. Reproduction of the photomicrographs in this specification for metallurgical inspection purposes is strictly prohibited. Original copies are available through T&SD Heat Treat Engineering, Design Control A556. This specification is applicable to all standard carburize and hardening combinations of heat treatments except 1E2204 carburize in combination with 1E0288 induction hardening.

3.0 ACCEPTANCE STANDARDS

3.1 Unless otherwise qualified, microstructure quality levels for each micro-constituent requiring control are designated in the carburize hardening specifications or by precedence in a commodity specification. Quality levels are designated as acceptable, borderline, and rejectable. Borderline level implies tentative acceptance of immediate production quantities provided action is taken to bring subsequent parts produced up to acceptance levels. Photographs in this specification are polished samples of carburize hardened structures, lightly etched with nital, and observed at 500 magnifications.

ON-LINE VIEWERS NEEDING BETTER RESOLUTION OF PHOTOS THAN AVAILABLE ON SCREEN SHOULD CONTACT DESIGN CONTROL.

THE INFORMATION HEREON IS THE PROPERTY OF CATERPILLAR INC. AND/OR ITS SUBSIDIARIES. WITHOUT WRITTEN PERMISSION, ANY COPYING, TRANSMITTAL TO OTHERS, AND ANY USE EXCEPT THAT FOR WHICH IT IS LOANED, IS PROHIBITED.

3.2 The photomicrographs are identified alpha numerically. The letter designates the micro-constituent under evaluation (see Figure 1) and the number indicates the relative quantity or depth present.

A	Series Retained Austenite
C	Series Carbide Networks
B	Series Surface Bainite/Pearlite
BB	Series Subsurface Bainite
M	Series Microcracks
O	Series Oxides
F	Series Ferrite
D	Series Decarburization
DC	Series Direct Quench Carbides

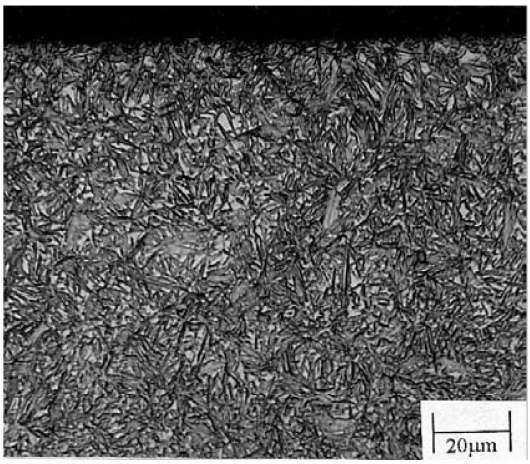
Figure 1

4.0 REFERENCES

Caterpillar Specifications 1E0288, 1E2204

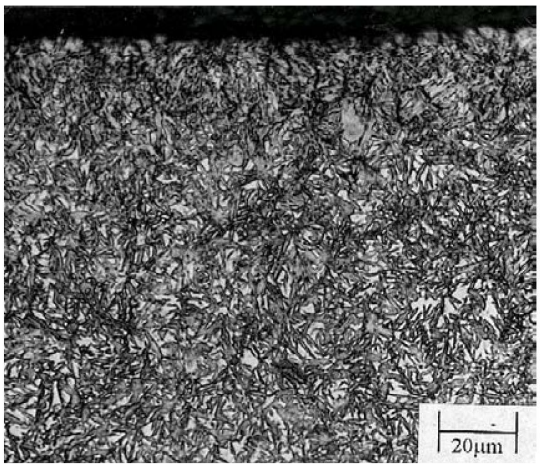
THE INFORMATION HEREON IS THE PROPERTY OF CATERPILLAR INC. AND/OR ITS SUBSIDIARIES. WITHOUT WRITTEN PERMISSION, ANY COPYING, TRANSMITTAL TO OTHERS, AND ANY USE EXCEPT THAT FOR WHICH IT IS LOANED, IS PROHIBITED.

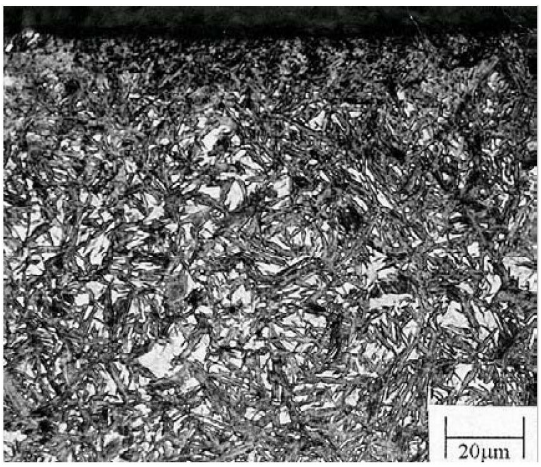
RETAINED AUSTENITE (500 MAGNIFICATIONS)



A1
24%

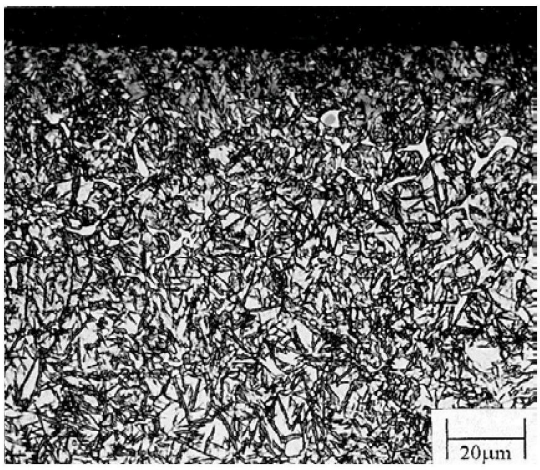
A2
30%

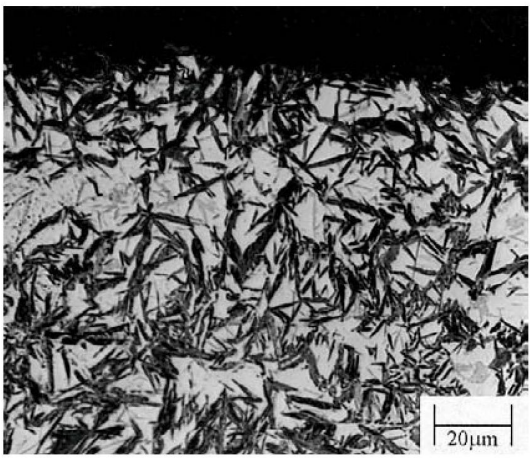




A3
36%

A4
48%





A5
55%

Note:

1. Designated percentages of retained austenite were obtained from x-ray diffraction. Optical estimates will tend to be lower.

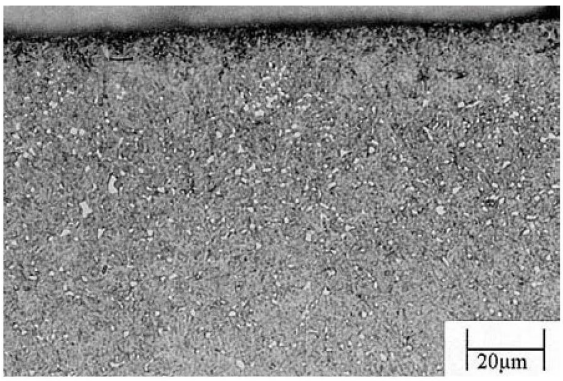
2. These photomicrographs are direct quenched microstructures. Reheat hardened structures will at times be more refined, making optical estimations difficult.

3. Unless otherwise specified, final acceptance of retained austenite shall be upon conformance to surface hardness requirements.

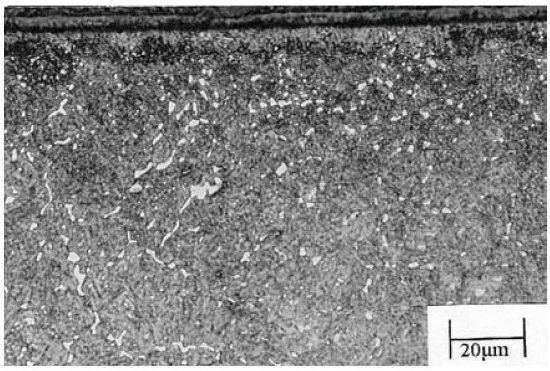
THE INFORMATION HEREON IS THE PROPERTY OF CATERPILLAR INC. AND/OR ITS SUBSIDIARIES. WITHOUT WRITTEN PERMISSION, ANY COPYING, TRANSMITTAL TO OTHERS, AND ANY USE EXCEPT THAT FOR WHICH IT IS LOANED, IS PROHIBITED.

NETWORK CARBIDES (500 MAGNIFICATIONS)

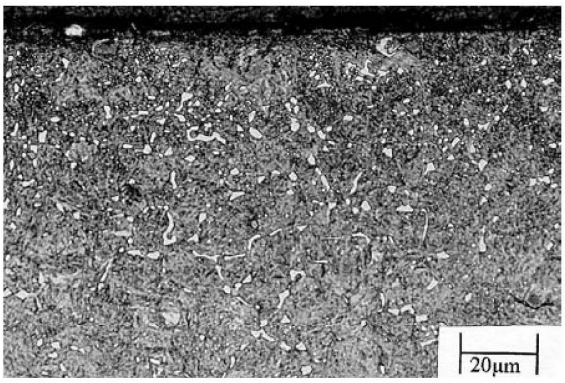
C1



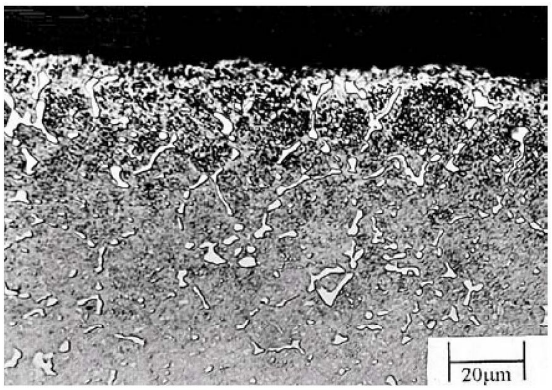
C2



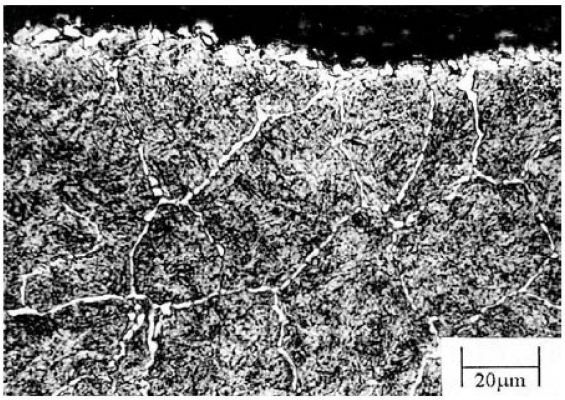
C3



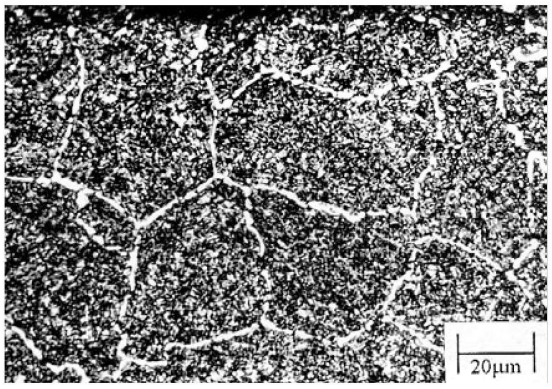
C4



C5



C6

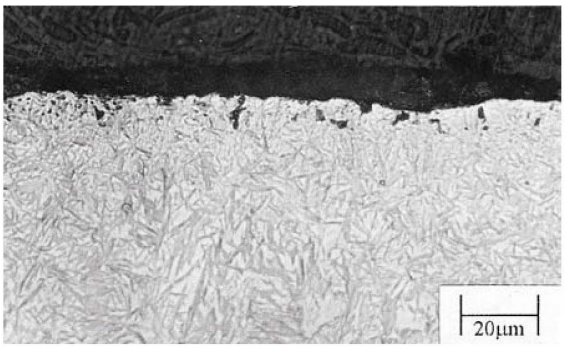


Note: Carbide ratings should be based on shape and tendency to form a carbide network, not on size or depth.

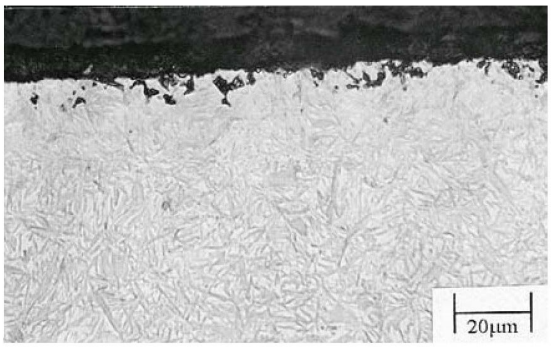
THE INFORMATION HEREON IS THE PROPERTY OF CATERPILLAR INC. AND/OR ITS SUBSIDIARIES. WITHOUT WRITTEN PERMISSION, ANY COPYING, TRANSMITTAL TO OTHERS, AND ANY USE EXCEPT THAT FOR WHICH IT IS LOANED, IS PROHIBITED.

SURFACE BAINITE/PEARLITE (500 MAGNIFICATIONS)

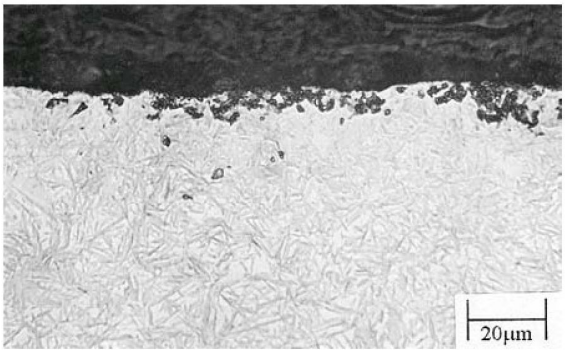
B1



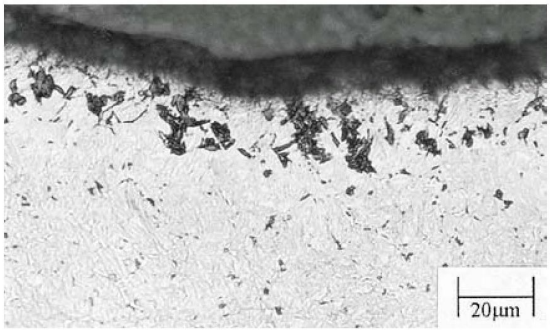
B2



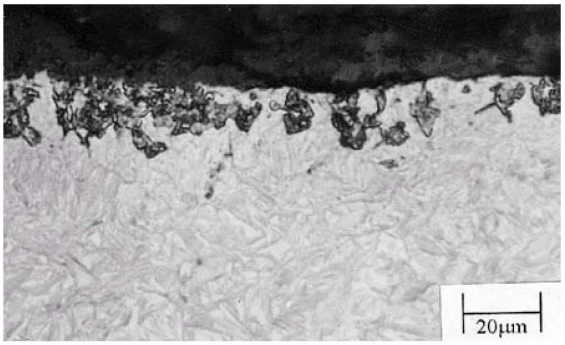
B3



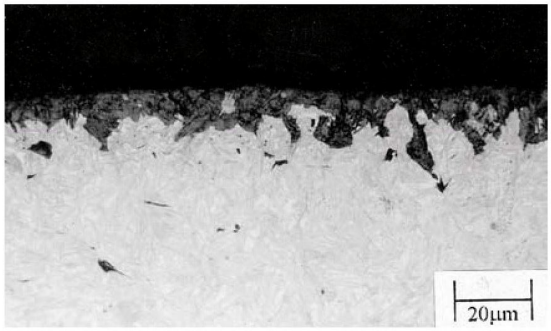
B4

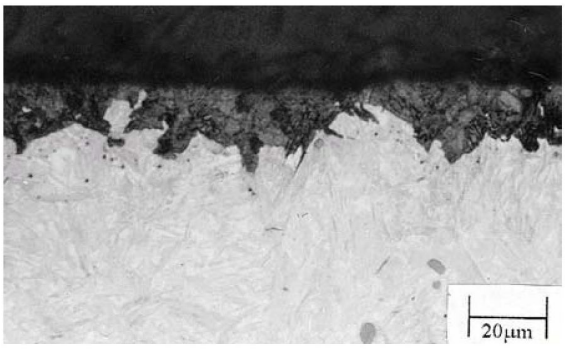


B5



B6



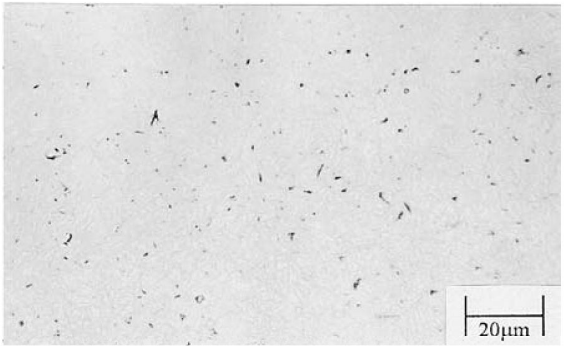


Note: Bainite/Pearlite ratings should be based on tendency to form a continuous layer, not on the depth of individual islands.

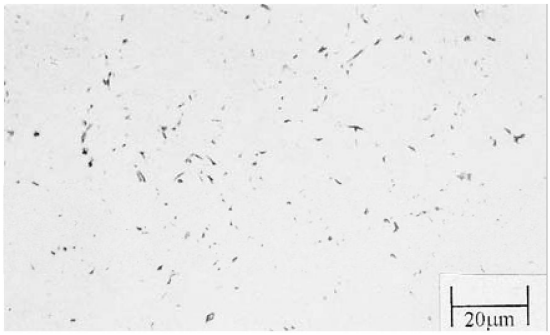
THE INFORMATION HEREON IS THE PROPERTY OF CATERPILLAR INC. AND/OR ITS SUBSIDIARIES. WITHOUT WRITTEN PERMISSION, ANY COPYING, TRANSMITTAL TO OTHERS, AND ANY USE EXCEPT THAT FOR WHICH IT IS LOANED, IS PROHIBITED.

SUBSURFACE BAINITE (500 MAGNIFICATIONS)

BB1

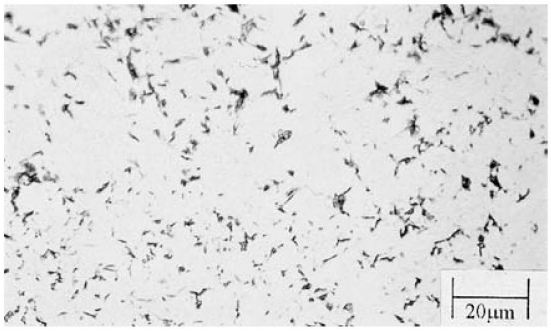


BB2

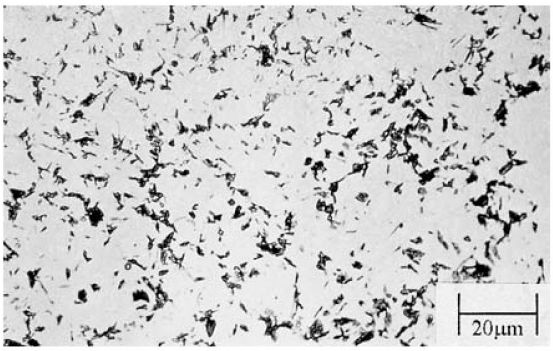


BB3

BB4



BB5



BB6

BB7

Note: Subsurface bainite ratings should be based on tendency to form a continuous layer, not on the depth of individual islands.

THE INFORMATION HEREON IS THE PROPERTY OF CATERPILLAR INC. AND/OR ITS SUBSIDIARIES. WITHOUT WRITTEN PERMISSION, ANY COPYING, TRANSMITTAL TO OTHERS, AND ANY USE EXCEPT THAT FOR WHICH IT IS LOANED, IS PROHIBITED.

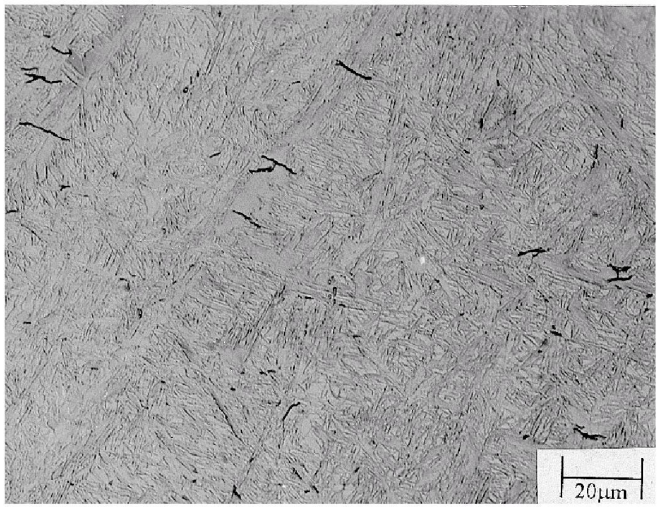
MICROCRACKS (500 MAGNIFICATIONS)

M1

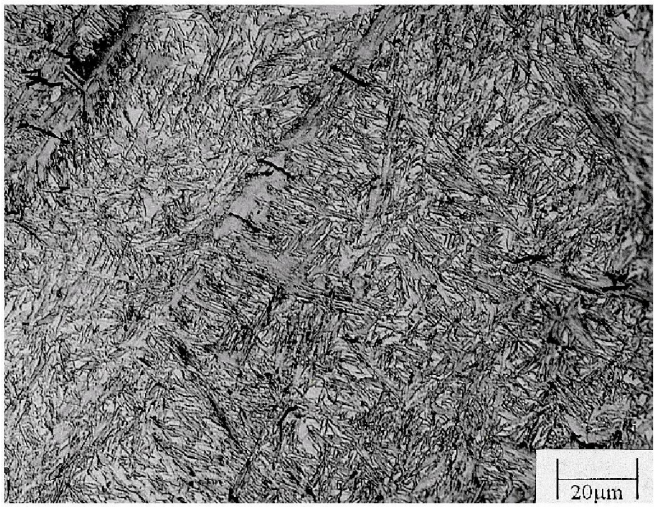
Note: A specimen shall be rated as M1 or higher under either of the following conditions:

1. Seven or more microcracks are visible in any field at 500X.

2. The longest microcracks in any field at 500X is 4 mm or longer.



M2



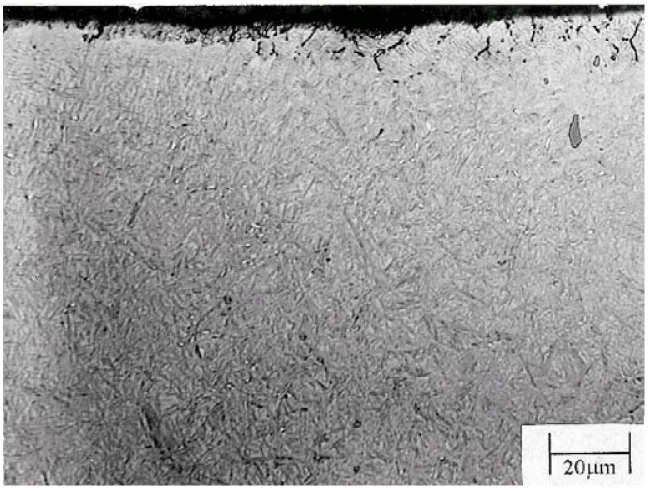
$M2^1$

Note: M2 is an example of resolution of microcracks by light etching. $M2^1$ is an example of masking of microcracks by dark etching, which improves resolution of martensite and retained austenite but tends to obscure resolution of microcracks. M2 and $M2^1$ are from the same sample and field.

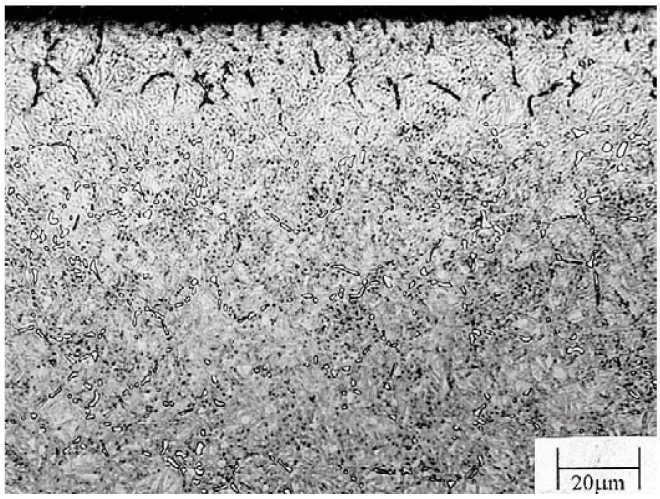
THE INFORMATION HEREON IS THE PROPERTY OF CATERPILLAR INC. AND/OR ITS SUBSIDIARIES. WITHOUT WRITTEN PERMISSION, ANY COPYING, TRANSMITTAL TO OTHERS, AND ANY USE EXCEPT THAT FOR WHICH IT IS LOANED, IS PROHIBITED.

OXIDES (500 MAGNIFICATIONS)

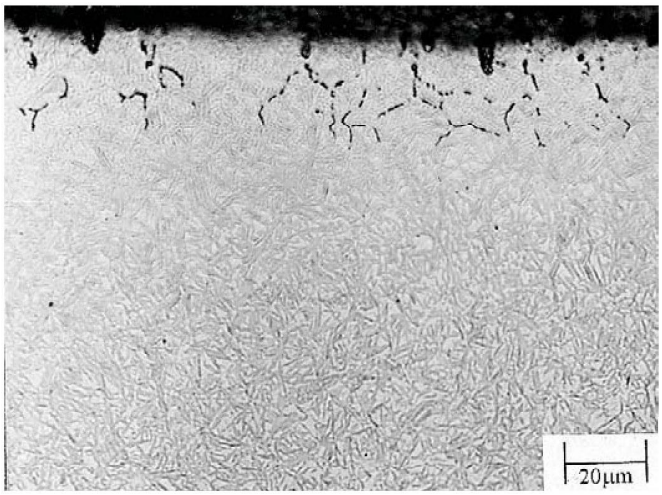
O1 (4 micrometers)



O2 (12 micrometers)



O3 (24 micrometers)

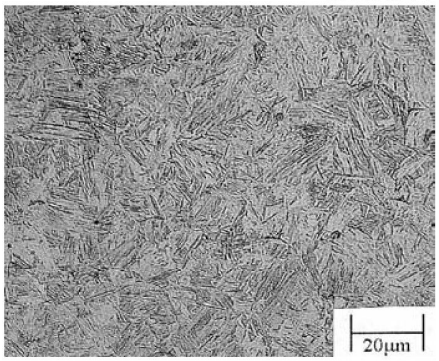


O4 (32 micrometers)

Note: Oxide rating should be based on depth rather than continuity.

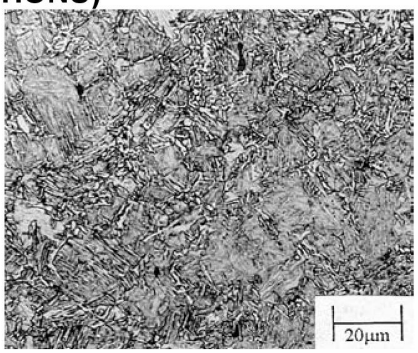
THE INFORMATION HEREON IS THE PROPERTY OF CATERPILLAR INC. AND/OR ITS SUBSIDIARIES. WITHOUT WRITTEN PERMISSION, ANY COPYING, TRANSMITTAL TO OTHERS, AND ANY USE EXCEPT THAT FOR WHICH IT IS LOANED, IS PROHIBITED.

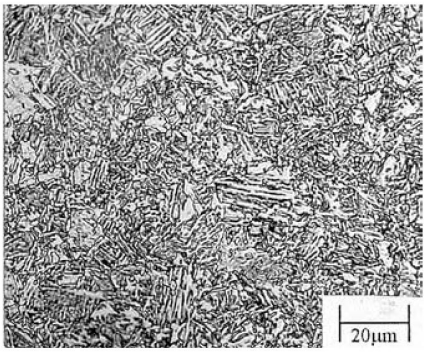
CORE FERRITE (500 MAGNIFICATIONS)



F1 43 HRC

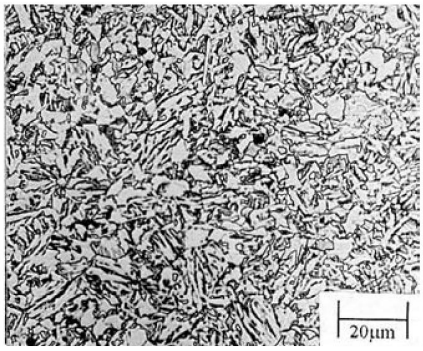
F2 38 HRC

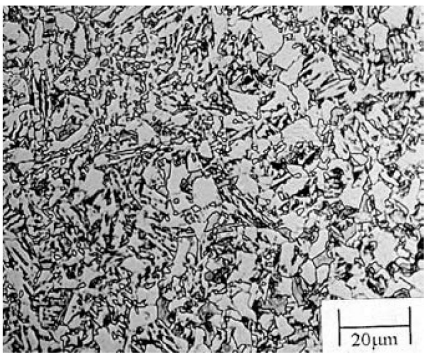




F3 30 HRC

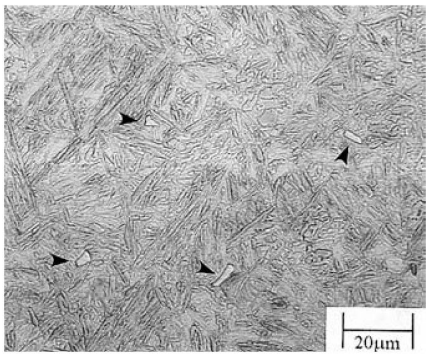
F4 25 HRC





F5 20 HRC

NOTE: F1 – F5 show transformation ferrite formed upon cooling from a fully austenitic condition. F6 and F7 show islands of undissolved or blocky ferrite, evidence of incomplete austenization prior to quenching.

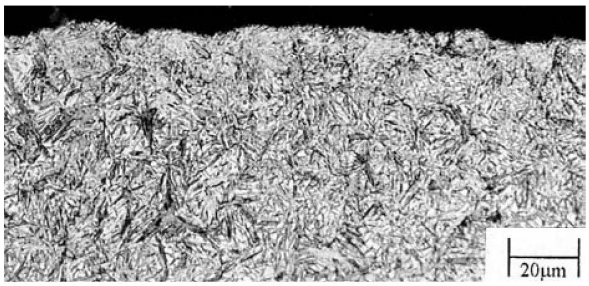


F6

F7

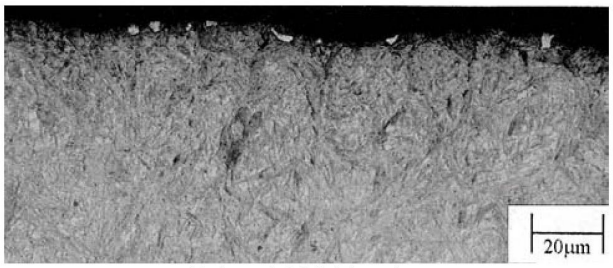
THE INFORMATION HEREON IS THE PROPERTY OF CATERPILLAR INC. AND/OR ITS SUBSIDIARIES. WITHOUT WRITTEN PERMISSION, ANY COPYING, TRANSMITTAL TO OTHERS, AND ANY USE EXCEPT THAT FOR WHICH IT IS LOANED, IS PROHIBITED.

DECARB (500 MAGNIFICATIONS)

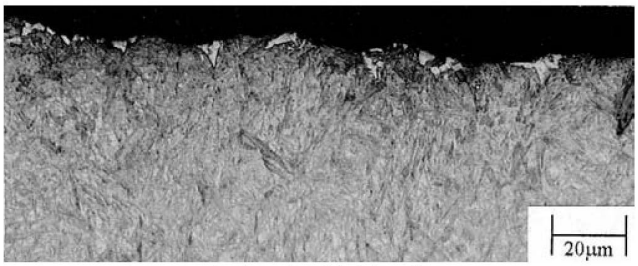


D0 - No Ferrite

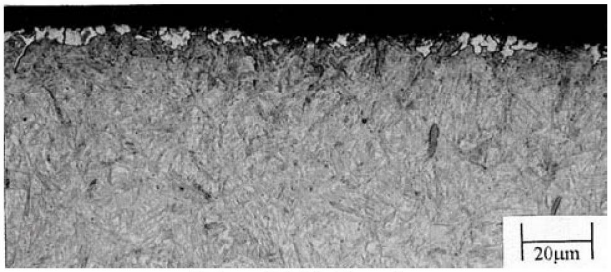
NOTE: The D1 rating should be used to indicate percent surface ferrite for levels of decarburization less than a continuous surface layer. D2-D4 represents various depths of continuous surface ferrite layers.



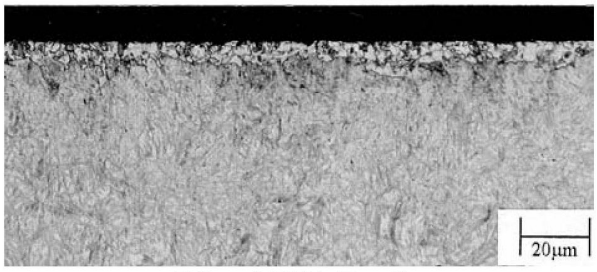
D1 – 10% Ferrite



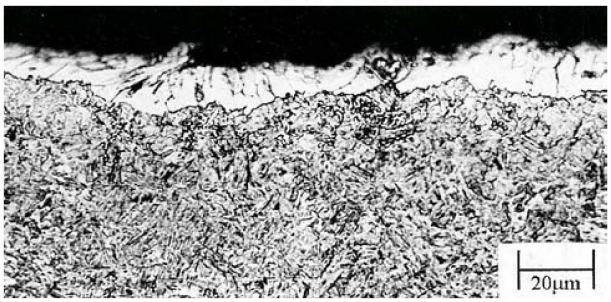
D1 – 30% Ferrite



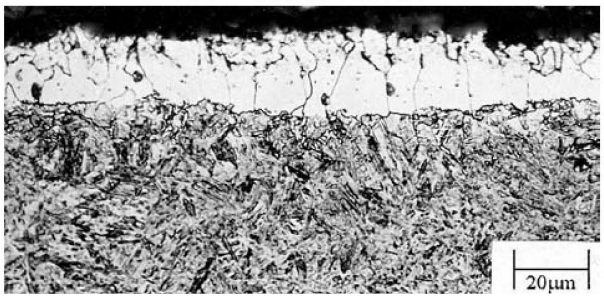
D1 – 50% Ferrite



D2 – 100% Ferrite



D3

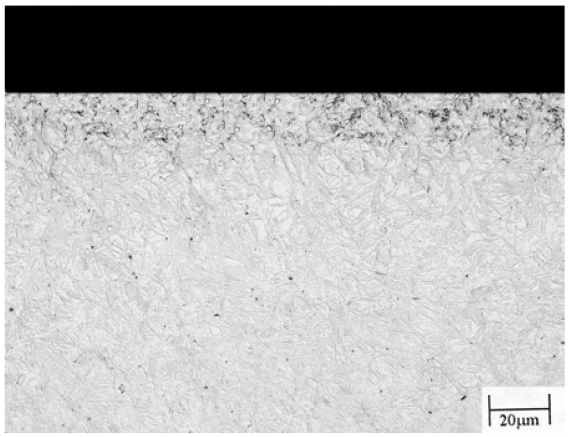


D4

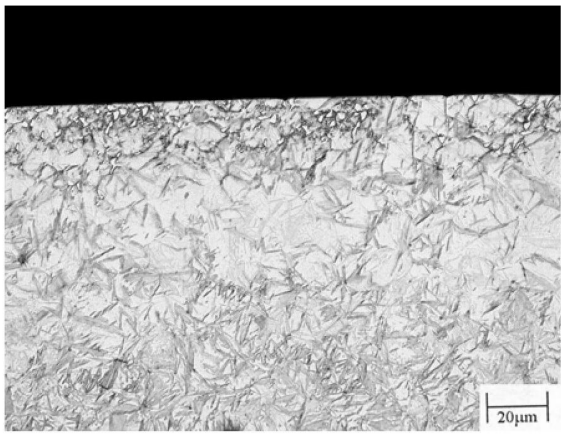
THE INFORMATION HEREON IS THE PROPERTY OF CATERPILLAR INC. AND/OR ITS SUBSIDIARIES. WITHOUT WRITTEN PERMISSION, ANY COPYING, TRANSMITTAL TO OTHERS, AND ANY USE EXCEPT THAT FOR WHICH IT IS LOANED, IS PROHIBITED.

DIRECT QUENCH CARBIDE (500 MAGNIFICATIONS)

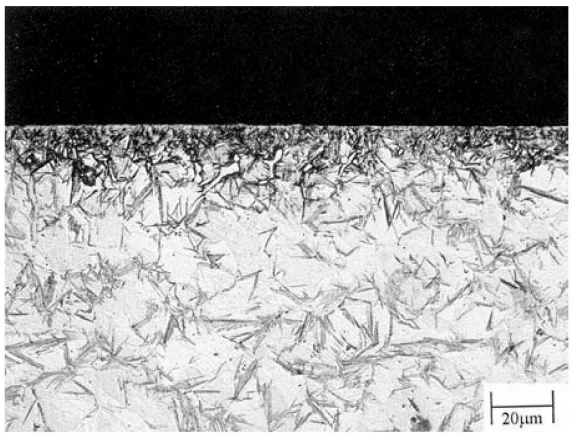
DC1



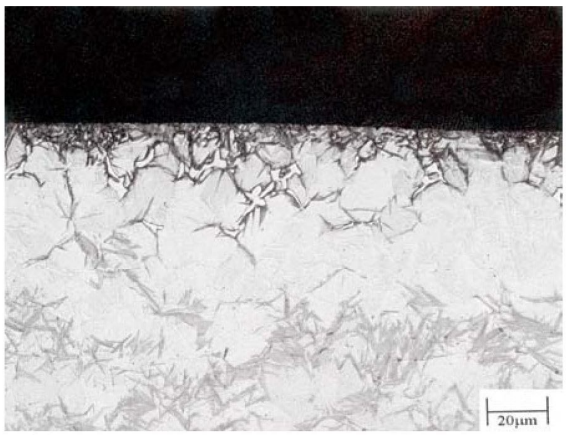
DC2



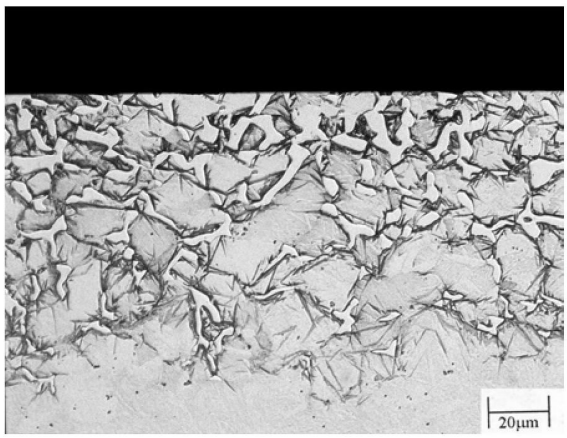
DC3



DC4



DC5



THE INFORMATION HEREON IS THE PROPERTY OF CATERPILLAR INC. AND/OR ITS SUBSIDIARIES. WITHOUT WRITTEN PERMISSION, ANY COPYING, TRANSMITTAL TO OTHERS, AND ANY USE EXCEPT THAT FOR WHICH IT IS LOANED, IS PROHIBITED.

1E2532 Quality Levels
Samples Polished, Light Nital Etched, and Observed at 500 Magnification (Except Oxides Unetched)

Retained Austenite	Bainite or Pearlite				Carbides	Decarb			Micro-cracks	Grain Boundary Oxides	Ferrite
	Surface to 0.02 mm Depth										
A3 Acceptable A4 Borderline A5 Rejectable **Note:** See 6.2.5.	Gears and External Splines	Loc "X"	B1 Acceptable B2 Borderline B3 Rejectable	Other Parts *	**For 1E2318 Processed Parts:** DC1 Borderline DC2 Rejectable	Gears and Splines	Tip Area	D0 Acceptable** D1 Borderline D2 Rejectable	**Note:** See 6.2.7	**Gears and Splines** O2 Acceptable O3 Borderline O4 Rejectable	F6 Rejectable **Note:** Any evidence of undissolved ferrite (incomplete austenization) in the core shall be cause for rejection.
		Loc "C"	B7 Acceptable (0.02 mm MAX Depth)	B3 Borderline B4 Rejectable							
	0.02 to 0.20mm Depth						Active Profile	D0 Acceptable** D1 Rejectable			
	Gears and External Splines		**At "X" Location** BB3 Borderline BB4 Rejectable **At "C" Location** BB5 Borderline BB6 Rejectable		**For Altn HT (1E2204/1E2203) Parts:** C2 Acceptable C3 Borderline C4 Rejectable	Other Parts	D0 Acceptable** D1 Borderline D2 Rejectable			**Other Parts** O3 Acceptable O4 Borderline	
	*Other Parts		BB4 Borderline BB5 Rejectable								

Figure 2

Note*: B7 and BB7 bainite is acceptable on internal splines, trunnions, trunnion bearings, and trunnion caps provided surface hardness and hardened depth are attained.

Note:** D0 decarb shall show no visual evidence of carbon depletion (affected depth).

Definition: Borderline means marginally acceptable. 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.

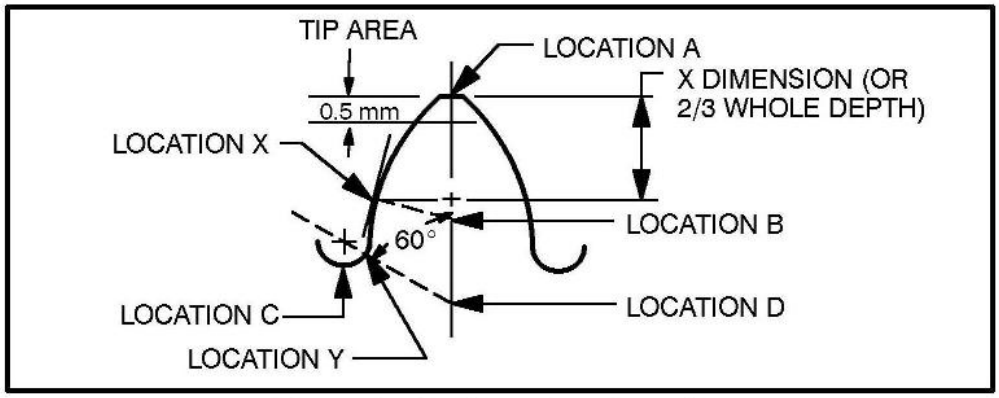


Figure 4 - X Dimension Location