

NAVISTAR, INC.		
Material, Parts, and Process Specifications (MPAPS)		NUMBER: MPAPS A-0 PART III
TITLE: Classification System for Heat Treated Steels	CURRENT Rev. No.: 1408	DATE: AUGUST 2014
WRITTEN/REVIEWED BY: Materials Engineering	APPROVED BY: Materials Engineering	SUPERSEDES: CEMS A-0 Pt III - August 2012
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<i>This specification may involve hazardous materials, equipment, and procedures. This specification does not purport to address all of the safety issues associated with its use. The user is responsible to consult appropriate safety and health practices and to determine the applicability of regulatory limits prior to use.</i>		
Change Notice: Changed to new MPAPS format; removed Table 4 for global steels, and old Table 5 became Table 4; editorial changes.		

1.0 SCOPE

MPAPS A-0 consists of three major sections:

Part I – Chemical Composition of Standard Steels

Part II – System of Steel Classification for Standard Steels

Part III – Classification System for Heat Treated Steels

1.1 Restricted Chemical Substances

Effective January 1, 2007, all product supplied to the requirements of this specification must comply with the requirements of the MPAPS B-50 specification.

2.0 INTRODUCTION

MPAPS A-0 Part III defines a system of classifying steels for heat treated applications by carbon content and hardenability, rather than by chemical composition. It can be used for quenched and tempered and carburized and hardened applications. This system should be used on engineering drawings throughout the Corporation wherever practicable. This system allows the use of optional steels for the manufacture of parts. The major objectives of this specification are:

2.1 To provide manufacturing with a system for the selection of equivalent steels, without the necessity of obtaining the approval of the controlling Design Engineering department. This allows for optimum use of inventory and will facilitate world-wide design.

2.2 To permit outside suppliers of finished parts the maximum freedom in steel selection consistent with maintaining the required properties.

2.3. To allow development and use of more economical steels.

3.0 CONTENTS

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4.0 REFERENCE DOCUMENTS

Unless otherwise specified, the latest issue of all referenced standards shall apply. The following standards, specifications and regulations are referenced in this specification.

Quality System Standard ISO 9001 or TS-16949	ASTM E 112
CFR Title 29, Part 1910	NAVISTAR CEMS AT-2
NAVISTAR Manufacturing Standard MS-D-13	NAVISTAR CEMS AT-3
NAVISTAR Engineering Procedural Std. EPS-89	ASTM A 255
NAVISTAR Engineering Procedural Std EPS-155	ASTM E 18
NAVISTAR MPAPS B-50	

5.0 CLASSIFICATION BY STEEL CODE

5.1 Selection of Steel Code

The responsibility for the selection of a steel code to be shown on the drawing is a function of the controlling design engineering department. It is imperative that Materials Engineering personnel be consulted by the designer before a code is selected. See EPS-89 and EPS-155, Design Control and World Design Standards and Control, respectively. For the selection of a particular steel within the required code, see “Steel Ordered by Navistar Operations,” Section 10.1, or “Steel Ordered by Outside Suppliers,” Section 10.2.

The basis for the classification system is the hardness-distance relationship as measured on a standard end quench test specimen (Jominy bar). Many standard steels have published hardenability bands which represent data from a large number of heats.

Selection of the carbon content and the hardenability required will define the steels that can be used. Steels with equivalent carbon content and hardenability will essentially have the same Jominy bar hardness-distance relationship.

5.2 Hardenability Criteria

The primary hardenability criterion used is the distance corresponding to the hardness of a 50% martensitic structure. This structure is more indicative of the comparative hardenability characteristics of steels than other percentages of martensite. However, provision is made for the use of criteria other than 50% martensite where required.

5.3 Description Of Code

This coding system for heat treated steels consists of two parts: carbon content and hardenability requirements. An example of the code would be:

C34-51E4-32

where the term “C34-51” indicates the allowable carbon content range (0.34 to 0.51%) and “E4-32” describes the hardenability requirements (50% martensite hardness values) in terms of Jominy bar (J) distances (4/16 to 32/16 inch). An “E” prefix indicates that the “J” distances are in 1/16 inch customary U.S. units; whereas, an “M” prefix would mean the “J” distances are in mm (metric units).

5.3.1 The code system describes four points on a hardenability plot. The first two points are related to the carbon range shown in the code and indicates the minimum and maximum RC hardness at J = 1/16

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inch (or 1.5 mm). Values are listed in Table 1 for carbon contents thru 0.65%. The other two points represent hardenability limits at J distances beyond 1/16 inch (or 1.5 mm) as shown in the second part of the code. A minimum hardness as related to the minimum carbon content is designated at the first J distance and a maximum hardness as related to the maximum carbon content is designated at the second J distance. Hardness values for these J distances are related to percent martensite in the heat treated structure and will vary according to the coding criteria used for a given application. Values for various percents martensite versus carbon content, through 0.70% Carbon, are listed in Tables 1 and 2.

5.3.2 Figure 1 illustrates a plot of the four points, based on 50% martensite, described by the example: C34-51E4-32 (See Table 1 for values.)

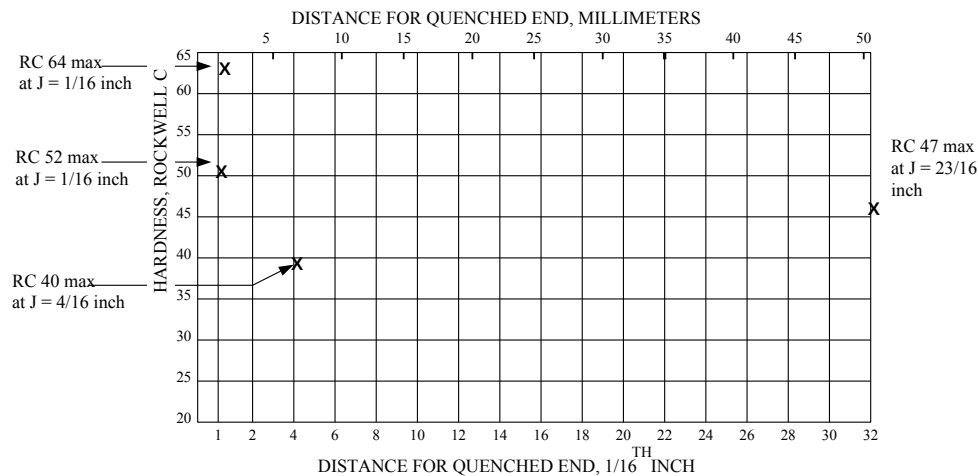


Figure 1 - Example Plot of C34-51E4-32

5.3.3 When desired to include free machining steels, the code may be modified to include an “F” suffix letter, e.g., C34-51E4-32F. See “Chemical Composition,” page 14. Numbers appearing in parentheses after the “J” distance number in this example, either after the 4 and/or 32, indicate minimum RC hardness for the 4/16 position and maximum RC hardness for the 32/16 position.

NOTE: Utilization of this coding system in specifying heat treated steels must be used in conjunction with a specific heat treatment note applied to the individual piece part drawing. It is to be recognized that this combination of material code and heat treat note is designed to provide the desired mechanical properties in the finished piece part. A change in material, even within a given code, may require an adjustment to the heat treat process.

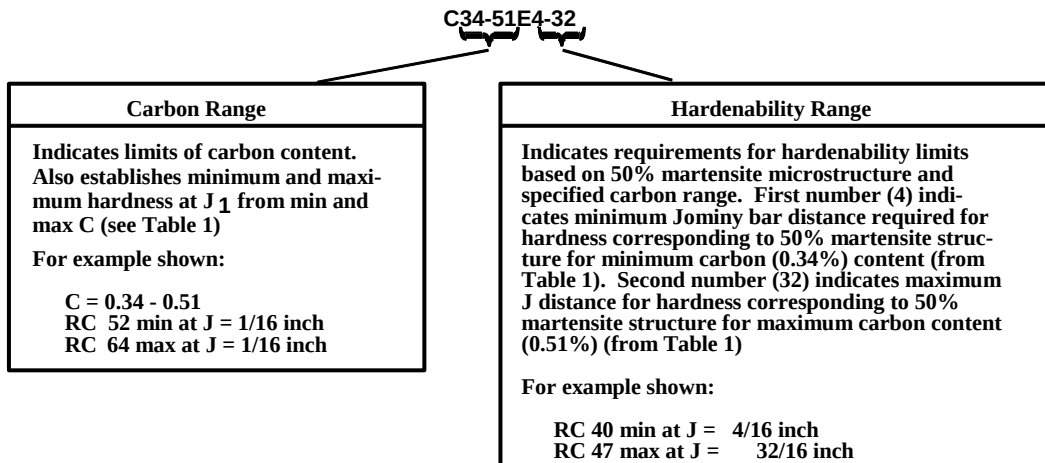
5.4 Coding Criteria

5.4.1 50% Martensite

The 50% martensite microstructure criteria as associated with D_I (Ideal Critical Diameter) is the most common indicator for comparing hardenability characteristics of steels. This is the primary method for selecting a code for heat treated steels and should be used wherever possible to allow the largest latitude in material sections. An example of a code thus selected is:

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5.4.2 Figure 2 shows a plot of the four points defined by the example C34-51E4-32. The hardenability band for 8640H is also plotted to demonstrate its compliance with this code. The complete band of the following steels also comply with this code: 15B41H, 4140H, 5140H and 8740H.

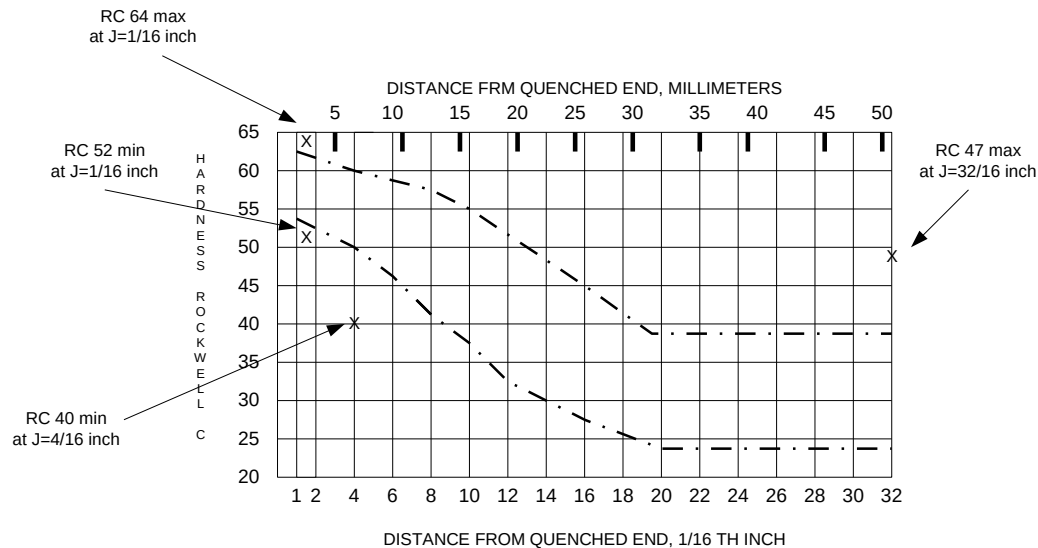


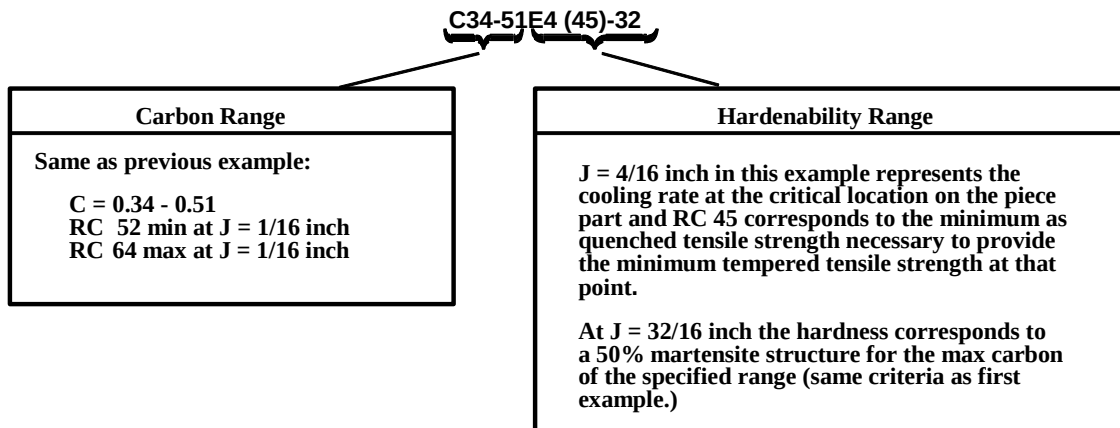
Figure 2 - Example C34-51E4-32 and 8640H Band

5.5 Hardness At A Jominy Distance

When a given application requires a specific minimum tensile strength in excess of what the 50% martensite criteria would indicate, the code can be modified to reflect these requirements at some location in the piece part. This is achieved by noting the hardness corresponding to the required as quenched tensile strength in parentheses following the specified minimum J distance in the code. The J distance shown in the code is to reflect the Jominy equivalent cooling rate at the critical location in the piece part. An example of this type of code is:

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5.5.1 Figure 3 shows a plot of the four points defined by the second example, C34-51E4(45)-32. The hardenability band for 4140H is also plotted to demonstrate its compliance with this code requiring hardness at a specified distance. The complete band of the following steels also complies with this code: 4137H, 15B41, 8340H and 5140H.

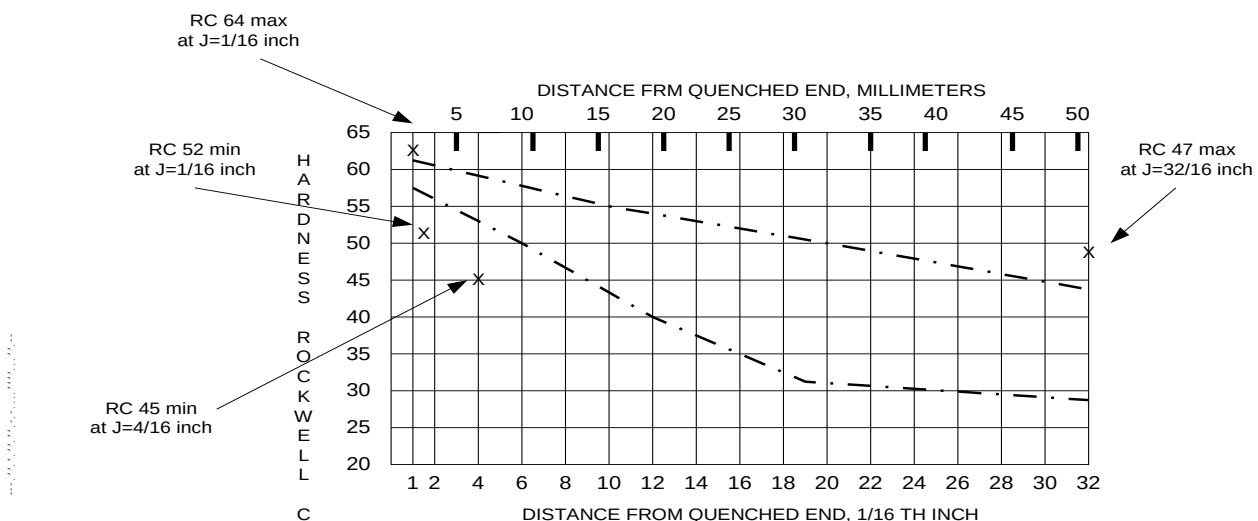


Figure 3 - Example C34-51E4(45)-32 and 4140H Band

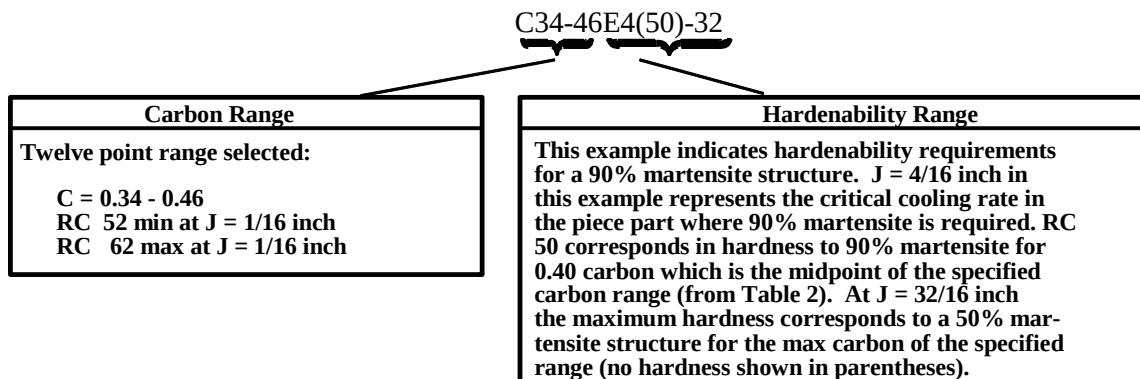
5.6 Hardness And Microstructure At A Jominy Distance

Other applications, for fatigue or other reasons, may require microstructure controls as well as strength requirements at some location in the piece part. The code can also be written to accommodate these needs. In these applications where an 80% or more martensitic structure is required, the recommended carbon range is limited to a 12 point spread (see discussion in Appendix for recommended carbon ranges). The minimum J distance shown in the code should reflect the Jominy equivalent cooling rate at the critical location on the piece part where the desired strength and microstructure are needed. A satisfactory code is developed by selecting the hardness corresponding to the desired percent martensitic structure for the midpoint carbon content of the specified carbon range and noting it in parentheses next

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to the minimum J distance requirement. Table 2 lists hardnesses versus carbon content for 80, 90, 95, and 99.9% martensite microstructures. An example of this type of code is:



5.6.1 The heat treat note that accompanies the steel code must contain information indicating that the required hardness of the piece part is based upon a specific percent martensite. An example of this is:

Steel Code: C34-46E4(50)-32, MPAPS A-0 Part III

Heat Treatment: Quench and Temper to HRC 30-37. HRC 25 minimum at the midradius with a minimum 90% martensite

5.6.2 Previous steel codes denoting microstructure requirements may have used an asterisk in parentheses (*) next to the minimum J distance requirement plus a note indicating the percent martensite required. See “Appendix - General Information” for explanation.

5.6.2.1 Figure 4 shows a plot of the four points defined by the example C34-46E4(50)-32. The hardenability band for 15B41H is also plotted to demonstrate its compliance with this code requiring a 90% martensite microstructure at a specified J distance. The complete band of the following steels also comply with this code: 8642H, 8640H, 50B40H and 4140H.

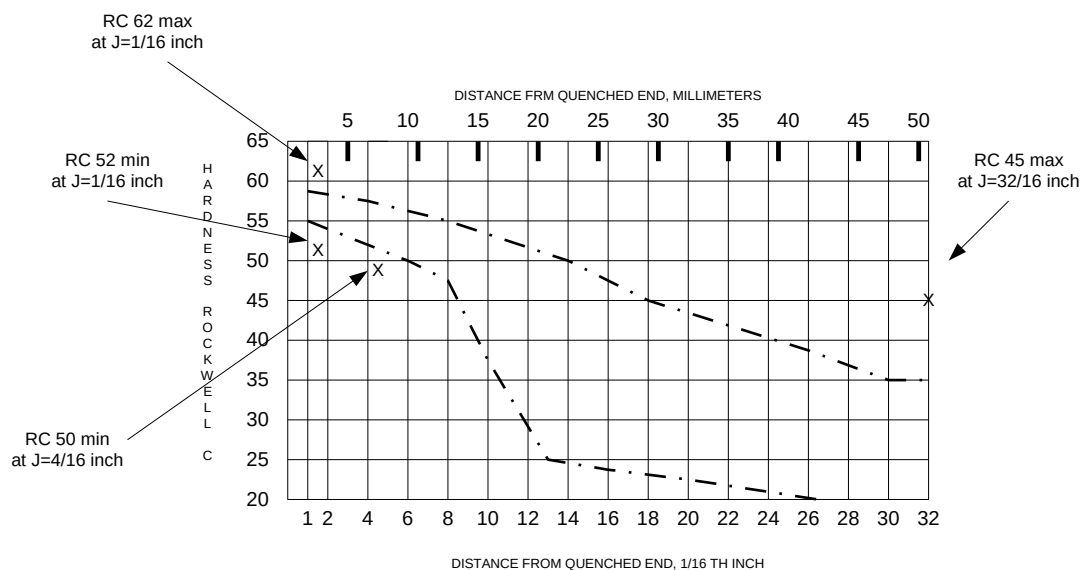


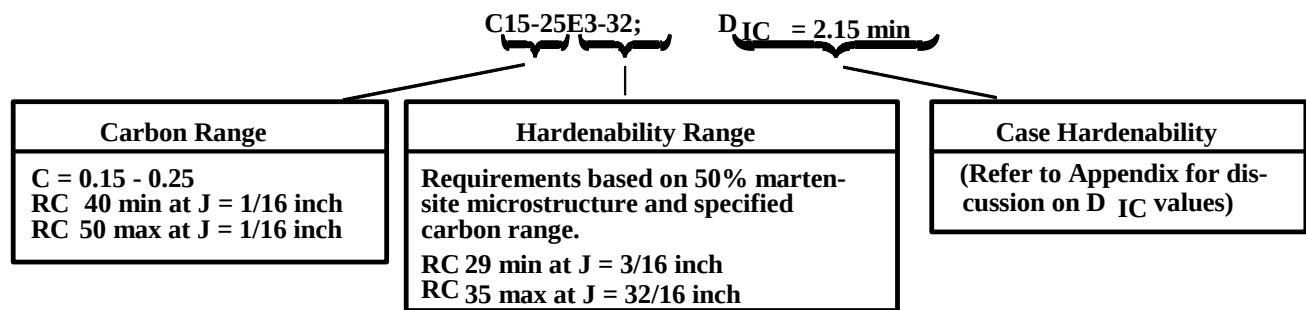
Figure 4 – Example C34-46E4(50)-32 and 15B41H Band

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5.7 Carburized And Hardened Applications

The coding system can be used for carburized and hardened steel applications to control core hardenability. In these applications it is also required to specify and control the minimum case hardenability. In these applications, it is also required to specify and control the minimum case hardenability D_{IC} . A method for calculating case hardenability is shown in CEMS AT-3 where D_{IC} values for many standard steels are also shown. The method for coding carburized applications is the same as for quenched and tempered parts except that the carbon contents will normally not exceed 0.30% and a minimum D_{IC} must be specified. When a minimum core hardness or microstructure is required, procedures should be followed for criteria other than 50% martensite as outlined in the preceding sections. An example of a code for a carburized application using the 50% martensite criteria is:



5.7.1 Figure 5 shows a plot of the four points defined by the example C15-25E3-32. The hardenability band for 8620H is also plotted to demonstrate its compliance with this code. The complete band of the following steels also comply with this code: 4320H, 4820H, PS15H, and PS16H. The minimum D_{IC} for 8620H is 4.45 inch.

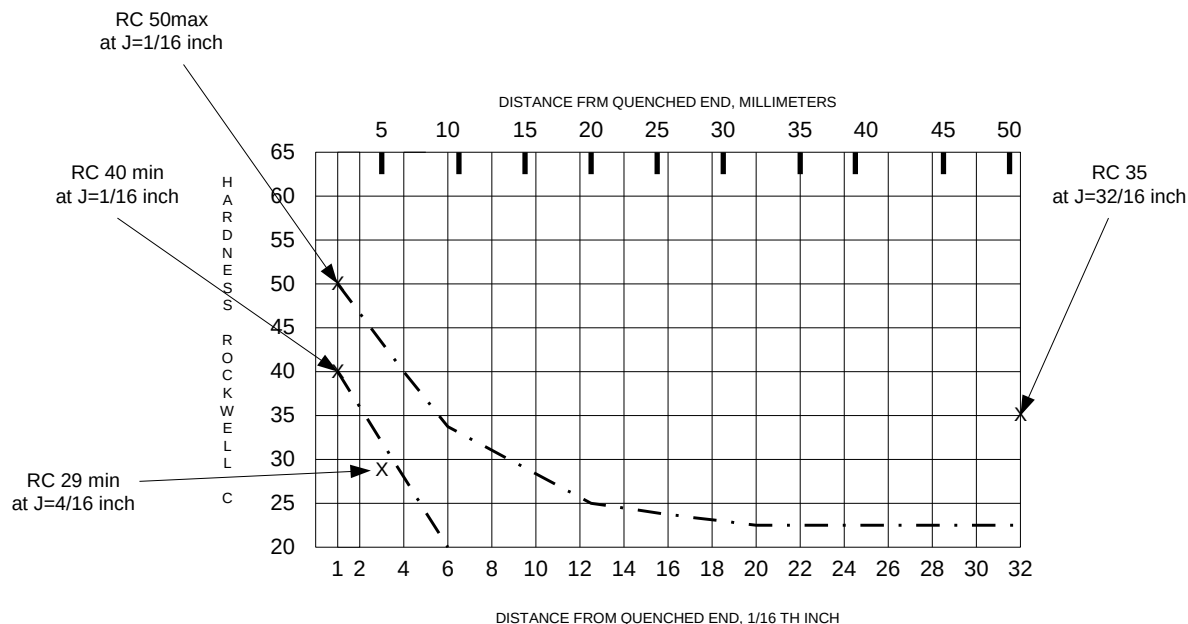


Figure 5 - Example C15-25E3-32 and 8620H Band

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5.8 Carbon Content Versus Hardness

The carbon content versus hardness requirements for J = 1/16 inch or 1.5 mm and for 50% martensite are shown in Table 1. Carbon content versus hardness for 80, 90, 95, and 99.9% martensite is shown in Table 2.

TABLE 1 - CARBON CONTENT VERSUS HARDNESS

Specified Carbon Content, %	Hardness, HRC		
	J Distance = 1/16 inch or 1.5 mm		50% martensite for specified carbon content
	carbon specified as min	carbon specified as max	
0.07*	36	--	25
0.08*	36	--	25
0.09*	36	--	26
0.10*	37	--	26
0.11*	37	--	27
0.12*	38	42	27
0.13*	38	43	28
0.14	39	43	28
0.15	40	44	29
0.16	40	44	30
0.17	41	45	30
0.18	42	45	31
0.19	43	46	31
0.20	44	46	32
0.21	44	47	32
0.22	45	48	33
0.23	46	48	34
0.24	47	49	34
0.25	48	50	35
0.26	49	51	35
0.27	49	51	36
0.28	50	52	36
0.29	50	53	37
0.30	50	54	37
0.31	51	55	38
0.32	51	55	38
0.33	51	56	39
0.34	52	56	40
0.35	53	57	40
0.36	53	57	41
0.37	53	58	41
0.38	54	58	42

Specified Carbon Content, %	Hardness, HRC		
	J Distance = 1/16 inch or 1.5 mm		50% martensite for specified carbon content
	carbon specified as min	carbon specified as max	
0.39	55	58	42
0.40	55	58	43
0.41	55	59	43
0.42	56	59	43
0.43	56	60	44
0.44	57	60	44
0.45	57	61	45
0.46	58	62	45
0.47	59	62	46
0.48	59	63	46
0.49	59	63	46
0.50	60	63	47
0.51	60	64	47
0.52	60	64	48
0.53	60	64	48
0.54	60	65	49
0.55	60	65	49
0.56	--	65	49
0.57	--	65	50
0.58	--	65	50
0.59	--	65	51
0.60	--	65	51
0.61	--	65	51
0.62	--	65	51
0.63	--	65	52
0.64	--	65	52
0.65	--	65	52
0.66	--	--	52
0.67	--	--	52
0.68	--	--	53
0.69	--	--	53
0.70	--	--	53

*Extrapolated

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**TABLE 2 - CARBON CONTENT VERSUS HARDNESS
FOR 80, 90, 95, AND 99.9 PERCENT MARTENSITE**

Carbon Content, %	Rockwell C Hardness for Percent Martensite Shown				Carbon Content, %	Rockwell C Hardness for Percent Martensite Shown			
	80%	90%	95%	99.9%		80%	90%	95%	99.9%
0.07*	28	30	32	37	0.39	46	50	52	55
0.08*	28	31	33	38	0.40	47	50	52	56
0.09*	29	31	33	38	0.41	47	51	53	56
0.10*	30	32	34	39	0.42	48	51	54	57
0.11*	31	33	35	39	0.43	48	52	54	57
0.12*	31	34	35	40	0.44	49	52	55	58
0.13*	32	34	36	40	0.45	49	53	55	58
0.14*	32	35	36	41	0.46	50	53	56	59
0.15	33	35	37	41	0.47	50	54	56	59
0.16	34	36	37	42	0.48	51	54	57	59
0.17	34	36	38	43	0.49	51	54	57	60
0.18	35	37	39	43	0.50	52	55	58	60
0.19	36	38	39	44	0.51	52	55	58	60
0.20	36	38	40	44	0.52	53	55	58	61
0.21	37	39	41	45	0.53	53	56	59	61
0.22	37	39	41	45	0.54	53	56	59	61
0.23	38	40	42	46	0.55	54	56	59	61
0.24	38	41	43	47	0.56	54	56	60	62
0.25	39	41	43	47	0.57	54	57	60	62
0.26	39	42	44	48	0.58	55	57	60	62
0.27	40	43	45	48	0.59	55	57	60	62
0.28	40	43	45	49	0.60	55	58	60	63
0.29	41	44	46	49	0.61	55	58	61	63
0.30	42	44	46	50	0.62	56	58	61	63
0.31	42	45	47	51	0.63	56	58	61	63
0.32	43	46	48	51	0.64	56	59	61	64
0.33	43	46	48	52	0.65	56	59	61	64
0.34	44	47	49	52	0.66	56	59	62	64
0.35	44	47	49	53	0.67	57	59	62	64
0.36	45	48	50	54	0.68	57	60	62	64
0.37	45	49	51	54	0.69	57	60	62	64
0.38	46	49	51	55	0.70	57	60	62	64

* Extrapolated

5.9 Detailed Hardenability Requirements For Steels

The selection of the carbon content and the J distances for 50% martensite are dependent upon the requirements of the part from the view points of both engineering and manufacturing.

Codes for steels used by the Company are shown in Table 3. The 50% martensite J distances for these steels are depicted graphically for ease of comparison and also for selection of appropriate J distances.

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