QUENCHING AND TEMPERING
(Process Specification)

1. SCOPE

1.1 This specification provides the required properties for quenched and tempered parts. It is intended to replace the Former CNH Company Quench and Temper Specifications listed in Table 1 and should be used on all applicable new and updated drawings. Quenching and tempering (Q&T) is also known as quench hardening and tempering or through hardening. Utilizing a protective atmosphere during austenitizing is known as neutral hardening.

1.2 All National Standards and related test method designations are to be latest issue unless otherwise specified.

2. APPLICATION

2.1 This specification is intended primarily for quenching and tempering of gray and ductile cast iron, fine grained medium and high carbon plain and alloy steel parts to obtain increased surface strength, core strength, and/or wear resistance. Quenched and tempered parts are first heated in a neutral (protective) atmosphere and held at an elevated temperature, such as 840°C (1550°F), which is above the material's austenitizing temperature. The parts are then rapidly cooled by immersion in oil, brine, water/polymer, or water quench, producing martensite and other transformation products. For most parts an oil quench is used, other quench types should be noted on the drawing. The depth of martensitic transformation from the surface will depend on material hardenability, carbon content, and quench severity.

2.2 Common quenched and tempered materials are specified in MAT1017, MAT1040, MAT1041, MAT1055, MAT1108, MAT1056, MAT2004, and MAT2006. Typical quenched and tempered parts are harrow disks, tractor axles (prior to induction hardening), tillage shanks and sweeps, and leaf springs.

2.3 The required inert or neutral austenitizing atmosphere will prevent further surface decarburization but should not be relied upon to eliminate decarburization present on incoming stock. Other heating methods such as induction heating are permitted as special methods where specified on the engineering drawing. Heating in a furnace without a controlled atmosphere is not permitted unless otherwise specified on the drawing.

Table 1	Former CNH Company Quenching & Tempering Specifications		
CASE	**NH Pennsylvania FNHA Standard**	**NH – Zedelgem Engineering Stds**	**NH Tractor Engineering**
P-6, P-7, P-8, P-9	2-P-004 (86516521)(A)	ES48.06 (A)	Fiat 50140 (A)

(A) Specification covers multiple types of heat treatment including quenching and tempering.

3. RELATED SPECIFICATIONS

ASTM E18 Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
CNH ENPJ100 (86619032) Significant Characteristics
CNH MAT1003 (86979049) Metallic Material Designations on Engineering Drawings
CNH MAT1017 (87034364) Medium Carbon and Alloy Steel, Hot Rolled Plate
CNH MAT1040 (87021630) Med Carbon, CD Bar
CNH MAT1041 (87021631) Med Carbon, HR Bar
CNH MAT1055 (87021650) Medium Carbon Alloy Steel, Cold Finished Bar
CNH MAT1056 (87021651) Medium Carbon Steel, Hot Rolled Alloy Bar
CNH MAT1108 (87303278) Boron Steels
CNH MAT2004 (87034347) Ductile Iron Castings
CNH MAT2006 (87034348) Gray Iron Castings
CNH MAT4050S (87317386) Quenched and Tempered Parts, Initial Supply Requirements
EN ISO 6508-1 Metallic Materials - Rockwell Hardness Test - Part 1: Test Method (Scales A, B, C, D, E, F, G, H, K, N, T)

4. PROCESS GUIDELINES & REQUIREMENTS

4.1 GENERAL

The austenitizing furnace, quench parameters, and tempering furnace used shall be appropriate for the part size and heat treated properties specified. The hardness aim of the quenching and tempering operations should be the midpoint of the specified hardness range. Process sheets should be developed for each part to record heat treatment parameters used, such as furnace settings, part loading, and quenchant temperature and agitation.

4.2 PART LOADING

4.2.1 Parts shall be free of any scale, rust, or soils that could interfere with quenching. Components must be thoroughly cleaned of oils, die lubricant, and related materials prior to introduction to the austenitizing and tempering furnaces.

4.2.2 For parts where distortion must be minimized (such as certain gears and shafts) appropriate fixturing shall be employed. The parts shall be suitably loaded to assure that every part is adequately heated during austenitizing and is properly exposed to the quenchant.

4.3 AUSTENITIZING FURNACE CONTROL

Parts shall be heated to a temperature at least 25°C (45°F) above the upper critical temperature (A_3) of the specified steel and held for a period of time to ensure complete austenitization of the part. The furnace atmosphere shall be either inert (e.g. nitrogen) or have a controlled carbon potential to maintain the nominal carbon level of the steel being heat treated. Carbon enrichment, where the carbon potential is above the specified range of the heat treated steel, is not permitted.

4.4 QUENCHING

Quenching equipment, media, agitation, and procedures shall be appropriate to fully quench the parts and materials processed and produce maximum hardness without cracking or causing excess distortion. The quenching method may be specified on the drawing if needed.

4.4.1 As-Quenched Surface Hardness

In general, the expected minimum hardness shown in Table 2 should be the minimum hardness obtained on the as-quenched surface prior to tempering to a lower hardness. For many commonly used materials, this as-quenched hardness is shown in Table 3.

4.5 TEMPERING REQUIREMENTS

After quenching, all parts shall be furnace tempered as soon as practical to prevent delayed cracking from internal stresses developed from quenching. Tempering within one hour is recommended.

While the proper tempering temperature depends on the specified material and hardness range, it shall be no less than 150°C (300°F). For most applications a tempering temperature greater than 370°C (700°F) is recommended. Parts shall be held for at least one hour at temperature. The tempering temperature and/or time may be specified on the drawing.

4.6 REWORKING OF PARTS

4.6.1 Reheating and quenching may be used as a rework process to meet all specified requirements. After rework, parts shall be inspected for cracking.

4.6.2 For parts severely decarburized prior to quenching and tempering, implementation of a carbon restoration atmosphere during austenitizing must be approved by CNH as a rework process to eliminate surface decarburization. Approval for carbon restoration may be noted on the engineering drawing if appropriate.

5. PART REQUIREMENTS

5.1 MICROSTRUCTURE

The microstructure obtained by quenching and tempering is dependent on the hardenability and carbon content of the steel used as well as part geometry (section size) and quench severity. Parts shall exhibit a tempered martensite structure to a depth within the hardenability limits of the specified steel. Structure shall show evidence of complete solution (austenitization). The average austenitic grain size shall be ASTM No. 5 or finer, per ASTM E112.

Surface microstructure shall not display any appreciable change in carbon content after heat treatment. Machined surfaces shall be free of surface decarburization. As-cast, hot rolled, or cold drawn surfaces shall not exhibit an increase in decarburization compared to the amount present before heat treatment.

5.2 HARDNESS

The surface hardness, and where specified the hardness in the core or at a fixed depth below the surface, shall meet the requirements on the engineering drawing. For machined areas, the surface hardness requirements shall be met both before and after a light grind. Otherwise, the surface hardness requirements shall be met after a light grind. Although a hardness check location may be specified for ease of measurement and quality control, the required surface hardness shall be met on the entire part, unless otherwise specified.

5.3 DIMENSIONS

Parts must meet drawing dimensional requirements after heat treatment and subsequent processing (grinding, plating, etc.).

6. TEST METHODS

6.1 MICROSTRUCTURE

Microstructure requirements shall be evaluated by light microscopy at 500X magnification.

The grain size after quenching and tempering shall be determined by the ASTM E112 method or a comparable method such as UNI 3245.

6.2 HARDNESS

Surface hardness, and where specified the hardness in the core or at a fixed depth below the surface, shall be measured per the test scale designated on the engineering drawing. For previously machined areas, the surface hardness requirements shall be met both before and after a light grind to detect any skin effect. For unmachined casting and wrought steel surfaces, the surface hardness requirements shall be met after a light grind. For the Rockwell scale, cylindrical surface corrections shall be per ASTM E18, EN ISO 6508-1, or equivalent.

7. INSPECTION AND REJECTION

7.1 Suppliers are not required to perform the specific test procedures listed but must ascertain that their products conform to the requirements of this specification and the Engineering drawing. Suppliers must be able to demonstrate the process capability and controls necessary to produce quenched and tempered parts that meet the specified limits when tested by the designated methods.

7.2 All parts supplied to this specification shall be equivalent in every respect to samples approved by the purchasing CNH location. While the purchasing location may test samples from incoming shipments for quality assurance, the supplier is responsible for ensuring that shipments meet the stated requirements without depending upon the purchaser's inspection.

8. INITIAL SAMPLE QUALITY

Quality requirements for initial samples submitted by suppliers to ensure compliance with this specification are provided in the CNH MAT4050S Quenched and Tempered Parts, Initial Supply Requirements specification. CNH MAT4050S requirements apply only to specified mechanical and microstructural requirements for a quenched and tempered part and are not intended to replace or supersede any other ISIR supplier quality requirements. The manufacturer of a part is responsible to meet applicable requirements of CNH Engineering Specification ENS0301 (86620212), CNH Supplier Quality Assurance (SQA) Approval of Manufactured Parts - Part Approval Process (PAP) Handbook CNH-SQA-F03Q, and any requirements on the Engineering drawing.

9. DESIGN CONSIDERATIONS

9.1 SPECIFYING HARDNESS RANGE

9.1.1 Standard Hardness Ranges

The hardness ranges shown in Table 4 should be the primary ranges specified. Also shown are the estimated yield and tensile strengths that correspond to the specified surface hardness level. Note that the hardness and strength will be highest at the part surface and will decrease towards the center. Any core hardness or hardness at depth requirements should be noted on the engineering drawing.

9.1.2 Achievable Surface Hardness

Table 3 shows maximum hardness levels that can be achieved on commonly used quenched and tempered CNH materials. It also indicates the maximum section size that can be expected to reach full hardness after a good oil quench and subsequent tempering. For parts with a larger section size, a lower hardness should be designated or a material with higher hardenability should be specified, see Section 9.3.

Although a hardness check location may be specified for ease of measurement and quality control, the required surface hardness shall be met on the entire part. Areas of a part with a heavier or lighter section size may require that a different hardness and check location be specified on the drawing for that section.

For optimum fatigue strength, impact strength, and/or wear resistance, specifying an as-quenched hardness in addition to the hardness after tempering is advisable. For parts with significant impact loading, a minimum tempering temperature of 370°C (700°F) should be specified on the engineering drawing.

9.1.3 Removing Pre-Existing Decarburization

Where decarburization and its associated lower surface hardness is not permitted, the bar surface should be machined to remove the surface decarburization. A machining requirement may be added to the engineering drawing. Table 5 shows the minimum stock removal necessary to eliminate surface decarburization. Table 5 values are conservative, actual decarburization on raw bar may be less. For turned and polished / ground bar, the minimum stock removal should be adjusted by the amount of material removed during turning, polishing, and/or grinding.

9.2 SELECTING A HARDNESS SCALE

The appropriate scale for specifying the surface hardness depends on the required strength level, part thickness, and whether pre-existing decarburization is expected at the hardness check location.

9.2.1 Minimum Thickness Considerations

Table 6 shows the required minimum hardness and thickness for different hardness scales. If the specified part thickness and hardness do not meet the guidelines in Table 6, a lighter load hardness scale, such as HRA or HR15N, should be used, consult with a Materials Engineer.

9.2.2 Machined or Decarburized Surfaces

The Rockwell C (HRC) scale should be specified for wrought steels with surfaces that are machined or ground prior to heat treatment. Decarburization, which typically lowers surface strength, may be present on hot rolled or cold drawn steel surfaces as well as cast surfaces. For surfaces that are not machined, a Brinell hardness (HB) scale should be specified. Where a Brinell indentation is not possible, the HRC scale should be specified. Specifying hardness in the HRC scale is preferred due its worldwide usage, although the Vickers (HV30) hardness scale may be specified instead.

9.3 CONSULTATION

Consultation with Materials Engineering personnel is recommended to aid in material selection and developing heat treatment drawing notes. Materials Engineering personnel can estimate heat treatment response and part properties as a function of component geometry, the material selected (hardenability & carbon content), quench severity, and tempering time and temperature.

10. DRAWING SPECIFICATIONS

10.1 The title block of engineering drawings shall contain material designations as described in CNH MAT1003 (86979049) Metallic Material Designations on Engineering Drawings. Certain drawing specifications may require the use of a significant characteristic per CNH Engineering Procedure ENPJ100 (86619032). This will be determined as part of the design review process.

10.2 For quenched and tempered parts, specify the following under the "Heat Treatment" heading:

- Prior heat treatment or processing
- Quench and Temper per CNH MAT4050
- Special quench (e.g. water quench)
- Surface hardness range
- Location(s) of hardness check. The hardness check location should be specified on the drawing so that the part can be used after testing. See Section 9.
- Furnace tempering required
- Any special mechanical requirements such as as-quenched surface hardness, core hardness or hardness at a fixed depth, impact strength, yield-tensile ratio, elongation, or percent reduction in area.
- Other requirements and secondary processing steps

Possible processing steps prior to quenching and tempering:

- Welding
- Forging
- Normalizing or annealing

10.3 DRAWING NOTES

10.3.1 Basic Quenching and Tempering Drawing Note

CNH Material
HR Round, CNH MAT1056, Grade B
Local Material
HR Round, EN 10083-1, Grade 42CrMo4+H

(Example note placed on drawing)
Heat Treatment:
Quench and Temper per CNH MAT4050
Furnace temper to a surface hardness of 30-35 HRC
Measure surface hardness at location indicated

10.3.2 Example of a Complete Drawing Note

The following example is for reference only, modify as necessary for each specific application.

CNH Material
Alloy HR Round, CNH MAT1056, Gr C
Local Material
Alloy HR Round, ASTM A304, 5160H

(Example note placed on drawing)
Heat Treatment:
Forge
Normalize Per Case Specification P-4

Quench and Temper per CNH MAT4050
As-Quenched Hardness 56-64 HRC
Furnace temper to a surface hardness of 45-50 HRC
Measure surface hardness at location indicated

Core hardness measured at mid radius shall be 38 HRC minimum.

Hard Finish Diameter YYY per CNH MAT4110, Class C

Table 2 Steel Carbon Content and Expected Minimum As-Quenched Surface Hardness									
Carbon Content, wt%	Minimum Hardness, HRC	Carbon Content, wt%	Minimum Hardness, HRC	Carbon Content, wt%	Minimum Hardness, HRC	Carbon Content, wt%	Minimum Hardness, HRC	Carbon Content, wt%	Minimum Hardness, HRC
0.21	39	0.31	45	0.41	51	0.51	55	0.61	58
0.22	39	0.32	46	0.42	51	0.52	55	0.62	58
0.23	40	0.33	46	0.43	52	0.53	56	0.63	58
0.24	41	0.34	47	0.44	52	0.54	56	0.64	59
0.25	41	0.35	47	0.45	53	0.55	56	0.65	59
0.26	42	0.36	48	0.46	53	0.56	56	0.66	59
0.27	43	0.37	49	0.47	54	0.57	57	0.67	59
0.28	43	0.38	49	0.48	54	0.58	57	0.68	60
0.29	44	0.39	50	0.49	54	0.59	57	0.69	60
0.30	44	0.40	50	0.50	55	0.60	58	0.70	60

Table 3 Recommended Max Hardness Ranges for Selected Materials and Sizes

CNH Material Specification	CNH Grade (1)	Carbon Level (2)	As-Quenched Hardness (3)	Max. Surface Hardness Range on Drawing (After Tempering)	Max. Dimension To Obtain Specified Hardness Range			
					Diameter (Round Bars)		Thickness (Plates / Flats)	
		wt%	HRC	HRC	Inch	mm	Inch	mm
MAT1017 (HR Plate)	A	0.37-0.50	49-60	45-50	N/A	N/A	0.23	5.8
	B	0.50-0.70	55-65	50-55	N/A	N/A	0.23	5.8
	C	0.37-0.46	49-59	45-50	N/A	N/A	0.80	20.5
MAT1040 (CD Bar)	A	0.27-0.39	43-56	33-39	0.25	6.5	0.17	4.5
	B	0.40-0.50	50-60	45-50	0.37	9.5	0.17	4.5
	C	0.47-0.55	54-63	50-55	0.37	9.5	0.17	4.5
MAT1041 (HR Bar)	A	0.27-0.39	43-56	33-39	0.25	6.5	0.17	4.5
	B	0.40-0.50	50-60	45-50	0.37	9.5	0.17	4.5
	C	0.47-0.60	54-63	50-55	0.37	9.5	0.17	4.5
MAT1055 (CD Alloy Bar)	A	0.37-0.45	49-59	45-50	1.92	49	0.87	22
MAT1056 (HR Alloy Bar)	A	0.30-0.45	44-59	40-45	1.55	39	0.67	17
	B	0.37-0.46	49-59	45-50	1.92	49	0.87	22
	C	0.47-0.65	54-64	50-55	1.55	39	0.67	17
	D	0.26-0.44	42-58	33-39	10	255	2.60	66
MAT1108 (Boron Steel)	A	0.24-0.42	41-59	33-39	1.55	39	0.67	17

(1) All grades are medium carbon steels; see Section 3 and individual specifications for additional information. If necessary to obtain a higher surface and/or core hardness, a specific Listed steel within a CNH Grade may be designated as a restricted (RSTR) material, see MAT1003 for additional information.

(2) In order to encompass the ASTM, EN and Fiat grades referenced in the CNH material specification, the carbon range shown may be wider than specified range of an individual grade.

(3) Lower end hardness values shown are based on minimum carbon level for specified materials and associated hardness values shown in Table 2. Table 2 contains the required minimum hardness for the actual carbon level of the material heat treated.

Table 4 Recommended Hardness Ranges and Estimated Surface Strengths				
Recommended Hardness Ranges			**Estimated Minimum Surface Strength Properties (1)**	
Rockwell C, HRC	**Brinell, HB (3000 kg)**	**Vickers, HV (30 kg)**	**Tensile Strength, MPa (psi)**	**Yield Strength, MPa (psi)**
22-29	235-277	250-295	790 (115,000)	640 (93,000)
25-32 (2)	255-302	265-320	875 (127,000)	735 (107,000)
30-35	285-331	300-345	970 (141,000)	840 (122,000)
33-39 (3)	311-363	325-380	1070 (155,000)	930 (135,000)
40-45	375-415	390-445	1295 (188,000)	1160 (168,000)
45-50	415-477	445-515	1445 (210,000)	1310 (190,000)
50-55	477-555	515-600	1675 (243,000)	1500 (218,000)
55-60	555-653	600-695	1965 (285,000)	1690 (245,000)

(1) Estimated strength properties do not reflect bulk strength of the part, which will be lower.
(2) Hardness level is similar to an SAE J429, Grade 5 and ISO 898-1, Class 8.8 bolt
(3) Hardness level is similar to an SAE J429, Grade 8 and ISO 898-1, Class 10.9 bolt

Table 5	Minimum Stock Removal Per Side		
Cold Finished Size		**Minimum Surface Stock Removed (1)**	
mm	inch	mm	Inch
≤16	≤0.625	0.40	0.016
>16 – 22	>0.625 – 0.875	0.55	0.021
>22 – 25	>0.875 – 1	0.60	0.023
>25 – 29	>1 – 1.125	0.65	0.025
>29 – 32	>1.125 – 1.25	0.70	0.028
>32 – 35	>1.25 – 1.375	0.75	0.030
>35 – 38	>1.375 – 1.5	0.85	0.033
>38 – 51	>1.5 – 2	1.10	0.042
>51 – 64	>2 – 2.5	1.35	0.052
>64 – 90	>2.5 – 3.5	1.85	0.072

(1) For round bars this means the minimum reduction in diameter will be twice the stock removal values shown.

Table 6	Minimum Thickness Requirements for Brinell and HRC Tests	
Minimum Thickness of Specimen		Minimum Hardness for which the Scale May be Used
mm	inch	
0.76	0.030	57 HRC
0.81	0.032	52 HRC
0.86	0.034	45 HRC
0.91	0.036	37 HRC
0.96	0.038	28 HRC
1.02	0.040	20 HRC
1.59	0.063	602 HB (3000 kg)
3.18	0.125	301 HB (3000 kg)
4.76	0.188	201 HB (3000 kg)