BOMBARDIER

Toronto Site

PROPRIETARY INFORMATION

PPS 30.04

PRODUCTION PROCESS STANDARD

STEEL HEAT TREATMENT - CARBON AND LOW ALLOY STEELS

Issue 34
- This standard supersedes PPS 30.04, Issue 33.
- Vertical lines in the left hand margin indicate technical changes over the previous issue.
- Direct PPS related questions to christie.chung@aero.bombardier.com or (416) 375-7641.
- This PPS is effective as of the distribution date.

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1 SCOPE

1.1 This Production Process Standard (PPS) specifies the procedure and requirements for the heat treatment of carbon and low alloy steels.

1.1.1 This PPS complements the engineering drawings that specify its use as an authorized instruction. The procedure specified in this PPS shall be followed to ensure compliance with all applicable specifications. In general, if this PPS conflicts with the engineering drawing, follow the engineering drawing. The requirements specified in this PPS are necessary to fulfil the engineering design and reliability objectives.

1.1.2 Refer to PPS 13.26 for the subcontractor provisions applicable to this PPS.

1.1.3 Procedure or requirements specified in a Bombardier BAPS, MPS, LES or P. Spec. do not supersede the procedure or requirements specified in this PPS. Similarly, the procedure and requirements specified in this PPS are not applicable when use of a BAPS, MPS, LES or P. Spec. is specified.

1.2 Refer to PPS 30.12 for general information and heat treat terminology.

2 HAZARDOUS MATERIALS

2.1 Before receipt at Bombardier Toronto, all materials shall be approved and assigned Material Safety Data Sheet (MSDS) numbers by the Bombardier Toronto Environment, Health and Safety Department. Refer to the manufacturer's MSDS for specific safety data on any of the materials specified in this PPS. If the MSDS is not available, contact the Bombardier Toronto Environment, Health and Safety Department.

3 REFERENCES

3.1 AMS 2759 - General Requirements for Heat Treatment of Steel Parts.

3.2 ASTM E8/E8M - Standard Test Methods for Tension Testing of Metallic Materials.

3.3 BAERD GEN-007 - Quality Control of Heat Treating Equipment and Hot Forming Equipment.

3.4 BAERD GEN-018 - Engineering Requirements for Laboratories.

3.5 DH Form #3520 - Process Control Record - Process Shop - *Bombardier Toronto internal Quality procedure*.

3.6 DH Form #3772A/3772B - Steel Heat Treatment Quality Control and Inspection Record - *Bombardier Toronto internal Quality procedure*.

3.7 MIL-S-10699 - Salts, Heat Treating (for Metals).

3.8 PPS 13.26 - General Subcontractor Provisions.

3.9 PPS 13.39 - Bombardier Toronto Engineering Process Manual.

3.10 PPS 15.01 - Part Marking.

3.11 PPS 20.01 - Magnetic Particle Inspection.

3.12 PPS 20.05 - Macro-Etch Examination of Machined or Ground, High Strength Low Alloy Steels.

3.13 PPS 20.08 - Hardness Testing of Metals.

3.14 PPS 30.02 - Sub-Zero Treatment of Steel Parts.

3.15 PPS 30.05 - Steel Case Hardening - Gas Nitriding.

3.16 PPS 30.11 - Steel Case Hardening (Carburizing).

3.17 PPS 30.12 - General Steel Heat Treatment.

3.18 PPS 30.16 - Steel Case Hardening - Liquid Nitriding.

3.19 PPS 31.03 - Cleaning of Carbon and Low Alloy Steels.

3.20 PPS 31.04 - Degreasing Processes.

3.21 PPS 33.02 - Removal of Metallic Coatings.

3.22 PPS 33.05 - Copper Plating (E7).

3.23 PPS 35.04 - Requirements for Steel Forgings.

3.24 PPS 35.07 - Requirements for Investment and Sand Castings.

3.25 PPS 37.04 - Fusion Welding of Ferrous and Nickel Alloys.

3.26 QDI-09-02 - Process Control - *Bombardier Toronto internal Quality procedure*.

3.27 SAE ARP 1820 - Chord Method of Evaluating Surface Microstructural Characteristics.

4 MATERIALS, EQUIPMENT AND FACILITIES

4.1 Materials

4.1.1 Heat treat salt, MIL-S-10699, Classes 1, 2, 4, 5, 6 and 8.

4.1.2 Salt bath rectifier (e.g., Park Thermal Ltd. No. 15 rectifier pellets or E.F. Houghton Co. Salt Bath Rectifier No. 4).

4.1.3 “Martempering oil”: Martempering oils for use in 300 to 400°F range for interrupted quenching (e.g., Houghton Mar-Temp oil No. 2525).

4.1.4 "Martempering salt": Salts with a working range of 350 to 1000°F for use in tempering operations (e.g., Houghton Draw Temp 275).

4.1.5 Argon, Compressed Gas Association (CGA) specification G-11.1, Grade E (dewpoint of -76°F or below, 5 ppm oxygen maximum).

4.1.6 Helium, CGA specification G-9.1, Grade C (dewpoint of -76°F or below, 5 ppm oxygen maximum).

4.1.7 Nitrogen, CGA specification G-10.1, Grade L (dewpoint of -90°F or below, 10 ppm oxygen maximum).

4.2 Equipment

4.2.1 General

4.2.1.1 Air furnaces and salt baths used for heat treatment shall be equipped with pyrometric control, and chart recorder controlled according to BAERD GEN-007.

4.2.1.2 Processing facilities shall contain the equipment described in Table I, set up in a suitable sequential manner to allow for effective controlled flow of production parts through all process steps required by this specification.

4.2.1.3 Instrumentation and equipment shall be qualified according to BAERD GEN-007.

4.2.2 Vacuum Furnaces

4.2.2.1 Vacuum furnaces for hardening steel by oil quench, ausbay quench or martempering shall be equipped with integral quench tanks.

4.2.2.2 Vacuum furnaces shall be equipped with vacuum sensing equipment to detect pressures from 0.1 micron (10^{-4} torr) to 1000 microns. Pressure sensors shall be located such that representative pressure measurements are obtained from each chamber within the furnace. During operation, the pressure in each heating chamber of the furnace shall be continuously recorded. A procedure and schedule shall be established for the calibration and testing of pressure sensing equipment and recorders.

4.2.2.3 The leak rate of the vacuum furnace when isolated from the pumping system shall not exceed 10 microns per hour at a pressure of 70 microns or less.

4.2.2.4 To operate vacuum furnaces, first evacuate the heating chamber to 70 microns or less. Then, use the following operating pressures:

- 1-100 microns for temperatures below 1500°F
- 10-100 microns for temperatures of 1500 to 1750°F (for working pressures over 100 microns, backfill the chamber with argon, helium or nitrogen)
- 50-100 microns for temperatures of 1751 to 1900°F

4.2.3 Air Furnaces

4.2.3.1 Air furnaces shall be electrically heated and have a means of recirculating the air. Gas-fired furnaces may be used provided that gases are muffled and do not impinge on part surfaces.

4.2.4 Controlled Atmosphere Furnaces

4.2.4.1 Acceptable atmospheres include nitrogen, argon, helium and endothermic-generated atmospheres. Do not use nitrogen from dissociated ammonia for nitrogen-based atmospheres.

4.2.4.2 Endothermic atmospheres shall be equipped with a dewpoint analyzer, preferably of the fog chamber-type (Alnor Dew Pointer or equivalent). The equipment shall be used to set the appropriate dew point temperatures according to the manufacturer's instructions.

4.2.4.3 Check the dew point of generated atmospheres at least once a week, or more often if necessary to provide control of carburization, decarburization or nitriding. If decarburization control specimens are processed twice weekly (a minimum of one specimen every 72 hours) and adequate control over the appropriate process is thereby assured, a dew point check is not mandatory.

4.2.4.4 Gases entering the furnace shall have a dew point of -70°F or lower and -40°F or lower at the exit of the working zone.

4.2.5 Salt Baths

4.2.5.1 Salt baths may be used for heat treat operations specified in Table II.

4.2.5.2 Salt baths shall not be used for parts of complex shapes (e.g., parts with internal recesses and/or small bores, etc.) that may entrap salt after removal from the bath, with the exception of salt baths used to quench at 350 to 550°F inclusive.

4.2.6 Quench Tanks

4.2.6.1 Quenching baths shall be able to adequately circulate and cool the quenching media. The use of compressed air for agitation is prohibited. Tanks shall be adequately sized for the work load involved and equipped with temperature gauges. Position quenching and handling equipment to obtain the specified speed of quench. At the initiation of the quenching operation, the temperature of the quenching medium shall not exceed 130°F.

4.2.6.2 Equip vacuum furnaces for drop bottom quenching.

4.2.6.3 Oil used in integral vacuum furnace systems, where the quench chamber is below atmospheric pressure, shall be hot vacuum degassed when the tank is first filled and again after each major oil addition.

4.2.6.4 If molten-salt baths are used, provide rinse tanks and pressure flushing for removal of all salt from the material surfaces. The tank shall be fitted with suitable heating coils necessary to maintain the water at the boiling point.

4.2.7 Temperature Control

4.2.7.1 The temperature at any point in the working zone of any heat treating furnace or salt bath shall not vary by more than what is specified in Table I from the set heat treating temperature after the charge has been brought up to temperature.

4.2.7.2 Use automatic controlling and recording temperature measuring instruments, preferable of the potentiometric type. Adequately protect thermocouples located in the working zone.

4.2.8 Approval of Equipment

4.2.8.1 All equipment and facilities shall be approved by Bombardier as meeting the requirements of this PPS and applicable facility Quality Instructions (e.g., QDI-09-02).

4.3 Facilities

4.3.1 This PPS has been categorized as a Controlled Critical Process according to PPS 13.39 and as such only facilities specifically approved according to PPS 13.39 are authorized to perform the heat treatment of carbon and low alloy steels according to this PPS.

4.3.2 Bombardier subcontractors shall direct requests for approval to Bombardier Aerospace Supplier Quality Management. Bombardier facilities shall direct requests for approval to the appropriate internal Quality Manager.

4.3.3 Facility approval shall be based on a facility report, a facility survey and completion of a qualification test program, if required. The facility report shall detail the materials and equipment to be used, the process sequence to be followed and the laboratory facilities used to show compliance with the requirements of this PPS. Any deviation from the procedure or requirements of this PPS shall be detailed in the facility report. Based upon the facility report, Bombardier Toronto Engineering may identify additional qualification and/or process control test requirements. During the facility survey, the facility requesting qualification shall be prepared to demonstrate their capability. Once approved, no changes to subcontractor facilities may be made without prior written approval from Bombardier Aerospace Supplier Quality Management.

4.3.3.1 For approval of subcontractor facilities to perform the heat treatment of carbon and low alloy steels according to this PPS, completion of a test program and submission of suitable test samples representative of production parts is required. Test samples shall meet the requirements specified in section 6.

4.3.3.2 All testing and evaluation specified herein shall only be performed by Bombardier Toronto Materials Laboratory or by laboratories accredited according to BAERD GEN-018.

TABLE I - EQUIPMENT REQUIREMENTS

OPERATION	EQUIPMENT	REQUIREMENT	TEMPERATURE UNIFORMITY
PRE-HEATING ANNEALING PROCESS ANNEALING NORMALIZING HARDENING (AUSTENITIZING)	Air Furnace Controlled Atmosphere Furnace Vacuum Furnace Salt Bath	Class 25 Type B per BAERD GEN-007	± 25°F
QUENCHING	Oil Bath	See section 4.2.6	—
	Salt Bath	Class 25 Type C per BAERD GEN-007	± 25°F
TEMPERING (NOTE 1)	Air Furnace	Class 15 Type B per BAERD GEN-007	± 15°F
	Salt Bath	Class 10 Type B per BAERD GEN-007	± 10°F
Note 1 When tempering H-11 Mod (AMS 6485 or AMS 6487, all tempers) and 300M (AMS 6419, 280-305 ksi), the temperature shall not vary more than ± 10°F (air furnace inclusive).			

5 PROCEDURE

5.1 General

5.1.1 Before heat treating, clean all parts and material according to PPS 31.03.

5.1.2 Refer to Table II for the recommended atmosphere to use for various materials and heat treating processes.

5.1.3 Control decarburization according to section 5.10.

5.1.4 During heat treatment, perform in-process identification of parts and material according to PPS 15.01.

TABLE II - RECOMMENDED HEAT TREATING ATMOSPHERES

HEAT TREAT PROCESS		FURNACE ATMOSPHERES AND BATHS									
		ENDOTHERMIC (GREATER THAN 1400°F)	INERT GAS (ARGON AND/OR HELIUM)	VACUUM	MIL-S-10699 SALT BATHS						AIR
					CLASS 1 (325 TO 1099°F)	CLASS 2 (550 TO 1099°F)	CLASS 4 (1100 TO 1650°F)	CLASS 5 (1300 TO 1650°F)	CLASS 6 (1650 TO 2000°F)	CLASS 8 (1650 TO 2350°F)	
NORMALIZING (RAW MATERIAL)	PRE-HEATING	—	Yes (Note 2)	Yes (Note 2)	Yes (Note 3)	Yes (Note 3)	Yes (Note 3)	—	—	—	Yes (Note 1)
	AT TEMPERATURE (1600 TO 1825°F)	Yes	Yes	Yes	—	—	—	—	—	—	—
AUSTENITIZING (RAW MATERIAL AND ROUGH MACHINED PARTS)	PRE-HEATING	Yes (Note 4)	Yes (Note 2)	Yes (Note 2)	Yes (Note 3)	Yes (Note 3)	Yes (Note 3)	—	—	—	Yes (Note 1)
	AT TEMPERATURE (1475 TO 1875°F)	Yes	Yes	Yes	—	—	Yes	Yes	Yes (Note 5)	Yes (Note 5)	—
AUSTENITIZING (COMPLETELY OR PARTIALLY FINISH MACHINED PARTS)	PRE-HEATING	Yes (Note 4)	Yes (Note 2)	Yes (Note 2)	Yes (Note 3)	Yes (Note 3)	Yes (Note 3)	—	—	—	—
	AT TEMPERATURE (1475 TO 1875°F)	Yes	Yes	Yes	—	—	Yes	Yes	Yes (Note 5)	Yes (Note 5)	—
ANNEALING (RAW MATERIAL)	PRE-HEATING	—	Yes (Note 2)	Yes (Note 2)	Yes (Note 3)	Yes (Note 3)	Yes (Note 3)	—	—	—	Yes (Note 1)
	AT TEMPERATURE (1375 TO 1750°F) AND FURNACE COOL TO LESS THAN 600°F	Yes	Yes	Yes	—	—	—	—	—	—	—
STRESS RELIEF	NON-HARDENED PARTS (1100 TO 1200°F)	—	Yes	Yes	—	—	Yes	—	—	—	Yes (Note 1)
	HARDENED AND FINISH MACHINED PARTS (375 TO 700°F)	—	Yes	Yes	Yes	Yes	—	—	—	—	—
TEMPERING	RAW MATERIAL AND ROUGH MACHINED PARTS	—	Yes	—	Yes	Yes	—	—	—	—	Yes (Note 1)
	COMPLETELY OR PARTIALLY FINISH MACHINED PARTS	—	Yes	—	Yes	Yes	—	—	—	—	—
EMBRITTLEMENT RELIEF	AT TEMPERATURE (370 TO 420°F)	—	—	—	—	—	—	—	—	—	Yes
SUB-CRITICAL ANNEALING	AT TEMPERATURE (UP TO 1250°F)	—	Yes	Yes	—	—	Yes	—	—	—	Yes (Note 1)

Note 1. Parts to be subsequently steel grit blast cleaned or machined.
Note 2. After the required pre-heat soaking time, the temperature may be ramped up to the required heat treat temperature.
Note 3. Low to medium temperature (950 to 1200°F) pre-heating for all low alloy steels.
Note 4. High temperature (1400 to 1450°F) pre-heating for H-11 Mod before austenitizing.
Note 5. Suitable for austenitizing H-11 Mod low alloy steel.

5.2 Heat Treatment Handling

5.2.1 Place or hang parts in suitable racks or supports to allow free circulation of heating and quenching media and to minimize warpage during heating and quenching.

5.2.2 Except when using a vacuum furnace, load parts by opening the furnace door, inserting the parts and closing the furnace door as rapidly as possible.

5.2.3 Except when pre-heating according to section 5.4 or using vacuum furnaces, only load furnaces when they are operating at the middle of the specified temperature range. Set temperature control instruments at the correct operating temperature. When using a vacuum furnace, parts may be loaded at room temperature.

5.2.4 While loading and unloading finished parts, take care to avoid nicks or other damage to the part surfaces.

5.3 Heating and Soaking

5.3.1 General

5.3.1.1 For copper plated parts, increase the soak time by at least 50% unless load thermocouples are used.

5.3.1.2 Heat parts at the specified temperature, for the particular material and type of thermal treatment being performed. Hold parts at this temperature for not less than the specified soaking time.

5.3.1.3 The soaking time commences depending on the type of furnace used.

- For air and air atmosphere, soak time shall be as specified in section 5.3.2.
- For vacuum furnaces, soak times shall be as specified in section 5.3.3.
- For salt baths, soak times shall be as specified in section 5.3.4.

5.3.2 Air and Air Atmosphere Furnaces

5.3.2.1 The soaking time commences when, after loading the furnace, the temperature has returned to the middle of the specified range.

5.3.3 Vacuum Furnaces

5.3.3.1 Soak times begins when the part temperature reaches the minimum of the furnace uniformity tolerance at the set temperature. Heat-up times shall be determined with load thermocouples attached to the thickest section of a part or dummy part surface.

5.3.3.2 When the use of load thermocouples is impracticable (multi chambers for quenching), the correct heat up time shall be determined with a test load. The simulated load shall incorporate load thermocouples but quenching is not required.

5.3.3.3 Once such load has been qualified per the above paragraphs, subsequent loads may be processed without load thermocouples provided they have an equal or fewer identical parts in the load, and that their distribution is the same as the one used for the qualification load.

5.3.4 Salt Baths

5.3.4.1 The soaking time commences when the control temperature returns to the specified set temperature after the insertion of the load.

5.4 Pre-heating

5.4.1 Before annealing, normalizing or austenitizing, pre-heat the following parts before charging into the appropriate heating furnace:

- Parts having a tensile strength range of 160 - 180 ksi or greater
- Parts of complicated shape or having a sharp re-entrant angle or drastic transitions in thickness. If doubt exists, pre-heat parts
- Any steel having a nominal carbon content of 0.40% or greater (refer to Table III for nominal carbon content of carbon and low alloy steels)
- All parts to be heat treated in a salt bath

5.4.2 Perform pre-heating in an air furnace according to Flow Chart 1.

5.5 Annealing

5.5.1 If required for formability, perform full annealing according to Flow Chart 2.

5.5.2 If required before machining rework of hardened and tempered HY-TUF parts, perform sub-critical annealing according to Flow Chart 3.

TABLE III - NOMINAL CARBON CONTENT OF CARBON AND LOW ALLOY STEELS

ALLOY	NOMINAL CARBON CONTENT
1010	0.10%
1020	0.20%
1095	0.95%
4130	0.30%
4140	0.40%
4330V	0.30%
4340	0.40%
7140 (135M)	0.40%

ALLOY	NOMINAL CARBON CONTENT
8615	0.15%
8630	0.30%
8630 Mod	0.30%
52100	1.00%
300M	0.42%
HY-TUF	0.25%
H-11 Mod	0.40%

5.6 Normalizing

5.6.1 Except as noted below, perform normalizing only if specified on the engineering drawing, Engineering Order or Product Specification. Parts which meet **all** the following conditions shall be normalized before austenitizing:

- Part is made of 4330V, 4340, 300M, HY-TUF and H-11 Mod alloy
- Parts is in a condition other than normalized, hardened and tempered or sub-critical annealed (HY-TUF only)
- Parts is to be hardened and tempered to 200 - 220 ksi or greater

5.6.2 Normalize according to Flow Chart 5.

5.7 Stress Relieving (Non-Hardened Parts)

5.7.1 Stress relieve all welded parts specified in PPS 37.04, or parts specified on the engineering drawing, Engineering Order or Product Sheet according to Flow Chart 4.

5.8 Hardening

5.8.1 General

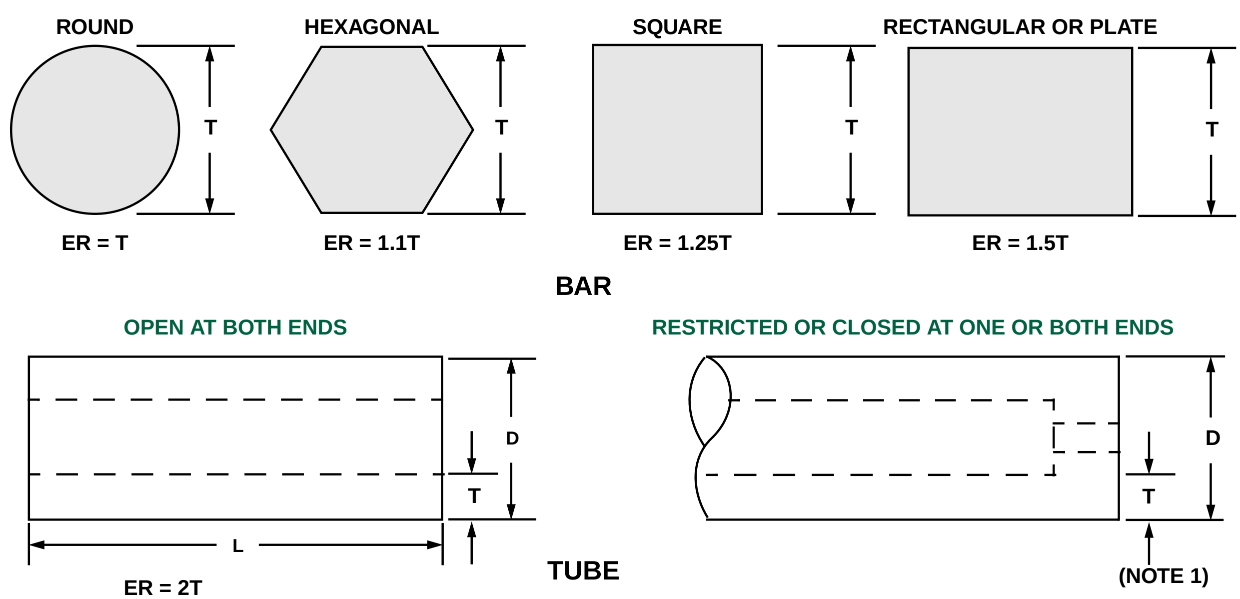
5.8.1.1 Perform hardening and tempering according to Flow Chart 6.

5.8.1.2 Refer to Table IV for maximum section sizes that may be hardened. Parts made from raw material greater than the maximum section size shall be rough or finish machined before heat treatment.

TABLE IV - MAXIMUM HARDENABLE SECTION SIZES (E.R.'S)

REQUIRED UTS (KSI) OR HARDNESS	ALLOY										
	1095	4130	4140	4330V	4340	8630	8630 MOD	52100	300M	HY-TUF	H-11 MOD
125 - 145 ksi	—	1.50"	1.50"	—	6.00"	1.50"	—	—	—	—	—
140 - 160 ksi	—	1.25"	—	—	5.00"	1.25"	—	—	—	—	—
150 - 170 ksi	—	1.00"	—	—	4.00"	1.00"	1.00"	—	—	—	—
160 - 180 ksi	—	0.75"	—	—	3.00"	0.75"	—	—	—	—	—
180 - 200 ksi	0.19"	0.50"	—	—	2.40"	0.50"	—	—	—	—	—
200 - 220 ksi	0.13"	—	—	—	2.00"	—	—	—	—	—	—
220 - 240 ksi	—	—	—	2.00"	—	—	—	—	—	4.00"	10.00"
240 - 260 ksi	—	—	—	—	—	—	—	—	—	—	10.00"
260 - 280 ksi	—	—	—	—	0.90"	—	—	—	—	—	10.00"
275 - 305 ksi	—	—	—	—	—	—	—	—	6.00"	—	—
Rc 60 - 65	—	—	—	—	—	—	—	1.70"	—	—	—

Note: This data is for round bars and denotes the maximum size which will give the properties specified. Refer to Figure 1 for the relationship between simple shapes and corresponding round size equivalent round (E.R.).



Note 1. Use maximum thickness for calculation.

Note 2.
a. For tube open at both ends, when L is less than D, consider the section as a plate of T thickness and ER=1.5T.
b. For tube open at both ends, when L is less than T, consider the section as a plate of L thickness and ER=1.5L.
c. For tube restricted or closed at one or both ends, when D is less than 2.5 inches, ER=2.5T.
d. For tube restricted or closed at one or both ends, when D is greater than 2.5 inches, ER=3.5T.

FIGURE 1 - EQUIVALENT ROUND COMPARISONS

5.8.2 Austenitizing

5.8.2.1 Austenitize parts by soaking at the temperature specified in Table V for the time specified in Table VI.

TABLE V - FULL ANNEALING, NORMALIZING AND AUSTENITIZING TEMPERATURES

ALLOY	FULL ANNEALING		NORMALIZE Soak Temperature	AUSTENITIZING Soak Temperature
	Soak Temperature	Furnace Cool Temperature (at 50°F/hour max.)		
WROUGHT ALLOYS (INCLUDING FORGINGS)				
1010	1575°F - 1650°F	900°F	N/A	See PPS 30.11 for austenitizing information (carburizing grade only)
1020				
1095	1450°F - 1525°F	900°F	N/A	1475°F - 1525°F
4130	1550°F - 1600°F	900°F	1625°F - 1675°F (Note 1)	1550°F - 1600°F (Note 1)
4140	1525°F - 1575°F	900°F	1600°F - 1650°F	1550°F - 1600°F
4330V	1525°F - 1575°F	800°F	1650°F - 1700°F	
4340	1525°F - 1575°F	800°F	1600°F - 1700°F	1500°F - 1550°F
8630	1550°F - 1600°F	900°F	1625°F - 1675°F (Note 1)	1550°F - 1600°F (Note 1)
7140 (135M)	1700°F - 1750°F	900°F	1775°F - 1825°F	See PPS 30.05 for austenitizing information (nitriding grade only)
52100	1400°F - 1450°F	700°F	1625°F - 1675°F	1500°F - 1550°F
300M	1525°F - 1575°F	600°F	1675°F - 1725°F	1575°F - 1625°F
HY-TUF	1375°F - 1425°F (Note 2)	1200°F	1700°F - 1750°F	1575°F - 1625°F
H-11 Mod	1500°F - 1550°F	1000°F	1625°F - 1675°F	1825°F - 1875°F
CASTINGS				
8615	N/A	N/A	1675°F - 1725°F	—
8630 Mod	N/A	N/A	1700°F - 1750°F (Note 1)	1575°F - 1625°F (Note 1)
4130	N/A	N/A	1700°F - 1750°F (Note 1)	1575°F - 1625°F (Note 1)

Note 1. For welded combinations of 4130, 4340 and 8630 alloy, normalize and austenitize within the highest temperature range specified for any of the detail alloys in the assembly.
Note 2. See Flow Chart 3 for sub-critical annealing of HY-TUF material.

TABLE VI - MINIMUM SOAKING TIMES

ALLOY	HEAT TREATMENT	THICKNESS (NOTE 2)	MINIMUM SOAKING TIME (NOTE 1)	
			FURNACES	SALT BATHS (NOTE 3)
1010 1020 1095 4130 4140 4330V 4340 8615 8630 8630 Mod 7140 (135M) 52100 300M HY-TUF	Pre-heating Full Annealing Normalizing Austenitizing Stress Relieving (Note 8) (Non-Hardened Parts)	Less than 0.100"	20 minutes	17 minutes
		0.100" - 0.249"	25 minutes	18 minutes
		0.250" - 0.500"	45 minutes	35 minutes
		0.501" - 1.000"	60 minutes	40 minutes
		1.001" - 1.500"	75 minutes	45 minutes
		1.501" - 2.000"	90 minutes	50 minutes
		2.001" - 2.500"	105 minutes	55 minutes
		2.501" - 3.000"	120 minutes	60 minutes
		3.001" - 3.500"	135 minutes	65 minutes
		3.501" - 4.000"	150 minutes	70 minutes
	Sub-Critical Annealing (HY-TUF only)	all	3 hours	
	Tempering (except 300M) (Notes 5 & 6)	all	2 hours plus an additional hour for each inch of thickness (Note 2) or fraction thereof greater than 1 inch	
	Tempering 300M (Note 4)	all	4 hours	
H-11 Mod	Pre-heating	all	30 minutes plus 15 minutes for each 1/2 inch of section thickness	
	Full Annealing Normalizing	all	Use annealing or normalizing soak times specified above	
	Austenitizing Stress Relieving (Non-Hardened Parts)	all	Up to 1/2 inch section - 15 minutes	
			1/2 to 1 inch section - 30 minutes	
			1 to 2 inch section - 45 minutes	
	Tempering (Note 7)	all	2 hours plus an additional hour for each inch of thickness (Note 2) or fraction thereof greater than 1 inch	

Note 1. The soaking time commences depending on the type of furnace used. See section 5.3 for determining when soaking time commences.
Note 2. Thickness is the minimum dimension of the heaviest section of a part or the minimum dimension of a multi-layer load, whichever is greater.
Note 3. Do not use salt baths for annealing.
Note 4. For 300M material, the soaking time applies to tempering after normalizing only. For tempering after austenitizing, see paragraph 5.8.3.4.2.
Note 5. For 4340 material, the soaking time applies to tempering to strength ranges other than 260-280 ksi. For tempering to 260-280 ksi, soak for 4 hours per inch of thickness (Note 2) or fraction thereof.
Note 6. For 4330V material, the soaking time does not apply. For tempering 4330V after austenitizing, see paragraph 5.8.3.4.3 and, after normalizing, see Flow Chart 5.
Note 7. For H-11 Mod material, the soaking time applies to tempering after normalizing only. For tempering after austenitizing, see paragraph 5.8.3.4.1.
Note 8. For HY-TUF material to be stress relieved after welding, see Flow Chart 4.

5.8.3 Tempering

5.8.3.1 The maximum permissible delay between quenching and tempering of HY-TUF (AMS 6418) steel and those alloys with 0.35% nominal carbon content or greater, is one hour (refer to Table III for nominal carbon content of alloys). Alloys with less than 0.35% carbon shall be tempered within 2 hours of quenching or reaching room temperature after sub-zero treatment according to PPS 30.02.

5.8.3.2 If the specified minimum tempering temperature exceeds 500°F (see Table VII) and tempering cannot be accomplished within a reasonable time limit, parts may be processed as follows to reduce chances of cracking:

Step 1. Allow parts to cool to 160°F or less after quenching.

Step 2. Heat parts (snap temper) at 350 - 410°F for 1 to 6 hours.

Step 3. Cool to 160°F or less.

Step 4. Perform any dimensional checks, fixturing, etc. but no machining or grinding.

Step 5. Perform required temper as soon as possible.

5.8.3.3 If only the minimum or maximum UTS value is specified, the acceptable range is 20,000 psi above the minimum or below the maximum, respectively.

5.8.3.4 Except as noted in paragraph 5.8.3.4.1 through paragraph 5.8.3.4.3, temper parts to the applicable tensile strength by soaking at the temperature specified in Table VII for the time specified in Table VI.

5.8.3.4.1 When tempering H-11 Mod. (AMS 6485 or AMS 6487) material to a tensile strength range of 220 - 240 ksi or greater, temper the parts three times for 2 hours plus an additional hour for each inch of metal thickness (or fraction thereof) greater than 1 inch at the temperature specified in Table VII. Air cool to room temperature between tempering operations.

5.8.3.4.2 When tempering 300M material to a tensile strength range of 280 - 305 ksi, temper the parts two times for 2 hours plus an additional hour for each inch of metal thickness (or fraction thereof) greater than 1 inch at the temperature specified in Table VII. Air cool to room temperature between tempering operations.

5.8.3.4.3 When tempering 4330V material to a tensile strength range of 220 - 240 ksi, temper the parts two times for 2 hours plus an additional hour for each inch of metal thickness (or fraction thereof) greater than 1 inch at the temperature specified in Table VII. Air cool to room temperature between tempering operations.

TABLE VII - APPROXIMATE TEMPERING TEMPERATURES (NOTE 1)

UTS (ksi) / ALLOY	90 to 120	100 to 120	125 to 145	140 to 160	150 to 170	160 to 180	180 to 200	200 to 220	220 to 240	240 to 260	260 to 280	280 to 305	Rc60 to Rc65
Wrought Alloys (including Forgings)													
1010	See PPS 30.11 for tempering information (carburizing grade only)												
1020													
1095	—	—	—	—	—	—	750 (Rc 40-43)	680 (Rc 43-46)	—	—	—	—	—
4130	1225°F	—	1025°F	975°F	950°F	850°F	725°F	—	—	—	—	—	—
4140	—	—	1100	—	—	—	—	—	—	—	—	—	—
4330V	—	—	—	—	—	—	—	—	600°F	—	—	—	—
4340 (Note 2)	1250°F	—	1200°F	1175°F	1100°F	1050°F	950°F	850°F	—	—	—	—	—
8630 (Note 2)	1150°F	—	1025°F	975°F	950°F	850°F	725°F	—	—	—	—	—	—
7140 (135M)	See PPS 30.05 for austenitizing and tempering information (nitriding grade only)												
52100	—	—	—	—	—	—	—	—	—	—	—	—	350°F
300M	—	—	—	—	—	—	—	—	—	—	—	575°F	—
HY-TUF	—	—	—	—	—	—	—	—	550°F	—	—	—	—
H-11 Mod	—	—	—	—	—	—	—	—	1075°F	1050°F	1025°F	—	—
Castings													
8615	—	—	—	—	—	—	—	—	—	—	—	—	—
8630 Mod (Note 2)	—	—	—	—	825°F	—	—	—	—	—	—	—	—
4130 (Note 2)	—	1150°F	—	—	—	—	—	—	—	—	—	—	—

Note 1. The temperatures specified in this table represent the approximate tempering temperature.
Note 2. If selection of tempering temperature for 4130, 4340 and 8630 alloys is based on “as quenched” hardness, the minimum temperatures specified in Table VIII apply.
For welded combinations of 4130, 4340 and 8630, the minimum tempering temperature shall be the lowest temperature specified for any of the detail alloys in the assembly.

TABLE VIII - APPROXIMATE "AS QUENCHED" TEMPERING TEMPERATURE FOR 4130, 4340 AND 8630 ALLOY

ALLOY	STRENGTH RANGE (ksi)	AS QUENCHED HARDNESS - ROCKWELL C (Rc)							
		38-40	**41-43**	**44-46**	**47-49**	**50-52**	**53-55**	**56-59**	**OVER 59**
4130 8630	125 - 145	725°F	800°F	875°F	950°F	1025°F	1100°F	—	—
	140 - 160	—	—	800°F	875°F	950°F	1025°F	—	—
	150 - 170	—	—	725°F	800°F	875°F	950°F	—	—
	160 - 180	—	—	700°F	750°F	825°F	900°F	—	—
	180 - 200	—	—	—	—	725°F	800°F	—	—
4340	125 - 145	—	—	—	925°F	1000°F	1075°F	1150°F	1200°F
	140 - 160	—	—	—	—	975°F	1050°F	1125°F	1175°F
	150 - 170	—	—	—	—	900°F	975°F	1025°F	1100°F
	160 - 180	—	—	—	—	825°F	900°F	975°F	1050°F
	180 - 200	—	—	—	—	725°F	800°F	875°F	950°F
	200 - 220	—	—	—	—	—	700°F	750°F	850°F
	260 - 280	—	—	—	—	—	410°F	450°F	490°F

5.8.4 Quenching

5.8.4.1 Quench parts in oil within 15 seconds of removal from the furnace, using vigorous agitation. Quench small thin parts, 0.025" thickness and less, within 5 seconds of removal from the furnace. At the start of the quenching operation, the temperature of the oil shall not exceed 130°F and shall not exceed 200°F at any time during quenching.

5.8.4.2 Parts shall remain in the oil until they reach the temperature of the oil. Then, remove the parts from the oil and cool to room temperature.

5.8.4.3 When a vacuum furnace with an integral oil quench is to be employed, the parts shall be transferred from the heating chamber to a chamber separated by a physical partition capable of being under partial pressure with an inert gas from which parts shall be quenched in circulating oil.

5.8.4.4 Inert gas employed for quenching in vacuum furnaces shall be as specified in section 4.1. The furnace shall be capable of recirculating the inert gas in order to achieve the required cooling rates.

5.8.4.5 In order to maintain control over quench delay times, check the quench delay time once per shift, using a suitable stop watch, and record the results (e.g., Process Control Record DH Form #3520 as specified in QDI-09-02). However, if automated quench equipment can demonstrate repeatability, submit substantiating data to Bombardier Toronto for review and, upon approval, a PSD may be issued to allow a weekly quench delay check in place of once per shift.

5.8.5 Martempering (Marquenching)

5.8.5.1 Martempering, also known as marquenching, is an elevated-temperature quench used to reduce thermal and dimensional stresses. It may be used to quench parts made of 4130, 4140, 4330V, 4340 and 8630 after austenitizing.

5.8.5.2 For parts meeting the size limitations of Table IX, martemper as follows:

Step 1. Prepare martempering bath of "martempering oil" at a temperature of 350 ± 50°F or "martempering salt" at a temperature of 375 ± 25°F.

Step 2. Leave parts in the martemper bath until the bath temperature stabilizes (20 minutes maximum). During the temperature stabilization period, the bath temperature shall not exceed 400°F. Agitate the bath to facilitate heat transfer. If parts are not stabilized within 20 minutes, transfer the parts to an oil quench having an initial temperature of 130°F maximum and cool to 200°F maximum.

Step 3. Cool in air or oil to 200°F maximum.

TABLE IX - MARTEMPER SIZE LIMITATIONS

STEEL TYPE	MAXIMUM SECTION SIZE				
	Round Bar (Diameter)	Square Bar (Thickness)	Flat Bar, Plate, Sheet, Forgings (Thickness)	Open Tubes (Wall Thickness)	Closed Tubes (Wall Thickness)
4130/8630	0.19"	0.15"	0.15"	0.10"	0.05"
4140	0.75"	0.60"	0.50"	0.38"	0.25"
4340	2.30"	1.85"	1.55"	1.15"	0.77"
4330V	2.60"	2.10"	1.75"	1.30"	0.88"

5.8.6 Sub-Zero Quench/Tempering of 52100 Alloy

5.8.6.1 After hardening and before final tempering, subject all parts of 52100 alloy to a multi-stage sub-zero quench/temper treatment as follows:

Step 1. Immerse parts in a refrigerant bath according to PPS 30.02 and allow parts to soak for 45 to 60 minutes.

Step 2. Remove parts from the refrigerant bath.

Step 3. Temper parts in an air furnace at 325 ± 25°F for 30 to 40 minutes.

Step 4. Air cool parts to room temperature.

Step 5. Repeat Step 1 through Step 4.

Step 6. Repeat Step 1 and Step 2.

5.8.7 Ausbay Quench of 300M Alloy

5.8.7.1 Ausbay quenching is limited to 300M alloy and only when specified on the engineering drawing.

5.8.7.2 Ausbay quenching reduces internal stresses and minimizes distortion during the hardening process of 300M alloy.

5.8.7.3 Ausbay quench shall be performed utilizing salt baths or in an integrated vacuum furnace. Ausbay quench into a vacuum furnace or salt bath at 1000 ± 25° F, equalize at temperature, followed by subsequent oil quenching at 140 ± 10° F.

5.8.7.4 Ausbay quenching involves the hardening of 300M alloy by first rapidly cooling from the austenitizing temperature to an intermediate temperature above that where martensitic transformation begins. Cooling from the austenitizing temperature to the ausbay region shall be relatively fast. By interrupting the cooling process, the ausbay quenching technique reduces the internal stresses that are created within the material due to thermal shock. Cooling the load quickly to the stabilizing temperature in the ausbay region ensures that an austenitic structure is maintained. Subsequent quenching from this lower ausbay temperature further reduces thermal shock due to the high thermal process.

5.9 Stress Relief (Hardened Parts)

5.9.1 Springs made of 1095 alloy; QQ-W-470; AMS 5112; or ASTM A228/A228M wire shall be stress relieved according to Table X after forming. Air cool to room temperature after stress relief.

5.9.2 If the following parts have been machined, ground, or rolled in the finish heat treat condition, stress relieve according to Table X as soon as possible after such operations and before any required acid cleaning or plating. Air cool to room temperature after stress relief:

- All parts having a final heat treat temper of 180 - 200 ksi or greater
- Threaded parts of 160 - 180 ksi or greater

TABLE X - STRESS RELIEF (HARDENED PARTS) AND EMBRITTLEMENT RELIEF

<table>
<tr><th rowspan="2">ALLOY</th><th rowspan="2">CONDITION</th><th colspan="2">STRESS RELIEF</th><th colspan="2">EMBRITTLEMENT RELIEF</th></tr>
<tr><th>TEMPERATURE (± 25°F)</th><th>SOAKING TIME (HOURS)</th><th>TEMPERATURE (± 25°F)</th><th>SOAKING TIME (Note 3)</th></tr>
<tr><td rowspan="2">1095</td><td>180 - 200 ksi (Rc 40 - 43)</td><td>700°F (Note 1)</td><td>2 - 3 hours (Note 1)</td><td rowspan="2">395°F</td><td rowspan="2">4 - 5 hours</td></tr>
<tr><td>200 - 220 ksi (Rc 43 - 45)</td><td>605°F (Note 1)</td><td>1 - 2 hours (Note 1)</td></tr>
<tr><td>4330V</td><td>220 - 240 ksi</td><td>525°F (Note 1)</td><td>1 - 2 hours (Note 1)</td><td>395°F</td><td>8 - 9 hours</td></tr>
<tr><td rowspan="4">4340</td><td>150 - 170 & 160 - 180 ksi</td><td>N/A</td><td>N/A</td><td rowspan="2">395°F</td><td rowspan="2">8 - 9 hours</td></tr>
<tr><td>180 - 200 & 200 - 220 ksi</td><td>700°F (Note 1)</td><td>1 - 2 hours (Note 1)</td></tr>
<tr><td rowspan="2">260 - 280 ksi and over</td><td rowspan="2">375°F (Note 2)</td><td rowspan="2">3 - 4 hours</td><td rowspan="2">375°F (Note 2)</td><td>8 - 9 hours (Note 4)</td></tr>
<tr><td>23 - 25 hours (Note 5)</td></tr>
<tr><td>52100</td><td>Rc 55 and over</td><td>N/A</td><td>N/A</td><td>300°F</td><td>4 - 5 hours</td></tr>
<tr><td>300M</td><td>280 - 305 ksi</td><td>525°F (Note 1)</td><td>4 - 5 hours (Note 1)</td><td>395°F</td><td>12 - 13 hours</td></tr>
<tr><td>HY-TUF</td><td>220 - 240 ksi</td><td>450°F (Note 1)</td><td>1 - 2 hours (Note 1)</td><td>395°F</td><td>8 - 9 hours</td></tr>
<tr><td>H-11 Mod</td><td>220 - 240 ksi and over</td><td>700°F (Note 1)</td><td>1 - 2 hours (Note 1)</td><td>395°F</td><td>23 - 25 hours</td></tr>
<tr><td>QQ-W-470;
AMS 5112;
ASTM A228/
A228M
Music Wire</td><td>As purchased</td><td>500°F (Note 1)</td><td>30 - 40 minutes (Note 1)</td><td>395°F</td><td>23 - 25 hours</td></tr>
<tr><td>Carburized, Carbonitrided or Cyanided Parts</td><td>Case or Core: 150 - 170, 160 - 180 ksi and over</td><td colspan="2">See PPS 30.11 for stress relief information</td><td>300°F</td><td>4 - 5 hours</td></tr>
<tr><td>Liquid Nitrided Parts</td><td>Case or Core: 150 - 170, 160 - 180 ksi and over</td><td colspan="2">See PPS 30.16 for stress relief information</td><td>395°F</td><td>4 - 5 hours</td></tr>
<tr><td>Gas Nitrided Parts</td><td>Case or Core: 150 - 170, 160 - 180 ksi and over</td><td colspan="2">See PPS 30.05 for stress relief information</td><td>395°F</td><td>4 - 5 hours</td></tr>
<tr><td>All internally and externally threaded parts</td><td>160 - 180 ksi and over</td><td>395°F</td><td>3 - 4 hours</td><td>395°F</td><td>23 - 25 hours</td></tr>
<tr><td>All Others (4130, 8630, etc.)</td><td>160 - 180 ksi and over</td><td>Tempering temperature or 700°F whichever is lower (Note 1)</td><td>1 - 2 hours (Note 1)</td><td>395°F</td><td>4 - 5 hours</td></tr>
<tr><td colspan="6">Note 1. Stress relief temperature and soaking time applies to parts other than shot peened parts. Parts requiring stress relief according to section 5.9 which have previously been shot peened shall be stress relieved at 395 ± 25°F for 10 - 12 hours.
Note 2. ± 15°F instead of ± 25°F.
Note 3. For acid or electrolytic cleaned parts and for macro etch (burn detection) treated parts, a soaking time of 3 - 4 hours may be used.
Note 4. For brush cadmium plated parts and chrome (deposited directly on base metal) plated parts.
Note 5. For parts other than brush cadmium plated or chrome (deposited directly on base metal) plated.</td></tr>
</table>

5.10 Decarburization Control

5.10.1 Control decarburization by a combination of machining after heat treatment, copper plating and/or atmospheric controls.

5.10.2 The following parts, when austenitized, should be heat treated in either an inert or endothermic atmosphere, vacuum furnace or salt bath meeting the applicable requirements stated in section 4.2:

- Parts machined on any surface to within 0.025" of the final drawing dimensions
- Extrusions, as received or machined to any extent
- Parts to be hardened to above 220 ksi
- Parts heat treated in either an inert or endothermic atmosphere or salt bath may require copper plating (0.002" - 0.003" over the entire surface) according to PPS 33.05. The decision to apply the copper plate is at the discretion of the heat treating facility. However, decarburization test specimens meeting the requirements of section 6.5 shall accompany each batch of parts and the requirements of section 6.5.2.3 shall be met. If parts are to be heat treated in a vacuum furnace, copper plating will not be required
- ZERO DECARB is required on all Bombardier Toronto 300M (AMS 6419, 280 - 305 ksi) steel parts and when specified on the engineering drawing. This requirement can be met by heat treating parts in the semi-finished machined condition. Any holes for lock wires, etc. should be drilled before heat treat. Partial DECARB within the depth of such holes is allowed

5.10.3 Parts for which none of the conditions specified in paragraph 5.10.2 apply may be heat treated in an air furnace.

5.11 Embrittlement Relief

5.11.1 Within 4 hours of etching, pickling or plating, embrittlement relieve according to Table X all parts specified by the applicable cleaning or plating PPS or if required after burn detection according to PPS 20.05. Then, air cool to room temperature.

5.12 Salt Removal

5.12.1 After heating in a salt bath and before any further heating operations, remove salt residues as follows:

Step 1. Immerse parts in agitated boiling water for 30 minutes minimum.

Step 2. Flush out tube bores and parts having recessed areas with high pressure boiling water.

Step 3. Check for entrapped salt and, if necessary, repeat Step 2 until the salt is completely removed.

5.13 Removal of Copper Plating

5.13.1 After heat treatment, strip copper plated parts according to PPS 33.02.

6 REQUIREMENTS

6.1 General

6.1.1 For the purposes of this PPS, the term “MRB” (Material Review Board) shall be considered to include Bombardier Toronto MRB and Bombardier Toronto delegated MRB.

6.1.2 All testing and evaluation specified herein shall only be performed by Bombardier Toronto Materials Laboratory or by laboratories accredited according to BAERD GEN-018.

6.2 Magnetic Particle Inspection

6.2.1 Magnetic particle inspect parts and material as specified in PPS 20.01 or on the engineering drawing.

6.3 Hardness Testing

6.3.1 General

6.3.1.1 After heat treatment, hardness test parts or material specified in section 6.3.2 through section 6.3.4 to verify mechanical properties specified on the engineering drawing.

6.3.2 Wrought Alloys

6.3.2.1 Heat Treated Stock Material

6.3.2.1.1 After hardening and tempering bar, rod or plate (rough shapes) stock material, cut a test piece from one piece in each furnace load to a length equal to the diameter or minimum thickness of the largest section. Hardness test as specified in section 6.3.5 close to the centre of the test specimen cut surface.

6.3.2.2 Heat Treated Rough Machined Parts

6.3.2.2.1 Perform hardness testing as specified in section 6.3.5 on the heaviest sections of parts selected according to the sampling requirements specified in AMS 2759.

6.3.2.3 Heat Treated Finish Machined Parts

6.3.2.3.1 Perform hardness testing as specified in section 6.3.5 on the heaviest suitable sections which are not detrimental to the function of the finish machined parts (i.e., non-stressed surface) according to the sampling requirements specified in AMS 2759.

6.3.3 Castings

6.3.3.1 After final heat treatment, hardness test one casting from each lot of castings as specified in section 6.3.5.

6.3.4 Forgings

6.3.4.1 After final heat treatment, hardness test one forging from each lot of forgings as specified in section 6.3.5.

6.3.5 Hardness Test Procedure

6.3.5.1 Perform hardness testing, when specified, according to PPS 20.08.

6.3.5.2 Perform hardness testing of 52100 alloy parts using the Rockwell B scale only.

6.3.5.3 Take at least three hardness readings on each part to be checked.

6.3.5.4 Minimum and maximum hardness values obtained on any one part shall not differ more than 3 Rockwell C points, or equivalent, and all values shall be in the range specified on the engineering drawing or in this standard.

6.3.5.5 Refer to PPS 20.08 for the conversion figures from ultimate tensile strength (UTS) values to Rockwell hardness values. If only the minimum or maximum UTS values are specified, the acceptable range shall be considered to be 20,000 psi above the minimum or below the maximum, respectively.

6.4 Tensile Testing

6.4.1 General

6.4.1.1 After heat treatment, tensile test parts and material as specified in section 6.4.2, section 6.4.3 or section 6.4.4.

6.4.2 Wrought Alloys

6.4.2.1 Parts heat treated to a tensile strength range of 200 - 220 ksi or greater, two tensile test specimens are required from each furnace load, if possible from the same material batch as that of the production parts.

6.4.2.2 Test specimen dimensions shall conform to ASTM E8/E8M or the Laboratory drawing listed in Table XI.

6.4.2.3 Submit one test specimen to an approved laboratory as specified in paragraph 4.3.3.2 for testing. The submitted tensile test specimen shall meet the tensile strength requirements specified in Table XII or on the engineering drawing. If only the minimum or maximum UTS values are specified, the acceptable range shall be considered to be 20,000 psi above the minimum or below the maximum, respectively. If the tensile test specimen fails to meet the specified requirements refer the batch of parts represented to MRB for disposition.

6.4.2.4 If MRB has specified re-heat treatment after failure of a test specimen, include the remaining test specimen in the same furnace load as the parts to be re-heat treated. After parts are re-heat treated, submit the test specimen to an approved laboratory as specified in paragraph 4.3.3.2 for testing. The submitted tensile test specimen shall meet the tensile strength requirements specified in Table XII or on the engineering drawing. If the tensile test specimen fails to meet the specified requirements refer the batch of parts represented to MRB for disposition. Determine and correct the cause of failure (i.e., material or process).

TABLE XI - WROUGHT ALLOY TENSILE TEST SPECIMENS (NOTE 1)

BAR AND PLATE PARTS	
DIAMETER/THICKNESS	**LAB DRAWING**
Less than 0.250"	None (Note 2)
0.250" - 0.499"	LAB 027-1
0.500" - 0.561"	LAB 011-7
0.562" - 0.749"	LAB 011-5
0.750" - 0.874"	LAB 011-3
0.875" - 0.999"	LAB 011-2
1.000" or greater	LAB 009-1

TUBE	
OUTSIDE DIAMETER	**LAB DRAWING**
Less than 1.0"	LAB 012
1.0" and over	LAB 013

SHEET AND STRIP	
THICKNESS	**LAB DRAWING**
All	LAB 025-2

Note 1. Dimensions specified in the lab drawings are finished part dimensions. Unless the material is to be issued in length, it will be necessary to increase the length to accommodate chucking.
Note 2. According to Laboratory instructions.

TABLE XII - MECHANICAL PROPERTIES OF CARBON AND LOW ALLOY STEELS

ULTIMATE TENSILE STRENGTH (KSI)	MINIMUM 0.2% YIELD STRENGTH (KSI)	MINIMUM % ELONGATION						MINIMUM REDUCTION IN AREA (%) (NOTE 3)
		ROUND SPECIMEN (NOTE 1)	SHEET SPECIMENS (NOTE 2)			TUBE (NOTE 2)		
			OVER 0.060"	0.032" TO 0.060"	LESS THAN 0.032"	FULL TUBE	STRIP	
125 - 145	103	17	10	7	5	12	7	55
140 - 160	121	15	9	7	5	11	7	53
150 - 170	132	14	9	6	4	10	6	52
160 - 180	147	13	8	6	4	9	6	50
180 - 200	163	12	7	5	3	8	5	47
200 - 220	176	10	6	4	3	6	5	43
220 & over	Note 4							

Note 1. Elongation in 4D.
Note 2. Elongation in 2 inches.
Note 3. Applicable to round test bars only.
Note 4. Mechanical properties of parts having a specified tensile strength range of 220 - 240 ksi or greater shall be specified on the engineering drawing.

6.4.3 Castings

6.4.3.1 After final heat treatment, tensile test castings according to PPS 35.07.

6.4.4 Forgings

6.4.4.1 After final heat treatment, tensile test forgings according to PPS 35.04.

6.5 Carburization/Decarburization (Carb/Decarb) Control

6.5.1 General

6.5.1.1 Unless subsequent machining will remove at least 0.025" from all surfaces, process one LAB 045 carb/decarb control test specimen as specified in Table XIII with each batch of parts which are to be final tempered to a tensile strength range of 180 - 200 ksi or greater. Once weekly, check each furnace or salt bath used to heat treat parts to a tensile strength range of 160 - 180 ksi and below for carb/decarb control using a LAB 045 test specimen specified in Table XIII.

6.5.1.2 The carb/decarb test specimen shall be subjected to all annealing, normalizing and austenitizing heat treat operations together with the parts represented. Carb/decarb test specimens shall not be subjected to stress relief, embrittlement relief or tempering to final temper heat treatment.

6.5.1.3 If the parts require re-heat treatment, other than re-tempering, include the carb/decarb control test specimen, or remnants thereof, with the parts.

TABLE XIII - CARB/DECARB CONTROL TEST PIECES

ALLOY	TEST PIECE
1095	LAB 045-6
4130	LAB 045-3
4330V	LAB 045-3
4340	LAB 045-5
8630	LAB 045-3
52100	LAB 045-6
HY-TUF	LAB 045-9
300M	LAB 045-4
H-11 MOD	LAB 045-4

6.5.2 Carb/Decarb Test Procedure

6.5.2.1 General

6.5.2.1.1 Cut the carb/decarb test specimen approximately in half through the 1/4 inch dimension and perform a micro-hardness traverse on the cut face at 0.001" intervals. Take care to prevent partial tempering resulting from heat generated during the cutting operation.

6.5.2.1.2 When ZERO DECARB is required by this PPS or the engineering drawing, use the chord method according to SAE ARP 1820 to measure decarb depth.

6.5.2.2 Carburization

6.5.2.2.1 The surface hardness shall not be greater than 25 Knoop points above the core hardness and the microstructure shall show no evidence of carburization.

6.5.2.2.2 Evidence of an increase in hardness at the surface of the sample due to carburization shall be cause to reject the batch of parts represented.

6.5.2.3 Decarburization

6.5.2.3.1 The depth of decarburization is defined as the perpendicular distance from the surface to the non-decarburized zone below which there is no increase in hardness.

6.5.2.3.2 There shall be no evidence of full/partial decarburization on finish machined parts of 300M material. Process 300M parts according to section 5.10.

6.5.2.3.3 There shall be no full decarburization on any part. For materials, other than 300M, heat treated to a tensile strength of 200 ksi or greater, the depth of partial decarburization shall not exceed 0.003". For materials heat treated to below 200 ksi, the depth of partial decarburization shall not exceed 0.005". The hardness values determined in the micro-hardness survey of the partial decarburization zone shall not be more than 25 Knoop points below the core hardness.

6.5.2.3.4 Excessive decarburization is acceptable if subsequent machining or grinding of the parts represented will reduce the decarburization depth to meet the above requirements.

6.6 Intergranular Attack Control

6.6.1 All parts heat treated to a tensile strength range of 180 - 200 ksi or greater shall be examined for intergranular attack using the carb/decarb test specimen, sectioned according to section 6.5. The carb/decarb specimen shall be lightly etched, to a point where the microstructure is still not visible, in a 2% Nital solution.

6.6.2 Except as noted in paragraph 6.6.2.1, the test specimen shall show no intergranular attack in excess of 0.0007" for steel heat treated to under 200 ksi and 0.0005" for steel heat treated to 200 ksi and over.

6.6.2.1 If subsequent machining removes material from all surfaces, intergranular attack is acceptable provided the requirements of paragraph 6.6.2 are met after such machining.

7 SAFETY PRECAUTIONS

7.1 Do not ingest any of the materials used in the salt bath furnaces. Wash hands before eating or smoking.

7.2 Observe standard plant safety precautions when performing the procedure specified herein.

7.3 Whenever possible, stay behind the plexiglass protective wall while working with the salt bath furnace. If it is necessary to work inside the plexiglass wall, wear the following protective clothing at all times when loading or unloading the salt bath:

- *Bombardier approved splash shield*
- *Protective gloves (e.g., DSC 422-3)*
- *Aluminized fire-proof jacket*

7.4 Wear the following personal protective clothing whenever loading or unloading heat treat furnaces:

- *Protective gloves (e.g., DSC 422-3)*
- *Aluminized fire-proof jacket and hood*

8 PERSONNEL REQUIREMENTS

8.1 This PPS has been categorized as a Controlled Critical Process according to PPS 13.39. Refer to PPS 13.39 for additional personnel requirements. Certified and/or qualified personnel shall have a good working knowledge of the following, as applicable:

- engineering drawings, work order instructions and PPS sections regarding the heat treatment of carbon and low alloy steels
- how to set up and operate steel heat treat furnaces, salt baths, thermocouples, quenching and rinsing equipment, hardness testing machines
- equipment requirements specified herein
- importance of pre- and post-heat treatment cleaning of parts
- how to correctly handle parts when performing heat treatment
- able to define soaking time
- quenching requirements
- appropriate furnace atmosphere and quenching media for various carbon and low alloy steels
- importance of carburization/decarburization control
- procedures and requirements for pre-heating, full annealing, sub-critical annealing, stress relieving, normalizing, hardening and carburization/decarburization control of carbon and low alloy steels
- how to record data on the appropriate heat treat record
- physical and mechanical properties of carbon and low alloy steels

9 MAINTENANCE OF SALT BATH

9.1 Once weekly, submit a sample from the salt bath for determination of the pH value.

9.2 The pH shall be maintained within the range of 6.5 to 8.5, using small additions of salt containing sodium dichromate to lower the pH, as follows:

Step 1. Measure sodium dichromate in increments of 0.5% by weight of the total heat treat salt capacity of the salt bath.

Step 2. Mix the required amount of sodium dichromate (0.5% by weight) with salt in the ratio of 5 parts salt to 1 part sodium dichromate to reduce the pH by 0.5.

9.3 When making additions, the salt bath temperature shall be lowered to a maximum of 600°F. If small additions no longer maintain the pH, add sodium dichromate as necessary.

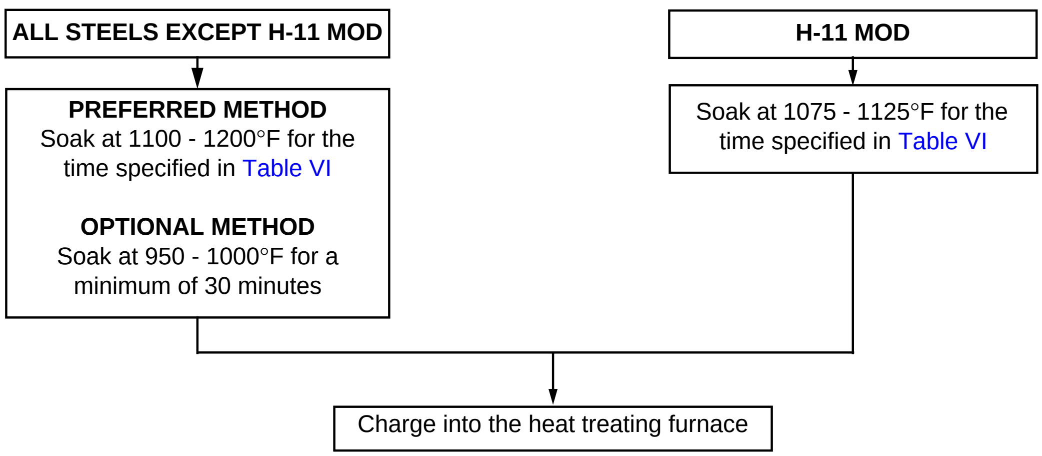
9.4 pH values between 8.5 and 10 are acceptable during bath stabilization following sodium dichromate additions. Any pH reading above 10 shall be reported immediately and corrective action taken.

9.5 Keep a record of salt and sodium dichromate additions made.

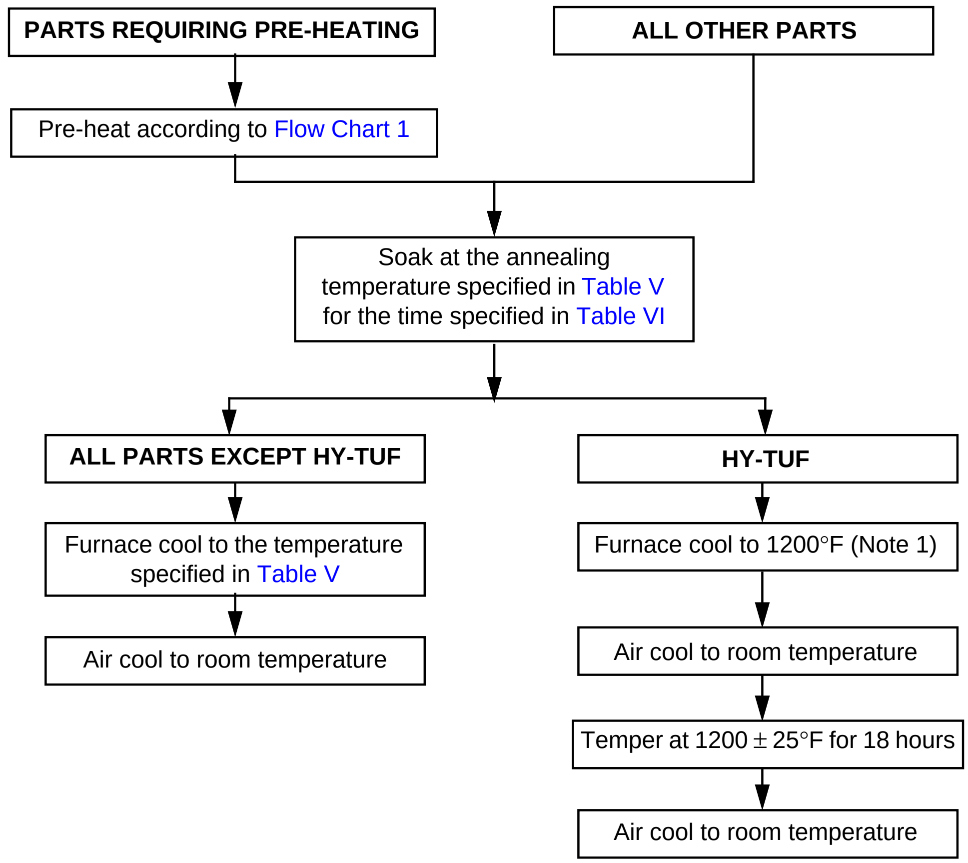
10 HEAT TREAT RECORDS

10.1 Records shall be kept of all heat treat operations, giving information as to Work Order Number, Job Card Number, Part Number, material specification, furnace or bath, quantity of parts, heating time, soaking time and temperature, cooling time (when cooled in furnace) and average Rockwell hardness (e.g., DH Form #3772A/3772B).

FLOW CHART 1 - PRE-HEATING

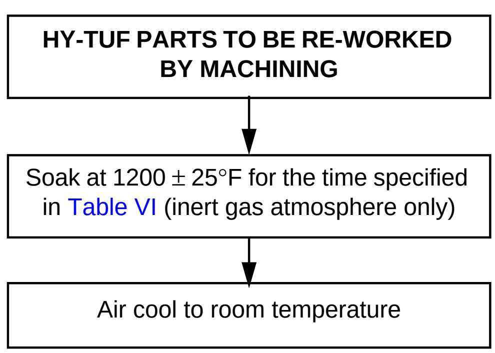


FLOW CHART 2 - FULL ANNEALING

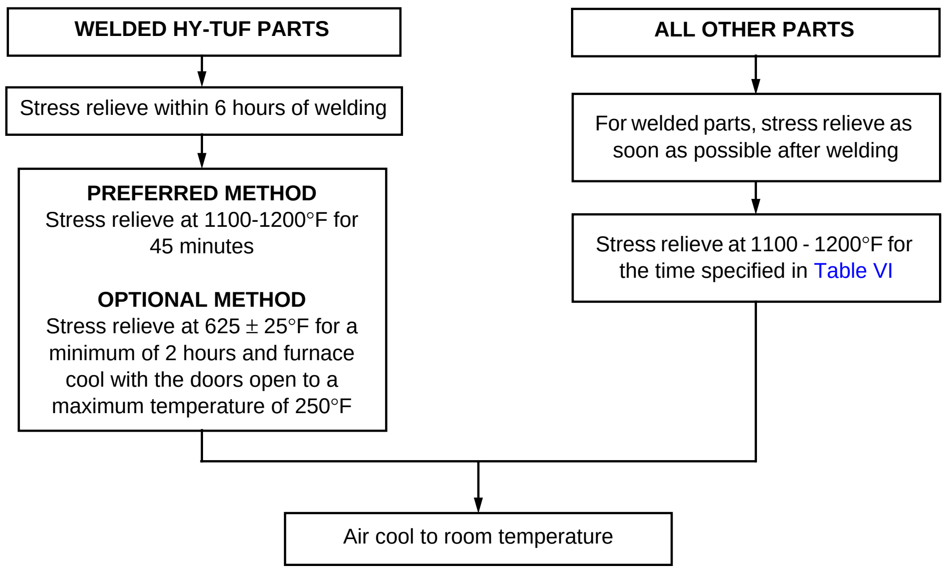


Note 1. Maximum cooling rate is 50°F per hour.

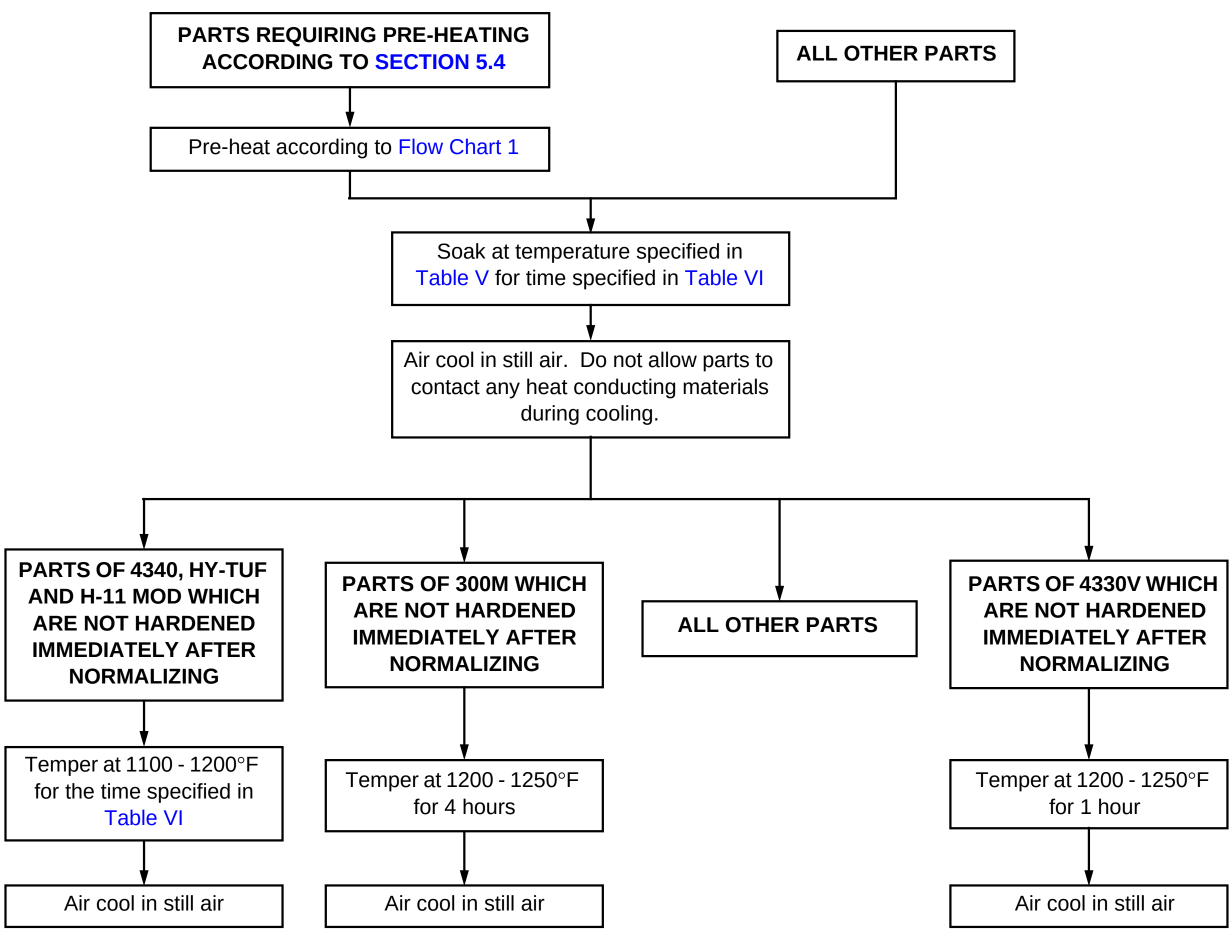
FLOW CHART 3 - SUB-CRITICAL ANNEALING



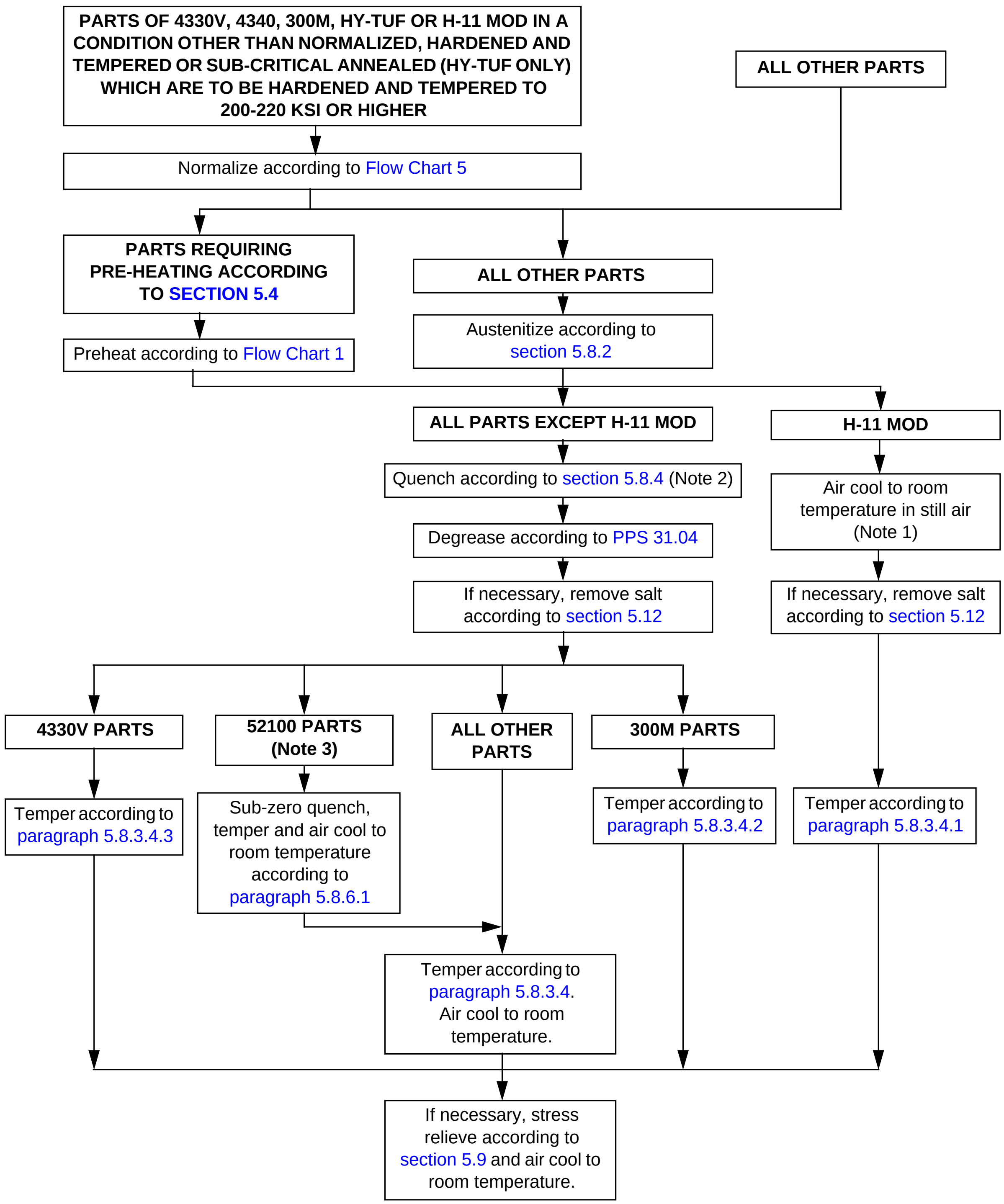
FLOW CHART 4 - STRESS RELIEVING (NON-HARDENED PARTS)



FLOW CHART 5 - NORMALIZING



FLOW CHART 6 - HARDENING CARBON AND LOW ALLOY STEELS



Note 1. Do not allow parts to come into contact with any heat conducting material during cooling.
Note 2. For 300M parts only, it is acceptable to ausbay quench to section 5.8.7.
Note 3. Other parts where sub-zero quenching is specified on the engineering drawing.