

1.0 SCOPE

This specification defines common requirements for wrought steels supplied to Caterpillar Inc., either directly in the form of steel products or indirectly in the form of steel parts. **This is a multi-variation specification (ref Article 4.0).**

2.0 APPLICATION

2.1 1E0024 defines product requirements such as composition and grain size as well as requirements for sampling, testing and data reporting. It outlines requirements for sourcing from approved suppliers and for use of substitute materials, defined in more detail in 1E1861 and 1E2349 respectively.

2.2 Product requirements in individual 1E specifications referencing 1E0024 take priority over the default requirements in 1E0024.

3.0 QUALIFYING SPECIFICATIONS

1E0038	Steel Hardenability Calculation
1E0552	Test Specimens - Metallic Materials
1E1821	Surface Quality - Plate and Sheet
1E1861	Wrought Steel - Approved Suppliers
1E2177	Mill Tolerances - Steel Products
1E2349	Materials Application - Substitute
1E2700	Strand Cast Steel - Application and Quality
1E4467	Registration, Evaluation, Authorization, and Restriction of Chemical Substance

4.0 DRAWING DESIGNATIONS

Current Designation	Former Designation	Application
1E0024A	1E0024	Steels with Jominy hardenability requirements
1E0024B	1E0038	All other steels

Figure 1

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WROUGHT STEEL – GENERAL REQUIREMENTS

DATE
08 MAR 2018

CHG NO
45

NUMBER
1E0024

5.0 PRODUCT REQUIREMENTS

5.1 Use of the word “shall”: The word “shall” is used in Caterpillar 1E specifications to specify a requirement.

5.2 Composition

5.2.1 Carbon - Product analysis tolerance for carbon shall be ± 0.01 WT %. All other elements shall conform to the specified composition ranges with no product analysis tolerance. For 1E steel specifications specifying a carbon range less than 0.05 WT %, the product analysis tolerance for carbon shall be ± 0.02 WT % for ingot cast steel only.

5.2.2 Sulfur - All bar and forging steels furnished to this specification, except bars without further machining, flat bar, and rolled sections, shall contain at least 0.010 WT % sulfur.

NOTE: Suppliers of purchased finished parts may use bar steels with lower sulfur content for parts that are not subsequently machined by Caterpillar.

5.2.3 Aluminum shall not exceed 0.08 WT % to prevent aluminum nitride grain boundary embrittlement and rock candy (intergranular) type fracture.

5.2.4 Titanium shall not exceed 0.065 WT % to prevent detrimental effects on machinability.

5.2.5 Incidental Elements - Certain elements may be present in steel that are not specified or required. These incidental elements shall not exceed the limits in Figure 2:

ELEMENT	MAXIMUM
Nickel (Ni)	0.30 WT %
Chromium (Cr)	0.20 WT %
Molybdenum (Mo)	0.08 WT %
Copper (Cu) (*)	0.35 WT %
Lead (Pb)	0.02 WT %
Tin (Sn)	0.03 WT %
Arsenic (As)	0.03 WT %

Figure 2

Note (*): Copper up to 0.50 WT% maximum is permitted for sheet, plate and cutting edge sections only.

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WROUGHT STEEL – GENERAL REQUIREMENTS

DATE
08 MAR 2018

CHG NO
45

NUMBER
1E0024

5.3 Boron Practice – 1E0024A qualified steels that specify boron for hardenability, for example 1E5053, shall be produced by a steelmaking practice that has been approved and noted in 1E1861. Boron steels require aluminum deoxidation and a titanium addition sufficient to bind all nitrogen, protecting the boron so it effectively increases hardenability. Boron steels with no Jominy requirements shall have a Ti:N ratio of 4.0 or greater. All boron steels require nitrogen testing (from the final ladle sample or a tundish sample) and reporting of both nitrogen and titanium.

5.4 Grain Refinement

5.4.1 When austenitic fine grain (5 or finer), measured according to ASTM E112, or fine grain practice is specified in 1E steel specifications, a minimum of 0.015 WT % aluminum (Al_{total}) is required, except as noted in section 5.4.2, or if a lower minimum aluminum value is stated in the material specification. Unless requested, grain size testing is not required for steel heats with aluminum ≥ 0.015 WT%.

5.4.2 Flat rolled steel, requiring fine grain practice, is not required to meet the minimum aluminum content specified in 5.4.1, provided the steel does not require heat treatment after rolling to meet specified mechanical property requirements.

5.4.3 For those heats requiring grain size measurement, austenitic grain size shall be determined according to ASTM E112 Annex A3.2.1.2 (McQuaid-Ehn), A3.2.1.3, A3.2.1.4, or A3.2.1.6.

5.4.4 For steel alloys intended for carburizing or induction hardening applications, only ASTM E112 A3.2.1.2 (McQuaid-Ehn) or A3.2.1.3 testing at 927°C shall be applied for austenite grain size measurement.

5.5 Soundness - For bar products and semi-finished forging steels, internal soundness and quality shall be verified by macro-etch testing per ASTM E381 or equivalent procedure. Samples shall represent the entire cross-section of the product. The face to be macro-etched shall be ground to a finish with roughness average of 2.5 microns or less.

5.6 Cleanliness - When individual 1E steel specifications are not qualified by 1E2661, assessment and reporting of microcleanliness is not required. However, maximum inclusion content for all steel shall conform to the ASTM E45 Method A requirements in Figure 3. While testing and reporting is not required, steel exceeding these limits is rejectable.

B		C		D	
THIN	HEAVY	THIN	HEAVY	THIN	HEAVY
2.5	2	1.5	1	1.5	1.5

Figure 3

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WROUGHT STEEL – GENERAL REQUIREMENTS

DATE
08 MAR 2018

CHG NO
45

NUMBER
1E0024

5.7 Radioactivity - Steel for Caterpillar products shall not have levels of radioactivity exceeding natural background levels.

5.8 Identification - Product shipped shall be identified to maintain heat traceability.

6.0 SAMPLING AND TESTING REQUIREMENTS

6.1 1E0024A Heat Sampling and Identification - Samples from each heat shall be identified alphabetically with the letter "A" designating the first material cast for Caterpillar use, and the letter "Z" designating the last material cast for Caterpillar use. All sampling shall be done after routine cropping and discard. Details of this system depend on the casting process.

6.1.1 Bottom Poured Ingots - The "A" sample shall be taken from the top of a random ingot in the first cluster (plate) cast and the "Z" sample from the bottom of an ingot in the last cluster (plate) cast.

6.1.2 Strand Cast In Single Heats - The "A" sample shall be taken from the first usable material regardless of strand and the "Z" sample from the last usable material regardless of strand.

6.1.3 Sequence Cast Strand Cast Steel - "A" and "Z" samples shall be taken from the first and last material assigned to a heat, with transition material defined according to Article 6.2.2.

6.1.4 Partial Heat Boron Steel Sampling - If the quantity applied to Caterpillar is less than fifteen tons, a single random product sample is acceptable.

6.1.5 Small Heat Boron Steel Sampling - If the heat size is less than 50 tons, single random Jominy and chemistry samples are acceptable. Small shipments from heats larger than 50 tons do not qualify for this exemption from "A" and "Z" product sampling.

6.1.6 Alloy Steel Product Chemistry Sampling - A single ladle chemistry sample is acceptable for steels that do not use boron as a hardenability intensifier.

6.2 Sequence Casting Restrictions - Multiple heats of strand cast steel may be cast in a continuous sequence with the following restrictions:

6.2.1 Sequence casting shall only be done with heats of similar grade and carbon range. Boron steels may not be sequence cast with non-boron steels.

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WROUGHT STEEL – GENERAL REQUIREMENTS

DATE
08 MAR 2018

CHG NO
45

NUMBER
1E0024

6.2.2 When grades with DI or Jominy hardenability requirements are cast as billets or blooms, transition material between heats shall be tested and assigned to heats based on DI calculations using the following ratios to ensure consistent heat treat response within each heat.

6.2.2.1 Front and back samples (“A” and “Z”) shall be tested for chemistry at transition boundaries. Calculated DI per 1E0038, SAE J406, or ASTM A255 using all elements except boron shall be used to assign the transition material to either of the adjacent heats.

6.2.2.2 If the ratio of the calculated DI for the two heats is between 0.80 and 1.20, the transition metal may be assigned to either heat, provided that both fulfill the specified composition and hardenability requirements.

6.2.2.3 If the ratio of the calculated DI for the two heats is not between 0.80 and 1.20, and both heats satisfy specification requirements for chemistry and hardenability, extra testing shall be done on the transition material to determine which billets or blooms can be assigned to either heat. Such testing and assignment shall assure that the DI ratio of the transition material and its assigned heat is between 0.80 and 1.20.

6.3 Specimens for Jominy Hardenability Testing (1E0024A Steels Only)

6.3.1 Forged Sampling - Specimens machined from forged samples representing the full cross-section of the product are optimal. The forged sample dimensions and test specimen locations are shown in Figure 4.

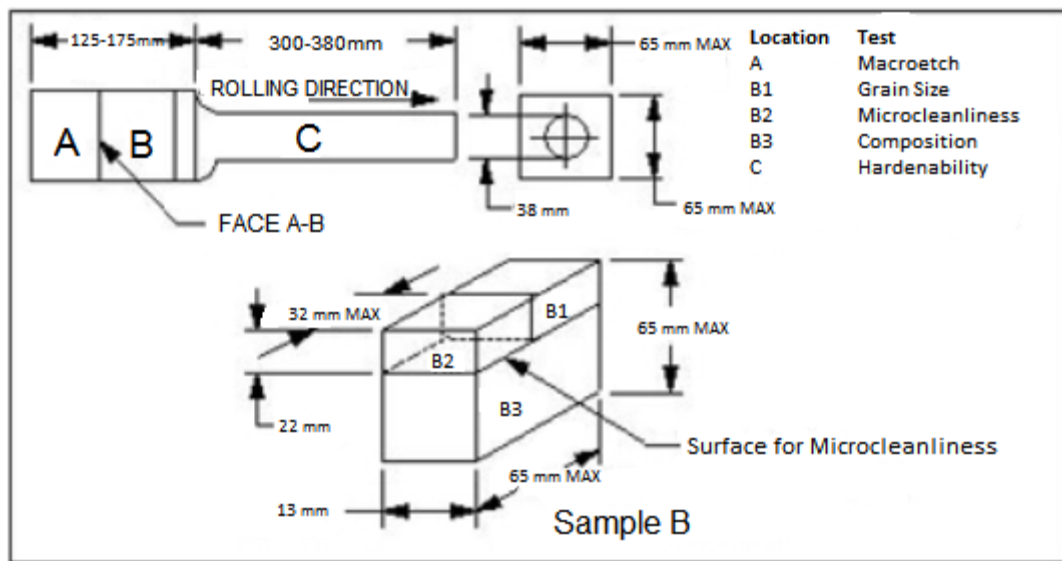


Figure 4 - Forged Mill Sample and Test Locations

Note: Dimensions in Figure 4 are for reference only.

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WROUGHT STEEL – GENERAL REQUIREMENTS	DATE 08 MAR 2018	CHG NO 45	NUMBER 1E0024

6.3.2 Rolled Sampling - Specimens may be machined directly from rolled product, provided the reduction ratio is at least 6:1 for bar and 3:1 for plate for both ingot cast and strand cast product. Both the Jominy specimen and hardness measurement locations shall be as near as possible to the mid-radius or quarter width of the rolled bars and plate.

6.3.2.1 Jominy Specimens from Bar - Jominy specimens shall be machined from bar as specified in SAE J406 and as shown in Figure 5.

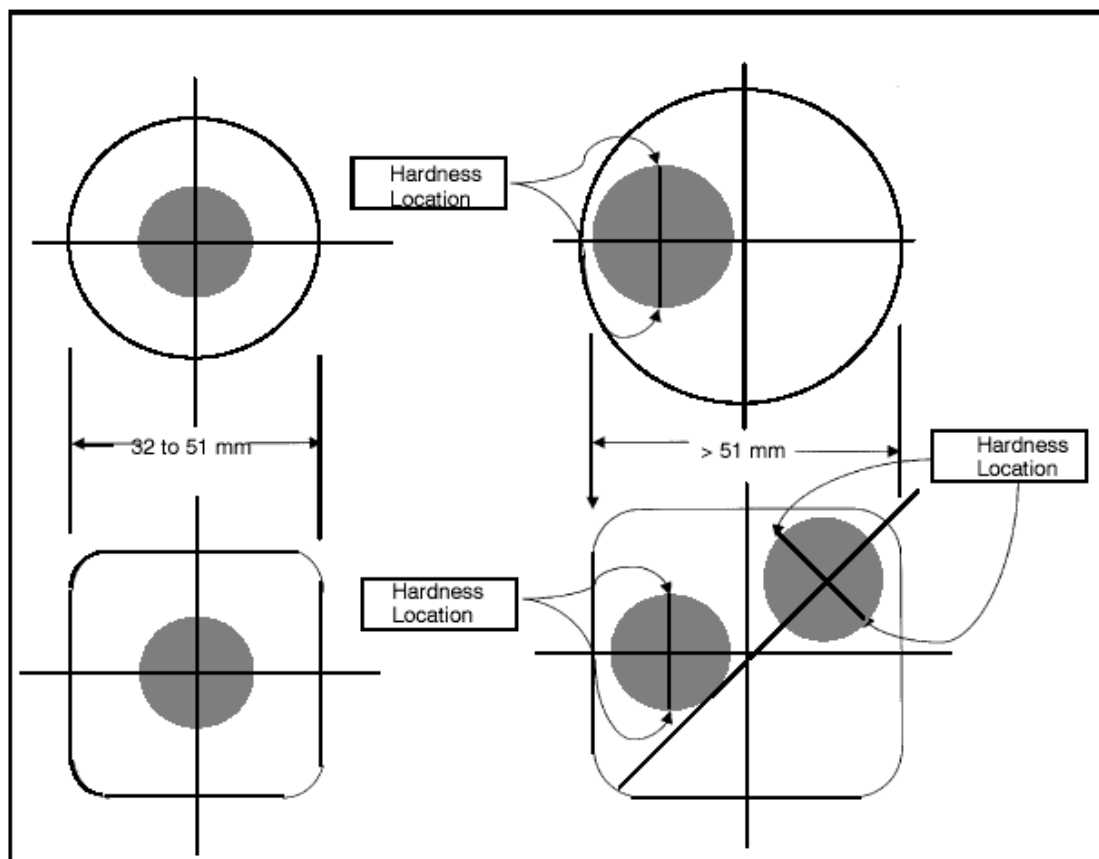


Figure 5 - Jominy Location for Bar Samples

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WROUGHT STEEL – GENERAL REQUIREMENTS

DATE
08 MAR 2018

CHG NO
45

NUMBER
1E0024

6.3.2.2 Jominy Specimens from Plate - As permitted by plate thickness, Jominy specimens shall be machined with the specimen center axis at the quarter thickness of flat rolled products. For thinner plates, Jominy samples shall be machined to place one side of the sample at the quarter thickness location as shown in Figure 6. Hardness probes shall be taken on the quarter thickness surface of the end quench specimen.

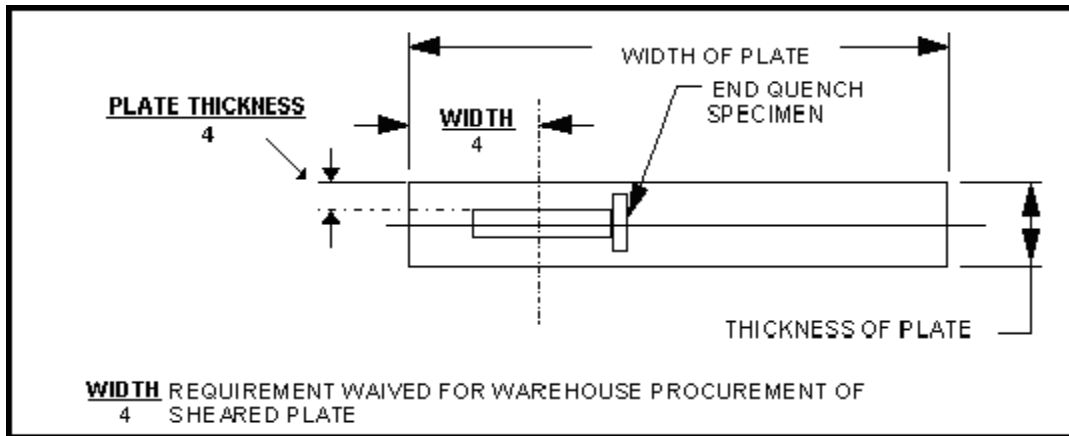


Figure 6 - Plate Sample

Note: Hardness probes shall be taken on the “PLATE THICKNESS/4” surface of the end quench specimen.

6.3.3 Cast Specimens - Cast specimens are permitted for non-boron grades provided that the practice has been approved by the regional dispositioning Caterpillar facility (ref Article 9.0).

6.4 Sampling for Chemical Analysis

6.4.1 Both 1E0024A and 1E0024B steels require analysis of a ladle sample.

6.4.2 Boron steels also require analysis of product samples.

6.4.2.1 Samples shall be identified with the heat number and the sample position within the heat per Article 6.1.

6.4.2.2 Chemical analysis shall be determined at any of the following locations (ref. Figures 4 and 6):

- Midway between the surface and center on Face A-B of the forged mill sample, or
- Mid-radius on the 38 mm diameter section of the forged mill sample, or
- Mid-radius on the Jominy hardenability specimen (as near as possible to $\frac{1}{4}$ section on plate).

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WROUGHT STEEL – GENERAL REQUIREMENTS

DATE
08 MAR 2018

CHG NO
45

NUMBER
1E0024

6.5 Jominy Hardenability Testing (1E0024A Steels Only)

6.5.1 Hardenability shall be determined by the Jominy end quench test per ASTM A255 or SAE J406 using specimen 1E0552-K1. In addition to those procedures contained in SAE J406C, the following guidelines shall be employed to ensure accurate and reproducible results.

6.5.2 Rockwell C hardness measurements shall be reported in inch (ref 6.5.2.1) or mm (ref 6.5.2.2) increments from the quenched end.

6.5.2.1 Inch increments shall start at 1/16 inch from the quenched end stopping when Rockwell C20 is reached or at 32/16 inches. Record Rockwell C hardness at 1/16-inch intervals up to and including 10/16 inch, at 1/8-inch intervals from 10/16 inch up to and including 20/16 inch, and at ¼ inch intervals beyond 20/16 inch.

6.5.2.2 Millimeter increments shall start at 1.5 mm from the quenched end stopping when Rockwell C20 is reached or at 50 mm. Record Rockwell C hardness at 1.5 and 3.0 mm, at 2 mm intervals up to and including 15 mm, and at 5 mm intervals beyond 15 mm.

6.5.3 Two traverses 180° apart shall be taken on each end quench specimen and the Rockwell C readings rounded to the nearest whole number. For each end quench specimen, the two hardness values at identical distances shall be averaged and rounded to the nearest whole number and that value reported. A single traverse shall be taken and reported for thinner plates (per 6.3.2.2).

6.5.4 If the two probes on opposite sides differ by more than 4 points RKW C at any one position, the test shall be repeated on new flats ground 90° from the first two. If the retest also has greater than 4 points RKW C variation, a new specimen shall be prepared and tested. Reheat of Jominy specimens is not permitted.

6.5.5 The distance from the quenched end to the center of the first hardness indentation shall be measured on each flat and reported as the "S" distance. If the "S" distance of either of the probes is not between 1.50 mm and 1.70 mm a retest shall be done.

6.5.6 Jominy testing is not required for 1E0024B qualified steels. Jominy data may be included in the specification for reference and may be requested in cases where there is question on the actual hardenability of the material.

6.6 Mechanical Property Testing

6.6.1 Any specified mechanical property tests shall be conducted on the material in the condition delivered to Caterpillar.

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WROUGHT STEEL – GENERAL REQUIREMENTS

DATE
08 MAR 2018

CHG NO
45

NUMBER
1E0024

6.6.2 Unless otherwise specified, methods of analysis, test and inspection shall conform to the latest appropriate ASTM standard (or appropriate National Standard)

6.6.3 Unless otherwise specified in the individual 1E specification, tensile tests shall report yield strength at 0.2% offset. If the material exhibits a well-defined yield point, this yield point may be reported as the yield strength. (Refer to ASTM A6, Section 11.7)

6.6.4 Unless otherwise permitted, compliance with specification requirements shall be based on the qualities of individual samples and not average qualities of a group of samples.

6.6.5 The testing frequency for tensile testing shall follow ASTM A6. Testing frequency for Charpy impact testing shall follow ASTM A673 heat testing (H) requirements.

6.6.6 Retest allowance for tensile and Charpy testing shall follow the requirements of ASTM A6 and ASTM A673, respectively.

6.7 1E0024A Sample Retention - Samples from chemistry and hardenability tests on 1E0024A steels shall be retained for at least 120 days after the data is submitted to Caterpillar.

7.0 REPORTING REQUIREMENTS

7.1 Heat data shall be reported to the regional dispositioning facility (ref Article 9.0) for all steels qualified by 1E0024.

7.2 Reporting Responsibility

7.2.1 Caterpillar approved mills and steel suppliers have the primary responsibility for submitting heat data to their regional dispositioning facility for all steel produced to a Caterpillar 1E specification.

7.2.2 Forgers, service centers, or other suppliers that purchase steel to industry standard grades (non-1E specifications) are responsible for reporting heat data to the receiving Caterpillar facility or to the regional dispositioning facility designated by the receiving facility.

7.2.3 Service Centers, forgers or other component suppliers that purchase steel made to 1E specifications from Caterpillar approved mills and steel suppliers are not required to report heat data. Caterpillar approved mills producing the steel will report it directly to Caterpillar (per 7.2.1).

7.2.4 Producers of forgings with requirements for tensile, impact and/or hardness properties after forging shall report test results with their submission of heat codes.

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WROUGHT STEEL – GENERAL REQUIREMENTS

DATE
08 MAR 2018

CHG NO
45

NUMBER
1E0024

7.2.5 Forgers shall report all part numbers and applied forging codes (per 1E0100) for a heat of steel.

7.2.6 Semi-finished or finished component suppliers that purchase steel to a 1E specification from forgers, service centers, or other second tier steel suppliers are not required to report heat data.

7.3 Data requirements

7.3.1 Steel suppliers shall assure themselves that a heat fulfills the requirements of the applicable 1E specifications before submitting samples or test results for approval by the regional dispositioning facility.

7.3.2 Heat data shall be submitted to Caterpillar by electronic methods. Suppliers should consult their regional dispositioning facility or their purchasing contact for details on the methods used in their region.

7.3.3 Significant Digits in Test Data – For purposes of determining conformance to specifications, an observed value or a calculated value shall be rounded to the nearest unit in the last right-hand digit used in expressing the specification limit (1 MPa for Tensile and Yield Strength), in accordance with the Rounding Method of ASTM Practice E29 for Using Significant Digits in Test Data. As an alternate practice, tensile and yield strength data shall be rounded to the nearest 1 MPa, 5 MPa or 10 MPa, depending on strength level, per ASTM A370, Annex A8. Examples of rounding practice are provided in Figure 7.

Requirement	Specification	Measurement	Heat Submission
Carbon	0.45-0.51	0.446	0.45
Manganese	0.60-0.90	0.712	0.71
Sulfur	0.050 MAX	0.009	0.009
Yield Strength	290-500 MPa	499.2 MPa	499 MPa
Alternate ASTM A370, Annex A8 Practice for Tensile Testing:			
Yield Strength	550 MPa MIN	548 MPa	550 MPa

Figure 7

7.3.4 Minimum Requirements – Figure 8 lists the minimum data to be reported. Individual 1E steel specifications may require additional data.

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WROUGHT STEEL – GENERAL REQUIREMENTS	DATE 08 MAR 2018	CHG NO 45	NUMBER 1E0024

	Reference	1E0024A	1E0024B
Heat Number		✓	✓
Supplier Name		✓	✓
1E1861 Mill Code	1E1861	3 digits	3 digits
Purchasing Supplier Code		7 digits	7 digits
Submission Date		✓	✓
Commodity Description		e.g. bar, plate, sheet, tubing	e.g. bar, plate, sheet, tubing
Gauge Size	Paragraph 7.3.5	✓	✓
Cat 1E steel specification		✓	✓
Reduction ratio	1E2700	✓	✓
Chemical Composition	Article 5.2	Ladle heat analysis and product analysis of "A" and "Z" mill samples shall be reported for the following elements: C, Mn, P, S, Si, Ni, Cr, Mo, Cu, Al	Ladle heat analysis shall be reported for the following elements: C, Mn, P, S, Si, Ni, Cr, Mo, Cu, Al
		Ti, Zr, Nb, V, Ta, W, N, and Ca when intentionally added or specified.	Ti, Zr, Nb, V, Ta, W, N, and Ca when intentionally added or specified.
	Paragraph 5.3	B, Ti and N when B is specified.	
	1E0038	Actual "A" and "Z" Boron factors (per 1E38)	
	1E2661 1E1801	O, Ca, or H (PPM) as required by these specs	O, Ca, or H (PPM) as required by these specs
Hardenability	Articles 6.3 & 6.5	Jominy results	DI per 1E0038, when specified
Charpy impact testing, when specified. Test per ASTM A370.	Article 6.6		Test 3 specimens. Report all 3 values, their average, the specimen type, orientation to the rolling direction, and test temperature.
Tensile testing, when specified. Test per ASTM A370.	Article 6.6		Tensile results per specification requirements

Figure 8

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WROUGHT STEEL – GENERAL REQUIREMENTS

DATE
08 MAR 2018

CHG NO
45

NUMBER
1E0024

7.3.5 Gauge thickness reporting

Steel product size shall be reported in millimeters, based on product form per Figure 9.

Form	Dimension Reported for Gauge.
Sheet and Plate	Thickness
Round Bar	Diameter
Round-Corner-Square (RCS) Bar	Width Across Flat Faces
Flat Bar	Thickness
Tubing	Wall Thickness (ID and OD in note)
Sections	Indicate section 1Espec or national spec in note

Figure 9

7.3.6 For steels specifying Carbon Equivalent, CE shall be calculated per the following formula:

$$\text{Carbon Equivalent} = C + \text{Mn}/6 + (\text{Cr} + \text{Mo} + \text{V})/5 + (\text{Ni} + \text{Cu})/15$$

7.3.7 For steels specifying boron as a hardenability intensifier, boron effectiveness shall be monitored and reported with the boron factor calculation defined in the 1E0038 Caterpillar Hardenability Calculations. Predicted boron factors shall not be reported.

7.3.8 Predicted calculated, simulated, theoretical, or otherwise similarly described Jominy hardenability results shall not be reported. If Jominy results are required per the 1E specification, then the melting mill shall be contacted to measure and provide Jominy data.

7.4 Certification

7.4.1 Test certificates that accompany steel produced and purchased to a 1E specification or a standard national steel grade used to fulfill a 1E specification shall affirmatively state that the material satisfies the 1E specification or national grade's requirements.

7.4.2 When requested in a 1E specification or on a purchase order, the mill shall also submit a digital copy of the steel heat inspection certificate. The inspection certificate shall include all information required to demonstrate conformance with the 1E specification or standard national steel grade used to fulfill the 1E specification, as well as a statement of conformance with the 1E specifications or a national grade approved to fulfill the 1E specification, consistent with EN 10204, Inspection Certificate 3.1.

7.4.3 Suppliers shall contact their regional dispositioning facility for further information on approved usage of the restricted heats, unless the test certificate specifically states the part numbers involved.

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WROUGHT STEEL – GENERAL REQUIREMENTS

DATE
08 MAR 2018

CHG NO
45

NUMBER
1E0024

7.5 Release for Shipping

7.5.1 For 1E0024A qualified steels, the supplier shall obtain approval of the steel heat submission from Caterpillar before shipment, when purchased by anyone other than Caterpillar or its subsidiaries.

7.5.2 1E1861 approved suppliers may ship fully conforming steel before obtaining Caterpillar disposition when this practice has been approved by the regional dispositioning facility. Test data shall be transmitted before the steel is received.

7.5.3 Final application of a mill heat to Caterpillar orders shall include only that portion of a heat that conforms within the extremes represented by the samples or test data approved by Caterpillar.

8.0 APPROVED SUPPLIERS

All steel shall be purchased from mills on the Caterpillar Approved Supplier List (Ref 1E1861) or from mills specifically authorized by the receiving or regional dispositioning Caterpillar facility (ref Article 9.0).

9.0 DISPOSITIONING FACILITY AND HEAT DATA SUBMISSION PROCESS

9.1 A Caterpillar dispositioning facility is the Quality or Technical Department of the designated Caterpillar plant within a geographical region which monitors steel quality, maintains the corporate mill heat data base, dispositions heats of steel, and provides metallurgical approval support for mills, service centers, and suppliers. 1E1861 lists the dispositioning facilities within geographical regions. The receiving Caterpillar facility within a region is the primary disposition facility.

9.2 Steel heat data for 1E0024 qualified materials shall be submitted via EDI or by using the Mill Heat application in EtQ. Those steel suppliers without access to EtQ should contact their regional dispositioning facility for guidance on steel heat data submission.

10.0 MATERIAL SUBSTITUTION

1E2349 governs the use of industry standard grades in place of Caterpillar steels defined by individual 1E specifications. Suppliers must refer to both 1E2349 and the individual 1E steel specification for information on how to identify acceptable substitutes and how to get approval for their use.

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WROUGHT STEEL – GENERAL REQUIREMENTS

DATE
08 MAR 2018

CHG NO
45

NUMBER
1E0024

11.0 REFERENCES

Abbreviations	1E0011
Caterpillar Specifications	1E0038, 1E0100, 1E0522, 1E1801, 1E1861, 1E2349, 1E2661 1E2700, 1E5053
ASTM	A6, A255, A370, A673, E29, E45, E112, E381
EN	10204
SAE	J406

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