



GE Power and Water
Materials and Processes Engineering

PROCESS SPECIFICATION

P14A-AL-0220

Page 1 of 25

GENERAL REQUIREMENTS - HIGH STRENGTH WIND FASTENERS

DOCUMENT REVISION STATUS: DETERMINED BY THE LAST ENTRY IN THE "REV" AND "DATE" COLUMN

REV.	DESCRIPTION	SIGNATURE	REV. DATE
-	THIS PROCESS SPECIFICATION SUPPLEMENTS ENGINEERING REQUIREMENTS CONTAINED IN THE APPLICABLE MATERIAL SPECIFICATIONS AND DRAWINGS FOR THE MANUFACTURE AND INSPECTION OF ROLL-THREADED BOLTS AND STUDS, NUTS AND WASHERS FOR WIND APPLICATIONS. THIS SPECIFICATION GIVES THE GENERAL REQUIREMENTS FOR QUALIFICATION AND PRODUCTION OF SAID PRODUCTS, INCLUDING DESTRUCTIVE AND NON-DESTRUCTIVE TESTING; DCI NO. 06007844. (S. SATHIAN)	CR TRIPEPI	
A	UPDATED REFERENCES TO EUROPEAN FASTENER STANDARDS AND INCLUDED ADDITIONAL COMMENTS AND REQUIREMENTS; DCI NO. 08024555. (S. SATHIAN)	CR TRIPEPI	2008 JUL 24
B	ADDED P24C-AG2 AS APPLICABLE DOCUMENT; UPDATED QUALIFICATION REQUIREMENTS; UPDATED SURFACE INSPECTION REQUIREMENTS; UPDATED DELTA MKS COATING THICKNESS REQUIREMENTS; UPDATED LUBRICATION REQUIREMENTS; ECR3037694, ECO1220562 (E. HUANG)	CR TRIPEPI	2012 APR 20
C	CLARIFICATION OF REQUIREMENTS. EDITORIAL CHANGES TO MAKE SPEC READ EASIER. UPDATED TABLE 6 TO INCLUDE MAX REQUIREMENTS. ADDED NEW HIGHER MECHANICAL PROPERTY CLASS FOR CERTAIN BLADE STUDS. ECO1516005 (J. RIDGE)	TM MOORS	2015 APR 28

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GENERAL REQUIREMENTS - HIGH STRENGTH WIND FASTENERS

1. SCOPE

1.1 This process specification supplements requirements for threaded high strength fasteners for Wind Energy applications. This specification gives the general requirements for qualification and production.

1.1.1 This specification is applicable to all safety critical or high strength fasteners. Property class 10.9 and above are considered as high strength fasteners and shall meet the requirements given in current GE specification. Other grades/class of fasteners may be applied to high strength fastener category if called out in the related drawings/documents or in the PO.

1.1.2 There are two strengths classes for grade 10.9 fasteners specified in this specification, A and B. By default class A will be required unless specifically called out in the part drawing. Class B is a subset of grade 10.9 fasteners and will only be used in select cases where a higher mean strength is needed.

1.2 Communication

1.2.1 External Supplier - General Electric Company - Sourcing Organization is the authorized interface for all communication between GE and the External Supplier. All questions or requests for additional information shall be submitted to Sourcing for clarification. Conflicts between applicable Specifications and/or drawings shall be submitted to GE Sourcing - for resolution by Engineering.

1.2.2 Internal Supplier - All communication, including questions or requests for additional information, shall be submitted to Materials and Processes Engineering (MPE) or the appropriate Design Engineering component.

2. APPLICABLE DOCUMENTS

2.1 The following documents shall form a part of this specification to the extent specified herein. Unless otherwise specified, the latest issue shall apply.

2.1.1 General Electric Company

E50A119 Testing of Metallic Materials

P3A-AG1 Magnetic Particle Testing

P10A-AG2 Heat Treatment and Process Control



- P28A-AL-0001 Critical to Quality Process Capability Data Collection
- P28A-AL-0203 Non-Destructive Testing Process Qualification and Approval
- P14A-AL-0218 Acceptance Requirements for Zinc Flake Corrosion Resistant Coatings for Wind Turbine Fasteners
- P23E-AL-0255 General Requirements - Marking, Preservation, Packaging and Shipping

2.1.3 American Society for Testing of Materials (ASTM)

- ASTM A 143 Standard Practice for Safeguarding Against Embrittlement of Hot Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement
- ASTM A 370 Mechanical Testing of Materials
- ASTM B117 Standard Practice for Operating Salt Spray (Fog) Apparatus

2.1.4 Society for Automotive Engineers (SAE)

- AMS 2750 Heat-Treatment Requirements

2.1.5 American Society for Nondestructive Testing (ASNT)

- SNT-TC-1A Recommended Practice for Personnel Qualification

2.1.6 International Organization of Standards (ISO)

- ISO 148-1 Metallic materials - Charpy pendulum impact test – Part 1: Test method
- ISO 898-1 Mechanical properties of fasteners made of Carbon steel and alloy steel – Part 1: Bolts, screw and studs
- ISO 898-2 Mechanical properties of fasteners – Part 2: Nuts with specified proof load values – Coarse thread
- ISO 1502 ISO general – purpose metric screw threads – Gauges and gauging



ISO 4759-1	Tolerance for fasteners Part 1: Bolts, screws, studs and nuts – Product grades A, B and C
ISO 4759-3	Tolerance for fasteners Part 3: Plain washers for bolts, screws and nuts – Product grade A and C
ISO 6157-2	Fasteners - Surface discontinuities – Part 2: Nuts
ISO 6157-3	Fasteners: Surface discontinuities; Part 3 : Bolts, screws and studs for special requirements
ISO 6506-1	Metallic materials – Brinell hardness test – Part 1: Test method
ISO 6507-1	Metallic materials – Vickers hardness test – Part 1: Test method
ISO 6508-1	Metallic materials – Rockwell hardness test – Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T)
ISO 6892	Metallic materials – Tensile testing at ambient temperature
ISO 7089	Plain washers – Normal series – Product grade A
ISO 7090	Plain washers, chamfered – Normal series – Product grade A
ISO 8992	Fasteners – General requirements for bolts, screws, studs and nuts
ISO 9227	Corrosion tests in artificial atmospheres – Salt spray
ISO 9712	Nondestructive testing – Qualification and certification of NDT personnel – General principles
ISO 9934:1-3	Non-destructive testing – Magnetic particle testing
ISO 10683	Fasteners – Non-electrolytically applied zinc flake coatings
ISO 10684	Fasteners – Hot dip galvanized coatings



- ISO 15330 Fasteners – Preloading test for the detection of hydrogen embrittlement
- ISO 16047 Fasteners – Torque / Clamp force testing
- ISO 17025 General requirements for the competence of testing and calibration laboratories

2.1.7 European Standards (EN)

- EN 14399-1 High-strength structural bolting assemblies for pre-loading – Part 1: General requirements
- EN 14399-2 High-strength structural bolting assemblies for pre-loading – Part 2: Suitability test for preloading
- EN 14399-4 High-strength structural bolting assemblies for pre-loading – Part 4: System HV – Hexagon bolt and nut assemblies
- EN 14399-6 High-strength structural bolting assemblies for pre-loading – Part 6: Plain chamfered washers

3. DEFINITIONS

3.2 Specification Deviation Documents

3.2.1 Applicable to External Supplier

- 3.2.1.1 Supplier Deviation Request (SDR) - A method for the documentation, approval and control of a waiver for materials, processes, or dimensions, which deviate from Purchase Order documents (drawings, specifications, engineering instructions, etc.
- 3.2.1.2 SDRs shall include all of the applicable information available (i.e. test properties, dimensions, heat treatment history, etc.) which would be required by the Purchaser for prompt disposition
- 3.2.1.3 Applicable to Internal Supplier: Non Conformance Report (NCR) - GE Manufacturing Department non-conformance report initiated during processing through the factory. Used by Manufacturing to document non-conformance to governing documents and request corrective action.



3.3 Documentation

- 3.3.1 Manufacturing Process Plan (MPP) - A GE-approved, detailed, chronological step-by-step list of operations by which the parts are planned to be processed, tested and inspected. In-process and final inspection operations associated with the various manufacturing operations shall be included. Each step in the process shall include a brief description of that operation.
- 3.3.2 Once the process is qualified, the MPP completely describes the process that was utilized to manufacture the part for first piece qualification. This process is considered frozen and shall not be changed without GE approval.
- 3.3.3 Product Quality Plan (PQP) - A detailed, step-by-step list of operations and requirements by which a supplier identifies a process of how, what, why, when and who will perform tests or inspections. PQP shall also list reviews, tests, inspections, and any other documents maintained to ensure quality during production, as applicable. This may also be referred to by some businesses as an Inspection and Test Plan (I.T.P.).
- 3.3.4 Technical Terms
- 3.3.4.1 CAV: Characteristic Accountability Verification. A reporting of all drawing characteristics to confirm compliance to specification and determine future measurement frequency.
- 3.3.4.2 Cpk: Represent the potential short-term capability of the process. Estimates what the process is capable of producing, considering that the process mean may not be centered between the specification limits.
- 3.3.4.3 Decarburization Layer: Surface layer of a steel part with reduced carbon content due to loss of carbon.
- 3.3.4.4 HDG: Hot Dip Galvanizing
- 3.3.4.5 Hydrogen Embrittlement: Embrittlement of steel caused by the absorption of hydrogen during processing such as acid pickling and electroplating.
- 3.3.4.6 In-Feed Process: A roll-threading process wherein the die and work piece geometries are such that the die axes are parallel, have a helical thread geometries, and closes on the work-piece, resulting in essentially no longitudinal translation between the dies and work-piece.
- 3.3.4.7 PLQ Lot: The PLQ Lot is defined as parts from the same Master Heat, formed in a common forming operation of a common Drawing.



- 3.3.4.8 Rolled Thread: Threads that have been manufactured by a rolling process with tools showing the negative thread geometry. Threads are produced by rolling rather than machining.
- 3.3.4.9 Through - Feed Process: Roll-threading processes wherein the dies have annular thread geometry, and their axes are skewed when mounted in the thread-rolling machine. When the dies close on the work-piece, the work-piece is drawn into the dies, forming the threads during the longitudinal translation of the work-piece through the dies. This process is not allowed.
- 3.3.6.10 Lot: Shall be all parts of the same design, fabricated from the same alloy, heat treated to the same property requirements in the same furnace(s) at the same time, and presented for processor's inspection at the same time. In addition, for a continuous furnace, it shall be those parts heat treated as a continuous production run during an eight-hour shift (or 12 hours if the same operators are used). When testing parts after operations (ex. stress relieving, baking, hot or warm straightening) that occur after the final step of the heat operation (ex. tempering, aging), a lot, in addition to the above, shall consist of parts stress relieved, baked, hot or warm straightened, etc. using the same equipment at the same time. If a batch exceeds this definition of Lot, then the fasteners shall be marked with a different shift number.
- 3.3.6.11 Part family: A group of parts that only vary in length (same alloy, diameter, heat treatment process, coating, and special processes).

4. QUALIFICATION REQUIREMENTS

- 4.1 A comprehensive evaluation for Qualification shall be required for
- New Supplier or sub tier supplier
 - When there is a significant change in the approved MPP,
 - Supplier has not performed this process on the same family of parts within the two years prior to Purchase Order placement.
- 4.2 There are 2 strength classes covered by the specification.
- 4.2.1 Class A: This class has all mechanical property requirements per referenced ISO specifications and Table 2 sections 3.1 and 3.2 of this specification. This is the default class and shall be used unless explicitly stated on the drawing.
- 4.2.2 Class B: This is a special class where the lower ultimate tensile strength and yield strength limits of a grade 10.9 fastener have been increased. Tensile strength properties shall meet those in Table 2 sections 3.1 and 3.3.



4.3 The Qualification shall, as a minimum, include the following:

- 4.3.1 MPP approved by the MPE, SQE and design engineer prior to initiation of the PLQ.
- 4.3.2 PQP, documenting the way of characteristic verification during production.
- 4.3.3 Reference the NDT qualification SQ number. Non-destructive testing (NDT) data per P3A-AG1.
- 4.3.4 Dimensional data, typically documented on a CAV form, to a ballooned GE drawing. This shall document the drawing requirements, variable results data (when possible), measurement equipment, and how the feature was generated. 100% of the dimensions, material data and test results on the PLQ lot are required to be documented on the CAV forms. For the test results the applicable test reports have to be referenced.
- 4.3.5 Certificate of test, for each heat of material used.
- 4.3.6 Certification of conformance, from the supplier and any sub tier which performs a special process.
- 4.3.7 The PLQ lot quantity requirements: The PLQ lot quantity will be at least 30 parts for a Cpk, or other quantity as determined by the qualification team. The PLQ lot will be subject to the qualification test requirements as listed in this specification. The part qualification will not be complete until all members of the GE qualification team sign the PLQ and the SQE completes final closure actions in the qualification.
- 4.3.8 Mechanical testing:
 - 4.3.8.1 The number of parts used for mechanical property testing is per sections 4.3.8.2 and 4.3.8.3 depending on type of furnace used. If changes in any critical parameters or a set-up occur during a run, the SQE shall be consulted regarding the need for additional qualification samples.
 - 4.3.8.2 Continuous furnace - Shall be taken hourly, or 3 parts each from the first, middle and last of a continuous furnace heat lot, unless otherwise agreed upon with GE qualification team.
 - 4.3.8.3 Batch furnace - Shall be per the supplier submitted and MPE approved test plan.



4.3.8.4 Mechanical property testing shall include:

- Hardness (surface, core, carburization and decarburization)
- Tensile (UTS, yield, % elongation, % R of A) - If full sized pieces are used for tensile testing then neither elongation nor reduction of area are required.
- -40°C Charpy v-notch
- Proof of load bolt/stud \leq M39, or as approved by design engineering in the MPP
- Proof of load for nuts, all sizes

4.3.9 Metallography:

4.3.9.1 Thread analysis samples shall come from the first, middle and last thread rolled parts in batch unless otherwise agreed upon with GE qualification team.

4.3.9.2 Metallography testing shall include:

- Thread analysis - grain flow, root imperfections and laps along flanks and at the thread tip.
- Presence of δ -ferrite
- % martensite at the core

4.4 Dimensional - Gauge R&R shall be conducted on measuring equipment.

4.5 Qualification Package - The Supplier shall submit one (1) copy of the qualification documentation for review/approval.

4.6 In the case of conflicts between applicable document requirements are as follows (decreasing importance order):

- Contract / Order Tech-Qual. Attachment
- Applicable Drawing
- Material Specification
- Applicable GE Procedure
- Applicable EN and ASTM Standards or Others

4.7 Upon receipt of written notification of approval of the qualification, the Supplier is approved for production of the qualified part. The MPP shall be "FROZEN", not to be changed without approval of a new MPP.

4.8 The following is a partial list of items that, when changed, will require comprehensive evaluation for PLQ.



**TABLE 1 - PARTIAL LIST OF ITEMS WHEN CHANGED REQUIRES
COMPREHENSIVE EVALUATION OF PLQ**

Item	Description
1	- New bar stock Supplier
2	- New thread roll Supplier and/or changes to that process
3	- Significant change in part dimensions
4	- Significant change in roll-thread dimensions (ex. pitch, diameter)
5	- New plant or new facility for a current Supplier
6	- Change of location of equipment
7	- New forging source and/or changes to that process
8	- New heat treating source and/or changes to that process
9	- New source for mechanical property testing
10	- New machining source and/or changes to that process - For journal surface and adjacent undercut
11	- New plating /coating source and/or changes to that process
12	- New NDT source and/or changes to that process
13	- New bar stock alloy
14	- Lubrication

5. PRODUCTION PROCESS REQUIREMENTS

- 5.1 It shall be the responsibility of the Supplier to thoroughly understand the work scope and all documentation needed to complete the work. This responsibility shall apply to the prime Supplier for any or all operations performed by sub-tier Supplier(s).
 - 5.1.1 All sub-tier suppliers will be audited and qualified by the Direct supplier and documentation will be presented to GE for review. Any sub-tier supplier engaged in special processes shall be approved for those special processes / specifications. Sub-tier suppliers will have a mutual non-disclosure agreement with the Supplier. The supplier receiving the PO from GE is responsible to ensure that all its sub-tier supplies have the current specifications and drawing revisions.
- 5.2 The manufacturing of the fasteners shall be conducted in accordance with a documented Frozen MPP. The Supplier shall monitor the actual process, compare the process to the MPP and report to the Purchaser any variances using the SDR/QCR. The MPP shall include, as a minimum, information detailing and describing the following items and processes, as applicable with sufficient depth of detail to allow a frozen process:



- Supplier Name, GE Supplier Vendor Code
 - Date
 - Applicable GE Drawing Numbers, including revision level
 - All Material and Process Specifications, including revision level
 - Supplier documents (indicate proprietary, non-proprietary)
 - Identification of Sub-tier Suppliers - Name, address, MPP documentation
 - Description of the identification marking system used for finished parts
 - Forging process including temperatures
 - Heat Treatment
 - Machining
 - Tests and Inspection
 - NDT Procedures
 - Roll-Threading Machine Control Settings and Ranges
 - Coating Procedures
 - Any crest polishing or other process used
 - Nut tapping dimensions (if applicable)
 - Dimensional and other measurements to assure drawing requirements are met.
 - Lubrication (if applicable)
 - Packing and shipping
- 5.3 Deviations - Any deviation from the requirements of this specification shall be submitted by SDR/QCR and approved by Engineering disposition before the item is shipped.
- 5.4 The number of specimens required for mechanical testing and metallography will be per the approved MPP.
- 5.5 All fasteners shall meet the requirements detailed in Table 2 unless otherwise specified in the drawing:



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TABLE 2 – SUMMARY OF REQUIREMENTS

List	Description	Requirements
1	Raw material	<p><u>Bar Stock:</u></p> <ul style="list-style-type: none"> - ISO 898-1 (chemistry for bolts and studs) - ISO 898-2 (chemistry for nuts) - EN 14399-6 (chemistry washers) <p><u>Additional requirements (bolts/studs and nuts):</u></p> <ul style="list-style-type: none"> - Bar material shall be obtained from an approved source to the requirements of the applicable material specification and additional requirements as follows: - S: 0.02 wt. % maximum - P: 0.02 wt. % maximum - Total P+S ≤ 0.03 wt. % maximum - Cleanliness rating shall be K3<20 per EN 10247
2	Heat treatment & furnace calibration	<p><u>Furnace calibration:</u></p> <ul style="list-style-type: none"> - AMS 2750 - P10A-AG2 <p><u>Additional requirements:</u></p> <ul style="list-style-type: none"> - Hold temperature tolerance: ± 25°F (± 14°C) maximum - Hold time tolerance: ± 15 minute maximum - Any additional heat treating or annealing or reheat-treatment steps of the parts are not permitted.
3.1	<p><u>Bolts/Studs</u></p> <p>Mechanical properties</p>	<ul style="list-style-type: none"> - ISO 898-1 - EN 14399-1 - ISO 17025 (lab qualification) - ASTM A 370 <p><u>Tensile property and testing specifications (as applicable to sample):</u></p> <ul style="list-style-type: none"> - E50A119 or ISO 6892 or ASTM E8 <p><u>Charpy property and testing specifications:</u></p> <ul style="list-style-type: none"> - ISO 148-1 or ASTM E23



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		<p><u>Hardness (surface, core, carburization/decarburization):</u></p> <ul style="list-style-type: none"> - ISO 6507-1 (Vickers hardness) - ISO 6508-1 (Rockwell hardness) - ISO 6506-1 (Brinell hardness) <p><u>Proof load:</u></p> <ul style="list-style-type: none"> - ISO 898-1 - DAST 021 guideline <p><u>Additional requirements:</u></p> <ul style="list-style-type: none"> - Any lab performing testing and certification for GE shall meet the requirements in ISO 17025 and be approved by MPE. - Surface carburization/decarburization shall be verified through microhardness testing unless approved by MPE. The surface readings shall be taken from the non-threaded section due to work hardening of the threads. Average of 3 tests taken 0.12 mm below the surface. - -40°C Charpy V-notch impact test shall meet 27J minimum. - Proof load Nominal Stress Area ($A_{s, nom}$) for sizes \leq M39 and the formula for calculating it can be found in ISO 898-1.
3.2	<p><u>Bolts/Studs</u></p> <p>Class A</p>	<p><u>Additional requirements:</u></p> <ul style="list-style-type: none"> - <u>For property class 10.9:</u> - Maximum tensile strength of 1170 MPa (test specimen tensile method) - Maximum surface hardness 375 HV_{0.3}
3.3	<p><u>Bolts/Studs</u></p> <p>Class B</p>	<p><u>Additional requirements for Class B:</u></p> <ul style="list-style-type: none"> - Tensile strength: 1080 - 1220 MPa - 0.2% yield strength: 990 MPa min - % elongation: 9 min - % reduction of area: 46 min - Hardness 34-39 HRC - Maximum surface hardness 390 HV_{0.3}



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3.4	<p><u>Nuts</u></p> <p>Mechanical properties</p>	<p><u>Hardness:</u></p> <ul style="list-style-type: none"> - ISO 898-2 - ISO 6507-1 (<i>Vickers hardness</i>) - ISO 6508-1 (<i>Rockwell hardness</i>) - EN 14399-1 <p><u>Proof load:</u></p> <ul style="list-style-type: none"> - ISO 898-2 - DAST 021 guideline <p><u>Additional requirements:</u></p> <ul style="list-style-type: none"> - If required by the drawing -40°C Charpy V-notch impact test shall meet 27J minimum. - A table showing the nominal stress area for sizes M39 - M72 can be found in figure 4, and are per DAST 021.
3.5	<p><u>Washers</u></p> <p>Mechanical properties</p>	<p><u>Hardness:</u></p> <ul style="list-style-type: none"> - EN 14399-6, ISO 7089 or ISO 7090 (<i>as applicable</i>) - ISO 6507-1 (<i>Vickers hardness</i>) - ISO 6508-1 (<i>Rockwell hardness</i>)
4	<p>Dimensional data</p>	<ul style="list-style-type: none"> - Dimensional Data, typically documented on a CAV form. - The CAV form shall include, at a minimum, the following items: <ul style="list-style-type: none"> ✓ Identification of components ✓ Characteristics and feature accountability ✓ Inspection and test results ✓ Production Product Acceptance Criteria - Product acceptance criteria shall be established during the qualification process review of the CAV form. Once the level of inspection and product acceptance requirement has been determined and specified on the CAV form, it shall be applied to all production components hereafter to ensure controlled processes for maintaining drawing features and characteristics. - 100% of the dimensions on the PLQ Lot are required to be documented on the CAV forms. - Gauging and instrumentation used to certify the part to the drawing and specification will be calibrated in the range of the GE drawings and specifications. - Submit a completed CAV.
5	<p><u>Bolts/Studs and Nuts</u></p>	<ul style="list-style-type: none"> - SNT-TC-1A or EN 9712 (<i>Qualification of NDT personnel</i>) - ISO 6157-2 (<i>nuts – defect acceptance criteria</i>)



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	<p>Surface Inspection - Visual and Magnetic Particle Inspection</p>	<ul style="list-style-type: none"> - ISO 6157-3 (<i>bolts/studs – defect acceptance criteria</i>) - P3A-AG1 or EN 9934-1, -2, -3 - P28A-AL-0203 (<i>NDT qualification</i>) <p><u>Additional comments:</u></p> <ul style="list-style-type: none"> - 100% part inspection bolts and nuts. - Machined surfaces shall exhibit no indications of cracks, laps or folds. - Rolled threads shall exhibit no indication of cracks, laps or folds except at the crest where the roll-threading process can leave such a feature. - MPI shall be done prior to surface treatment/coating. Fluorescent medium shall be used. - All NDT processes shall be qualified per P28A-AL-0203. - NDT procedures shall be approved by GE Level III. The inspection can be performed by qualified Level I or II personnel.
<p>6</p>	<p>Threading operation</p>	<ul style="list-style-type: none"> - Threads shall be rolled after heat treatment at room temperature unless otherwise approved by MPE. <p><u>Roll Threading:</u></p> <ul style="list-style-type: none"> - Threads shall be fully formed by a <u>single cold rolling operation</u> on material that is fully heat-treated per the requirements of the applicable material specification. No secondary rolling is permitted. - Threads shall be rolled on the smooth cylindrical surface of a precisely prepared journal surface. No pre-grooving of the surface to be rolled is permitted. - Only the In-Feed Roll threading process is acceptable. Through-Feed or hybrid In-Feed/Through Feed processes are not permitted. - Roll threaded profile shall be characterized by a slightly under filled thread crest contour (non-fully packed thread) within the major diameter limitations for the particular thread size.
<p>7</p>	<p>Thread tolerance</p>	<ul style="list-style-type: none"> - EN 14399-1 - ISO 10683 (zinc flake fasteners) - ISO 10684 (HDG fasteners) - ISO 1502 (thread gauging) <p><u>Additional comments:</u></p> <ul style="list-style-type: none"> - Enlarged radius underneath head (HV standard and EN 14399 codes apply)




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		<ul style="list-style-type: none"> - <u>HDG bolts:</u> <ul style="list-style-type: none"> o Thread tolerance prior to HDG: 6g o Nuts: 6AZ with HDG bolt/stud - <u>Zinc flake coated fasteners:</u> <ul style="list-style-type: none"> o Thread tolerances follow ISO 10683. o Other tolerances or over tapped data, which are not defined in ISO 10683, may be allowed with GE engineering approval. <u>One example:</u> <ul style="list-style-type: none"> ▪ Bolt/stud: thread tolerance position 6g prior to coating ▪ Nuts: 6H with a plus tolerance per MPP/PQP <ul style="list-style-type: none"> • < M30 if over tapped + 0.150 mm • > M30 if over tapped + 0.200 mm o Specific tolerance data shall be approved in MPP/PQP by GE engineering. o The reduction of mechanical properties and corrosion protection are not allowed due to the change of thread tolerance.
8	Machining / Grinding	<ul style="list-style-type: none"> - ISO 4759-1, -3 (<i>dimensional tolerances</i>) - ISO 8992 <p><u>Additional requirements:</u></p> <ul style="list-style-type: none"> - All grinding, machining, and abrasive wheel cutting operations shall be controlled so that they do not cause burning and discoloration. - Post process grinding on bolt head after hot dip galvanizing (HDG) near shank areas is not permitted.
9	<u>Bolts/studs</u> Metallography	<p><u>Thread quality and microstructure:</u></p> <ul style="list-style-type: none"> - ISO 898-1 - EN 14399-1 - ISO 17025 (<i>lab certification</i>) - ISO 6157-3 (<i>bolts/studs - defect acceptance criteria</i>) <p><u>Additional requirements (finished product):</u> The entire threaded end shall be metallurgical evaluated. The sample length shall extend at least 1/4" (6.5 mm) beyond the last existing thread and shall not be plated.</p> <ul style="list-style-type: none"> - Flow lines on etched cross sections shall be continuous and follow the general thread contour (Fig. 1, 3). - The maximum flow line density shall be at the bottom of the root radius (Fig. 3).



		<ul style="list-style-type: none"> - Root imperfections such as notches, slivers, folds, roughness or oxide scale are not allowed. The root shall exhibit a fully formed thread profile with no perturbations to the profile seen at a magnification of 100X. - Laps on the thread flanks, visible at a magnification of 100X, are not permitted regardless of the propagation direction. - A single lap at the thread crest, viewed at a magnification of 100X, is permitted if it meets the requirements per ISO 6157-3 (Fig. 4). - Slight deviations from thread contour are allowed at the crest of the thread within the major diameter limits. Note that the maximum major diameter is less than the diameter of a “fully formed” thread. - Presence of δ-ferrite which can be detected metallographically is not acceptable. - Core microstructure >90% martensite.
10	Coating type	<ul style="list-style-type: none"> - Coating type shall be HDG or zinc flake per drawing.
10.1	Hot Dip Galvanizing (HDG)	<ul style="list-style-type: none"> - ISO 10684 (<i>coating thickness</i>) <p><u>Additional comments:</u></p> <ul style="list-style-type: none"> - Zinc bath temperature range shall be 455-480°C or as approved by MPE. - Fasteners having hardness > 31 HRC require a bake out at 300°C for 4 hours after the acid pickling option to eliminate/minimize hydrogen embrittlement issues. Alternative methods may be used, but requires written approval from MPE. - Bake out operation may not be necessary if the supplier uses alkaline cleaning instead of an acid cleaning operation prior to the galvanizing process. - Fasteners may be abrasive blast cleaned followed by flash pickling to reduce detrimental effects of pickling. Such flash pickling shall be < 1 minute and in well inhibited and controlled baths. - Hot dip galvanizing is not permitted on grade 12.9 fasteners.
10.2	Zinc flake coatings	<ul style="list-style-type: none"> - ISO 16047 (<i>friction test</i>) - ISO 9227 – (<i>neutral salt spray</i>) or ASTM B117 (<i>salt spray test</i>) - P14A-AL-0218

<p>P14A-AL-0220 REV. C</p>	 <p style="text-align: center;"><i>GE Power and Water</i> <i>Materials and Processes Engineering</i></p> <p style="text-align: center;">GE CLASS II (INTERNAL CRITICAL) UNCONTROLLED WHEN PRINTED OR TRANSMITTED ELECTRONICALLY</p>	<p>Page 18 of 25</p>
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		<p><u>Additional requirements:</u></p> <ul style="list-style-type: none"> - Protection coating in black with a GZ lubrication additive, overall friction (thread + under the head) between $\mu=0.08-0.14$. - Coating shall be applied as required by the specific coating system. - Salt spray test required every 6 months or as approved by MPE.
<p>10.3</p>	<p>Washer coating</p>	<ul style="list-style-type: none"> - The fastener suppliers are permitted to purchase washers from a sub-tier, however it is required that the coating on the washers match the fasteners coating and meets the mechanical property requirements (hardness, chemical composition etc.).
<p>11</p>	<p>Hydrogen embrittlement test</p>	<ul style="list-style-type: none"> - ISO 15330 <p>OR</p> <ul style="list-style-type: none"> - Fasteners which have surface hardness greater than 31 HRC which are Hot Dip Galvanized, acid pickled, and or electroplated shall be tested for hydrogen embrittlement per ASTM 143. - One galvanized and/or plated piece from each lot of galvanized/plated parts and one non coated part should be bent in same manner until cracking of the (base) steel occurs, or to 90° whichever is less. The galvanized and /or plated piece should withstand substantially the same degree of bending as the non-galvanized and/or non-plated piece. Flaking or spalling of the coating is not to be construed as embrittlement failure. The tests shall be made on the unthreaded portions. If one test specimen should be found embrittled, two additional tests should be conducted. Failure of either the second or the third specimen shall be cause for rejection of the lot.



12	Lubrication	<ul style="list-style-type: none"> - EN 14399-3 - Zinc flake coated fasteners shall not be lubricated with MoS₂. <p><u>HDG Fasteners:</u></p> <ul style="list-style-type: none"> - MoS₂ spray coating or equivalent shall be evenly applied in 360° coverage around the bolt threads, nut threads or both so that the complete system (bolt, nut and washer) meets the torque preload relationship requirements in section 5.6 and Table 3. - Excessive or insufficient lubrication is unacceptable. - Excessive lubrication which could cause dripping during torqueing is not permitted.
13	Mixing of bolts, nuts and washers and hardware set requirements	<ul style="list-style-type: none"> - EN 14399-1 <p><u>Additional comments:</u></p> <ul style="list-style-type: none"> - Mixing of bolts and nuts from different sources is not permitted. Hardware shall be ordered as a complete set from the same supplier, no mix matching of suppliers is permitted. - The kit supplier is responsible for the entire fastener even though the washers and nuts may be obtained from a different sub-supplier, if approved in the MPP.
14	Marking	<ul style="list-style-type: none"> - ISO 898-1 - ISO 898-2 - EN 14399-1 <p><u>Additional comments:</u></p> <ul style="list-style-type: none"> - If a manufacturer is a subtier, the direct supplier will have its ID marked onto the part alongside the subtier's ID and heat code. - Each part shall be properly and legibly identified. - The identification shall be in the location specified on the applicable code or as specified in the drawing. - Fasteners shall be identified with an identification that ensures their traceability to material and heat-treatment batch. - Bolts and nuts shall be physically lot marked to ensure lot traceability by the manufacturer. - If Suppliers are unsure of which end of a specific stud to stamp, they should refer to the part drawing or contact GE Sourcing Quality Engineer for clarification. - The end opposite of the part identification shall be smooth and free from marking.
15	Packaging and shipping	<ul style="list-style-type: none"> - P23E-AL-0255

		<u>Additional comments:</u> <ul style="list-style-type: none"> - Supplier shall protect the parts against mechanical damage and the introduction of dirt and water in a manner that meets the requirements of GE specification. - Bolts shall be separated by part number for shipment, and shall be packed in such a manner as to be suitably protected from damage or loss during shipment. - Each shipping container shall be legibly marked with the purchase order number, the supplier's name, the purchaser's complete address (including building and door number) and all other information required by the Purchase Order documents and the requirements of GE specification.
16	Purchaser testing	<ul style="list-style-type: none"> - GE reserves the right to pick a part at random from a production run and perform the First Piece Qualification evaluations. Failure to pass any of the "First Piece" requirements shall be cause for the review and possible rejection by the Purchaser of all suspect parts. Any such rejection shall require requalification.
17	Certificate of conformance	<ul style="list-style-type: none"> - All special processes, material, mechanical properties, drawing requirements.
18	Qualification document	<ul style="list-style-type: none"> - Documents shall be stored at the supplier and shall be provided on request. - If the supplier's native language is not English, all qualification documents submitted to GE for review shall be in dual language, both the native language and English. - All data shall be submitted in metric units
19	Record retention	<ul style="list-style-type: none"> - EN 14399-1 - 10 years minimum.

5.6 For Hot Dip Galvanized HV sets lubricated with MoS₂ consisting of bolts per ISO 898-1, nuts per ISO 898-2 and washers per EN 14399-6 and respectively bolts and nuts per EN 14399-4 and washers per EN 14399-6, the following torque preload relationship has to be met for nut side tightening. Other means of determining torque – preload relationship shall have approval from Design Engineering and MPE. Bolt set according to DAST guideline 021 apply (see figure 4 and 5).

5.6.1 The bolts and nuts used for this test shall be taken from lubricated production parts. No lubrication shall be removed or added prior to testing.

5.6.2 Five (5) bolts shall be tested per heat treat lot unless otherwise approved by MPE.



TABLE 3 - TORQUE- PRELOAD RELATIONSHIP

Thread Diameter	Nominal Torque Nm	Min Preload kN
M30	1650	350
M36	2800	510
M39	3500	610
M42	4500	710
M45	5500	820
M48	6500	930
M56	10000	1280
M64	15000	1680

5.7 Critical To Quality (CTQs)



Here is the list of critical to quality (CTQ) for fasteners that need to be measured/ reported. Most of the acceptable CTQ specification limits are found in ISO 898-1 and EN 14399.

1. Mechanical properties of fasteners (YS, UTS, %E, R of A, CVN, etc.) A minimum of three (3) -40°C Charpy V notch tests is required.
2. Thread dimensions (lot basis)
3. Finish dimensions: are required to be measured and process capability captured per P28A-AL-0001:
 - a. THE FOLLOWING CHARACTERISTICS HAVE BEEN IDENTIFIED AS CRITICAL FOR ALL BOLTING (GENERAL FASTENERS)
 - i. Hardness: hardness is indicated by size or depth of local plastic deformation from appropriate hardness testing machine. Hardness to be measured after final thermal operation.
 - ii. Pitch diameter : maximum distance across thread diameter measured with suitable pitch micrometer or equivalent
 - iii. Thread Pitch: axial spacing of threads
 - b. THE FOLLOWING CHARACTERISTICS HAVE BEEN IDENTIFIED AS CRITICAL TO THE QUALITY OF STUDS AND BOLTS.
 - i. Straightness: total variation in run-out on shank surface
 - ii. Stud Diameter: diameter of cylindrical portions of stud (excludes threads and shoulders)
 - iii. Thread Length: axial length of fully formed threads
 - iv. Overall Length: total length, end to end



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- v. Thread Form: thread and root profile
- c. THE FOLLOWING CHARACTERISTICS HAVE BEEN IDENTIFIED AS CRITICAL TO THE QUALITY OF NUTS.
 - i. Pressure Face Flatness: flatness measured over entire pressure face
 - ii. Face Perpendicularity: perpendicularity between pressure face and thread axis
- 4. Bake out for hydrogen relief, if applicable
- 5. Surface quality
- 6. Lubrication, if applicable
- 7. Correct pre-load achieved at prescribed torque, if applicable.
- 8. Finish Dimensions: For production parts, the suppliers can reduce the 100% measurement frequency level of CTQs to a sampling plan. However, this would have to be addressed in the specific MPP and PQP. PLQ parts shall be measured to establish the process and determine process capability cpk and sigma levels. CTQs on production parts shall be tracked and cpk levels reported.
- 9. Process capability as established by P29A-AL-0001 will be reported to GE for mechanical, dimensional, and coating quarterly.

6. INSPECTION / TEST PROCEDURES AND REQUIREMENTS

- 6.1 Certificate of Conformance - Internal and External Suppliers shall promptly submit the Certificate of Conformance to GE Manufacturing Quality Assurance or to the Purchaser address shown on the Purchase Order, respectively.
- 6.2 External Suppliers, after performing all of the required testing, shall promptly submit to the Purchaser a Certificate of Conformance (CC) for each lot of parts supplied. The CC shall state that the parts were processed by the Supplier in complete conformance with the requirements of this GE specification, Approved Process Plan and Purchase Order. The Certificate of Conformance duly signed and dated by an authorized representative of the Supplier shall include the following information:
 - 1. Supplier Name, Address and Vendor Code
 - 2. GE Purchase Order Number and date
 - 3. GE Drawing /Part Number including Revision Letter or Number
 - 4. Quantity of Parts identified by Drawing Part Number and heat/heat treat lot identification.
 - 5. Serial identification numbers
 - 6. Heat Number(s), Material Source
 - 7. Material Specification, including Revision Number and Material Class
 - 8. Dimensional report to all drawing features

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9. Identification of subtiers, if used
10. Heat Number(s), Material Source
11. Statement of conformance with the requirements of this specification.
12. Supplier Process Plan Identification Including Revision Level, Revision Date and Sourcing Quality Number
13. All required Test Data
14. Attachments: SDR(s)/QCR (s) - As Applicable
15. Certificate of Test for the raw material
16. Preload testing results (verified to achieve right pre-load), if applicable
17. Surface quality, in particular, head-shank radius, undercut and threaded areas

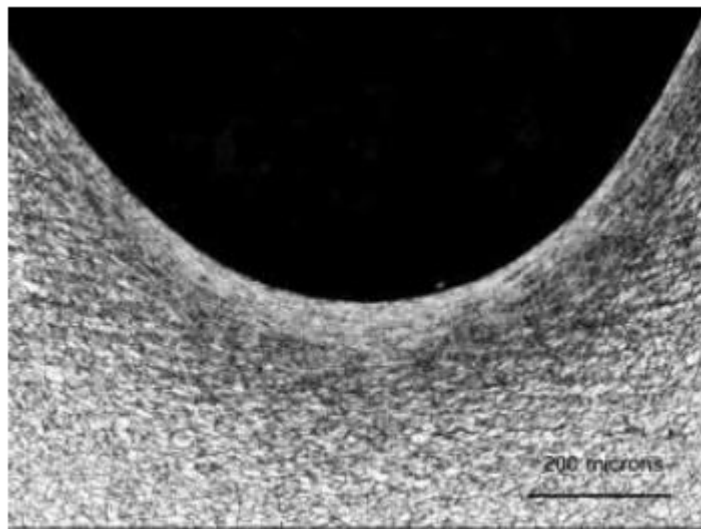
6.3 Audit: the purchaser reserves the right to periodically audit the supplier's facilities and practices. Such audit shall not relieve the supplier from the responsibility of producing the material in suitable condition.



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FIGURE 1 – ROLLED THREAD FLOW LINES



**FIGURE 2 - CROSS SECTION SHOWING ACCEPTABLE GRAIN FLOW
AND THREAD PROFILE WITH NO PERTURBATIONS AT 100 X**



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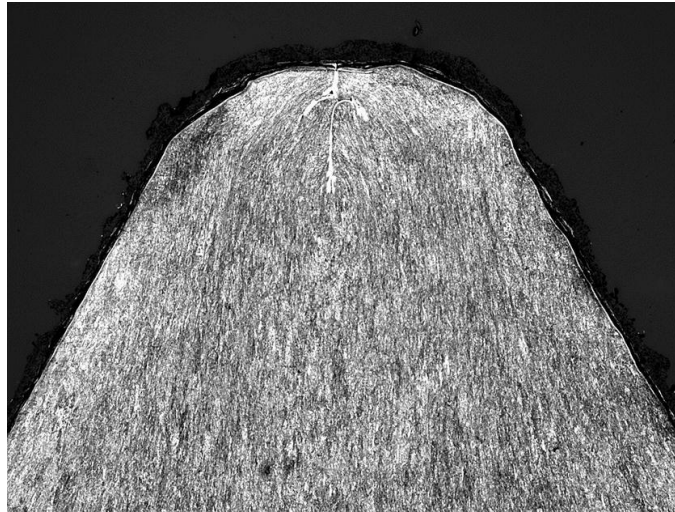


FIGURE 3 - MATERIAL FLOW PATTERN AT 100X. FOLLOWING THE GENERAL THREAD CONTOURS. LAP AT THREAD TIP ALLOWED PER ISO 6157-3.

	Thread (d)						
	M39	M42	M45	M48	M56	M64	M72
Nominal Stress Area $A_{s, nom} \text{ mm}^2$	976	1121	1306	1473	2030	2676	3463

FIGURE 4 - NOMINAL CROSS SECTION AREA (MM) FOR THREAD SIZES M39 TO M72

- Table 1: Bolt geometry M39 - M64
- Table 2: Bolt lengths M39 - M64
- Table 4: Nut geometry M39 - M64
- Table 5: Washer geometry M39 - M64

Table footnotes:

- ¹⁾ Dimensions in mm
- ²⁾ P = Thread pitch (standard threads)
- ³⁾ $D_{wmax} = S_{ist}$
- () Non preferred sizes

FIGURE 5 - DAST GUIDLINE 021 TRANSLATIONS OF APPLICABLE TABLES

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