1.0 SCOPE

This specification provides instructions to forging suppliers concerning practices and procedures necessary to assure quality forgings for Caterpillar Inc.

2.0 APPLICATION

Applies to all ferrous and nonferrous forgings.

3.0 QUALIFYING SPECIFICATIONS

1E0015 Numeral Code
1E0024 Wrought Steel - General Requirements
1E0507 Identification - Part Number
1E1861 Wrought Steel - Approved Suppliers
1E2177 Mill Tolerances - Steel Products
1E2600 Interpretation - Profile Tolerance - Casting and Forging Drawings
1E2728 Quality Requirements - Steel for Near-Net Shape Forgings
1E2349 Material Application - Substitute

4.0 QUALITY PLANNING AND CONTROL

4.1 To ensure forgings comply with Caterpillar requirements prior to production or following a process or material change, Caterpillar Advanced Product Quality Planning (APQP) process, such as Production Part Approval Process (PPAP), Process Change Notice (PCN), Engineering Change Notice (ECN), Material Deviation Request (Form 01-008359 or plant specific deviation forms), or an approved alternate procedure shall be used. Caterpillar Global Supply Network Division will provide information explaining these procedures and when the procedure is required for new part introduction or for process changes. Caterpillar Global Supply Network Division will provide the forms to be used.

4.1.1 Examples of deviations from Caterpillar requirements include, but are not limited to:

- Method of application or location of markings (See Paragraph 6.2)
- Critical forging temperatures (See Paragraph 6.5.1)
- Salvage operations (See Paragraph 7.4)

5.0 SAMPLE FORGINGS

5.1 Images of forging flow lines may be requested as part of the Advanced Product Quality Planning (APQP) process, or at any other time as part of a component performance evaluation. A macroetched cross section of sample forgings can be submitted to Caterpillar or retained by the forger for on-site review when a photograph of a macroetched cross section cannot be obtained or is determined to be of insufficient quality to plainly show grain structure. .

5.2 Sample forgings may be requested as part of the APQP process or at any time for review by the receiving plant. The sample shall be identified by a sample tag indicating part number, engineering change number, and the die identity. A copy of the requested APQP documentation or other forms will accompany the sample forging.

5.3 MQ1000-511

5.3.1 The Manufacting Practice MQ1000-511 (for Caterpillar internal use only) lists the forging suppliers covered by 1E0100, and their one- or two-digit identification codes for traceability. Over time the names of suppliers change for various reasons, and suppliers will need to be added and deleted. As a result, this Manufacturing Practice is a dynamic document requiring a regularly scheduled review.

5.3.2 Global Supply Network Division Forgings Segment has the lead in communicating changes in sourcing plans and therefore is responsible for assuring worldwide Global Supply Network Division awareness and participation in supporting maintenance of MQ1000-511. To request changes, contact the Global Supply Network Division Technical Representative.

5.3.3 To have a new code assigned, Global Supply Network Division Forgings Segment - will contact Advanced Materials Technology (MM-2, Design Control A518 by electronic mail (Quality_Services@cat.com).

5.3.4 Requests should describe what revision is needed in Manufacturing Practice MQ1000-511, including (1) the name, city, state and country, as applicable, for a new forger, (2) the new name of a forger when a name change is involved, (3) name of forgers that are no longer being used as forging sources, or (4) other reasons deemed appropriate to support change requests. Upon receipt of the request, Advanced Materials Technology will make the required code assignments so new sourcing actions can move forward on a timely basis. As changes are collected per the above categories, revisions will be issued on a periodic basis to assure availability of information.

5.3.5 After receiving communication from Global Supply Network Division as described above, the assignment of supplier codes shall be determined by Advanced Materials Technology. Existing lists of codes will be reviewed for available “letters” and the assignment will be communicated to Global Supply Network Division.

6.0 MARKINGS

6.1 All forgings covered by 1E0100 shall bear legible markings as required by the markings class specified on the part number drawing. Markings classes define the information required and method of markings application for an individual forging and may be supplemented or modified by notes on the part number drawing.

6.2 If the design of the part or the method of forging will not permit the use of the markings required in Paragraph 6.3, markings may be omitted, or alternate methods of marking such as dot matrix stamping, may be used only with written permission from the Caterpillar Global Supply Network Division Purchasing Buyer or Technical Representative. The Global Supply Network Division buyer shall get approval from part design control for marking location and method.

6.3 Marking Classes

6.3.1 Class I

6.3.1.1 Forgings specified as Class I shall carry the following markings:

- Part Number
- Die Identity
- Forger’s Identification Letter(s) Assigned by Caterpillar (See Paragraph 5.3)
- Material Identity
- Caterpillar Trademark

6.3.1.2 All markings shall be either forged or stamped figures.

6.3.2 Class II

6.3.2.1 Forgings specified as Class II shall carry the following markings:

- Part Number
- Die Identity
- Forger's Identification Letter(s) Assigned by Caterpillar (See Paragraph 5.3)
- Material Identity
- Caterpillar Trademark

6.3.2.2 All markings shall be raised forged figures unless the drawing specifically allows the markings to be hot stamped or depressed and indicates the area for markings. No cold stamping is permitted.

6.3.3 Class III

6.3.3.1 Forgings specified as Class III shall carry the following markings:

- Part Number
- Die Identity
- Forger's Identification Letter(s) Assigned by Caterpillar (See Paragraph 5.3)
- Material Identity
- Caterpillar Trademark

6.3.3.2 All markings except material identity shall be either forged or stamped figures. The material identity may be painted in accordance with Paragraph 6.4.4.

6.3.4 Class IV

6.3.4.1 Forgings specified as Class IV shall carry the following markings:

- Part Number
- Forger's Identification Letter(s) Assigned by Caterpillar (See Paragraph 5.3)
- Die Identity
- Material Identity at Option of Forger
- Caterpillar Trademark

6.3.4.2 All markings shall be either forged or stamped figures.

6.4 Marking Details

6.4.1 Part Number - The part number is required on all forgings unless omission is specified on the part number drawing. In cases where the part number will be machined off, 1E0507 identification may be specified in the specification block to cover method of identification after machining. 1E0507 does not apply to forger's method of identification.

6.4.2 Die Identity Required by All Marking Classes - The die identity shall be permanently marked in the die and shall not exceed two letters. After **Code DD** is used, the die identity shall return to unity (**Code U**).

6.4.2.1 If the design of the part or the method of the forging will not permit the use of this marking, or if the die design makes such a designation meaningless, it may be omitted, but only with written permission from the Caterpillar Global Supply Network Division Buyer or Technical Representative.

6.4.3 Forger's Identification Assigned by Caterpillar - The forger's identification shall be a letter(s) assigned by Caterpillar Advanced Materials Technology and recorded in Manufacturing Practice MQ1000-511 (for Caterpillar internal use only). When the material identity is either forged or stamped, the forger's identification letter(s) shall be located in front of, but separated from, the material identity by a distance equivalent to one full letter spacing.

6.4.3.1 When the material identity is not forged or stamped, the forger's identification letter(s) shall be used alone and shall be enclosed in a circle.

6.4.4 Material Identity - Required by Markings Classes I, II, and III; Optional with Markings Class IV. There shall be one heat identity assigned per mill heat. Material identity shall be forged or stamped in accordance with the markings class specified on the part number drawing and NUMERALKOD. (Refer to 1E0015). It shall consist of either three or four letters directly following the forger's identification letter(s), separated by one full letter spacing.

6.4.4.1 Once a forged or stamped practice of marking the material identity or the number of letters used has been established, written approval from the Caterpillar Global Supply Network Division Buyer or Technical Representative is required before changing.

6.4.5 Trademarks

6.4.5.1 Cat Trademark - (Per 1E0198) - Unless otherwise specified on the part number drawing or purchase order, the Cat trademark is required on all forgings covered by 1E0100. On forgings where the trademark is placed on a surface that will be subsequently machined, the Cat trademark may be omitted.

6.4.5.2 Forger's Trademark - Forger's trademark shall not appear on forgings covered by 1E0100.

6.4.5.3 The trademark requirements specified above shall be enforced on all new dies and at the next rework or update of existing dies.

6.4.5.4 Other Markings - Markings other than those enumerated here may be placed on forgings only with the written approval from the Caterpillar Global Supply Network Division Buyer or Technical Representative. "Country of Origin" markings shall be applied as required by 1E0011.

6.5 Application

6.5.1 Methods of Application - The method of application shall result in legible markings. If the method of application is not indicated on the part number drawing, it is assumed that the forging supplier will use raised markings. On new and updated part number drawings, method of application will be shown regardless of type since using raised markings is no longer considered standard practice. If the specified type of marking is not consistent with good forging practice to ensure legibility of markings, the forging supplier shall request a change to the part number drawing and submit a marked print showing the proposed location to the Caterpillar Global Supply Network Division Buyer or Technical Representative.

6.5.1.1 Raised Markings - Unless otherwise specified, raised markings shall be as large as is consistent with the size of the part or the space available. On new and updated part number drawings, raised markings will be specified.

6.5.1.2 Raised Markings in a Recess - Used only when recesses are shown on the forging part number drawing. The size of the recess shall be approximately 5 mm larger than the specified size of the markings. If size of marking is not specified, the size of the recess shall be consistent with the area on which it is to be placed to ensure legibility of the markings. The depth of the recess shall be 2.5 mm on an unmachined surface. On machined surfaces, the depth of the recess shall include the maximum finish allowance to retain markings.

6.5.1.3 Depressed Markings - These may be hot or cold stamped figures, except where Class II markings are specified on the part number drawing. Depth of markings shall not exceed 50% of finish allowance on surfaces to be machined. Unless otherwise specified, depressed markings when cold stamped shall be a minimum of 5 mm, with 8 mm the desired size, and when hot stamped a minimum of 10 mm.

6.5.2 If the design of the part will permit it, markings will have at least 2 mm between individual characters, and all markings shall be in numeral code (Refer to 1E0015) except part numbers.

6.5.3 Location of Markings

6.5.3.1 The markings shall be located on the forging in the order given as illustrated in Figure 1.

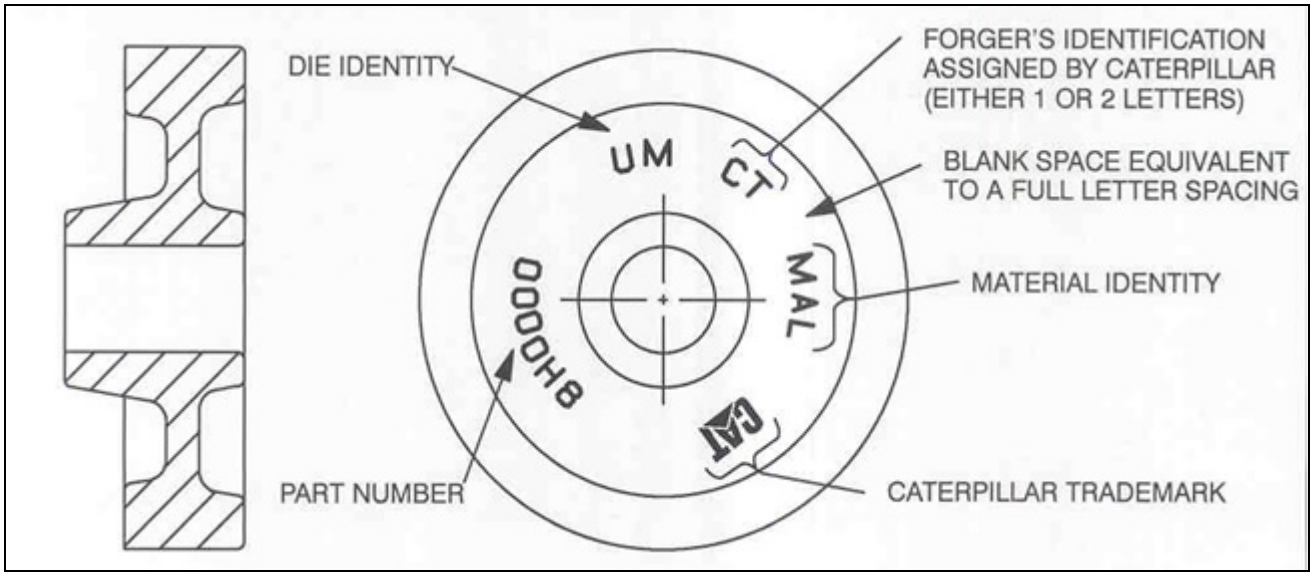


Figure 1 - Forging Markings

6.5.3.2 If possible all markings shall be placed on a surface not requiring subsequent machining, coin pressing, or bolt head seating.

6.5.3.3 Markings should be located such that they will not interfere with initial datum targets (locating areas) specified on part number drawings. In cases where the part is symmetric, the primary datum plane should be located on the opposite side from the markings.

6.5.3.4 Markings shall be spaced to prevent any misunderstanding arising from combined or too closely spaced markings.

6.5.3.5 When markings are placed on surfaces having punched holes, (e.g., the web of a gear blank) the forging shall be positioned for punching so as not to remove the markings. When this procedure is not practical or when the holes are to be drilled, the forger shall use duplicate markings. In cases where space will not permit the use of duplicate markings, the part number and material identity shall be duplicated on another surface.

7.0 MATERIAL TESTING, APPROVALS AND REPORTS

7.1 This article shall apply for all Caterpillar end-use forgings, both Caterpillar worked and purchased finished. Steel forging suppliers shall meet the requirements of this article for material control, material testing, approvals, and reporting to assure metallurgical quality of forging material and forged products.

7.2 Non-ferrous material forging suppliers shall resolve requirements for material testing, approvals, and reporting with the receiving plant, due to the wide variety of alloys available.

7.3 Forging temperatures of various materials shall conform to commonly accepted industry standards and should not exceed the recommended maximum hot working temperatures for the individual materials. 1E Material Specifications shall be reviewed to ensure specific hot working requirements (if specified), are followed.

7.4 Salvage operations, such as repair welding, shall not be permitted unless approved by the engineering design control and/or specified on the part number drawing.

7.4.1 Authorization to weld repair forgings in no sense obligates acceptance of said forgings by Caterpillar should subsequent examination indicate that the repair welds were unsatisfactory.

7.4.2 All repair welding shall conform to a Weld Procedure Sheet written by the supplier. The Weld Procedure Sheet shall include: electrode, welding parameters, method of removing defects, preheat (if needed), finishing requirements, post heat treatment, etc. The current Weld Procedure Sheet shall be made available upon request for audit by Caterpillar. Caterpillar reserves the right to change weld procedures where required to assure quality of product.

7.5 Material Control - All suppliers shall maintain a system adequate to control and identify heats from receipt of steel to shipment of forgings, and to prevent rejected material from being shipped. Suppliers shall have a system adequate to control deviated or restricted material by part number. As part of the heat approval process, control systems shall contain provisions for special tagging and notification to receiving plants at time of shipment.

7.6 Material Testing - Composition of material to be forged shall be verified according to the following guidelines.

7.6.1 Frequency of Analysis

7.6.1.1 A chemical analysis is required for shipments from an approved steel mill if the original mill bundling is broken when received. Approved steel mills are listed in 1E1861.

7.6.1.2 Prior to forging, a chemical analysis shall be run on a shipment of steel received from an approved steel mill when requested.

7.6.1.3 A chemical analysis is required for each shipment of steel received from another forger, a warehouse, or a steel mill not listed in 1E1861.

7.6.1.4 A “shipment” is defined, as material from the same heat with the same shipping date regardless of the number of vehicles required to transport the material.

7.6.2 Minimum Analysis - Chemical analysis to verify the composition of a heat to be forged shall include at least the following elements: Carbon, Manganese, Silicon, Chromium, Molybdenum, Nickel, Copper.

7.6.3 Chemical Analysis Results

7.6.3.1 The forging supplier shall compare the chemical analysis of a heat of material against the following:

- 1E Material Specification
- Shipping Notice/Test Certificate

7.6.3.2 The test certificate shall affirmatively assert that the material meets the 1E Specification. When a heat is restricted or deviated, steel suppliers shall report on the test certificates to the receiving facilities that a restriction exists. End users shall contact their dispositioning facility for further information on approved usage of the heat, unless the test certificate specifically states the part numbers and purchase order numbers involved.

7.6.3.3 Forge shops may not fill orders with steels from National Standard steel grades, from unapproved steel sources, or from heats with a lower reduction ratio than 1E Specification requirements, without approval prior to shipment. The approval shall come from the Metallurgical Department of the receiving Caterpillar facility or from the dispositioning facility. In the case of National Standard grades being substituted for Caterpillar 1E Specification material, a data card (Steel Inspection Report No.16-020586 - XX) or Electronic Data Interchange equivalent shall be submitted to the dispositioning facility. (Refer to 1E0024 for more complete details.)

7.6.3.4 The steel certification shall accompany any steel transfers between forge shops. It is both the responsibility of the originating and receiving forge shops to implement this.

7.6.3.5 Product analysis tolerances are defined by 1E0024.

7.6.3.6 If a discrepancy is found, the forger should contact the Caterpillar dispositioning facility for resolution. Dispositioning facility contact information is found in 1E1861.

7.6.4 Alternate Test Methods - Alternate test methods for verifying heat composition of steel materials may be applied as follows.

7.6.4.1 Spark Or Portable Spectrograph Testing - Material composition of 1E steel specifications may be verified by spark testing or portable spectrograph testing 90% of all bars or product.

7.6.4.2 Where such testing is employed, a Steel Inspection Report (SIR - Paragraph 6.7.1.) or acceptable method of EDI (Electronic Data Interchange) shall be submitted for every shipment indicating “90% spark tested” or “90% portable spectro tested”. “OK” or “Not OK” shall be indicated in composition block on the Steel Inspection Report (SIR) or comments field of EDI transmissions.

7.6.4.3 Chemical Analysis of Steel Mill Presample - This method is unacceptable. Chemical analysis shall be run on a sample taken from the actual material received.

7.6.5 Forgers shall review mill documentation to determine whether steel is strand cast or ingot cast. Forgers shall verify that the reduction ratio of strand cast steel meets the minimum requirements for each part produced. The process (ingot or strand) and the reduction ratio shall be reported on the Steel Inspection Report (SIR) or EDI transmission.

7.6.6 Verification of Flow Lines

7.6.6.1 New Forgings - The forging supplier shall verify by macro etch examination that the flow line pattern is satisfactory to produce sound forgings, free of injurious defects (i.e., interrupted flow lines, folds, laps, etc.).

7.6.6.2 Existing Forgings - The forging supplier shall re-verify by macro etch examination the flow line pattern in any existing forging, which undergoes a major change in part configuration, forging stock, die design, or forging process.

7.6.7 Grain Size and Microstructure - Forging processes shall be controlled and monitored to ensure consistent microstructure, grain size, and surface decarburization throughout the production history of the component. The forging process shall be validated each time the source or the process changes, and critical elements shall be characterized and documented as part of the PPAP process. Once the initial production process and components are approved, the process shall be controlled with documented control plan to ensure consistent forgings are delivered to Caterpillar and its suppliers. The forging process shall not permit either excessive grain growth (more than associated with normal forging temperatures) or unfavorable microstructure, which may be detrimental to the function or the machinability of the part.

7.6.8 Magnetic Properties of Forgings - Forgings shall not be magnetized as a result of the forging operations or subsequent inspection. The residual magnetism shall be measured by a gauss meter with a traceable calibration standard. Recommendations for a suitable gauss meter can be supplied by the materials technology group of the receiving facility. The residual magnetism shall not exceed 5 gauss.

7.7 Approvals of Steel

7.7.1 1E0024 Wrought Steel - General Requirements - All forging steel produced to 1E Specifications incorporating the requirements of 1E0024 are to be dispositioned (approved) by Caterpillar dispositioning facility. Forgers shall review the data furnished by steel suppliers to verify that steel meets specification. If a discrepancy is found, the forger shall contact their dispositioning facility to resolve the issue.

7.8 Reporting Results to Caterpillar

7.8.1 Steel Inspection Report (SIR) - Following assurance by chemical tests, etc., and assignment of a material code (as required per Paragraph 6.4.4), a Steel Inspection Report (SIR) shall be promptly forwarded to the Caterpillar dispositioning facility using the latest issue of Form 16-21-20586-1, (provided by Caterpillar Materials Technology East Peoria plant). However, an acceptable form of EDI (Electronic Data Interchange) is the preferred method of reporting data. A Steel Inspection Report shall be submitted to Caterpillar one time for each heat. The form shall contain the following information:

- Forger and Mill Names
- Date SIR is Completed
- Heat Number
- Part Number and/or Purchase Order Number
- 1E Material Specification and Specification Change Number
- Mill and Forger Compositions
- Material Code
- DI, if Applicable
- Mill Hardenability, if Applicable
- Steel Casting Process (Ingot or Strand)
- Reduction Ratio
- Customer Name (Purchased Finished Parts Only)
- Mechanical Properties, if Applicable
- Cleanliness Data Per 1E2661, if Applicable

Note: The SIR is not limited to usage by forging suppliers, but may also be utilized to report data by warehouses or other suppliers, as requested.

7.8.2 Material Analysis and Steel Usage Report (MASUR)

7.8.2.1 Shipments Directly To Caterpillar - A Material Analysis and Steel Usage Report (MASUR), Form 01-009613-latest Issue, provided by Global Supply Network Division shall be completed for each shipment. Specific instructions for sending MASUR's are included on the form and shall be followed.

7.8.2.2 Shipments Indirectly To Caterpillar - For shipments sent to suppliers for interim machining, heat treatment, etc. prior to shipment to Caterpillar, MASUR's shall be sent by the forger directly to the Caterpillar receiving plant regardless of the transportation method.

7.8.2.3 An acceptable method of Advanced Shipment Notification (ASN) may be used in lieu of the MASUR form. All forge shops are required to send ASN with heat number and forging code before material is shipped.

7.8.3 Record Retention - Records concerning all shipments shall be retained by the forger according to the following requirements:

ITEM	MINIMUM RETENTION TIME
Material Disposition for Heats Received by Forger	2 Years
Backup Paperwork for Specific Shipments, Including Chemical Analysis, Code, etc.	5 Years

8.0 MICROALLOYED STEELS

8.1 This article provides processing, testing, and reporting requirements for microalloyed steel forgings. Microalloyed steel forgings are strengthened by precipitation hardening during controlled cooling after forging. This allows elimination of quench and temper heat treatment operations and shifts responsibility for providing mechanical properties to the forger.

8.1.1 Forgers of microalloyed steels are responsible for controlling forging parameters (within the limits defined below) to provide the specified mechanical properties. The forger shall work closely with and seek approval from technical representatives from Caterpillar to define proper processing parameters, testing locations, etc.

8.2 The temperature of the mult should be 1150 ºC – 1250 °C to assure complete dissolution of the microalloying precipitates and to avoid excessive grain growth. Excessive mult temperature can result in grain growth which can affect mechanical properties and machinability. Higher mult heating temperatures may only be used with prior approval of the Caterpillar Global Supply Network Division Buyer or Technical Representative. Such approvals may be made only on an individual part number basis.

8.2.1 Uniform heating of the mult is critical to achieve the required mechanical properties and microstructure. The temperature difference between the surface and the core shall be minimized.

8.2.2 Finish forge temperatures shall be controlled to provide the specified mechanical properties. Lower finishing temperatures will increase tensile ductility and toughness, but will reduce hardness, yield strength, and tensile strength.

8.3 The cooling rate after forging shall be carefully controlled to assure proper precipitation hardening.

8.3.1 Forgings shall be cooled separately from each other on a conveyer or similar system until they reach a temperature of 600 °C or less. Premature placement in a tub or container will retard cooling, producing low and erratic tensile properties. Forgings shall not be placed on or against any insulating surface or any surface that would block airflow around the part.

8.3.2 Forced air cooling shall only be used when approved by the receiving Caterpillar facility.

8.4 Although microalloyed forgings can be straightened, the amount of deformation that can be tolerated is less than for heat treated grades. Stress relief after straightening shall not exceed 580 ^{o}C.

8.5 Hardness testing shall be performed at a frequency that is appropriate to assure conformance to the specified hardness range. The receiving Caterpillar facility shall determine minimum frequency of tensile testing and may require test reports.

8.6 Forgings that do not meet specified mechanical properties may be reworked by high temperature normalizing or a quench and temper operation, when approved by the dispositioning Caterpillar facility. Separate approval is required for rework of different part numbers, heat numbers, and forging lots.

8.7 Documented process controls in place at the forger shall include, but not be limited to, the following:

- Mult Reheat Practice
- Maximum and Minimum Mult Temperature
- Maximum and Minimum Time at Temperature
- Finish Forge Temperature
- Controlled Cooling Practice
- Established Practice for Statistical Surface Hardness Control

8.8 Prior to any process change of a microalloyed steel forging, the forger shall contact Caterpillar Global Supply Network Division Buyer or Technical Representative listed on the purchase order for approval.

9.0 NEAR-NET SHAPE FORGINGS (NNSF) - GEARS

9.1 This article provides processing, testing and reporting requirements that are specific to near-net shape forgings of gears and is in addition to the other requirements of this specification. In the NNSF process the forger is responsible for generating the tooth involute form within a specified stock envelope. This requires that certain gear technology be incorporated into the die design and that forgers have the ability to check gear form and involute profile.

9.2 Forgers are responsible for producing proper tooth geometry, involute profile and fillet, as required in the print tooth control block, in accordance with the tooth profile process option designated by the procuring plant. Proper inspection equipment shall be available to check these items.

9.3 1E2728 shall be called out on the forger die card stating the bar surface quality level required, which is determined by the machining stock which will be removed from the forging by the receiving Caterpillar plant. 1E2728 Quality Level B may be specified for gears with 0 - 0.4 mm stock removal when written approval is given by Global Supply Network Division and the receiving Caterpillar facility. This will be subject to the demonstrated capability of the steel mill to provide the surface quality required in the as rolled condition and the forger to have quality control procedures in place that will ensure the requirements of Paragraph 9.5, below, are met.

9.4 The NNS forging process shall have controlled heating to minimize scale formation and other surface conditions which may adversely affect the finished part.

9.5 Finished forgings shall not contain any marks or surface defects that would not be removed by a limited amount of machining or grinding, as indicated by the allowable stock envelope. NNS forgings shall not be tumble blasted.

9.6 The cooling rate after forging shall be carefully controlled to avoid distortion. This cooling rate shall also be consistent from piece-to-piece and run-to-run.

9.7 When the NNS forgings are cold sized to provide closer tolerances on the tooth profile, a high quality, extreme pressure, sulfur-chlorinated, cold forming lubricant (e.g., Extrudoil 469 °F by Metal Lubricants Co.) shall be used during the sizing operation. Surfaces, which are to be used in the as-sized condition, shall be free of tearing, checking or craze cracking. Detection of these defects requires high magnification.

9.8 Prior to any process change of a near-net shape forging, the forger shall contact Caterpillar Global Supply Network Division Buyer or Technical Representative listed on the purchase order for approval.

10.0 ROLLED RING REDUCTION RATIO

10.1 This article provides processing, testing and reporting requirements for rolled ring forgings.

10.2 Strand cast and ingot cast steel with reduction ratios less than the 1E2700F requirements may be used for rolled rings provided that the total rolling reduction ratio of the finished product is greater than 6:1, per the method of calculation described in American Gear Manufacturer's Association specification AGMA 923-A00 or an equivalent method approved by Global Supply Network Division and the dispositioning Caterpillar facility. This calculated total rolling reduction shall be submitted to the dispositioning facility along with the forger traceability information. The AGMA equation for calculated total rolling reduction is as follows*:

Calculated Total Rolling Reduction = (A/B) x (C/D) x (E/G) x (F/H)

Where:
A = The cross sectional area of the cast ingot or continuous cast billet.
B = The cross sectional area of the billet prior to upsetting.
C = The height of the forging mult prior to upsetting.
D = The height of the upset blank after upsetting and before piercing.
E = The height of the upset blank after piercing.
F = The wall thickness of the upset blank after piercing, before bore expansion associated with piercing.
G = The height of the finish forged or rolled ring.
H = The wall thickness of the finish forged or rolled ring.

Note*: Extracted from AGMA 923-A00 with the permission of the publisher, the American Gear Manufacturers Association, 1500 King Street, Suite 201, Alexandria, Virginia 22314.

10.3 Prior to any process change of a rolled ring forging, the forger shall contact Caterpillar Global Supply Network Division Buyer or Technical Representative listed on the purchase order for approval.

11.0 CLEANING

11.1 Cleaning of forgings implies complete removal of hot rolling and forging scale that may interfere with subsequent operations such as heat treating, machining, welding, painting, etc. Cleaning of forgings does not imply “rust free”, if the forging is required to be rust free this requirement shall be specified in the packaging instructions. Cleaning of the forging by the forger will also aid critical inspection and give assurance of a sound forging, free from injurious laps, seams, cracks, checks, and other surface defects. For this reason it is mandatory that some forgings be cleaned by the most revealing process, pickling. Parts requiring this critical inspection shall have a note on the drawing **Pickle Forging**, whereas other forging drawings shall specify either **Clean Forging** or **As Forged.**

11.2 Pickle Forging - Replaced by clean forging with magnetic particle inspection, unless authorized by Caterpillar Global Supply Network Division. In addition to complete scale removal, “pickle forging” implies thorough inspection by the forger for all surface defects. This method of cleaning will be required for parts subjected to severe stress on un-machined forged surfaces.

11.3 Clean Forging - This note permits the forger to use any one of the following methods of cleaning at his disposal: sand blasting, shot blasting, wheelabrating, or hydroblasting. Tumbling or any other cleaning method that destroys legibility of markings and hides defects are not permitted. Complete scale removal shall be obtained by the process used.

11.4 As Forged - This note applies to those forgings on which the presence of a normal amount of scale, consistent with the type of forging equipment used, will not be objectionable.

12.0 PROCESSING PRECAUTIONS

12.1 Billets and Bars for Upsetting

12.1.1 Cross Section - Part number drawings may specify the maximum or minimum cross section of billet or bar to be employed in the making of any forging. The forger shall select the optimum stock size to be used for each upset gear forging to ensure maximum density and flow line structure in the gear rim.

12.1.2 Corner Radii - Corner radii on billets and bars furnished for forging stock shall be consistent with mill practice and conform to those published in the latest AISI publications.

12.2 Cooling Precaution

12.2.1 Precautions should be taken, if necessary, in cooling forgings from forging temperature to avoid internal ruptures, especially through the temperature range of 540 ºC to 150 °C, for temperature sensitive alloy forgings having large sections.

12.2.2 Any forging with carbon content greater than 0.15% should not be liquid quenched from above the lower critical temperature unless it is immediately tempered.

12.2.3 Where “maximum hardness as forged” or any other mechanical property is specified on part number drawing, it may be necessary to control cooling of the forging from the forging temperature to acquire such properties.

13.0 PROCEDURE FOR FULFILLING ORDERS

The forger shall estimate his commitments for steel and order the fewest possible number of mill heats for making one part number. The sequence of fulfilling orders shall use the oldest heats first, with the least possible overlapping of forgings made from subsequent heats. If overlapping of heats is unavoidable, the forger shall make a distinct separation (at the minimum, separate tubs) between heats during handling and shipping. If a material specification for a forging is changed, the forger shall make certain that his plant is cleared of all forgings made from the previous material before his first shipment of forgings from the succeeding material are made.

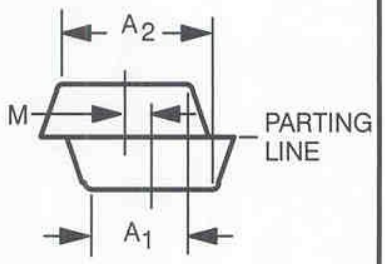
14.0 DRAWING/TOLERANCE INTERPRETATION

14.1 This article interprets drawing dimensioning and tolerancing requirements for the two dimensioning and tolerancing systems, which have been employed on Caterpillar forging drawings. General requirements apply to both systems. Unique features of the individual systems are described in separate paragraphs.

14.2 General

14.2.1 Mismatch Tolerance - This allowance relates to the displacement of a point in one die-half of the forging from a corresponding point in the opposite die-half of the forging, in a direction parallel with the parting plane. Unless lesser or greater amounts are shown on the part number drawing, the values shown in Figure 2 apply to mismatch on as forged surfaces. On drawings employing the profile tolerance system mismatch allowance is a further restriction to profile tolerance.

Mismatch Allowance		
*Weight In kg		
Over	Incl	Tolerance mm
0	0.4	0.4
0.4	1.0	0.5
1.0	1.7	0.6
1.7	3.5	0.8
3.5	5.0	0.9
5.0	11.0	1.0
11.0	22.0	1.3
22.0	45.0	1.5
45.0	90.0	2.3
90.0	135.0	3.0



MISMATCH $M = \frac{A_2 - A_1}{2}$

*THE WEIGHT OF THE UNMACHINED FORGING IS TO BE USED TO DETERMINE THE MISMATCH TOLERANCE.

Figure 2 - Mismatch Allowance

14.2.2 Machining (Upsetter) Forgings

14.2.2.1 Tolerances On Unforged Portion of Bars - Tolerances broader than commercial mill tolerances for bar and tube (Refer to 1E2177, etc.) are required for the unforged portion of the original bar or tube within the gripper area of upset forgings which retain the original bar or tube as a portion of the forging. The gripper length varies from forger to forger and the diameter tolerances listed in Figures 3 and 4 are required in the entire gripper length area of the bar or tube portion on the as forged part. These tolerances are broad enough to cover the original mill tolerances on the bar or tube where **(1E0100 Tol)** or **(Stock Tol)** is shown after a nominal size on the bar or tube portion of an upset head forging. The tolerances listed in Figures 3 or 4 apply to the entire unforged bar or tube portion as well as the gripper area, since gripper length cannot be specified. Tolerances on other diameters forged within the upset die shall be as specified on the part number drawing.

NOMINAL BAR SIZE, mm	1E0100 DIA TOLERANCES, mm
OVER INCL	
--- To 50	+1.5 -0.5
50 To 115	+2.3 -0.8
115 To 140	+2.8 -0.8
140 To 165	+3.8 -0.8

Figure 3 - 1E0100 Tolerance For Gripper Diameter And Original Bar Diameter

NOMINAL OD SIZE, mm		1E0100 DIA TOLERANCE, mm	
OVER	INCL	OD	ID
---	To 75	+1.5 -0.8	-1.5 +0.8
75	To 165	+2.3 -1.5	-2.3 +1.5
165	To 274	+3.0 -2.3	-3.0 +2.3

Figure 4 - 1E0100 Tolerance For Outside Diameter And Inside Diameter In Gripper Area And Original Tube Portion

14.2.2.2 Protrusion of flash on machine (upsetter) forgings shall not exceed 1.0 mm from the adjacent forged surface unless otherwise specified on the part number drawing.

14.2.3 Datum Targets (Locating Areas)

14.2.3.1 Datum targets (locating areas) shall be used as the basis for dimensional checking.

14.2.3.2 Parts shall be made such that markings and parting lines do not fall within an area designated as a datum target (locating area). In cases where the part is symmetric, the primary datum plane should be located on the opposite side from the markings. If this is not practical, the datum targets and the method of manufacture shall be resolved with the Caterpillar Global Network Supply Division Buyer or Technical Representative.

14.2.3.3 Refer to 1E0011/1E2600 for interpretation of datum target symbols.

14.3 Profile Tolerance System - (See Figure 5)

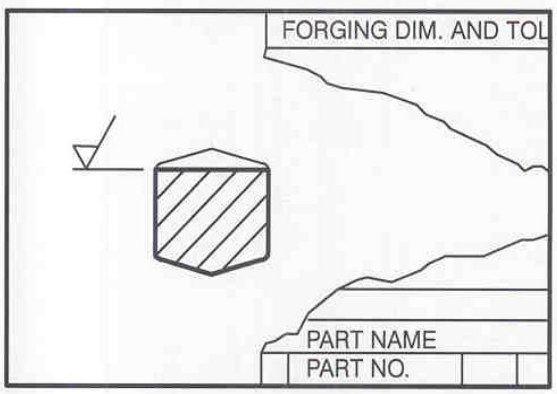


Figure 5 - Drawing - Profile Tolerance System

14.3.1 Characteristics of Figure 5

- Forging Dimension and Tolerance Block
- Forged Surfaces Defined on the Same Views as Machined Surfaces
- Machined Surfaces Identified by Machining Required ✓Symbol

14.3.2 Drawings with the above characteristics of Figure 5 are dimensionally interpreted in 1E2600.

14.3.3 Surface Condition Tolerances - This tolerance relates to depth of dress-outs or scale pits allowed on forging surfaces.

14.3.3.1 On surfaces to be machined, the material under a dress-out or scale pit shall meet the minimum machining allowance specified on the drawing.

14.3.3.2 On surfaces that are not to be machined, grinding out surface defects is permitted, provided the depression is minimal and blended, and it does not cause that surface to fall outside of the limits defined by the applicable profile tolerance. Machining to eliminate surface defects is allowed providing the defects are completely removed, and the machined surface is within the profile tolerance. If the defect is not totally removed by these processes, or the surface falls outside the applicable profile tolerance, the part is rejectable.

14.4 Separate Forging View/Machining View System - (See Figure 6)

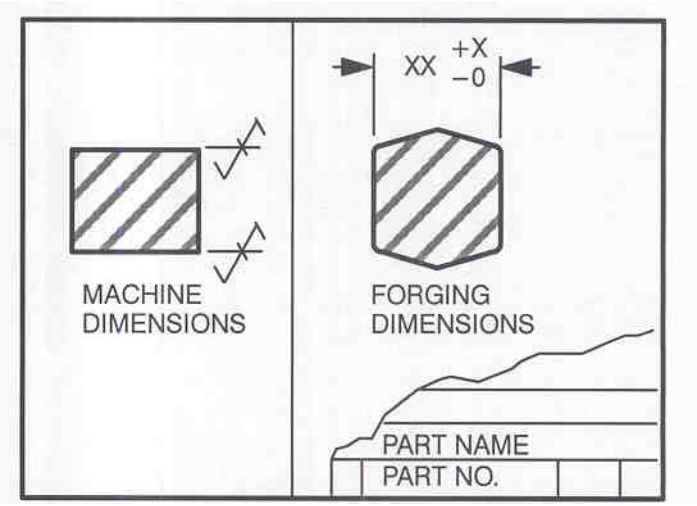


Figure 6 - Drawing - Separate Forging View

14.4.1 Characteristics of Figure 6

- Unilateral Tolerances on Individual Forging Dimensions
- Separate Views for Forging Dimensions and Machine Dimensions
- Machined Surfaces are Identified by √ Symbol

14.4.2 Drawings with the above characteristics of Figure 6 are dimensionally interpreted below.

14.4.3 Tolerances on forging dimensions that are shown unilaterally are to be considered as overall tolerances that include individual tolerances for die wear, die closure, and length. Specified tolerances are applicable to all related surfaces and dimensions. Therefore, every dimension may not carry an individual tolerance.

14.4.3.1 When datum targets (locating areas) are shown on the drawing, forging tolerances shall be taken from the datum targets.

14.4.3.2 On part numbers that require a checking fixture to establish the usability of the forging, Caterpillar will supply the forger with a checking fixture to be used for determining acceptance or rejection of a forging.

14.4.3.3 Where machining is required, mismatch shall not exceed 50% of the machining allowance as indicated by the difference between the forging dimensions and the machine dimensions.

14.4.3.4 Where there is no machining, mismatch shall not exceed the values specified in Figure 2.

14.4.3.5 Flash extension allowances for normal trim are additional to forging dimension tolerances and are shown in Figure 10. Tolerances on other than normal trim (close trim, straight trim or pierce, or loose trim) are the same as the tolerances specified on the forging dimensions.

14.4.3.6 General overall tolerance notes in the title block of drawings do not apply to forging dimensions.

14.4.3.7 Forging dimensions and tolerances are further qualified where geometric symbols and tolerances for flatness, etc., are shown on forging features.

14.4.4 Unless otherwise specified on the part number drawing, allowances for draft angle, radii, and flash extension are as follows:

14.4.4.1 Draft Angle Tolerance - This tolerance relates to the angular deviation allowable on the as forged part from the draft angle specified on the part number drawing. Unless another tolerance is specified on the part number drawing, a tolerance of +2° -1° applies to the specified draft angle.

14.4.4.2 Radii Tolerance - Unless a tolerance or other restriction is specified on the part number drawing, corner and fillet radii are allowed to deviate from specified size in accordance with Figure 7.

RADIUS, mm		TOLERANCE, PERCENT			
		FILLET RADIUS		CORNER RADIUS	
OVER	INCL	PLUS	MINUS	PLUS	MINUS
0	9.5	50	25	25	50
9.5	25	40	20	20	40

Figure 7

14.4.4.3 Flash Extension Allowance - This allowance relates to the ridge of metal (flash) remaining on the forging at the parting line after trimming.

14.4.4.4 Normal trim applies to the bulk of forgings produced and is indicated pictorially on the forging dimensions portion of the part number drawing as illustrated in Figure 8. A trim dimension is not specified on the part number drawing for normal trim. Due to piece part shift during the trimming operation, flash extension may be a maximum on one side and completely removed on the side opposite, resulting in a flat area. (See Figure 9) The size of the flat area is dependent upon the amount the forging shifts in the trim die, the draft angle, and the thickness of the flash extension. Trimmer shift shall not exceed the maximum flash extension allowance shown in Figure 10.

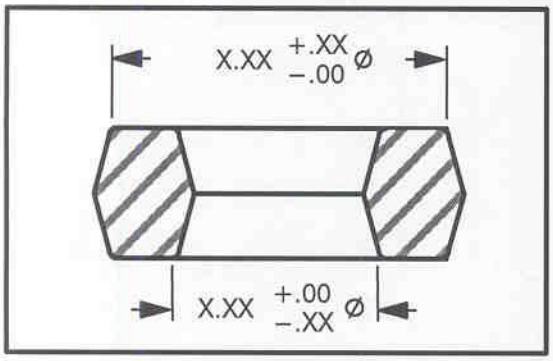


Figure 8 - Normal Trim - Forging Drawing

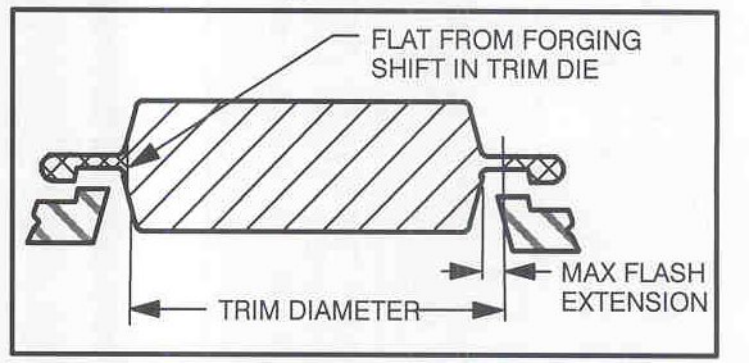


Figure 9 - Normal Trim - Flash Removal

CARBON STEEL - LOW ALLOY STEEL - ALUMINUM		
WEIGHT, kg		**MAXIMUM FLASH EXTENSION PER SIDE, mm**
OVER	**INCL**	
0	0.4	0.8
0.4	11.0	1.5
11.0	23.0	2.5
23.0	45.0	3
45.0	90	5
*For stainless steels and super alloys under 22.5 kg, add 0.8 mm to figures given for carbon steel, and when 22.5 kg and over, add 1.6 mm to figures given for carbon steel.		

Figure 10 - Flash Extension Allowance For Normal Trim

14.4.4.5 Other Than Normal Trim - On part number drawings requiring close trim or loose trim, “X.X Trim” dimension is specified. For straight trim, only “X.X” dimension is specified at the origin of draft. Straight sides are shown to indicate the requirement for straight trim or pierce. The tolerance on these trim dimensions is the same as the tolerance specified on the forging dimension at the origin of draft.

14.4.5 Surface Condition Tolerance - This tolerance relates to the depth of dress-outs or scale pits allowed on forging surfaces.

14.4.5.1 On surfaces that are to be machined, the material under a dress-out or scale pit shall provide a minimum of 1.5 mm stock removal or 50% of the machining allowance whichever is smaller.

14.4.5.2 On surfaces that are not to be machined, the depth of dress-outs or scale pits shall not exceed 50% of the die closure or thickness tolerance.

15.0 REFERENCES

Abbreviations	1E0011
Caterpillar Specifications	1E0198, 1E2661, 1E2700F
Caterpillar Manufacturing Practice	MQ1000-511
Caterpillar Forms	No. 01-008359 – Material Deviation Request
	No. 01-009613 – Material Analysis & Steel Usage Report
	No. 16-21-20586-1 – Steel Inspection Report
Caterpillar Documents	Advanced Product Quality Planning (APQP)
	Production Part Approval Process (PPAP)
	Process Change Notice (PCN)
	Engineering Change Notice (ECN)
AGMA	923-A00