1.0 SCOPE

This specification covers the quality and process control aspects of continuous and ingot casting processes. In addition, it also defines the reduction ratio requirements for acceptable centerline condition and material work for various applications of rolled products. Also included is a description of the classification system used to rate the capability of a casting process. This is a multiple variation specification (by reduction ratio requirements) and applies to steels of all cast shapes. (See Article 3.0, Drawing Designations)

2.0 APPLICATION

This specification provides a system for designating wrought steels through a combination of minimum reduction ratio and mill classification level. Wrought steel purchased to this specified combination or to a higher quality level will provide acceptable component performance.

3.0 DRAWING DESIGNATIONS

3.1 The following designations (See Figure 1) define minimum required reduction ratios from the as-cast billet, bloom, ingot, or slab to the product size shipped by the steel rolling mill. The reduction ratio for various forms is defined.

3.2 Billets and Blooms - Ratio of the original as-cast cross sectional area to the cross sectional area of the final mill product.

3.3 Tapered Ingots - Ratio of the original as-cast cross sectional area at the mid-point height of the ingot to the cross sectional area of the final mill product.

3.4 Slabs - Ratio of the thickness of the slab to the thickness of the final mill product.

CURRENT DESIGNATION	REDUCTION RATIO REQUIREMENTS*
1E2700A(1)	As-Cast (No Reduction Required)
1E2700B(2)	3:1 Reduction Minimum
1E2700C(3)	6:1 Reduction Minimum**
1E2700D	Fulfilled by 1E2700C
1E2700E(4)	Fulfilled by 1E2700A Except No Mid-Radius Cracks Are Permitted
1E2700F(5)	3:1 Reduction Minimum

(1) Historically, this designation has been used for seamless tubing and forgings where adequate work is introduced during forging.
(2) Historically, this designation has been used primarily for plate and sheet.
(3) Historically, this designation has been used primarily for machined components using as-rolled bar.
(4) Historically, this designation has been used for forgings where adequate work is introduced during forging but require additional cast product quality.
(5) Historically, this designation has been used for bar that undergoes a subsequent forging process.

Figure 1

Note*: For purposes of determining conformance with these requirements, all specified limits are **absolute limits**, as defined in ASTM Practice E29. For example, 3:1 reduction minimum means the same as 3.0:1 and rounding is not allowed.

Note:** 1E2700C may be fulfilled by 1E2700F for applications where billets, ingots, or bars are subsequently hot forged. **This does not apply to upset forgings where only a portion of the cross-section is upset, for example flanged shafts and bevel gear blanks.**

4.0 CONTINUOUS CAST AND INGOT CASTING PROCESS CLASSIFICATIONS SUMMARY

4.1 Suppliers awarded a classification under this specification shall conform to the requirements provided in Figures 2 and 3 which summarize the minimum requirements for each continuous caster and ingot casting process classification, respectively. These requirements are further defined in Article 5.0 - Continuous Caster Classification Requirements and Article 7.0 - Ingot Casting Process Classification Requirements.

4.2 The classification awarded to each approved supplier is recorded in 1E1861 “Wrought Steel - Approved Suppliers”.

CLASS	LADLE TO TUNDISH SHROUD SYSTEM PARAGRAPH 5.1.1	MONITORING AND CONTROLLING CASTER VARIABLES PARAGRAPH 5.2	TRACKING SYSTEM PARAGRAPH 5.3	TUNDISH TO MOLD SHROUD SYSTEM PARAGRAPH 5.1.3	ELECTROMAGNETIC STIR (EMS) OR ELECTROMAGNETIC BRAKE (EMB) PARAGRAPH 5.4
1A	Shroud – Gas Purged Submerged Ceramic or "Box-Type"	Automated or Continuous Real-Time or Alternate Approved Practice	Automated	Gas Purged Submerged Ceramic or Box-Type Gaseous Continuous O_2 Monitoring	EMS or EMB
1B	Shroud – Gas Purged Submerged Ceramic or "Box-Type"	Real-Time or Alternate Approved Practice	Present	Adequate Controlled Submerged Ceramic or Box-Type Gaseous Adequate O_2 Monitoring	Not Required
3	Shroud – Gas Purged Submerged Ceramic or "Box-Type"	Manual	Present	Effective Gaseous	Preferred
5	Unknown Quality Level				

Figure 2 - Summary – Continuous Caster Classification Requirements

CLASS	POURING PARAGRAPH 7.1	LADLE TO TRUMPET SHROUD PARAGRAPH 7.2	INGOT PROTECTION PARAGRAPH 7.3	RATE OF FILL PARAGRAPH 7.4	PROPER TOP AND BOTTOM CROPPING PARAGRAPH 7.5	MONITORING AND CONTROLLING OF CASTING VARIABLES PARAGRAPH 7.6	TRACKING SYSTEM PARAGRAPH 7.7
1	Bottom Poured	Shroud – Minimum Gap + Inert Gas (Positive Pressure)	Mold Flux + Hot Top Compound	Continuous Monitoring or Alternate Approved Practice	Documented Cropping Procedure	Continuous Real Time or Alternate Approved Practice	Present
5	Top or Bottom Poured	Unknown Quality Level					

Figure 3 - Summary – Ingot Casting Process Classification Requirements

5.0 CONTINUOUS CASTER CLASSIFICATION REQUIREMENTS

5.1 Shrouding - Protects the flow of molten steel from reoxidation, and may also control its flow, during transfer from one vessel to another.

5.1.1 Ladle to Tundish Shroud System - Either a submerged ceramic shroud or a “box-type” gaseous shroud is required from the ladle to the tundish. Submerged ceramic shrouds are preferred.

5.1.1.1 A submerged ceramic shroud shall use inert gas at the shroud joints/couplings to prevent air from aspirating into the molten steel-pouring stream. (See Figure 4). The purge gas flow shall be continuously monitored and controlled within established limits. A procedure shall be in place to inspect the shroud. If the ceramic shroud is cracked, broken, or shows evidence of leaking, a mechanism shall exist to quarantine the affected product.

5.1.2 A box-type shroud shall protect the steel stream from exposure to oxygen by surrounding the steel stream with an inert gas. (See Figure 5) An effective "box-type" gaseous shroud shall maintain the oxygen level in the vicinity of the molten stream at 0.5% or less. Continuous monitoring and control are required for the variables associated with the operation of gaseous shrouds. A mechanism shall exist to identify and quarantine all product cast when the shrouds are not operating within the established limits

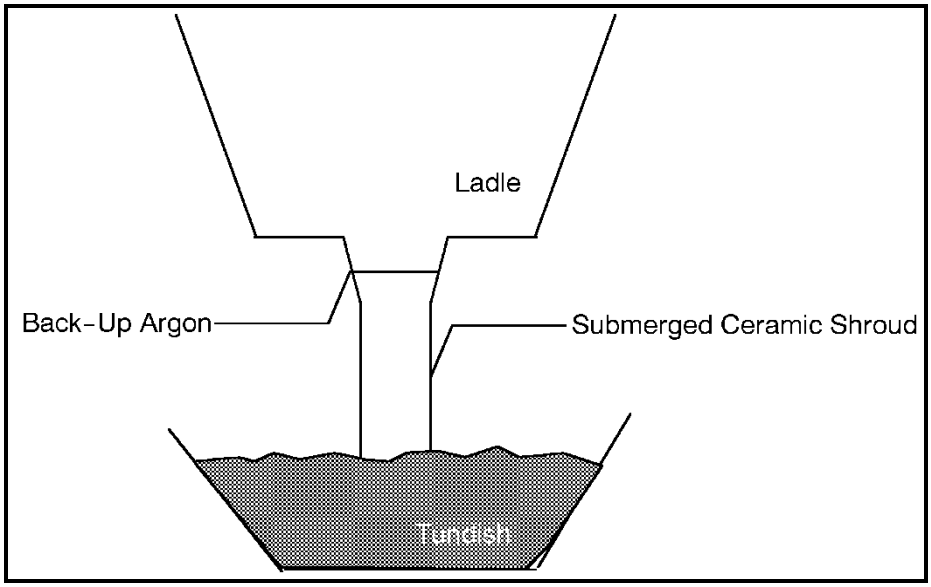


Figure 4 - Submerged Ceramic Shroud

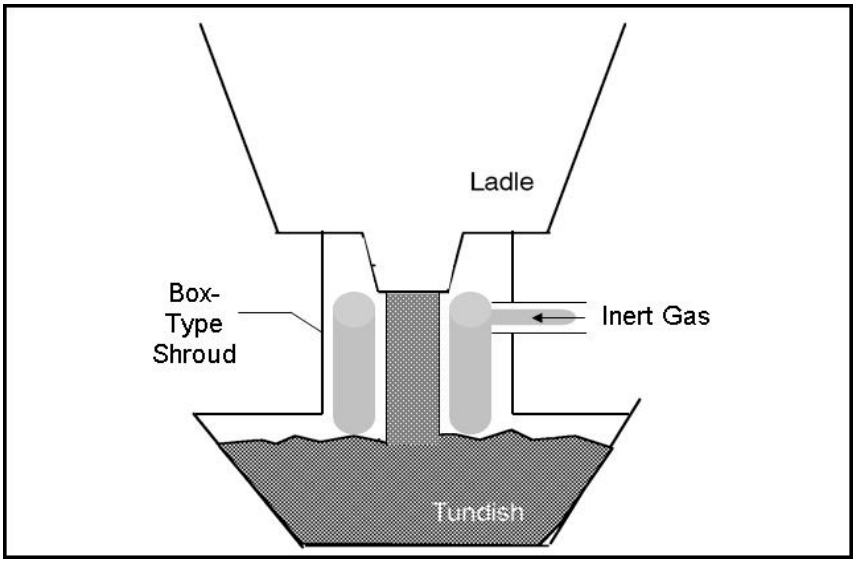


Figure 5 - Box-Type Shroud

5.1.3 Tundish to Mold Shroud System - Either a submerged entry nozzle (SEN) or a well-sealed “box-type” inert gas purged shroud is required from the tundish to the mold. Submerged entry nozzles are preferred.

5.1.3.1 A one piece, submerged entry nozzle (SEN) is a ceramic shroud that extends out from inside the tundish to protect the steel stream from exposure to oxygen by allowing the steel to exit the shroud below the surface of the steel in the mold. If a jointed submerged ceramic shroud is used from tundish to mold, then back up inert gas flow is required at shroud joints/couplings to prevent air from aspirating into the molten steel pouring streams. The purge gas flows shall be monitored and controlled within established limits to prevent trapping gas and bubbling in the mold. If the shroud is cracked or broken, or if the purge gas flow deviates from prescribed limits, a system shall track and quarantine for disposition, the entire length of the affected strand.

5.1.3.2 A well-sealed “box-type” inert gas purged shroud with continuous monitoring of the gas flow is acceptable if evidence can be produced that the oxygen level is less than 0.5% inside the shroud environment. A procedure shall be in place to inspect the shrouds. If the gas flow in the box-type shroud deviates from prescribed limits or oxygen ingress is suspected, a system shall track and quarantine for disposition, the entire length of the affected strand.

5.2 Monitoring and Controlling Caster Variables - The Caster Operating Procedures shall specify all casting variables and tolerances needed to produce the steel quality level required by each caster classification. Monitoring shall provide traceability between casting parameters and a discrete length of end product.

5.2.1 Automated or Continuous, Real-Time Monitoring and Control System - The system samples the variables on a nearly continuous basis. Data is recorded and accessible. Operators can monitor and control all variables from the pulpit.

5.2.2 Real-Time Monitoring and Control System - The system samples the variables at less frequent intervals than that of an automated or continuous, real-time control system. Operators can monitor and control all variables from the pulpit. Alternate practices demonstrating a robust and disciplined system of control may be approved by Caterpillar as fulfilling the requirements of a caster class 1A or 1B classification.

5.2.3 Manual Control System - Sampling the variables only occurs when an operator monitors the individual measuring device for each variable and manually reports them to a central location. The measurements are then recorded by manual log entry.

5.2.4 For all caster classes, the following variables shall be monitored using the system specified for each classification in Figure 2:

- Tundish superheat
- Backup inert gas flow to pouring stream ceramic shroud joints/couplings
- Oxygen content of inert gas in gaseous “box-type” shrouds
- Mold oscillation and stroke
- Mold level fluctuations
- Casting speed
- Mold and secondary cooling water temperature and pressure

5.2.4.1 Additionally, Caster Class 1A mills shall monitor Electro-Magnetic Stirring (EMS) or Electro-Magnetic Brake (EMB) operating parameters.

5.3 Tracking System - Shall track and quarantine for disposition strand lengths produced when casting variables have deviated outside the specified tolerance ranges according to the tracking system specified in Figure 2. The tracking system shall ensure complete containment of the affected cast product.

5.3.1 Automated - When the monitoring system detects deviation from the specified tolerance ranges, direct communication between the monitoring system and the tracking system enables quarantine of affected cast product.

5.3.2 Present - When the monitoring system detects deviation from specified tolerance ranges, operators at the runout table are alerted to quarantine the affected cast product.

5.4 Electromagnetic Stirring (EMS) or Electromagnetic Braking (EMB) - Caster Class 1A requires either EMS or EMB in the strands during casting. Class 3 casters are not required to have EMS or EMB, but it is preferred. These operating parameters shall be monitored continuously as required in Paragraph 5.2.

5.4.1 The EMS operating parameters shall be optimized to minimize “ghost lines” or “white bands” on the macroetch slices.

5.5 Additional Requirements - The following requirements are not summarized in Figure 2.

5.5.1 Tundish Design - The size and design of the tundish shall be adequate to assure proper residence time, promote inclusion flotation and minimize turbulence. This shall be accomplished by water or computer modeling techniques. The modeling shall consider the non-isothermal conditions that exist during the transition between heats. As a general guideline, the capacity of the tundish should be at least one tenth of the heat size. It is recommended that the tundish be purged with inert gas before filling. After filling, the tundish shall be fully enclosed with positive inert gas pressure or shall have a slag cover at all times.

5.5.1.1 Additionally, a dry tundish practice is required for Class 1 and 3 casters, and a tundish heater may be used to lower the required superheat to improve strand quality.

5.5.2 Tundish and Mold Alloy Additions - Additions of deoxidizers, grain refiners, and boron shall be made in the ladle. Wire feeding of these additions directly into individual strand molds or the tundish is prohibited unless specifically approved by the Metallurgical Division of the dispositioning Caterpillar Inc. facility.

5.5.3 Calcium - Strand casting without calcium is preferred. When calcium additions are used for castability purposes, Class 1A casters for bloom/billet product are expected to control residual calcium to below 20 PPM. In such cases, the mill shall report the calcium content on the heat card for both the A and Z product chemistries. When calcium additions are made for inclusion shape control to achieve improved transverse or Z-direction toughness, Class 1A slab casters are expected to control residual calcium to below 30 PPM.

5.5.4 Grain Refinement - Caster Classes 1 and 3 are required to use aluminum for grain refinement, unless otherwise specifically approved by the Metallurgical Division of the dispositioning Caterpillar facility.

5.5.5 Reoxidation - Reoxidation of the molten steel shall be prevented. Verification of reoxidation protection shall be provided by monitoring the tundish slag cover, argon cover gas, box type shroud oxygen, and mold powder. Evidence of reoxidation in any portion of a heat may result in rejection of the entire heat (subject to negotiation between Caterpillar and the steel supplier).

5.5.5.1 Smooth pouring streams shall be maintained.

5.5.5.2 Oxygen lancing to open clogged ladle nozzles over the tundish is not a desired practice. When lancing is necessary, the steel maker shall establish an acceptable process to prevent the resultant sand, slag, and oxides from entering the strands. This can be established during process development by thorough evaluation of the transition material for macro-cleanliness, micro-cleanliness and oxygen content. Methods to prevent material from falling into the tundish could include:

- Oxygen lancing when ladle is not above the tundish.
- Using a launder under the nozzle.

5.5.6 Hydrogen Control - Steel mills shall exercise special precautions to ensure a dried and preheated tundish when casting steel that requires 1E1801 Hydrogen Control.

5.5.7 Ladle Stirring - Ladle stirring (prior to casting) with inert gas through a porous plug or with Electro-Magnetic Stirring (EMS) is required for chemical homogeneity, temperature uniformity, and to promote flotation of inclusions. Gentle stirring with gas flow through a lance is permitted prior to ladle refining and degassing. However, for Caster Classes 1 and 3, stirring with gas flow through a lance is not a recommended practice after ladle refining and degassing.

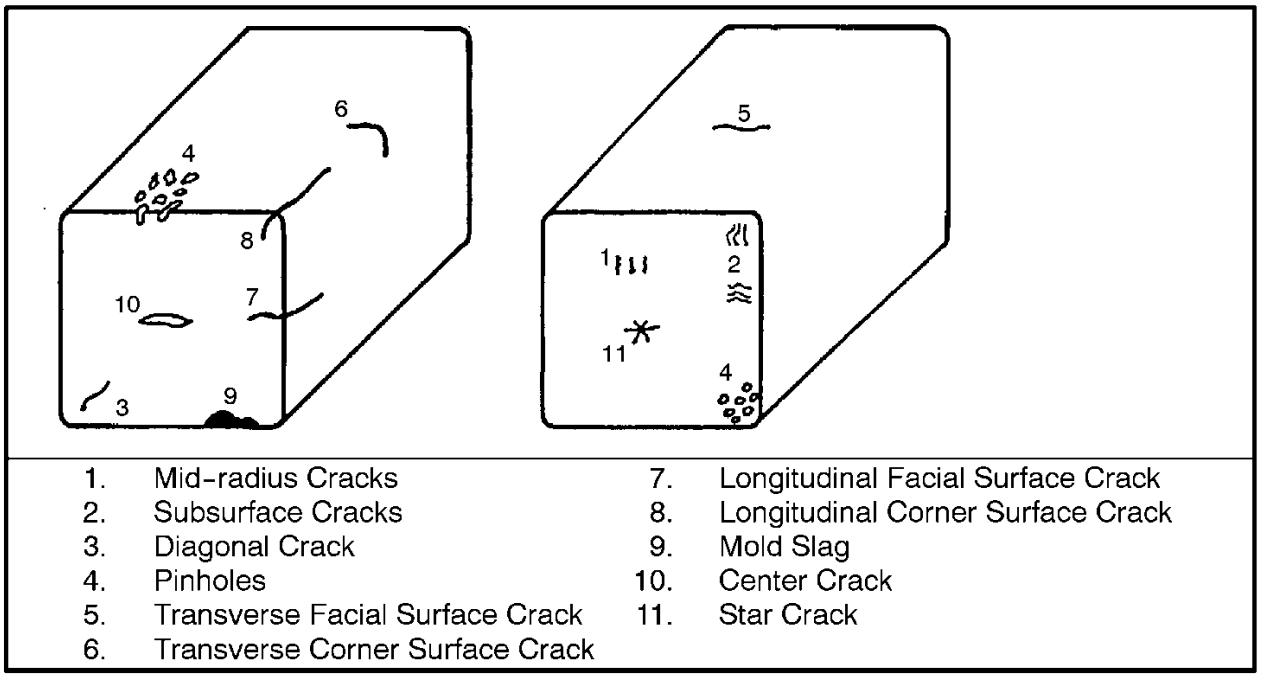
6.0 CONTINUOUS CAST STEEL QUALITY REQUIREMENTS

6.1 The Process Control Plan shall specify the sampling location and testing frequency required to ensure the specified quality level. Mechanisms shall exist to identify and quarantine all product cast when casting variables are not operating within the established limits. This product shall be dispositioned and action shall be taken to correct process variability. When requested by Caterpillar , the supplier shall furnish records showing conformance to this specification and all applicable industry standards.

6.2 Imperfections occasionally observed in strand cast steel are illustrated in Figure 6. Other detrimental imperfections not shown include shape defects (rhomboidity or ovality), center unsoundness, dark center, and chemical segregation.

6.3 Gross defects such as pipe or center void, hydrogen-induced cracking, hydrogen flaking, and large non-metallic inclusions are not permitted.

6.3.1 Hydrogen Flaking - Internal fissures of crack like discontinuities associated with the presence of hydrogen usually located around the central portion of the product.



1.	Mid-radius Cracks	7.	Longitudinal Facial Surface Crack
2.	Subsurface Cracks	8.	Longitudinal Corner Surface Crack
3.	Diagonal Crack	9.	Mold Slag
4.	Pinholes	10.	Center Crack
5.	Transverse Facial Surface Crack	11.	Star Crack
6.	Transverse Corner Surface Crack		

Figure 6 - Potential Imperfections In Strand Cast Steel

6.4 As-Cast Acceptance Requirements

6.4.1 Cast Structure - As-cast, strand cast steel usually exhibits three distinct zones of solidification; from surface to center these zones are chill, dendritic (or columnar), and equiaxed. Evidence of the cast structure will typically persist through considerable amounts of reduction. Whenever the cast structure is observed, a uniform continuous chill zone shall be present. Surface conditioning of 1E2700A and 1E2700E material shall not expose the columnar zone to any free surface.

6.4.2 As-cast steel produced to this specification shall be free from harmful surface defects such as cracks, tears, pinholes or entrapped slag. As-cast surfaces may be conditioned to remove surface defects provided that additional surface irregularities are not produced that will form laps in subsequent rolling or forging. Surface conditioning shall not expose the Columnar Zone to any free surface.

6.4.2.1 Linear Conditions

Note: X = Cross Sectional Area of the As-Cast Strand.

- **Mid-Radius Crack -** A crack perpendicular to the surface of the product located approximately halfway between the surface and center of the product. (Also called halfway cracks). Except for 1E2700E, a few scattered mid-radius cracks are permitted. Mid-radius cracks shall be no longer than $(0.06)\times\sqrt{X}$.

- **Subsurface Crack -** A crack perpendicular to and just beneath the surface of the product. Subsurface cracks shall be no longer than $(0.05)\times\sqrt{X}$.

- **Center Crack -** A crack with an aspect (length/width) ratio of approximately 3 or greater located at or near the center of the product. Center cracks shall be no longer than $(0.05)\times\sqrt{X}$.

- **Diagonal Crack -** A crack that lies completely or partially in the diagonal regions of non-round product where adjacent columnar or dendritic growth patterns intersect. Diagonal cracks are not permitted.

- **Surface Crack -** Any crack that extends into the chill zone or to the surface of the product. Surface cracks are not permitted.

6.4.2.2 Circular Conditions - The diameter of circular conditions is the diameter of the smallest possible circle which may be drawn around the features as described below.

- **Dark Center -** Center segregation is observable as a “dark center” condition on an etched section. Dark center will etch darker than the surrounding product. Dark center is solid material and should not be confused with center unsoundness. The maximum permitted diameter of dark center shall be $(0.03)\times\sqrt{X}$.

- **Center Unsoundness -** Multiple round or irregular shaped voids concentrated at the center of the product. An area of discontinuous center unsoundness with a diameter not exceeding $(0.02) \times \sqrt{X}$ is permitted. Fine, scattered porosity is not considered center unsoundness.

- **Star Crack -** A star shaped or multi-rayed crack (star crack) at the center of the product. A star crack shall not have a diameter exceeding $(0.03) \times \sqrt{X}$.

- **Pipe or Center Void -** A single large void located at or near the center of the product. Pipe or center void shall not have a diameter exceeding $(0.02) \times \sqrt{X}$.

6.4.2.3 The following other conditions are not permitted:

- **Pinholes -** Small pores that lie at or just beneath the surface of the product.

- **Mold Slag -** Slag inclusions, which are usually associated with entrapped mold powder and are normally located at or just beneath the surface of the product.

7.0 INGOT CASTING PROCESS CLASSIFICATION REQUIREMENTS

7.1 Pouring - For Class 1, bottom pouring is required. Proper start of casting procedure shall be followed to prevent nozzle sand from entering the trumpet. The pouring process shall be controlled to avoid exposure and reoxidation of the molten stream. A “red eye” or an exposure of molten steel at the bottom of the molds at the beginning of the pour shall be prevented. Pouring rates shall be controlled to avoid sudden changes in fill rate.

7.2 Ladle to Trumpet Shroud - Minimize the gap between the ladle and the trumpet, and protect the molten stream with a shroud and positive pressure of an inert gas to prevent reoxidation. (See Figure 7)

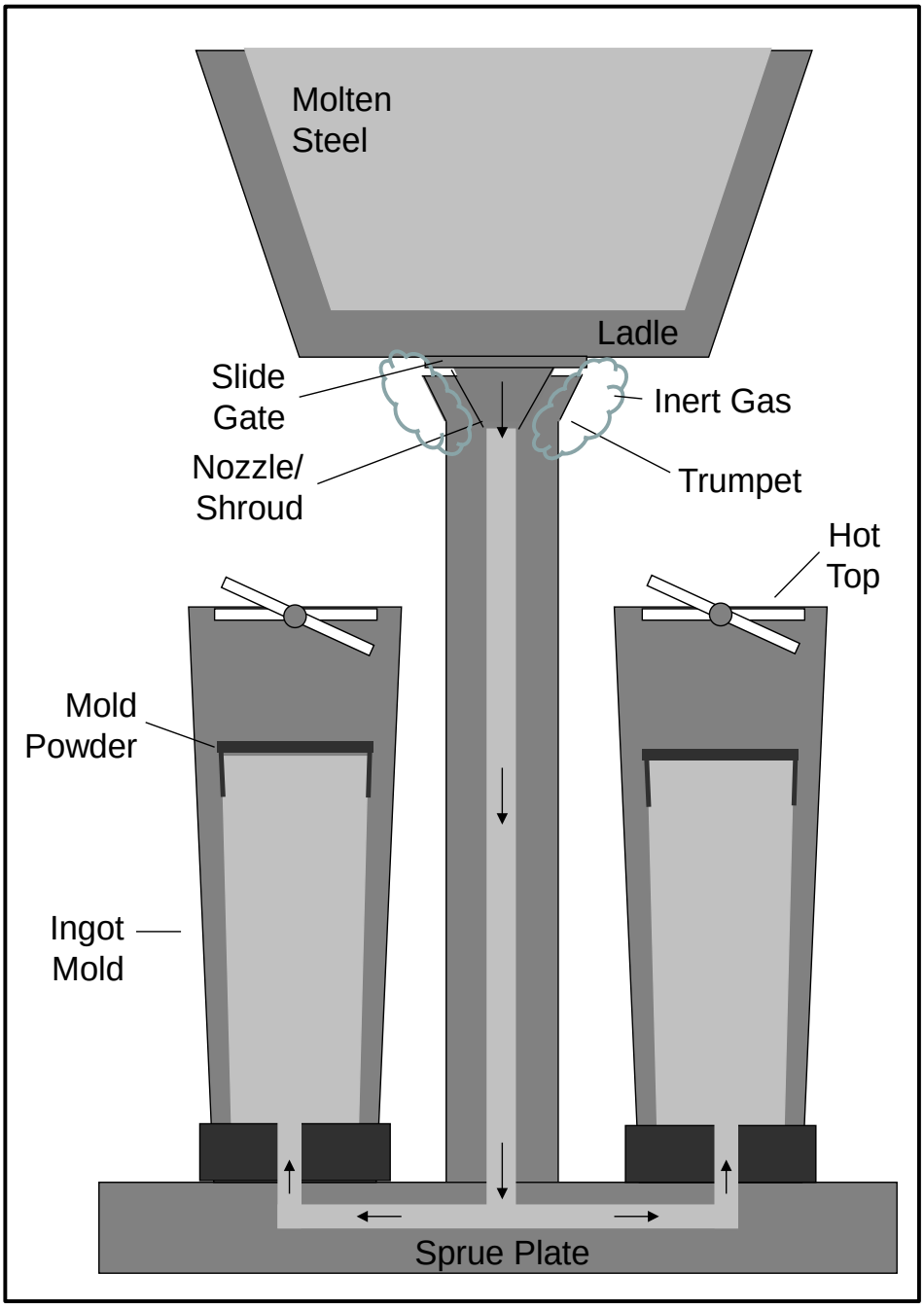


Figure 7 – Bottom Poured Ingot Casting

7.3 Ingot Protection - The steel grade dictates the type of mold flux that is used. The method used to apply the mold powder shall prevent entrapment. Hot top shall be adequate to ensure minimum amount of piping. Periodically, the mold walls shall be treated to ensure they are clean and smooth. The surface finish of the mold can affect the surface finish of the ingot which can manifest as surface or sub-surface defects on rolling of the ingot.

7.4 Rate of Fill - As the mold is filled, a constant rate of fill shall be maintained to prevent mold flux entrapment. This shall be measured and monitored on a continuous basis, or with an alternate approved practice for Class 1. A digitally recorded rate of fill is the desired method.

7.5 Proper Top and Bottom Cropping - For Class 1, an approved inspection method and documentation is required to support that the amount of cropping is sufficient to prevent pipe and excessive centerline segregation at the top of the ingot from being rolled into product.

7.6 Monitoring and Controlling Casting Variables

7.6.1 Automated or Continuous, Real-Time Control System - The system samples the variables on a nearly continuous basis. Data is recorded and accessible. Operators can monitor and control all variables from the pulpit.

7.6.2 Real-Time Control System - The system samples the variables at less frequent intervals than that of an automated or continuous, real-time control system. Operators can monitor and control all variables from the pulpit. Alternate practices demonstrating a robust and disciplined system of control may be approved by Caterpillar as fulfilling the requirements of a caster class 1 classification.

7.6.3 Manual Control System - Sampling of variables only occurs when an operator monitors the individual measuring device for each variable and manually reports them to a central location. The measurements are then recorded by manual log entry.

7.6.4 For all ingot casting classes, the following variables shall be monitored using the system specified for each classification in Figure 3:

- Inert Gas Flow Rate And Pressure To The Shroud
- Rate Of Fill

7.7 Tracking System - Shall track and quarantine for disposition ingots produced when casting variables have deviated outside the specified tolerance ranges according to the tracking system specified in Figure 3. The tracking system shall ensure complete containment of the affected cast product.

7.8 Additional Requirements - The following requirements are not summarized in Figure 3.

7.8.1 Reoxidation - Reoxidation of the molten steel shall be prevented. Evidence of reoxidation in any portion of a heat may result in rejection of the entire heat (subject to negotiation between Caterpillar and the steel supplier).

7.8.1.1 Smooth pouring streams shall be maintained.

7.8.1.2 Oxygen lancing to open clogged ladle nozzles over the trumpet is not a desired practice. When lancing is necessary, the steel maker shall establish an acceptable process to prevent the resultant sand, slag, and oxides from entering the trumpet. This can be established during process development by thorough evaluation of the transition material for macro-cleanliness, micro-cleanliness and oxygen content. Methods to prevent material from falling into the trumpet could include:

- Oxygen lancing when ladle is not above the trumpet.
- Using a launder under the nozzle.

7.8.2 Ladle Stirring - Ladle stirring (prior to casting) with inert gas through a porous plug or with Electro-Magnetic Stirring (EMS) is required for chemical homogeneity, temperature uniformity, and to promote flotation of inclusions. Gentle stirring with gas flow through a lance is permitted prior to ladle refining and degassing. However, for Class 1 ingot shops, stirring with gas flow through a lance is not a recommended practice after ladle refining and degassing.

8.0 INGOT CAST STEEL QUALITY REQUIREMENTS

8.1 Proper mold cleaning operations and ingot surface inspection for as-cast defects are required. Additionally, adequate cropping (See Paragraph 7.5) is required to ensure internal quality of the ingots.

8.2 The Process Control Plan shall specify the sampling location and testing frequency required to ensure the specified quality level. Mechanisms shall exist to identify and quarantine all product cast when casting variables are not operating within the established limits. This product shall be dispositioned and action shall be taken to correct process variability. When requested by Caterpillar, the supplier shall furnish records showing conformance to this specification and all applicable industry standards.

9.0 FINISHED PRODUCT ACCEPTANCE REQUIREMENTS

9.1 This section applies to all wrought product whether it is produced by continuous or ingot casting process

9.1.1 Micro-Cleanliness - Steels qualified by 1E0024 shall meet the maximum inclusion content limits specified in 1E0024 when micro-cleanliness is not specified in the individual steel specification.

9.1.2 Macro-Cleanliness - The macro-cleanliness for Classes 1 and 3 casters shall be determined by appropriate methods and evaluated against the mill's own internal standards. These standards shall be reviewed, accepted, and approved by Caterpillar for quarantined steel, additional testing, such as NDT, or other appropriate testing, shall be employed to ensure proper dispositioning.

9.1.3 Additional Requirements

9.1.3.1 Shape defects in rolled product are restricted to the same extent as for billets (or blooms) rolled from ingots, i.e., all billets and blooms shall conform to the appropriate tolerances in the latest Iron and Steel Society (ISS) Steel Products Manual and 1E2177.

9.1.3.2 For 1E2700A; Rhomboidity, R = 5% MAX, where:

$$R = \frac{D_1 - D_2}{D_2} \times 100$$

D_1 = Long Diagonal
D_2 = Short Diagonal

9.1.3.3 Hardenability testing (when required) shall be per 1E0024.

9.2 Strand Cast Product Only

Note: Y = Cross sectional area of the final mill product.

9.2.1 1E2700C and 1E2700F shall be sound products and shall contain no internal cracks. Unless otherwise specified, finished flat rolled product qualified by 1E2700B, may contain internal cracking or crack-like defects parallel to the surface of the plate. The size of these defects shall not exceed 125 mm in diameter.

9.2.2 The smallest diameter around the dark center shall be no more than $(0.03)\times\sqrt{Y}$ for 1E2700B, 1E2700C, and 1E2700F steel.

9.2.3 No center unsoundness or porosity are permitted in 1E2700B, 1E2700C, 1E2700D, or 1E2700F steel.

10.0 MACROETCH SAMPLING, TESTING, AND DISPOSITIONING

10.1 Sampling

10.1.1 For billet, bloom, and slab casters producing orders for the first time for Caterpillar Inc., as-cast transverse sections (and longitudinal sections when requested) for macroetch shall be cut from the front and back of each strand from each heat or sequence. As requested, as-cast strands that do not meet the requirements of Paragraph 6.4 shall be quarantined and dispositioned per Paragraph 10.3. As-cast macroetched sections are not required for ingot cast product.

10.1.2 Fully approved Class 1 and 3 billet and bloom casters are required to macroetch not less than one random transverse sample per strand per sequence when the steel being produced is qualified as 1E0024A, General Testing Requirements for Critical Steels. 1E0024B-qualified material does not require a random transverse sample per strand per sequence unless the caster is producing orders for the first time (See Paragraph 10.1.1) or a significant process change is made. (See Paragraph 10.1.3) If as-cast sections are used, the macroetch tests shall be evaluated per Paragraph 6.4. However, macroetch sections from rolled product are permissible. If rolled product is tested, strand identity shall be maintained. Test results from rolled product shall be evaluated against the mill's own internal standards. These standards shall be reviewed by Caterpillar and accepted as capable of ensuring acceptable internal quality per Article 9.0. Strands that do not meet the requirements of Article 9.0 shall be quarantined and dispositioned per Paragraph 10.3.

10.1.3 Fully approved Class 1 and 3 slab casters shall cut transverse and longitudinal macroetch sections in the as-cast condition for the following reasons:

- New specification or major specification change.
- Significant process change at the caster.
- Periodically to ensure the quality level specified in Paragraph 6.4.

10.1.4 Strands that do not meet the requirements of Paragraph 6.4 shall be quarantined and dispositioned per Paragraph 10.3.

10.2 Testing

10.2.1 All sections shall be macroetched per ASTM E381. Unless otherwise approved by Caterpillar, mills shall use a 1:1 mixture, by volume, of concentrated hydrochloric acid (HCl) and water. The etching solution shall be clear and free from scum (surface film). It shall be heated to 70 – 80 °C (160 – 180 °F). The etching solution may be reused if it has not become excessively contaminated or weakened. Etch the specimens to reveal the structure clearly. Overetching can lead to misinterpretation. In most cases, 15 to 30 min will be sufficient.

10.2.2 Upon visual examination of macroetched sections, if there is uncertainty regarding the existence of cracks, magnetic or dye penetrant inspection shall be applied.

10.2.3 Sulfur printing may be substituted for ASTM E381 macroetching.

10.3 Dispositioning

10.3.1 Additional macroetch sections may be taken from strands that are quarantined based on macroetch testing. For 1E2700A and 1E2700E product, if examination of the additional sections isolates the non-conforming material to a specific portion of the strand, only the isolated defective portion shall be rejected.

10.3.2 Strands or portions of strands for 1E2700B, 1E2700C, and 1E2700F product that have been quarantined in the as-cast condition may be salvaged after rolling if the as-cast defects are fully healed. Such material shall be identified as having been quarantined in the as-cast condition. Macroetch sections shall be taken from the front and back of each quarantined portion after final rolling and shall conform to the requirements specified for the designated reduction ratio.

11.0 SAMPLE AND DATA RETENTION

11.1 Strand Cast Product

11.1.1 Samples - All macroetch slices or sulfur print samples from heats produced for Caterpillar shall be retained on file for 120 days. However, good quality photographic evidence of macroetch results or sulfur prints may be retained as a substitute for actual samples.

11.1.2 Records - The Caster Operating Records for each heat shall be maintained in a permanent file that shall be adequate to demonstrate conformance to this specification.

11.1.3 Additional Information - In addition, the Caster or Heat Records shall also contain the following information:

11.1.3.1 The number of strands cast and the number of billets, blooms, or slabs produced from each strand.

11.1.3.2 The shrouding method used and a description of any shrouding problems encountered.

11.1.3.3 Records of ladle free-open, any tundish nozzle blockage, super heat, unacceptable mold-level fluctuation, EMS/EMB operating parameters, etc.

11.1.3.4 Oxygen level measurements in the vicinity of the molten streams (for gas type shrouds only).

11.1.3.5 Results of the macroetch or sulfur print tests.

11.1.3.6 Results of surface conditions as evaluated per Paragraph 6.4.2, specifying the determination method used.

11.1.3.7 Reason for rejecting any portion of the heat and documentation that the portion was either scrapped or salvaged under Paragraph 10.3.2 if applicable.

11.2 Ingot Cast Product

11.2.1 Records - The Ingot Casting Operating Records for each heat shall be maintained in a permanent file that shall be adequate to demonstrate conformance to this specification.

11.2.2 Additional Information - In addition, the Caster or Heat Records shall also contain the following information:

11.2.2.1 The number of ingots on a sprue plate, number of sprue plates, and ingot identification according to their location on each sprue plate.

11.2.2.2 The shrouding method used and a description of any shrouding problems encountered.

11.2.2.3 Records of ladle free-open, any ladle nozzle blockage, super heat, unacceptable rate of fill, etc.

11.2.2.4 Evidence of positive inert gas protection in the vicinity of the molten streams.

11.2.2.5 Results of surface conditions as evaluated per Paragraph 8.1, specifying the determination method used.

11.2.2.6 Reason for rejecting any portion of the heat and documentation that the portion was either scrapped or salvaged.

12.0 REFERENCES

Abbreviations	1E0011
Caterpillar Specifications	1E0024, 1E0024A, 1E0024B, 1E1801, 1E1861, 1E2177
ASTM	E29, E381
ISS	Steel Products Manual