Advanced Manufacturing Technology Development

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DIE INSERT MATERIAL AND HEAT TREATMENT PERFORMANCE REQUIREMENTS

GENERAL APPLICATIONS

CHANGE RECORD

Date	Letter	Page	Description	Engr.	Appr.
12/3/99	A.1.	19	Added Orvar Supreme, Uddeholm	B. Link	B. Guthrie
	A.2.	4-16	Made final logisitical changes on numerous pages		
2/24/00	B.1.	10,20,21	Added Thyssen Materials E38K and 2367.	B. Link	B. Guthrie
2/5/01	C.1.	All	Added metric unit equivalents.	K. Regeniter	B. Guthrie
	C.2.	10,18	Removed KDA-1		
	C.3.	10,18	Added Kind & Co. TQ1 material.		
	C.5.	10	Added Dynamic Metal Treating.		
	C.6.	10	Added Thyssen Marathon Heat Treatment.		
	C.7.	10	Added AMAT Material Testing.		
	C.8.	10	Added Bodycote-Nederlands.		
	C.9.	6,17-21	44-46 HRC –was- 45 HRC		
	C.10.	7	Section C.2.2., 3 charpy V-notch specimens –was- 5 …specimens		
	C.11.	8	Section C.7.1., austenitizing temp per indiv. Spec sheets –was- 1175 F.		
	C.12.	9	Section C.7.1., 30 minutes minimum –was- 30 minutes.		
	C.13.	6	Section C.1.1.. added "or Inductively Coupled Plasma method."		
	C.14.	8	Section C.5. Plate I-R –was- Plate III		
	C.15.	22,23	Modified inclusion tolerance.		
	C.16.	24	Reduced Phosphorous tolerance.		
	C.17.	22,23,24	Added Vince Adkar; Jim Peters –was- Craig Van Thyne		
	C.18.	19	10 ft.lb was 11 ft.lb, 30 ft.lb was 35 ft.lb, 8 ft.lb was 9 ft.lb		
8/3/01	D.1.	11,24,28	Added Bohler W403VMR and Microfine KDA-1A	B. Guthrie	B. Guthrie
	D.2.	11	Added Hansen-Balk Steel Treating Co.		
	D.3.	11	Bohler Uddeholm Thermo Tech –was- Uddeholm Heat Treat Limited.		
	D.4.	21,22,23	Modified Representative Contact information per Bohler Uddeholm merger.		

CHANGE RECORD (Continued)

Date	Letter	Page	Description	Engr.	Appr.
2/18/02	E.1.	20	Mn .30-.50 -was- .40-.50 (Kind RPU-1.2367)	B. Guthrie	B.Guthrie
	E.2.	21	Mn .30-.50 -was- .40-.50 (Uddeholm Orvar Supreme)		
	E.3.	23	Mn .30-.50 -was- .35-.45 (Bohler W302 ISOBLOC)		
	E.4.	24	Mn .15-.30 -was- .20-.30 (Bohler W403 VMR)		
	E.5.	25	C .33-.38 -was- .31-.36 (Thyssen Thyrotherm E38K)		
	E.6.	25	Mn .20-.40 -was- .32-.42 (Thyssen Thyrotherm E38K)		
	E.7.	25	Cr 4.75-5.25 -was- 4.85-5.15 (Thyssen Thyrotherm E38K)		
	E.8.	25	Mo 1.25-1.45 -was- 1.30-1.50 (Thyssen Thyrotherm E38K)		
	E.9.	26	Mn .30-.50 -was- .25-.35 (Thyssen Thyrotherm 2367 Supra)		
	E.10.	26	Cr 4.80-5.20 -was- 4.70-5.00 (Thyssen Thyrotherm 2367 Supra)		
	E.11.	26	Mo 2.80-3.10 -was- 2.90-3.10 (Thyssen Thyrotherm 2367 Supra)		
	E.12.	27	Mn .30-.50 -was- .32-.42 (Thyssen Thyrotherm 2344 Supra)		
9/6/02	F.1.	3	Mailing address change for B. Guthrie	B. Guthrie	B. Guthrie
	F.2.	11	Added Bodycote Thermal Processing		
	F.3.	11, 29	Added Dunn Specialty Steel DSS#13		
	F.4.	17	Added Section F.7. Test Coupon Procedures		
2/17/03	G.1.	3	Mailing address change for B. Guthrie	B. Guthrie	B. Guthrie
	G.2.	11, 30	Added A. Finkl & Sons DC-Xtra Steel		
	G.3.	11, 31	Added Aubert & Duval ADC-3 Steel		
11/6/03	H.1.	11	Added Therm-Tech of Waukesha	B. Guthrie	B. Guthrie
	H.2.	11	Added Bodycote Thermal Processing-St. Louis Site.		
	H.3.	12	Promoted Orvar Supreme, Uddeholm to Full Approval (was Provisional)		
	H.4.	12	Promoted Dievar, Uddeholm to Full Approval (was Provisional)		
	H.5.	12	Promoted Thyrotherm 2344 Magnum to Full Approval (was Provisional)		
	H.6.	12	Promoted Century Sun Metal Treating to Full Approval (was Provisional)		
	H.7.	11	Added Thyssen Marathon to Provisional Testing Laboratories.		
	H.8.	Multiple	NADCA 207-2003 Specification was NADCA 207-97		
6/17/04	J.1.	12	Added TAG s.r.l., Dolzago (Lecco) Italy to Provisional Heat Treat	B. Guthrie	B. Guthrie
	J.2.	12	Added Oppy Heat Treatment, Abbotsford, Victoria, Australia		
	J.3.	12	Added Thyssen Heat Treat, Carol Stream, IL to Provisional Heat Treat		
	J.4.	13	Promoted Bodycote Thermal Processing, Sturtevant, WI to Full Approval		
	J.5.	12	Added Aubert & Duval SMV-4 Steel		
	J.6.	12	Added Bodycote Varnebehandling, Denmark to Provisional Heat Treat		
2/12/05	K.1.	11, 33	Added Ellwood Specialty Steel ExELL H-13 SMDQ-N	B. Guthrie	B. Guthrie
	K.2.	11, 34	Added Daido DHA		
	K.3.	11	Added Climax Research Services		
	K.4.	16	Sections F.1, F.3, F.4, F.5: Corrected differential Temperature conversions		
2/17/06	L.1.	26	Thyrotherm 2367: 1885 F –was- 1925 F	B. Guthrie	B. Guthrie
	L.2.	19, 20	Updated contact information for Kind Specialty Steels		
	L.3.	25-27	Updated information and name change for Swiss Steel (was Thyssen)		
	L.4	11,35	Added Hitachi DAC-P		
	L.5	6	Section B.) added "including stress relief"		
	L.6	13	Section E.2.) removed "except where prohibited by block size"		
	L.7	11	Added FPM, Elk Grove, IL, Removed Thyssen Carol Stream		

Purpose

The purpose of this specification is to provide the material property and heat treatment requirements of die steels (generically referred to as Premium Grade H-13).

Scope

This specification is applicable to smaller sized dies used to manufacture high pressure aluminum die castings for Ford. If desired, this specification can be referenced as a requirement for any die purchased by Ford Motor Co., or it's enterprises, for production of components at an outside casting supplier.

Distribution

The Ford Advanced Manufacturing Technology Development (AMTD) will maintain this document and make it available to Ford casting operations and selected parts suppliers for their use in specification and distribution to suppliers of dies, tooling materials, and heat treatment services. The specification will be distributed as needed by the responsible plant manufacturing engineering section at the beginning of the procurement process for a new die, or when a die is being re-engineered per the specification content.

Revisions

Because it is imperative that all engineering standards be maintained on a current basis at all times, periodic improvement through revision will be necessary. The front cover page of this specification serves as the recording document for all revisions to this specification. Outside requests for improvements to this specification are welcome and should be addressed in writing to:

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Specification Contents:

A.) GENERAL NOTES

The die materials and heat treatment requirements identified by this specification are intended to provide die cavity and core components with maximum resistance to heat checking and maximum fracture toughness while in production service. This specification is written to communicate both material property requirements and procedural recommendations. While company inspectors will review supplier adherence to the procedural recommendations during audits for potential sourcing approvals, the primary acceptance criteria reflect the materials submitted by the steel sources for qualification testing. The die-steel material properties will be audited by approved metallurgical testing laboratories.

Material and mechanical properties addressed in the specification include:

A.1.) Alloy Chemical Composition.
A.2.) Fracture Toughness.
A.3.) Heat Check Resistance.
A.4.) Alloy Segregation (High Alloy / Low Alloy Bands).
A.5.) Inclusion Content.
A.6.) Carbide Content
A.7.) Grain Size and Microstructure.
A.8.) Hardness.

A.1.) Alloy Chemical Composition

Research & Development testing has proven that within the traditional H-13 steel alloy chemistry tolerances there are significant gains in die life which result from tolerance refinement. With research funded by a consortium of automotive companies in the United States, specific alloy chemistries and their manufacturing processes were found to have a clear advantage over traditional alloy compositions. The reader will note that some alloy compositions specified within the content of this specification may be considered "hybrids". For practical reasons, all approved sources for die materials listed in the body of this specification have been selected based on laboratory and field testing. Unless otherwise specified, standard size core pins (less than 3 inches in diameter) may have higher sulfur content, or other free machining additives.

A.2.) Fracture Toughness

Fracture Toughness is a property that is characterized by performing a Charpy V-notch impact test on a hardened steel specimen. The specimens that must be tested are hardened in two distinctly independent ways: a.) oil quenched and triple tempered under laboratory controlled conditions and b.) quenched and tempered with the production work piece. The laboratory quenched and tempered specimen establishes a baseline for material impact toughness (maximum potential material performance), which must pass a minimum criteria. The specimens which are quenched and tempered with the work piece are tested to assess the acceptability of the heat treat process done on the work piece and must be at a previously defined percentage of the maximum potential material performance. The acceptance criteria for the heat treated specimen is representative of what was required to pass the "Dunker-cycle" test.

A.3.) Heat Check Resistance

Heat check resistance is a difficult property to assess with a low-cost, easily replicated laboratory test. Therefore, all approved materials have been pre-screened at Case Western Reserve University (Cleveland, Ohio) using their "Dunker-cycle" test rig, where the test method was developed with DOE-NADCA funding. Once the prepared set of test specimens passes the dunker-cycle test (no cracking after 15,000 cycles), the specimen conditions are carefully analyzed for establishing the acceptance criteria for the metallurgical testing outlined in this specification. Generally, important factors include: Alloy Chemistry, Quench Rate, Microstructure, and Hardness.

A.4.) Alloy Segregation

Alloy segregation (also referred to as "micro-banding") is considered an unacceptable defect if it surpasses the limitations outlined by the micro-photographic reference levels in the NADCA 207-2003 specification for die materials. The presence of micro-banding on the etched sample indicates a stratified alloying condition within the steel ingot volume. These bands of "high" and "low" alloy conditions create sites where uneven thermal stresses occur during the production cycling of the die, due to different levels of thermal expansion coefficients. For this reason, micro-banding has been identified as an important factor in heat-checking resistance. To minimize micro-banding, a recommendation is placed on the upset ratio for forging steel billets.

A.5.) Inclusion Content

Inclusions create high stress concentration points from thermal distortions occurring in both the heat treat and die casting processes. To minimize the inclusion content, steel refinement technologies have been developed and are considered in this specification. Because the Electro-Slag Remelt (ESR) and Vacuum Arc Remelt (VAR) processes are known to yield higher refinements of steel alloy cleanliness, either method is the preferred method used for the production of approved die steels listed in this specification, except for small round stock when availability is non-existent. For clarification, all round stock work pieces greater than 3 inches (76 mm) in diameter, or the equivalent rectangular size, should be produced by ESR or VAR.

A.6.) Carbide Content

Carbides are known to be present in the as-received annealed condition of most die steels. However, these carbides must be dissolved into the alloy solution during the heat treat austenitizing soak (just prior to quenching). Research work at Case Western Reserve University has carefully screened candidate materials for carbide solubility and sensitivity for grain growth. For this reason, the recommended austenitizing temperatures may be slightly higher than the temperatures referenced in the NADCA 207-2003, GM DC-9999-1 and the obsolete Ford Specification RDC-2010. In order to evaluate the compliance to the recommended austenitizing temperature, this specification requires a micro examination of a test coupon removed from the production work piece after heat treat. This specimen will be analyzed to assess whether all of the primary and most of the secondary carbides have gone into solution and that the grain size is acceptable.

A.7.) Grain Size and Microstructure

Grain size is known to affect die life. Generally, the finer grain yields better performance. For this reason, the grain size limitation will be based on the grain size present for the qualifying laboratory and field test specimens. The reader will note that the grain specification is generally finer than the limit referenced in the NADCA 207-2003 and GM DC-9999-1 specifications. Microstructure is assessed using the NADCA 207-2003 chart: "Acceptance References Annealed H-13 Steel Microstructures".

A.8.) Hardness

Testing of materials in the Case Western Reserve University dunker-test machine and in field evaluation sites has indicated that hardness is a factor in the resistance to thermal fatigue surface cracks (i.e. heat checking) and erosion. However, the hardness also has a major affect on the post-heat-treat machining steps. This specification indicates a slightly higher hardness (which improves the heat check resistance) for the larger die-insert sections required for some dies. By limiting the hardness to the specification limit, the Tool Source has the opportunity to finish machine the inserts using high speed milling practices in lieu of EDM cavity machining. To assure uniformity of hardness throughout the entire work piece, triple tempering after quench is specified.

B.) QUALIFICATION OF DIE MATERIALS AND HEAT TREATMENT PROCEDURE

The Tool Source will manage and report the results for the complete test program sequence outlined by this specification. This includes the pre-qualification of materials prior to machining and the heat treatment quality of the materials, including stress tempering. The Tool Source will coordinate all the activities of the Die Steel Suppliers, Heat Treatment Service Suppliers and Metallurgical Testing Laboratories. The Tool Source will coordinate these activities using the provided list of suppliers as outlined per section D.) of this specification. The Tool Source will provide copies of the metallurgical test results to the responsible plant Manufacturing Engineer along with all other pre-delivery documentation.

If the Tool Source fails to insure that the material and heat treatment qualification tests for an insert are properly performed, they will be required to replace the entire insert to include material, heat treat and labor, unless subsequent heat treat test data indicates an acceptable insert. If the insert(s) are assessed as acceptable after delivery to the plant, then US$1000 will be deducted from the invoice for each incidence of non-compliance. The purpose of testing is to insure that proper die insert materials are used for die inserts. The testing also serves as a quality measurement and rating system of the Die Steel Suppliers and Heat Treatment Service Suppliers. The Tool Source is the guarantor (though not necessarily the provider) of acceptable die steel materials and heat treatments. This provision does not change any previous Tool Source responsibilities.

All small inserts cut in multiples from a single piece of tool steel must have one coupon sent for material analysis to represent all the inserts from that piece. If multiple heats of tool steel are used to complete a single die's inserts then a maximum of two steel heats will be tested, unless otherwise stated by the responsible manufacturing engineer. For example, if a given die is comprised of twelve inserts coming from five different heats of tool steel only two of those heats will be tested for steel quality and later heat treatment. The two heats are to be chosen at random by the tool source. Test coupons will be removed from the raw steel ingot material per section E.4.) of this specification.

The qualification of materials per this specification is to be performed under the responsibility of an approved metallurgical testing laboratory. Approved and Provisional steel suppliers that have metallurgical testing laboratories are not considered "self-certified". All materials to be tested will be submitted to one of the approved testing laboratories per the specified steps, as outlined in this section. If test results indicate a condition where the material or heat treatment is in non-compliance, the Tool Source will work with the respective supplier to provide an acceptable replacement piece as soon as possible.

This specification requires two distinct points in the workflow for a die where qualification testing is required:

B.1.) **Initial Material Qualification Analysis**, as received, annealed condition.

This series of tests is a pre-screening step that must be performed on each ingot heat purchased by the die maker for the construction of any die which is subject to this specification. All small inserts cut in multiples from a single heat of tool steel must have one test coupon sent to an approved metallurgical testing lab to represent all of the inserts made from that piece. If multiple heats of tool steel are used to complete a single die's inserts then a maximum of two steel heats will be tested, unless otherwise stated by the responsible manufacturing engineer. It is not acceptable to qualify individual work pieces based on a single qualification of the steel supplier's heat reference. The acceptance criteria must be certified by the approved testing lab(s) prior to the start of any machining to the insert work piece(s).

B.2.) **Work Piece Heat Treat Qualification Analysis**. Quenched and tempered specimens with work piece, per work piece hardness requirement, testing lab performs no heat treat.

This series of tests is performed to evaluate the heat treatment quality and quench-rate benefit made to the actual work piece. Where the initial material qualification analysis quantifies the maximum potential material performance of the die steel that is possible in the actual production application, this step quantifies how well the heat treatment process prepared the work piece to take advantage of the maximum potential material performance. The acceptance criteria in this specification are established to take advantage of the improved properties resulting from higher quench rates, improved carbide solubility, and the uniform hardness resulting from a triple-tempering process. Generally, the heat treatment service provider should be capable enough to treat the steel so it delivers a minimum of 80% of the maximum potential material performance.

C.) MATERIAL PROPERTY TESTING AND ACCEPTANCE CRITERIA

C.1.) Alloy Chemical Composition

C.1.1) **Initial Material Qualification Analysis**, as received, annealed condition using Optical Emission Spectroscopy or Inductively Coupled Plasma method.

See Individual Specification Sheets in Section H of this document.

C.1.2) **Work Piece Heat Treat Qualification Analysis**. Quenched and tempered specimens with work piece, per work piece hardness requirement, testing lab performs no heat treat.

Chemical Analysis not required after heat treatment.

C.2.) Fracture Toughness

C.2.1.) **Initial Material Qualification Analysis**, as received, annealed condition.

Charpy V-Notch Testing (per ASTM E23), lab oil quench, 44-46 HRC, triple temper.

Steel supplier will submit one of the test coupons to an approved metallurgical testing laboratory, removed from the tool block per the procedure outlined in this specification. The testing laboratory will machine 5 charpy V-notch specimens for each impact test temperature. After the impacts, the testing laboratory will calculate the average impact strength by not counting the highest and lowest values of the 5 specimens. The lowest acceptable value will be determined from the remaining 3 specimen values.

Acceptance Criteria:

See Individual Specification Sheets in Section H of this document.

C.2.2) Work Piece Heat Treat Qualification Analysis. Quenched and tempered specimens with work piece, per work piece hardness requirement, testing lab performs no heat treat.

Charpy V-Notch Testing (per ASTM E23), as quenched and tempered with work piece.

Heat Treat Source will submit the other coupon (removed from the tool block per the procedure outlined in this specification) to the same metallurgical testing laboratory after it has been quenched and tempered while attached to the work piece. The testing laboratory will machine 3 charpy V-notch specimens for each impact test temperature. After the impacts, the testing laboratory will calculate the average impact strength of the 3 specimens. The lowest acceptable value will be determined from the lowest of the 3 specimen values

Acceptance Criteria:

See Individual Specification Sheets in Section H of this document.

C.3.) Heat Check Resistance

C.3.1.) Initial Material Qualification Analysis, as received, annealed condition.

All provisional and approved die materials have been selected on the basis of their laboratory performance from the dunker-cycle test rig at the Case Western Reserve University (Cleveland, Ohio). The provisional and approved materials have demonstrated complete resistance to cracking after 15,000 dunking cycles with quenched & tempered test specimens. It is at the discretion of the Die Steel Supplier to specify the quench rate and prepare the test specimens for the dunker test. Because this test is time consuming, it is not required for each purchased tool block, but may be performed at any time by Ford Motor Co. If the materials are found to exhibit cracking under the same test conditions as original, then a problem solving team consisting of members from Ford and the die material supplier will be formed to correct the problem. The steel supplier may be removed from the approved list.

C.3.2) Work Piece Heat Treat Qualification Analysis. Quenched and tempered specimens with work piece, per work piece hardness requirement, testing lab performs no heat treat.

Testing not required at this step.

C.4.) Alloy Segregation (High Alloy / Low Alloy Bands)

C.4.1.) Initial Material Qualification Analysis, as received, annealed condition.

The annealed microstructure shall be free of significant micro-banding or chemical segregation. Examine banding at 50X and 100X magnification, per ASTM E3 procedure. The annealed microstructure shall exhibit a uniform distribution of fine spheroidized carbide throughout a ferrite matrix. Photomicrographs of acceptable and non-acceptable limits will be determined by NADCA's Acceptance Reference chart contained in NADCA 207-2003. Carbide microstructure is to be examined at 500X magnification.

C.4.2.) Work Piece Heat Treat Qualification Analysis. Quenched and tempered specimens with work piece, per work piece hardness requirement, testing lab performs no heat treat.

Testing not required after heat treatment.

C.5.) Inclusion Content

C.5.1.) Initial Material Qualification Analysis, as received, annealed condition.

The permissible limits of microcleanliness (severity levels of non-metallic inclusion content) shall be determined by ASTM E-45, Method A (latest revision). Plate I-R should be used to obtain rating increments of 0.5.

The maximum allowable limits are:

See Individual Specification Sheets in Section H of this document.

C.5.2.) Work Piece Heat Treat Qualification Analysis. Quenched and tempered specimens with work piece, per work piece hardness requirement, testing lab performs no heat treat.

Testing not required after heat treatment.

C.6.) Carbide Content

C.6.1.) Initial Material Qualification Analysis, as received, annealed condition.

The presence of large primary carbides will be cause for rejection. The microstructure of the heat treated charpy specimens should reflect the fine spheroidized carbide structure witnessed in the annealed steel.

C.6.2.) Work Piece Heat Treat Qualification Analysis. Quenched specimen with work piece, testing lab performs no heat treat.

The test specimen will be attached to the work piece prior to heat treatment and removed after heat treatment is complete. The presence of primary or unacceptable secondary carbides in the specimen will be cause for rejection. The basis for rejection will be that the austenitizing temperature and dwell period were insufficient to dissolve the carbide presence. The reader will note that the recommended austenitizing temperatures are established with regard to the ability to dissolve carbides without causing grain growth.

C.7.) Grain Size and Microstructure

C.7.1.) Initial Material Qualification Analysis, as received, annealed condition.

Specimens will be prepared using the direct quench method per ASTM E112 by austenitizing at the specified temperature per the individual specification sheets for 30 minutes minimum, rapidly quenched and tempered at 1100°F (590 C) minimum. Grain size to be measured by using the ASTM comparative method and shall be predominately ASTM #9 or finer.

Microstructure to be examined per ASTM E3, using NADCA 207-2003 Acceptance Reference chart for annealed H-13 steel (500X). Acceptance criteria is delineated per NADCA chart standards.

C.7.2.) Work Piece Heat Treat Qualification Analysis. Quenched specimen with work piece, testing lab performs no heat treat.

Specimen will pass NADCA 207-2003 Specification for bainite/pearlite and intergranular segregation.

C.8.) Hardness

C.8.1.) Initial Material Qualification Analysis, as received, annealed condition.

The hardness of the steel in the annealed condition, tested per ASTM A-681, will not exceed 217 BHN.

The minimum hardness for the as-quenched sample will be 50 HRC, using a specimen that is not greater than one inch thick, air quenched for 30 minutes from the specified maximum austenitizing temperature.

C.8.2.) Work Piece Heat Treat Qualification Analysis. Quenched and tempered specimens with work piece, per work piece hardness requirement, testing lab performs no heat treat.

The hardness of the removed test specimen and work piece will be 44-46 HRC.

D.) PROVISIONAL AND APPROVED SOURCES

D.1.) Provisional Sources:

A Provisional Source is not an approved source. A Provisional Source is one that has demonstrated the capability to meet all the requirements of this specification, but has not developed a long history of metallurgical test analysis from production tooling that will statistically confirm the capability to meet the specification. A wide spectrum and large population of insert sets must be tested in actual production to confirm capability. The confirmation process and requirements are as follows:

- The provisional testing period shall last a maximum of 30 months from the first production insert test submitted. The provisional source must meet all requirements of this specification.
- During this period a minimum of 25 pieces shall be tested at an approved metallurgical testing laboratory. Ford Motor Co. has no obligation to create the opportunity to test these pieces within the prescribed period of time.
- The first time acceptance rate must be 88% or better for the total population of inserts.
- When a piece is rejected, a new block of steel must be substituted by the steel supplier at his cost. This substitute piece must meet the requirements of the specification. If it fails, then the provisional testing period is at an end and the steel supplier must start the whole process again.
- If 30 months is not sufficient time to complete the confirmation process, the Supplier may elect to begin the process again subject to the approval of Ford Motor Co.
- The steel supplier's mill will be inspected by Ford Motor Co. at the end of the testing period if all the conditions are met. This inspection will primarily focus on QS-9000/ISO 9000 series audit items with particular emphasis placed on process control and quality systems. This is not a QS/ISO certification on the part of Ford Motor Co.

A Supplier becomes an "Approved Source" when it meets all the requirements of the provisional testing period and the Ford Motor Co. on-site audit.

D.1.1.) Provisional Sources Are:

Die Steel Materials & Suppliers:

1. Kind TQ1 material, Kind & Co.
2. Kind RPU material, Kind & Co.
3. W302 ISOBLOC, Bohler
4. W403 VMR, Bohler
5. Thyrotherm E38K, Swiss Steel
6. Thyrotherm 2367, Swiss Steel
7. Microfine KDA-1A, Nippon Koshuha Steel Co., Ltd.
8. DSS#13, Dunn Specialty Steel, Inc.
9. DC-Xtra, A. Finkl & Sons Co.
10. ADC-3, Aubert & Duval
11. SMV-4, Aubert & Duval
12. ExELL H-13, SMDQN, Ellwood Specialty Steel
13. DHA, Daido Steel Co., Ltd
14. DAC-P, Hitachi

Heat Treatment Service Suppliers:

1. Bohler Uddeholm Thermo Tech, Mississauga, Ontario
2. Kind & Co., Wiehl, Germany.
3. Dynamic Metal Treating, Canton Township, MI
4. Swiss Steel Marathon Heat Treatment, Old Castle (Windsor), Ontario
5. Hansen-Balk Steel Treating Co., Grand Rapids, MI
6. Therm-Tech of Waukesha Inc., Waukesha, WI
7. Bodycote Thermal Processing-St. Louis, St. Louis, MO
8. TAG s.r.l., Dolzago (Lecco) Italy
9. Oppy Heat Treatment, Abottsford, Victoria, Australia
10. Bodycote Varnebehandling, Herlev, Denmark
11. FPM, Elk Grove, IL

Metallurgical Testing Laboratories:

1. AMAT-Materials Engineering Pty, Ltd., Melbourne, Australia
2. Bodycote-Nederlands, Emmen, NL
3. Swiss Steel Marathon, Windsor, ON (Swiss Steel materials & Marathon H.T. only).
4. Climax Research Services, Wixom, MI

D.2.) Approved Sources:

Normally, all hot work tool steels may only be supplied to the responsible die casting plant and it's Tool Sources by mills designated in the Approved Source list. An "Approved Source" has obtained this status after successfully completing the "Provisional" status for the appropriate period of time. If there are no specific sourcing designations by the responsible plant manufacturing engineer, the Tool Source will select the material from the list of Approved Sources such that material cost and heat treatment services are competitively priced to Ford. It is not permissible for a steel supplier to buy steel from a mill not designated and sell it as their own. The Steel Supplier may not change mills without approval from Ford Motor Co. A Ford Motor Co. designated Metallurgical Testing Lab must certify any mills not presently approved before they can supply steel on Ford Motor Co. die inserts. An Approved Source cannot be self-certified. That is, all Approved Sources continue to be obligated to submit samples to an Approved Metallurgical Testing Laboratory for each piece of purchased steel.

D.2.1.) <u>Approved Sources Are:</u>

Die Steel Materials & Suppliers:

1. Orvar Supreme, Uddeholm
2. Dievar, Uddeholm
3. Thyrotherm 2344, Thyssen

Heat Treatment Service Suppliers:

1. Century Sun Metal Treating, Traverse City, MI
2. Bodycote Thermal Processing-Sturtevant, Sturtevant, WI

Metallurgical Testing Laboratories:

1. Bodycote Taussig Inc., Skokie, IL

E.) DIE STEEL PROCESSING

This part of the specification applies to the material to be used in making hot work tool steel inserts for Aluminum and Magnesium die-casting-die cavity steel. It is also useful in other applications when tools are made from steels where hot working conditions exist. This is the premium grade hot work tool steel material specification and is applicable to all approved die materials.

E.1.) Alloy Refinement Process

Because the Electro-Slag Remelt (ESR) and Vacuum Arc Remelt (VAR) processes are known to yield higher refinements of steel alloy cleanliness, either method is preferred for the production of approved die steels listed in this specification, except for small round stock when availability is non-existent. For clarification, all round stock work pieces greater than 3 inches (76.2 mm) in diameter, or the equivalent rectangular size, should be produced by ESR or VAR.

E.2.) Billet/Ingot Forging

Forgings for dies should be double upset and have a minimum upset forging ratio of 5 to 1 and forging should be done in three directions. Forging ratios are determined linearly. Back forging is permitted but is not used in calculating forging ratio.

E.3.) Ingot Testing Requirements

Final annealed block is to be rough machined and ultrasonically tested by the steel supplier. Block will be rechecked (at Ford Motor Co.'s option) ultrasonically after block is finished and ready for machining by the Tool Source. Block is to be free of stringers, pipes, oxides, and other defects deemed likely to cause failure. Block is to be rough machined to dimensions indicated on the purchase order.

E.4.) Tool Block Cutting & Sizing

The size and shape of the tool block will be specified on the purchase order. The tool block should be cut from a parent block that allows for minimum parent block thickness. In essence, the smallest of the three tool block dimensions will determine the parent block thickness. For example, a purchased tool block that is 14” X 20” X 22” (355 X 508 X 558 mm) will use a 14” (355 mm) (in the short, or thickness direction) parent block. The parent block must not be more than 2” (50 mm) thicker than the tool block, unless the thickness of the parent block is 12” (300 mm) or less. The maximum thickness parent block used for Ford Motor Co. tool blocks shall never be larger than 20” (508 mm) in the short or thickness direction. The width must be kept to the smallest possible dimension so that the forging and mill heat treatments produce the required properties. The steel supplier should also minimize the number of heats supplied to complete all of the individual die's inserts as best as possible.

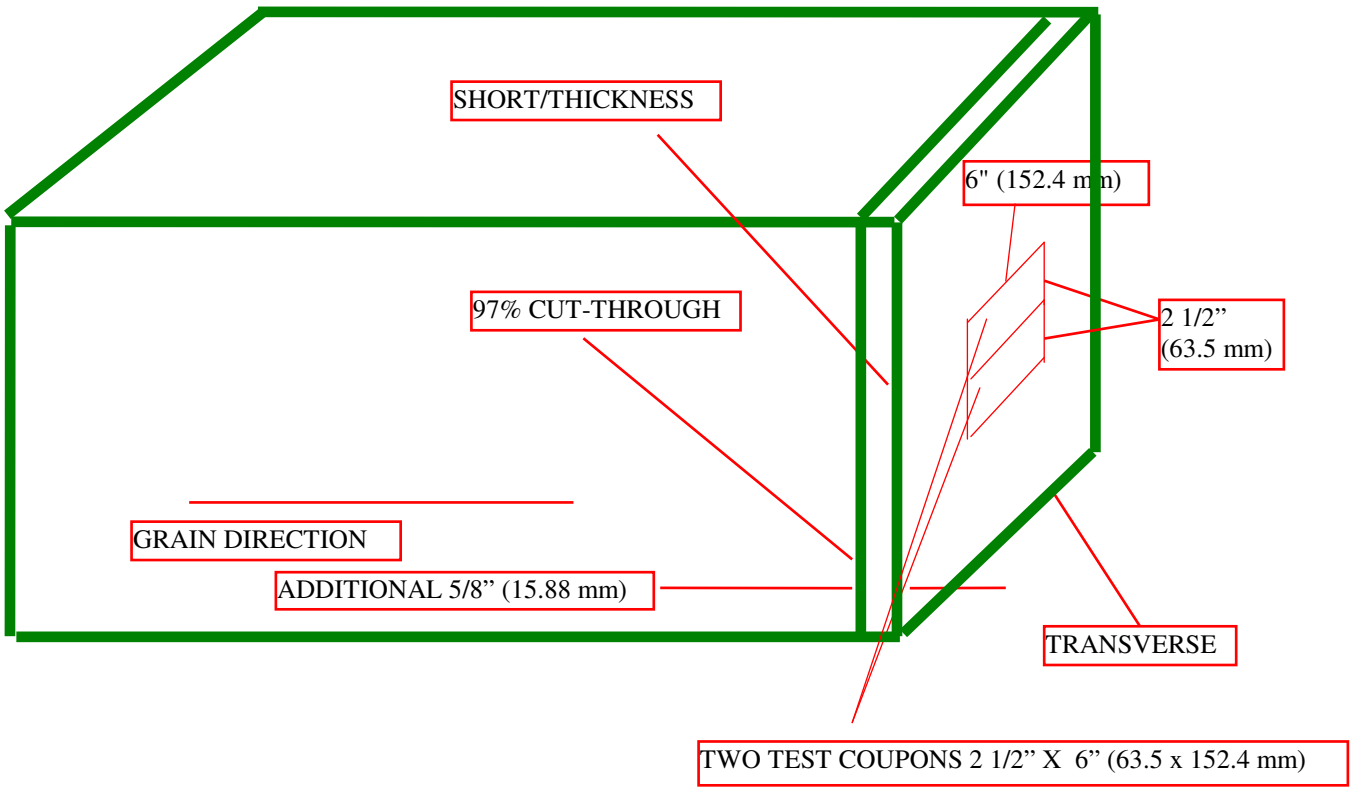
The following two sections describe the manner in which the steel supplier and tool source should provide extra material and remove samples for testing. These sections only apply to steel blocks that are a minimum of 3" x 6 ½" x 1" (76 x 165 x 25 mm) or round stock 6 ½" (165 mm) dia. x 1" (25 mm) long. That is, steel blocks that are large enough to take test coupons for steel and heat treatment testing. Note, all inserts cut in multiples from a single heat of tool steel must have one coupon sent for material analysis to represent all the inserts from that heat. Therefore the steel supplier should only add material to one insert block representing that heat. If the steel supplier supplies multiple heats of steel for any given die's inserts, the steel supplier should add material on one insert block for EACH heat supplied. The tool source will then choose a MAXIMUM OF TWO of the heats at random to send out for testing (note, the tool source will not necessarily be sending all supplied heats out for testing).

E.4.1) Tool Blocks a minimum of 6" x 6 ½" x 1" (152 x 165 x 25 mm) or round stock

The Tool Source will order or release the rough (tool) block for the insert to size. All directions refer to the parent block. The Steel Supplier will then be responsible for adding 5/8" (15.88 mm) in the longitudinal (grain) direction of the parent block to allow test coupons to be taken in the short-transverse plane. The steel supplier must cut this plane to insure the Tool Source correctly samples the block. The cut should not completely sever the coupon (testing) plane. A 97% cut-through is sufficient, such that the coupon plane is adequately held to the insert block. The Tool Source will cut the remainder. The Steel Supplier must also engrave (stamp) the die number assigned by the responsible die casting plant on the block.

The Tool Source must remove two test coupons from the center of the testing plane, 2 1/2" X 6" X 1/2" (63.5 X 152.4 X 12.7 mm) or (for round sections) 6" (152.4 mm) dia. X 1/2" (12.7 mm) long (± 1/8" (3 mm) tolerance), from each block. The 2 1/2" (63.5 mm) dimension will be in the same direction as the thickness of the parent block. Both coupons should be engraved with an electric (vibratory) engraver with the same die number assigned to the block (insert) by the responsible die casting plant, as well as the parent block size. Note, if multiple heats are used for the die's inserts the tool source should send samples from a maximum of two heats for testing.

The first coupon will be sent immediately to an Approved Metallurgical Testing Lab for analysis of the material. It is not permitted to accumulate material test coupons and subsequently send large groups to the testing lab. This causes delays. Send coupons as soon as they are removed from insert blocks. The second coupon will accompany the insert through heat treat and will be analyzed for heat treat quality.

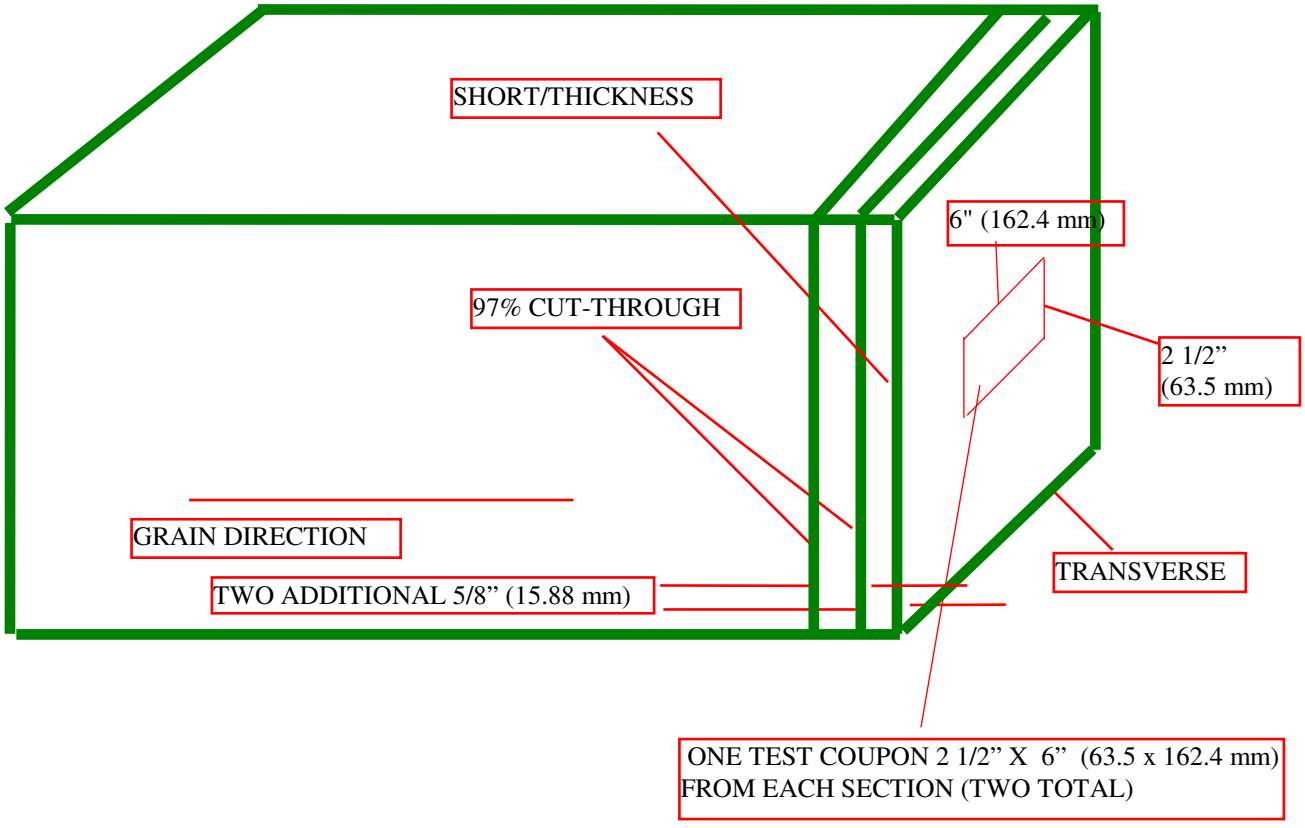


E.4.2) Tool Blocks smaller than 6" x 6 ½" x 1" (152 x 165 x 25 mm) (but large enough for testing)

The Tool Source will order or release the rough (tool) block for the insert to size. All directions refer to the parent block. The Steel Supplier will then be responsible for adding enough material to allow for two 5/8" (15.88 mm) samples to be taken back-to-back in the longitudinal (grain) direction of the parent block to allow test coupons to be taken in the short-transverse plane. The steel supplier must cut this plane to insure the Tool Source correctly samples the block. The cut should not completely sever the coupon (testing) plane. A 97% cut-through is sufficient, such that the coupon plane is adequately held to the insert block. The steel supplier must cut two 97% cut-throughs back to back, each section of which must be 5/8" (15.88 mm) in the longitudinal direction. The reason for cutting two samples is due to the small block size and the need for two test coupons. The Tool Source will cut the remainder. The Steel Supplier must also engrave (stamp) the insert die number assigned by the responsible die casting plant on the block.

The Tool Source must remove one test coupon from the center of the testing plane, 2 1/2" X 6" X 1/2" (63.5 X 152.4 X 12.7 mm), from each section of each block. The 2 1/2" (63.5 mm) dimension will be in the same direction as the thickness of the parent block. Both coupons should be engraved with an electric (vibratory) engraver with the same die number assigned to the block (insert) by the responsible die casting plant, as well as the parent block size. Note, if multiple heats are used for the die's inserts the tool source should send samples from a maximum of two heats for testing.

The first coupon should be sent immediately to an Approved Metallurgical Testing Lab for analysis of the material by the tool source. It is not permitted to accumulate material test coupons and subsequently send large groups to the testing lab. This causes delays. Send coupons as soon as they are removed from insert blocks. The second coupon will accompany the insert through heat treat and will be analyzed for heat treat quality.



F.) HEAT TREATMENT PROCESSING

Research and Development activities focused on improving die life have found that the heat treatment process has a significant effect on the ability for the die materials to meet, or exceed, the performance requirements outlined in this specification. Of particular importance is a rapid quench rate and the documentation to certify compliance to the practices outlined.

F.1.) Vacuum Furnace or Liquid Quench

If a vacuum furnace is used for the heat, the furnace capable of obtaining the fastest quench rate for the given insert sizes must be used. If a water or oil quench process is used, it must be capable of interrupting the quench to maintain a maximum surface-to-core temperature difference of 200°F (111 C). In the case of a liquid quench process, it is recommended that the process be developed through experimental trials for purposes of minimizing distortion and preventing cracking. For clarification, quenching systems described as "fluidized bed" are not acceptable.

F.2.) Instrumentation and Process Recording

Thermocouples will be placed on the work pieces per the NADCA 207-97 specification. Minimally, 2 thermocouples will be placed on the work piece to provide recording data for the Surface Temperature (Ts) and Core Temperature (Tc). The Ts thermocouple hole location is specified by the heat treating company, and machined by the Tool Source, roughly centered on the back of the insert 1/8" (3.18 mm) dia x 5/8" (15.88 mm) deep. This location is mandatory unless conditions are such that a proper heat treat will not occur unless the insert is placed on it's back. In this case, the heat treat source is responsible to specify a more appropriate placement of the hole for the Tool Source to machine. The Tc thermocouple is located in the central interior portion of the insert (a water fountain is a good place). If multiple pieces (must be similarly sized) are to be heat treated together, place the thermocouples in the largest piece.

F.3.) Stress Relieving

Stress relieving will be at the option of the Tool Source during rough machining steps (not immediately before heat treat). Some complex pieces may need stress relief. Stress relieve to remove cold work effects due to rough machining. Heat to 1100-1150°F (593-637 C) and hold Tc at 1100-1150°F (593-637 C) for 60 minutes. Heat at a rate not exceeding 400°F (222 C) per hour. Cool to 800°F (427 C) at a rate not exceeding 200°F (93 C) per hour and then air cool to below 150°F (65.5 C). Time, temperature and rates are based upon the core thermocouple, Tc.

F.4.) Austenitizing Temperature

Attach surface (Ts) and core (Tc) thermocouples to the piece per NADCA 207-2003 specification (or previously agreed-on locations). Ts must be inserted in the dedicated thermocouple hole. If multiple pieces are to be hardened together, place the thermocouples in the largest piece. On multiple piece loads, insert sizes should be similar. Do not mix large and small inserts. Load into cold furnace. Heat to 1100-1200°F (593-649 C) at a rate not exceeding 400°F (222 C) per hour based upon Tc. Continue heating to 1575°F $\pm$ 25°F (857$\pm$ 13.9 C) at a rate not exceeding 300°F (149 C) per hour based upon Ts, then hold until surface and core temperatures equalize. Raise insert temperature to Austenitizing Temperature (Ta) +/- 10°F (5.5 C) at a rate not exceeding 300°F (167 C) per hour based upon Ts. Hold for 30 minutes after Ts - Tc < 25°F (13.9 C) degrees, or 90 minutes maximum after Ts = Ta (not Tc).

See Individual Specification Sheets at End of Document for austenitizing temperatures.

F.5.) Quenching

All inserts will be quenched in either a vacuum furnace or in a liquid quench medium. In any case, quench rate should be as high as possible without risk to the tool to improve the metallurgical properties. To determine maximum quench rate possible, pre-testing with similar shape geometries may be required.

Because the quench rates are rapid, the cycle may require an interruption if the core and surface temperatures indicate an excessive internal gradient. The quench process will be monitored and controlled per the following:

> From the austenitizing temperature, quench the work piece down to 800°F +/- 15 (427 +/- 8.3 C) degrees based upon surface thermocouple Ts, then interrupt the quench if needed to reduce the temperature differential between the surface and the core. If the interrupt differential (Ts - Tc) is less than 200 °F (111 C) when Ts first reaches 800°F (427 C) then the interrupt is not required, and quench must not be interrupted. Hold interrupt until either 1.) temperature differential between Ts and Tc is less than 200°F (111 C), or 2.) Ts reaches 750°F (399 C), or 3.) 15 minutes has lapsed, whichever occurs first. Additional heat energy shall not be added with heating elements during the interrupt. If the surface temperature increases to 825°F (440 C) during interrupt additional cooling should be used to keep Ts between 775°F (413 C) and 825°F (440C) during the interrupt. For large inserts, the quench rate shall be a minimum of 50°F (28 C) per minute down to 1000°F (538 C), that is, it will take less than 18 minutes to quench down to 1000°F (538 C) from the austenitizing temperature (Ta). Quench gas pressure after interrupt shall be the same as before interrupt. Resume quench to 300°F (149 C) when the above conditions are satisfied. Interrupt times should be kept to a minimum, and avoided when not necessary. Remove from the furnace and continue cooling in still air until Tc is below 150°F (65 C). The use of floor fans or open doorways is absolutely forbidden.

F.6.) Tempering

Upon cooling to 150°F (65 C), immediately temper at 1000-1140°F (538-615 C) for one hour per inch of thickness, two hours minimum. Cool to room temperature and measure hardness.

Retemper at 1025-1140°F (552-615 C) to obtain the specified hardness of 44-46 HRC, except when specified differently. The heat treat source will contact the steel supplier if any question concerning tempering temperatures exists. Hold at temperature one hour minimum per inch of thickness, two hours minimum total. Cool in still air and measure hardness. If desired hardness is attained, retemper at 1000-1050°F (538-565 C) for one hour per inch of thickness, one hour minimum. If desired hardness is not attained, retemper to appropriate temperature, hold one hour per inch of thickness, two hours minimum total. Measure and record final hardness. **Minimum of three total draws (tempers) required.**

F.7.) Test Coupon Procedures

The following guidelines will enable the test coupon properties to more closely represent those of the actual insert after commercial heat treating.

> Coupon to be machined flat and parallel.
> Surface finish to be 150 RMS, or better.
> Coupon must be affixed to the insert with a similar surface finish for complete contact.
> The coupon should be TIG welded with a 1-1.5 mm filler rod.
> Weld should be .12-.25 inch long on center of 3 ½ inch coupon dimension.

G.) EDM PROCESSED INSERTS & STRESS TEMPERING

While EDM processing is commonly used in the manufacturing of die insert cavity geometry, the preferred method is direct, high-speed machining. The reason for preferring high-speed machining is because it leaves the surface with fewer residual stresses after completion. The use of EDM can produce effects at the surface of a tool that will seriously affect the life of the tool. When EDM is used, the following steps are required:

G.1.) EDM Erosion

Leave enough stock from rough EDM to eliminate arc puddles during finish EDM. Adjust EDM process (current, frequency, etc.) to achieve the proper balance between rough and finish operations. It is expected that Tool Source will not exceed those erosion currents specified for the particular machine and electrode shape being used, and that these currents will be greatly reduced during the final stages of machining (to reduce the thickness of the white layer).

G.2.) Residual White Layer

After low-current final EDM forming, stone or sand blast the EDM'd surfaces of the insert to completely remove the white layer, before stress tempering. The white layer thickness to remove is approximately 20 µm deep.

G.3.) Stress tempering (after finish machining)

To perform the stress tempering, heat the work piece to 30-50°F (17-28 C) below the highest tempering temperature. Hold it for one hour per inch of section thickness or for two hours minimum. Cool in still air to room temperature.

H.1.) Individual Die Steel Specification Sheet

Material: TQ-1

Die Steel Supplier: Kind & Co

Representative Contacts:

USA: Robert Borgeson
Kind Specialty Steels Inc.
5480 Churchill Lane
Libertyville, IL 60048
TEL. 847-668-8030
FAX 847-367-5402

Europe: Kind & Co, Edelstahlwerk
Bielsteiner Strasse 128-130
D-51662 Wiehl, Germany
TEL. (2262) 84-0
FAX (2262) 84-175

Ref. - C.) MATERIAL PROPERTY TESTING AND ACCEPTANCE CRITERIA

Ref. C.1.)Alloy Chemical Composition – TQ-1

Carbon	.33-.40
Manganese	.30-.50
Phosphorus	.020 Max
Sulfur	.002 Max
Silicon	.10-.50
Chromium	5.00-5.50
Molybdenum	1.70-2.00
Vanadium	.50-.70

Ref. C.5.) Inclusion Content – TQ-1

	Inclusions	
Type	Thin	Heavy
A (sulfide)	0.5	0
B (aluminate)	1.0	0.5
C (silicate)	0	0
D (globular oxides)	1.0	1.0

Ref. C.2.) Fracture Toughness.

C.2.1.) **Initial Material Qualification Analysis**, as received, annealed condition.
Charpy V-Notch Testing (per ASTM E23), lab oil quench, 44-46 HRC, triple temper.

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	12 ft.lb (16.3 J)	10 ft.lb (13.6 J)
450°F (232 C)	32 ft.lb (43.4 J)	27 ft.lb (36.6 J)

C.2.2) **Work Piece Heat Treat Qualification Analysis**. Quenched and tempered specimens with work piece, per work piece hardness requirement, testing lab performs no heat treat.
Charpy V-Notch Testing (per ASTM E23), as quenched and tempered with work piece

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	10 ft.lb (13.6 J)	7 ft.lb (9.5 J)
450°F (232 C)	80% of initial analysis	21 ft.lb (28.5 J)

Ref. - F.4.) Austenitizing Temperature (Ta) = 1860 +/- 10°F (1015 +/- 5 C)

H.2.) Individual Die Steel Specification Sheet

Material: RPU (1.2367)

Die Steel Supplier: Kind & Co

Representative Contacts:

USA: Robert Borgeson
Kind Specialty Steels Inc.
5480 Churchill Lane
Libertyville, IL 60048
TEL. 847-668-8030
FAX 847-367-5402

Europe: Kind & Co, Edelstahlwerk
Bielsteiner Strasse 128-130
D-51662 Wiehl, Germany
TEL. (2262) 84-0
FAX (2262) 84-175

Ref. - C.) MATERIAL PROPERTY TESTING AND ACCEPTANCE CRITERIA

Ref. C.1.)Alloy Chemical Composition - RPU

Carbon	.35-.40
Manganese	.30-.50
Phosphorus	.020 Max
Sulfur	.003 Max
Silicon	.30-.50
Chromium	4.70-5.20
Molybdenum	2.70-3.00
Vanadium	.50-.70

Ref. C.5.) Inclusion Content - RPU

	Inclusions	
Type	Thin	Heavy
A (sulfide)	0	0
B (aluminate)	1.0	0.5
C (silicate)	0	0
D (globular oxides)	1.0	0.5

Ref. C.2.) Fracture Toughness.

C.2.1.) **Initial Material Qualification Analysis**, as received, annealed condition.
Charpy V-Notch Testing (per ASTM E23), lab oil quench, 44-46 HRC, triple temper.

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	10 ft.lb (13.6 J)	8 ft.lb (10.8 J)
450°F (232 C)	28 ft.lb (38.0 J)	25 ft.lb (33.8 J)

C.2.2) **Work Piece Heat Treat Qualification Analysis**. Quenched and tempered specimens with work piece, per work piece hardness requirement, testing lab performs no heat treat.
Charpy V-Notch Testing (per ASTM E23), as quenched and tempered with work piece

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	8 ft.lb (10.8 J)	6 ft.lb (8.1 J)
450°F (232 C)	80% of initial analysis	20 ft.lb (27.1 J)

Ref. - F.4.) Austenitizing Temperature (Ta) = 1886 +/- 10°F (1030 +/- 5 C)

H.3.) Individual Die Steel Specification Sheet

Material: Orvar Supreme

Die Steel Supplier: Uddeholm, Assab

Representative Contacts:

USA:	Canada:	Europoe:	China:
Inside Sales Mgr.	Inside Sales Mgr.	Bengt Klarenfjord	Assab Pacific Group
548 Clayton Court	2595 Meadowvale Blvd.	Uddeholm Tooling, AB	www.assabsteels.com
Wood Dale, IL 60191	Mississauga, ON L5N 7Y3	S-683 85 Hagfors, Sweden	
TEL. 800-638-2520	TEL. 800-638-2520	TEL. (563) 17000	
FAX 630-350-0880	FAX 800-812-8658	FAX (563) 17400	

Ref. - C.) MATERIAL PROPERTY TESTING AND ACCEPTANCE CRITERIA

Ref. C.1.) Alloy Chemical Composition - Orvar Supreme

Carbon	.37-.42
Manganese	.30-.50
Phosphorus	.020 Max
Sulfur	.002 Max
Silicon	.90-1.10
Chromium	5.00-5.30
Molybdenum	1.35-1.55
Vanadium	.90-.1.1

Ref. C.5.) Inclusion Content - Orvar Supreme

	Inclusions	
Type	Thin	Heavy
A (sulfide)	0.5	0
B (aluminate)	1.0	0.5
C (silicate)	0	0
D (globular oxides)	1.0	0.5

Ref. C.2.) Fracture Toughness.

C.2.1.) **Initial Material Qualification Analysis**, as received, annealed condition.
Charpy V-Notch Testing (per ASTM E23), lab oil quench, 44-46 HRC, triple temper.

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	10 ft.lb (13.6 J)	8 ft.lb (10.8 J)
450°F (232 C)	30 ft.lb (40.6 J)	25 ft.lb (33.8 J)

C.2.2) **Work Piece Heat Treat Qualification Analysis**. Quenched and tempered specimens with work piece, per work piece hardness requirement, testing lab performs no heat treat.
Charpy V-Notch Testing (per ASTM E23), as quenched and tempered with work piece

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	8 ft.lb (10.8 J)	6 ft.lb (8.1 J)
450°F (232 C)	80% of initial analysis	20 ft.lb (27.1 J)

Ref. - F.4.) Austenitizing Temperature (Ta) = 1885 +/- 10°F (1029 +/- 5 C)

H.4.) Individual Die Steel Specification Sheet

Material: Dievar

Die Steel Supplier: Uddeholm

Representative Contacts:

USA:	Canada:	Europoe:	China:
Inside Sales Mgr.	Inside Sales Mgr.	Bengt Klarenfjord	Assab Pacific Group
548 Clayton Court	2595 Meadowvale Blvd.	Uddeholm Tooling, AB	www.assabsteels.com
Wood Dale, IL 60191	Mississauga, ON L5N 7Y3	S-683 85 Hagfors, Sweden	
TEL. 800-638-2520	TEL. 800-638-2520	TEL. (563) 17000	
FAX 630-350-0880	FAX 800-812-8658	FAX (563) 17400	

Ref. - C.) MATERIAL PROPERTY TESTING AND ACCEPTANCE CRITERIA

Ref. C.1.) Alloy Chemical Composition - Dievar

Carbon	.32-.38
Manganese	.40-.55
Phosphorus	.020 Max
Sulfur	.002 Max
Silicon	.10-.50
Chromium	4.80-5.30
Molybdenum	2.20-2.50
Vanadium	.50-.70

Ref. C.5.) Inclusion Content - Dievar

	Inclusions	
Type	Thin	Heavy
A (sulfide)	0	0
B (aluminate)	1.0	0.5
C (silicate)	0	0
D (globular oxides)	1.0	0.5

Ref. C.2.) Fracture Toughness.

C.2.1.) **Initial Material Qualification Analysis**, as received, annealed condition.
Charpy V-Notch Testing (per ASTM E23), lab oil quench, 44-46 HRC, triple temper.

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	10 ft.lb (13.6 J)	8 ft.lb (10.8 J)
450°F (232 C)	28 ft.lb (37.9 J)	25 ft.lb (33.8 J)

C.2.2) **Work Piece Heat Treat Qualification Analysis**. Quenched and tempered specimens with work piece, per work piece hardness requirement, testing lab performs no heat treat.
Charpy V-Notch Testing (per ASTM E23), as quenched and tempered with work piece

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	8 ft.lb (10.8 J)	6 ft.lb (8.1 J)
450°F (232 C)	80% of initial analysis	20 ft.lb (27.1 J)

Ref. - F.4.) Austenitizing Temperature (Ta) = 1875 +/- 10°F (1024 +/- 5 C)

H.5.) Individual Die Steel Specification Sheet

Material: W302 ISOBLOC

Die Steel Supplier: Bohler

Representative Contacts:

USA: Inside Sales Mgr.
548 Clayton Court
Wood Dale, IL 60191
TEL. 800-638-2520
FAX 630-350-0880

Canada: Inside Sales Mgr.
2595 Meadowvale Blvd.
Mississauga, ON L5N 7Y3
TEL. 800-638-2520
FAX 905-812-8658

Europe: Johann Hasenburger
Bohler Edelstahl
Mariazeller Strasse, 25
A-8605, Kapfenberg (Austria)
TEL 011-43-3862-207000
FAX 011-43-3862-207576

Ref. - C.) MATERIAL PROPERTY TESTING AND ACCEPTANCE CRITERIA

Ref. C.1.) Alloy Chemical Composition – W302 Isobloc

Carbon	.37-.42
Manganese	.30-.50
Phosphorus	.020 Max
Sulfur	.002 Max
Silicon	1.00-1.20
Chromium	5.00-5.30
Molybdenum	1.30-1.50
Vanadium	.90-.1.1

Ref. C.5.) Inclusion Content – W302 Isobloc

Type	Inclusions Thin	Heavy
A (sulfide)	0	0
B (aluminate)	1.0	0.5
C (silicate)	0	0
D (globular oxides)	1.0	0.5

Ref. C.2.) Fracture Toughness.

C.2.1.) **Initial Material Qualification Analysis**, as received, annealed condition.
Charpy V-Notch Testing (per ASTM E23), lab oil quench, 44-46 HRC, triple temper.

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	10 ft.lb (13.6 J)	8 ft.lb (10.8 J)
450°F (232 C)	30 ft.lb (47.4 J)	25 ft.lb (33.8 J)

C.2.2) **Work Piece Heat Treat Qualification Analysis**. Quenched and tempered specimens with work piece, per work piece hardness requirement, testing lab performs no heat treat.
Charpy V-Notch Testing (per ASTM E23), as quenched and tempered with work piece

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	8 ft.lb (10.8 J)	6 ft.lb (8.1 J)
450°F (232 C)	80% of initial analysis	20 ft.lb (27.1 J)

Ref. - F.4.) Austenitizing Temperature (Ta) = 1885 +/- 10°F (1029 +/- 5 C)

H.6.) Individual Die Steel Specification Sheet

Material: W403 VMR

Die Steel Supplier: Bohler

Representative Contacts:

USA: Inside Sales Mgr.
548 Clayton Court
Wood Dale, IL 60191
TEL. 800-638-2520
FAX 630-350-0880

Canada: Inside Sales Mgr.
2595 Meadowvale Blvd.
Mississauga, ON L5N 7Y3
TEL. 800-638-2520
FAX 905-812-8658

Europe: Johann Hasenburger
Bohler Edelstahl
Mariazeller Strasse, 25
A-8605, Kapfenberg (Austria)
TEL 011-43-3862-207000
FAX 011-43-3862-207576

Ref. - C.) MATERIAL PROPERTY TESTING AND ACCEPTANCE CRITERIA

Ref. C.1.) Alloy Chemical Composition – W403 VMR

Carbon	.37-.42
Manganese	.15-.30
Phosphorus	.020 Max
Sulfur	.003 Max
Silicon	.10-.50
Chromium	5.00-5.50
Molybdenum	2.75-3.05
Vanadium	.60-.80

Ref. C.5.) Inclusion Content – W403 VMR

Type	Inclusions Thin	Heavy
A (sulfide)	0	0
B (aluminate)	1.0	0.5
C (silicate)	0	0
D (globular oxides)	1.0	0.5

Ref. C.2.) Fracture Toughness.

C.2.1.) **Initial Material Qualification Analysis**, as received, annealed condition.
Charpy V-Notch Testing (per ASTM E23), lab oil quench, 44-46 HRC, triple temper.

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	10 ft.lb (13.6 J)	8 ft.lb (10.8 J)
450°F (232 C)	28 ft.lb (37.9 J)	25 ft.lb (33.8 J)

C.2.2) **Work Piece Heat Treat Qualification Analysis**. Quenched and tempered specimens with work piece, per work piece hardness requirement, testing lab performs no heat treat.
Charpy V-Notch Testing (per ASTM E23), as quenched and tempered with work piece

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	8 ft.lb (10.8 J)	6 ft.lb (8.1 J)
450°F (232 C)	80% of initial analysis	20 ft.lb (27.1 J)

Ref. - F.4.) Austenitizing Temperature (Ta) = 1875 +/- 10°F (1029 +/- 5 C)

H.7.) Individual Die Steel Specification Sheet

Material: Thyrotherm E38K

Die Steel Supplier: Swiss Steel International

Representative Contacts:

USA: Patrick Gerkin
365 Village Drive
Carol Stream, IL 60188
TEL. 630-682-3900
FAX 630-682-4259

Canada: Rod Pressey
2555 North Talbot Road
Old Castle (Windsor), ON
Canada, NOR 1L0
TEL 800-265-0862
FAX 519-737-1613

Europe: Bernd Gehricke
EWK
Auestrasse 4
D-5810 Witten 1
TEL. 011-49-2302-29-4165
FAX 011-49-2302-29-2295

Ref. - C.) MATERIAL PROPERTY TESTING AND ACCEPTANCE CRITERIA

Ref. C.1.) Alloy Chemical Composition – Thyssen E38K

Carbon	.33-.38
Manganese	.20-.40
Phosphorus	.015 Max
Sulfur	.002 Max
Silicon	.20-.40
Chromium	4.75-5.25
Molybdenum	1.25-1.45
Vanadium	.30-.50

Ref. C.5.) Inclusion Content – Thyssen E38K

Type	Inclusions Thin	Heavy
A (sulfide)	0	0
B (aluminate)	1.0	0
C (silicate)	0	0
D (globular oxides)	0.5	0.5

Ref. C.2.) Fracture Toughness.

C.2.1.) **Initial Material Qualification Analysis**, as received, annealed condition.
Charpy V-Notch Testing (per ASTM E23), lab oil quench, 44-46 HRC, triple temper.

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	12 ft.lb (16.3 J)	8 ft.lb (10.8 J)
450°F (232 C)	30 ft.lb (40.7 J)	25 ft.lb (33.8 J)

C.2.2) **Work Piece Heat Treat Qualification Analysis**. Quenched and tempered specimens with work piece, per work piece hardness requirement, testing lab performs no heat treat.
Charpy V-Notch Testing (per ASTM E23), as quenched and tempered with work piece

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	8 ft.lb (10.8 J)	6 ft.lb (8.1 J)
450°F (232 C)	80% of initial analysis	20 ft.lb (27.1 J)

Ref. - F.4.) Austenitizing Temperature (Ta) = 1875 +/- 10°F (1024 +/- 5 C)

H.8.) Individual Die Steel Specification Sheet

Material: Thyrotherm 2367 Supra

Die Steel Supplier: Swiss Steel International

Representative Contacts:

USA: Patrick Gerkin
365 Village Drive
Carol Stream, IL 60188
TEL. 630-682-3900
FAX 630-682-4259

Canada: Rod Pressey
2555 North Talbot Road
Old Castle (Windsor), ON
Canada, NOR 1L0
TEL 800-265-0862
FAX 519-737-1613

Europe: Bernd Gehricke
EWK
Auestrasse 4
D-5810 Witten 1
TEL. 011-49-2302-29-4165
FAX 011-49-2302-29-2295

Ref. - C.) MATERIAL PROPERTY TESTING AND ACCEPTANCE CRITERIA

Ref. C.1.) Alloy Chemical Composition - Thyssen 2367

Carbon	.35-.40
Manganese	.30-.50
Phosphorus	.020 Max
Sulfur	.002 Max
Silicon	.18-.38
Chromium	4.80-5.20
Molybdenum	2.80-3.10
Vanadium	.50-.70

Ref. C.5.) Inclusion Content – Thyssen 2367

Type	Inclusions Thin	Heavy
A (sulfide)	0.5	0
B (aluminate)	0.5	0.5
C (silicate)	0	0
D (globular oxides)	0.5	0.5

Ref. C.2.) Fracture Toughness.

C.2.1.) **Initial Material Qualification Analysis**, as received, annealed condition.
Charpy V-Notch Testing (per ASTM E23), lab oil quench, 44-46 HRC, triple temper.

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	10 ft.lb (13.6 J)	8 ft.lb (10.8 J)
450°F (232 C)	30 ft.lb (40.7 J)	25 ft.lb (33.8 J)

C.2.2) **Work Piece Heat Treat Qualification Analysis**. Quenched and tempered specimens with work piece, per work piece hardness requirement, testing lab performs no heat treat.
Charpy V-Notch Testing (per ASTM E23), as quenched and tempered with work piece

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	8 ft.lb (10.8 J)	6 ft.lb (8.1 J)
450°F (232 C)	80% of initial analysis	20 ft.lb (27.1 J)

Ref. - F.4.) Austenitizing Temperature (Ta) = 1885 +/- 10°F (1029 +/- 5 C)

H.9.) Individual Die Steel Specification Sheet

Material: Thyrotherm 2344 Supra

Die Steel Supplier: Swiss Steel International

Representative Contacts:

USA: Patrick Gerkin
365 Village Drive
Carol Stream, IL 60188
TEL. 630-682-3900
FAX 630-682-4259

Canada: Rod Pressey
2555 North Talbot Road
Old Castle (Windsor), ON
Canada, NOR 1L0
TEL 800-265-0862
FAX 519-737-1613

Europe: Bernd Gehricke
EWK
Auestrasse 4
D-5810 Witten 1
TEL. 011-49-2302-29-4165
FAX 011-49-2302-29-2295

Ref. - C.) MATERIAL PROPERTY TESTING AND ACCEPTANCE CRITERIA

Ref. C.1.) Alloy Chemical Composition - Thyssen 2344

Carbon	.37-.42
Manganese	.30-.50
Phosphorus	.015 Max
Sulfur	.002 Max
Silicon	.90-1.10
Chromium	5.00-5.30
Molybdenum	1.10-1.30
Vanadium	.90-1.10

Ref. C.5.) Inclusion Content – Thyssen 2344

	Inclusions	
Type	Thin	Heavy
A (sulfide)	0.5	0
B (aluminate)	1.0	0.5
C (silicate)	0	0
D (globular oxides)	0.5	0.5

Ref. C.2.) Fracture Toughness.

C.2.1.) **Initial Material Qualification Analysis**, as received, annealed condition.
Charpy V-Notch Testing (per ASTM E23), lab oil quench, 44-46 HRC, triple temper.

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	10 ft.lb (13.6 J)	8 ft.lb (10.8 J)
450°F (232 C)	28 ft.lb (38.0 J)	25 ft.lb (33.8 J)

C.2.2) **Work Piece Heat Treat Qualification Analysis**. Quenched and tempered specimens with work piece, per work piece hardness requirement, testing lab performs no heat treat.
Charpy V-Notch Testing (per ASTM E23), as quenched and tempered with work piece

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	8 ft.lb (10.8 J)	6 ft.lb (8.1 J)
450°F (232 C)	80% of initial analysis	20 ft.lb (27.1 J)

Ref. - F.4.) Austenitizing Temperature (Ta) = 1890 +/- 10°F (1032 +/- 5 C)

H.10.) Individual Die Steel Specification Sheet

Material: Microfine KDA-1A

Die Steel Supplier: Nippon Koshuha Steel Co., Ltd.

Representative Contacts:

USA: Alloy Tool Steel, Inc.
13525 East Freeway Dr.
Santa Fe Springs, CA 90670-5686
TEL. 562-921-8605
800-288-9800
FAX 562-802-1728

Europe: Same as USA

Ref - C.) MATERIAL PROPERTY TESTING AND ACCEPTANCE CRITERIA

Ref. C.1.) Alloy Chemical Composition - KDA-1A

Carbon	.34-.40
Manganese	.40-.60
Phosphorus	.020 Max
Sulfur	.002 Max
Silicon	.10-.50
Chromium	4.90-5.40
Molybdenum	1.50-1.70
Vanadium	.40-.60

Ref. C.5.) Inclusion Content - KDA-1A

Type	Inclusions Thin	Heavy
A (sulfide)	0	0
B (aluminate)	0.5	0.5
C (silicate)	0	0
D (globular oxides)	0.5	0.5

Ref. C.2.) Fracture Toughness.

C.2.1.) **Initial Material Qualification Analysis**, as received, annealed condition.
Charpy V-Notch Testing (per ASTM E23), lab oil quench, 44-46 HRC, triple temper.

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	10 ft.lb (13.6 J)	8 ft.lb (10.8 J)
450°F (232 C)	28 ft.lb (38.0 J)	25 ft.lb (33.8 J)

C.2.2) **Work Piece Heat Treat Qualification Analysis**. Quenched and tempered specimens with work piece, per work piece hardness requirement, testing lab performs no heat treat.
Charpy V-Notch Testing (per ASTM E23), as quenched and tempered with work piece

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	8 ft.lb (10.8 J)	6 ft.lb (8.1 J)
450°F (232 C)	80% of initial analysis	20 ft.lb (27.1 J)

Ref. - F.4.) Austenitizing Temperature (Ta) = 1915 +/- 10°F

H.11.) Individual Die Steel Specification Sheet

Material: DSS#13

Die Steel Supplier: Dunn Specialty Steels

Representative Contacts:

USA: Fred Dunn
Dunn Specialty Steels, Inc.
23333 Sherwood
Warren, MI 48091
TEL. 586-757-4775
800-880-2078
FAX 586-757-4354

Europe: Same as USA
www.dunnsteel.com

Ref - C.) MATERIAL PROPERTY TESTING AND ACCEPTANCE CRITERIA

Ref. C.1.) Alloy Chemical Composition – DSS#13

Carbon	.37-.42
Manganese	.20-.40
Phosphorus	.020 Max
Sulfur	.002 Max
Silicon	.95-1.15
Chromium	5.00-5.50
Molybdenum	1.20-1.40
Vanadium	.85-1.05

Ref. C.5.) Inclusion Content – DSS#13

	Inclusions	
Type	Thin	Heavy
A (sulfide)	0	0
B (aluminate)	0.5	0.5
C (silicate)	0	0
D (globular oxides)	0.5	0.5

Ref. C.2.) Fracture Toughness.

C.2.1.) **Initial Material Qualification Analysis**, as received, annealed condition.
Charpy V-Notch Testing (per ASTM E23), lab oil quench, 44-46 HRC, triple temper.

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	10 ft.lb (13.6 J)	8 ft.lb (10.8 J)
450°F (232 C)	28 ft.lb (38.0 J)	25 ft.lb (33.8 J)

C.2.2) **Work Piece Heat Treat Qualification Analysis**. Quenched and tempered specimens with work piece, per work piece hardness requirement, testing lab performs no heat treat.
Charpy V-Notch Testing (per ASTM E23), as quenched and tempered with work piece

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	8 ft.lb (10.8 J)	6 ft.lb (8.1 J)
450°F (232 C)	80% of initial analysis	20 ft.lb (27.1 J)

Ref. - F.4.) Austenitizing Temperature (Ta) = 1885 +/- 10°F

H.12.) Individual Die Steel Specification Sheet

Material: DC-Xtra

Die Steel Supplier: A. Finkle & Sons Co.

Representative Contacts:

USA: Michael Wido
A. Finkl & Sons Co.
2011 N. Southport Ave.
Chicago, IL 60614
TEL. 773-975-2510
800-343-2562
FAX 773-348-5347

Europe: Steve Hadley, Finkl UK
Langley Green Road
Langley, Oldbury
Warley, West Midlands U.K.
B 69 4TR
TEL 011-44-121-544-4506
FAX 011-44-121-544-4752

Ref - C.) MATERIAL PROPERTY TESTING AND ACCEPTANCE CRITERIA

Ref. C.1.) Alloy Chemical Composition – DC-Xtra

Carbon	.37-.42
Manganese	.25-.45
Phosphorus	.020 Max
Sulfur	.002 Max
Silicon	.80-1.00
Chromium	5.00-5.50
Molybdenum	1.20-1.40
Vanadium	.80-1.00

Ref. C.5.) Inclusion Content – DC-Xtra

	Inclusions	
Type	Thin	Heavy
A (sulfide)	0	0
B (aluminate)	1.0	0.5
C (silicate)	0	0
D (globular oxides)	1.0	0.5

Ref. C.2.) Fracture Toughness.

C.2.1.) **Initial Material Qualification Analysis**, as received, annealed condition.
Charpy V-Notch Testing (per ASTM E23), lab oil quench, 44-46 HRC, triple temper.

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	10 ft.lb (13.6 J)	8 ft.lb (10.8 J)
450°F (232 C)	28 ft.lb (38.0 J)	25 ft.lb (33.8 J)

C.2.2) **Work Piece Heat Treat Qualification Analysis**. Quenched and tempered specimens with work piece, per work piece hardness requirement, testing lab performs no heat treat.
Charpy V-Notch Testing (per ASTM E23), as quenched and tempered with work piece

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	8 ft.lb (10.8 J)	6 ft.lb (8.1 J)
450°F (232 C)	80% of initial analysis	20 ft.lb (27.1 J)

Ref. - F.4.) Austenitizing Temperature (Ta) = 1885 +/- 10°F

H.13.) Individual Die Steel Specification Sheet

Material: ADC3

Die Steel Supplier: Aubert & Duval

Representative Contacts:

North America: Kevin McCarron
Aubert & Duval USA
95 Fulton st
Boonton NJ 07054

TEL. 630-906-1783

Europe: Aubert & Duval
Tour Maine Montparnasse
33, Avenue Du Maine
75755 Paris Cedex 15
FRANCE
TEL.011-33-1 44 1024 00
FAX 011-33-1 44 1024

China: Peter Li
ERAMET - China
No. 2607-2612, 26 Floor
Bank of China Tower
No. 200 Yin Chen Dong Road
Shanghai
TEL 86-21-61006161
Peter.li@eramet-international.com

Ref - C.) MATERIAL PROPERTY TESTING AND ACCEPTANCE CRITERIA

Ref. C.1.) Alloy Chemical Composition – ADC3

Carbon	.34-.39
Manganese	.20-.40
Phosphorus	.009 Max
Sulfur	.002 Max
Silicon	.20-.40
Chromium	4.75-5.25
Molybdenum	1.20-1.40
Vanadium	.40-.60

Ref. C.5.) Inclusion Content – ADC3

	Inclusions	
Type	Thin	Heavy
A (sulfide)	0	0
B (aluminate)	1.0	0.5
C (silicate)	0	0
D (globular oxides)	1.0	0.5

Ref. C.2.) Fracture Toughness.

C.2.1.) **Initial Material Qualification Analysis**, as received, annealed condition.
Charpy V-Notch Testing (per ASTM E23), lab oil quench, 44-46 HRC, triple temper.

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	14 ft.lb (19.0 J)	8 ft.lb (10.8 J)
450°F (232 C)	35 ft.lb (57.4 J)	25 ft.lb (33.8 J)

C.2.2) **Work Piece Heat Treat Qualification Analysis**. Quenched and tempered specimens with work piece, per work piece hardness requirement, testing lab performs no heat treat.
Charpy V-Notch Testing (per ASTM E23), as quenched and tempered with work piece

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	12 ft.lb (16.3 J)	6 ft.lb (8.1 J)
450°F (232 C)	80% of initial analysis	20 ft.lb (27.1 J)

Ref. - F.4.) Austenitizing Temperature (Ta) = 1885 +/- 10°F

~~**H.14.) Individual Die Steel Specification Sheet**~~

Material: SMV4

Die Steel Supplier: Aubert & Duval

Representative Contacts:

North America: Kevin McCarron
Aubert & Duval USA
95 Fulton st
Boonton NJ 07054

TEL. 630-906-1783

Europe: Aubert & Duval
Tour Maine Montparnasse
33, Avenue Du Maine
75755 Paris Cedex 15
FRANCE
TEL.011-33-1 44 1024 00
FAX 011-33-1 44 1024

China: Peter Li
ERAMET - China
No. 2607-2612, 26 Floor
Bank of China Tower
No. 200 Yin Chen Dong Road
Shanghai
TEL 86-21-61006161
Peter.li@eramet-international.com

Ref - C.) MATERIAL PROPERTY TESTING AND ACCEPTANCE CRITERIA

Ref. C.1.) Alloy Chemical Composition – SMV4

Carbon	.37-.42
Manganese	.30-.50
Phosphorus	.015 Max
Sulfur	.002 Max
Silicon	.80-1.0
Chromium	5.00-5.45
Molybdenum	1.20-1.40
Vanadium	.80-1.0

Ref. C.5.) Inclusion Content – SMV4

	Inclusions	
Type	Thin	Heavy
A (sulfide)	0.5	0
B (aluminate)	1.0	0.5
C (silicate)	0	0
D (globular oxides)	1.0	0.5

Ref. C.2.) Fracture Toughness.

C.2.1.) **Initial Material Qualification Analysis**, as received, annealed condition.
Charpy V-Notch Testing (per ASTM E23), lab oil quench, 44-46 HRC, triple temper.

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	12 ft.lb (19.0 J)	8 ft.lb (10.8 J)
450°F (232 C)	35 ft.lb (57.4 J)	25 ft.lb (33.8 J)

C.2.2) **Work Piece Heat Treat Qualification Analysis**. Quenched and tempered specimens with work piece, per work piece hardness requirement, testing lab performs no heat treat.
Charpy V-Notch Testing (per ASTM E23), as quenched and tempered with work piece

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	12 ft.lb (16.3 J)	6 ft.lb (8.1 J)
450°F (232 C)	80% of initial analysis	20 ft.lb (27.1 J)

Ref. - F.4.) Austenitizing Temperature (Ta) = 1885 +/- 10°F

H.15.) Individual Die Steel Specification Sheet

Material: ExELL H-13, SMDQN

Die Steel Supplier: Ellwood Specialty Steel

Representative Contacts:

North America: Greg Denis
Ellwood Specialty Steel
499 Honeybee Lane
New Castle, PA 16105
TEL. 800-932-2188
FAX 724-654-9550
Email: esssales@elwd.com

Europe: See Web Site
www.ess.elwd.com

China: See Web Site
www.ess.elwd.com

Ref - C.) MATERIAL PROPERTY TESTING AND ACCEPTANCE CRITERIA

Ref. C.1.) Alloy Chemical Composition – SMDQN

Carbon	.37-.42
Manganese	.20-.40
Phosphorus	.020 Max
Sulfur	.002 Max
Silicon	.80-1.0
Chromium	5.00-5.45
Molybdenum	1.20-1.40
Vanadium	.80-1.0

Ref. C.5.) Inclusion Content – SMDQN

	Inclusions	
Type	Thin	Heavy
A (sulfide)	0	0
B (aluminate)	1.0	0.5
C (silicate)	0	0
D (globular oxides)	1.0	0.5

Ref. C.2.) Fracture Toughness.

C.2.1.) **Initial Material Qualification Analysis**, as received, annealed condition.
Charpy V-Notch Testing (per ASTM E23), lab oil quench, 44-46 HRC, triple temper.

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	10 ft.lb (13.6 J)	8 ft.lb (10.8 J)
450°F (232 C)	28 ft.lb (38.0 J)	25 ft.lb (33.8 J)

C.2.2) **Work Piece Heat Treat Qualification Analysis**. Quenched and tempered specimens with work piece, per work piece hardness requirement, testing lab performs no heat treat.
Charpy V-Notch Testing (per ASTM E23), as quenched and tempered with work piece

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	8 ft.lb (10.8 J)	6 ft.lb (8.1 J)
450°F (232 C)	80% of initial analysis	20 ft.lb (27.1 J)

Ref. - F.4.) Austenitizing Temperature (Ta) = 1885 +/- 10°F

H.16.) Individual Die Steel Specification Sheet

Material: DHA

Die Steel Supplier: Daido Steel Co., Ltd.

Representative Contacts:

North America: Daido Steel America, Inc.
1111 Plaza Drive
Suite 740
Schaumburg, IL 60173
TEL 847-517-7950
FAX 847-517-7951

Europe: See Web Site
www.daidosteel.com

China: See Web Site
www.daidosteel.com

Ref - C.) MATERIAL PROPERTY TESTING AND ACCEPTANCE CRITERIA

Ref. C.1.) Alloy Chemical Composition – DHA

Carbon	.37-.42
Manganese	.30-.50
Phosphorus	.015 Max
Sulfur	.002 Max
Silicon	.95-1.15
Chromium	5.00-5.50
Molybdenum	1.00-1.30
Vanadium	.45-.65

Ref. C.5.) Inclusion Content – DHA

Type	Inclusions Thin	Heavy
A (sulfide)	0.5	0
B (aluminate)	1.0	0.5
C (silicate)	0	0
D (globular oxides)	1.0	0.5

Ref. C.2.) Fracture Toughness.

C.2.1.) **Initial Material Qualification Analysis**, as received, annealed condition.
Charpy V-Notch Testing (per ASTM E23), lab oil quench, 44-46 HRC, triple temper.

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	10 ft.lb (13.6 J)	8 ft.lb (10.8 J)
450°F (232 C)	28 ft.lb (38.0 J)	25 ft.lb (33.8 J)

C.2.2) **Work Piece Heat Treat Qualification Analysis**. Quenched and tempered specimens with work piece, per work piece hardness requirement, testing lab performs no heat treat.
Charpy V-Notch Testing (per ASTM E23), as quenched and tempered with work piece

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	8 ft.lb (10.8 J)	6 ft.lb (8.1 J)
450°F (232 C)	80% of initial analysis	20 ft.lb (27.1 J)

Ref. - F.4.) Austenitizing Temperature (Ta) = 1885 +/- 10°F

H.17.) Individual Die Steel Specification Sheet

Material: DAC-P

Die Steel Supplier: Hitachi

Representative Contacts:

North America: Hitachi Metals America, Ltd.
2 Manhattanville Road, Suite 301
Purchase, NY 10577
TEL 914-304-4814
FAX 914-694-6552
www.hitachimetals.com

Europe: See Web Site

China: See Web Site

Ref - C.) MATERIAL PROPERTY TESTING AND ACCEPTANCE CRITERIA

Ref. C.1.) Alloy Chemical Composition – DAC-P

Carbon	.35-.42
Manganese	.30-.50
Phosphorus	.015 Max
Sulfur	.002 Max
Silicon	.90-1.10
Chromium	5.00-5.50
Molybdenum	1.00-1.30
Vanadium	.70-.90

Ref. C.5.) Inclusion Content – DAC-P

Type	Inclusions Thin	Heavy
A (sulfide)	0	0
B (aluminate)	1.0	0.5
C (silicate)	0	0
D (globular oxides)	1.0	0.5

Ref. C.2.) Fracture Toughness.

C.2.1.) **Initial Material Qualification Analysis**, as received, annealed condition.
Charpy V-Notch Testing (per ASTM E23), lab oil quench, 44-46 HRC, triple temper.

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	10 ft.lb (13.6 J)	8 ft.lb (10.8 J)
450°F (232 C)	28 ft.lb (38.0 J)	25 ft.lb (33.8 J)

C.2.2) **Work Piece Heat Treat Qualification Analysis**. Quenched and tempered specimens with work piece, per work piece hardness requirement, testing lab performs no heat treat.
Charpy V-Notch Testing (per ASTM E23), as quenched and tempered with work piece

Acceptance Criteria:

Specimen Temperature	Average (Min.)	Lowest of 3 Impacts (Min.)
Room Temp.	8 ft.lb (10.8 J)	6 ft.lb (8.1 J)
450°F (232 C)	80% of initial analysis	20 ft.lb (27.1 J)

Ref. - F.4.) Austenitizing Temperature (Ta) = 1885 +/- 10°F