GM	GLOBAL MANUFACTURING ENGINEERING STANDARDS	CASTING TOOLING STANDARDS	Standard ID: HPDC-G-2

Die Insert Material and Heat Treating

Table of Contents

1 GENERAL REQUIREMENTS

1.1 PURPOSE

1.1.1 HPDC-G-2 is the standard procedure and specification that ensures the quality of all hot work tool materials and their heat treatment as required for GM tooling projects. This document is available for use by any GM allied organization. A copy will be made available by sending an email request to a GM employee involved in the relevant tooling project.

1.2 SCOPE

1.2.1 All hot work tool steel inserts, cores and core pins must be built to the standards of this specification; if not, they must be replaced by the Tool Source at their expense. All inserts or core pins that are not independently tested per this procedure must still meet the standards contained herein. The requirements of this specification supersede material and/or heat treat specifications given on individual insert drawings or CAD models.

1.3 RESPONSIBILITY

1.3.1 It is the responsibility of GM Commodities Management, Manufacturing Engineering, Laboratory, GM's Tooling Suppliers and Material & Heat Treat Sources to comply with or ensure compliance to this procedure. The Tool Supplier has primary responsibility to ensure compliance regardless of the buyer of material and heat treat. When the Tool Source is required to replace an insert (due to their failure to comply), it means that they will buy all material and heat treat per this specification and machine the insert to the specifications of their current contract. In other words, replacement will be at the expense of the Tool Source.

1.4 MATERIAL AND HEAT TREAT SOURCES

1.4.1 The current list of approved and provisionally approved material and heat treat sources will be made available by sending an email request to a GM employee involved in the relevant tooling project.

1.5 APPROVED SOURCES

1.5.1 H-13 and all other hot work tool steels may only be supplied to GM or its Tool Sources by mills designated by the approved or provisional suppliers. Provisional and Approved material sources are designated by the mill that produces the material. In effect it is the mill that is approved as the supplier. 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 General Motors. General Motors must certify any mills not presently designated before they can supply steel to GM.

1.5.2 Provisional and Approved heat treat sources are designated by the facility that contains the approved furnace. It is not permissible for the heat treater to heat treat at another facility that is not approved by General Motors.

1.5.3 An approved source cannot be self-certified. That is, all approved sources continue to be obligated to submit samples for each piece of purchased steel.

1.5.4 No material may be sold to GM or its Tool Sources that does not meet the requirements of this specification. If the material fails any of the Steel Mill

Certification tests then it may not be shipped for use in GM tooling projects. Steel Mill Certification must demonstrate that all relevant values meet this specification especially with regard to Charpy Impact values.

1.6 PROVISIONAL SOURCES

1.6.1 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 insert test results statistically confirming their capability.

1.6.2 The material or heat treat source shall be in close communication with GM throughout this process. GM reserves the right to review and witness all work in order to assure that this process is being conducted in the proper manner.

1.6.3 For a material source, a large population of various sized insert steels must be tested in an actual tool source production environment (tools built for GM) to confirm capability. The confirmation process and requirements are as follows:

1.6.4 The material source will obtain a serial number from GM and then send a piece of premium grade steel (steel size 400 mm X 400 mm X 400 mm approximate weight is 532 kg.) with a 13 mm sampling plane cut 98% through the sample to the approved testing lab for metallurgical tests. The sampling plane must be cut perpendicular to the grain direction of the steel. Grain direction and short transverse (thickness) direction shall be indicated on the steel block by way of etchings, hand ground arrows or engraving.

1.6.5 The approved testing lab will remove several samples and forward the test results to the potential material supplier and GM. The material source will pay for this testing.

1.6.6 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.

1.6.7 During this period a minimum of 25 pieces shall be tested at the approved lab; 15 pieces must be at least 250 mm thick. GM has no obligation to create the opportunity to test these pieces within the prescribed period of time. The material source will have the chemistry of two randomly chosen pieces (different heats) verified by one of the approved independent labs at their own expense.

1.6.8 The first time acceptance rate must be 88% or better for the total population of inserts.

1.6.9 When a piece is rejected, a new block of steel must be substituted by the 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 Supplier must start the whole process again.

1.6.10 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 GM.

1.6.11 The Supplier's mill will be inspected by GM 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 General Motors**.**

1.6.12 For a heat treat source, a large population of insert steels must be tested in an actual tool source production environment (tools built for GM) to confirm capability. The confirmation process and requirements are as follows (The heat treat source will do the following):

1.6.13 The heat treat source will buy a piece of premium grade hot work tool steel that meets this material specification. For example: steel size 400 mm X 400 mm X 400 mm (approximate weight is 532 kg.). Make sure the steel source cuts the 13 mm sampling plane 98% through. Obtain a serial number from GM.

1.6.14 Send the piece of steel to the approved testing lab for testing. They will remove several samples and forward the test results to the potential heat treat supplier and GM. All testing will be at the expense of the heat treat source.

1.6.15 Upon verification of material quality, the steel will be shipped to the heat treat source for heat treat. Surface thermocouple holes must be placed in the center of all six sides of the block. A core thermocouple hole must also be installed to the exact center of the block. The surface thermocouple hole may be offset 12 -13 MM from the core thermocouple hole. Data must be recorded from all seven thermocouples.

1.6.16 After heat treating the steel per this specification, send the entire block to the approved testing lab for analysis. Also send the furnace charts to the plant metallurgist at GM. The testing lab will remove several test pieces and forward the results to the potential heat treat supplier and GM. Both sides of the block in the short transverse plane may be sampled.

1.6.17 The metallurgist at the Die Caster will analyze and compare the results to the initial heat treat potential test and determine if the heat treat source is capable of meeting the GM specification.

1.6.18 Once the heat treater has demonstrated capability his name will be added to the current version of this specification as a source with provisional approval. The provisional testing period shall last a maximum of 40 months from the first production insert test submitted. The provisional source must meet all requirements of this specification. Full approval is only possible after heat treating 45 pieces (25 being at least 250 mm thick) of hot work tool steel for GM with an acceptance rate of 95% or more.

1.6.19 When a piece is rejected, it must be re-heat treated by the Supplier at his cost. This heat treat must then meet the requirements of the specification. If it fails, then the provisional testing period may be terminated by GM depending upon the circumstances and the Supplier must start the whole process again.

1.6.20 If 40 months is not sufficient time to complete the confirmation process, the Supplier may elect to begin the process again subject to the approval of GM.

1.6.21 The heat treater's facility will be inspected by GM 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 General Motors.

1.6.22 A Supplier becomes an Approved Source when it meets all the requirements of the provisional testing period and the GM on-site audit.

1.7 HEAT TREAT CONTRACTS

1.7.1 The end user (the die caster or casting organization using the tools in production) may elect to create contracts for the heat treat of the inserts. Otherwise, the Tool Source will create the heat treat contract with the Heat Treater. All invoices will be honored after the successful completion of the heat treat as determined by the lab test results, subject to applicable contract provisions.

1.8 INSERTS TO BE TESTED

1.8.1 All large die cavity inserts must be tested. 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. A coupon must be sent through heat treat and its' analysis will represent the heat treat results for all the small inserts heat treated in that particular furnace lot. If necessary, a surrogate coupon (defined later) may be used. This means that large inserts must have two coupons representing the material and heat treat respectively of each; whereas small insert coupons can represent more than one small insert, either material or heat treat. The end result

must be that coupons will be submitted representing the material and heat treat of all inserts built by the Tool Source. The Tool Source must submit in advance a listing of all inserts that will be considered small inserts for the purpose of testing for approval by the GM Engineer.

1.8.2 If the Tool Source is unsure of the category of an insert (large vs. small), they must test per the requirements of a large insert, unless clarification is sought from the GM Engineer. The Engineer will then determine the category and the Tool Source will apply the proper test coupon representation.

1.8.3 Requests for minor exceptions to the testing program must be submitted in advance and in writing by the Tool Source to the GM Engineer. Generally they will not be granted and cannot be granted to rectify an error made by the Tool Source, Material Supplier or Heat Treater. The Tool Source is not relieved of the responsibility of building to the standards of this specification if test exceptions are granted. Therefore, the Tool Source will still be liable for replacing the insert at their expense if either the material or heat treat does not comply with this specification.

1.9 TESTING PROGRAM AND INVOICES

1.9.1 The Tool Source shall be required to maintain a testing program (per this specification) to verify and ensure compliance with the entire procedure and assure that only the highest quality premium grade hot work tool steel and heat treat is utilized. All tests will be performed by an outside, independent test lab (see listing in this specification). This lab will determine the suitability of the material and heat treat for each insert. The GM Metallurgist may, at his option, overrule the Laboratory's determination. The Tool Source will co-ordinate all the activities of the Material Suppliers and Heat Treaters in regard to the proper testing required in this specification. Heat Treat and Annealed test results (copies of lab reports) must be submitted with insert invoices and die build/rebuild invoices (where some or all of the inserts in the die are supplied by the die builder) to the GM Engineer. Invoices will not be paid without both test results. Altered test certificates will not be accepted. If altered, the test must be performed again to insure that the correct insert has been tested. All costs related to the removal of a test piece (late testing), testing and subsequent repair of the insert will be the responsibility of the Tool Source.

1.10 FAILURE TO PROPERLY TEST MATERIAL OR HEAT TREAT

1.10.1 If the Tool Source fails to test or fails to insure that the material test of the insert is 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 heat treat is acceptable then a penalty will apply ($400US or equivalent) to be deducted from the invoice for failure to test the insert material. The purpose of testing is to insure that proper die insert material is used in GM inserts. The testing also serves as a quality measurement and rating system of the Steel Suppliers. The Tool Source is the guarantor (though not necessarily the provider) of acceptable material. This provision does not change any previous Tool Source responsibilities.

1.10.2 If the Tool Source fails to test or fails to insure that the heat treat test of the insert is properly performed, they will be required to replace the entire insert to include material, heat treat and labor. The purpose of testing is to insure that properly heat treated inserts are installed in GM tooling. The Tool Source is the guarantor (though not necessarily the provider) of acceptable heat treat. This provision does not change any previous Tool Source responsibilities. GM will have no obligation to test an insert once it has been received.

1.11 REJECTION OF MATERIAL

1.11.1 Rejection can occur at (but is not limited to) the following times:

1.11.1.1 At submission of certification (rejected by GM)

1.11.1.2 After test results from independent lab

1.11.2 The certification will be reviewed (optional) by GM and release/rejection will be forwarded immediately to the Tool Source. Work may not proceed on an insert until the independent lab test results are reviewed by the Tool Source. The test results constitute acceptance or rejection of the work piece. In the case of rejection, the Die Caster's metallurgist must be notified immediately. The independent lab release can be rescinded by the Die Caster if, in its' opinion, the test results are questionable.

1.11.3 In the case of rejected material, the Tool Source will work with the Supplier to furnish a replacement piece as quickly as possible. The Supplier will be responsible for all the related transportation, testing and machining costs.

1.12 REJECTION OF HEAT TREAT

1.12.1 Rejection can occur at (but is not limited to) the following times:

1.12.1.1 At submission of HT101 form by the Heat Treater

1.12.1.2 After test results from independent lab

1.12.2 The HT101 will be reviewed (optional) by GM and release/rejection will be forwarded immediately to the Tool Source.

1.12.3 Finish machining may not proceed on an insert until test results are reviewed by the Tool Source. The test results constitute acceptance or rejection of the heat treated work piece. In the case of rejection the Die Caster's metallurgist must be notified immediately. The independent lab test results can be rescinded by the Die Caster if, in its opinion, the results are questionable.

1.12.4 In the case of rejected heat treat, the Heat Treater shall pay for a replacement piece, all machining to date, related transportation and additional testing. The Tool Source will work with the Heat Treater to assure that this occurs as quickly as possible. After discussion with the Die Caster and at their option; the insert may be re-heat treated. The tool is to be annealed before any second heat treat of the tool. A surrogate coupon with a Charpy Impact capability of over 13.5 Nm must be attached in the specified manner and then tested at the Heat Treater's expense.

1.12.5 The cost of the replacement tooling including machining, material, heat treat, additional testing, transportation and other related costs will be paid by the Tool Source when a heat treat failure (generally quench cracking) is attributable to the Tool Source failing to collaborate or take adequate measures to prevent cracking as outlined in the heat treat section of this specification

1.13 TEMPERATURES

1.13.1 All temperatures specified are in degrees Celsius unless otherwise noted.

1.14 OTHER DOCUMENTS

1.14.1 There are several documents related to this specification. These documents supplement and provide information necessary to the proper implementation of this specification. They are issued and retained by GMPT and revised as needed. They are:

1.14.1.1 Material and Heat Treat Sources
1.14.1.2 Heat Treat Austenitizing Temperatures
1.14.1.3 Die Insert Hardness Table

2 PREMIUM GRADE HOT WORK TOOL STEEL

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 where hot working conditions exist. This is the premium grade hot work tool steel material specification.

Applications

Choice of the optimum hot work tool steel alloy for a given tool application involves balancing the alloy's resistance to heat check and its toughness properties.

Of all alloys tested to date, DIN 1.2367 offers the highest resistance to heat check. The current premium grades of this alloy offer excellent toughness as well, making it a preferred choice for most hot work applications. Unfortunately, availability remains an issue with this alloy.

DIN 1.2344 (H13) offers good heat check resistance and the newer premium grades offer more than adequate toughness for most applications. It is readily available from a supply perspective, providing another advantage.

Modified DIN 1.2344 alloys offer higher toughness levels as well as good heat check resistance.

Modified DIN 1.2343 alloy offers extremely high toughness levels. This alloy is an excellent choice for applications requiring high toughness such as block water jacket inserts. Applying a PVD coating with an ion nitride base significantly improves the performance of this alloy when used in small to medium size tooling. However, its heat check resistance is significantly lower than the alloys listed above, and should only be used where very high toughness properties are required. Improvements in the toughness levels of DIN 1.2344 and 1.2367 and their variants have made obsolete many of the historical advantages of this alloy.

DIN 1.2343 has high toughness but lacks in heat check and mechanical deformation resistance when compared to Din 1.2367, 1.2344, and similar alloys. DIN 1.2344 and 1.2367 material and heat treat improvements have reduced the need for this alloy due to similar toughness levels achieved by those alloys with superior heat check resistance.

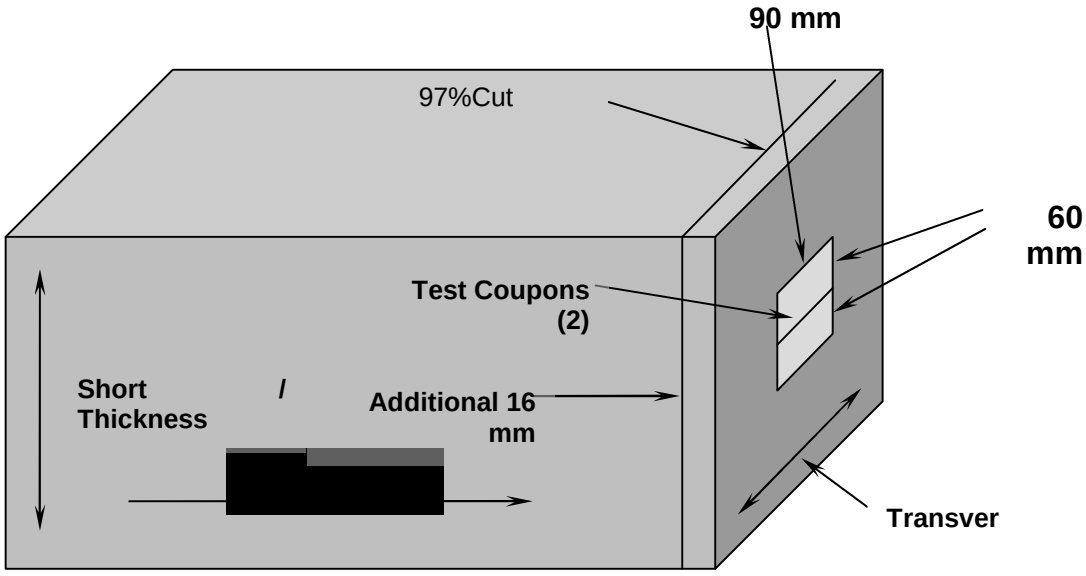
2.1 SIZE, SHAPE AND TEST COUPONS

2.1.1 The size and shape of the tool block must 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 350 X 500 X 550 mm will use a 350 mm (in the short , or thickness direction) parent block. The parent block must be less than 50 mm thicker than the tool block, unless the thickness of the parent block is 300 mm or less. The 50 m thickness differential does not apply for parent blocks 300 mm or less. The width must be kept to the smallest possible dimension so that the forging and mill heat treatments produce the required properties.

2.1.2 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 16 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 barely held to the insert block. The Tool Source will cut the remainder. The Steel Supplier must also engrave (stamp) the insert serial number assigned by GM on the block in an area not likely to be removed by machining operations.

2.1.3 The Tool Source must remove two test coupons from the center of the testing plane, 60 mm (parallel to the short/thickness direction) X 90 mm X 13 mm or (for round sections) 90 mm dia. X 13 mm long (+ 3 mm tolerance), from each block and engrave (in cursive with a high speed, small diameter bit, minimum 13 mm high) with the same serial number assigned to the block (insert) by GM. The 60 mm dimension will be in the same direction as the thickness of the parent block. The Steel supplier must stamp the insert block to correctly and clearly indicate this direction.

2.1.4 The first coupon will be sent immediately to the approved testing lab for analysis of the material. It is not permitted to accumulate material test coupons and suddenly send large groups to the testing lab. This causes delays. Send coupons as soon as they are removed from insert blocks. Batches greater than six will be cause for a delay in invoice payment to the Tool Source by GM. The second coupon will accompany the insert through heat treat and will be analyzed for heat treat quality.



Material Block

2.2 Material Chemistry, Properties & Requirements

2.2.1 DIN 1.2344 (H-13) steel shall conform to the following chemical tolerances:

C	0.37-0.42
Mn	0.20-0.50
Si	**0.80-1.20**
S	0.003 Max.
Cr	5.00-5.50
V	0.80-1.20
Mo	1.20-1.75
P	0.015 Max.

2.2.1.1 All other hot work tool materials must conform to DIN or submitted factory specifications.

2.2.2 ESR / VAR

2.2.2.1 All DIN 1.2344 (H-13) *DIN 1.2367, DIN 1.2343, and modified DIN 1.2344 alloy* steel shall be produced using the electro-slag remelt (ESR) or vacuum arc remelt (VAR) process except small round stock when availability is non-existent. Under no circumstances may any piece above 75 mm in diameter be a non-ESR or VAR steel.

2.2.3 Forging

2.2.3.1 Forgings for dies must have a minimum upset forging ratio of 5 to 1, except where prohibited by block size; forging must be done in three directions. Forging ratios are determined linearly. Back forging is permitted but must not used in calculating forging ratio.

2.2.4 Heat Treatment

2.2.4.1 Block after forging must have a maximum hardness of 235 HBW.

2.2.5 Inspection

2.2.5.1 Final annealed block is to be rough machined and ultrasonically tested by supplier. Block will be rechecked at GM'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.

2.2.6 Grain Size

2.2.6.1 Refer to paragraph "F" of NADCA 207-2003. Grain size shall be developed using the Direct Quench method per ASTM E-112 by austenitizing for 30 minutes at temperature determined by material and Table A at end of this specification. Rapidly quench and temper at 593 C

minimum. Hardening should be in a protective media or by using an appropriately oversize sample in a non-protective media. Grain size to be measured by using the ASTM comparative method and shall be predominately ASTM no. 7 or finer.

2.2.6.2 An alternative method to rate the grain size may be used. The Shepherd Fracture Grain Size shall be predominately no. 7 or finer when made on a hardened (air cooled after heating for 30 minutes at 1030° C in a protective media or using an appropriately oversize sample in a non-protective media) and untempered specimen taken from a representative sample.

2.2.7 Annealed Microstructure

2.2.7.1 The annealed microstructure shall be free of significant banding or chemical segregation per the Banding Segregation Reference Chart NADCA 207-2003. Examine banding at 50X magnification. The annealed microstructure shall exhibit a uniform distribution of fine spheroidized carbide throughout a ferrite matrix at 500X after being polished and etched with 5% Nital. Photomicrographs of acceptable and non-acceptable limits will be determined by the Annealed Quality Microstructure Chart contained in NADCA 207-2003.

2.2.8 Primary Carbides

2.2.8.1 The presence of large primary carbides will be cause for rejection. Heat treated microstructure should reflect the fine spheroidized carbide structure specified in the annealed steel.

2.2.9 Microcleanliness

2.2.9.1 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:

Inclusions Type	Thin	Heavy
A (sulfide)	0.5	0.5
B (aluminide)	1.5	1.0
C (silicate)	0.5	0.5
D (globular oxides)	1.5	1.0

2.2.10 Impact Capability

2.2.10.1 Specimens shall be tested per NADCA #207-2003 I.E. page 4 items 1 – 7 with the exception that the austenitizing of the Charpy sticks will be at a temperature determined by the material and the Austenitizing Table which is a separate document issued by General Motors. The test specimens will be hardened to the same hardness as the destination insert by the testing lab. The five specimens shall be tested at room temperature on machines that meet the requirements of ASTM E23. The values of the

highest and lowest specimens shall be discarded and the average of the remaining three results shall be computed.

2.2.10.2 The impact capability of die steel must average no less than 13.5 Nm with any single value to be no less than 10.8 Nm (Charpy V-Notch).

2.3 Certification of Conformance

2.3.1 Certification of Conformance (by the Steel Supplier) for premium grade hot work tool steel supplied in accordance with this document shall include the following information:

2.3.1.1 Supplier Heat Designation

2.3.1.2 Annealed Brinell Hardness

2.3.1.3 Chemical Analysis

2.3.1.4 Microcleanliness Levels

2.3.1.5 Confirmation that Ultrasonic Testing has been performed

2.3.1.6 Grain Size number

2.3.1.7 Microbanding Designation Level (Pass / Fail)

2.3.1.8 Annealed Microstructure Rating Number

2.3.1.9 Response to Heat Treatment

2.3.1.10 Impact Capability Test results (should include all results plus average, heat treatment and final hardness of specimens). Average of three values shall be no less than 13.5 Nm with any single value to be no less than 10.8 Nm.

2.3.2 The Tool Source must clearly indicate to the Steel supplier (a P.O. number is not sufficient) that the die steel is destined for use at GM so that he will properly prepare the certification for transmittal. The above certification shall be sent immediately by the Steel Supplier (at the time of shipment) to the Tool Source and to the GM die caster's plant metallurgist. The original certification shall be sent to the Tool Source.

2.3.3 The purchaser (or GM) reserves the right to monitor the control processes of the supplier to determine compliance with this specification.

2.3.4 In addition, the serial number engraved on each block by the Steel Supplier shall be provided in the purchase order or release by the Tool Source.

2.4 TESTING REQUIREMENTS (MATERIAL)

2.4.1 Test items shall be those listed in the Certification of Conformance.

2.4.2 Frequency of testing - 100% . All inserts will be tested without exception.

2.4.3 Testing to be performed by the approved testing lab. The test results are to be forwarded to the Tool Source, Steel Supplier and appropriate GM Metallurgical Laboratory.

3 HEAT TREAT OF PREMIUM GRADE HOT WORK TOOL STEELS

3.1 EQUIPMENT AND CALIBRATION

3.1.1 This part of the procedure applies to PREMIUM GRADE DIN 1.2344 (H-13) die steel and other die steels heat treated at approved, off-site Heat Treat Sources. To meet the requirements of this specification, the following equipment is required:

3.1.1.1 Vacuum furnace with a capability of at least ten bar nitrogen pressure backfill. The capacity of the furnace must be sufficient to achieve a minimum quench rate of 40° C per minute (based on the surface thermocouple placed in the center of the back of the die, 16 mm deep) under load. This will require a furnace of sufficient size to accept large blocks while maintaining adequate circulation to minimize distortion of the block. **Exception: Tools less than 90 Kg in weight may be heat treated in a 5 bar minimum vacuum furnace provided the tool is quenched at a minimum rate of 37.7 C per minute. Both rates are calculated based on the temperature drop from the austenitizing temperature to 537.7 C.**

3.1.1.2 Programmable furnace controller capable of monitoring at least six thermocouples simultaneously and capable of programming specified quench rates with an isothermal hold and a high differential between thermocouples. The thermocouple size must be 3 mm diameter to match the size of the dedicated thermocouple holes. Inconel sheathed, Type K 3 mm thermocouples are required.

3.1.1.3 Digital data recorder capable of capturing an entire heat treating cycle including heat-up, austenitizing, and quench to below 150 °C. Numerical data acquisition is required in order to completely record and define the heat treat process; the numerical data must be imported to an Excel spreadsheet and be made available to the Die Caster's metallurgist and Tool Source. A color coded chart can be a supplement to the digital data but not a substitute for it.

3.1.1.4 Furnace must be certified and maintained in accordance with MIL-H-6875. Thermocouples and furnace controller must be calibrated to an NBS (NIST) traceable standard within 90 days prior to use on GM materials.

3.2 Steel Purchase

3.2.1 Purchase steel per this specification. See the Premium Grade H-13 Material portion of this specification. Use GM approved or provisional suppliers only.

3.3 Tool Source / Heat Treater Consultation

3.3.1 The Tool Source must consult with the Heat Treater in either the design phase or steel purchase phase of the tool project (whichever is sooner) to avoid potential cracking problems during heat treat. The Heat Treater is expected to quench die inserts at a very high rate. It is the responsibility of the Tool Source to rough machine the tool in such a manner that minimizes the danger of quench cracking. Adjacent thick and thin sections (widely varying cross sections) should generally be avoided in the die design and build especially for large inserts. Sharp edges or corners are not allowed

during rough machining. Generous radii, bridges between thick and thin areas and elimination of sharp edges all minimize the risk of quench cracks. Some portions of the insert will distort more than others. Sufficient machine stock must be included to accommodate for the expected distortion due to high quench rates. **It is also recommended the heat treat supplier position the tool in the furnace so that it is evenly cooled, and not focus the quench towards the coupon area. This causes undue stress to the tooling, and has resulted in quench cracks.**

3.3.2 **Radius Recommendations: As a general guide line, inside radii smaller than 5.0 mm should be avoided in large tooling to reduce the risk of quench cracking. Although 3.0 mm radii will work in some applications, it still carries some risk of cracking when the geometry of the tool is complex. Larger steps and complex geometry will require larger radii, typically ranging in size from 5.0 mm to 6.5 mm. Steps larger than 150 mm may require a radius of 13.0 mm. Also, all holes should have a minimum 3.0 mm chamfer at the surface.**

3.3.3 **This guide line does not relieve the tool maker of their responsibility to communicate with the heat treater regarding rough machining issues.**

3.4 Hole work, Coupons & Test Criteria

3.4.1 The Tool Source will add the hole work for the surface thermocouple after consulting with the Heat Treater and will surface grind the coupon face that will make contact with the insert.

3.4.2 The Tool Source shall attach the coupon (tack welded) to the insert detail at the center of the largest surface **on the same plane as the cavity face whenever non-cavity face room allows** (firmly in contact, no gaps) and be subjected to the same heat treat as the insert. **The heat treater is not allowed to move the coupon without the die casters permission. Moving the coupon without the die casters permission is grounds for loss of source approval.** No tack welds will be allowed in the area of the Charpy notches. Consult testing lab. See the diagram below. If the coupon is missing from the insert then the Heat Treater must notify the Tool Source and the Caster. No insert may be heat treated without the attached coupon. Forward the insert detail, Form #HT101 (see Exhibit A), and the attached coupon (per this specification) to the heat treat source. This coupon will be removed by the heat treater after heat treat then forwarded to the testing lab along with a completed HT101 form. The coupon must be hardened to Rc44 – 46 in order to insure a valid comparison to the material Charpy impacts. The Heat Treater will hold the insert until approval is obtained from the approved testing lab. The Tool Source may at their own risk continue the machining of the insert pending test results.

3.4.3 As an alternate the Tool Source may have a supply of coupons prepared in advance to be used as heat treat coupons. These coupons must also be surface ground to assure proper contact with the tool surface. The coupons must be produced from a small, high quality heat of steel that is homogeneous and removed from a block no larger than 150 mm thick. The length (grain direction) may not exceed 600 mm. The width may not exceed 350 mm. The 60 mm dimension of each coupon will be parallel to the thickness (short transverse direction). The Charpy impact capability of the heat of steel must be checked by the approved lab to provide the capability of the small block (and particular heat) that serves as the source for all the coupons. When the coupon is marked for identification, the serial number shall have a suffix attached with the letter “S” and a number identifying the coupon batch. (Such as serial # 10899-S1) The Die Caster’s metallurgical lab must be provided with a list of coupon batch capability values from any Tool Source using these surrogate coupons. When the heat treat is tested using these coupons the Charpy impact average of three (after high and low are discarded) must exceed 80% of the capability of the coupon less ½ the