DC-9999-1 Rev. 18 Hyperlinks

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Change Log

Change Level	Change Date	Brief Description of Change
11	10-10-95	Updated to current practice.
12	8-1-96	Re-organized text & upgraded processes and definitions.
13	1-13-97	Hardness revised; note added to supersede insert drawing specifications.
14	4-9-98	Add provisional material sources and alter the heat treat quench method.
15	11-25-98	Quench pressure minimum of 9 bars to reflect current practice. FWD side and bottom cores hardness raised to Rc 44-46. Steel Mill Certs must meet requirements of this spec. Austenitizing temperatures have been changed (raised).
16	7-28-99	Added mandatory dedicated surface thermocouple hole.
17	6-25-01	Deleted shot sleeves from the spec. Added internet web addresses for this spec. Made additions to list of Provisional Material Sources. Made additions to list of Provisional Heat Treat Sources. Collaboration between Tool Source and Heat Treater is required before rough machining of inserts. Anneal tool before a second heat treat. Developed two quenching protocols – methods 1 & 2. Reduced time at austenitizing temperature and time at Isothermal hold (if used). Added new version of flow chart. Inconel Type K thermocouples required, no longer optional. Surface grinding of heat treat test coupon is now required. Surrogate coupons for primary heat treat are allowable.
18	3-1-05	Require digital time & temperature data from heat treat furnace. Minimum quench rate now 70° F. Commercial heat treat Charpys now at least 80% of Annealed Charpys minus ½ difference of the high and low values (5 samples). All Charpys at Rc44 –46. Temper trigger changed to Ts < 120° F. Added detail regarding grain size. Added new NADCA 207 – 2003 material and heat treat photomicrograph charts

and banding chart. No tack welds on coupon near potential Charpy notches. Test coupons stacked rather than side by side. Check post stress relief hardness. Stress relieving must be performed by Approved or Provisional Heat Treat Sources only. More detail added. New website locations; minor changes to provisional sourcing procedures. Added Provisional and Approved sources. Heat treat contracts with caster only. 5 Impact samples, throw out the high and the low. Additional detail to heat treat process (temperature ramp and quenching).

GENERAL REQUIREMENTS

PURPOSE

DC-9999-1 is the standard procedure and specification that ensures the quality of all H-13 and other hot work tool materials and their heat treatment as required for GM tooling projects.

SCOPE

All H-13 and other 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.

LOCATION ON THE WORLD WIDE WEB

This document is available for use by any allied organization. It can be found on the internet at two sites; either site will download the latest version to any remote computing system. The site addresses are:

Bohler - Uddeholm Site `http://www.bucorp.com/hotworksteels/specsdc99991.asp`. The GM logo is on the right hand side of the webpage. Click on it and just choose one of three formats by clicking (.pdf file; .doc Microsoft Word file and .htm for viewing via the web browser); each will download to your computer.

NADCA Site http://www.diecasting.org/information/specs/Rev18.pdf . This document is also available by sending an email request to edward.flynn@gm.com. Generally the document will be sent return email within one business day to the originator.

RESPONSIBILITY

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.

DOCUMENT CONTROL

Document No.	Location	Retention Period
Eng. Spec. # 9999-1	s:\group\toolensn\eng_spec	1 year after revision or obsolescence

APPROVED SOURCES

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.

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.

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.

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.

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 insert test results statistically confirming their capability.

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.

Material (Steel):

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:

- The material source will obtain a serial number from GM and then send a piece of premium grade steel (steel size 16”X16”X16” approximate weight is 1173 lbs.) with a 1/2” 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.
- 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.
- 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 the approved lab; 15 pieces must be at least 10” 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.
- 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 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.
- 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.

- 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**.**

Heat Treat:

As with the material provisional sources, 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:

- The heat treater will buy a piece of premium grade H-13 steel that meets the current material specification per DC-9999-1. This steel must be bought from either Thyssen or Uddeholm, steel size 16"X16"X16" (approximate weight is 1173 lbs.). Make sure the steel source cuts the 1/2" sampling plane 98% through. Obtain a serial number from GM.
- 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.
- 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 one half inch from the core thermocouple hole. Data must be recorded from all seven thermocouples.
- After heat treating the steel per DC-9999-1 latest revision, 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.
- 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.
- Once the heat treater has demonstrated capability his name will be added to the current version of DC-9999-1 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 10" thick) of H-13 steel for GM with an acceptance rate of 95% or more.

- 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.
- 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.
- 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.

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

HEAT TREAT CONTRACTS

The end user (the diecaster 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.

INSERTS TO BE TESTED

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.

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.

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.

TESTING PROGRAM AND INVOICES

The Tool Source shall be required to maintain a testing program (see sections V. and 7.0) 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 at end of 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.

FAILURE TO PROPERLY TEST MATERIAL OR HEAT TREAT

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 $400 will be deducted from the invoice for the insert for failure to test 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.

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.

REJECTION OF MATERIAL

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

1) At submission of certification (rejected by GM)
2) After test results from independent lab

The certification (item 1) 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 workpiece. 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.

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.

REJECTION OF HEAT TREAT

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

1) At submission of HT101 form by the Heat Treater
2) After test results from independent lab

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

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 workpiece. 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.

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 10-12 foot pounds must be attached in the specified manner and then tested at the Heat Treater's expense.

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 section 2.0 of the heat treat section of this specification.

TEMPERATURES

All temperatures specified are in degrees Fahrenheit unless otherwise noted.

OTHER DOCUMENTS

There are several documents related to this specification. They are:

Material and Heat Treat Sources
Heat Treat Austenitizing Temperatures
Die Insert Hardness Table

These documents supplement and provide information necessary to the proper implementation of this specification. They are issued and retained by GMPT – Bedford and revised as needed.

PREMIUM GRADE H-13/HOT WORK TOOL MATERIAL

I. SECTION DEFINITION

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.

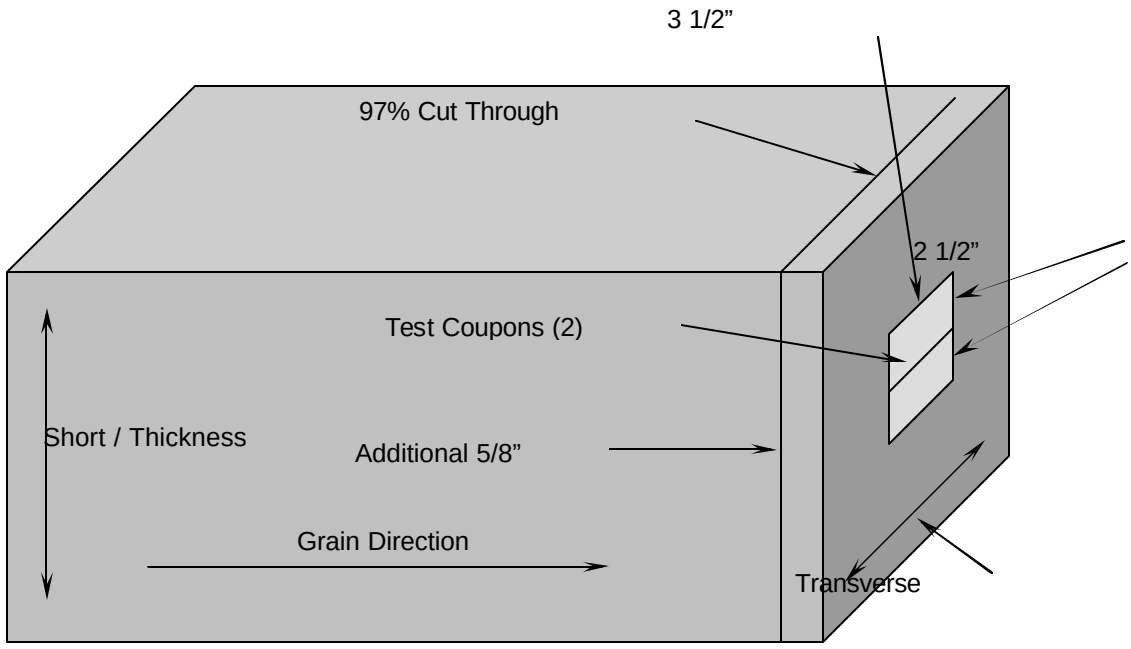
II. SIZE, SHAPE AND TEST COUPONS

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 14” X 20” X 22” will use a 14” (in the short , or thickness direction) parent block. The parent block must be less than 2” thicker than the tool block, unless the thickness of the parent block is 12” or less. The 2” thickness differential does not apply for parent blocks 12” or less. The width must be kept to the smallest possible dimension so that the forging and mill heat treatments produce the required properties.

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” 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.

The Tool Source must remove two test coupons from the center of the testing plane, 2 1/2" (parallel to the short/thickness direction) X 3 1/2" X 1/2" or (for round sections) 3 1/2" dia. X 1/2" long (± 1/8” tolerance), from each block and engrave (in cursive with a high speed, small diameter bit, minimum 1/2” high) with the same serial number assigned to the block (insert) by GM. The 2 1/2" 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.

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

See page 30 for more test coupon details, orientation and information.

III. Material Chemistry, Properties & Requirements

3.1 Chemistry

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. (was .02 max)

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

3.2 ESR / VAR

All H-13 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 3" in diameter be a non-ESR or VAR steel.

3.3 Forging

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.

3.4 Heat Treatment

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

3.5 Inspection

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.

3.6 Grain Size

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 1100 F 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.

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 1885° F (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.

3.7 Annealed Microstructure

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.

3.8 Primary Carbides

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.

3.9 Microcleanliness

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

3.10 Impact Capability

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.

The impact capability of die steel must average no less than 10 ft-lbs. with any single value to be no less than 8 ft-lbs (Charpy V-Notch).

IV. CERTIFICATION OF CONFORMANCE (Mill Cert)

Certification of Conformance (by the Steel Supplier) for premium grade H-13 steel supplied in accordance with this document shall include the following information :

- Supplier Heat Designation
- Annealed Brinell Hardness
- Chemical Analysis
- Microcleanliness Levels
- Confirmation that Ultrasonic Testing has been performed
- Grain Size number
- Microbanding Designation Level (Pass / Fail)
- Annealed Microstructure Rating Number
- Response to Heat Treatment
- 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 10 ft-lbs. with any single value to be no less than 8 ft-lbs. All test results shall be in Ft.-Lbs. not Joules.

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.

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

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.

V. TESTING REQUIREMENTS (MATERIAL)

- Test items shall be those listed in the Certification of Conformance.
- Frequency of testing - 100% . All inserts will be tested without exception.
- 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.

HEAT TREAT OF PREMIUM GRADE H-13/HOT WORK TOOL STEEL

I. SECTION DEFINITION

This part of the procedure applies to PREMIUM GRADE GM H-13 die steel and other die steels heat treated at approved, off-site Heat Treat Sources.

II. EQUIPMENT AND CALIBRATION

To meet the requirements of this specification, the following equipment is required :

A. 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 70° F per minute(based on the surface thermocouple placed in the center of the back of the die, 5/8" 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.

B. 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 1/8th inch diameter to match the size of the dedicated thermocouple holes. Inconel sheathed, Type K 1/8 inch thermocouples are required.

C. Digital data recorder capable of capturing an entire heat treating cycle including heat-up, austenitizing, and quench to below 300 °F. 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.

D. 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.

III. Steel Purchase

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

IV. Tool Source / Heat Treater Consultation

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.

V. Holework, Coupons & Test Criteria

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

The coupon shall be attached (tack welded) to the insert detail at the center of the largest surface (firmly in contact, no gaps) and be subjected to the same heat treat as the insert. 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 section II) 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.

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 6" inches thick. The length (grain direction) may not exceed 24". The width may not exceed 14". The 2 ½" 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 difference of the high and low values or 8 Ft. –Lbs. whichever is greater. Individual values below 6 Ft. – Lbs. will be cause for rejection.

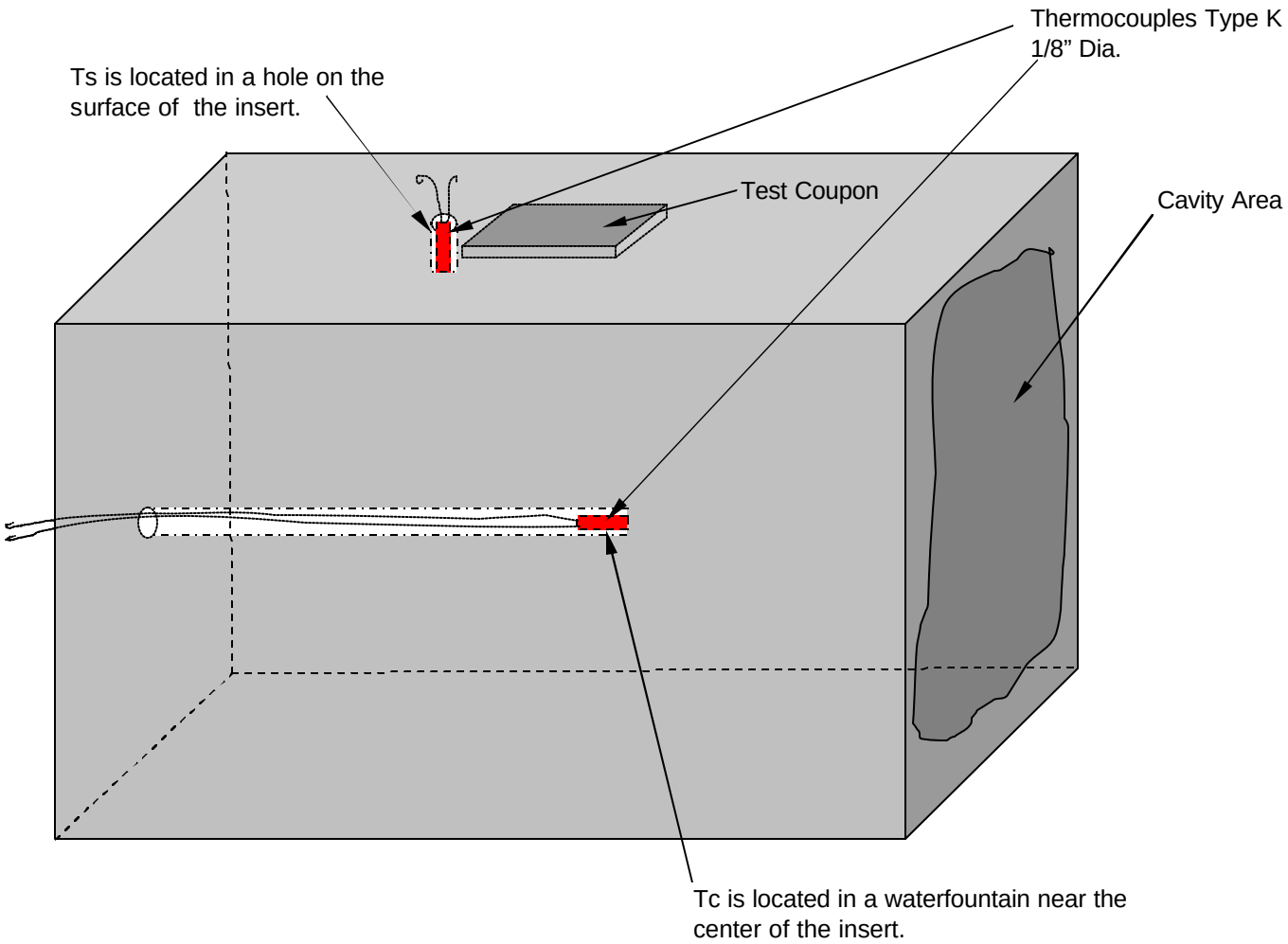
If an insert fails commercial heat treat then the die caster must be notified by the tool source. The insert may be heat treated again after annealing. A surrogate coupon shall be attached meeting the requirements of the previous paragraph or the coupon may be derived from left over stock in the original sampling plane of the insert.

VI. Heat Treatment

All heat treatment processes are to comply with the following requirements. Deviations must be requested by the heat treater in writing and approved by GM. Rarely, will deviations be permitted. Attach two thermocouples to the piece to measure surface Ts and core Tc temperatures. (The Ts thermocouple hole is located and machined (by the Tool Source) on the center of the back of the insert 1/8" dia. x 5/8" deep. This location is mandatory unless conditions are such that a proper heat treat will not occur unless the insert is placed on its back. Then the heat treater is responsible for proper placement of the hole.) Use of this dedicated thermocouple hole is mandatory. If the heat treater receives a tool that does not have this hole properly drilled in it; the heat treater shall either return the tool to the machine shop or drill the hole themselves. It is the responsibility of the heat treater and the tool builder to determine proper hole placement. Heat treatment without this dedicated thermocouple hole may be cause for rejection.

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.

Heat Treat Insert



6.1 Stress relieving will be at the option of the heat treat source. Some complex pieces may need stress relief. Stress relieve to remove cold work effects due to rough machining. Heat to 1100 -1150 °F and hold Tc at 1100-1150 °F for 60 minutes. Heat at a rate not exceeding 400 °F per hour. Cool to 800 °F at a rate not exceeding 200 °F per hour and then air cool to below 150 °F. Time, temperature and rates are based upon the core thermocouple, T_c.

6.2 Austenitize – See Table A at end of specification for approved austenitizing temperatures. Attach surface (Ts) and core (Tc) thermocouples to the piece as indicated above. Ts must be inserted in the dedicated thermocouple hole as described in paragraph 3.0. 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. If in doubt consult the GM Metallurgist. Load into cold furnace Heat to 1100-1200 °F at a rate not exceeding 400 °F per hour based upon Tc and hold until Ts – Tc is less than 200 °F. Continue heating to 1575 $\pm$ 25 °F at a rate not exceeding 300 °F per hour based upon Tc and hold until Ts – Tc is less than 100 °F. Rapidly raise furnace gas temperature 10°F above the austentizing temperature (eg. 1900°F + 10°F = 1910°F). When Ta – Ts <= 5°F then hold for 30 minutes; at the end of the hold quench as rapidly as possible.

6.3 Quenching - Inserts should all be quenched at 9 bar or higher. In any case, quench pressure should be as high possible without risk to the tool to improve the metallurgical properties**.**

6.4 Interrupt - Method 1

Gas quench to 800°F plus or minus 15°F 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 when Ts first reaches 800°F 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, or (2.) Ts reaches 750°F or (3.) 5 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 during interrupt additional cooling should be used to keep Ts between 775°F and 825°F during the interrupt. Quench rate shall be a minimum of 70°F per minute down to 1000°F, that is, it

will take less than 13 minutes to quench down to 1000°F from the austenitizing temperature (Ta).

Quench gas pressure after interrupt shall be the same as before interrupt. Resume quench to 300 °F (Tc) 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 Ts is below 120 °F. The use of floor fans or open doorways is absolutely forbidden.

Interrupt - Method 2

The heat treater using his own discretion based on good technical data may delete the 800°F hold from the quenching process and simply quench down to 300°F (based on Tc) at a rate exceeding 70°F per minute (based on Ts down to 1000° F). The 9 bar quench pressure may be reduced once the insert temperature is below 800 °F consistent with the fan horsepower and thermal balance requirements of the furnace. Quenching must remain as rapid as possible.

NORTHSTAR Water Jackets- Quench with full 10 bar pressure with no interrupt. Position jackets so the quench gas flows directly through the cylinder bore holes in the insert cavity to achieve maximum quench rate. This would mean the 5" x 17" plane will be parallel to the ground in most cases. Rc 42-44 required.

6.5 Upon cooling Ts to 120 °F, immediately temper at 1000-1050 °F for one hour per inch of thickness, two hours minimum. Cool to room temperature in still air and measure hardness. Again, no floor fans or open doorways allowed.

6.6 Retemper at 1025-1140 °F to obtain the specified hardness of Rc 44-46 except for Northstar water jackets, which must be hardened to Rc 42-44. (Front wheel drive side and bottom cores are now the normal Rc 44-46.) Contact 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 to room temperature and measure hardness. If desired hardness is attained, retemper at 1000-1050 °F 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.

VII. Requirements for EDM Processed Inserts

7.1 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.

7.2 Before stress relieving, stone or sand blast insert to remove the white layer.

7.3 Stress relieve after finish machining - Heat the insert to 1000°F or 50 °F below the highest tempering temperature if known. Hold it for one hour per inch of section thickness or for two hours minimum.

7.4 Cool in still air to room temperature.

VIII. Stress Relief (General)

8.1 Stress relieve all inserts when all machining operations are complete and the insert is in a ready to ship condition. This is a requirement regardless of EDM status. Stress relieve per the requirements of 7.3 and 7.4 Only approved or provisional suppliers of heat treat may provide stress relieving service, no exceptions no matter what the reason for stress relieving.

8.2 Both the heat treat supplier and the tool supplier must recheck hardness of the tool after final stress relief. Both parties must check a minimum of 3 areas on the tool and record the average. Any average hardness checks that fall out of the specified hardness range given in paragraph 4.6 must be reported both verbally and in writing to the GM Metallurgist within 24 hours of the test. The heat treat supplier shall record the post stress relief hardness for all inserts in an Excel spreadsheet that can be made available to GMPT Bedford on request. The tooling supplier must record the final hardness after stress relief on the HT-101 form.

IX. Welding

9.1. Inserts that have weld in the cavity area before heat treat must be annealed by the heat treater before commencing heat treat. The Tool Source must notify the heat treater of existing welds.

9.2. Inserts welded in the cavity area after heat treat must be sent to the heat treat source to be stress relieved. Stress relieve the insert at a temperature 50 °F below the highest tempering temperature using thermocouple placement as defined in 3.1. Hold at this temperature for 60 minutes. Heat at a rate not exceeding 400 °F per hour. Cool to 800 °F at a rate not exceeding 200 °F per hour and then air cool to below 150 °F. Time, temperature and rates are based upon the core thermocouple, Tc. The tooling supplier must check the hardness of the tool after this stress relief per the requirements in Section 8.2

X. Documentation Requirements

10.1 Die Shop Responsibility

10.1.1 Issue a Heat Treatment Purchase Order or Release to the selected heat treatment source containing the following information:

- Quantity of each detail to be heat treated
- Detail name
- Detail number
- GM drawing number or CAD model name
- GM part number
- GM serial number

10.1.2 Furnish the Heat Treat Source the following information on a shipping document accompanying each insert shipment per attached form # HT101:

- Builder's name (Die shop name).
- Shipment date.
- GM Part Number.
- GM Detail Number.
- GM Drawing Number or CAD model name.
- GM detail name.
- Quantity of each detail being shipped.
- Brand name of steel.
- Shipping weight of each detail.
- GM serial number.
- Die Number (if known)
- Caster's Heat Treat Source P.O. number
- Required final hardness (Rc).

- Die steel's heat number

10.1.3 All heat treat coupons returned to the Tool Source must be stored for three years.

10.1.4 Maintain shipment/receipt records of each shipment of steel shipped for heat treatment for five years.

10.2 Heat Treat Source Responsibility

10.2.1 Submit each invoice to the proper party for payment of heat treatment of steel received from GM Tool Sources with the following information:

- Quantity of each detail heat treated and serial numbers.
- GM detail number.
- Weight of each detail heat treated.
- Type of heat treatment furnished.
- Heat Treat Purchase Order number.
- GM Purchase Order item number (for insert build).
- Testing Lab report - acceptable heat treat.

10.2.2 Complete GM form #HT101 and return it and the insert to the die builder after approval by the testing lab. Conformance to DC-9999-1 specifications must be certified to General Motors via GM form #HT101 with the following information:

- Equalization temperatures and times at temperature.
- Furnace temperature at start of first temper.
- Temperature, time at temperature, and hardness for all tempers and final stress relieve temperature.
- As-quenched hardness no longer required.
- Quench interrupt temperature and quench rate.

The Tool Source will forward a copy of the HT101 form to the GM Metallurgical Lab.

10.2.3 Maintain sufficient records of each Heat Treat Purchase Order to comply with this procedure (i.e. furnace charts, process sheets, etc.) for a minimum of five years.

XI. Testing Requirements (Heat Treat)

11.1 Charpy Impact, microstructure (to include carbide precipitation, bainite/pearlite and hardened structure, use NADCA 207-2003 “HS” Heat Treated Microstructure Reference Chart), surface condition (decarburization, carburization, nitride effects) and hardness tests will be performed on the test coupon removed from the insert. Five Charpy impacts will be broken. The high and the low values will not be used in computing the average, the remaining three values will be used to compute an average which must be the greater of 8 ft-lbs. or 80% of the annealed Charpy average (ideal lab heat treat at material test) minus one half the difference between the high and low values of the the five heat treat Charpy impacts. Any single value of the three shall be no less than 6 ft-lbs. The hardness shall be the same as the insert.

Example: HT Charpy values -- >>> 14, 14, 16, 13,15.. Material Charpy = 16
Average = (14+14+15)/3 = 14.3 ; half difference = (16 – 13)*.5 = 1.5
Pass / Fail criteria = .8*16 – 1.5 = 11.3 .. 14.3 > 11.3 thus heat treat has acceptable Charpy impact value.

The microstructure specimen will be etched with a 5% Nital solution and be prepared per ASTM E3. The microstructure shall consist primarily of tempered martensite and some bainite. There will be no evidence of pearlite, retained austenite, decarburization, carburization or excessive intergranular precipitation.

11.2 Frequency of testing - 100% . Every insert must be tested.

11.3 Testing to be performed at an outside independent lab. See the listing at the end of the specification. The test results are to be forwarded to the Tool Source and Heat Treater. The results and the completed HT101 form must be sent to the GM Metallurgical Laboratory.

11.4 The heat treater will make at least 5 hardness checks (four corners and a central region) on the insert per ASTM E10, E18, A956, E384.

XII. Miscellaneous

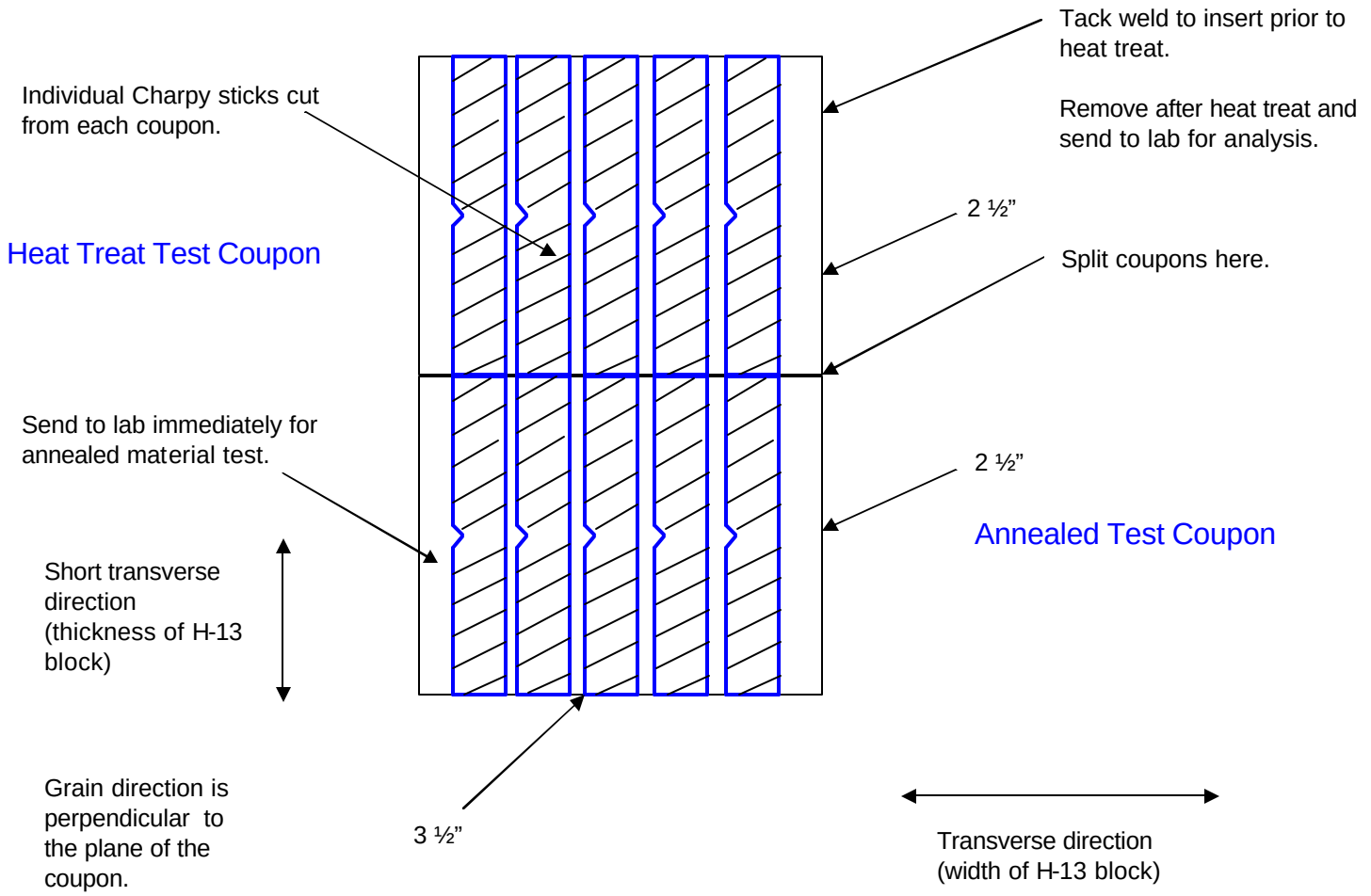
The GM metallurgical lab will inspect & store HT 101 forms and independent lab reports as part of its records. Any heat treat that deviates from this procedure will be reported in writing to the Superintendent, Manufacturing Engineering & Senior Engineer, Tooling Procurement.

XIII. Patent Liability

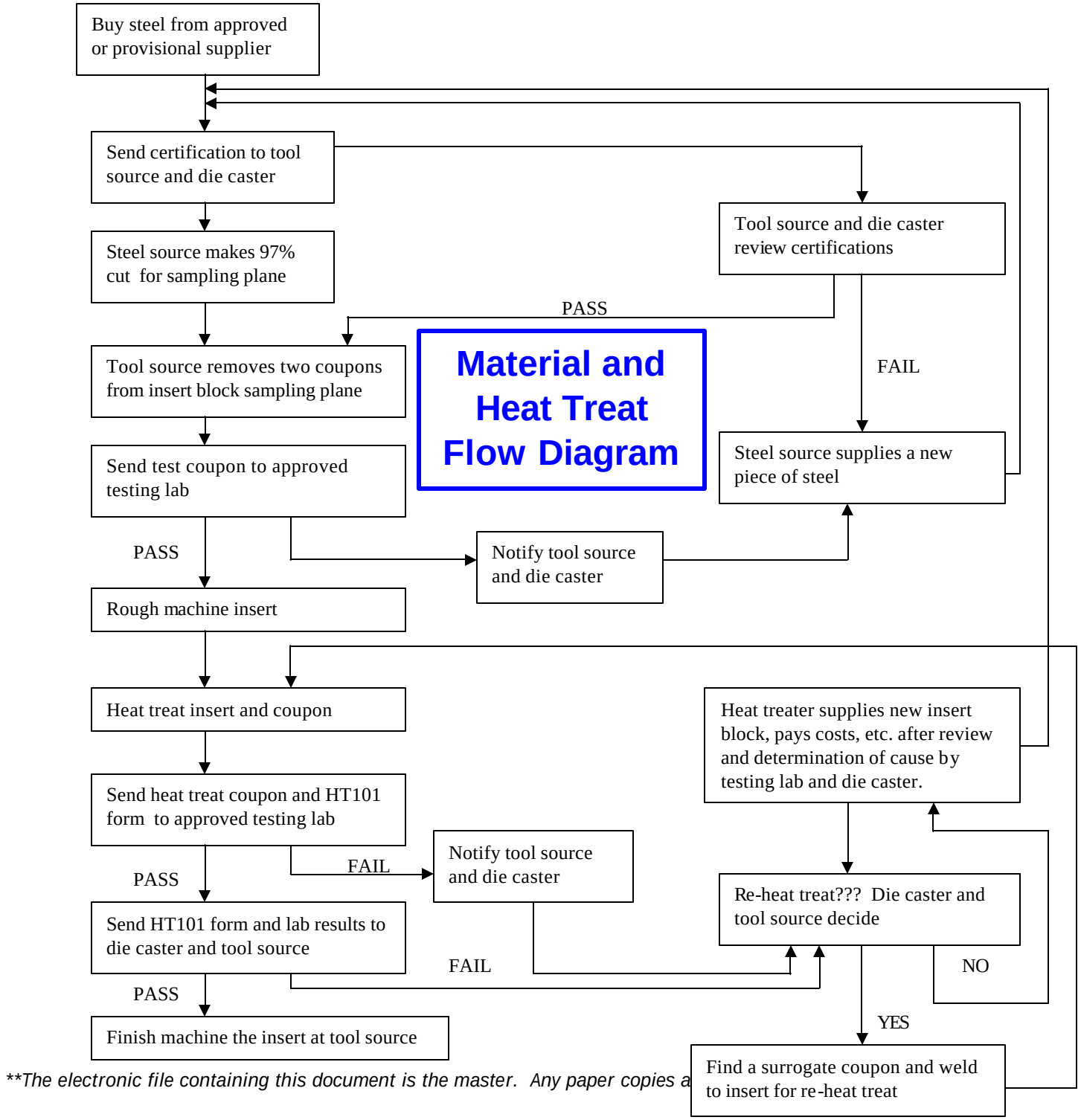
By accepting this specification, the supplier agrees to defend, protect, and save harmless the buyer, its successors, assignees, customers and users of its products against all suits at law or in equity, and from all damages, claims and demands for actual or alleged infringement of any United States or foreign patent or copyright by reason of the use of sale of the material ordered.

Note:

Approved for Issue...Documentation of Approval on File in GM Powertrain-Bedford Tool Engineering Department



Test Coupon Details


Material and Heat Treat Flow Diagram
Buy steel from approved or provisional supplier
Send certification to tool source and die caster
Steel source makes 97% cut for sampling plane
Tool source removes two coupons from insert block sampling plane
Send test coupon to approved testing lab
PASS
Rough machine insert
Heat treat insert and coupon
Send heat treat coupon and HT101 form to approved testing lab
PASS
Send HT101 form and lab results to die caster and tool source
PASS
Finish machine the insert at tool source
Tool source and die caster review certifications
PASS
FAIL
Steel source supplies a new piece of steel
Notify tool source and die caster
FAIL
Notify tool source and die caster
FAIL
Heat treater supplies new insert block, pays costs, etc. after review and determination of cause by testing lab and die caster.
Re-heat treat??? Die caster and tool source decide
NO
YES
Find a surrogate coupon and weld to insert for re-heat treat

General Motors
HEAT TREAT DOCUMENTATION
FORM HT101

Tool Builder_____ Job No._____Date_____

Part Description _____ Serial No. _____

PTB Part No. _____ Item Code _____

PTB Detail No. _____ Ship Wt. Ea. _____

PTB CAD No. _____ HT P.O. No. _____

Steel Brand Name _____ No. of Pieces _____

Specification _____DC-9999-1_____ Material _____

Required Hardness _____ Ship Date _____

Heat Number _____

Builder's Signature _____Telephone_____

Heat Treat Source:_____

Operation	Temp	Time	Furn	Hardness
Anneal				
Normalize				[redacted]
Stress R	**Optional**			
Pre-Heat				
Pre-Heat				
High Heat				
Quench Rate				
Quench Pressure				
Interrupt Temp				
Temper #2				
Temper #3				
Post Stress Relief				

We certify that the above statements are true and correct and that all temperatures were obtained with standard and approved equipment.

Final Inspection _____Rc Test Blocks Attached: Yes ☐ No ☐

Work Order No. _____

Authorized Signature _____

Approved Suppliers

Supplier	Location	Type
Uddeholm Steel	Hagfors, Sweden	H-13 & Dievar
Bohler Steel	Kapfenberg, Austria	H-13 & W403 VMR
Thyssen Steel	Edestahl, Germany	H-13
Aubert & Duval	Les Ancizes, France	ADC3
A. Finkl & Sons	Chicago, IL	H-13
Ellwood Specialty Steel	Ellwood City, PA	H-13
Erie Steel Treating	Toledo, Ohio	Heat Treat
FPM	Elk Grove, Illinois	Heat Treat
Century Sun	Traverse City, MI	Heat Treat
Thyssen-Marathon	Windsor, Ontario	Heat Treat

Today's Date Is June 02, 2005

Revised:2/2/2005

Note: This is the master file for the approved and provisional suppliers.

Provisional Sources

Supplier	Location	Type
Kind&Co	Wiehl, Germany	H-13
Kind&Co	Wiehl, Germany	TQ1
Hitachi Steel	Yasugi Works, Japan	DAC-55
Dunn Steel (Latrobe)	Detroit, MI	DSS-13
Dynamic Metal Treating	Canton, MI	HT
Hansen - Balk	Grand Rapids, MI	HT
Paulo Products	Nashville, TN	HT
Bodycote - Sturtevant	Strutevant, WI	HT
Bodycote - St. Louis	St. Louis, MO	HT
Kind&Co	Wiehl, Germany	HT
TAG srl	Dolzago, Italy	HT
Thermo Tech	Mississauga,Ontario	HT
Therm - Tech	Waukesha, WI	HT

Test Pieces:

Material = 25 pcs	15 pcs >= 10" Thick
Heat Treat = 45 pcs	25 pcs >= 10" Thick

Approved Labs

Supplier	Location	Type
Bodycote Materials Testing	Skokie, IL	Lab
Climax Research Services	Wixom, MI	Lab

Today's Date Is June 02, 2005

Revised:2/2/2005

Note: This is the master file for the approved and provisional suppliers.

Austenitizing Temperatures

Material	Austenitizing Temperature
H-13	1900°F +/- 10°F
KDA1	1900°F +/- 10°F
DAC55	1900°F +/- 10°F
ADC3	1850°F +/- 10°F
1.2367(3% moly) alloy materials (LOW SILICON)	1900°F +/- 10°F
1.2367(3% moly) alloy materials	1925°F +/- 10°F

Today's Date Is June 02, 2005

Revised: 2/2/2005

Note: This is the master file for the approved austenitizing temperatures of the above listed materials.