GUIDELINES FOR USE OF

ASME CODE CASE N-483

Prepared by

Electric Power Research Institute

Joint Utility Task Group

Code Case N-483 Technical Working Group

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PSE
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NOTICE

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ABSTRACT

This report addresses product verification testing to reasonably assure that the supplied material is as represented by the Certified Material Test Report (CMTR). The principal focus is on nondestructive methods which are appropriate to confirm that the product meets the material specification while not repeating the destructive tests which are required by the material specification. Established national standards have been referenced to the maximum extent practical. Tolerances are provided based on the repeatability and reproducibility of testing methods. This report provides technical input for consideration by the American Society of Mechanical Engineers (ASME) in further development of material testing requirements similar to those addressed by Code Case N-483.

ACKNOWLEDGMENTS

The following individuals were ongoing members of the Code Case N-483 Technical Working Group (TWG) which is part of the EPRI Joint Utility Task Group. As such they made significant contributions to the development of this guideline by attending meetings, reviewing/commenting on various drafts, and writing portions of the document.

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TABLE OF CONTENTS

1.0 INTRODUCTION

ASME Code Case N-483 "Alternative Rules to the Provisions of NCA-3800, Requirements for Purchase of Material Section III, Division 1, provides a means for: 1) purchasing materials from suppliers who do not have an NCA-3800 quality assurance program, 2) testing to verify the material is as represented on the CMTR, and 3) using the material in ASME Section III applications.

The Code Case does not provide the specific requirements for material testing. In response to a request from interested utilities, the Plant Support Engineering (PSE) program of the EPRI Nuclear Power Division undertook development of a guideline to provide utility recommendations on implementation of the Code Case. A Technical Working Group (TWG) was formed under the Joint Utility Task Group (JUTG) to develop this guideline. The TWG was comprised of experienced utility engineers and consultants knowledgeable of the issue. Technical experts from Bechtel Corporation and Reedy Associates provided recommendations on material testing requirements. This document is a consensus product of the TWG. It is intended to provide technical input and recommendations to the appropriate ASME Committees (e.g., Sections III and XI) for consideration during the anticipated development of specific details on material testing requirements similar to those provided in Code Case N-483.

Code Case N-483 allows Owners, operating under the provisions of ASME Section XI and 10CFR50 Appendix B, to obtain materials from sources which do not have an NCA-3800 program, subject to restrictions which are identified in the Code Case. Code Case N-483 provides Owners and N-type Certificate Holders the same alternatives. This document has been prepared from the Owners viewpoint.

The use of material sources is similar to the approach of ASME Section I for boilers, and ASME Section VIII, Division 1 and Division 2 for pressure vessels, where Certified Materials Test Reports (CMTRs) are required.

While providing greater flexibility for the source(s) of material in comparison to ASME Section III, NCA-3800, the Code Case is positive and more restrictive in that it requires additional verification testing which had not been required previously. This report proposes specific requirements for the verification testing. The purpose of verification testing is to increase confidence that the supplied material is as represented by the CMTR, and to help screen out errant or counterfeit materials. The material testing prescribed herein is a reasonable method for verifying the material is as represented on the CMTR. The scope of material verification testing prescribed by this guideline is limited to that necessary to reasonably assure the validity of the CMTR and is not intended to duplicate each chemical and mechanical test conducted when the CMTR was produced by the manufacturing mill. Material verification testing may be performed using different methods and techniques. These methods are addressed in Section 4 of this report.

The Code Case also has requirements for non-destructive examination (NDE) required by ASME Section III, NX-2500. Section 5 of this report addresses NDE requirements.

These guidelines are not appropriate for the acceptance of weld filler metals unless all the applicable material specification testing requirements are repeated.

2.0 ESTABLISH TRACEABILITY TO CMTR

Each piece, or container of small items, of each heat or lot shall be procured with a CMTR and inspected as follows:

(a) Check identification of material for marking of the applicable material specification, grade, heat number, or heat code of material for traceability to the CMTR. Symbols or code numbers when used shall be explained on the CMTR.

(b) Check marking of containers of small items for traceability to the CMTR.

Pieces, or containers of small items, with material identification markings not traceable to the CMTR shall be considered unacceptable.

3.0 MATERIAL MARKINGS DOCUMENTED ON CMTR

The N-type Certificate Holder or Owner shall assure that the material identification markings on the material are documented on the Certified Material Test Report.

4.0 MATERIAL TESTING

Purpose

The purpose of verification testing is to increase confidence that the supplied material is as represented by the CMTR, and to help screen out errant or counterfeit materials. The Code Case should require the Owners to test a sample of each heat or lot to verify conformance to the chemical composition and ultimate tensile strength requirements of the material specification. If the Owner chose to replicate the tests performed by the material manufacturer as reported on the CMTR, that would be acceptable, but not required. The test methods contained in the material specifications are often not suitable for verification testing. These tests generally require that all or part of the material be destroyed to obtain the required physical or chemical test samples. Additional mechanical tests such as impact, bending or flattening tests destroy full size portions of the material. Such testing methods may be inappropriate.

The material testing prescribed herein is a reasonable method for verifying that the material is as represented by the CMTR. The scope of material testing prescribed by this guideline is limited to that necessary to reasonably assure the validity of the CMTR and is not intended to duplicate each chemical and mechanical test conducted when the CMTR was produced by the manufacturing mill. Material verification testing may be performed using different methods and techniques.

This section on material testing is further subdivided into sections on mechanical testing, chemistry testing, and sample selection.

4.1 Mechanical Test for Ultimate Tensile Strength and Hardness

The following mechanical testing is required:

(1) A sample of each heat/lot of ferritic and martensitic steels shall be hardness tested for correlation to ultimate tensile strength of both the value specified in the material specification and the value reported in the CMTR.

(2) A sample of each heat/lot of ferrous and non-ferrous materials shall be hardness tested for evaluation of the hardness value when the material specification specifies minimum or maximum hardness limits and the CMTR reports a hardness value. If a hardness test is performed per item (1) above it need not be repeated.

The samples to be tested shall be selected without bias. Recommendations on selection of sample sizes are provided in Section 4.3.

One of the hardness testing methods described below shall be used to verify the ultimate tensile strength and/or hardness.

(a) Standard Test Method for Brinell Hardness of Metallic Materials, ASTM E 10.

(b) Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials ASTM E 18.

(c) Standard Test Method for Indentation Hardness of Metallic Materials by Portable Hardness Testers, ASTM E 110.

(d) Operating Instruction Hardness Tester Equotip
Owners Manual and Recommended Practices
Proceq SA, Zurich, Switzerland

Brinell and Rockwell hardness values for ferritic and martensitic steel shall be converted to tensile strength using the conversions established in ASTM A 370.

Equotip hardness values shall be converted to ultimate tensile strength (UTS) using the equation $UTS=0.265 \times L_D - 29.891$ ksi, where L_D is the Equotip hardness value. This conversion is valid only to 90 ksi. Section 4.1.3 discusses the basis for this conversion. Appendix A provides guidance for the use of the Equotip hardness tester.

Equotip methods shall not be used above 90 ksi until a strength to hardness correlation is established empirically.

When the material specification specifies minimum or maximum hardness limits, the hardness requirements should be evaluated utilizing the measured hardness values directly or hardness conversions in ASTM A 370 or the Equotip Conversion Tables as appropriate.

Each test shall consist of one of the following:

Equotip: Each Equotip test shall consist of five readings. The high and low values shall be deleted and the remaining three values averaged to determine the hardness value.

Brinell or Rockwell: Brinell and Rockwell require only one test to determine the hardness value.

Alternatively, testing to verify conformance to the ultimate tensile strength of the material specifications may use the same procedures, methods and specifications as required by the material specification, where appropriate.

4.1.1 Acceptance Criteria for Mechanical Test

Ultimate tensile strength and hardness values reported on the CMTR shall meet the requirements of the material specification.

Hardness test results shall be evaluated as follows:

(1) The UTS converted from the measured hardness shall meet both of the following:

(a) be within 10% of the UTS of the material specification; and

(b) be within 20% of the UTS reported on the CMTR.

(2) The measured hardness shall meet all of the following:

(a) be within 10% of the specified hardness when the material specification specifies minimum or maximum hardness limits; and

(b) be within 20% of the UTS reported on the CMTR; and

When a material specification requires hardness in a specific measurement scale, the 10% tolerance should be applied to the specified value, not to the measured value, which may be reported in other units prior to conversion to the specified units.

These same tolerances also apply if alternate UTS and hardness testing per the material specification is repeated.

4.1.2 Retests

If an item does not meet the acceptance criteria, it is acceptable to perform two retests of the item. Both retest results shall be acceptable for the item to be accepted.

When performing the retests, different test methods may be used which will provide more accurate results, and material surfaces may be reprepared.

Only if retest results are unacceptable is it necessary to increase the sample size. If one piece of the retested sample fails, a second sample shall be tested. Another sample failure shall reject the heat or lot, or require testing of each piece. All failed pieces shall be considered unacceptable.

4.1.3 Technical Basis for Mechanical Test

The ultimate tensile strength verification relies on established relations between hardness and ultimate tensile strength. The correlation between UTS, and Brinell Hardness and Rockwell Hardness is published in ASTM A 370 for ferritic and martensitic steel.

The correlation between Equotip Hardness values and UTS was developed in the EPRI/NUMARC response to NRC Bulletin 88-05 and is reliable up to 90 ksi UTS. Figure 1 shows the results of the hardness to strength correlation tests. The correlation may be valid at higher strength levels, however there has been insufficient data in that higher range to provide a direct Equotip hardness to UTS correlation. This correlation was developed with carbon steel (ferritic) and does not apply to austenitic steels (e.g., type 304 stainless).

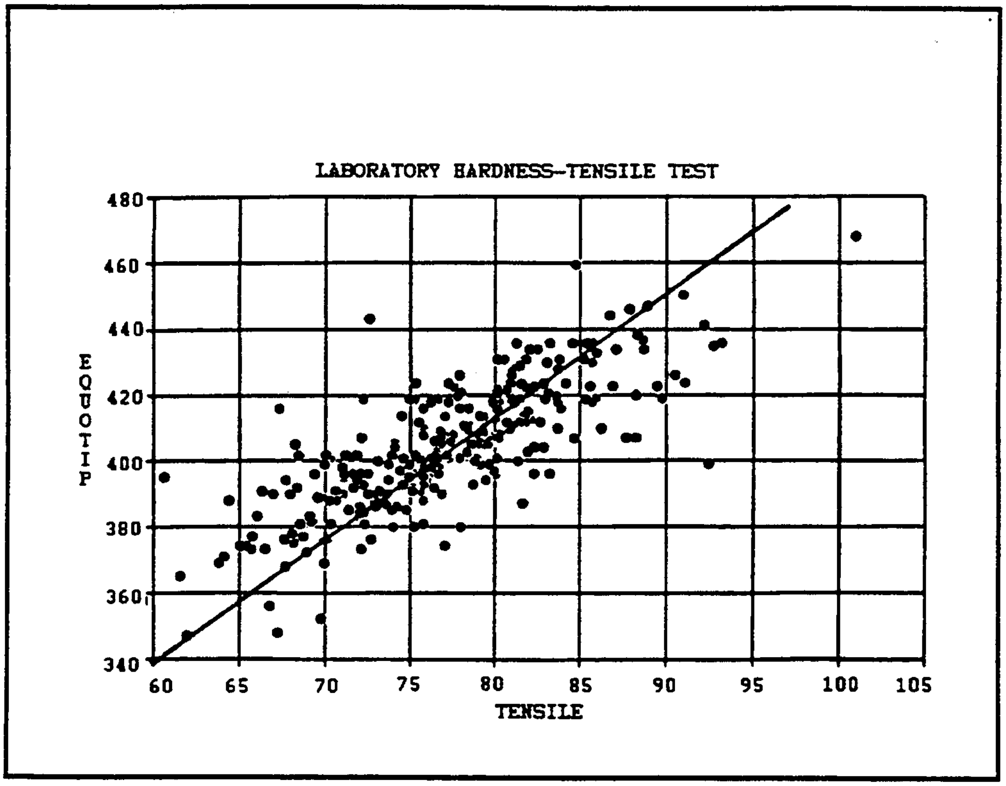

Figure 1
Equotip Hardness to UTS Conversion
(from NUMARC 88-01 "*Response to NRC Bulletin 88-05*")

4.1.4 Technical Basis for Mechanical Test Tolerances

Previous studies by the American Iron and Steel Institute (AISI) (Reference 1) have demonstrated that steel is not uniform and that there are variances in mechanical test results obtained on products compared to mill test reports. These variances have been shown to be as much as 20%.

The results of the EPRI/NUMARC testing in response to NRC Bulletin 88-05 showed that tensile test results can vary by as much as 10% from the specified minimum requirements. These tolerances have been accepted by NRC in resolution of NRC Bulletin 88-05.

4.2 Chemistry Test for Chemical Composition

Chemical composition may be verified in accordance with the Standard Methods, Practices and Definitions for Chemical Analysis of Steel Products, ASTM A 751. X-ray fluorescence spectrometers may be used for stainless steels as well as other materials (where carbon verification is not needed).

Chemical composition determination procedures shall comply with the relevant ASTM standards where these exist, and with the analytical apparatus manufacturers recommendations.

A sample of the heat/lot shall be tested for the metallic elements, and non-metallic carbon and nitrogen (for specific grades of stainless steel), identified in the material specification. The specific testing requirements are as follows:

Carbon and Low Alloy Steels

Verification testing for carbon and low alloy steels shall be performed for copper, nickel, manganese, chromium, molybdenum, vanadium (if specified) and columbium/niobium (if specified).

Stainless Steels

Verification testing for stainless steel shall be performed for chromium, nickel, molybdenum (if specified), carbon (if specified maximum is less than 0.04%) and nitrogen (if specified minimum is 0.10% or greater).

Other Metals and Alloys

Verification testing for all other metals and alloys (e.g., copper alloys, nickel alloy, aluminum alloys, copper-nickel, aluminum-bronze) shall be performed for those metallic elements (e.g., copper, aluminum, nickel, iron, manganese, zinc, lead, chromium, molybdenum) specified by the material specification. This verification testing is only required when the material specification requires a chemical analysis.

Additionally, carbon shall be verified when the material specification requires a minimum or maximum carbon content.

The samples to be tested shall be selected without bias.

Recommendations on selection of sample sizes are provided in Section 4.3.

Alternatively, testing to verify conformance to the chemical properties of the material specifications may use the same procedures, methods and specifications as required by the material specification, where appropriate.

4.2.1 Acceptance Criteria for Chemistry Test

The chemistry reported on the CMTR shall meet the requirements of the material specification..

Chemistry test for verification of chemical composition utilizing essentially nondestructive analyses of the prepared product surfaces shall be acceptable if the tested elements conform to the following:

(a) meets the chemistry requirements of the material specification including the product analysis tolerances contained in the material specification or in a referenced general requirements specification shall be applied. An additional 10% of the specified value shall be added to tolerances shown in the specification.

If specific product analysis requirements are not identified in the material specification, or by reference, the product analysis tolerances contained in ASTM A 480 shall be used for stainless steels regardless of product form, and, the product analysis tolerances in ASTM A 29 shall be used for carbon steel and alloy steel (not stainless) regardless of product form. An additional 10% of the specified value shall be added to the tolerances shown in the specification.

This additional 10% shall be added to the product analysis tolerance. For example, if the material specification minimum is 1% and the product analysis tolerance is 0.2%, the additional 10% tolerance will result in the final acceptance minimum of $1 - (0.2 + 0.1) = 0.7\%$.

AND

(b) the chemistry results are within 20% of the value reported on the CMTR.

The verification materials tests conducted using the standards and methods described in the ASTM material specifications shall be accepted if the results meet the requirements of the material specification, including applicable product analysis tolerances. The same tolerances stated above also apply.

4.2.2 Retests

If an item does not meet the acceptance criteria, it is acceptable to perform two retests of the item. Both retest results shall be acceptable for the item to be accepted.

When performing the retests, different test methods may be used which will provide more accurate results, and material surfaces may be reprepared.

Only if retest results are unacceptable is it necessary to increase the sample size. If one piece of the retested sample fails, a second sample shall be tested. Another sample failure shall reject the heat or lot, or require testing of each piece. All failed pieces shall be considered unacceptable.

4.2.3 Technical Basis for Chemistry Test

Analysis of specified metallic elements is sufficient when combined with the ultimate tensile strength test to confirm the validity of the CMTR and hence compliance with the material specification.

Verification testing methods may take advantage of modern chemical analytical apparatus which operates on prepared material surfaces and are essentially nondestructive. The chemical analytical testing methods are referenced to ASTM A 751 and have established bases of acceptance in industry. Optical emission, X-ray emission and X-ray fluorescence spectrometric methods have been identified together with combustion and wet chemical methods.

Many of the analytical methods are applied to carefully prepared surfaces and are essentially nondestructive. Spark affected metal from optical spectrographic methods can be buffed off to eliminate any potential damage. The surface preparation areas are generally in the range of one inch diameter although some equipment will work on smaller areas. Accuracy may be reduced on small samples. Surface preparation is critical to successful application.

The identified methods are sufficiently accurate to confirm conformance with the material specification. Some methods have broader ranges of application, and some achieve greater accuracy. The users need to evaluate the methods in relation to the application. Not all spectrometric methods can determine carbon content. It may be necessary to remove small samples from low carbon stainless steel (for carbon and nitrogen verification), and aluminum alloy (for aluminum verification).

Carbon and Low Alloy Steels

Manganese limits are usually specified for the carbon steels permitted for ASME Section III construction (e.g., SA-105, SA-106). Therefore, the manganese analysis combined with hardness measurements provides a good check on the identity of the material. Together with carbon, the elements listed to be checked are those which most strongly influence the weldability of carbon steel. These elements are also the ones that are found in the low alloy steels permitted in ASME Section III construction. The proposed limits should give positive identification of the steel and insure proper weldability.

Although carbon, silicon, phosphorus and sulfur are found in all steels, they cannot be analyzed by common portable analysis equipment. Carbon analysis is not needed because the hardness check will provide reasonable assurance that the carbon limits have been met. The silicon levels for the carbon and low alloy steels used in ASME Section III construction have considerable overlap and the main purpose of the silicon addition is for deoxidization practice; therefore, a silicon analysis would not be of particular benefit in confirming the grade of the sample. Modern steel making practices are such that they produce sulfur and phosphorus contents that are considerably below the allowed maximums. Therefore, it is not necessary to check for these elements in the verification analysis.

Stainless Steels

The corrosion characteristics of stainless steels are controlled by carbon, chromium, nickel and molybdenum contents. The elevated temperature properties of nitrogen bearing stainless steels are strongly influenced by nitrogen content.

Carbon analysis is required only for low carbon grades (L-Grades) of stainless steel because for these grades low carbon is critical to performance in corrosive service. For other grades of stainless steel commonly used carbon is chiefly a strengthening agent. If the required strength is verified, and is not excessive, there is little concern for the carbon content.

Other Metals and Alloys

The metallic elements are those that control the properties of these alloys. Generally, these alloys are produced to a low carbon content, however, when a carbon minimum or maximum is specified it is to ensure high temperature properties. In this case it is prudent to check the carbon content.

4.2.4 Technical Basis for Chemistry Test Tolerances

The product analysis tolerances provided in ASTM Standards are reasonable for product analysis testing by the manufacturer, based on the accuracy of most analytical methods and product variances. The accuracy obtained with portable instruments analyzing material surfaces, is dependent on the analytic method and upon the surface preparation and size of the item. The ASTM product analysis tolerances have been established based on laboratory methods and mill testing. For testing by the Owner, an additional 10% is added to the ASTM product analysis tolerances to account for non-homogeneity of the material and variations in the accuracy and reproducibility of test results using different test methods and testing available material locations since sectioning them would destroy them..

When an analytical apparatus has a limiting precision which is greater than the product analysis tolerance, the test accuracy may be improved by repeated analysis and improved surface preparation. Also, other analytical methods should be considered.

The AISI study cited previously reported that variations in product analysis chemical tests varied by more than 20% from the ladle analysis values reported by the mill. For this reason the product analysis results are permitted to vary from the CMTR values by as much as 20%.

4.3 Sample Selection

The N-type Certificate Holder or Owner shall test a sample of the number of pieces in each heat or lot received from each supplier to verify conformance to the chemical composition and ultimate tensile strength requirements of the material specification. If one piece of the sample fails, a second sample of equivalent size to the first sample shall be tested. Another failure shall reject the heat or lot, or require testing of each piece. All failed pieces shall be considered unacceptable.

Historically, sample selection has been based on a statistical approach. MIL-STD 105 is an example of this approach and has been frequently used in the nuclear utility industry to develop sampling plans.

However, other approaches with a sound technical basis for developing sampling plans are also available. One of these other approaches currently being utilized in the nuclear industry is based on EPRI NP-7218 "Guideline for the Utilization of Sampling Plans for Commercial-Grade Item Acceptance (NCIG-19).(Reference 2). The approach provided in NP-7218 combines a technical evaluation of the factors which are representative of product quality with a statistical basis. This approach provides a high level of assurance of product quality while minimizing the sample size. Depending on the outcome of the technical evaluation of factors affecting product quality, different tables of recommended sample size (i.e., normal, reduced, and tightened) are provided.

Because of the types of products and controls applied during manufacture of those products, the approach provided in NP-7218 appears particularly well-suited to use in application of the Code Case. The "reduced" plan may be appropriate for material procured with a CMTR while the "tightened" plan may be appropriate for material procured with a Certificate of Conformance.

5.0 NX-2000 REQUIREMENTS

The Owner shall perform any applicable tests required by NX-2200, NX-2300, or NX-2400 that have not already been performed by the material manufacturer and shall perform the applicable examinations and repairs required by NX-2500.

The Owner shall verify that all applicable tests and examinations required by NX-2200, NX-2300 and NX-2400 are documented on the CMTR. If such test or examinations have not been performed by the material manufacturer they shall be performed by the Owner. In addition, the Owner shall perform all applicable examinations required by NX-2500.

The Owner or the Owner's agent shall perform the NDE examinations under the Owners ASME Code Section XI program meeting all the requirements of NX-2500. Personnel may be qualified in accordance with ASME Section XI in lieu of Section III. Alternatively, applicable non-destructive examinations required by NX-2500 may be performed by an organization qualified under ASME Code Section III using the same procedures, methods, and specifications as required by NX-2500.

NDE shall be done per the ASME III Code year as applied to the purchase of the material.

6.0 PROCEDURES AVAILABLE TO ANI

The procedures for accepting material in accordance with this Case shall be made available to the Authorized Nuclear Inspector prior to acceptance of the material.

7.0 INCLUDE TEST RECORDS WITH CMTR

Use of this Code Case shall be indicated on the material certification records. Records of all testing shall be included with the Certified Material Test Report. These records shall be made available to the Authorized Nuclear Inspector.

8.0 REFERENCES

1. American Iron and Steel Institute "The Variations of Product Analysis and Tensile Properties Carbon Steel Plates and Wide Flange Shapes", September 1974. This document is included as Appendix C to NUMARC 88-01 "Response to NRC Bulletin 88-05".

2. EPRI Report NP-7218 "Guideline for the Utilization of Sampling Plans for Commercial-Grade Item Acceptance (NCIG-19)", June 1992

APPENDIX A - CONSIDERATIONS WHEN USING EQUOTIP

The following are some general, non-mandatory considerations when using Equotip hardness testers. Additional information is provided in operating manuals provided with the equipment.

1. The tester should be calibrated prior to use.

2. The tested surface shall be free or any surface coating or scale and have a smooth finish. For best results the surface finish should be equivalent to that produced by 120 grit abrasive or finer. Surface preparation shall cover an area large enough for at least five readings.

   NOTE: An excessively rough surface will produce inaccurate results and have a large variation in readings.

3. Surface preparation may be performed using grinders, flapper wheels, sanding or filing. Do not use wire wheels on the surface.

   Care must be used when selecting the location on the part for performing the tests. This is to avoid possible damage to areas such as bearing surfaces, seals, etc.

   When using power tools for surface preparation the following techniques must be used to prevent overheating or work hardening the surface.

   a. Do not exert sudden or excessive pressure when applying the abrasive tool to the test surface. Apply pressure gradually and uniformly over the test surface.

   b. Do not hold the abrasive tool on a localized spot. Keep the tool moving over the surface being prepared.

   c. Do not apply the abrasive tool for more than a few seconds at a time. Cool the test piece in water between applications if it becomes hot to the touch.

4. The following are recommended surface preparations based on product type and manufacturing processes.

   a. Castings, hot formed parts and parts that have been heat treated as the final processing step in their manufacture will normally have a rough surface and generally be dark in color due to scale or oxidation of the surface. These parts are also subject to decarburization, a shallow condition that may result in surface hardness lower than the hardness of the underlying metal.

Surface preparation for this type of part should consist of removing enough material to produce a smooth finish. This will frequently be adequate to remove any decarburization if it is present.

If test results are erratic or do not meet the acceptance criteria further surface preparation may be necessary.

Note that decarburization is restricted to the surface layer to a depth of 1/32" - 3/32".

b. Machined parts or cold formed parts are generally clean, silver bright in color and relatively smooth. These parts may be tested without surface preparation unless the machined surface is obviously too rough.

Decarburization is not as likely on these parts.

If test results are erratic or do not meet the acceptance criteria, additional surface preparation may be necessary.

c. Parts that have been case hardened by processes such as carburizing, carbo-nitriding, nitriding, flame hardening and induction hardening are intended to be significantly harder on the surface than in the core.

Case hardened surfaces will normally be quite smooth and frequently they will be polished. Do not remove any metal from the surface of a case hardened part. The test should be performed directly on the original surface in order to determine the hardness of the case and preserve the hardened surface.

Carburizing and nitriding processes normally produce case depths of 1/16" or less. Flame hardening and induction hardening can produce case depths of 3/16" and deeper. If core hardness is to be determined it may be necessary to section the part in order to get below the case.

5. The test piece should:

    a. Weigh at least 2 kg (4.4 lbs.)

    b. Be compact in shape, and have sufficient support below the tested surface.

    c. A test piece lighter than 2 kg or less than 1/4" thick shall be coupled to a thicker, heavier and non-yielding support.

       Coupling can be done either by locking the two pieces together in a clamping device, or by applying couplant at the interface between the bottom of the testing piece and the top of the supporting piece. The mating surface should be clean and flat and have a thorough coating of couplant.

6. When testing a curved surface whose radius of curvature is less than 30 mm (1-1/4"), a support ring needs to be used at the bottom of the impact device.

7. Ambient temperature of the test piece should be between 40° - 200°F.

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