SAE The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

AEROSPACE STANDARD

SAE AS7101

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Submitted for recognition as an American National Standard

NATIONAL AEROSPACE AND DEFENSE CONTRACTORS ACCREDITATION PROGRAM (NADCAP)

GENERAL REQUIREMENTS FOR MATERIALS TEST LABORATORY ACCREDITATION PROGRAM

1. SCOPE:

1.1 This standard establishes the minimum requirements for materials testing laboratories (MTL) accredited by NADCAP. The following test methods and processes for metallic material systems are covered in this standard.

a. Chemical
b. Mechanical
c. Metallography and Microhardness
d. Hardness
e. Corrosion and Oxidation
f. Mech. Test Specimen Preparation
g. Differential Thermal Analysis
h. Heat Treat of Specimens
i. Other Non-Conventional/Engineering Tests
j. Fastener Testing

2. REFERENCES:

2.1 Applicable Documents:

2.1.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AS7001	National Aerospace and Defense Contractors Accreditation Program (NADCAP) - Program Description
AS7002	National Aerospace and Defense Contractors Accreditation Program (NADCAP) - Rules for Implementation
AS7003	National Aerospace and Defense Contractors Accreditation Program (NADCAP) - Program Operation
AMS 2248	Chemical Check Analysis Limits - Wrought Corrosion and Heat Resistant Steels and Alloys, Maraging and Other Highly-Alloyed Steels
AMS 2249	Chemical Check Analysis - Titanium and Titanium Alloys
AMS 2259	Chemical Check Analysis Limits - Wrought Low-Alloy and Carbon Steels

2.1.1 (Continued):

AMS 2268 Chemical Check Analysis Limits - Cast Nickel and Nickel Alloys
AMS 2269 Chemical Check Analysis Limits - Wrought Nickel and Nickel Alloys
AMS 2280 Trace Element Control, Nickel Alloy Castings
AMS 2750 Pyrometry
J784 Residual Stress Measurement by X-Ray Refraction
SP 453 Retained Austenite and its Measurements by X-Ray Diffraction

2.1.2 PRI Publications: Available from PRI, 402 Commonwealth Drive, Warrendale, PA 15086-0001.

PRI AC7101/1 General Requirements
PRI AC7101/2 Survey of Chemical Lab
PRI AC7101/3 Survey of Mechanical Testing Lab
PRI AC7101/4 Survey of Metallography & Microhardness Testing
PRI AC7101/5 Survey for Hardness Testing
PRI AC7101/6 Survey for Corrosion and Oxidation Testing
PRI AC7101/7 Survey for Mechanical Test Specimen Preparation
PRI AC7101/8 Survey for Differential Thermal Analysis
PRI AC7101/9 Survey for Heat Treat of Specimens
PRI AC7101/10 Survey for Nonconventional and Engineering Tests
PRI AC7101/11 Survey for Fastener Testing

2.1.3 ASTM Publications: Available from ASTM, 1916 Race Street, Philadelphia, PA 19103-1187.

ASTM B 117 Method of Salt Spray (Fog) Testing
ASTM B 214 Test Method for Sieve Analysis of Granular Metal Powders
ASTM E 3 Methods of Preparation of Metallographic Specimens
ASTM E 4 Standard Practices for Load Verificatoin of Testing Machines
ASTM E 8 Test Methods of Tension Testing of Metallic Materials
ASTM E 10 Test Method for Brinell Hardness of Metallic Materials
ASTM E 18 Test Method for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
ASTM E 21 Recommended Practice for Elevated Temperature Tension Tests of Metallic Meterials
ASTM E 23 Methods for Notched Bar Impact Testing of Metallic Materials
ASTM E 29 Practice for Using Significant Digits in Test Data to Determine Conformance With Specifications
ASTM E 45 Practice for Determining the Inclusion Content of Steel
ASTM E 74 Stantard Practice of Calibration of Force-Measuring Instruments for Verifying the Load In Direction of Testing
ASTM E 82 Method for Determining the Orientation of a Metal Crystal

2.1.3 (Continued):

ASTM E 83	Standard Practice for Verification and Classification of Extensometers
ASTM E 92	Test Method for Vickers Hardness of Metallic Materials
ASTM E 112	Methods for Determining Average Grain Size
ASTM E 139	Recommended Practice for Conducting Creep, Creep-Rupture and Stress-Rupture Tests of Metallic Materials
ASTM E 140	Hardness Conversion Tables for Metals
ASTM E 220	Method for Calibration of Thermocouples by Comparison Techniques
ASTM E 228	Test Method for Linear Thermal Expansion of Solid Materials with a Vitreous Silica Dilatometer, 3.01, 14.02
ASTM E 290	Test Method for Semi-Guided Bend Test for Ductility of Metallic Materials
ASTM E 292	Practice for Conducting Time for Rupture Notch Tension Test of Materials
ASTM E 340	Method for Macroetching Metals and Alloys
ASTM E 384	Test Method for Microhardness of Materials
ASTM E 399	Test Method for Plane-Strain Fracture Toughness of Metallic Materials
ASTM E 407	Methods for Microetching Metals and Alloys
ASTM E 466	Recommended Practice for Constant Amplitude Axial Fatigue Tests of Metallic Materials
ASTM E 606	Recommended Practice for Constant Amplitude Low-Cycle Fatigue Testing
ASTM E 647	Test Method for Measurements of Fatigue Crack Growth
ASTM E 876	Practice for Use of Statistics in the Evaluation of Spectrometric Data
ASTM E 915	Method of Verifying the Alignment of X-Ray Diffraction Instrumentation of Residual Stress Mesurement
ASTM E 930	Methods of Estimating the Largest Grain Observed in a Metallographic Section
ASTM E 975	Practice for X-Ray Determination of Retained Austenite in Steel with Near Random Crystallographic Orientation
ASTM E 1012	Practice for Verification of Specimen Alignment Under Tensile Loading
ASTM Volume 3.01	Metals - Mechanical Testing: Elevated and Low-Temperature Tests; Metallography
ASTM Volume 3.02	Wear and Erosion; Metal Corrosion
ASTM Volume 3.05	Chemical Analysis of Metals and Metal Bearing Ores

2.1.4 Military Publications: Available from Naval Publications and Forms Center, Attn: NPODS, 5801 Tabor Avenue, Philadelphia, PA 19120-5099.

MIL-H-6875
MIL-I-45208
MIL-Q-9858
MIL-STD-45662

2.2 Definitions:

ACCEPTANCE TESTS/PROPERTIES: Tests/properties which are required to be included on each certification for acceptance of the delivered product (for example: Tensile, stress rupture, hardness, and metallographic tests).

CAPTIVE LAB: A laboratory that belongs to a material supplier, with systems that are dependent on those of the supplier, and with testing capabilities that are limited to those required by the supplier's material.

CERTIFICATE OF CONFORMANCE: Document issued by the Laboratory which confirms conformance of material to the material specification and which may describe the testing performed, but does not include the numerical values of results obtained.

CERTIFICATE OF TEST, TEST REPORT: Document issued by the Laboratory describing the testing performed, the specific results obtained, and whether results conform to the material specification.

CHECK ANALYSIS: An analysis made by the purchaser or supplier of the metal after it has been worked into semi-finished or finished forms or fabricated into parts. This analysis is either for the purpose of verifying the composition of a heat or lot or to determine variations in the composition within the purchaser on the basis of this check analysis. In the analysis of finished parts, these values do not apply to elements whose percentage can be varied by fabricating techniques employed (e.g., surface hydrogen in steels and titanium alloys) unless the sample is taken in such a manner as to exclude such changes. [This definition taken from AMS Check Analysis specifications.]

CUSTOMER: The company who places the order for testing on the Lab.

INDEPENDENT LAB: A laboratory whose systems are not dependent on those of specific material suppliers. (Ownership by a material supplier does not exclude a Lab from being considered 'Independent'.)

INSTRUMENTAL ANALYSIS: Includes SELF-CALIBRATING TESTS, and other testing which is essentially controlled by the equipment but which may not be independent of operator technique and/or interpretation. Restrictions, requirements, and examples are given in the sections for test families.

INVALID TEST VALUE: A test value considered to be untrue because it does not fit the population of other values from the same sample and the non-validity is evaluated and reported per Appendix B.

2.2 (Continued):

LOW CYCLE FATIGUE (LCF): Fatigue test characterized by hysteresis behavior from loading-unloading in plastic region. Generally strain control per ASTM E 606, but may include load-control and torsional LCF testing. Note: Hysteresis behavior may only be exhibited during the first full cycle.
LOW STRESS GRINDING (LSG): Grinding/polishing under controlled conditions to minimize and produce required compressive surface stresses.

MATERIAL CERTIFICATION: The certificate of Test or Conformance issued by the Lab.

MATERIAL SPECIFICATION: The document(s) describing which tests are to be performed and the conformance limits required/expected, and (sometimes) the test specification(s) to be used. This definition can include drawings or other purchasing documents.

MATERIAL SUPPLIER: A company who supplies material under the Purchaser's order (e.g., under Purchase Order or cooperative agreements).

NIST (United States National Institute of Standards and Technology): The highest level international or national organizations or agencies responsible for standardization of weights, measures, and chemistry standards.

NON-CONFORMING TEST RESULT: A test result that does not conform to the material specification.

PROCUREMENT DOCUMENT: The Purchase Order (P.O.) that establishes contractual quality requirements for the material. In certain business arrangements which do not include issuance of P.O.s (e.g., revenue share agreements) imposition of this specification is by way of the Quality Plan.

PROFICIENCY TESTING: Testing used for a capability study to determine the continued performance of the laboratory.

PURCHASER: The procuring activity that issued the procurement document, for material or services, which invoked this document.

RE-TEST: A repeat of a TEST by the same lab, using the same method, equipment (of equivalent accuracy or better), and sample. Usually performed in response to suspect or non-conforming results from the original test(s).

REFEREE TEST: A repeat of a TEST from the same SAMPLE by a different lab, or using more accurate or precise methods/equipment.

2.2 (Continued):

REPLACED TEST ("NO-TEST): A test whose results are considered to be untrue because of identified causes other than properties of the material being tested (e.g., errors in specimen machining or testing).

REPLACEMENT TEST: A test made as a result of a Replaced Test.

RESIDUAL ELEMENT: An unspecified element, originating in raw materials, melting equipment (e.g., furnace refractory lining), or melting fluxes-slags-atmospheres defined by the melting practice, or as defined by specification.

ROUND ROBIN TESTING: Testing of specimens from the same sample by different laboratories and/or by different test methods or equipment. Requirements and restrictions are given in the sections for the generic test types.

SAMPLE: Material supplied for testing. (see also "SPECIMEN".)

SELF-CALIBRATING TEST METHOD: Testing that is essentially controlled by and results reported by the equipment, independent of operator technique (other than specimen loading), for which equipment is calibrated by testing certified standard specimens prior to and after testing required specimens. Examples, requirements, and restrictions are given in the sections for the generic test types.

SPECIMEN: A portion of the SAMPLE selected for testing to accurately represent the entire SAMPLE.

SQA: Software Quality Assurance. A program to ensure software used to control tests and/or generate data is not altered without adequate validation and documentation control.

SUBSTANTIATION: All of the following terms mean the same thing.

- Substantiation
- Source Substantiation (SS, S.S., or S/S)
- VSE (Vendor Substantiation Engineering)

SUBSTANTIATION TEST: Any test whose result is required for Substantiation. These include (but are not limited to) all Acceptance and Capability tests established by drawing.

SUB-TIER LAB: A laboratory which does not belong to a direct material supplier. Systems for such labs must qualify as "INDEPENDENT".

TEST CODE: The single-letter or double-letter code denoting the specific test type qualified. NOTE: Double-letter codes will have "X_" prefixes.

2.2 (Continued):

TEST RECORDS: Records maintained by the lab; to be available for review, but not required to be furnished with cert unless specified.

TEST SPECIFICATION: Document describing the method(s) and procedures(s) by which material is to be tested.

TRACE ELEMENT: A residual element that occurs in very low concentrations, generally less than 0.01%.

WORKING STANDARD: Standardized material used during routine testing to ensure that testing equipment is properly calibrated for the material which requires testing.

3. SURVEY REQUIREMENTS:

3.1 Survey information has been divided into parts as follows:

PRI AC7101/1 NADCAP GENERAL REQUIREMENTS, ALL MATERIALS TEST LABORATORIES

This part contains general information regarding quality systems that would be collected for a survey of any laboratory.

PRI AC7101/2	NADCAP MATERIAL TEST LABORATORIES - CHEMICAL LAB
PRI AC7101/3	NADCAP MATERIAL TEST LABORATORIES - MECHANICAL TESTING LAB
PRI AC7101/4	NADCAP MATERIAL TEST LABORATORIES - METALLOGRAPHY & MICROHARDNESS TESTING
PRI AC7101/5	NADCAP MATERIAL TEST LABORATORIES - HARDNESS TESTING
PRI AC7101/6	NADCAP MATERIAL TEST LABORATORIES - CORROSION AND OXIDATION TESTING
PRI AC7101/7	NADCAP MATERIAL TEST LABORATORIES - MECHANICAL TEST SPECIMEN PREPARATION
PRI AC7101/8	NADCAP MATERIAL TEST LABORATORIES - DIFFERENTIAL THERMAL ANALYSIS
PRI AC7101/9	NADCAP MATERIAL TEST LABORATORIES - HEAT TREAT OF SPECIMENS
PRI AC7101/10	NADCAP MATERIAL TEST LABORATORIES - NONCONVENTIONAL AND ENGINEERING TESTS
PRI AC7101/11	NADCAP MATERIAL TEST LABORATORIES - FASTENER TESTING

3.1.1 These PRI Audit Criteria form a part of this standard to the extent referenced herein.

This information package will be reviewed by NADCAP and approval to schedule the audit will be obtained. PRI will coordinate with the laboratory to obtain any additional information in support of the audit.

4. REQUIREMENTS: ALL LABORATORIES

4.1 Lab Accreditation:

Lab accreditation is for three years with proficiency testing at one year intervals. Accreditation requires all of the following:

4.1 (Continued):

a. Conformance to applicable provisions of this standard.

b. Completion by the Laboratory of matrixes describing facilities and calibration practices.

c. Acceptable evaluation to NADCAP checklists for applicable Codes which are derived from this standard, from standard testing specifications (e.g., ASTM), and from recognized standards of good laboratory practice.

d. Acceptable completion of the NADCAP proficiency tests required for applicable areas of testing as listed in AS7105.

e. Proficiency testing is required at the initial survey and at one year intervals during the three year accreditation term.

f. If the proficiency tests are not applicable to the tests being accredited, then a round robin program shall be mandatory.

4.1.1 Checklists for each test type are designed to utilize "YES/NO" questions. All "No" answers require an explanation. A "not applicable" explanation is not acceptable without further information.

Corrective action is required for any NADCAP Standard violation.

4.2 Quality Manual:

Each laboratory is required to have a quality manual. Captive Labs may be covered by the quality manual of the material supplier plus detailed manuals covering laboratory operations. The manual and documents referenced therein shall cover all requirements of this standard including approval of non-traditional and alternate procedures permitted by this standard. Changes shall be recorded on a revision page; any changes which might affect conformance to this standard require a notification to NADCAP for evaluation of accreditation status. Changes shall be made available for the NADCAP audit.

4.3 Facility:

The following factors will be considered in NADCAP accreditation of the laboratory, and may be cause for accreditation to be refused.

a. Testing environment free from external vibrations, electrical transients, voltage fluctuations, RF pollution, and atmospheric contamination. These factors shall have been considered in design of the facility itself or of individual equipment sets.

b. Temperature and humidity control. (See specific tests.)

c. Cleanliness, housekeeping, and orderly handling of material.

d. Safety - Each Laboratory shall follow standard safety regulations including safety glasses, eye wash stations, safety showers, proper chemical storage and labeling, fire extinguishers, machine guarding and other requirements needed to meet regulations.

e. Hazardous Materials - Each laboratory shall have appropriate programs for the proper storage and disposal of hazardous materials.

4.3.1 FAX Capability or equivalent is required so that recovered data may be forwarded immediately.

4.4 Systems:

4.4.1 Laboratory systems shall include provisions for self-audit. A routine, internal audit program shall be described in writing and carried out according to a written format and to a published schedule. Internal audits are carried out to check:

a. Correct application of testing methods
b. Compliance with customer orders
c. Correct application of procedures
d. Correct preparation of certificate
e. Cause and corrective actions for revealed discrepancies

Internal audit reports shall be transmitted to the laboratory management with the application of corrective action controlled. The Q.A. function shall:

a. Use a central log to record deviations and corrective actions
b. Investigate to determine probable cause
c. Participate in the development of corrective actions
d. Control the application of corrective actions

4.5 Personnel:

A central file shall be maintained convenient to the lab, containing the names and relevant qualifications (education + training + experience) of lab personnel responsible for test results reported on certifications. If degreed personnel "or equivalent" are required, justification for "equivalent" shall be documented. Records shall identify key personnel (i.e., personnel whose knowledge or techniques are essential to proper performance of the test); records shall be made available for audit. Notification of NADCAP is required for changes in specific key personnel.

4.6 Test Procedures:

Written procedures or computer programs, under revision control and (as applicable) SQA control, shall be issued and followed for all applicable tests. Procedures shall reference testing specifications from which they are derived, and shall include specimen location and preparation. They shall be sufficiently detailed so that the test can be consistently reproduced in that laboratory. General procedures (e.g., ASTM E 8) which contain two or more optional methods for individual operations are not satisfactory for this purpose.

4.6.1 Non-Standard Test Procedures: Work completed in support of special investigations shall be fully documented using test logs per paragraph 4.12 and test reports per paragraph 4.13. All procedures used during these non-standard tests shall be documented to the extent that the test could be reproduced.

4.7 Specimen Identification and Tracking:

A unique set of identifying numbers shall be assigned to each test, to ensure traceability from the certificate issued to the customer order, material tested, test methods used, test results and original cutting plan. The laboratory's systems shall provide for tracking and accountability of all specimens.

4.8 Equipment Calibration and Maintenance:

Written procedures, referenced in the Quality Manual, shall be provided and utilized for calibration of all measuring and testing equipment and measurement standards which are pertinent to certified results (ref. MIL-STD-45662). Calibrations shall be traceable to NIST or other sources as described in MIL-STD-45662. If an outside agency performs calibration, they shall be required to provide such procedures. As a minimum, the procedures shall specify the precision of the instrument being calibrated, the accuracy of the standards used and their traceability to primary standards, the minimum frequency of calibration, and detailed calibration instructions (e.g., for lab furnace calibration, the thermocouple type and placement, and rules for temperature stabilization). Calibration shall be summarized for each lab using a matrix located in the applicable checklist. All equipment not under calibration control shall be explained and so identified.

4.8.1 Preventive maintenance shall be in accordance with a written plan. There shall be evidence that this plan has been implemented. The plan shall discuss any major equipment. Calibration may be considered part of the lab's program.

4.8.2 Calibration and maintenance records shall be available upon request.

4.8.3 Calibration Identification: Calibration status stickers (last/next) should be posted on each test machine. "Calib. Not Req'd." stickers should be used where applicable.

4.9 Replacement Testing and Re-Testing:

A written policy for replacement testing and re-testing in accordance with customer requirements, shall be established and referenced through the Quality Manual.

4.9.1 Accountability: All specimens provided to the Lab shall be accounted for on the Certificate or (for Captive Labs) the test report, whether tested to completion or failure, or replaced. When sufficient material is available for replacement specimens to be made by the Lab from the same sample, replaced specimens need not be reported on the Certificate, but should be documented in the lab's internal records.

4.9.2 Invalidation of test results is permitted only when authorized by the material specification, or other contractual documents. Invalid test results shall be evaluated and reported per Appendix B.

4.10 Errors in Testing:

A written policy shall be established and referenced through the Quality Manual, as follows, including definition of significant out-of-tolerance conditions and designation of individuals (or job titles) responsible for action. When errors in testing are detected which could result in a significant out-of-tolerance condition (MIL-STD-45662), the suspect population shall be defined and documented. If all affected material is not contained and correctness of results verified, all customers to whom the lab sent incorrect or suspect test results shall be notified immediately.

Example: "Significant out-of-tolerance" conditions might include excursions exceeding chemical check analysis limits (Section 5.0), exceeding the precision claimed by capability matrices, or exceeding 25% of the tolerance band (Ref. MIL-STD-45662). All tests since the last correct calibration are suspect unless the population can be further restricted.

4.11 Certificate of Test/Conformance:

4.11.1 Contents: The following items shall be included in each Certificate, in addition to requirements established by the applicable specification.

a. The Laboratory's identification: name and address

b. The company for whom the testing was performed.

c. The number(s) and issue(s)/revision(s) of the specification(s) against which material was tested.

d. The testing specification used, if not called out by the material specification.

e. Certificate of Test: Include the numerical results of all tests and inspections performed for which the material specification establishes numerical requirements. When certifying to a specific specification (as opposed to all certifications which may later be referenced against many individual specifications), the certificate shall show that the results are in accordance with the requirements of that specification or the tests performed.

EXAMPLE: Specification limits should be included on the certificates (either by the lab or material supplier), in such a "manner as to facilitate comparison of material specification requirements versus test results, and to ensure that all items (e.g., all chemical elements) have been evaluated.

f. Description of the results (e.g., conform/non-conform) of all tests for which the material specification does not establish numerical requirements. Report any unusual observations (identify as "Observation"). The separation of conforming and non-conforming results on separate certificates is not permitted.

g. For applicable tests (see the sections for the testing groups and Table 1), the specific test conditions and techniques used. Examples: stress rupture load, temperature, and "step loading"; low cycle fatigue parameters.

h. Unique identification on each certification which will prevent copying (e.g., seal).

TABLE 1 - Specific Requirements for Test Certificates

Applicable Test Codes	Reference Standard	Requirement or Provision
ALL	General	(1) Any general lab specification(s) which is to be used for approved non-standard or equivalent practices must be referenced. (2) All Test Codes to be accredited must be referenced. (3) Any non-standard practices must be referenced.
Mech. Tests	6.7.2	Reference outside specimen preparation source(s).
F, G, S_1, S_2, W	5.5.1, 5.12.1 Apx. D	Use of methods other than wet chemistry for certifying primary spectro standards. Reference AMS 2280 for Trace Element Analysis.
A, B	6.5.5	Induction furnaces must be approved by customers.
C, XA	6.9, 6.10	Spot Welded T/Cs, shoulder attachment of extensometer are non-standard practice.
FT	14.	List individual tests for fastener testing.
L	7.6	Approved surface evaluation(s) must be noted
M	8.10	Use of hardness test methods other than specified may be considered to be non-standard; see Section 8.0 for restrictions and approval for equivalent methods. Methods may be included in the Lab's general specification.
Mech. Test Specimen Prep.	6.7.2	Outside machining source(s) used for specimen preparation must be referenced. References may be included in the lab's general specification.
Advanced Testing	13.	Procedures/methods used must be referenced.
Sub-Contract	4.1.1	Subcontracting of individual operations to non-AMTL sources (e.g. testing of boron in Inco 718, machining of macroetch slabs) may be authorized provided such operations are under AMTL's control.

*AMTL: Accredited Materials Test Laboratory

4.11.2 Preparation of Certificate: Each page of the cert shall be numbered "page __ of __ ", and shall have unique identification traceable to the job and lab identification. Use of 'white-out' or erasures on the signed or notarized cert or copies thereof is prohibited: corrections may be lined out and initialed. Test results for all specimens in the same set shall be included on the same cert; that is, separate certs shall not be issued for conforming versus nonconforming material. Re-test values, and values known to be nonconforming (i.e., when compared against mandatory specification values), shall be clearly identified as such. All specimens provided to the lab must be accounted for; e.g., by stating "Specimen 4A253: No Test - broke in grips." Test values from replaced specimens need not be reported.

Computer generated certificates require either (a) an actual or facsimile signature, or (b) a letter accompanying the certificate, signed by the lab's manager attesting that the lab is using a computerized system, the typed name on the document is an authorized employee, and the lab is responsible for the information it contains.

4.11.3 A Certificate of Conformance (in lieu of a Certificate of Test) shall not be provided unless specifically required by the material specification.

4.11.4 Statement of Conformance: When testing is performed against material specifications that require certificates to state that a test "conforms to specification", conformance shall be clearly noted; statements to the effect that "values are true and accurate" are not sufficient.

4.11.5 Appendix C lists errors most frequently found on certificates. This Appendix should be used for audit by both the Lab and the material supplier.

4.11.6 Electronic Data Interchange (EDI) will be controlled in accordance with ANSI Standard ASC X12 (when implemented).

4.12 Test Logs:

A numbered and bound log, or equivalent system that prevents substitution or deletion of data, shall be used.

4.12.1 Logging - All Tests: All tests shall be logged against the unique identifying numbers assigned for traceability, and shall be traceable to the specific testing procedure used and test data generated.

4.12.2 Logging - Replaced Tests, Invalidated Tests, Nonconforming Tests, and Re-Tests: Such tests shall be identified as such, and cross-indexed against each other where applicable. Reason(s) for replacement testing or re-testing shall be noted. Lab management authorization shall be noted for re-tests not specifically authorized by the Lab's customer. Logs shall be reviewed at least quarterly for trends which could indicate deterioration in testing disciplines.

4.13 Test Records:

Records shall be maintained, traceable to each cert issued, which would permit reproducing the test method in that facility, or permit identification of suspect tests if any element of testing were found to be incorrect at a later date. Examples of items which should be recorded are: location of specimen(s) within the sample, equipment set (test stand, tooling, recorders, etc.), temperature and dimensional tolerances (if not reported on the cert), comparison standards, personnel.

4.14 Retention and Recovery:

Minimum retention times are separate from requirements that may be placed on the material supplier by the Purchaser, and apply after the certification is issued to the customer. Recovery shall require a maximum of 3 working days.

a. Test Data (including metallographic exhibits) relevant to material certification, including Test Logs which relate test results to the material tested, supporting data (e.g., tensile test printouts), and Calibration data shall be defined via the Quality Manual, and shall be retained as specified by the customer.

NOTE: The material supplier is required to retain test data relevant to certification of substantiated material for 30 years minimum, or as specified by the customer.

b. Test material (specimens and extra sample material) not returned to the lab's customer shall be retained for 6 months. Special requirements may be established for the retention of hazardous materials if required by local or company safety codes.

c. Laboratory shall implement a system to provide back-up storage, in case of fire, water damage, or other cause which could destroy the originals.

4.15 Round Robin Testing:

Each laboratory should participate in Round Robin (R/R) program(s). While participation in external laboratory programs is desired, intra-laboratory programs may be acceptable unless otherwise specified (e.g., chemical and LCF labs require inter-lab programs). Some expected elements of R/R programs are as follows:

a. Material supplied by one source and controlled for uniformity. Specimens sets prepared by one or more participants; duplicate specimens from each set tested by each participant and/or test method.

b. (External laboratory program) Participating labs identified by code to minimize the possibility of bias during data analysis.

c. Statistical analysis and correlation performed on results.

d. Results used to identify and correct problems, and/or to initiate changes in testing methods or practices (e.g., action taken if lab's results are more than 2 sigma from mean value).

e. For multi-participant internal lab R/R of relatively inexpensive tests such as spectrographic analysis and tensile testing, R/R testing every 2 years (max.) is recommended; while 5 years maximum is recommended for cyclic testing. For more limited programs (e.g., inter-lab, 2 or 3 participants), greater frequency is recommended. The lab may participate in a customer or industry R/R, or (if none exist within the recommended time period) initiate its own R/R.

f. Internal R/R programs require documentation and evidence of corrective action implementation.

4.16 Security:

Security shall be provided to protect the confidentiality of customer specifications.

4.17 Audit:

All procedures and records required by this standard are subject to audit at the laboratory facility.

5. CHEMICAL TESTING:

5.1 Test Types/Codes:

Codes are as follows for chemical tests:

D Wet Chemistry (gravimetric)
F Atomic emission Spectroscopy
  F1 Direct Coupled Plasma (DCP)
  F2 Inductively Coupled Plasma (ICP)
  F3 Spark/Arc (OES)
  F4 Glow Discharge
G Elemental Analysis (Combustion or Fusion)
  G1 Carbon
  G2 Hydrogen
  G3 Nitrogen
  G4 Oxygen
  G5 Sulfur
S X-Ray Fluorescence
V Mass Spectrometry
W Atomic Absorption
  W1 Flame
  W2 Graphite Furnace

5.1.2 Alloy Families for Chemical Testing:

Ni Base
Co Base
Ti Base
Al Base
Mg Base
Cu Base
Fe Base, Low Alloy
Fe Base, High Alloy

5.1.3 Additional Chemistry Definitions: Definitions of and requirements for the following terms relevant to chemical analysis are given in AMS 2248, AMS 2249, AMS 2259, AMS 2268, and AMS 2269.

CHECK ANALYSIS, VARIATION LIMIT, REMAINDER, OTHER ELEMENTS EACH (MAX.), OTHER ELEMENTS TOTAL (MAX).

5.1.4 Self-Calibrating Tests: Equipment shall have demonstrated statistical capability (precision) for each alloy family to be tested.

5.2 Test Methods and Procedures:

5.2.1 Source of Chemical Test Procedures: Methods and procedures for chemical analysis shall be as called out by the material specification. If none are specified, the applicable ASTM Method or Procedure from Volume 3.05 "Chemical Analysis of Metals and Metal Bearing Ores" shall be used. Gas fusion method shall be used for test codes G1-G5, or other methods as approved by the customer and verified by round robin and proficiency testing.

5.2.2 Working Procedures: Written procedures are required which are sufficiently detailed for each type and sequence of analysis to insure accurate and repeatable results.

5.3 Chem Lab Matrix:

A Matrix located in the applicable checklist shall be completed for applicable tests, and shall demonstrate that calibration standards, including permitted extrapolations, cover minimum (if applicable) and maximum percents for each applicable element to be analyzed. "Applicable" elements include those required or limited by specifications for those aerospace alloys expected to be analyzed by the lab.

5.4 Personnel:

Personnel shall be trained commensurate with their degree of control over testing. Required training shall be documented via the Quality Manual.

5.4.1 Operators of laboratory instrumentation shall have sufficient training to recognize proper versus improper operation of the equipment.

5.4.2 Laboratory Management shall be responsible for completing or assigning the following functions:

a. Review and approval of data to be analyzed.
b. Wet chemical analysis.
c. Interpretation of Raw data from equipment that does not provide direct numerical read-outs.
d. Authorization of re-testing for nonconforming test values.
e. Preparation or approval of detailed testing procedures (other than those issued by the equipment manufacturer).
f. The above functions are performed by a degreed chemist or equivalent and equivalency is defined in the Quality Manual.

5.5 Standards and Reagents - Chemical Testing:

5.5.1 Spectroscopy shall utilize reference materials as described in Appendix D. All reference materials shall have documented traceability of analysis. Non-certified reference materials require documented multiple analysis against certified reference materials or wet chemical analysis.

5.5.2 Analytical reagents which take part in a reaction or end up in the analyzed sample, e.g., solvents and diluents, shall be of the highest quality necessary to insure the integrity of the analysis results.

5.5.3 Standards having a shelf life shall be properly labeled to ensure they are not used after the expiration date. Shelf life disciplines shall be documented and maintained for standards susceptible to deterioration (e.g., evaporation of liquid standards, reaction with glass storage container).

5.6 Test Specimens:

5.6.1 Chemical Specimen Preparation: Written procedures shall be used which clearly define the proper preparation technique to avoid contamination or loss of sample integrity.

5.6.2 Hydrogen in Titanium: Unless the Lab is informed otherwise by its customer, specimens shall be taken to include the processed surface(s).

5.7 Rounding Off of Chemical Composition Values:

An observed value or a calculated value shall be rounded off "to the nearest unit" in the last right hand place of numbers used by the material specification in expressing the limiting value, in accordance with ASTM E 29. Exception: for trace elements, an observed value may be reported to the precision level of the analysis method used.

5.8 Re-Testing:

5.8.1 Nonconforming Chemical Test Values: When the original test value does not conform, three additional specimens may be tested from the same sample. Nonconformance of a re-test specimen precludes further re-testing. All specimens shall be logged and all results recorded; analysis of results recorded. Statistical analysis of the chemical results shall be in accordance with ASTM E 876 to determine if original result was an outlier.

5.9 Check Analysis:

The customer shall define the specification used for material certification. The customer shall identify the specification used for check limits if not called out in the material specification. Check limits may not be used to extend specification acceptance limits for initial vendor qualification.

5.10 Equipment Calibration:

Calibration requirements and methods shall be documented and referenced in the Quality Manual. Calibration frequency, standardization, and requirements shall meet the minimum requirements of Appendix D.

5.11 Chemical Round Robin Testing:

Each chemical laboratory shall participate in a planned, periodic inter-laboratory program whose results are available for review by NADCAP. Round Robin testing shall include all alloy families and elements which are tested; restrictions on alloy families and/or elements shall be documented on the matrix.

5.12 "All Other" Elements - Residual and Trace Elements:

5.12.1 Qualification to Trace Element Analysis requires demonstration of ability to analyze to the limits of AMS 2280 (as called out by the material specification).

5.12.2 Required Analyses: Analysis for specific residual and trace elements is required when called out by supplemental specifications referenced in the material specification (ref. AMS 2280), and when the material supplier informs the laboratory of known or suspected residual and trace elements (ref. Appendix A).

5.12.3 Acceptance of Unspecified Elements: Analysis is not required for such elements except as described above. If, however, analysis is performed and such elements are found, reporting and acceptance shall be as described below.

a. If the specification has allowable limits for "All Other" elements, acceptance shall be to these limits. (Such notes will be present in most titanium alloy specs.) Elements having specific percents determined should be reported.

b. Other elements found need not be reported if they do not exceed the following limits:

All Alloy Families: Elements reported as "< 0.xxx", where "0.xxx" represents the minimum (calibrated) detection limit of the test method. For such cases, when this minimum detection limit is higher than 0.001 and the element is detected, it should be recorded in the lab's analysis records.

Iron, Nickel, Cobalt Alloys: (Maximum for each element and maximum total of all elements within that group.)

Total	Each	
----	0.005%	B (in Fe alloys)
0.015%	0.015%	B (in Ni, Co alloys), Mg
0.010%	0.05%	Al, Zr
0.30%	0.15%	Ti, V, Cr, Cu, Fe, Cb[Nb], Hf, Ta, W, Mo (in Ni alloys)
----	0.50%	Mo (in Co alloys)
1.00%	1.00%	Ni, Co

5.12.3 (Continued):

c. Uncalibrated (semi-quantitative) Findings: If instrumental analysis detects and reports unspecified elements above background levels, but the analysis procedure is not calibrated for those elements, the lab shall develop a documented procedure for disposition. Procedures should be sensitive to significant trends or abnormally high levels of indicated results; data should be included in the lab's records.

6. MECHANICAL PROPERTY TESTING:

6.1 Test Types, Codes, Methods and Procedures:

Codes are as follows for mechanical property tests. The noted test specifications and standards apply unless otherwise specified or approved.

Code	Test Type	Test Spec/Standard
A	ROOM TEMPERATURE TENSILE	ASTM E 8/E 21
B	ELEVATED TEMPERATURE TENSILE	ASTM E 21
C	STRESS RUPTURE	ASTM E 139 (Smooth), ASTM E 292 (Notched)
XA	CREEP	ASTM E 139
N	IMPACT TESTING	ASTM E 23
O	HIGH CYCLE FATIGUE (HCF)	ASTM E 466
P	FRACTURE TOUGHNESS	ASTM E 399
Y	LOW CYCLE FATIGUE (LCF)	ASTM E 606
XE	CRACK PROPAGATION MEASUREMENT	ASTM E 647
XH	CYCLIC RUPTURE	ASTM E 139

6.2 Mechanical Test Procedures:

Written procedures are required which are sufficiently detailed to be followed for the specific test equipment to be used and specific test to be performed.

6.3 Mechanical Test Lab Matrix:

A matrix in the applicable check list shall be completed for applicable tests, and shall include reference to applicable R/R programs.

6.4 Mechanical Test Personnel:

Per Section 4 (no additional requirements).

6.5 Mechanical Testing Equipment:

See also paragraphs for specific tests.

6.5.1 Calibration Frequencies: Shall be per Appendix E unless otherwise noted.

6.5.2 Tensile, stress rupture, and creep test machines shall be calibrated per ASTM E 4; calibration equipment shall be per ASTM E 74.

6.5.3 Extensometers shall conform to ASTM E 83, Class B-2 or better. Calibration shall be per ASTM E 83 or equivalent. Extensometers shall be calibrated for a particular machine and electronics set-up.

6.5.4 Temperature Measuring Devices shall be either a Group B precision potentiometer or alternate device calibrated and traceable to the NIST.

6.5.5 Specimen Furnaces shall be resistance, circulating hot air, or other types and approved during qualification via documentation per matrix located in the applicable checklist. Induction heating shall not be used for tensile, stress rupture, or creep tests unless permitted by the customer; for other tests, calibration studies shall demonstrate that differences in response between the thermocouple and specimen do not introduce temperature errors. Furnace surveys shall be made to establish the locations at which measurement and control thermocouples are required. Furnace design and practice shall prevent overtemperature outside the measured section.

6.5.6 Loading Weights shall be calibrated to produce a loading accuracy (including leverage effects if applicable) of 0.5% or better. Re-calibration frequency shall be 5 years or sooner. Weights which are checked on a calibrated scale prior to each use do not require a separate calibration program.

6.5.7 Calibration and Maintenance Records: Applicable information shall be supplied on the matrix. Records shall include:

a. Machine identity, including type, manufacturer's name, serial number, and capabilities or capacity.

b. Calibrating procedure. Standards used to calibrate instruments must be traceable to the NIST. Calibration equipment records shall include type, manufacturer's name, serial number, date of last calibration and next scheduled calibration, and accuracy.

c. Name and address of the calibrating organization.

6.5.8 If testing is interrupted due to power outage, equipment failure, etc., test records shall document the following: Date and time interruption occurred, equipment malfunction explanation, current status of test, data recorded prior to interruption, corrective action taken, if required.

Laboratory shall notify customer(s) of test interruption as applicable.

6.6 Thermocouples (T/C) shall be selected in accordance with customer criteria. T/Cs used for elevated temperature tests shall be reported. Prior to re-use of any T/C, kinked wire shall be removed and that junction replaced; all obviously oxidized or damaged junctions shall be removed and replaced.

6.6.1 T/C calibration: Wire shall be calibrated per ASTM E 220 (including limits of error) at the maximum and minimum temperatures, and at the maximum intervals given below. Individual T/Cs may be calibrated in lieu of wire calibration.

INTERVALS

200°F (111°C): Types "R" and "S"
50°F (28°C): Types "N" above 1000°F (538°C)
50°F (28°C): All other types (except "K" as required below)

6.6.2 Type "K" T/C Calibration:

a. Only "premium" grade wire is permitted.

b. Each spool shall be certified at both ends and middle of the spool per ASTM E 220 (including limits of error) at the maximum and minimum temperatures.

c. A certification data point within 150°F of the test temperature shall be required for test temperatures between 950°F and 1550°F. For example, a T/C certification at 1100°F and 1400°F will allow the T/C to be used for test temperatures from 950°F to 1550°F.

d. A certification point within 50°F is required for temperatures below 950°F and above 1550°F.

6.6.3 Type "K" Thermocouple Restrictions: T/Cs may not be re-used unless all wire previously exposed at temperatures above 1000°F (538°C) has been removed and a new junction made.

a. Type "K" may not be used for testing above 1800°F (982°C) unless lab has demonstrated wire stability in the testing environment (typically thin T/C). Wire is subject to rapid deterioration. Stability is defined as T/C performance per ASTM E 220 (premium wire) for the test duration.

b. T/C Junctions: Above 1600 °F (870 °C), compression bonded junctions are preferred; welded junctions may be used if data for the welding process used demonstrates that progressive corrosion of the joint does not result in drift outside the limits noted below. (Note: Welded junctions in Types "R" and "S" may be used at any temperature.)

6.6.3 (Continued):

c. Wire stability for creep and stress rupture testing above 1600°F (870°C) shall be determined by the comparison method of ASTM E 220. The exposure temperature must equal or exceed the maximum temperature at which the wire will be used; exposure time shall be 25 hours minimum. The wire is acceptable provided the indicated temperature does not drift more than 5°F (3°C) during exposure.

6.7 Mechanical Test Specimens:

6.7.1 Configuration shall be in accordance with the applicable test method/procedure. If not specified, the lab may select specimen configuration for requested test which is documented in its internal manual. Specimen drawing shall be recorded.

6.7.2 Preparation: Specimen preparation shall be as called out in Section 10. The lab shall ensure that specimen configuration and preparation procedures are documented. If a preparation is done by an outside source, the outside source shall be identified.

Separate certification to Test Code "Z" is required for cyclic Test Codes Y and XH, and for any other test for which the material specification requires low stress grinding (LSG).

6.7.3 Specimen Dimension Control: SPC (Statistical Process control) shall be used by the testing facility when 100% measurement is not used for gage section dimensions or other dimensions which might affect testing axiality or stress concentration. Examples: diametral uniformity, concentricity, required taper, undercut of radii at gage section.

6.8 Specimen Heat Treatment:

Heat treating of material to be tested requires qualification to Lab Test Code "XG". Specific specimen heat treat method used shall be noted on the certificate.

6.9 Thermocouple Attachment:

Thermocouple attachment by spot welding directly on the reduced section of the specimen is prohibited. Methods of attachment are test type and material type dependent. Procedures shall identify standard attachment practice.

6.10 Extensometer Attachment:

Extensometers shall be attached directly to the reduced section of the test sample. Standard specimens with integral external notched lips at the ends of the reduced section to prevent slippage are permitted. Extensometers attached to grips, pull bars, or the load train assembly shall not be used for required measurements. Extensometer attachment practices are test type and material type dependent. Procedures shall identify attachment practices.

6.11 Alignment Capability:

Calibration of alignment capability per Appendix E is required for tests requiring axial loading. Calibration of elevated temperature test equipment may be performed at room temperature due to strain gage temperature limitations. For assurance of alignment disciplines, and analysis of test results, reference ASTM E 1012. For additional information; however, requirements of this specification take precedence.

6.11.1 Required Capability: Maximum bending capability shall be demonstrated as follows: ("Brittle materials" are those with expected percent elongations less than five percent in 4D. Reference ASTM E 606 for techniques).

Static Tests: 10% (non-brittle materials)
8% (brittle materials)
Cyclic Tests: 5%

Tests, as defined by the customer, requiring specific maximum bending strain (i.e., specific equipment and fixtures) shall require alignment verification immediately prior to test and demonstrate repeatable capability to the above limits.

Percent bending strain is the greatest difference in axial strain under load between the average strain (of 3 or 4 strain gages in any circumferential set) and any individual gage in that set, divided by the average strain, times 100. Percent bending strain shall be calculated in accordance with ASTM E 1012.

6.11.2 Loads During Evaluation: For the test conditions described below, "lowest maximum load" is as follows, considering the material strengths and specimen cross-sections to be evaluated.

- Tensile tests: Lowest load for required yield strength.
- Constant load tests: Lowest load for producing specified stress.

Cyclic tests: Load representing the minimum stress or strain, tensile and/or compressive, specified for the test.

6.11.3 Static Test Equipment: Test set-up shall include the test machine, grips, and selected pull train. Strain readings shall be taken at zero load, at the lowest maximum load of the set-up for which the machine is being qualified, and two step loads at higher values.

6.11.4 Cyclic Test Equipment: Test set-up shall include the test machine and grips. Calibration is performed under static load conditions, but must include two or more test repetitions. Strain readings shall be taken at zero load, at the lowest maximum load/strain (both tensile and, if used, compressive) of the set-up for which the machine is being qualified, and two step loads at higher values.

6.11.5 Calibration Specimen(s): Bars shall represent the minimum and typical reduced section lengths to be tested. A strain gage set comprises axial strain gages located at either 90° or 120° intervals around the circumference of the specimen reduced section. The number of sets is dependent on the length of the reduced sections, as follows:

a. Specimens with reduced sections of 0.75 in (19 mm) or shorter: One set at center.
b. Specimens with reduced sections longer than 0.75 in (19 mm): One set each at center and each end.

6.12 Replacement Mechanical Property Tests:

Specimens and test set-ups shall always be visually checked for damage prior to testing, to preclude subsequent replacement of tests insofar as possible. Accepted reasons for replacement of mechanical tests are as follows:

a. Original specimen had a poorly machined surface or had other visible surface damage prior to testing.
b. Original specimen had incorrect dimensions.
c. Incorrect preparation procedures were used which may have affected properties (e.g., grinding without lubricant).
d. The test procedure was incorrect, or was performed incorrectly.
e. Failure of mechanical test specimens occurred outside the reduced area or gage length.
f. For elongation determinations, the fracture was outside the middle half of the gage length.
g. Malfunction of the testing equipment, including thermocouple malfunctions.
h. Improper heat treatment of the specimen, when the specimen heat treatment does not represent the product condition ordered (e.g., "capability" tests on aged specimens for products which are ordered in the annealed condition).

These conditions shall be reason to replace either conforming or non-conforming test results. Shall not be used as a convenient way to conduct replacement tests when non-conforming conditions exist.

6.13 Re-Testing:

Re-testing (as opposed to replacement testing) for product acceptance is permitted per Appendix A (three re-tests) or as authorized by the material specification or other contractual document. Nonconformance of a re-test specimen precludes further re-testing. All specimens shall be logged and all results recorded; analysis of results and reporting results on the Certification shall be in accordance with Appendix A.

6.13.1 Re-tests for Information: After material has been found to be nonconforming, additional re-testing may be performed at the option of the material supplier and results reported in the nonconformance document, as an aid for disposition of the nonconforming condition.

6.14 Round Robin Testing - Mechanical Properties:

Each specimen set should be prepared from homogeneous material by the same source, with a minimum of three specimens each tested either by two (minimum) different laboratories or on two (minimum) completely different equipment sets. Additional sets should be included as necessary to represent different sources for specimen preparation.

6.15 Tensile Testing - Additional Requirements:

All tensile tests shall be conducted in accordance with ASTM E 21 (unless ASTM E 8 or other specification is specified by customer), and in addition the strain rates shall be kept constant through yield and documented. The following detailed requirements are imposed by this specification, and are in addition to requirements of standard test methods.

6.15.1 Tensile Test Records: As a minimum, test records shall include the requirements listed in ASTM E 21, and the following information if applicable. Upon request, records shall be furnished to the Purchaser within three working days.

- Failure location.
- Identification of equipment used including make and capacity of testing machine, make and class of extensometer, make and size of furnace, type of controller, and description of thermocouple including material, wire size, attachment technique and shielding.
- Name of individual performing test and date of test.

6.15.2 Conversion from SI (Metric) Stress Into English Units: When strength values are determined in the SI (metric) system, SI data are to be tabulated in MPa, then converted into psi per ASTM E 380 Method A. Rounding off may then be done in the English system as provided herein. Conformance shall be determined against the English limits of the specification, unless SI units are specified.

6.15.3 Rounding Off Tensile Data: Rounding per ASTM E 21, ASTM E 8, and ASTM E 29 shall be used for determining conformance to specified limits, and shall be used to report observed or calculated test values.

6.16 Stress Rupture Creep - Testing (Codes C-XA):

The following requirements are in addition to standard test methods (ASTM E 139).

6.16.1 Creep Test Records: As a minimum, test records shall include the following information, plus all data listed in ASTM E 139 for which the lab is responsible.

a. Incremental loading curves or data showing specimen strain on loading. Record elastic and plastic components, zeroing the curve to exclude extraneous movement within the pull train.

6.16.1 (Continued):

b. Tabulated creep strain vs. time data from which creep strain and time to corresponding minimum creep rate may be obtained.
c. Time to failure or discontinuation of test.
d. Plot of creep strain vs. time with X-axis labeled HOURS and Y-axis labeled STRAIN. NOTE: Plots provided to the Purchaser shall be "log-log"; a combined curve of total elastic strain [(a)+(d)] is desired.

6.16.2 Test Continuation: Unless otherwise specified, Stress Rupture tests shall be continued until failure, and Creep tests shall be continued until maximum allowable creep is reached.

6.16.3 Rounding off Stress Rupture and Creep Data: Rounding as follows may be used to report observed or calculated test values for determining conformance to specified limits. Reference ASTM Recommended Practices E 29 and E 380.

For This Property -	If In This Range -	Round to Nearest
Test Stress	Must be within 1% of specified.	Round to specified stress.
Time	Below specified min. time Above specified min. time	0.1 h 1 h
Elongation and Reduction of Area	5% or above Below 5%	whole percent half percent

6.17 Fatigue Testing - Additional Requirements (Codes Y-XH):

The following requirements are in addition to requirements of standard test methods. Modern hydraulic fatigue test machines may also be capable of performing other types of high cycle fatigue testing.

6.17.1 Facility Temperature and Humidity: Temperature and humidity shall be measured and recorded continually. The temperature of the test facility shall be maintained in the range of 15-29°C (59-84°F). More stringent limits shall be used if necessary to ensure consistent operation of equipment.

6.17.2 LCF Equipment: Each test machine shall be capable of controlling wave shape, and shall provide for and guarantee limits for at least one of the following: piston displacement, force, specimen displacement. Tests shall be controlled as per ASTM E 606.

6.17.3 Test Continuation and Failed Specimen Retention: Fatigue tests shall be continued until failure unless otherwise specified. Upon completion of testing, failed bars shall be preserved to protect the fracture faces and returned to the customer as required.

6.17.4 LCF, Strain Control to Load Control: Switching from Strain Control mode to Load Control is permitted only when authorized by the appropriate material specification, part specification, or written customer direction.

6.18 Cyclic Rupture Testing - Additional Requirements (Code XH):

6.18.1 Testing shall be performed to the requirements of this standard, and the applicable Material Specification.

6.18.2 Cycle Times: Ramp up, hold time, and ramp down shall be verified using a digital timer.

6.18.3 Temperature and cycle time monitoring shall be at 8 h (max.) intervals. Checks should be made more frequently during the first day.

6.18.4 Test Report - Cyclic Rupture shall, as a minimum, include the applicable requirements listed in ASTM E 139.

6.18.5 Round Robin: Since Cyclic Rupture requirements are established by specific drawings, Round Robin programs shall be as established by quality plans for the affected product(s).

6.19 Impact Testing:

6.19.1 Impact testing should be conducted to ASTM E 23, unless specified by the customer.

6.19.2 Notched-bar impact testing shall be completed by either the Charpy or the Izod method.

6.19.3 Test Report: Impact testing shall meet the requirements listed in ASTM E 23.

6.20 Fracture Toughness:

6.20.1 Fracture toughness testing should be conducted to ASTM E 399, unless specified by the customer.

6.21 Crack Propagation:

6.21.1 Crack propagation testing should be conducted to ASTM E 647, unless specified by the customer.

6.22 Bend Testing:

6.22.1 Bend testing should be conducted to ASTM E 290, unless specified by the customer.

7. METALLOGRAPHY AND MICROHARDNESS:

7.1 Test Types - Codes:

Codes are as follows:

L METALLOGRAPHY (GENERAL MICRO)
L1 MICROHARDNESS (INTERIOR)
XL METALLOGRAPHY (MACRO)
LS MICRO: SURFACE CONDITIONS
L2 ALLOY DEPLETION
L3 OXIDATION/CORROSION
L4 CASTING (MOLD) REACTIONS
L5 MICROHARDNESS (SURFACE)
L6 DIFFUSION COATINGS
L7 IGA, IGO
L8 ALPHA CASE: WROUGHT TITANIUM
L9 ALPHA CASE: CAST TITANIUM

7.1.1 Metallographic Lab Matrix: A matrix shall be completed for applicable tests, including reference to all specific evaluations which are required by this standard to be referenced.

7.1.2 Code "L1" MICROHARDNESS (ASTM E 384) applies to microhardnesses at applied loads less than 1 kgf performed on mounted and metallographically polished specimens. Test Code "M" HARDNESS includes Vickers hardness (ASTM E 92) at applied loads of 1 kgf to 120 kgf.

7.1.3 Test Code "XL" (Macro) is intended to apply to macroetch of material sections (as would be performed by a lab).

7.1.4 Metallographic and microhardness testing by other sources (e.g., heat treat, plating, metal spray, diffusion coating sources) may be approved and documented for the applicable special process.

7.2 Test Methods and Procedures:

Methods and procedures for metallographic testing and examination shall be as called out by the material specification.

Detailed written procedures for preparation and etching of specimens and required metallographic comparison standards as required for proper evaluation shall be convenient to the operator.

7.3 Metallographic Personnel:

All personnel shall be trained in accordance with a written plan, which shall include general and specific aspects of the examinations to be performed. Training for all personnel shall include essential elements of both preparation and interpretation of specimens. Evaluators are responsible for accepting the quality of specimen preparation and etching.

7.3.1 Degreed metallurgists or equivalent are required for the approval of acceptance standards generated by the laboratory. "Equivalency" requires formal training in metallurgy plus extensive applicable experience.

7.4 Specimen Material Supply:

The laboratory shall maintain a supply of materials or specimens for the purpose of operator training in preparation and interpretation and for metallographic process verification. Alloys shall be of the appropriate type and form (wrought or cast) as alloys generally examined; photographic standards may be used for interpretation. A written procedure shall be maintained which describes standards and their use.

7.5 Surface Preparation:

Surface preparation method(s) shall produce a uniform texture. The prepared specimen shall show no evidence of smearing, machining or grinding marks, or overheating from preparation (neither before or after etching). Electropolish methods may be used for removal of mechanically stressed surface layers prior to mechanical polishing. When used for final polishing prior to etching, electropolished surfaces shall be sufficiently free from scratches and pits (prior to etch) to permit proper evaluation (before or after etch, as required.) Electropolishing shall not be used when microexamination of edges is required.

7.6 Etching:

7.6.1 Etchant Control: Any container of an etchant which is to be stored (i.e., not used immediately) or re-used shall be identified with regard to composition, make-up date, shelf life and storage considerations, and precautions for use. Macroetch tanks shall be controlled by chemical analysis and/or etching response on known material.

7.6.2 Fixed Etching Practices: The etching method shall be selected and described with respect to its purpose (e.g., segregation, grain flow, relative grain size). As a minimum, procedures shall define the following: intended purposes, material surface preparation, etchant types and concentrations, material and etchant temperatures, agitation, rinsing and drying, electrical current and voltage (if used), known defect and comparison standards. Changes in procedure shall be documented, with reason for change.

7.6.3 Etched Surface Appearance: Zones to be evaluated shall be essentially free from evidence of mechanical stress from specimen preparation, and from staining and water spots.

7.7 Metallographic Standards and Photographs:

7.7.1 Standards: The laboratory shall maintain controlled metallographic standards for evaluations to be performed under contract requirements. Standards may be photographs, specimens, or other representations (e.g., microscope reticules for grain size measurements). When standards are

7.7.1 (Continued):

not established by the material specification or by the material supplier, initial or supplemental standards may be issued by the laboratory at the time the evaluation is performed.

7.7.2 Photographs (including replicas) provide permanent records of the material evaluated. When made, they shall be identified with respect to the job, specimen number, material location represented, magnification, and etchant used.

7.8 Microexamination and Microhardness at Near-Surface Sections:

Typical surface conditions requiring special precautions during evaluation include those listed below.

a. Alloy depletion
b. Oxidation/corrosion layers, including alpha case
c. Casting surface reactions (mold reactions)
d. Microhardness: Vickers (Diamond Pyramid Hardness: DPH), Knoop
e. Diffusion coatings (e.g., carburizing, nitriding)
f. Intergranular Attack (IGA), Intergranular Oxidation (IGO)
g. Alpha Case: Wrought
h. Alpha Case: Cast

7.8.1 Edge Retention: Specimens shall be cut, mounted, and polished to produce a surface cross-section examination zone that is free from distortion of the metal structure and within the same focal plane at the magnifications required. There shall be no gap between the surface and the mounting material that would subsequently result in bleed-out of etchant.

7.8.2 Surface Layer Etching: Because ASTM E 407 etching practices are not generally designed for evaluating surface reaction effects, the laboratory must have its own detailed procedures for any such evaluation it performs. Specimens with known surface conditions of the type to be evaluated shall be available for personnel training and process verification.

7.8.3 Magnification: Minimum magnification for evaluation shall be:

- Layers up to 0.001 in (0.03 mm) 400X
- Layers thicker than 0.001 in (0.03 mm) 100X
- Layers thicker than 0.010 in (0.25 mm) 40X

7.8.4 Alpha Case on Titanium shall be evaluated per the applicable specification for wrought alloy or castings. A specimen (same alloy) with known case shall be run at the beginning and end of dispensed etchant use to verify detection; if white layer is not shown, fresh etchant shall be prepared, verified, and the lot of process specimens rerun.

7.9 Micro Evaluation:

A written procedure and/or customer specification shall cover selection of the specimen areas to be evaluated, and measurement techniques for surface layers. For example: (1) For grain size, scan the entire specimen at low magnification and select "typical", and "extreme" area for detailed characterization; (2) For surface layer thickness, examine 5 to 10 areas at random and report min.-max.-average.

7.10 Macro Examination of Cross Sections:

7.10.1 Surface Preparation: Method(s) used shall produce a uniform texture, free from surface conditions (e.g., grind marks, stresses, overheating) that could affect etching response or interpretation. Chemical methods may be used to remove mechanically-stressed surface layers prior to etching.

7.10.2 Macro Etching: The etching method shall be selected and described with respect to its purpose. For example: detection of chemical segregation, grain flow, relative grain size.

7.11 Round Robin:

"Round robin" comparisons shall be made annually for each person responsible for evaluating microstructural features to numerical limits (e.g., grain size, percent retained austenite, inclusion content). Comparisons shall be recorded.

7.12 Certificate/Test Report:

In addition to information required by Section 4 and the applicable specification, the Cert shall describe:

a. Etchant used
b. Magnification used
c. Specimen number
d. Material location represented
e. Preparation and evaluation procedures
f. Characteristic(s) evaluated
g. One of the following:
   - Numerical values (e.g., grain size)
   - Reference to established standards (e.g., specification microstructure levels)
   - Specimens or photographs (including replicas) identified with respect to the job

8. HARDNESS:

8.1 Hardness Test Types - Codes:

Codes are as follows:

M HARDNESS (General)
M1 HARDNESS (Brinell)
M2 HARDNESS (Rockwell)
M3 HARDNESS (Vickers)

8.1.1 Hardness testing by other sources (e.g., heat treat, plating, metal spray sources) may be approved as documented.

8.2 Test Methods and Procedures:

8.2.1 The following apply unless otherwise specified.

ASTM E 10 Brinell Hardness
ASTM E 18 Rockwell Hardness
ASTM E 92 Vickers Hardness
ASTM E 140 Hardness Conversions

8.2.2 Written instructions shall cover the following testing variables.

a. Number of impressions for each test value reported.
b. Reading techniques for non-digital-readout testing (e.g., parallax considerations in reading Rockwell dials).
c. In-process calibration procedures and recording.

8.2.3 Rockwell hardness machines used for acceptance testing of material shall fall within the "±" tolerance for the standard test block. For non-superficial scales, repetitive machine error beyond the test block tolerance, up to ±2 points, is permitted until the machine can be adjusted and reverified, if appropriate corrections are made (added or subtracted as applicable) to the subsequent test values. Such corrections shall be documented.

8.3 Hardness Test Matrix:

A Matrix in the applicable checklist or equivalent shall be completed to include all equipment which is used for acceptance testing of material. It shall include reference to applicable Round Robin programs.

8.4 Hardness Test Personnel:

Operators who read test machine dials or microscopically measure indentations shall be evaluated against other operators for consistency. Such evaluations may also be used to satisfy Round Robin requirements.

8.5 Test Specimens:

8.5.1 Optimum specimens have all of the following characteristics, and should be used for all tests which require both minimum and maximum limits.

a. All specimens

- Specimen center of gravity supported by standard anvil.
- Smooth test surface finish; max. roughness.

Brinell	125 μin (3.20 μm)
Rockwell	63 μin (1.60 μm)
Rockwell superficial	32 μin (0.80 μm)
Vickers	16 μin (0.40 μm)

- Sufficient thickness so that testing is confined to the specimen (i.e., so that anvil has no effect).

- No local protrusions on anvil-side surface.

b. Flat specimens

- Test surface and opposite surface machined or ground flat, with no local protrusions (such as mechanical marking) on the anvil-side surface; and parallel within 2.0°.
- Mounted specimens should be used for Rockwell superficial or superficial or Vickers hardness only.

c. Contoured specimens

- Cylindrical and spherical material (e.g., ball bearings, ground bar) with proper surface finish, tested in proper holding fixtures, and with appropriate correction factors.

8.5.2 Non-Optimum specimens, such as large parts which require special fixturing or parts of irregular geometry, may be used only for tests which require minimum limits only, unless correlation studies have shown equivalency with optimum specimens. Generally, the only conditions which can give artificially high readings are equipment/indenter damage, test surface convexity, and inadequate specimen thickness.

8.6 Routine Calibration Checks:

Routine calibration checks shall be made on standard test block(s) representing the hardness range(s) to be tested; minimum frequencies are noted below. Three indentations shall be made and shall fall within the hardness range tolerances listed for the test block. Alternate frequencies or calibration procedures may be permitted based on statistical evaluation of performance. If calibration is based on the average of multiple readings, acceptance testing also requires multiple readings. Test results and any correction factors to be used shall be recorded.

8.6 (Continued):

Frequency: Check once each working shift during which the tester will be used. Equipment that can be changed by the operator (e.g., Rockwell testers with several loads/indenters): check prior to each test run, defined as testing of material using the same equipment set-up while the machine is under the control of the same operator.

8.7 Hardness Re-Testing and Referee Tests:

8.7.1 Hardness Re-Test: Because problems such as specimen wobbling may occur which are apparent only to the operator and only at the time of testing, operators may choose to disregard test impressions they suspect of being irregular. Provided two additional impressions are made, both of which give conforming values and whose variations are typical for the material and hardness procedure, the suspect test may be disregarded and need not be recorded in the log or on the certificate.

8.7.2 Hardness Referee Tests: Common referee tests include:

a. Re-preparation of the specimen to improve surface finish, parallelism, and/or flatness.

b. When "alternate" test methods are permitted, use of a hardness method or scale that best represents the material being tested: for example

- Use of spherical indenter methods when material is work-hardenable.
- Use of Brinell hardness on castings or other large-grain material.
- Use of Brinell hardness when "Brinell or alternate" is specified.
- Selection of load which produces maximum sensitivity of readings (higher loads for higher hardnesses).

c. Use of Rockwell "N" brales for "C/A/D" scales.

d. Use of direct-reading digital equipment instead of equipment requiring human interpretation of readings.

e. Make three or five impressions. All readings should conform to specification; report the median value.

8.8 Hardness Round Robin Testing:

Hardness round robin testing should be performed within each facility, among interchangeable equipment sets, among operators who read non-digital equipment, and non-optimum configurations.

8.9 Alternate Hardness Methods:

Alternate hardness methods may be used when permitted by the material specification or otherwise accepted as a "non-standard practice" for the applicable application; (ref. Table 1). Hardness conversions shall be reported per ASTM E 140. When Rockwell hardness is converted from Brinell, Brinell indentation diameters shall be measured to give an equivalent sensitivity of ½ Rockwell number. Prior to use of ASTM E 140 or other conversions, a calibration report is required (primary versus equivalent method) for the following:

- Alloy groups not covered by ASTM E 140
- Work-hardenable materials
- Castings and other coarse-grain materials
- Microhardness in lieu of Rockwell or Brinell; or vice versa

9. CORROSION AND OXIDATION TESTING:

9.1 Corrosion and Oxidation Test Types - Codes:

Test codes are as follows:

Q CORROSION
Q_1 STRESS CORROSION
Q_2 OXIDATION TESTING

9.1.1 Corrosion and oxidation testing by other sources (e.g., diffusion coating sources) may be approved and documented for the applicable process.

9.2 Test Methods and Procedures:

Methods and procedures for corrosion and oxidation testing shall be as called out by the material specification. If none are specified, the applicable ASTM Method or Procedure from Volume 3.02 "Erosion and Wear; Metal Corrosion" shall be used. Reference specification: ASTM A 262 and ASTM B 117.

Written procedures shall be issued to identify the methods and procedures used, and to relate details of the test specification to the actual equipment and practices in that laboratory. Instructions shall incorporate lessons learned with regard to invalidation of testing.

9.3 Personnel:

Personnel shall be trained in preparation and handling of specimens, in maintenance of equipment, and in corrosion theory as it applies to corrosion testing.

9.4 Test Specimens:

Specimens shall be prepared and handled so as to preclude the introduction of foreign materials or non-representative stresses to surfaces.

9.5 Visual Standards:

When the laboratory is responsible for acceptance of test results (rather than simply performing the tests), visual or photographic standards shall be maintained for acceptance to specifications which permit acceptance of some degree of visible corrosion.

9.6 Continuation of Testing (Corrosion/Stress Corrosion):

If nonconformance to required life is noted in one specimen among multiple specimens from the same set, it is recommended that testing of remaining specimens be continued beyond 1.5 times the required life or until failure, whichever time is less. For proposed acceptance of unexplained nonconformances, a set should contain at least three acceptable tests for each nonconformance. All results should be reported on the nonconformance document.

10. PREPARATION OF MECHANICAL TEST SPECIMENS:

10.1 Specimen Preparation - Codes:

Test codes are as follows:

Z STANDARD PREPARATION
Z1 LOW STRESS GRINDING
Z2 LOW STRESS GRINDING AND POLISHING
Z3 CAST SPECIMENS
Z4 SPECIAL PURPOSE SPECIMENS

Codes "Z1 and Z2" apply to Test Codes "Y, XH", and to any other test specimen for which the material specification requires low stress grinding (LSG). Other requirements of this section apply to preparation of all mechanical test specimens.

10.2 Preparation Procedures:

Written procedures shall be maintained and followed which establish specific values for each combination of specimen and material, for each process variable (e.g., speed, feed, grinding wheel type); these may include reasonable tolerances to recognize limits of process controllability and material response. A 100% verification or SPC is required for all gage section dimensions or other dimensions which might affect testing axiality or stress concentration.

10.3 Technical Objective and Requirements:

Ideally, specimen preparation techniques eliminate any effects of that preparation on the properties resulting from the test. Factors that must be considered include:

- Distortion of specimen dimensions.
- Physical damage (e.g., cracks, tears, scratches).
- Residual stresses (tensile or compressive).
- Metallurgical damage (e.g., local overheating, melting, decarburization, alloy depletion).

10.3.1 Straightening: Mechanical straightening of specimens prior to testing is not permitted. Exception: For castings which permit straightening followed by solution treat and age, as-cast test bars may also be straightened followed by solution treat and age.

10.3.2 Blanking: Blanking may be done by machining, grinding, Electrical Discharge Machining (EDM), pressing (flat specimens), or other methods which do not distort the material or produce surface effects deeper than would be removed by final finishing. A minimum of 0.010 in (0.25 mm) shall remain on blanked surfaces for final finishing operations. For sheet specimens, as-finished sheet surfaces should remain intact.

10.3.3 Special Purpose Specimens: For testing of weld and braze joints, tubes, miniature bars, and other material conditions which are not suitable for standard flat or cylindrical specimens, blanking and finishing operations shall be covered by written procedures.

10.3.4 Inspection: Visual inspection (20X) of finished specimens is required for Code Z2 and is recommended for other specimens.

10.4 Residual Stresses:

It is recommended that residual stresses be determined initially for each generic preparation procedure: thereafter, an audit plan should provide for evaluation of a minimum of one procedure per year, with all procedures being evaluated in the shortest possible time.

10.5 Round Robin, Code "Z2" Low Cycle Fatigue (LCF) Specimen Preparation:

Lab Accreditation shall include participation in a NADCAP sponsored Round Robin program; see Appendix F.

11. DIFFERENTIAL THERMAL ANALYSIS (DTA):

11.1 Test Types - Codes (DTA):

Code is as follows for DTA:

XJ DIFFERENTIAL THERMAL ANALYSIS (DTA)

11.2 DTA Test Methods and Procedures:

Methods and procedures for DTA shall be developed by the laboratory and calibrated statistically against metallographic methods. Procedures shall include photomicrographs which define the metallurgical transformations to be evaluated (e.g., alpha-beta transus in titanium, gamma-prime solvus in nickel alloys).

11.2.1 Specimen Re-Cycling: Each specimen shall be subjected to heating and cooling through the phase transformation cycle only once, unless otherwise specified or permitted by the customer's testing instructions.

11.3 Beta Transus, Titanium Alloys:

Procedures or standards from the material producer or material customer shall define what percent alpha comprises the "transus", and which DTA inflection point corresponds to that value.

12. HEAT TREAT OF SPECIMENS:

12.1 Test Types - Codes:

Test codes are as follows:

XG HEAT TREAT OF SPECIMENS

This code applies to heat treatment performed under conditions other than production heat treatment of the material represented. For example: Heat treatment of specimens, partially machined blanks, separated samples (test rings, prolongs); sample parts heat treated in the lab rather than in production facilities; specimen material aged for "capability" properties when material is to be supplied in the solution treated condition.

12.2 Personnel:

Personnel shall be trained in handling of specimens and use of equipment commensurate with applicable requirements, including furnace loading and specimen quenching.

12.3 Furnaces:

Furnaces shall be surveyed to the requirements of AMS 2750 Class 1 or by an equivalent procedure approved by the Purchaser. For captive laboratories of material sources, surveys may be per the applicable alloy heat treat specification (e.g., MIL-H-6875 for steels). Working zones shall be defined by procedure if not inherent in the equipment design. Minimum frequency of temperature uniformity surveys shall be per AMS 2750.

12.4 Time and Temperature:

Heat treat times and temperatures shall be as specified by the customer. Temperature shall be set to achieve the nominal specified value as closely as possible; metal temperature tolerances are intended only to limit maximum furnace tolerances. Times and temperatures shall be recorded on the certificate of test. If time tolerances are not given, specified time is minimum, minus zero, plus 10%. Time is measured from the time that the metal reaches the required temperature; the lab shall have a written rationale for determining this time (e.g., for light loads of a few well-spaced specimen blanks, time cycle might begin when the furnace recovers to temperature).

12.5 Quench Method:

When options are permitted in quench rate (e.g., specification calls out "air, oil, or water quench"), the slowest method shall be used unless otherwise specified by the customer.

RATIONALE: Slower quench rates tend to produce lower tensile strength in Quench + Temper and Solution + Age alloys. For example, properties of water quenched specimen material may not adequately represent oil or air quenched parts. (And in most cases, specimen material has less effective thickness -- hence a naturally faster cooling rate -- than the parts represented even when the same type quench is used.)

12.6 Specimen Condition:

Unless otherwise specified, specimens shall be heat treated in the blanked or rough machined condition.

12.6.1 Heat Treatment of Finished Specimens: If heat treating of finished specimens is specified, specimens shall be inspected for evidence of distortion prior to testing.

12.7 Certificate of Test:

The following items shall be described:

a. Heat treat times and temperatures.
   NOTE: Test records shall document metal time at temperature (heaviest section), including tolerances, and temperature tolerances.
b. Quench methods.
c. If heat treatment was performed on finished specimens, note this fact and describe atmosphere.