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Introduction

The information collected in this document is intended to serve as a preliminary guideline for determining solutions for material testing applications. Its focus is on common test methods for metal specimens.

This document should be used in the *Discovery and Influence* (D&I) and *Create Solution* stages of the selling process. Iterative interaction with the customer is required to specify the final product offering.

Recommended Use:

1. Discover the customer's requirements
2. Use this reference to help identify possible solutions, as well as potential tradeoffs of the choices
3. Refer to the product data sheets and Services & Accessories catalog for detailed product information (specifications, etc.)
4. Review the selections to verify that they make sense for your customer
5. Refine selection as more is learned about the customer's requirements
6. Verify the configuration with Application Engineers (AE) and/or Systems Engineers

Assumptions:

The following assumptions were made in developing these guidelines to ensure the highest probability for success:

- The following components will be used with MTS equipment:
 - Model 318 or 370 load frames
 - 493 or 494 Controllers
 - Model 793 Software
 - TestWorks or MTS TestSuite software
- All equipment is in good working order:
 - Load frame is in alignment
 - Transducers have valid calibrations
- The customer's facility structure supports the desired test
 - Floor stability
 - Electrical requirements
 - Hydraulic power requirements
 - Isolation
- Other factors:
 - Load frame attachment kit information available
 - Software version and build number available

Note: Some products referenced in this document may not be featured in the current MTS Services & Accessories catalog or product data sheets



Low Cycle Fatigue (LCF) & Advanced LCF Tests

Applicable Standards

ASTM E606-04e1	Standard Practice for Strain-Controlled Fatigue Testing
ISO / DIS 12111	Metallic materials - Fatigue testing - Strain-controlled thermomechanical fatigue testing method
ASTM E739-91(2004)e1	Standard Practice for Statistical Analysis of Linear or Linearized Stress-Life (S-N _e) and Strain Life (e-N) Fatigue Data
ISO 12106:2003	Metallic materials - Fatigue testing - Axial-strain-controlled method
BS 7270:2006	Metallic materials. Constant amplitude strain controlled axial fatigue. Method of test
DIN EN 3874	Aerospace series - Test methods for metallic materials - Constant amplitude force-controlled low cycle fatigue testing
DIN EN 3988	Aerospace series - Test methods for metallic materials - Constant amplitude strain-controlled low cycle fatigue testing
JIS Z2279	Method of high temperature low cycle fatigue testing for metallic materials
GE E50TF148	Axial strain control low cycle fatigue testing of metal test bars

General Comments

Load Frame

- Model 370.10 / 318.10 - 25 kN and 50 kN load frames are not suitable for LCF
 - Rod / seal design not adequate - needs to be very stiff
 - Use a small servovalve (252.21* or 252.22*) with 100 kN actuator for best performance
*4 lpm (1 gpm) or 9.5 lpm (2.5 gpm)

Software

- The MTS TestSuite Low Cycle Fatigue and Advanced Low Cycle Fatigue Modules support ASTM E606.

Room Temperature

Specimen	Extensometer Clip Gage (COD)	Grips	Wedges	Alignment	Grip Supply
Round w/parallel gage section	632.13 634.11/.12/.31	646.10	Collets	609	Load frame integrated or 685
		647.10	Round		
			Vee		
Hourglass	632.18/.19/.20	646.10	Collets	609	
		647.10	Round		
			Vee		
Other	Contact AE				

Notes

Specimen dictates extensometer choice. Factors include gauge length, travel, environmental concerns

- Model 646 is the premier LCF grip - should be used if LCF testing is the customer's expertise or if it's a difficult specimen
- Model 647 is a good alternative for LCF testing, especially for customers where testing flexibility is desired (run multiple test types)
- If the 647 is chosen, better results can be achieved with round wedges; vee wedges offer more flexibility and less specimen preparation
- Alignment is strongly recommended for LCF applications



Accessories Guide for Common Tests of Metal Specimens

Advanced / High Temperature

Specimen	Extensometer	Grips	Wedges	Misc	Furnace	Alignment	Grip Supply
Round w/parallel gage section	632.50	680	Specimen Adapter	Hand pump Water cooling kit	653	609	-
	632.51		Collets	Water cooling kit			Load frame integrated or 685
	632.53	Round, H2O					
	632.54	Vee, H2O					
Hourglass	632.60	680	Specimen Adapter	Hand pump Water cooling kit	653	609	-
		646.10	Collets	Water cooling kit			Load frame integrated or 685
		647.10	Round, H2O				
			Vee, H2O				
Other	Contact AE						

Notes

- Specimen dictates extensometer choice. Factors include gauge length, travel, environmental concerns
- Choice of 680 grip versus 646 or 647 can depend on specimen size
- 680 can extend into the furnace. Used in conjunction with 3-zone, better control of temperature gradients
- 646 and 647 heat the specimen only (grips can't go in furnace)
 - Potential for greater temperature gradients
 - May be OK if the specimen is very long
 - Standard system oil can be used in the grip supply
 - Water cooling is required
- If there are multiple specimen types, may be beneficial to use 646/680 combination
 - Additional flexibility with plate to adapt 646 to button-head specimens
- For 646 versus 647 grip considerations, see LCF testing at room temperature notes
- Furnace selection should include consideration of acceptable specimen heating and thermal gradients at the system level
- Alignment is strongly recommended for LCF applications

Contact an MTS Application Engineer for assistance if you have an application that:

- Requires temperatures greater than 1000°C
- Requires forces greater than 10 kN at 1000°C
- Uses a non-metallic specimen (ceramic coating or solid ceramic)



Thermomechanical Fatigue (TMF) Test

Applicable Standards

ASTM E2368-04	Standard Practice for Strain Controlled Thermomechanical Fatigue Testing
ISO TMF-STANDARD	Thermomechanical fatigue - the route to standardization

General Comments

- *TMF is a complex application, requiring a custom solution; an AE must be involved for system configuration*

Load Frame

- Model 370 / 318 - 25 kN and 50 kN load frames are not suitable for LCF
 - Rod / seal design not adequate - needs to be very stiff
 - Recommend a 250 mm actuator stroke
 - Use a small servovalve (252.21* or 252.22*) with 100 kN actuator for best performance
*4 lpm (1 gpm) or 9.5 lpm (2.5 gpm)

Software

- The MTS TestSuite TMF Module will be available in 2010. Contact your MTS AE for further information.
- If using MTP, a TMF template is required.

Specimen	Extensometer Clip Gage (COD)	Grips	Wedges	Misc	Furnace	Alignment	Grip Supply
Round w/parallel gage section (smooth or threaded ends)	632.50 632.51 632.53 632.54 632.68 (A/T)	646.10 646.25	Collets	Water cooling kit	Induction (Contact AE)	609	Load frame integrated or 685

Notes

- There is a special version of the 646 grip that will allow air cooling through the center of the specimen (if using a hollow specimen). An axial-torsional option is also available



High Cycle Fatigue (HCF) Test

Applicable Standards

ASTM E467-08	Standard Practice for Verifications of Constant Amplitude Dynamic Forces in an Axial Fatigue Testing System
ASTM E466-07	Standard Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials
ISO 1099:2006	Metallic materials - Fatigue testing - Axial force-controlled method

General Comments

Load Frame

- Applications above 30 Hz may require a load frame column tie bar, pneumatic pads, performance analysis (SPOOL), acceleration compensation - contact an AE
- Applications above 100 Hz may require specialty load frame and/or custom grips - contact an AE

Software

- The MTS TestSuite High Cycle Fatigue Module supports ASTM E466.

Specimen	Extensometer Clip Gage (COD)	Grips	Wedges	Alignment	Grip Supply
Round w/parallel sides	Not typically required. For up to 150 Hz 632.27 can be used.	647	Vee	609	Load frame integrated or 685
			Round		
		646	Collets		
Hourglass (tangentially blended fillets)		647	Vee		
			Round		
		646	Collets		
Flat parallel		647	Flat		
Flat hourglass		647	Flat		

Notes

- Although the ASTM standard allows for flat specimens, round specimens are required for the best results
- HCF is often a load control test with no extensometer
- MTS 1000 Hz system is available



Fracture Toughness Tests

Applicable Standards

ASTM E1820-08a	Standard Test Method for Measurement of Fracture Toughness
ASTM E399-08	Standard Test Method for Linear-Elastic Plane-Strain Fracture Toughness K_{Ic} of Metallic Materials
ASTM E1290-08	Standard Test Method for Crack-Tip Opening Displacement (CTOD) Fracture Toughness Measurement
ASTM E561-05e1	Standard Test Method for K-R Curve Determination
ASTM B645-07	Standard Practice for Linear-Elastic Plane-Strain Fracture Toughness Testing of Aluminum Alloys
ISO 12737:2005	Metallic materials - Determination of plane-strain fracture toughness
ISO 12135:2002	Metallic materials - Unified method of test for the determination of quasi-static fracture toughness
BS EN ISO 12737:2005	Metallic materials. Determination of plane-strain fracture toughness. (Identical to ISO 12737:2005)
BS 7448-1	Fracture mechanics toughness tests. Method for determination of K_{Ic} , critical CTOD and critical J value soft metallic materials (Partially replaced by BS EN ISO 12737:1999 - withdrawn and replaced by 2005)
prEN2002-22	Test methods for metallic materials - Part 22: Plane strain fracture toughness test

General Comments

Software

- The MTS TestSuite K_{Ic} Module supports ASTM E399. Specimen supported FFC(T), SE(B).
- The MTS TestSuite CTOD Module supports ASTM E1290. Specimen supported FFC(T), LLC(T), and SE(B).
- The MTS TestSuite J_{Ic} Module supports ASTM E1820. Specimen supported FFC(T), LLC(T) and SE(B).

Room Temperature

Specimen	Extensometer Clip Gage (COD)	Grips	Wedges	Alignment	Grip Supply
C(T) Compact Tension	632.02 632.03	640 Clevis Grips	-	-	-
SE(B) Single Edge Bend Flat with vee notch	632.02	642 3-point	Rollers	-	-
M(T) Middle Tension Center crack	-	647	Extra wide flat wedges (Custom)	-	Load frame integrated or 685



Accessories Guide for Common Tests of Metal Specimens

Notes

Specimen dictates extensometer choice: Factors include gauge length, travel, and environmental concerns

SE(B)	Potential space constraints with bend fixture, extensometer
	Smallest combination - 642.10 and 632.02
	Roller sizes - point loading desirable
	ASTM E399 and E1820 requirements
	Roller as wide as the specimen
	Top roller = $W/4$; Bottom roller = $W/2$ to W (where W is specimen thickness)
	642.001 includes rollers
M(T)	This specimen type often requires custom fixtures (bolt to the specimen)
	Consult AE

High Temperature (500 to 1000°C)

General Comments

- *High Temperature Fracture Mechanics is a complex application, requiring a custom solution; an AE must be involved for system configuration*
- Use clip-on displacement gage Model 632.65 (high temperature with quartz rods)

Fatigue Crack Growth Test

Applicable Standards

ASTM E647-08	Standard Test Method for Measurement of Fatigue Crack Growth Rates.
ISO 12108:2002	Metallic materials - Fatigue testing - Fatigue crack growth method
prEN 3873	Aerospace series - Test methods for metallic materials - Determination of fatigue crack growth rates using corner-cracked (CC) test pieces (01/705746 DC:2001-03-21)
BS 6835-1:1998	Method for the determination of the rate of fatigue crack growth in metallic materials. Fatigue crack growth rates of above 10 ⁻⁸ m per cycle (Replaced by BS ISO 12108:2002)
DIN EN 4524:1999-06	Aerospace series - Metallic materials - Test methods; measurement of fatigue crack growth rates

General Comments

Software

- The MTS TestSuite Clip Gage Fatigue Crack Growth Module supports ASTM E647. Method of measurement is via clip gage. Specimens supported FFC(T), SE(B) and M(T).
- The MTS TestSuite Crack Gage Fatigue Crack Growth Module supports ASTM E647. Method of measurement is via crack gage. Specimen supported FFC(T).
- The MTS TestSuite Direct Current Potential Drop (DCPD) Fatigue Crack Growth Module supports ASTM E647. Method of measurement is via DCPD. Specimen supported FFC(T).

Room Temperature

Specimen	Extensometer Clip Gage (COD)	Grips	Wedges	Alignment	Grip Supply
C(T) Compact Tension	632.02 632.03	640 Clevis Grips	-	-	-
SE(B) Single Edge Bend Flat with vee notch	632.02	642 3-point	Rollers	-	-
M(T) Middle Tension Center crack	Need two ext and average	647	Extra wide flat wedges (Custom)	-	Load frame integrated or 685

Notes

- Specimen dictates extensometer choice: Factors include gauge length, travel, and environmental concerns

SE(B)	Potential space constraints with bend fixture, extensometer
	Smallest combination - 642.10 and 632.02
	Roller sizes - point loading desirable
	ASTM E399 and E1820 requirements
	Roller as wide as the specimen
	Top roller = W/4; Bottom roller = W/2 to W (where W is specimen thickness)
	642.001 includes rollers
M(T)	This specimen type often requires custom fixtures (bolt to the specimen)
	Consult AE



High Temperature (500 to 1000°C)

General Comments

- *High Temperature Fracture Mechanics is a complex application, requiring a custom solution; an AE must be involved for system configuration*
- Use clip-on displacement gage Model 632.65 (high temperature with quartz rods)

Direct Current Potential Drop (DCPD)

General Comments

- High frequency (above 60 Hz), for both low and high temperatures
- Two channels per specimen (with reference standard) = default
- Documentation to guide specifications with DCPD will be available in the future
- MTS has an offering for DCPD, but it is not CE compliant
- If you have an application that requires DCPD, please contact an MTS Application Engineer

Software

- MTS TestSuite software will support DCPD (Direct Current Potential Drop).



Tensile Test

Applicable Standards

ASTM E8/E8M-08	Standard Test Methods for Tension Testing of Metallic Materials
ASTM E21-05	Standard Test Methods for Elevated Temperature Tension Tests of Metallic Materials
ASTM E517-00(2006)e1	Standard Test Method for Plastic Strain Ratio r for Sheet Metal
ASTM E646-07	Standard Test Method for Tensile Strain-Hardening Exponents (n -Values) of Metallic Sheet Materials
ASTM B557-06	Standard Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products
ASTM A370-09	Standard Test Methods and Definitions for Mechanical Testing of Steel Products
ISO 6892:1998	Metallic materials - Tensile testing at ambient temperature
BS EN 10002-1:2001	Tensile testing of metallic materials. Method of test at ambient temperature
AS 1391-2007	Metallic materials - Tensile testing at ambient temperature
prEN 2002-1	Aerospace series Metallic materials Test methods Part 1: Tensile testing at ambient temperature
prEN 2002-2	Aerospace series Metallic materials Test methods Part 1: Tensile testing at elevated temperature

General Comments

- 100 - 300 kN load frame generally adequate

Software

- TestWorks software provides specific templates for tensile testing.
- MTS TestSuite MP or MPT may be suitable depending on specific types of test to be run. Contact AE.

Room Temperature

Specimen	Extensometer Clip Gage (COD)	Grips	Wedges	Alignment	Grip Supply
Round	632.13/.24 634.11/.12/.25/.28/.31	Advantage wedge grips	Vee	None	-
		647	Vee		Load frame integrated or 685
Flat		Advantage wedge grips	Flat		-
		647	Flat		Load frame integrated or 685

Notes

- Advantage wedge grips are the most cost-effective option for tensile-only testing
- 647 grips are more flexible - enable fatigue testing



Accessories Guide for Common Tests of Metal Specimens

High Temperature

Specimen	Extensometer	Grips	Wedges	Misc	Temp	Environment	Alignment	Grip Supply
Round	632.13/.24 634.11/.12/.25/.28/.31	Advantage wedge grips	Vee	-	-130°C to +315°C (-200°F to 600°F)	651	None	-
		647 .02/.10	Vee	-	-40°C to 177°C (-40°F to 350°F)	651		685 Stand alone
		647.25	Vee	-	-40°C to 177°C (-40°F to 350°F)	651.06E-04		685 Stand alone
		647 All Temp	Vee	-	-130°C to 315°C (-200°F to 600°F)	651		Load frame integrated or 685
		647 All Temp	Vee	-	-130°C to 540°C (-200°F to 1000°F)	651.10E-04		Load frame integrated or 685
		647	Vee H2O	Water Cooling Kit	1400°C 2550°F	653		Load frame integrated or 685
Flat		Advantage wedge grips	Flat	-	-130°C to 315°C (-200°F to 600°F)	651		-
		647 .02/.10	Flat	-	-40°C to 177°C (-40°F to 350°F)	651		685 Stand alone
		647.25	Vee	-	-40°C to 177°C (-40°F to 350°F)	651.06E-04		685 Stand alone
		647 All Temp	Flat	-	-130°C to 315°C (-200°F to 600°F)	651		Load frame integrated or 685
		647 All Temp	Flat	-	-130°C to 540°C (-200°F to 1000°F)	651.10E-04		Load frame integrated or 685
		647	Flat H2O	Water Cooling Kit	1400°C 2550°F	653		Load frame integrated or 685



Notes

- Specimen dictates extensometer choice. Factors include gauge length, travel, environmental concerns
- Advantage wedge grips are the most cost-effective option for tensile-only testing
- 647 grips are more flexible - enable fatigue testing, higher temperatures
- Temperature rating of 647.02/.10/.25 limited by the grip, not the chamber
- Furnace selection should include consideration of acceptable specimen heating and thermal gradients at the system level



Compression Test

Applicable Standards

ASTM E9-89a(2000)	Standard Test Methods of Compression Testing of Metallic Materials at Room Temperature
ASTM E209-00	Standard Practice for Compression Tests of Metallic Materials at Elevated Temperatures with Conventional or Rapid Heating Rates and Strain Rates

General Comments

Software

- TestWorks software provides specific templates for compression testing.
- MTS TestSuite MP or MPT may be suitable depending on specific types of test to be run. Contact AE.

Room Temperature

Specimen	Extensometer Clip Gage (COD)	Grips	Alignment	Grip Supply
-	-	643 Compression Platen (Spherical / Fixed)	-	-
-	-	643 Compression Platen (Fixed)		

Notes

- Extensometer not generally used; potential to crush; mechanical stops recommended; contact AE for extensometer
- If there is a side loading concern, use spherical (not fixed) compression platens
- 643 compression platen size dictated by specimen, not force capacity

High Temperature

Specimen	Extensometer Clip Gage (COD)	Grips	Temperature	Environment	Alignment	Grip Supply
-	-	643 Compression Platen (Spherical / Fixed)	-130°C to +175°C (-200°F to 350°F)	651	-	-
-	-	643 Compression Platen (Fixed)				

Notes

- Extensometer not generally used; potential to crush; mechanical stops recommended; contact AE for extensometer
- Temperature rating above limited by the compression platens, not the 651 chamber
- For temperatures above 350°F, contact AE



Bend Test

Applicable Standards

ASTM E290	Standard Test Methods for Bend Testing of Materials for Ductility
ASTM C1211-02(2008)	Standard Test Method for Flexural Strength of Advanced Ceramics at Elevated Temperatures
ASTM C1161-02c(2008)e1	Standard Test Method for Flexural Strength of Advanced Ceramics at Ambient Temperature
JIS R 1604	Testing method for flexural strength (modulus of rupture) of fine ceramics at elevated temperature
JIS R 1601	Testing method for flexural strength (modulus of rupture) of fine ceramics at room temperature

General Comments

- *Contact an AE if you have a high temperature bend application*

Software

- TestWorks software provides specific templates for tensile testing.
- MTS TestSuite MP or MPT may be suitable depending on specific types of test to be run. Contact AE.

Room Temperature

Specimen	Extensometer Clip Gage (COD)	Grips	Wedges	Alignment	Grip Supply
-	632.06H	642 3-point	Rollers	-	-

Notes

- Potential space constraints with bend fixture, extensometer; 632.06H can be used with 642.01, 642.10 or 642.25; Mod available for the 642.01 and 642.10 mounting / ext
- Roller diameter is based on the specimen thickness
- 642.001 includes rollers

High Temperature

Specimen	Extensometer Clip Gage (COD)	Grips	Wedges	Temperature	Environment	Alignment	Grip Supply
50 mm long 3 - 4 mm thick	-	642.85	Rollers	-	653.03/.04	-	-
-	-	642.05	Rollers	-		-	-