

Gleeble Catalog and Specifications

Release 1.22.11.01.0633

Dynamic Systems Inc

Oct 02, 2026

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IMPORTANT NOTICES

Specifications subject to change without notice. Dynamic Systems Inc. (DSI) reserves the right to make changes at any time in order to improve design and supply the best product possible. Pictures and diagrams show the latest models as of time of publication. Actual appearance may vary.

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Version: 1.22.11.01.0633

Section 1

Introduction

1.1 What Is a Gleeble®?

A Gleeble is a dynamic research system that can simulate a wide variety of thermal-mechanical metallurgical conditions to aid researchers in developing new materials, solving metallurgical challenges or optimizing production processes.

Dynamic Systems Inc. (DSI) is the manufacturer of the Gleeble line of Thermal-Mechanical Simulators. In a Gleeble, samples of material are heated and mechanically worked while various performance parameters of interest are measured and recorded for analysis. After the simulation or test is done, the microstructure of the material may also be examined.

Gleeble Systems are produced in a number of different sizes and configurations. These machines typically have a high-speed heating system, a servo-hydraulic system and a computer control and data acquisition system.

Reliability

Gleeble systems have been designed for maximum reliability and ease of service. The present Gleeble systems are the result of over 60 years of evolution and refinement in the design and manufacture of high-speed thermal-mechanical testing systems. The result is a time-tested combination of the latest in advanced robust technology and reliability.

1.2 What is Physical Simulation?

Physical simulation is the reproduction of the thermal and mechanical processes a material is subjected to during the manufacturing process or end use. This process is completed in a controlled laboratory environment. Physical simulation is a valuable tool used to study metallurgical processes, develop new materials and replicate real world conditions in the laboratory. Benefits include:

Lower Costs - Reduce product development, processing & energy costs

Optimize Manufacturing Processes - Develop new procedures & troubleshoot existing processes

Optimize Materials - Develop new materials and applications

Increase Production - Reduce scrap and maximize output and efficiency

Faster Product Development - Reduce time to market and R&D expense

Improved Product Quality - Improve product consistency and quality

DSI products provide a cost effective way to physically simulate high-temperature processes and applications at a far lower cost than full scale tests while providing excellent correlation and results which can then be applied to the actual process or application.

1.3 Popular Gleeble Applications

Materials Testing Applications:

- Hot/warm tensile testing
- Hot/warm compression testing
- Uniaxial compression
- Plane strain compression
- Strain Induced Crack Opening (SICO)
- Stress vs. strain curves
- Melting and solidification
- Nil-strength testing
- Hot ductility testing
- Thermal cycling/heat treatment
- Dilatometry/phase transformation
- Thermal Fatigue
- Stress relaxation studies
- Creep/stress rupture
- Thermal-mechanical Fatigue

Process Simulation Capabilities:

- Continuous casting
- Mushy zone processing
- Hot rolling
- Forging
- Extrusion
- Weld HAZ cycles
- Upset butt welding
- Diffusion bonding
- Continuous strip annealing
- Heat treating
- Quenching
- Powder metallurgy/sintering
- Synthesis (SHS)

Over 60 Years Small

The DSI team is passionate about advancing the art and science of metallurgy and materials science. If you are faced with a research or production challenge where physical simulation or testing may be required, please contact a member of our team today to learn more about the impressive capabilities of the Gleeble line of thermal-mechanical physical simulators.

Section 2

Gleeble Thermal-Mechanical Simulation Systems

Contents

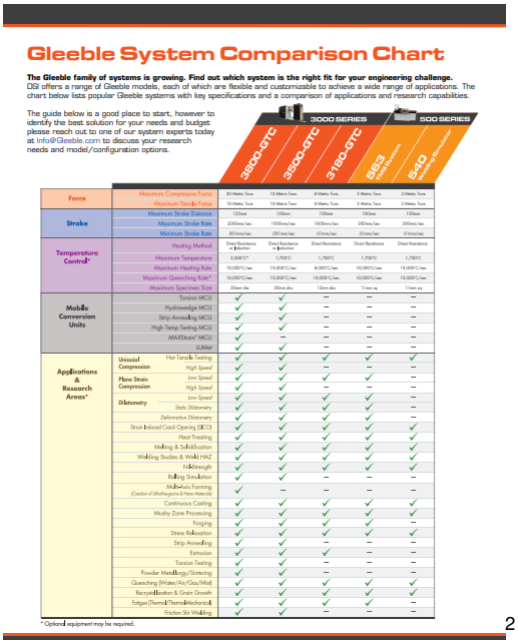
- *Gleeble Thermal-Mechanical Simulation Systems* (page 5)
- *Gleeble 3000 Series Systems* (page 6)
- *Gleeble 500 Series Systems* (page 6)
- *Gleeble Subsystems* (page 6)
  - *Load Unit* (page 6)
  - *Control Console - Human-Machine Interface (HMI)* (page 6)
  - *Hydraulic Power Unit (HPU)* (page 7)
  - *Thermocouple Welder* (page 7)
  - *Mobile Conversion Unit (MCU)* (page 7)
  - *Vacuum System* (page 8)
  - *Process Fluid Chillers* (page 8)
  - *Air Compressors* (page 8)

2.1 Gleeble Thermal-Mechanical Simulation Systems

A Gleeble system incorporates interrelated subsystems that vary based on customer needs and facility parameters. Dynamic Systems Engineers work closely with customers to integrate a Gleeble into new or existing facility requirements. The integration and installation process of a Gleeble into various constraints imposed by existing building design or layout do not affect the performance of the Gleeble. World class Gleeble performance is maintained in all system installations maintaining world-class performance.

Gleeble Systems Comparison

Click here[1] to view a comparison guide of all Gleeble systems.



[2]

[1] https://gleeble.com/products/gleeble-systems/comparison-chart.html
[2] https://gleeble.com/products/gleeble-systems/comparison-chart.html

2.2 Gleeble 3000 Series Systems

An Unstoppable Work Horse

The Gleeble 3000 series includes the *Gleeble 3180-GTC* (page 90), *Gleeble 3500-GTC* (page 28), and *Gleeble 3800-GTC* (page 11) systems. The Gleeble 3000 series is designed to serve as a platform through which thermal-mechanical testing and simulation requirements of researchers around the world can be met. By selecting from multiple designs and optional equipment, Gleeble systems can be customized to address specific testing and simulation needs. Driven by a powerful heating transformer and a robust hydraulic system, the Gleeble 3000 series provides researchers with an unparalleled combination of thermal and mechanical capability

2.3 Gleeble 500 Series Systems

Small Gleeble. . . Big Impact!

While quite powerful and flexible, Gleeble 3000 systems have a large footprint and require a significant initial investment that may be unrealistic for smaller facilities or organizations with limited budgets. In 2015, DSI introduced the Gleeble 500 Series, which is designed to provide maximum value by delivering world-class performance in a smaller, more affordable package. The Gleeble 500 series includes the *Gleeble 525* (page 134), *Gleeble 540* (page 120), and *Gleeble 563* (page 104) systems.

Each of the systems in the 500 Series offers industry-leading heating capabilities and responsive, dynamic controls, including the new touchscreen-based user interface.

Gleeble System Site Installation Requirements

Reference the Gleeble Site Perpetration Checklist[3] for laboratory requirements including minimum plumbing, electrical, and pneumatic requirements for all Gleeble systems.

2.4 Gleeble Subsystems

2.4.1 Load Unit

The Gleeble load unit contains the majority of the thermal, hydraulic, and pneumatic components. Depending on the Gleeble model, it may also include the vacuum tank, also know as the specimen testing chamber. The Gleeble 3500-GTC Pedestal, 3180-GTC, and 500 series models include an integrated vacuum tank. Gleeble 3500C-GTC and 3800-GTC models can accept Mobile Conversion Units (MCUs) each of which contain a vacuum tank. See *Mobile Conversion Units* (page 46) for more information.

2.4.2 Control Console - Human-Machine Interface (HMI)

Gleeble systems provide immediate user feedback through a Human-Machine Interface (HMI). The HMI is integrated into the freestanding control console of legacy 3000 series or current *Gleeble Touch Control* (page 9) enabled systems. The Gleeble HMI is the control hub of the Gleeble system. It contains an embedded computer, signal conditioner modules, instrument modules, and a touch screen display of system variables. The Gleeble HMI also allows for manual control of the Gleeble.

[3] https://www.gleeble-tech.com/gleebledocs/g3/3800_site_prep/index.html

500 series systems utilize a re-imagined control console. No longer an independent piece of equipment, the control console is now seamlessly fused with the Gleeble 500 series test frame. The core components, the embedded computer, instrument modules, and other control hardware are now housed within the test frame. The 500 series' HMI is now located on an articulating arm, providing the operator greater flexibility when viewing live test data. By integrating the control console into the test frame, the smaller footprint of a Gleeble 500 series enables customization of the Gleeble lab space.

2.4.3 Hydraulic Power Unit (HPU)

To meet the mechanical requirements of the various processes being simulated, each Gleeble system is supplied with a hydraulic power unit. The size and capabilities of the HPU vary by Gleeble model. Some hydraulic pumps are standalone units, while others are integrated into the main Gleeble unit. An appropriate HPU is supplied with a Gleeble system as required.

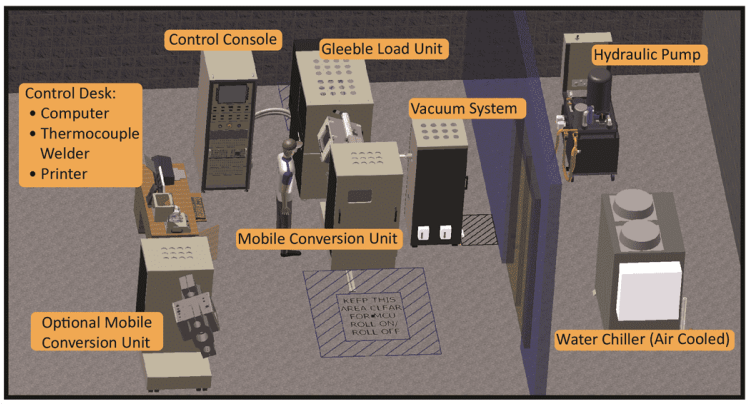


Fig. 2.1: Typical Design of a Gleeble Lab.

2.4.4 Thermocouple Welder

Thermocouples are used extensively with most Gleeble applications and tests. Therefore thermocouple welders are included in the scope of all Gleeble systems. See *Thermocouple Welder and Wire* (page 326) for more information.

2.4.5 Mobile Conversion Unit (MCU)

For Gleeble models designed to accept Mobile Conversion Units, Gleeble 3500C-GTC and 3800-GTC, an MCU must be connected to the Gleeble load unit in order for the system to function properly. The 3500C-GTC and 3800-GTC can accept Mobile Conversion Units. The General-Purpose MCU, (often referred to as a "Pocket Jaw") is typically included in base 3500C or 3800 installations. Specialty application MCUs include the Hydrawedge II, MAXStrain II, Hot Torsion, Large-Sample Strip Annealing, and High-Temperature, systems. See *Mobile Conversion Units* (page 46) for more information on the MCUs available from DSI.

Gleeble stand alone models (525, 540, 563, 3180-GTC and 3500-GTC Pedestal) have many of the same capabilities and can perform the many functions offered by other Gleeble systems, but they do not require an MCU.

2.4.6 Vacuum System

The vacuum system is used to evacuate air from the vacuum tank, allowing the user to control the environment around the specimen. The vacuum system includes a roughing pump and may include an optional diffusion pump. Additionally, specific vacuum system models can accommodate the backfill of inert gas into the vacuum tank. See *Vacuum Pumping Systems* (page 309) for more information.

2.4.7 Process Fluid Chillers

Chilled process fluid must be available to all Gleeble systems to cool critical components. DSI offers a variety of process fluid chillers, also know as water chillers, to provide a chilled process fluid supply at a closely controlled temperature for the Gleeble system and its equipment. DSI recommends an isolated, closed-loop circuit to provide chilled process fluid to the Gleeble and its components. See *Gleeble Chillers* (page 316) for more information.

2.4.8 Air Compressors

Compressed air is required to operate many Gleeble systems' features. It is also required for many options including the quench and vacuum systems. Compressed air can be provided from a compressor sold by Dynamic Systems or by an existing compressed air system in the Gleeble lab. See *Air Compressors* (page 323) for more information.

Section 3

Gleeble Touch Control

3.1 The Next Generation of Gleeble Systems Control



[4]

Fig. 3.1: Gleeble GTC

The Gleeble Touch Control (GTC) is a significant system upgrade to the Gleeble 3000 Series. The new GTC is now shipping with new Gleeble systems and is available as an upgrade to most existing Gleeble 3500 and 3800 systems.

Designed with ease of use in mind, the design team listened to user feedback to develop a more intuitive user interface. Integrating updated hardware and software, the GTC includes a range of enhancements, including improved usability and performance.

3.1.1 Improved Usability

Many design features have been incorporated into the GTC:

- Configurable touch screen display
- Large screen and clear icons improve usability for Gleeble operators
- Two display modes: Configuration Mode and Run Mode simplify usability and provide the right data and controls at the right time
- Redesigned Virtual Panel Meters (VPMs) provide clear and organized information at a glance
- During testing, users are presented with real-time data as well as operating ranges
- Absolute and relative transducer status and values are clearly displayed
- New Real Time Graph feature can display multiple user-selected variables graphically as the test progresses, making it easier for the user to know if the test is running as intended
- Faster user training - current and new Gleeble users will quickly and easily learn how to use the system

[4] https://gleeble.com/support/touch-control-upgrade.html

3.1.2 Improved Performance

Performance-enhancing features of the GTC include:

- New Instrument Modules (IMs) provide improved control & data acquisition
- Easier PID tuning and customization for control signals including Stroke, Thermal, or Strain control
- Expandability – the modular control system is designed with integrated future expansion capabilities
- Reduced User Error – improved data presentation via new Virtual Panel Meters provides for a more intuitive display of information, allowing the user to review performance data at a glance
- Improved user experience and accelerated work flow result in increased productivity and throughput
- Improved system diagnostics and error-logging process enable enhanced service
- Better access to data files – data files are stored in standard Windows® folders for more convenient access and backup

Part Number	Description	Sold As
32627-Console	Gleeble Touch Control (GTC) Upgrade	Ea.

Section 4

Gleeble 3800-GTC

Contents

- *Hydro-Mechanical* (page 13)
- *Thermal Subsystems* (page 17)
  - *Thermocouple Wire Types* (page 18)
  - *Heating Rates* (page 18)
  - *Cooling Rates* (page 19)
  - *Temperature Uniformity Within the Specimen* (page 20)
- *Specimen Size Considerations* (page 22)
- *Additional Features* (page 24)
- *Gleeble Physical Dimensions* (page 27)
  - *Frame and Machine Stiffness* (page 27)



5

Fig. 4.1: Gleeble 3800-GTC.

Our flagship model, the Gleeble 3800-GTC, is the most capable platform available from DSI. This system is well-suited for hot rolling and multi-hit forging simulations. The impressive force and speed provides the ability to use large samples, test advanced materials, achieve high strain rates and test a wide spectrum of temperatures.

By selecting the various options from a family of designs, a Gleeble system can address specific testing and simulation needs. Each system can be built from the large selection of available combinations of Gleeble GTC technologies. Gleeble 3800 can be configured with any of the available *Mobile Conversion Units* (page 46).

Note: Current Gleeble users can access the Gleeble 3800 Operator's Manual here.[6]

The Gleeble 3800 consists of four major units - the *Control Console/HMI* (page 6), the *Load Unit* (page 6), a *General-Purpose MCU* (page 46), and a *Hydraulic Power Unit* (page 7)- all the necessary components required to perform simulations. The digital closed-loop thermal-mechanical control system and software is thoroughly tested prior to leaving the factory. A wide variety of options and accessories are available to tailor the machine to specific applications.

Material Testing Capabilities of the Gleeble 3800-GTC

- Hot Tensile Testing
- High or Low Speed Uniaxial Compression
- Strain Induced Crack Opening (SICO) Studies
- High or Low Speed Plane Strain Compression Simulations
- Static Dilatometry Studies
- Deformation Dilatometry Studies
- Heat Treatments
- Melting & Solidification Simulations
- Welding Studies
- Weld HAZ Studies
- Nil-Strength Studies
- Rolling Simulation
- Continuous Casting Simulations
- Mushy Zone Processing Studies
- Forging Simulations
- Stress Relaxation Simulations
- Strip Annealing Simulations
- Extrusion Simulations
- Torsion Testing Studies
- Powder Metallurgy/Sintering Studies
- Quenching (Water/Air/Gas) Simulations
- Recrystallization Studies
- Grain Growth Studies
- Thermal Fatigue Simulations
- Mechanical Fatigue Simulations
- Friction Stir Welding Simulations
- Multi-Axis Forming Studies
- Ultra Fine Grain & Nanomaterial Studies

Part Number	Description	Sold As
3800-20:10/2-75	Gleeble 3800-GTC with General-Purpose MCU	System

[5] https://gleeble.com/products/gleeble-systems/gleeble-3800.html
[6] https://support.gleeble.com/portal/en/kb/articles/series-3-gtc-3500-3800-gleeble-operations-manual-user-manual

A Special Note on Gleeble Specifications

Unless otherwise stated all of the following specifications are for a Gleeble 3800-GTC with a *General-Purpose Mobile Conversion Unit* (page 49) MCU installed.

4.1 Hydro-Mechanical

Every Gleeble system derives its power from a servo-controlled hydraulic system. The capabilities of the hydro-mechanical system will vary based on Gleeble options.

Characteristic	Specification
Test Frame	Horizontal type with dual 99 mm (3.9 in) diameter columns
Mechanical System	Closed-loop hydraulic servo control
Data Acquisition Channels	User selectable, up to 16 channels simultaneously, 18-bit ADC
Data Sampling Rate	User selectable, up to 50 kHz.
Maximum Static Force in Compression	20,000 kgf (~ 44,000 lbf) (196 kN)
Maximum Static Force in Tension	10,000 kgf (~ 22,000 lbf) (98 kN)
Maximum Force Continuously Reversing (Fatigue Rating)	±9,070 kgf (±20,000 lbf) (±88 kN)
Maximum Stroke Rate (no load)	2,000 mm/s (78.74 in/s) in tension or compression
Minimum Stroke Rate	0.001 mm/s (3.93^{-5} in/s) in tension or compression
Maximum Stroke Distance	125 mm (4.92 in)
Maximum Number of Compression Hits	No Specific Limit

Note: The maximum stroke distance may be limited by certain jaw configurations.

Note: The total number of compression hits possible is dependent upon many test characteristics. These include the number of deformations, the initial position of the hydraulic stroke, and time between deformations.

Note: Accuracy is measured at a temperature of 23°C (73°F). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30°C (86°F).

Maximum Dynamic Force

The maximum dynamic force for a Gleeble 3800 is based on the following graph. For a given stroke speed the hydraulic system will provide a corresponding force. All performance figures for the system are based on operating within the recommended operating region below the Force vs. Stroke curve. The specifications are not valid for tests conducted outside this operating range.

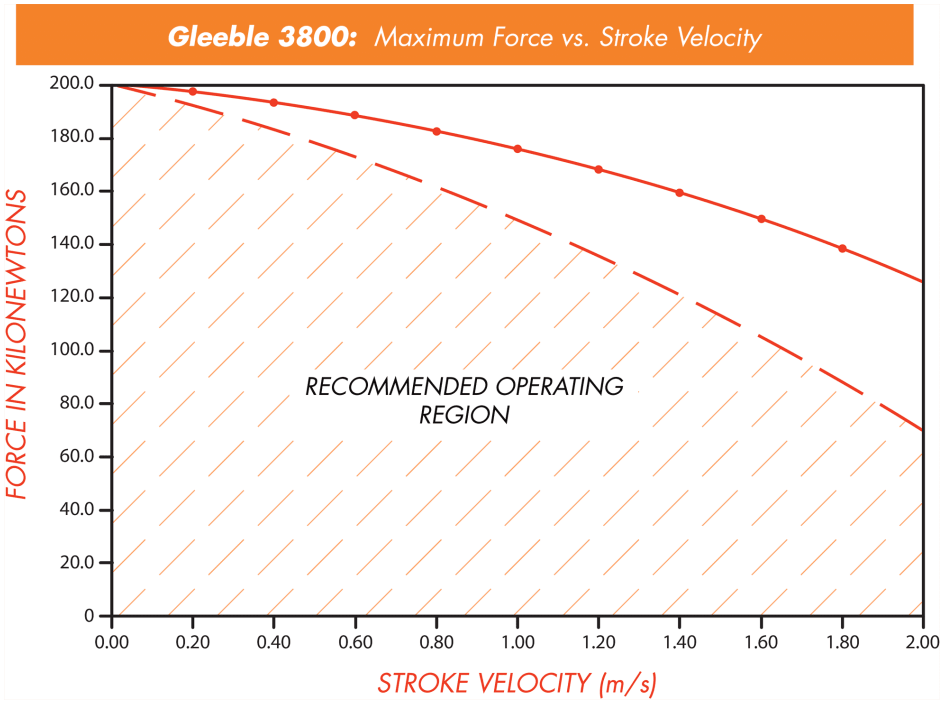


Fig. 4.2: Force vs. Stroke Velocity for Gleeble 3800.

Hydraulic Servo Response

The graphs below show the time and distance required for the piston to reach the programmed rate.

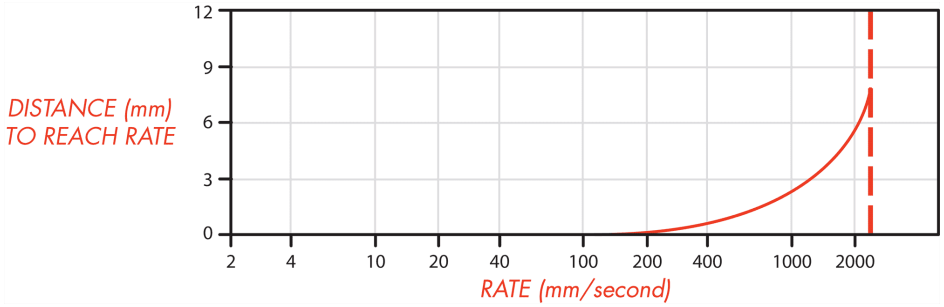


Fig. 4.3: Distance to achieve programmed rate.

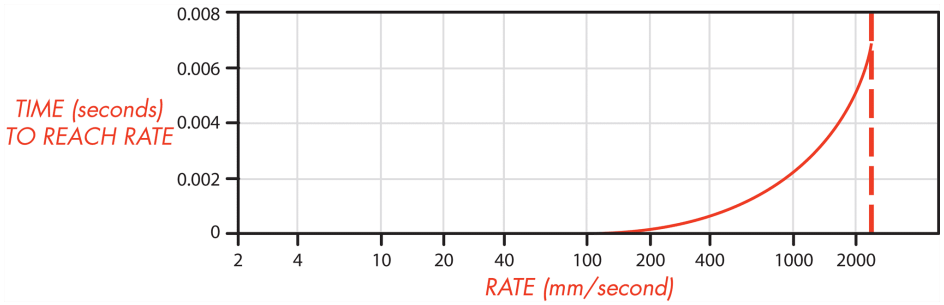


Fig. 4.4: Time to achieve programmed rate.

Limits of High-Speed Testing

While the high-speed servo-systems provide the capability for high-speed compression and tension testing, there are certain limitations in the overall system which must be observed.

For all types of operation the Stroke Rate and Force must be within the operating range as described in the Maximum Force vs. Stroke graph.

For constant Strain Rate programs the duration of the deformation for each hit must be ten times the rated response time of the hydraulic servo valve. The Gleeble system uses high-speed valves with a rated response time of 0.006 seconds. Therefore the duration of the actual deformation of the material during the hit must be equal to or greater than 0.060 seconds.

Load Cell

Characteristic	Specification
Non-linearity	±0.1 % of full scale
Hysteresis	±0.08 % of full scale
Non-Repeatability (Maximum)	±0.03 % of full scale
Overload Rating	150 % of capacity
Deflection - Full Scale	0.076 mm (0.003 in)
Force Measurement Accuracy	±1.0 % of full scale
Force Measurement Resolution	±1 kgf (2.2 lbf)

Note: Accuracy is measured at a temperature of 23°C (73°F). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30°C (86°F).

Stroke Transducer

Characteristic	Specification
Type	LVDT
Linear Range	±62.5 mm (±2.5 in)
Non-Linearity	±0.25 % of full scale
Stroke Measurement Accuracy	±0.5 % of full scale
Stroke Measurement Resolution	0.002 mm (7.87×10^{-5} in)

Note: Accuracy is measured at a temperature of 23°C (73°F). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30°C (86°F).

4.2 Thermal Subsystems

All Gleeble systems offer a high-speed thermal system with industry-leading performance. Gleeble 3500 and 3800 systems can heat a specimen using an integrated, direct resistance heating system or an optional *induction heating system* (page 167).

Direct resistance heating provides the ability to reproduce the wide variety of thermal profiles that materials undergo in actual processes. This is critical to the success of thermal-mechanical testing and physical simulation. All Gleeble systems have high-speed heating and cooling rates that can accurately replicate nearly any thermal profile required.

Induction heating is well-suited for use in uniaxial compression testing where it can provide a uniform temperature across the specimen from anvil to anvil. Induction heating can also be used in tensile testing, heat treating applications, and plane strain compression testing. Induction heating is also compatible for custom test setups due to the flexibility it offers.

The integration of the Gleeble Induction Heating System does not impact the functionality of the direct resistance heating capabilities. The Induction Heating System retains the performance standards researchers have come to know and expect from their Gleeble systems. Choosing between standard direct resistance heating and optional induction heating is available through the configuration mode of a GTC system. Only one heating method can be used per test.

Characteristic	Specification
Primary Heating System Type and Control	Direct resistance with closed-loop control
Optional Heating System Type and Control	*Gleeble Induction Heating System (IHS)* (page 167) with closed-loop control
Temperature Controller	Digital closed-loop control using 18-bit ADC and 32-bit digital processor
Temperature Range	-150℃ to 3,000℃ (-238℃ to 5,432℉)
Response Rate	10,000℃/s (18,000℉/s)
Temperature Monitoring Source	Thermocouple or Optional *Pyrometer Control Cameras* (page 274)
Thermocouple Sampling Rate	Twice the power line frequency (100 - 120 Hz)
Resolution	±1℃ or℉
Maximum Number Of Simultaneous Thermal Channels	4 thermocouple channels, or 2 thermocouple channels and 1 pyrometer channel
Accuracy of Control	±1℃ (in steady state)
Accuracy of Measurement	±2℃ or ±1 % of temperature (whichever is greater) plus the accuracy of the thermocouple wire (in steady state)

Note: An optional *Pyrometer Control Camera* (page 274) is required for temperatures above 2,100℃ (3,812℉). An optional *Cryogenic Quench System* (page 291) kit is required for temperatures below room temperature.

Note: As the specimen size, diameter, length, or cross-sectional area increases the effective heating rate will decrease.

4.2.1 Thermocouple Wire Types

Gleeble systems are capable of recording specimen temperature with various thermocouple wire types. The following types of thermocouple wire can be used on any Gleeble system.

Part Number	TC Type	Material	Sold As
Operating Range: 0 - 1,450°C (32 - 2,642°F)			
TC005	R- or S-	Pt 100%	Inch
TC006	R+	Pt 87% - Rh 13%	Inch
TC009	S+	Pt 90% - Rh 10%	Inch
Operating Range: -200 - 1,250°C (-328 - 2,282°F)			
TC014	K-	Alumel	Spool
TC015	K+	Chromel	Spool
Operating Range: 0 - 1,700°C (32 - 3,092°F)			
TC017	B-	Pt 94% - Rh 6%	Inch
TC018	B+	Pt 70% - Rh 30%	Inch
Operating Range: 0 - 750°C (32 - 1,382°F)			
TC030	J+	Fe 100%	Spool
TC031	J-	Constantan	Spool
Operating Range: -200 - 900°C (-328 - 1,652°F)			
TC032A	E+	Chromega	Spool
TC033	E-	Constantan	Spool
Operating Range: 0 - 2,320°C (32 - 4,208°F)			
TC010	C+	W 95% - Re 5%	Inch
	C-	W 74% - Re 26%	

Note: TC wire types C, K, J, and E have a nominal wire diameter of 0.254 mm (0.01 in). TC wire types R, S, and B have a nominal wire diameter of 0.2032 mm (0.008 in).

Note: Gleeble systems can support additional thermocouple wire types not shown. *Contact Dynamic Systems* (page 373) for additional information regarding the use of alternate thermocouple wire types.

4.2.2 Heating Rates

Heating rates are based on using a 480 V / 200 A power supply, full contact copper grips, and 1018 carbon steel specimens in the *General-Purpose Mobile Conversion Unit* (page 49) MCU. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

Specimen	Free Span	Drawing Number	Maximum Heating Rate
			°C/s (°F/s)
6 mm dia x 71 mm long	10 mm	SMR002B	10,000 (18,000)
10 mm dia x 71 mm long	10 mm	SMR009B	1,000 (1,800)
10 mm dia x 15 mm long *With non ISO-T Anvils* (page 218)		SMC203B	50 (90)
10 mm dia x 15 mm long *With ISO-T Anvils* (page 216)			5 (9)

4.2.3 Cooling Rates

Free Cooling Rates

The Gleeble system is able to control the specimen cooling rate based on conductive heat transfer. The efficiency and maximum rate of conductive cooling is directly impacted by grip and specimen geometry, material, cleanliness, and system's chilled process fluid flow rate.

The free cooling rates are achieved using full contact copper grips on 1018 carbon steel specimens. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

Specimen	Free Span	Drawing Number	Temperature Range	Cooling Rate
			℃ (℉)	℃/s (℉/s)
6 mm dia x 71 mm long	10 mm	SMR002B	950 - 800 (1,742 - 1,472)	140 (252)
			800 - 500 (1,472 - 932)	78 (140.4)
10 mm dia x 84 mm long	10 mm reduced to 6 mm dia x 6 mm long	SMR202B	950 - 800 (1,742 - 1,472)	330 (594)
			800 - 500 (1,472 - 932)	200 (360)

Quench Cooling Rates

Optional quench systems are available which can use compressed air, inert gas, or water to cool the specimen at higher rates than are achievable when relying solely on conduction cooling.

Specimen	Free Span	Drawing Number	Temperature Range	Rate
			℃ (℉)	℃/s (℉/s)
1 mm thick x 10 mm wide x 100 mm long	25 mm	SMF002B	1,000 - 600 (1,832 - 1,112)	10,000 (18,000)
6 mm dia x 86 mm long	25 mm	SMR005B	1,000 - 600 (1,832 - 1,112)	2,000 (3,600)

Note: The cooling rates are achieved using full contact copper grips on 1018 carbon steel specimens quenched with water. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

4.2.4 Temperature Uniformity Within the Specimen

The Gleeble system has the unique ability to control the temperature uniformity and thus the thermal gradient within the test specimen. Tests can be performed with very uniform temperature within the specimen work zone, equivalent to a furnace-based test, or with the large thermal gradients needed to accurately simulate welding and other processes.

When using Joule heating, the current density in a Gleeble specimen is uniformly distributed across the entire specimen cross-sectional area, meaning that the Gleeble is able to heat the entire specimen simultaneously, from surface to center. Since the Gleeble grips are cool, the heat generated in the specimen will diffuse into the grips, creating a thermal gradient with the ends of the specimen generally being cooler than the center. The severity of the steady state thermal gradient is defined by the rate of heat generated in the specimen, offset by the heat lost to the grips. This gradient can be controlled by utilizing grips of materials with differing thermal and electrical conductivity and contact area. Thermally and electrically conductive grips with a large specimen contact area will be kept cold more readily with the water-cooled jaws, and will accept significant heat from the specimen, resulting in “cold ends” and a very steep thermal gradient.

Grips with smaller contact area and higher thermal resistance will pull much less heat from the specimen. Grips manufactured from material with higher electrical resistance will, themselves, heat under the same current that is heating the specimen. These factors will result in very little heat being pulled from the specimen and a very flat thermal gradient. In some cases the grips or anvils holding the specimen may reach temperatures equal to or higher than the specimen, creating a “reverse” thermal gradient.

When considering Gleeble thermal gradients, it is also critical to differentiate between the axial thermal gradient (along the length of the specimen), and the transverse thermal gradient (across the diameter or cross section of the specimen). Even in situations where a specimen experiences a very high axial thermal gradient, the transverse, or crosswise thermal gradient will be very small. This ability to generate isothermal planes is a critical benefit of the Gleeble. In contrast to furnace or induction heating methods, where the specimen can only be heated on the surface or to a limited “skin depth”, the center of a Gleeble specimen is heated at the same rate as the surface regardless of the heating rate. This ability to generate isothermal planes allows for the Gleeble platform to perform dilatometry and welding heat affected zone experiments at heating and cooling rates relevant to welding and other processes on specimens that are large enough for subsequent mechanical property or toughness testing. This is not feasible on furnace or inductively-heated systems that rely on thermal conduction to heat the center of the specimen. Axial thermal uniformity within a specimen is reported as the difference between the specimen’s center to edge thermal measurements and is dependent upon:

- Material
- Thermal Resistivity
- Electrical Resistivity
- Grip Contact Surface to Specimen Volume Ratio
- Specimen Length
- Specimen Cross Section
- Free Span
- Grip Selection
- Heating Rate
- Isothermal Holding Time
- Interface Resistance

The following data was obtained using Stainless Steel partial contact grips on 1018 carbon steel specimens. Measurements are taken at steady state temperatures. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

Specimen	Free Span	Drawing Number	Temperature Uniformity
Lengthwise Thermal Gradient			
10 mm dia x 111 mm long	50 mm	SMR023B	±0.5% of T_{avg} for 7 mm of midspan
Crosswise Thermal Gradient			
10 mm dia x 86 mm long	25 mm	SMR012B	±0.5% of T_{avg}

Note: T_{avg} is the average of the specimen cross section temperature at 1,000°C (1,832°F).

Reproducibility

Thermal gradients in resistance-heated specimens are dependent upon on the properties of the specimen. All specimens with the same physical, mechanical, electrical, and chemical properties will have the same gradients within the accuracy of the thermal system, provided that the specimen grips are in good condition.

4.3 Specimen Size Considerations

Gleeble systems are capable of testing a wide variety of material compositions and specimen geometries. Inherent limitations of the system, such as distance between the jaw or anvil faces, the maximum or minimum stroke speed, test temperature, and force limitations for the individual system must be considered when selecting a specific *specimen geometry* (page 378).

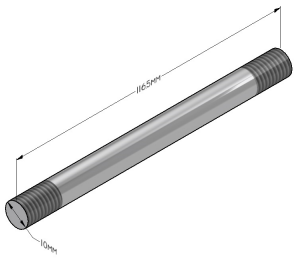


Fig. 4.5: Hot Tensile Specimen - SMR111.

The target temperature of a test will also impact the size of a specimen that can safely be tested with a Gleeble system. For example, when considering a standard uniaxial compression specimen, it is possible for a soft material such as aluminum or copper to be tested at ambient temperature. Harder materials, such as steel or titanium alloys, are expected to be tested at elevated temperatures.

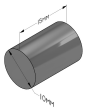


Fig. 4.6: Uniaxial Compression Specimen - SMC203.

The Gleeble 3500 and 3800's vacuum tank configuration limits the maximum and minimum specimen geometry that can be tested. Due to the modularity of the Gleeble systems, the possible specimen geometries can rage from a 260 mm long strip specimen to a 10 mm long compression specimen. When configured with the General-Purpose MCU's Pocket Jaws or the Gleeble 3500 Pedestal's Pocket Jaws, a specimen with a maximum free span of 120 mm can be tested.

Specimen geometry will vary with any specific test. DSI has identified recommended specimen geometries for commonly performed simulation tests. *Contact Dynamic Systems* (page 373) for assistance identifying a recommended specimen geometry as needed.

Popular Specimen Sizes			
Specimen Length	**Specimen Width**	**Specimen Thickness**	**Drawing Number**
Bar Specimens			
116.5 mm	10 mm dia	N/A	SMR111
121.5 mm	10 mm dia	N/A	SMR112
71 mm	6 mm dia	N/A	SMR002
71 mm	11 mm Sq	N/A	SMS006
Flat Specimens			
100 mm	10 mm	1 mm	SMF002
Uniaxial Compression			
9 mm	6 mm dia	N/A	SMC206
12 mm	8 mm dia	N/A	SMC200
15 mm	10 mm dia	N/A	SMC203
Plane Strain			
20 mm	15 mm	10 mm	SMC001
35 mm	25 mm	15 mm	SMC007

To achieve the best thermal control, flat specimens should have a cross-sectional area between 25 mm^2 and 400 mm^2 (0.0387 in^2 and 0.620 in^2).

Note: To test highly conductive specimens, additional grounding blocks must be installed on the Gleeble. See *Heating Modification for a Highly Conductive Specimen* (page 344) for more information. The use of hot grips is recommended for highly conductive specimens. See *Gleeble Grips* (page 179) for more information

regarding the selection of grips.

4.4 Additional Features

Vacuum Tank

One of the distinguishing features of a Gleeble system is the ability to test materials in a controlled atmosphere. Researchers can simulate processes and test specimens in standard atmosphere, in rough vacuum, in high vacuum or in an inert gas environment. This environmental control is possible due to the large vacuum tank, also referred to as a "test chamber," that is incorporated into every Gleeble. The vacuum tank is fully integrated into the Gleeble system and can be controlled with manual controls or through software controls. A popular approach to atmosphere control in the Gleeble includes "washing cycles" which involve pumping down to a rough vacuum in the tank and then backfilling with an inert gas. This can be conducted multiple times to ensure that the desired atmosphere is achieved.

Most Gleeble vacuum tanks include viewing ports, typically incorporated into the tank doors to allow visual observation of simulations. In some cases, viewing windows are removed or covered to protect users from the light intensity of specimens at elevated temperatures. Depending on the Gleeble model, vacuum tanks may include one or two doors with viewing windows as well as additional ports for measurement devices or equipment feedthroughs.

Feedthroughs are an important feature in the Gleeble vacuum tanks. They allow researchers to install equipment that can measure or interact with the specimen during a test while still controlling the atmosphere. For example, vacuum-sealed electrical feedthroughs allow communication with transducers such as thermocouples, load cells, and strain transducers. Piping feedthroughs enable atmosphere control (e.g. inert gas backfill and vacuum supply) as well as allowing quenching media to be utilized.

Warning: The Gleeble vacuum tank is designed to operate under vacuum or atmospheric pressure, with either air or an inert gas surrounding the specimen. Positive atmospheric pressure, explosive, flammable or corrosive gases, or any mixtures of these gases, should never be used as part of the vacuum tank atmosphere.

Air Ram

The air ram is designed to maintain a constant force on the specimen in either tension or compression. When properly used it can simplify many Gleeble tests and increase the versatility of the Gleeble system.

The air ram system consists of twin air pressure cylinders connected to the moving jaw of the Gleeble. The same compressed air source used for the rest of the Gleeble system supplies the air ram. The air ram can be activated automatically during a Gleeble test or manually by a button on the HMI. Additional controls are provided for selecting compression or tension, and the pressure (force) applied to the specimen. The maximum force of the air ram is 450 kgf (992 lbf) at 5.6 kg/cm ^{2} (80 psi) Gleeble air supply pressure.

The following are some typical applications of the air ram:

- **Resistance Butt Welding:** To prevent arcing across the specimen interface, a compressive force is applied prior to heating in order to keep the two faces of the specimen in contact.
- **Hot Rolling:** A compressive force is applied to hold the specimen between the anvils prior to heating and during subsequent deformation.
- **Continuous Strip Annealing:** To compensate for thermal expansion, a small tensile force is maintained during the test in order to move the jaw and keep the strip specimen from bowing.

Hydraulic Power Unit

Gleeble 3500 and 3800 systems are equipped with an independent hydraulic power unit (HPU). The HPU is the primary source of mechanical motion for these Gleeble systems. The HPU is capable of regulating the output pressure of the hydraulic fluid based on the Gleeble system configuration.



Fig. 4.7: Gleeble Hydraulic Power Unit.

Typical Gleeble configurations allow the user to choose between a high and low output pressure. The pressure can be manually selected with a button on the HMI (Human-Machine Interface) or through the programming of a Gleeble test.

Special configurations of the Gleeble will limit the pressures available for testing. When a low-force load cell is installed, the Gleeble will automatically limit the HPU output to a low pressure. Users will not be able to select a higher hydraulic pressure. With a *Hot Torsion* (page 64) MCU installed, the Gleeble will automatically reduce the high pressure output to to an intermediate pressure. The user can select between the standard low pressure or the newly reduced high pressure.

Note: Reference *Hydraulic Oil* (page 360) for common service parts.

The Gleeble HPU uses the same process fluid chiller as the Gleeble system to enable automatic control of the hydraulic oil temperature. By automatically regulating the temperature of the hydraulic oil, the Gleeble is capable of maintaining peak performance in a variety of temperature environments. The HPU is protected by sensors that detect high oil temperature, and high or low oil level.

Characteristic		**Specification**
Pump Motor		20 hp
Variable Pressure Output	Low Pressure	68.94 bar (1000 psi)
	Intermediate Pressure	137.89 bar (2000 psi)
	High Pressure	206.84 bar (3000 psi)
Hydraulic Oil Reservoir Capacity		170 L (45 gal)

Hydraulic Pump Sound Damping Enclosure

The 35343 Hydraulic Pump Sound Damping Enclosure is designed for locations where additional noise reduction is required at the pump installation site.



Fig. 4.8: Hydraulic Power Unit Sound Damping Enclosure - DSI# 35343.

This acoustic enclosure consists of quilted material barrier panels with a quilted material roof. These panels are hung on a frame mounted to the hydraulic pump. A typical Gleeble 3500 or 3800 hydraulic power unit, without a sound damping enclosure, produces 86 to 90 dBA, depending on the surroundings and mounting position. HPUs with the sound damping enclosure produce 67 to 70 dBA.

The 35343 Hydraulic Pump Sound Damping Enclosure includes the following:

- Four-sided sound damping enclosure with a roof
- One (1) 254 mm (10 in) x 254 mm (10 in) viewing window
- Exhaust fan for cooling which is powered from the hydraulic pump

The approximate size of the enclosure is 1.524 m (60 in) long x 1.117 m (44 in) wide x 1.879 m (74 in) high. The enclosure will only accommodate the currently supplied 20 hp HPU. This enclosure is portable allowing removal of the panels for maintenance and service. Installation and assembly is required, and available at an additional cost.

Part Number	Description	Sold As
35343	Sound Damping Enclosure for 20 hp Hydraulic Power Unit	Ea

4.5 Gleeble Physical Dimensions

Equipment	Height	Depth	Width	Weight
Control Console	180 cm (71 in)	66 cm (26 in)	61 cm (24 in)	195 kg (430 lb)
3800 Load Unit	160 cm (63 in)	86 cm (34 in)	239 cm (94 in)	1,425 kg (3,143 lb)
3500C Load Unit	160 cm (63 in)	86 cm (34 in)	239 cm (94 in)	1,425 kg (3,143 lb)
3500 Pedestal Load Unit	160 cm (63 in)	86 cm (34 in)	273 cm (107 in)	1,732 kg (3,819 lb)
Hydraulic Power Unit with Oil	155 cm (61 in)	142 cm (56 in)	74 cm (29 in)	655 kg (1,444 lb)
General-Purpose MCU for 3500C and 3800	158 cm (62 in)	86 cm (34 in)	157 cm (62 in)	565 kg (1,245 lb)

Note: The Hydraulic Power Unit weighs 529 kg (1,168 lb) without oil.

Note: For complete information on all of the MCUs offered by DSI, please see *Mobile Conversion Units* (page 46).

4.5.1 Frame and Machine Stiffness

Frame Stiffness: (includes columns and crossheads)

- 5.02 x 10E-9 m/N
- 8.78 x 10E-7 in/lbf

Section 5

Gleeble 3500-GTC

Contents

- *Hydro-Mechanical* (page 31)
- *Thermal Subsystems* (page 37)
  - *Thermocouple Wire Types* (page 38)
  - *Heating Rates* (page 38)
  - *Cooling Rates* (page 39)
  - *Temperature Uniformity Within the Specimen* (page 39)
- *Specimen Size Considerations* (page 41)
- *Additional Features* (page 42)
- *Gleeble Physical Dimensions* (page 45)
  - *Frame and Machine Stiffness* (page 45)



[7]

Fig. 5.1: Gleeble 3500-GTC Pedestal.

[7] https://gleeble.com/products/gleeble-systems/gleeble-3500.html

The Gleeble 3500-GTC is the industry standard for thermal-mechanical physical simulation. With its high-speed heating and wide range of mechanical capabilities, the Gleeble 3500-GTC is ideal for weld HAZ simulations, nil-strength, thermal cycles, heat treatment studies, low-force tests, hot tensile tests, high-speed compression, multi-hit hot deformation tests, melting, solidification, and strip annealing simulations.

Current Gleeble Users

Current Gleeble users can access the Gleeble 3500 Operator's Manual here.[8]

Unmatched Customization

A Gleeble 3500 system can be customized to meet a researcher's needs. The base model, a Gleeble 3500-GTC Pedestal, is built with an integrated vacuum tank and cannot accept Mobile Conversion Units (MCUs). A Gleeble 3500C-GTC is configured similar to a Gleeble 3800. The 3500C-GTC system retains its modularity by accepting *Mobile Conversion Units* (page 46). Most MCUs offered by Dynamic Systems Inc. can be used on this system.



[9]

Fig. 5.2: Gleeble 3500C-GTC with MCU.

Advanced Power Options

Further customization of a Gleeble 3500 system is possible through the selection of the hydraulic servo valve assembly. A Gleeble 3500 can be configured with a single 60 gpm valve or a dual valve system. The dual valve configuration, also known as a Gleeble 3500 High-Speed system, consists of one 10 gpm servo valve and one 100 gpm valve. The dual valve configuration offers an impressive combination of high-speed, high force movements with low speed and low-force control.

Material Testing Capabilities of the Gleeble 3500-GTC

- Hot Tensile Testing
- High or Low Speed Uniaxial Compression
- Strain Induced Crack Opening (SICO) Studies
- High or Low Speed Plane Strain Compression Simulations
- Static Dilatometry Studies

[8] https://support.gleeble.com/portal/en/kb/articles/series-3-gtc-3500-3800-gleeble-operations-manual-user-manual
[9] https://gleeble.com/products/gleeble-systems/gleeble-3500.html

- Deformation Dilatometry Studies
- Heat Treatments
- Melting & Solidification Simulations
- Welding Studies
- Weld HAZ Studies
- Nil-Strength Studies
- Rolling Simulation
- Continuous Casting Simulations
- Mushy Zone Processing Studies
- Forging Simulations
- Stress Relaxation Simulations
- Strip Annealing Simulations
- Extrusion Simulations
- Torsion Testing Studies
- Powder Metallurgy/Sintering Studies
- Quenching (Water/Air/Gas) Simulations
- Recrystallization Studies
- Grain Growth Studies
- Thermal Fatigue Simulations
- Mechanical Fatigue Simulations
- Friction Stir Welding Simulations

Gleeble systems are supplied with all necessary components for immediate set-up and operation. The digital closed-loop thermal-mechanical control system and software are thoroughly tested prior to any system leaving the factory floor. A wide variety of options and accessories are available to tailor the machine to specific applications.

Gleeble 3500-GTC Pedestal

Part Number	Description	Sold As
3500-10/1-75	Gleeble 3500-GTC - Pedestal	System
3500-10/1HS-75	Gleeble 3500-GTC - High-Speed, Pedestal	System
3500-TS-75	Gleeble 3500-GTC - Thermal Only System	System
35013	Gleeble 3500-GTC - Pedestal to MCU Upgrade	Kit

Gleeble 3500C-GTC with Mobile Conversion Unit

Part Number	Description	Sold As
3500C-10/1-75	Gleeble 3500-GTC - with General-Purpose MCU	System
3500C-10/1HS-75	Gleeble 3500-GTC - High-Speed, with General-Purpose MCU	System

A Special Note on Gleeble Specifications

Unless otherwise stated all of the following specifications are for a Gleeble 3500-GTC Pedestal or a 3500C-GTC with a *General-Purpose Mobile Conversion Unit* (page 49) MCU installed.

5.1 Hydro-Mechanical

Every Gleeble system derives its power from a servo-controlled hydraulic system. The capabilities of the hydro-mechanical system will vary based on Gleeble options.

Characteristic	Specification
Test Frame	Horizontal type with dual 99 mm (3.9 in) diameter columns
Mechanical System	Closed-loop hydraulic servo control
Data Acquisition Channels	User selectable, up to 16 channels simultaneously, 18-bit ADC
Data Sampling Rate	User selectable, up to 50 kHz.
Maximum Static Force in Compression	10,000 kgf (~ 22,000 lbf) (98 kN)
Maximum Static Force in Tension	10,000 kgf (~ 22,000 lbf) (98 kN)
Maximum Force Continuously Reversing (Fatigue Rating)	±5,000 kgf (±11,023 lbf) (±49 kN)
Maximum Stroke Rate (no load)	1,000 mm/s (39.36 in/s) in tension or compression
Minimum Stroke Rate	0.001 mm/s (3.93^{-5} in/s) in tension or compression
Maximum Stroke Distance	125 mm (4.92 in)
Maximum Number of Compression Hits	No Specific Limit

Note: Maximum stroke distance may be limited by certain jaw configurations.

Note: The total number of compression hits possible is dependent upon many test characteristics. These include the number of deformations, the initial position of the hydraulic stroke, and time between deformations.

Note: Accuracy is measured at a temperature of 23°C (73°F). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30°C (86°F).

Maximum Dynamic Force

The maximum dynamic force for the Gleeble 3500 is based on the following graph. For a given stroke speed the hydraulic system will provide a corresponding force. All performance figures for the system are based on operating within the recommended operating region below the Force vs. Stroke curve. The specifications are not valid for tests conducted outside this operating range.

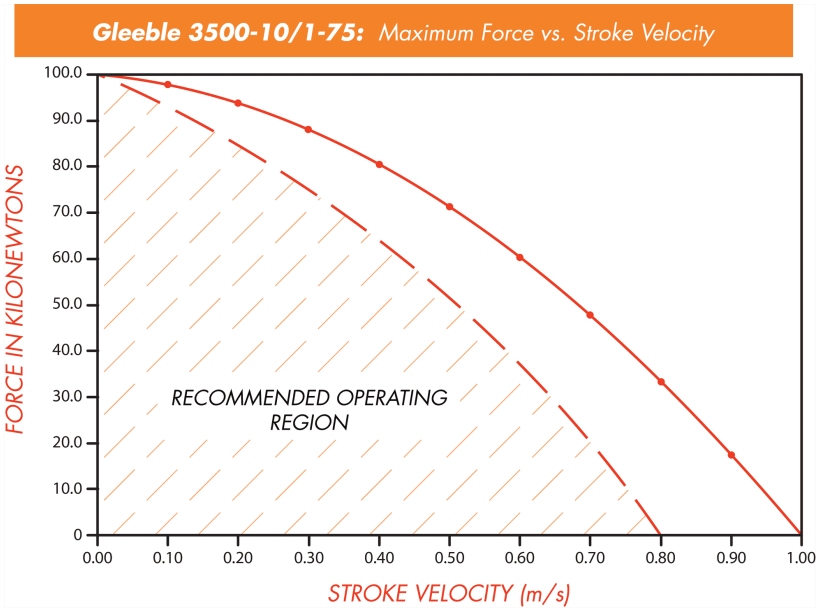


Fig. 5.3: Force vs. Stroke Velocity Gleeble 3500.

Maximum Dynamic Force - High-Speed

The maximum dynamic force for the Gleeble 3500 High-Speed is based on the following graph. For a given stroke speed the hydraulic system will provide a corresponding force. All performance figures for the system are based on operating within the recommended operating region below the Force vs. Stroke curve. The specifications are not valid for tests conducted outside this operating range.

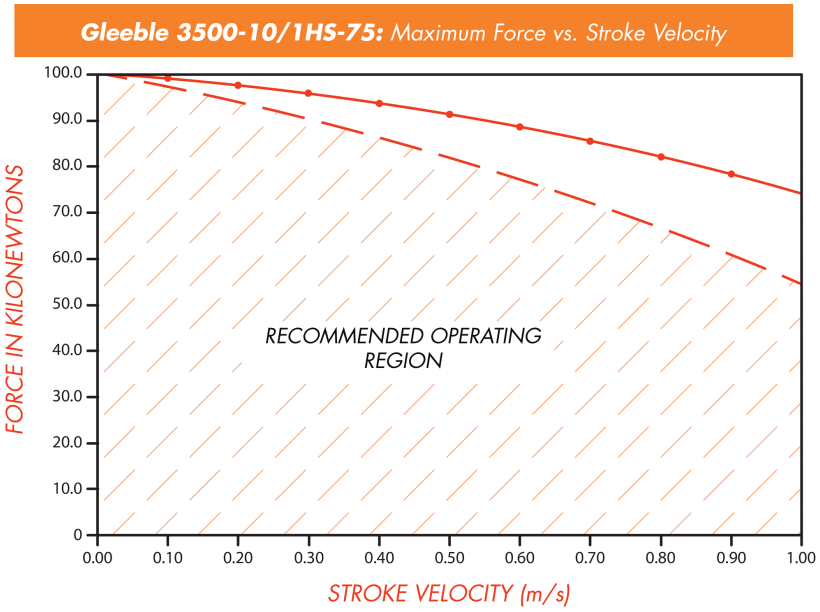


Fig. 5.4: Force vs. Stroke Velocity Gleeble 3500 High-Speed.

Hydraulic Servo Response

The graphs below shows the time and distance required for the piston to reach the programmed rate for a 60 gpm and 100 gpm servo valve respectively.

3500C-10/1-75

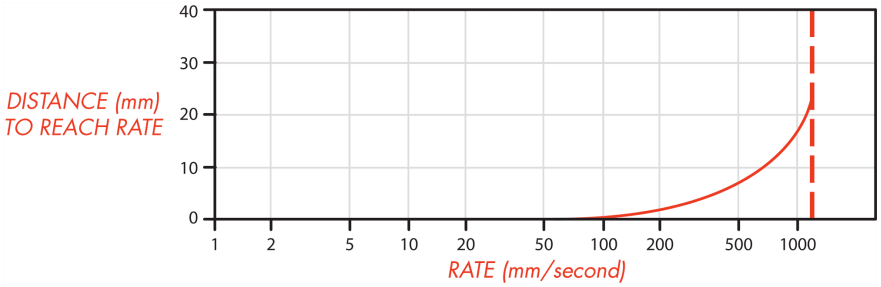


Fig. 5.5: Distance to achieve programmed rate.

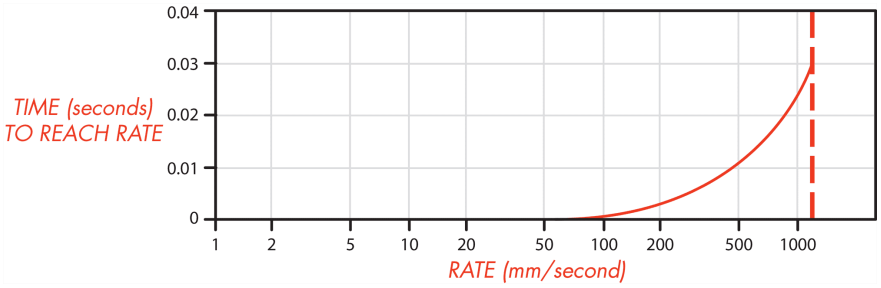


Fig. 5.6: Time to achieve programmed rate.

3500C-10/1HS-75

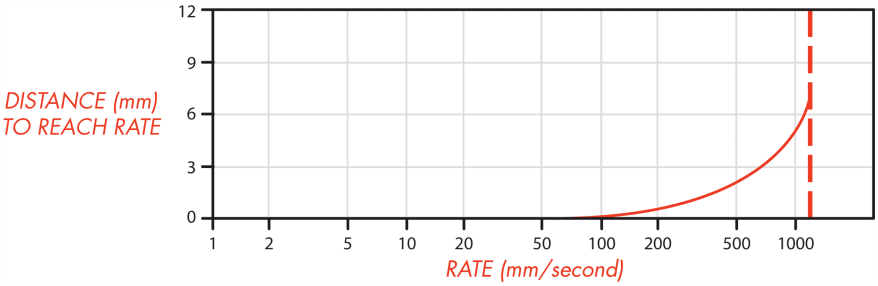


Fig. 5.7: Distance to achieve programmed rate.

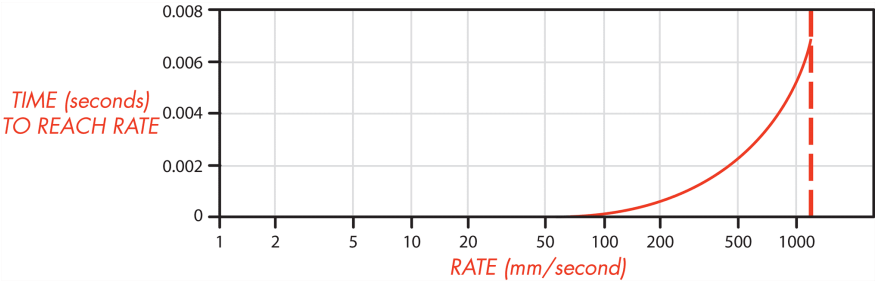


Fig. 5.8: Time to achieve programmed rate.

Limits of High-Speed Testing

While the high-speed servo-systems provide the capability for high-speed compression and tension testing, there are certain limitations in the overall system which must be observed.

For all types of operation the Stroke Rate and Force must be within the operating range as described in the Maximum Force vs. Stroke graph.

For constant Strain Rate programs the duration of the deformation for each hit must be ten times the rated response time of the hydraulic servo valve. The Gleeble system uses high-speed valves with a rated response time of 0.006 seconds. Therefore the duration of the actual deformation of the material during the hit must be equal to or greater than 0.060 seconds.

Load Cell

Characteristic	Specification
Non-linearity	±0.1 % of full scale
Hysteresis	±0.08 % of full scale
Non-Repeatability (Maximum)	±0.03 % of full scale
Overload Rating	150 % of capacity
Deflection - Full Scale	0.076 mm (0.003 in)
Force Measurement Accuracy	±1.0 % of full scale
Force Measurement Resolution	±1 kgf (2.2 lbf)

Note: Accuracy is measured at a temperature of 23°C (73°F). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30°C (86°F).

Stroke Transducer

Characteristic	Specification
Type	LVDT
Linear Range	±62.5 mm (±2.5 in)
Non-Linearity	±0.25 % of full scale
Stroke Measurement Accuracy	±0.5 % of full scale
Stroke Measurement Resolution	0.002 mm (7.87×10^{-5} in)

Note: The Stroke range on a Gleeble 3500 is limited to ±60 mm.

Note: Accuracy is measured at a temperature of 23°C (73°F). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30°C (86°F).

5.2 Thermal Subsystems

All Gleeble systems offer a high-speed thermal system with industry-leading performance. Gleeble 3500 and 3800 systems can heat a specimen using an integrated, direct resistance heating system or an optional *induction heating system* (page 167).

Direct resistance heating provides the ability to reproduce the wide variety of thermal profiles that materials undergo in actual processes. This is critical to the success of thermal-mechanical testing and physical simulation. All Gleeble systems have high-speed heating and cooling rates that can accurately replicate nearly any thermal profile required.

Induction heating is well-suited for use in uniaxial compression testing where it can provide a uniform temperature across the specimen from anvil to anvil. Induction heating can also be used in tensile testing, heat treating applications, and plane strain compression testing. Induction heating is also compatible for custom test setups due to the flexibility it offers.

The integration of the Gleeble Induction Heating System does not impact the functionality of the direct resistance heating capabilities. The Induction Heating System retains the performance standards researchers have come to know and expect from their Gleeble systems. Choosing between standard direct resistance heating and optional induction heating is available through the configuration mode of a GTC system. Only one heating method can be used per test.

Characteristic	Specification
Primary Heating System Type and Control	Direct resistance with closed-loop control
Optional Heating System Type and Control	*Gleeble Induction Heating System (IHS)* (page 167) with closed-loop control
Temperature Controller	Digital closed-loop control using 18-bit ADC and 32-bit digital processor
Temperature Range	-150 °C to 3,000 °C (-238 °C to 5,432 °F)
Response Rate	10,000 °C/s (18,000 °F/s)
Temperature Monitoring Source	Thermocouple or Optional *Pyrometer Control Cameras* (page 274)
Thermocouple Sampling Rate	Twice the power line frequency (100 - 120 Hz)
Resolution	±1 °C or °F
Maximum Number Of Simultaneous Thermal Channels	4 thermocouple channels, or 2 thermocouple channels and 1 pyrometer channel
Accuracy of Control	±1 °C (in steady state)
Accuracy of Measurement	±2 °C or ±1 % of temperature (whichever is greater) plus the accuracy of the thermocouple wire (in steady state)

Note: An optional *Pyrometer Control Camera* (page 274) is required for temperatures above 2,100 °C (3,812 °F). An optional *Cryogenic Quench System* (page 291) kit is required for temperatures below room temperature.

Note: As the specimen size, diameter, length, or cross-sectional area increases the effective heating rate will decrease.

5.2.1 Thermocouple Wire Types

Gleeble systems are capable of recording specimen temperature with various thermocouple wire types. The following types of thermocouple wire can be used on any Gleeble system.

Part Number	TC Type	Material	Sold As
Operating Range: 0 - 1,450°C (32 - 2,642°F)			
TC005	R- or S-	Pt 100%	Inch
TC006	R+	Pt 87% - Rh 13%	Inch
TC009	S+	Pt 90% - Rh 10%	Inch
Operating Range: -200 - 1,250°C (-328 - 2,282°F)			
TC014	K-	Alumel	Spool
TC015	K+	Chromel	Spool
Operating Range: 0 - 1,700°C (32 - 3,092°F)			
TC017	B-	Pt 94% - Rh 6%	Inch
TC018	B+	Pt 70% - Rh 30%	Inch
Operating Range: 0 - 750°C (32 - 1,382°F)			
TC030	J+	Fe 100%	Spool
TC031	J-	Constantan	Spool
Operating Range: -200 - 900°C (-328 - 1,652°F)			
TC032A	E+	Chromega	Spool
TC033	E-	Constantan	Spool
Operating Range: 0 - 2,320°C (32 - 4,208°F)			
TC010	C+	W 95% - Re 5%	Inch
	C-	W 74% - Re 26%	

Note: TC wire types C, K, J, and E have a nominal wire diameter of 0.254 mm (0.01 in). TC wire types R, S, and B have a nominal wire diameter of 0.2032 mm (0.008 in).

Note: Gleeble systems can support additional thermocouple wire types not shown. *Contact Dynamic Systems* (page 373) for additional information regarding the use of alternate thermocouple wire types.

5.2.2 Heating Rates

Heating rates are based on using a 480 V / 200 A power supply, full contact copper grips, and 1018 carbon steel specimens in the *General-Purpose Mobile Conversion Unit* (page 49) MCU. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

Specimen	Free Span	Drawing Number	Maximum Heating Rate
			°C/s (°F/s)
6 mm dia x 71 mm long	10 mm	SMR002B	10,000 (18,000)
10 mm dia x 71 mm long	10 mm	SMR009B	1,000 (1,800)
10 mm dia x 15 mm long *With non ISO-T Anvils* (page 218)		SMC203B	50 (90)
10 mm dia x 15 mm long *With ISO-T Anvils* (page 216)			5 (9)

5.2.3 Cooling Rates

Free Cooling Rates

The Gleeble system is able to control the specimen cooling rate based on conductive heat transfer. The efficiency and maximum rate of conductive cooling is directly impacted by grip and specimen geometry, material, cleanliness, and system's chilled process fluid flow rate.

The free cooling rates are achieved using full contact copper grips on 1018 carbon steel specimens. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

Specimen	Free Span	Drawing Number	Temperature Range	Cooling Rate
			℃ (℉)	℃/s (℉/s)
6 mm dia x 71 mm long	10 mm	SMR002B	950 - 800 (1,742 - 1,472)	140 (252)
			800 - 500 (1,472 - 932)	78 (140.4)
10 mm dia x 84 mm long	10 mm reduced to 6 mm dia x 6 mm long	SMR202B	950 - 800 (1,742 - 1,472)	330 (594)
			800 - 500 (1,472 - 932)	200 (360)

Quench Cooling Rates

Optional quench systems are available which can use compressed air, inert gas, or water to cool the specimen at higher rates than are achievable when relying solely on conduction cooling.

Specimen	Free Span	Drawing Number	Temperature Range	Rate
			℃ (℉)	℃/s (℉/s)
1 mm thick x 10 mm wide x 100 mm long	25 mm	SMF002B	1,000 - 600 (1,832 - 1,112)	10,000 (18,000)
6 mm dia x 86 mm long	25 mm	SMR005B	1,000 - 600 (1,832 - 1,112)	2,000 (3,600)

Note: The cooling rates are achieved using full contact copper grips on 1018 carbon steel specimens quenched with water. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

5.2.4 Temperature Uniformity Within the Specimen

The Gleeble system has the unique ability to control the temperature uniformity and thus the thermal gradient within the test specimen. Tests can be performed with very uniform temperature within the specimen work zone, equivalent to a furnace-based test, or with the large thermal gradients needed to accurately simulate welding and other processes.

When using Joule heating, the current density in a Gleeble specimen is uniformly distributed across the entire specimen cross-sectional area, meaning that the Gleeble is able to heat the entire specimen simultaneously, from surface to center. Since the Gleeble grips are cool, the heat generated in the specimen will diffuse into the grips, creating a thermal gradient with the ends of the specimen generally being cooler than the center. The severity of the steady state thermal gradient is defined by the rate of heat generated in the specimen, offset by the heat lost to the grips. This gradient can be controlled by utilizing grips of materials

with differing thermal and electrical conductivity and contact area. Thermally and electrically conductive grips with a large specimen contact area will be kept cold more readily with the water-cooled jaws, and will accept significant heat from the specimen, resulting in “cold ends” and a very steep thermal gradient.

Grips with smaller contact area and higher thermal resistance will pull much less heat from the specimen. Grips manufactured from material with higher electrical resistance will, themselves, heat under the same current that is heating the specimen. These factors will result in very little heat being pulled from the specimen and a very flat thermal gradient. In some cases the grips or anvils holding the specimen may reach temperatures equal to or higher than the specimen, creating a “reverse” thermal gradient.

When considering Gleeble thermal gradients, it is also critical to differentiate between the axial thermal gradient (along the length of the specimen), and the transverse thermal gradient (across the diameter or cross section of the specimen). Even in situations where a specimen experiences a very high axial thermal gradient, the transverse, or crosswise thermal gradient will be very small. This ability to generate isothermal planes is a critical benefit of the Gleeble. In contrast to furnace or induction heating methods, where the specimen can only be heated on the surface or to a limited “skin depth”, the center of a Gleeble specimen is heated at the same rate as the surface regardless of the heating rate. This ability to generate isothermal planes allows for the Gleeble platform to perform dilatometry and welding heat affected zone experiments at heating and cooling rates relevant to welding and other processes on specimens that are large enough for subsequent mechanical property or toughness testing. This is not feasible on furnace or inductively-heated systems that rely on thermal conduction to heat the center of the specimen. Axial thermal uniformity within a specimen is reported as the difference between the specimen’s center to edge thermal measurements and is dependent upon:

- Material
- Thermal Resistivity
- Electrical Resistivity
- Grip Contact Surface to Specimen Volume Ratio
- Specimen Length
- Specimen Cross Section
- Free Span
- Grip Selection
- Heating Rate
- Isothermal Holding Time
- Interface Resistance

The following data was obtained using Stainless Steel partial contact grips on 1018 carbon steel specimens. Measurements are taken at steady state temperatures. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

Specimen	Free Span	Drawing Number	Temperature Uniformity
Lengthwise Thermal Gradient			
10 mm dia x 111 mm long	50 mm	SMR023B	$\pm$0.5% of T_{avg} for 7 mm of midspan
Crosswise Thermal Gradient			
10 mm dia x 86 mm long	25 mm	SMR012B	$\pm$0.5% of T_{avg}

Note: T_{avg} is the average of the specimen cross section temperature at 1,000°C (1,832°F).

Reproducibility

Thermal gradients in resistance-heated specimens are dependent upon on the properties of the specimen. All specimens with the same physical, mechanical, electrical, and chemical properties will have the same gradients within the accuracy of the thermal system, provided that the specimen grips are in good condition.

5.3 Specimen Size Considerations

Gleeble systems are capable of testing a wide variety of material compositions and specimen geometries. Inherent limitations of the system, such as distance between the jaw or anvil faces, the maximum or minimum stroke speed, test temperature, and force limitations for the individual system must be considered when selecting a specific *specimen geometry* (page 378).

The target temperature of a test will also impact the size of a specimen that can safely be tested with a Gleeble system. For example, when considering a standard uniaxial compression specimen, it is possible for a soft material such as aluminum or copper to be tested at ambient temperature. Harder materials, such as steel or titanium alloys, are expected to be tested at elevated temperatures.

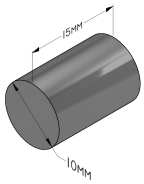


Fig. 5.9: Uniaxial Compression Specimen - SMC203.

The Gleeble 3500 and 3800's vacuum tank configuration limits the maximum and minimum specimen geometry that can be tested. Due to the modularity of the Gleeble systems, the possible specimen geometries can rage from a 260 mm long strip specimen to a 10 mm long compression specimen. When configured with the General-Purpose MCU's Pocket Jaws or the Gleeble 3500 Pedestal's Pocket Jaws, a specimen with a maximum free span of 120 mm can be tested.

Specimen geometry will vary with any specific test. DSI has identified recommended specimen geometries for commonly performed simulation tests. *Contact Dynamic Systems* (page 373) for assistance identifying a recommended specimen geometry as needed.

Popular Specimen Sizes			
Specimen Length	**Specimen Width**	**Specimen Thickness**	**Drawing Number**
Bar Specimens			
116.5 mm	10 mm dia	N/A	SMR111
121.5 mm	10 mm dia	N/A	SMR112
71 mm	6 mm dia	N/A	SMR002
71 mm	11 mm Sq	N/A	SMS006
Flat Specimens			
100 mm	10 mm	1 mm	SMF002
Uniaxial Compression			
9 mm	6 mm dia	N/A	SMC206
12 mm	8 mm dia	N/A	SMC200
15 mm	10 mm dia	N/A	SMC203
Plane Strain			
20 mm	15 mm	10 mm	SMC001
35 mm	25 mm	15 mm	SMC007

To achieve the best thermal control, flat specimens should have a cross-sectional area between 25 mm^2 and 400 mm^2 (0.0387 in^2 and 0.620 in^2).

Note: To test highly conductive specimens, additional grounding blocks must be installed on the Gleeble. See *Heating Modification for a Highly Conductive Specimen* (page 344) for more information. The use of hot grips is recommended for highly conductive specimens. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

5.4 Additional Features

Vacuum Tank

One of the distinguishing features of a Gleeble system is the ability to test materials in a controlled atmosphere. Researchers can simulate processes and test specimens in standard atmosphere, in rough vacuum, in high vacuum or in an inert gas environment. This environmental control is possible due to the large vacuum tank, also referred to as a "test chamber," that is incorporated into every Gleeble. The vacuum tank is fully integrated into the Gleeble system and can be controlled with manual controls or through software controls. A popular approach to atmosphere control in the Gleeble includes "washing cycles" which involve pumping down to a rough vacuum in the tank and then backfilling with an inert gas. This can be conducted multiple times to ensure that the desired atmosphere is achieved.

Most Gleeble vacuum tanks include viewing ports, typically incorporated into the tank doors to allow visual observation of simulations. In some cases, viewing windows are removed or covered to protect users from the light intensity of specimens at elevated temperatures. Depending on the Gleeble model, vacuum tanks may include one or two doors with viewing windows as well as additional ports for measurement devices or equipment feedthroughs.

Feedthroughs are an important feature in the Gleeble vacuum tanks. They allow researchers to install equipment that can measure or interact with the specimen during a test while still controlling the atmosphere. For example, vacuum-sealed electrical feedthroughs allow communication with transducers such as thermocouples, load cells, and strain transducers. Piping feedthroughs enable atmosphere control (e.g. inert gas backfill and vacuum supply) as well as allowing quenching media to be utilized.

Warning: The Gleeble vacuum tank is designed to operate under vacuum or atmospheric pressure, with either air or an inert gas surrounding the specimen. Positive atmospheric pressure, explosive, flammable or corrosive gases, or any mixtures of these gases, should never be used as part of the vacuum tank atmosphere.

Air Ram

The air ram is designed to maintain a constant force on the specimen in either tension or compression. When properly used it can simplify many Gleeble tests and increase the versatility of the Gleeble system.

The air ram system consists of twin air pressure cylinders connected to the moving jaw of the Gleeble. The same compressed air source used for the rest of the Gleeble system supplies the air ram. The air ram can be activated automatically during a Gleeble test or manually by a button on the HMI. Additional controls are provided for selecting compression or tension, and the pressure (force) applied to the specimen. The maximum force of the air ram is 450 kgf (992 lbf) at 5.6 kg/cm ^{2} (80 psi) Gleeble air supply pressure.

The following are some typical applications of the air ram:

- **Resistance Butt Welding:** To prevent arcing across the specimen interface, a compressive force is applied prior to heating in order to keep the two faces of the specimen in contact.
- **Hot Rolling:** A compressive force is applied to hold the specimen between the anvils prior to heating and during subsequent deformation.
- **Continuous Strip Annealing:** To compensate for thermal expansion, a small tensile force is maintained during the test in order to move the jaw and keep the strip specimen from bowing.

Hydraulic Power Unit

Gleeble 3500 and 3800 systems are equipped with an independent hydraulic power unit (HPU). The HPU is the primary source of mechanical motion for these Gleeble systems. The HPU is capable of regulating the output pressure of the hydraulic fluid based on the Gleeble system configuration.



Fig. 5.10: Gleeble Hydraulic Power Unit.

Typical Gleeble configurations allow the user to choose between a high and low output pressure. The pressure can be manually selected with a button on the HMI (Human-Machine Interface) or through the programming of a Gleeble test.

Special configurations of the Gleeble will limit the pressures available for testing. When a low-force load cell is installed, the Gleeble will automatically limit the HPU output to a low pressure. Users will not be able to select a higher hydraulic pressure. With a *Hot Torsion* (page 64) MCU installed, the Gleeble will automatically reduce the high pressure output to to an intermediate pressure. The user can select between the standard low pressure or the newly reduced high pressure.

Note: Reference *Hydraulic Oil* (page 360) for common service parts.

The Gleeble HPU uses the same process fluid chiller as the Gleeble system to enable automatic control of the hydraulic oil temperature. By automatically regulating the temperature of the hydraulic oil, the Gleeble is capable of maintaining peak performance in a variety of temperature environments. The HPU is protected by sensors that detect high oil temperature, and high or low oil level.

Characteristic		**Specification**
Pump Motor		20 hp
Variable Pressure Output	Low Pressure	68.94 bar (1000 psi)
	Intermediate Pressure	137.89 bar (2000 psi)
	High Pressure	206.84 bar (3000 psi)
Hydraulic Oil Reservoir Capacity		170 L (45 gal)

Hydraulic Pump Sound Damping Enclosure

The 35343 Hydraulic Pump Sound Damping Enclosure is designed for locations where additional noise reduction is required at the pump installation site.



Fig. 5.11: Hydraulic Power Unit Sound Damping Enclosure - DSI# 35343.

This acoustic enclosure consists of quilted material barrier panels with a quilted material roof. These panels are hung on a frame mounted to the hydraulic pump. A typical Gleeble 3500 or 3800 hydraulic power unit, without a sound damping enclosure, produces 86 to 90 dBA, depending on the surroundings and mounting position. HPUs with the sound damping enclosure produce 67 to 70 dBA.

The 35343 Hydraulic Pump Sound Damping Enclosure includes the following:

- Four-sided sound damping enclosure with a roof
- One (1) 254 mm (10 in) x 254 mm (10 in) viewing window
- Exhaust fan for cooling which is powered from the hydraulic pump

The approximate size of the enclosure is 1.524 m (60 in) long x 1.117 m (44 in) wide x 1.879 m (74 in) high. The enclosure will only accommodate the currently supplied 20 hp HPU. This enclosure is portable allowing removal of the panels for maintenance and service. Installation and assembly is required, and available at an additional cost.

Part Number	Description	Sold As
35343	Sound Damping Enclosure for 20 hp Hydraulic Power Unit	Ea

5.5 Gleeble Physical Dimensions

Equipment	Height	Depth	Width	Weight
Control Console	180 cm (71 in)	66 cm (26 in)	61 cm (24 in)	195 kg (430 lb)
3800 Load Unit	160 cm (63 in)	86 cm (34 in)	239 cm (94 in)	1,425 kg (3,143 lb)
3500C Load Unit	160 cm (63 in)	86 cm (34 in)	239 cm (94 in)	1,425 kg (3,143 lb)
3500 Pedestal Load Unit	160 cm (63 in)	86 cm (34 in)	273 cm (107 in)	1,732 kg (3,819 lb)
Hydraulic Power Unit with Oil	155 cm (61 in)	142 cm (56 in)	74 cm (29 in)	655 kg (1,444 lb)
General-Purpose MCU for 3500C and 3800	158 cm (62 in)	86 cm (34 in)	157 cm (62 in)	565 kg (1,245 lb)

Note: The Hydraulic Power Unit weighs 529 kg (1,168 lb) without oil.

Note: For complete information on all of the MCUs offered by DSI, please see *Mobile Conversion Units* (page 46).

5.5.1 Frame and Machine Stiffness

Frame Stiffness: (includes columns and crossheads)

- 5.02 x 10E-9 m/N
- 8.78 x 10E-7 in/lbf

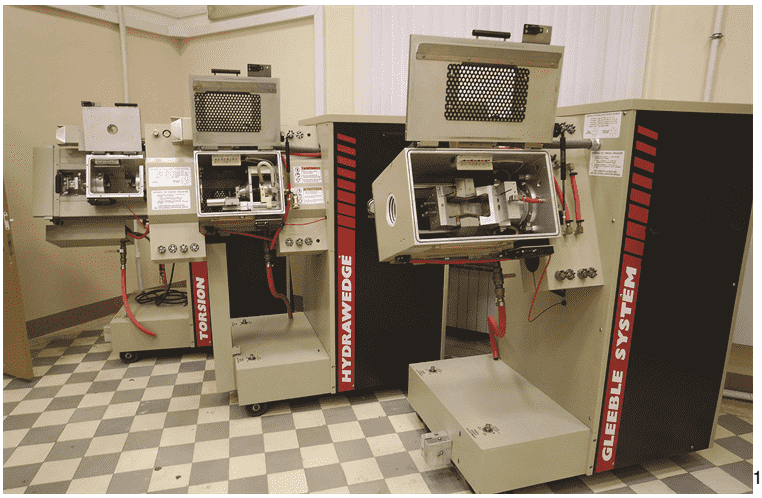
Section 6

Mobile Conversion Units

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  - *General-Purpose Jaws - Replacement Parts* (page 53)
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[10]

Fig. 6.1: MCUs Offered for a Gleeble System - Left to Right: Hot Torsion, Hydrawedge II, General-Purpose MCU.

Mobile Conversion Units (MCUs), available for the Gleeble 3500C and 3800, provide researchers with additional application-specific capabilities. While the General-Purpose MCU comes standard on most systems, additional available MCUs include the Hydrawedge II, MAXStrain II, Hot Torsion, Large-Sample Strip Annealing, and High-Temperature systems.

Mobile Conversion Units feature a rolling frame design enabling easy installation onto a Gleeble Load Unit. The wheeled fram of the MCU allows for quick and simple MCU changes providing a much wider range of testing capabilities. Changing the MCU eliminates the need to purchase separate stand-alone systems.

Note: Mobile Conversion Units are not compatible with Gleeble 3180, 3500-GTC Pedestal, or 500 Series systems.

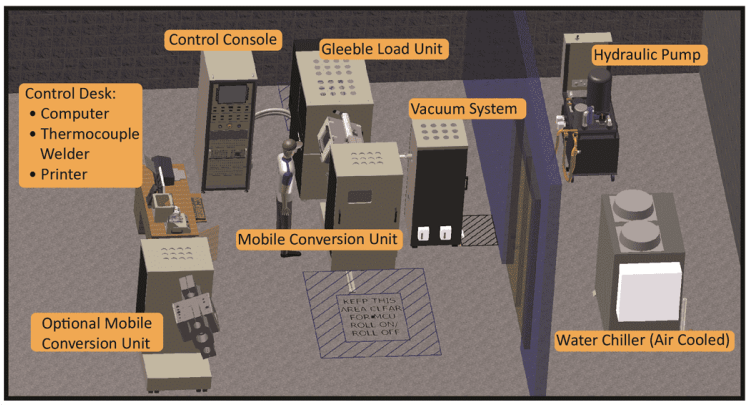


Fig. 6.2: Typical Design of a Gleeble 3800 or 3500C Lab with Two MCUs Supplied.

[10] https://gleeble.com/

6.1 General-Purpose Mobile Conversion Unit

Capable of conducting tension and compression tests, the General-Purpose Mobile Conversion Unit (MCU) (often referred to as a “Pocket Jaw”) provides the most versatile platform for the performance of a wide variety of simulations and tests. General thermal and mechanical specifications of a *Gleeble 3500-GTC* (page 28) or a *Gleeble 3800-GTC* (page 11) are measured while utilizing a General-Purpose MCU installed on the Load Unit. The General=Purpose MCU is supplied by default with these systems.

High-Temperature Testing Limitations: The General-Purpose MCU heating system can achieve temperatures up to the melting point of many materials. However at any temperature above 1,700°C (3,092°F) the vacuum tank and other instrumentation components may be damaged due to excessive radiant heat. Short-duration tests on small specimens may be conducted above 1,700°C (3,092°F) in a General-Purpose MCU. However DSI offers a *High Temperature Testing Upgrade Kit* (page 50) that includes enhanced cooling and capabilities that are optimized for higher temperature testing. For tests requiring temperatures above 1,700°C (3,092°F), contact a *DSI Engineer* (page 373) to discuss capabilities and limitations.

Note: Current Gleeble users can access the General-Purpose MCU operator’s manual here.[11]

Part Number	Description	Sold As
35010	General-Purpose MCU for Gleeble 3500C	Ea.
35012	General-Purpose MCU for Gleeble 3800	Ea.

[11] https://support.gleeble.com/portal/en/kb/articles/series-3-gtc-3500-3800-gleeble-operations-manual-user-manual

6.1.1 Upgrade Kits - General-Purpose Mobile Conversion Unit

High Temperature Testing Upgrade Kit

The High Temperature Testing Upgrade Kit includes modifications to the standard 3500 and 3800 General Purpose Mobile Conversion Units to increase the maximum sustained temperature that can be safely achieved in the vacuum tank. With the upgrade kit installed, standard specimens can be tested at temperatures up to 3,000℃ (5,432℉) for extended periods of time.

The kit includes equipment to cool and protect key systems in the Gleeble, including reinforced and actively cooled tank windows, modified cooling lines, quick-connect fittings and a heat exchanger to protect the thermocouple cold junction box. Note that during installation of the upgrade kit, the front and rear standard windows are replaced with smaller windows, therefore operator visibility will be limited and some measurement systems such as Digital Image Correlation and video recording devices are not compatible with the High Temperature Testing Upgrade Kit.

Standard windows can be reinstalled to allow for usage of these devices. The heat exchanger for the thermocouple cold junction box can remain installed as it does not interfere with existing measurement devices.

Usage of a *Pyrometer Control Camera* (page 274) (sold separately) is recommended to measure and control temperature of the specimen. DSI offers a series of pyrometers that have been optimized for specific temperature ranges.

Part Number	Description	Sold As
35055	High Temperature Testing Upgrade Kit - 3800 or 3500 General Purpose MCU	Ea.

Single Sided Heating

The Single Sided Heating kit allows the Gleeble system to heat a specimen from below. A radiative heating element is installed between the jaws redirecting the path of electrical current away from the specimen. This new electrical path ensures the specimen is heated only due to the radiation from the element. The Single Sided Heating kit is designed to perform thermal testing only, the Gleeble's mechanical deformation capabilities are limited.

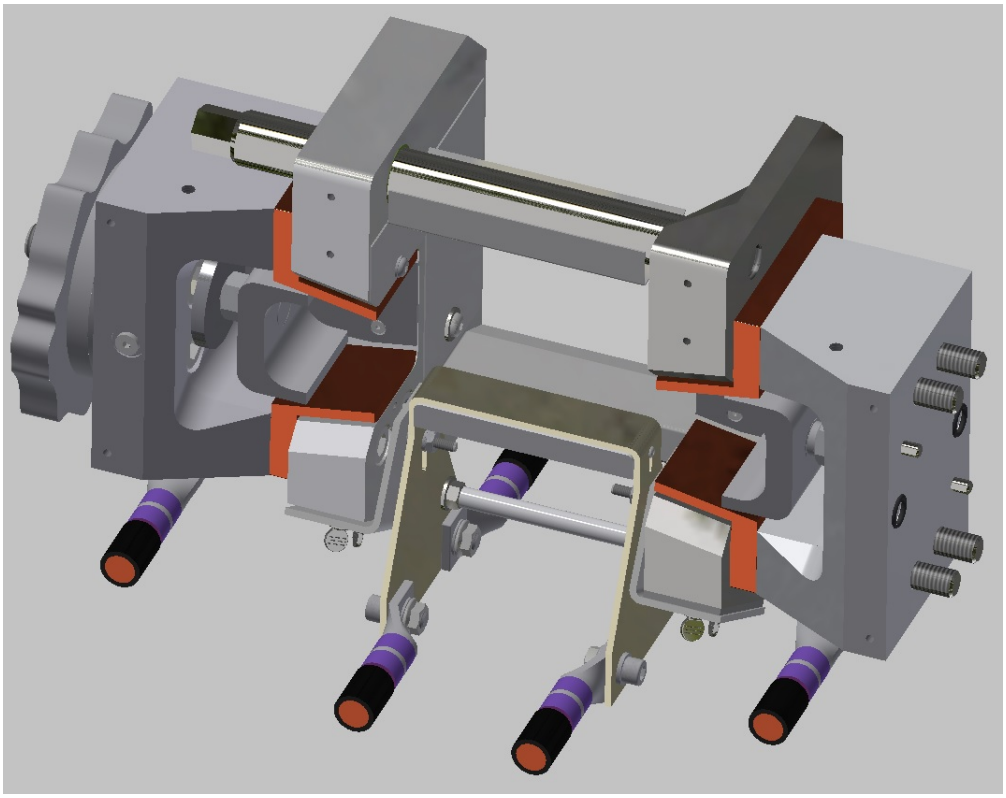


Fig. 6.3: Single Sided Heating Kit DSI # 37243

Part Number	Description	Sold As
37243	Single Sided Heating Kit - 3800 or 3500 General Purpose MCU	Ea.

General-Purpose MCU Pocket Jaw Rotation Kit

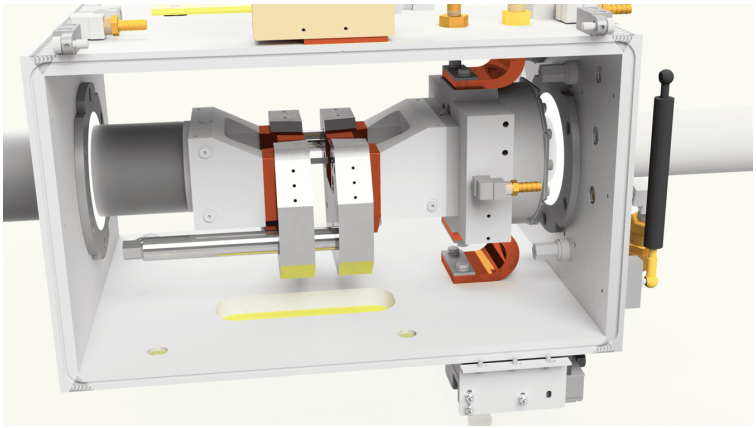


Fig. 6.4: General-Purpose MCU Pocket Jaw Rotation Kit - DSI# 37500.

The 37500 General-Purpose MCU - Pocket Jaw Rotation Kit contains the parts necessary to rotate the pocket jaws 90 degrees. After rotating the specimens, the face of the specimen will now be parallel to the vacuum tank doors. When used with standard grips devices such as *DIC cameras* (page 299), *optical micrometers* (page 269), *pyrometers* (page 274), or lasers will have a direct line of sight to the flat plane of the specimen. Viewing angles can be from either the front or back door vacuum tank windows.

Part Number	Description	Sold As
37500	General-Purpose MCU - Pocket Jaw Rotation Kit	Ea.

6.1.2 General-Purpose Jaws - Replacement Parts

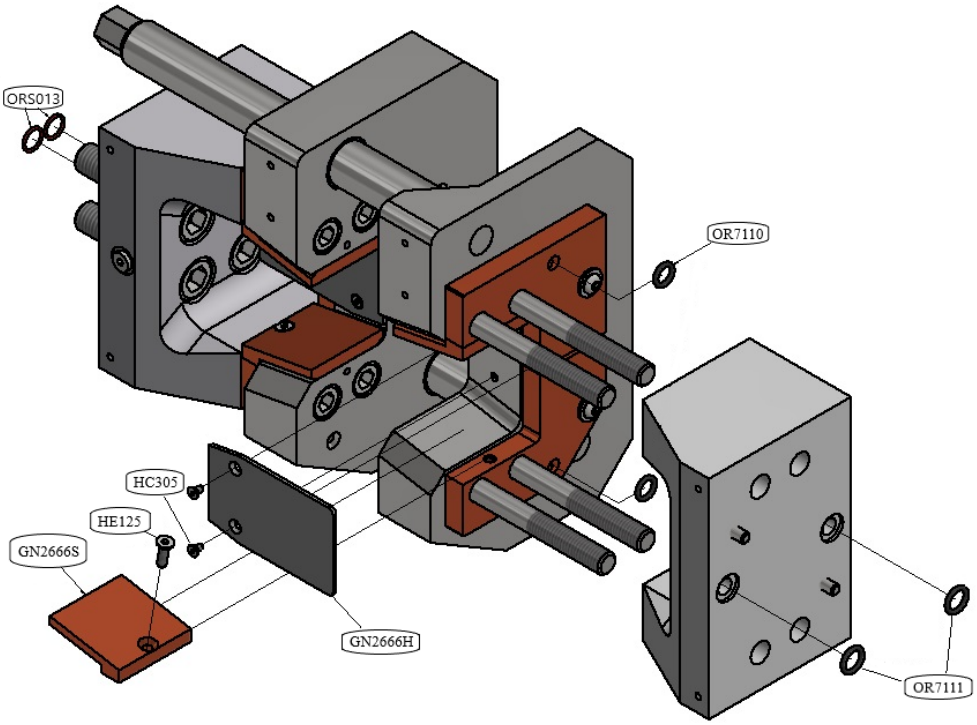


Fig. 6.5: Pocket Jaw Assembly.

Part Number	Description	Sold As
GN2666S	Universal Wear Plates	Ea.
HE125	Wear Plate Installation Hardware - 10-32 x 5/8 in FHSHCS S.S.	Ea.
GN2666H	Pocket Jaw Backing Plate	Ea.
HC305	Backing Plate Installation Hardware - 6-30 x 1/4 in FHSHCS S.S.	Ea.
OR7110	Inter-Jaw O-Ring	Ea.
OR7111	Fixed Side Jaw O-Ring	Ea.
ORS013	Moving Shaft O-Rings	Ea.
HZ020	Moving Shaft Dowel Pin - 1/4 x 1/2 in	Ea.
HL072	Moving Side Jaw Bolt - 5/8-11 x 2 1/2 in SHCS S.S.	Ea.
HK421	Fixed Side Jaw Bolt - 1/2-13 x 5 in SHCS S.S.	Ea.
32825	Jaw Alignment Fixture Kit	Kit
GN2665D	Moving Side Jaw	Ea.
GN2665E	Fixed Side Jaw	Ea.
GN2872C	Flexible Copper Grounding Lead	Ea.
WIND010	Vacuum Tank Door Window	Ea.

6.1.3 MCU Dimensions

Equipment	Height	Depth	Width	Weight
General-Purpose MCU for 3500C and 3800	158 cm (62 in)	86 cm (34 in)	157 cm (62 in)	565 kg (1,245 lb)

6.2 Hydrawedge II

The Hydrawedge II Mobile Conversion Unit (MCU) has been developed for researchers who wish to optimize multiple-hit, high-speed deformations. Such as multi-stand rolling mills and multi-hit forging processes. The Hydrawedge II offers excellent physical simulation capabilities.



[12]

Fig. 6.6: Hydrawedge II MCU - DSI# 35034.

Available as an option for Gleeble 3800 and 3500C systems, the Hydrawedge II is the only commercially available machine that offers the capability to perform high-speed deformation simulations with completely independent control of both strain and strain rate. The Hydrawedge II is available for both the *Gleeble 3800-GTC* (page 11) and the *Gleeble 3500-GTC* (page 28) systems. This MCU is specifically built to match the Force capabilities of the Load Unit it was purchased to be paired with.

The Hydrawedge II control software, *Hot Deformation Software (HDS)* (page 336), allows the system to be programmed with the same parameters as in a rolling mill schedule. The Hydrawedge II delivers test results without strain overshoot or strain rate deceleration, either one of which can reduce the accuracy of the simulation. Operators enter soak times and temperatures, rolling temperature, inter-pass time, controlled cooling time, strain rate, and amount of strain for each compressive movement. The software then calculates and programs the desired system movements that are needed to simulate the desired compression schedule on the Hydrawedge II.

When a system is equipped with a Hydrawedge II, deflection of the Gleeble system can occur. The unique design of the MCU allows it to compensate both for machine compliance and for thermal expansion of the compression anvils, delivering world-class accuracy.

The Hydrawedge II MCU is compatible with many optional accessories offered for the General-Purpose MCU. One of these options is the *Gleeble Induction Heating System (IHS)* (page 167). The Hydrawedge II benefits immensely from the induction heating system, which creates a more uniform thermal gradient across a uniaxial compression specimen

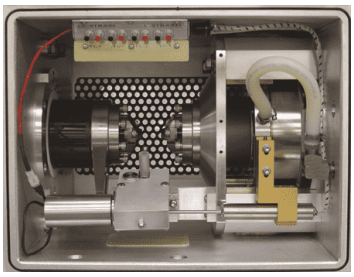


Fig. 6.7: Hydrawedge II MCU Vacuum Tank.

[12] https://gleeble.com/products/mobile-conversion-units/mcu.html

Conducting Tests Using The Hydrawedge II MCU

For replacement anvil assemblies and consumables, see *Uniaxial Compression Studies* (page 209) and *Plane Strain Studies* (page 221). See *Hydrawedge II Lengthwise Strain Gauge - Range: ±25.4 mm* (page 267) for specifications for the Hydrawedge II Jaw strain transducer.

Note: Current Gleeble users can access the Hydrawedge II MCU operator's manual here.[13]

Part Number	Description	Sold As
35033	Hydrawedge II MCU for Gleeble 3500C	Ea.
35034	Hydrawedge II MCU for Gleeble 3800	Ea.

6.2.1 Hydro-Mechanical

The Hydrawedge II system is capable of multiple compressions at high strain rates, which allows the accurate replication of an entire hot rolling or multi-hit forging process — from reheating, through multiple stand rolling, to controlled cooling.

Characteristic	Specification
Maximum Stroke Distance	36 mm (1.417 in)
Maximum Stroke Rate	330 mm/s (12.9 in/s)
Strain Control Range	25.4 mm (1 in)
Maximum Recommended Strain Rate	50/s
Maximum Compressive Force - Gleeble 3800	20,000 kgf (~44,000 lbf) (196 kN)
Maximum Compressive Force - Gleeble 3500C	10,000 kgf (~22,000 lbf) (98 kN)

Note: Accuracy is measured at a temperature of 23°C (73°F). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30°C (86°F).

[13] https://support.gleeble.com/portal/en/kb/articles/series-3-gtc-series-partnumber-part-description-users-manual

Load Cell

Characteristic	Specification
Non-linearity	±0.1 % of full scale
Hysteresis	±0.08 % of full scale
Non-Repeatability (Maximum)	±0.03 % of full scale
Overload Rating	150 % of capacity
Deflection - Full Scale	0.076 mm (0.003 in)
Force Measurement Accuracy	±1.0 % of full scale
Force Measurement Resolution	±1 kgf (2.2 lbf)

Note: Accuracy is measured at a temperature of 23°C (73°F). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30°C (86°F).

Hydrawedge II - Stroke Transducer

Characteristic	Specification
Type	LVDT
Linear Range	±18 mm (±0.7 in)
Linearity	±0.25 % of full scale
Stroke Measurement Accuracy	±0.5 % of full scale
Stroke Measurement Resolution	0.002 mm (7.87^{-5} in)

Note: Accuracy is measured at a temperature of 23°C (73°F). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30°C (86°F).

6.2.2 Thermal Subsystem

Hydrawedge II MCUs can heat a specimen with the default direct resistance heating subsystem or an optional *Gleeble Induction Heating System (IHS)* (page 167).

Direct resistance heating provides the ability to reproduce the wide variety of thermal profiles that materials undergo in actual processes. This is critical to the success of thermal-mechanical testing and physical simulation. All Gleeble systems have high-speed heating and cooling rates that can accurately replicate nearly any thermal profile required.

Induction heating is well-suited for use in uniaxial compression testing where it can provide a uniform temperature across the specimen from anvil to anvil. Induction heating can also be used in tensile testing, heat treating applications, and plane strain compression testing. Induction heating is also compatible for custom test setups due to the flexibility it offers.

The integration of the Gleeble Induction Heating System does not impact the functionality of the direct resistance heating capabilities. The Induction Heating System retains the performance standards researchers have come to know and expect from their Gleeble systems. Choosing between standard direct resistance heating and optional induction heating is available through the configuration mode of a GTC system. Only one heating method can be used per test.

Characteristic	Specification
Heating System Type and Control	Direct resistance with closed-loop control
Temperature Range	Room Temperature to 1,700℃ (3,092℉)
Direct Resistance Heating Sampling Rate	Twice the power line frequency (100 - 120 Hz)
Resolution	±1℃ or℉
Maximum Number of Thermal Channels	4 thermocouple channels, or 2 thermocouple channels and 1 pyrometer channel
Accuracy of Control	±1℃ (in steady state)
Accuracy of Measurement	±2℃ or ±1 % of temperature (whichever is greater) plus the accuracy of the thermocouple wire (in steady state)

Note: As the specimen size, diameter, length, or cross-sectional area increases the effective heating rate will decrease.

Resistance Heating Rates

Uniaxial Compression Sample Heating Rates

The maximum heating rates listed below are average rates for 1018 carbon steel specimens using 9219-062 Tungsten Carbide Anvil Caps, and resistance heating. See *Uniaxial Compression Studies* (page 209) for more information regarding the selection of anvil caps and assemblies.

Specimen	Drawing Number	Maximum Heating Rate
		℃/s (℉/s)
6 mm dia by 9 mm long	SMC206B	20 (34)
10 mm dia by 15 mm long	SMC203B	5 (9)

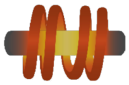
Plane Strain Sample Heating Rates

The maximum heating rates listed below are average rates for 1018 carbon steel specimens using 9105-252 Tungsten Carbide Plane Strain Anvils, and resistance heating. See *Plane Strain Studies* (page 221) for more information regarding the selection of anvil caps and assemblies.

Specimen	Drawing Number	Maximum Heating Rate
		℃/s (℉/s)
10 mm x 20 mm x 15 mm	SMC001B	5 (6)
30 mm x 30 mm x 30 mm	SMC010B	2 (3.6)

Induction Heating Rates

The maximum heating rates listed below are average rates for 1018 carbon steel specimens using a *Gleeble Induction Heating System (IHS)* (page 167).



Uniaxial Compression Heating Rates

The maximum heating rates listed below are average rates for 1018 carbon steel specimens using 9219-378 Silicon Nitride Uniaxial Compression Anvils, and a *Gleeble Induction Heating System (IHS)* (page 167). For more information regarding the selection of induction anvil caps and assemblies see *Compression Kits* (page 172).

Specimen	Drawing Number	Maximum Heating Rate
		℃/s (℉/s)
6 mm dia by 9 mm long	SMC206B	20 (36)
10 mm dia by 15 mm long	SMC203B	20 (36)
15 mm dia by 22 mm long	SMC210B	20 (36)

Note: See *Gleeble Induction Heating System (IHS)* (page 167) for specifications of the induction heater.

Plane Strain Heating Rates

The maximum heating rates listed below are average rates for 1018 carbon steel specimens using 9105-259 Extended Silicon Nitride Small Plane Strain Anvils, and a *Gleeble Induction Heating System (IHS)* (page 167). For more information regarding the selection of induction anvil caps and assemblies see *Compression Kits* (page 172).

Specimen	Drawing Number	Maximum Heating Rate
		℃/s (℉/s)
3 mm x 10 mm x 5 mm	SMC009B	20 (36)
10 mm x 20 mm x 15 mm	SMC001B	20 (36)
30 mm x 30 mm x 30 mm	SMC010B	20 (36)

Note: See *Gleeble Induction Heating System (IHS)* (page 167) for specifications of the induction heater.

6.2.3 Cooling Rates

Uniaxial Compression Quenching Rates

The maximum cooling rates listed below are average rates for 1018 carbon steel specimens, water quenched, using a 59013 High Flow Quench system and a 31733 Hydrawedge II - Multi-Function Open Quench Spray Nozzle Kit. See *Quench Systems* (page 283) for more information about quench kits and quench tanks.

Specimen	Drawing Number	Temperature Range	Cooling Rate
		℃ (℉)	℃/s (℉/s)
6 mm dia by 9 mm long	SMC206B	1,000-500 (1,832-932)	500 (900)
10 mm dia by 15 mm long	SMC203B	1,000-500 (1,832-932)	300 (540)
15 mm dia by 22 mm long	SMC210B	1,000-500 (1,832-932)	100 (180)

Plane Strain Quenching Rates

The maximum cooling rates listed below are average rates for 1018 carbon steel specimens, water quenched, using a 59013 High Flow Quench system and a 31733 Hydrawedge II - Multi-Function Open Quench Spray Nozzle Kit. See *Quench Systems* (page 283) for more information about quench kits and quench tanks.

Specimen	Drawing Number	Temperature Range	Cooling Rate
		℃ (℉)	℃/s (℉/s)
3mm x 10mm x 5mm	SMC009B	1,000-300 (1,832-572)	300 (540)
10mm x 20mm x 15mm	SMC001B	1,000-300 (1,832-572)	200 (360)
30mm x 30mm x 30mm	SMC010B	1,000-300 (1,832-572)	50 (90)

6.2.4 Specimen Size Considerations

Gleeble systems are capable of testing a wide variety of material compositions and specimen geometries. Inherent limitations of the system, such as distance between the jaw or anvil faces, the maximum or minimum stroke speed, test temperature, and force limitations for the individual system must be considered when selecting a specific *specimen geometry* (page 378).

The target temperature of a test will also impact the size of a specimen that can safely be tested with a Gleeble system. For example, when considering a standard uniaxial compression specimen, it is possible for a soft material such as aluminum or copper to be tested at ambient temperature. Harder materials, such as steel or titanium alloys, are expected to be tested at elevated temperatures.

The *uniaxial compression* (page 381) and *plane strain compression* (page 381) tests conducted with the Hydrawedge II MCU are typically run on specific specimen geometries. These geometries have been uniquely selected for optimal performance, data reliability, and test functionality. *Contact Dynamic Systems* (page 373) for assistance identifying a recommended specimen geometry.

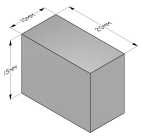


Fig. 6.8: Plane Strain Specimen - SMC001.

Popular Specimen Sizes			
Specimen Length	**Specimen Width**	**Specimen Thickness**	**Drawing Number**
Uniaxial Compression			
9 mm	6 mm dia	N/A	SMC206
12 mm	8 mm dia	N/A	SMC200
15 mm	10 mm dia	N/A	SMC203
Plane Strain			
20 mm	15 mm	10 mm	SMC001
35 mm	25 mm	15 mm	SMC007

6.2.5 MCU Dimensions

Equipment	Height	Depth	Width	Weight
Hydrawedge II MCU	158 cm (62 in)	84 cm (33 in)	150 cm (59 in)	885.8 kg (1,953 lb)

6.2.6 Hydrawedge II Lengthwise Strain Gauge - Range: ±25.4 mm

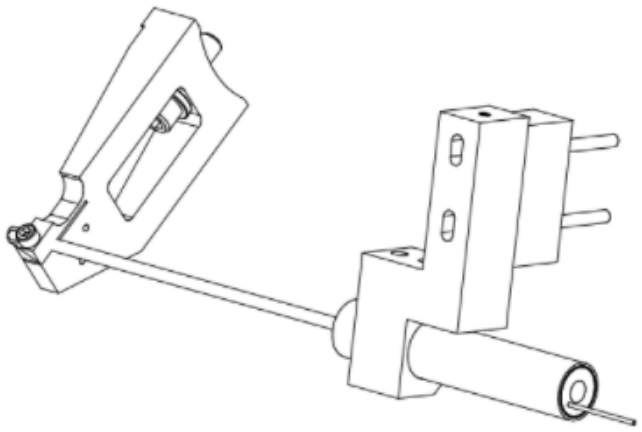


Fig. 6.9: Hydrawedge II Lengthwise Strain Gauge - DSI# 39057.

The 39055 Hydrawedge L-Strain System is designed specifically to be mounted in the *Hydrawedge II* (page 55) MCU.

Current Gleeble Users

Current Gleeble users can access the 39055 Hydrawedge L-Strain System operator's manual here.[14]

Characteristic	Specification
Type	LVDT
Linear Range	±25.4 mm (1.0 in)
Linearity	±0.25 % of full scale over ±25.4 mm (±1.0 in)
Resolution	±2 μm (7.87 x 10^{-5} in)
Gauge Length	0 to 31 mm (0 to 1.22 in)
Maximum Usable Stroke Rate	2,000 mm/s (78.74 in/s)
Maximum Recommended Strain Rate	50/s

Note: The effective maximum strain rate is dependent on the specimen material, size, and test temperature.

Part Number	Description	Sold As
39057	Hydrawedge II Lengthwise Strain Gauge - Kit and Module included	Kit
Replacement Parts		
TRN006	6 inch LVDT Stroke Transducer	Ea.
TRN006A	Measurement Core for TRN006	Ea.
TRN006B	Measurement Core Bushing for TRN006	Ea.

[14] https://support.gleeble.com/portal/en/kb/articles/series-3-gtc-series-partnumber-part-description-users-manual

6.3 Hot Torsion

The Hot Torsion MCU is available for both the *Gleeble 3500-GTC* (page 28) or the *Gleeble 3800-GTC* (page 11) systems.

The Hot Torsion Mobile Conversion Unit (MCU) adds world-class hot torsion testing capability to Gleeble 3500C and 3800 systems. Hot Torsion Systems from Dynamic Systems are the first commercially available torsion systems to incorporate direct resistance heating.

This torsion system is mounted on the roll-on/roll-off MCU design available with Gleeble 3500 and 3800 systems. With this unique design, the torsion hydraulics, electronics, vacuum tank, jaws, grips and load cell are all contained within a single MCU. This MCU can easily be connected and disconnected from the Gleeble load frame. This simplifies changeover from one major testing function to another. In a short period of time a Gleeble can be changed from hot compression testing to hot torsion testing. The Gleeble computer control automatically senses when a Hot Torsion MCU is attached and reconfigures the computer and electronics for hot torsion testing.



[15]

Fig. 6.10: Hot Torsion MCU - DSI# 35050.

Note: Current Gleeble users can access the Hot Torsion MCU operator's manual here.[16]

Part Number	Description	Sold As
35050	Hot Torsion MCU for Gleeble 3500C and 3800	Ea.

[15] https://gleeble.com/products/mobile-conversion-units/torsion.html
[16] https://support.gleeble.com/portal/en/kb/articles/series-3-gtc-35050-hot-torsion-mcu-user-manual

6.3.1 Hydro-Mechanical

The Hot Torsion MCU can be programmed for a partial revolution or multiple revolutions. Researchers can choose between radians, revolutions, or degrees of rotation as their preferred unit of angular measurement.

Characteristic	Specification
Motor Drive	Hydraulic Servo Actuator
Revolution Control	Computer-controlled
Maximum Thrust in Tension	500 kgf (1,102.31 lbf) 4.9 kN
Maximum Thrust in Compression	500 kgf (1,102.31 lbf) 4.9 kN
Maximum Torque	50 Nm (36.85 lbf/ft) with standard torque cell
	100 Nm (+ 73.75 lbf/ft) with optional torque cell
Angular Resolution	±0.1 degree
Maximum Number of Revolutions	90
Minimum Control Speed	2 rpm
Maximum Control Speed	1,500 rpm for 1 second
Maximum Acceleration	0 - 1,500 rpm in 7 ms
Maximum Deceleration	1,500 - 0 rpm in 7 ms

Note: Maximum acceleration and deceleration are specified under no load.

Note: For bidirectional torsion testing *Contact Dynamic Systems* (page 373) for more information.

Note: Accuracy is measured at a temperature of 23°C (73°F). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30°C (86°F).

Thrust Cell

The thurst cell measures lateral forces imparted to the specimen. The thrust cell load train can be uncoupled from the main hydraulics of the Gleeble system through a 550 kgf protective shear pin. The load train can be adjusted manually or mechanically to load or unload specimens.

Characteristic	Specification
Non-linearity	±0.1 % of full scale
Hysteresis	±0.08 % of full scale
Non-Repeatability (Maximum)	±0.05 % of full scale
Overload Rating	150 % of capacity
Deflection - Full Scale	0.076 mm (0.003 in)
Force Measurement Accuracy	±1.0 % of full scale
Force Measurement Resolution	±1 kgf (2.2 lbf)

Note: Accuracy is measured at a temperature of 23°C (73°F). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30°C (86°F).

Torque Cell

The torque cell of the Hot Torsion MCU measures the clockwise rotational forces experienced by a specimen. The torsional forces measured by the torque cell are then are then converted into strain values.

Characteristic	Specification
Non-linearity	±0.1 % of full scale
Hysteresis	±0.08 % of full scale
Non-Repeatability (Maximum)	±0.05 % of full scale
Overload Rating	150 % of capacity
Deflection - Full Scale	0.076 mm (0.003 in)
Torque Measurement Accuracy	±1.0 % of full scale
Torque Measurement Resolution	±1 Nm (0.73 lbf/ft)

Note: Accuracy is measured at a temperature of 23℃ (73℉). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30℃ (86℉).

6.3.2 Thermal Subsystem

The Hot Torsion MCU heats specimens using direct resistance heating. Specimens can be heated and deformed simultaneously.

Direct resistance heating provides the ability to reproduce the wide variety of thermal profiles that materials undergo in actual processes. This is critical to the success of thermal-mechanical testing and physical simulation. All Gleeble systems have high-speed heating and cooling rates that can accurately replicate nearly any thermal profile required.

Characteristic	Specification
Heating System Type and Control	Direct resistance with closed-loop control
Temperature Range	Room Temperature to 1,250℃ (2,282℉)
Temperature Monitoring Source	Thermocouple or Optional *Pyrometer Control Cameras* (page 274)
Thermocouple Sampling Rate	Twice the power line frequency (100 - 120 Hz)
Resolution	±1℃ or℉
Maximum Number Of Simultaneous Thermal Channels	4 thermocouple channels, or 2 thermocouple channels and 1 pyrometer channel
Accuracy of Control	±1℃ (in steady state)
Accuracy of Measurement	±2℃ or ±1 % of temperature (whichever is greater) plus the accuracy of the thermocouple wire (in steady state)

Note: As the specimen size, diameter, length, or cross-sectional area increases the effective heating rate will decrease.

Heating Rates

The maximum heating rates listed below are average rates for 1018 carbon steel specimen using a 480 V / 200 A power supply, 14 mm collet grips and resistance heating.

Specimen Type	Free Span	Drawing Number	Maximum Heating Rate
			℃ (℉)
20 mm gauge length, 10 mm dia	20 mm	SMT001B	200 (360)

Free Cooling Rates

The Gleeble system is able to control the specimen cooling rate based on conductive heat transfer. The efficiency and maximum rate of conductive cooling is directly impacted by grip and specimen geometry, material, cleanliness, and system's chilled process fluid flow rate.

The Gleeble system is able to control the specimen cooling rate based on conductive heat transfer. The efficiency of conductive cooling is directly impacted by grip geometry, material, cleanliness, and system chilled process fluid flow rate.

The following cooling rates are average rates for 1018 carbon steel specimen using 14 mm collet grips and conductive cooling.

Specimen Type	Free Span	Drawing Number	Temperature Range	Cooling Rate
			℃ (℉)	℃/s (℉/s)
20 mm gauge length, 10 mm dia	20 mm	SMT001B	1,200 - 1,000 (2,192 - 1,832)	6 (10.8)
			1,000 - 900 (1,832 - 1,652)	3.25 (5.85)
			900 - 700 (1,652 - 1,292)	2.5 (4.5)

6.3.3 Specimen Size Considerations

Gleeble systems are capable of testing a wide variety of material compositions and specimen geometries. Inherent limitations of the system, such as distance between the jaw or anvil faces, the maximum or minimum stroke speed, test temperature, and force limitations for the individual system must be considered when selecting a specific *specimen geometry* (page 378).

The target temperature of a test will also impact the size of a specimen that can safely be tested with a Gleeble system. For example, when considering a standard uniaxial compression specimen, it is possible for a soft material such as aluminum or copper to be tested at ambient temperature. Harder materials, such as steel or titanium alloys, are expected to be tested at elevated temperatures.

Gleeble's Torsion MCU *specimens* (page 386) are designed specifically to provide optimal results for a torsion test. The Torsion MCU is capable of accepting a wide variety of specimen geometries. However, specimens designed according to DSI's recommendations will perform better.

Specimen geometry will vary with the specific test being performed. DSI has identified recommended specimen geometries for commonly performed simulation tests. *Contact Dynamic Systems* (page 373) for assistance identifying a recommended specimen geometry.

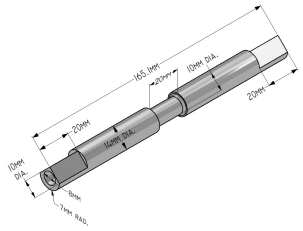


Fig. 6.11: Torsion Specimen - SMT001.

Popular Specimen Sizes				
Specimen Length	**Gauge Diame-ter**	**Gauge Length**	**Collet Size**	**Drawing Number**
165.1 mm	10 mm	20 mm	14 mm	SMT001
165.1 mm	10 mm	14.4 mm	10 mm	SMT007
165.1 mm	5.7 mm	11.4 mm	8 mm	SMT008

6.3.4 Collet Grips

The Hot Torsion MCU retains specially designed samples through the use of Stainless Steel collet grips. Redesigned in 2020, the Mark II Collet Grips are backward compatible for all Torsion MCUs. The redesigned grips make use of a single installation and removal tool, enabling researchers to quickly and easily change from one specimen size to another. The collet grip redesign also introduced a single top clamp designed for all thermal profiles. These redesigns further simplify the installation and testing of a torsion specimen.

Each Collet Grip Kit includes two clamps, two bases, and all necessary hardware to secure and orient the collet grips.

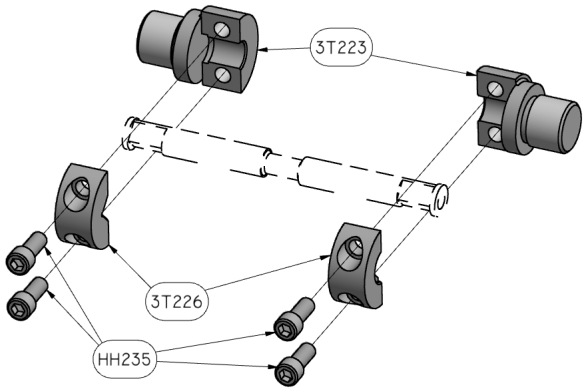


Fig. 6.12: 3T941 14 mm Collet Grips.

Part Number	Description	Sold As
8 mm Collet Grips		
3T943	8 mm Collet Grip	Kit
3T228	Jaw Clamp - Top	Ea.
3T225	Jaw Base - Bottom	Ea.
10 mm Collet Grips		
3T942	10 mm Collet Grip	Kit
3T227	Jaw Clamp - Top	Ea.
3T224	Jaw Base - Bottom	Ea.
14 mm Collet Grips		
3T941	14 mm Collet Grip	Kit
3T226	Jaw Clamp - Top	Ea.
3T223	Jaw Base - Bottom	Ea.
All Collet Grips		
3T821	Collet Grip Installation Tool	Ea.
3T143	0.020 in Copper Washer	Ea.
3T144	0.040 in Copper Washer	Ea.
3T188	0.015 in Copper Washer	Ea.
HH235	5/16 - 18 x 3/4 in Bolt	Ea.

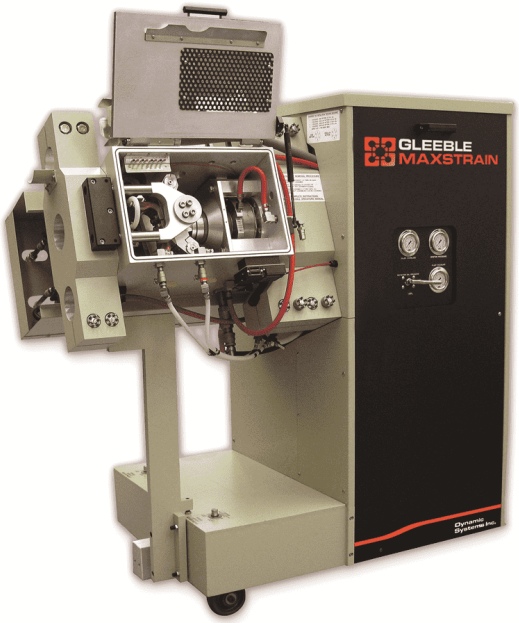
6.3.5 Replacement Parts

Part Number	Description	Sold As
3T948	Torsion Upgrade to enable heating during rotation. Slip Ring Drive Side Ground Assembly including Torsion Test Samples	Ea.
3T086	Shear Pin	Ea.
3T958	Torsion Grip Set Assembly - Through- Specimen Gas Cooling	Kit
3T947	Torsion Slip Ring Drive-Side Ground Assembly	Kit
3T939	Torsion End Heater Mounting Block with Face Seal - Mark II Design	Kit
3T131-L	Mounting Gauge Spacer Clip – Left Hand Side	Ea.
3T131-R	Mounting Gauge Spacer Clip – Right Hand Side	Ea.
3T126	Strip Heater - 2 heaters per set	Set

6.3.6 MCU Dimensions

Equipment	Height	Depth	Width	Weight
Hot Torsion MCU	158 cm (62 in)	84 cm (33 in)	150 cm (59 in)	683.1 kg (1,506 lb)

6.4 MAXStrain II



[17]

Fig. 6.13: MAXStrain II MCU - DSI# 35038.

The MAXStrain II multi-axis hot deformation system is a unique research tool that can subject materials to virtually unlimited strain under precise control of strain, strain rate, and temperature.

Specimens loaded into the MAXStrain are heated and rotated 90 degrees between multiple, successive compressions. The system restrains specimens lengthwise while allowing unlimited deformation in the other two dimensions. As a result, very high strain levels can be introduced into specimens to produce a sample of ultrafine grain or nano-scale material that is large enough for subsequent materials properties testing.

The MAXStrain provides an unparalleled degree of accuracy and reproducibility. Researchers can quickly and precisely produce target grain structure refinements in a laboratory environment. For anvil assemblies and consumables, see *Plane Strain Studies* (page 221).

Part Number	Description	Sold As
35038	MAXStrain II MCU for Gleeble 3800	Ea.

Note: The MAXStrain II MCU is only compatible with the *Gleeble 3800-GTC* (page 11).

[17] https://gleeble.com/products/mobile-conversion-units/maxstrain.html

6.4.1 Hydro-Mechanical

Characteristic	Specification
Test Frame	Horizontal type with dual 99 mm (3.9 inches) dia columns
Mechanical System	Closed-loop hydraulic servo control
Maximum Static Force in Compression	20,000 kg (~44,000 lb) (196 kN)
Maximum Dynamic Force in Compression	8,000 kg (~ 7,600 lb) (80 kN) at 700 mm/s (27.5 in/s)
Maximum Stroke Rate in Compression	350 mm/s (13.7 in/s)
Minimum Stroke Rate in Compression	0.01 mm/s (3.936996^{-4} in/s)
Maximum Stroke Distance	36 mm (1.41 in)
Maximum Number of Compression Hits	No Specific Limit

Note: Accuracy is measured at a temperature of 23℃ (73℉). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30℃ (86℉).

Load Cell

Characteristic	Specification
Non-linearity	±0.1 % of full scale
Hysteresis	±0.08 % of full scale
Non-Repeatability (Maximum)	±0.03 % of full scale
Overload Rating	150 % of capacity
Deflection - Full Scale	0.076 mm (0.003 in)
Force Measurement Accuracy	±1.0 % of full scale
Force Measurement Resolution	±1 kgf (2.2 lbf)

Note: Accuracy is measured at a temperature of 23℃ (73℉). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30℃ (86℉).

MAXStrain II - Stroke Transducer

Characteristic	Specification
Type	LVDT
Linear Range	±25.4 mm (±1.0 in)
Linearity	±0.25 % of full scale
Stroke Measurement Accuracy	±0.5 % of full scale
Stroke Measurement Resolution	0.002 mm (7.87^{-5} in)

Note: Accuracy is measured at a temperature of 23℃ (73℉). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30℃ (86℉).

6.4.2 Thermal Subsystem

The MAXStrain II MCU heats a specimen with direct resistance heating.

Direct resistance heating provides the ability to reproduce the wide variety of thermal profiles that materials undergo in actual processes. This is critical to the success of thermal-mechanical testing and physical simulation. All Gleeble systems have high-speed heating and cooling rates that can accurately replicate nearly any thermal profile required.

Characteristic	Specification
Heating System Type and Control	Direct resistance with closed-loop control
Temperature Range	Room Temperature to 1,700℃ (3,092℉)
Thermocouple Sampling Rate	Twice the power line frequency (100 - 120 Hz)
Resolution	±1℃ or℉
Maximum number of Thermal Channels	4 thermocouple channels, or 2 thermocouple channels and 1 pyrometer channel
Accuracy of Control	±1℃ (in steady state)
Accuracy of Measurement	±2℃ or ±1 % of temperature (whichever is greater) plus the accuracy of the thermocouple wire (in steady state)

Note: As the specimen size, diameter, length, or cross-sectional area increases the effective heating rate will decrease.

Heating Rates

The maximum heating rates listed below are average rates for 1018 carbon steel specimen using a 480 V / 200 A power supply and standard MAXStrain II grips and resistance heating.

Specimen	Free Span	Drawing Number	Maximum Heating Rate
			℃/s (℉/s)
15 mm Sq x 195.58 mm long with reduced center	10 mm square x 12 mm long	SMC408B	50 (90)

6.4.3 Cooling Rates

Free Cooling Rates

The Gleeble system is able to control the specimen cooling rate based on conductive heat transfer. The efficiency and maximum rate of conductive cooling is directly impacted by grip and specimen geometry, material, cleanliness, and system's chilled process fluid flow rate.

The following cooling rates are average rates for 1018 carbon steel specimen (SMC408B) using standard MAXStrain grips and conductive cooling.

Specimen	Drawing Number	Temperature Range	Cooling Rate
		℃ (℉)	℃/s (℉/s)
15 mm Sq x 195.58 mm long	SMC408B	1,000-800 (1,832-1,472)	15 (27)
		800-500 (1,472-932)	7 (12.6)

Quench Cooling Rates

Optional quench systems are available which can use compressed air or inert gas to cool the specimen at high rates. A mixture of compressed air and water can also be used as a quench medium for even higher cooling rates.

The maximum cooling rates listed below are average rates for 1018 carbon steel specimens, water quenched, using a 59013 High Flow Quench system. See *Quench Systems* (page 283) for more information about quench kits and quench tanks.

Specimen	Drawing Number	Temperature Range	Cooling Rate
		℃ (℉)	℃/s (℉/s)
15 mm Sq x 191.77 mm long	SMC408B	1,000-500 (1,832-932)	550 (990)
15 mm Sq x 191.77 mm long with ISO-Q Quench	SMC409B	1,000-500 (1,832-932)	50 (90)

6.4.4 Temperature Uniformity Within the Specimen

The Gleeble system has the unique ability to control the temperature uniformity and thus the thermal gradient within the test specimen. Tests can either be performed with very uniform thermal gradient within the specimen's work zone cross-sectional area, or with the large thermal gradients needed to accurately simulate welding and other processes.

Thermal gradients within a specimen are dependent upon:

- Material
- Thermal Resistivity
- Electrical Resistivity
- Grip Contact Surface-to-Specimen Volume Ratio
- Specimen Length
- Specimen Cross Section
- Free Span
- Grip Selection

The following specimen data were obtained using standard Stainless Steel MAXStrain II contact grips. Measurements were taken at steady state temperatures.

Specimen	Free Span	Drawing Number	Temperature Uniformity
15 mm Sq x 172.7 mm long	10 mm x 12 mm reduced	SMC409B	$\pm$3 % of T_{avg} for 10 mm of midspan

Note: T_{avg} is the average of the specimen cross sectional temperature at 1,000°C (1,832°F).

6.4.5 Specimen Size Considerations

Gleeble systems are capable of testing a wide variety of material compositions and specimen geometries. Inherent limitations of the system, such as distance between the jaw or anvil faces, the maximum or minimum stroke speed, test temperature, and force limitations for the individual system must be considered when selecting a specific *specimen geometry* (page 378).

The target temperature of a test will also impact the size of a specimen that can safely be tested with a Gleeble system. For example, when considering a standard uniaxial compression specimen, it is possible for a soft material such as aluminum or copper to be tested at ambient temperature. Harder materials, such as steel or titanium alloys, are expected to be tested at elevated temperatures.

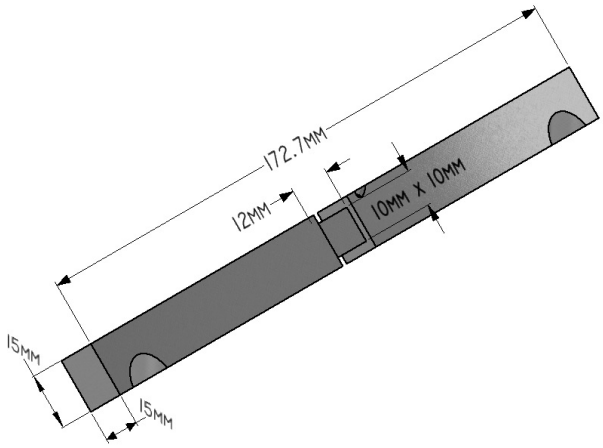


Fig. 6.14: MaxStrain Specimen - SMC408.

The MAXStrain II's vacuum tank configuration limits the maximum and minimum sample geometry that can be tested.

Specimen (page 387) geometry will vary with the specific test being performed. DSI has identified recommended specimen geometries for commonly performed simulation tests. *Contact Dynamic Systems* (page 373) for assistance identifying a recommended specimen geometry.

Popular Specimen Sizes				
Specimen Length	**Specimen Size**	**Gauge Size**	**Gauge Length**	**Drawing Number**
195.58 mm	15 mm Sq	10 mm Sq	12 mm	SMC408
191.77 mm	15 mm Sq	10 mm Sq	12 mm	SMC409
195.58 mm	15 mm Sq	15 mm Sq	12 mm	SMC416

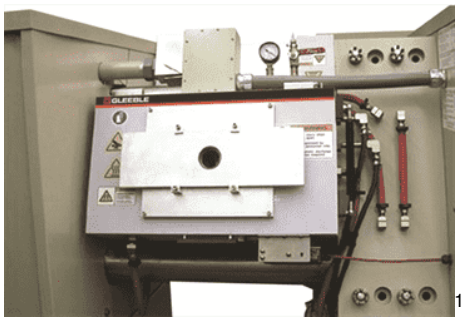
6.4.6 MCU Dimensions

Equipment	**Height**	**Depth**	**Width**	**Weight**
MAXStrain II MCU	158 cm (62 in)	84 cm (33 in)	150 cm (59 in)	953.9 kg (2,103 lb)

6.5 Large-Sample Strip Annealing

The Large-Sample Strip Annealing Mobile Conversion Unit (MCU) is designed to provide controlled heating and cooling cycles on large sheet steel specimens for replicating the heating and cooling cycles of sheet annealing processes.

The test specimen size is large enough to allow subsequent mechanical testing of the material, including furnishing limiting dome height test and tensile test coupons.



[18]

Fig. 6.15: Large-Sample Strip Annealing MCU - DSI# 35025.

This MCU's capabilities offer valuable tools to researchers and production engineers as they set up new continuous strip annealing lines, optimize existing lines, or efficiently develop new products and processes.

This MCU is equipped with the following:

- Vacuum tank for atmosphere control
- Spray heads and valve controls for air/gas quenching of specimens
- Quench valve controls integrated with the Gleeble computer
- Safety interlocks on the vacuum door for heat and mechanical operation
- Pneumatic grips for easy loading/unloading and consistent clamping pressures

Part Number	Description	Sold As
35025	Large-Sample Strip Annealing MCU	Ea.

[18] https://gleeble.com/products/mobile-conversion-units/large-sample-strip-annealing-system.html

6.5.1 Thermal Subsystem

The Large-Sample Strip Annealing MCU heats a specimen with direct resistance heating.

Direct resistance heating provides the ability to reproduce the wide variety of thermal profiles that materials undergo in actual processes. This is critical to the success of thermal-mechanical testing and physical simulation. All Gleeble systems have high-speed heating and cooling rates that can accurately replicate nearly any thermal profile required.

Characteristic	Specification
Heating System Type and Control	Direct resistance with closed-loop control
Temperature Range	Room temperature to 900℃ (1,652℉)
Maximum Heating Rate	15℃/s (27℉)
Thermocouple Sampling Rate	Twice the power line frequency (100 - 120 Hz)
Resolution	±1℃ or℉
Maximum Number of Thermal Channels	4 thermocouple channels, or 2 thermocouple channels and 1 pyrometer channel
Accuracy of Control	±1℃ (in steady state)
Accuracy of Measurement	±2℃ or ±1 % of temperature (whichever is greater) plus the accuracy of the thermocouple wire (in steady state)

Note: As the specimen size, diameter, length, or cross-sectional area increases the effective heating rate will decrease.

Thermal Gradient Considerations

For Gleeble systems with a standard 75 kVA heating transformer, standard specimen length is 254 mm (10 in). The chart below indicates maximum width based on specimen thickness. The temperature uniformity data is valid from 250 - 900℃ (482 - 1,652℉). Thermal uniformity within a specimen is reported as the difference between the temperature measurement at the center and the temperature measurement at the edge of the specimen. Each specimen's thermocouples are configured in the same manner. Three thermocouples are placed in specific locations on the specimen to verify the average temperature of the desired thermal uniformity area. The average temperature uniformity zone during the heating, holding and cooling cycles are listed based on the specimen size.

Specimen Thickness	Specimen Width	Uniform Zone Width	Uniform Zone Length	Temperature Uniformity on Heating	Temperature Uniformity on Holding	Temperature Uniformity on Cooling
				℃ (℉)	℃ (℉)	℃ (℉)
1 mm	127 mm	76 mm	76 mm	±15 (59)	±15 (59)	±25 (77)
2 mm	127 mm	76 mm	76 mm	±15 (59)	±20 (68)	±25 (77)
3 mm	127 mm	76 mm	76 mm	±20 (68)	±20 (68)	±20 (68)

Thermal uniformity within the specimen is verified by measuring thermocouples secured onto the specimen. The TC positioning measurements below use the top of the left edge of the specimen as an origin point. Secure thermocouples at the following location.

- TC1 Center: 127 mm x 63.5 mm (4.99 in x 2.49 in)
- TC2 38 mm above TC1: 165 mm x 63.5 mm (6.49 in x 2.49 in)
- TC3 38 mm to the right of TC1: 127 mm x 101.5 mm (6.49 in x 3.99 in)

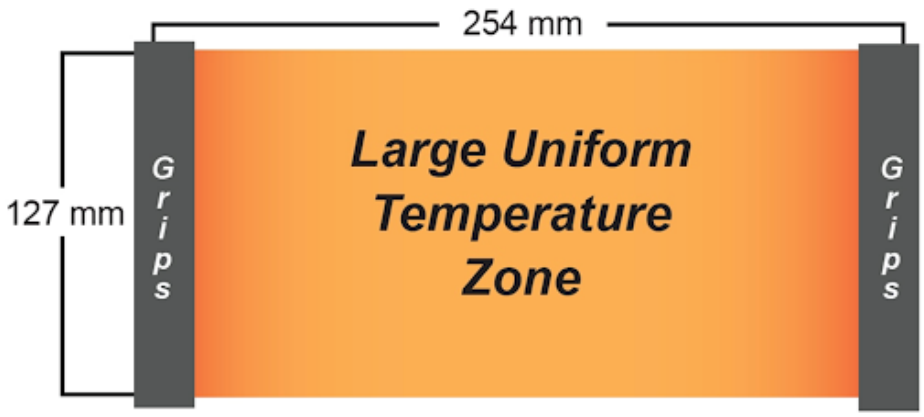


Fig. 6.16: Thermocouple Placement.

Heating Rate

Heating rates are based on using a 480 V / 200 A power supply, standard Large-Sample Strip Annealing grips, and 1018 carbon steel specimens in the Large-Sample Strip Annealing MCU.

Specimen	Thickness	Drawing Number	Maximum Heating Rate
			℃ (℉)
254 mm long x 127 mm wide	1 mm	SMF114B	15 (59)
254 mm long x 127 mm wide	2 mm	SMF115B	15 (59)
254 mm long x 127 mm wide	3 mm	SMF116B	15 (59)

Cooling Rate

The Gleeble system is able to control the specimen cooling rate based on conductive heat transfer. The efficiency and maximum rate of conductive cooling is directly impacted by grip and specimen geometry, material, cleanliness, and system's chilled process fluid flow rate.

Cooling rates are achieved using standard Large-Sample Strip Annealing grips, and 1018 carbon steel specimens in the Large-Sample Strip Annealing MCU, a *Proportional Quench System* (page 289) valve; and compressed nitrogen (N2) gas.

Specimen	Specimen Thickness	Drawing Number	Temperature Range	Cooling Rate
			℃ (℉)	℃/s (℉/s)
254 mm long x 127 mm wide	1 mm	SMF114B	900-500 (1,1652-932)	20 (36)
254 mm long x 127 mm wide	2 mm	SMF115B	900-500 (1,1652-932)	17.5 (31.5)
254 mm long x 127 mm wide	3 mm	SMF116B	900-500 (1,1652-932)	17.5 (31.5)

6.5.2 Specimen Size Considerations

Gleeble systems are capable of testing a wide variety of material compositions and specimen geometries. Inherent limitations of the system, such as distance between the jaw or anvil faces, the maximum or minimum stroke speed, test temperature, and force limitations for the individual system must be considered when selecting a specific *specimen geometry* (page 378).

The target temperature of a test will also impact the size of a specimen that can safely be tested with a Gleeble system. For example, when considering a standard uniaxial compression specimen, it is possible for a soft material such as aluminum or copper to be tested at ambient temperature. Harder materials, such as steel or titanium alloys, are expected to be tested at elevated temperatures.

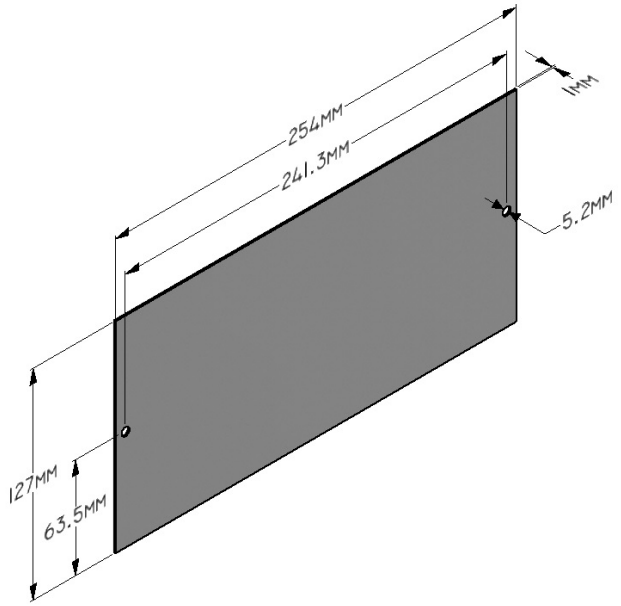


Fig. 6.17: Large-Sample Strip Annealing Specimen - SMF114.

The Large-Sample Strip Annealing MCU's vacuum tank configuration limits the maximum and minimum sample geometry that can be tested.

Specimen (page 385) geometry will vary with the specific test being performed. DSI has identified recommended specimen geometries for commonly performed simulation tests. *Contact Dynamic Systems* (page 373) for assistance identifying a recommended specimen geometry as needed.

Popular Specimen Sizes			
Thickness	**Length**	**Width**	**Drawing Number**
1 mm	254 mm	127 mm	SMF114
2 mm	254 mm	127 mm	SMF115
3 mm	254 mm	127 mm	SMF116
4 mm	254 mm	127 mm	SMF117

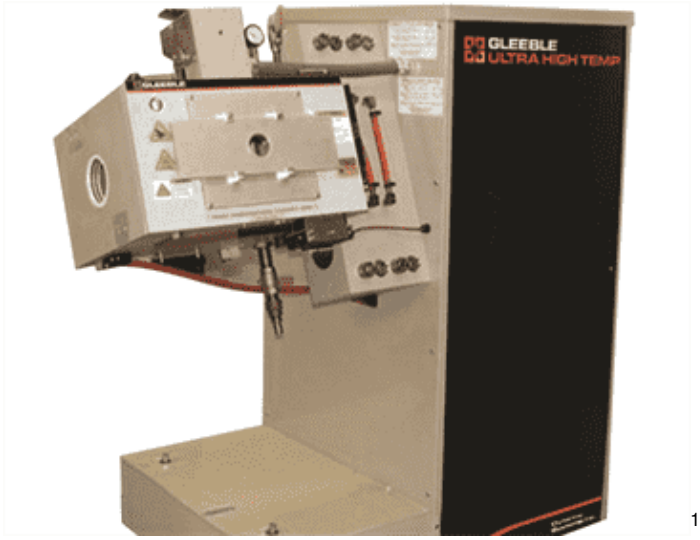
6.5.3 Pneumatic

The Large-Sample Strip Annealing MCU is equipped with a pneumatic system to actuate the specimen retention grips. The pneumatic system also applies a minimal tensile force on the specimen to prevent buckling during a test.

6.5.4 MCU Dimensions

Equipment	Height	Depth	Width	Weight
Strip Annealing MCU	158 cm (62 in)	86 cm (34 in)	157 cm (62 in)	565 kg (1,245 lb)

6.6 High-Temperature MCU



[19]

Fig. 6.18: High-Temperature General-Purpose MCU - DSI# 35024.

The High-Temperature MCU is used for testing or simulation applications that require high-temperatures for extended periods of time. The High-Temperature General-Purpose Mobile Conversion Unit (MCU) offers enhanced capabilities to accommodate more demanding requirements. This MCU is based on the *General-Purpose Mobile Conversion Unit* (page 49) MCU, which allows for the use of standard specimen grips and accessories.

The High-Temperature General-Purpose MCU is available for both the *Gleeble 3500-GTC* (page 28) and the *Gleeble 3800-GTC* (page 11) systems.

Characteristic	Specification
Heating System Type and Control	Direct resistance with closed-loop control
Temperature Range	-150 to 3,000℃ (-238 to 5,432℉)
Temperature Monitoring Source	Thermocouple or Optional *Pyrometer Control Cameras* (page 274)
Thermocouple Sampling Rate	Twice the power line frequency (100 - 120 Hz)
Resolution	±1℃ or℉
Maximum Number Of Simultaneous Thermal Channels	4 thermocouple channels, or 2 thermocouple channels and 1 pyrometer channel
Accuracy of Control	±1℃ (in steady state)
Accuracy of Measurement	±2℃ or ±1 % of temperature (whichever is greater) plus the accuracy of the thermocouple wire (in steady state)

Note: An optional *Pyrometer Control Camera* (page 274) is required for temperatures above 2,100℃ (3,812℉). An optional *Cryogenic Quench System* (page 291) kit is required for temperatures below room temperature.

[19] https://gleeble.com/products/mobile-conversion-units/high-temperature-testing.html

Note: As the specimen size, diameter, length, or cross-sectional area increases the effective heating rate will decrease.

Part Number	Description	Sold As
35023	High-Temperature Testing MCU for Gleeble 3500C	Ea.
35024	High-Temperature Testing MCU for Gleeble 3800	Ea.

6.6.1 MCU Dimensions

Equipment	Height	Depth	Width	Weight
General-Purpose MCU for 3500C and 3800	158 cm (62 in)	86 cm (34 in)	157 cm (62 in)	565 kg (1,245 lb)

6.7 MCU Superbolts

Standard Mobile Conversion Units, MCUs, are secured to the Gleeble Load Unit with Superbolts. Secured with DSI-supplied hand tools, the Superbolts apply adequate clamping force to secure each MCU for high-speed, high strength testing.

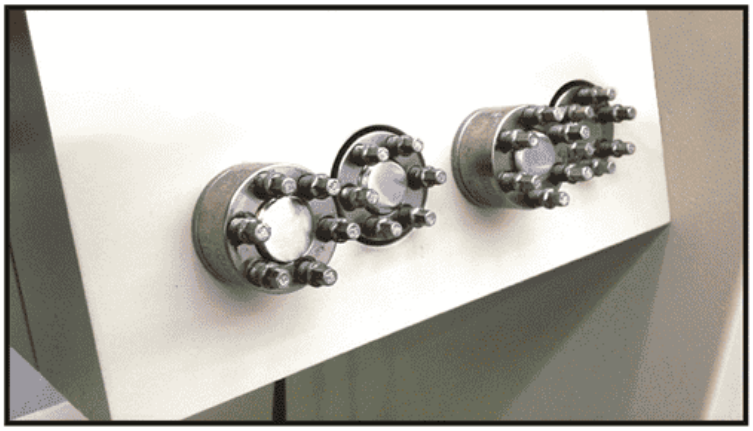


Fig. 6.19: Superbolt Assembly.

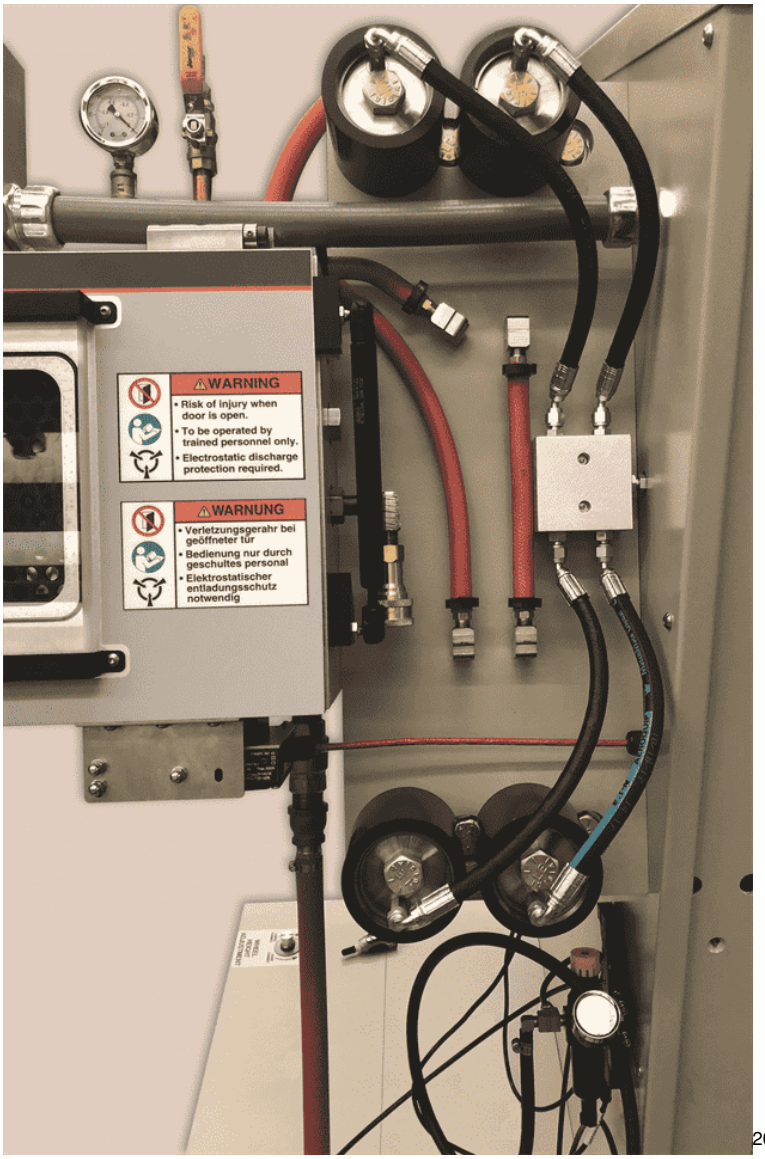


Fig. 6.20: Parts of a Superbolt Assembly.

Part Number	Description	Sold As
33929	Supernut Bolt	Ea.
HN100	Supernut with Washer	Ea.
HN101A	Jack Bolt for MCU Superbolts	Ea.
HN030	3/4 in Supernut Washer	Ea.
G389X	3/16 in Impact Socket, 1/4 in Drive for HN101A	Ea.
HN101B	Superbolt Lubricant	Ea.
HN103A	Torquing Screw for Load Cell Superbolts	Ea.

6.8 Hydraulic Crosshead Locks

DSI has introduced a new hydraulic crosshead locking system that eliminates the need for Superbolts and jack screws while maintaining optimal performance and system stiffness. These hydraulic locks greatly reduce the time required to switch MCUs, allowing Gleeble users to be more productive and spend more time running tests, and less time configuring equipment.



[20]

Fig. 6.21: Hydraulic Cross Head Locks.

Crosshead locks automatically engage when the Gleeble is powered on, ensuring a secure connection between the MCU and the Gleeble load unit. The hydraulic lock set include multiple locks, which are powered by an independent hydraulic system. The independent hydraulic pump is installed inside the Gleeble Load Unit. The second hydraulic pump ensures the Gleeble system continues to operate with the full potential power of it's standard hydraulic system; the same as systems not equipped with Hydraulic

[20] https://gleeble.com/products/mobile-conversion-units/mcu-hydraulic-crosshead-locks.html

Cross Head Locks.



Fig. 6.22: Hydraulic Crosshead Locks Eliminate the Need for Superbolts.

The Hydraulic Crosshead Locking System is not a standard feature. It is available as an option on new Gleeble systems and as a retrofit for most existing Gleeble MCUs. The system requires installation by a Certified Systems Service Engineer. The Hydraulic Power Pack is permanently incorporated into the Load Unit with dedicated locks installed on each MCU. Hydraulic quick-connect fittings allow for easy MCU hook-up to the load unit. Each MCU requires a different number of hydraulic locks. For instance, a Gleeble 3800 General-Purpose MCU utilizes 8 hydraulic locks.

6.8.1 Hydraulic Power Pack

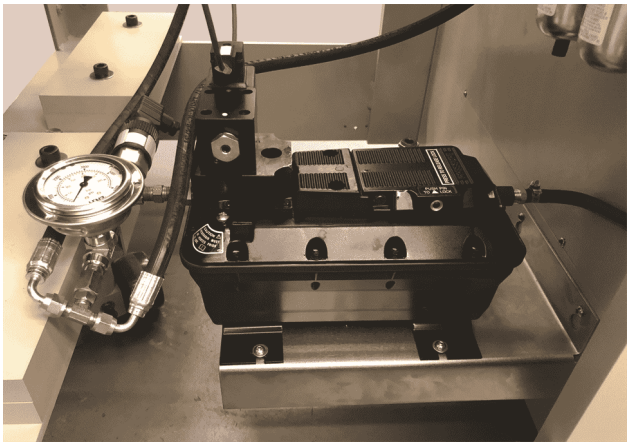


Fig. 6.23: Hydraulic Power Pack for Hydraulic Crosshead Locks.

The hydraulic power pack used with hydraulic crosshead locks is installed in the Gleeble Load Unit. With a pneumatic supply pressure of 5.51 bar (80 psi) a single hydraulic power pack supports all of the hydraulic crosshead locks installed on the MCUs.

Part Number	Description	Sold As
37620	Power Pack For Hydraulic Crosshead Locks - Factory Installed	Ea.
37620-GR	Power Pack For Hydraulic Crosshead Locks - Retrofit for GTC Console	Ea.
37620-3R	Power Pack For Hydraulic Crosshead Locks - Retrofit for Series 3 Control Console	Ea.

6.8.2 Gleeble 3500C Crosshead Locks

Each Hydraulic Crosshead Locks kit contains all of the required parts to be installed on a single, designated MCU. To fully retrofit or configure multiple MCUs, multiple Hydraulic Crosshead Locks kits are required.

The Hydraulic Crosshead Locks for a High-Temperature General-Purpose MCU utilize the same parts as the Hydraulic Crosshead Locks for a General-Purpose MCU. The Large-Sample Strip Annealing MCU can be retrofitted with the Torsion MCU's Hydraulic Crosshead Locks kit.

Crosshead Locks for Gleeble 3500C	
General-Purpose or High-Temperature General-Purpose MCU - 4 Locks per MCU	
37601	Factory Installed
37601-GR	Retrofit for GTC
37601-3R	Retrofit for Series 3 Control Console
Hydrawedge II MCU - 8 Locks per MCU	
37606	Factory Installed
37606-GR	Retrofit for GTC
37606-3R	Retrofit for Series 3 Control Console
Torsion or Large-Sample Strip Annealing MCU - 4 Locks per MCU	
37610	Factory Installed
37610-GR	Retrofit for GTC
37610-3R	Retrofit for Series 3 Control Console

6.8.3 Gleeble 3800 Crosshead Locks

Each Hydraulic Crosshead Locks kit contains all of the required parts to be installed on a single, designated MCU. To fully retrofit or configure multiple MCUs, multiple Hydraulic Crosshead Locks kits are required.

The Hydraulic Crosshead Locks for a High-Temperature General-Purpose MCU utilize the same parts as the Hydraulic Crosshead Locks for a General-Purpose MCU. The Large-Sample Strip Annealing MCU can be retrofitted with the Torsion MCU's Hydraulic Crosshead Locks kit.

Crosshead Locks for Gleeble 3800	
General-Purpose or High-Temperature General-Purpose MCU - 8 Locks per MCU	
37600	Factory Installed
37600-GR	Retrofit for GTC
37600-3R	Retrofit for Series 3 Control Console
Hydrawedge II MCU - 14 Locks per MCU	
37605	Factory Installed
37605-GR	Retrofit for GTC
37605-3R	Retrofit for 3000 Series
MAXStrain MCU - 10 Locks per MCU	
37615	Factory Installed
37615-GR	Retrofit for GTC
37615-3R	Retrofit for Series 3 Control Console
Torsion or Large-Sample Strip Annealing MCU - 4 Locks per MCU	
37610	Factory Installed
37610-GR	Retrofit for GTC
37610-3R	Retrofit for Series 3 Control Console

Section 7

Gleeble 3180-GTC

Contents

- *Hydro-Mechanical* (page 92)
- *Thermal Subsystems* (page 96)
  - *Thermocouple Wire Types* (page 97)
  - *Heating Rates* (page 97)
  - *Cooling Rates* (page 98)
  - *Temperature Uniformity Within the Specimen* (page 99)
- *Specimen Size Considerations* (page 101)
- *Additional Features* (page 102)
- *Gleeble Physical Dimensions* (page 103)



[21]

Fig. 7.1: Gleeble 3180-GTC

[21] https://gleeble.com/products/gleeble-systems/gleeble-3180.html

The Gleeble 3180-GTC provides a physical simulation system for researchers who require the quality and accuracy of a Gleeble system at an affordable price. The Gleeble 3180-GTC is ideal for weld HAZ simulations, hot tensile tests, thermal cycling, heat treatment studies, uniaxial compression and low-force tests.

The Gleeble 3180 system retains the premiere performance and reliability synonymous with Gleeble systems but in a smaller and more economical platform. The Gleeble 3180 was designed as a replacement for the famous Gleeble 1500 that dominated the physical simulation market for decades.

At the heart of the Gleeble 3180 are the features that have made all Gleeble systems world-renowned. The closed-loop direct resistance heating system continues to provide superior thermal control compared to a furnace heating method.

Material Testing Capabilities of the Gleeble 3180-GTC

- Hot Tensile Testing
- Low-Speed Uniaxial Compression
- Strain Induced Crack Opening (SICO)
- Low-Speed Plane Strain Compression
- Static Dilatometry Studies
- Deformation Dilatometry Studies
- Heat Treatments
- Melting & Solidification Simulations
- Welding Studies
- Weld HAZ Studies
- Nil-Strength Studies
- Continuous Casting Simulations
- Mushy Zone Processing Studies
- Forging Simulations
- Stress Relaxation Simulations
- Strip Annealing Simulations
- Extrusion Simulations
- Quenching (Water/Air/Gas) Simulations
- Recrystallization Studies
- Grain Growth Studies
- Thermal Fatigue
- Mechanical Fatigue

Part Number	Description	Sold As
3180	Gleeble 3180-GTC	System

7.1 Hydro-Mechanical

Every Gleeble system derives its power from a servo-controlled hydraulic system. The capabilities of the hydro-mechanical system will vary based on Gleeble options.

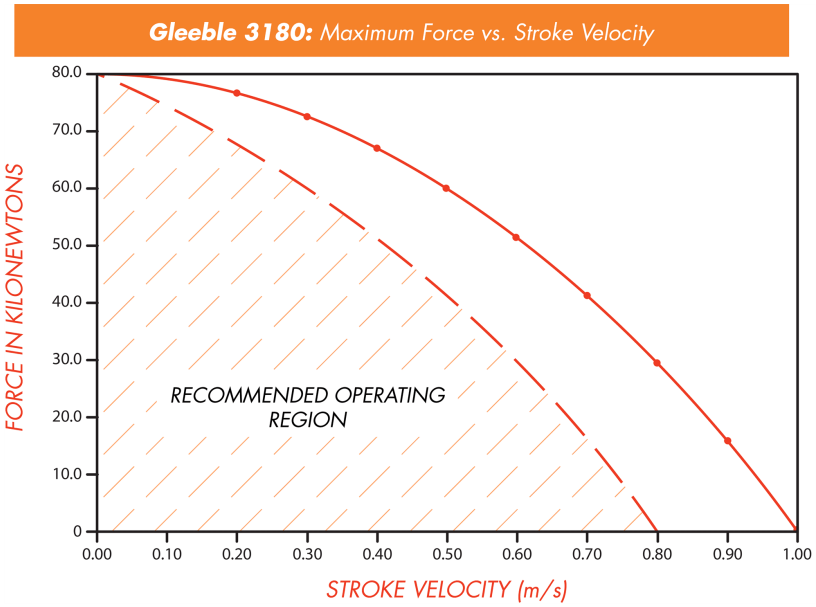
Characteristic	Specification
Test Frame	Horizontal type
Mechanical system	Closed-loop hydraulic servo control
Data Acquisition Channels	User selectable, up to 16 channels simultaneously, 18-bit ADC
Data Sampling Rate	User selectable, up to 50 kHz.
Maximum Static Force in Compression	8,165 kgf (18,000 lbs) (80 kN)
Maximum Static Force in Tension	8,165 kgf (18,000 lbs) (80 kN)
Maximum Force Continuously Reversing (Fatigue Rating)	±5,000 kgf (±11,023 lbs) (±49 kN)
Maximum Stroke Rate (no load)	1,000 mm/s (39.36 in/s) in tension or compression
Minimum Stroke Rate	0.01 mm/s (3.936996^{-4} in/s) in tension or compression
Maximum Stroke Distance	100 mm (3.93 in)
Maximum Number of Compression Hits	No Specific Limit

Note: The total number of compression hits possible is dependent upon many test characteristics. These include the number of deformations, the initial position of the hydraulic stroke, and time between deformations.

Note: Accuracy is measured at a temperature of 23°C (73°F). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30°C (86°F).

Maximum Dynamic Force

The maximum dynamic force for a Gleeble 3180-GTC is based on the following graph. For a given stroke speed the hydraulic system will provide a corresponding force. All performance figures for the system are based on operating within the recommended operating region below the force vs. stroke curve. The specifications are not valid for tests conducted outside this operating range.



Hydraulic Servo Response

The graphs below shows the time and distance required for the piston to reach the programmed rate.

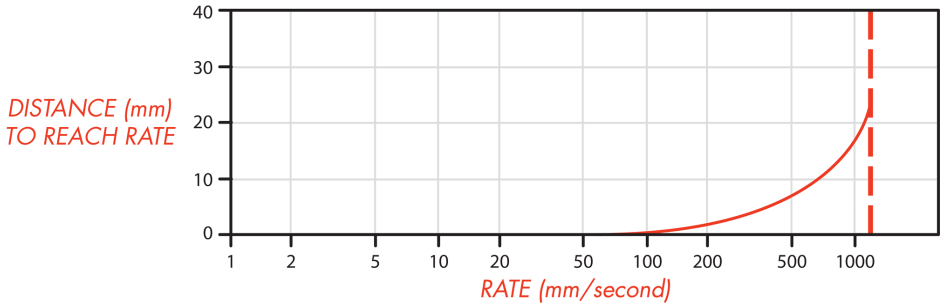


Fig. 7.2: Distance to achieve programmed rate.

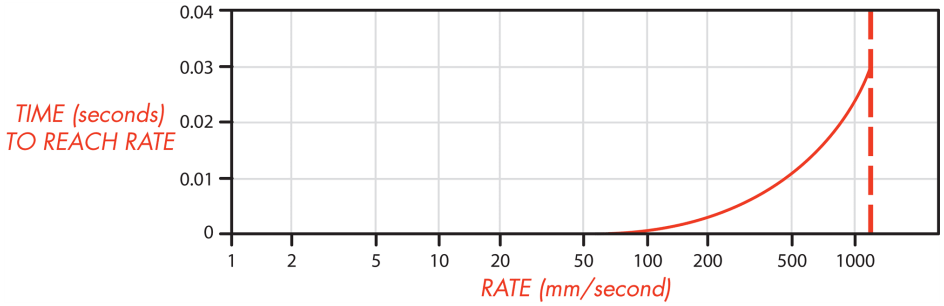


Fig. 7.3: Time to achieve programmed rate.

Load Cell

Characteristic	Specification
Non-linearity	±0.1 % of full scale
Hysteresis	±0.08 % of full scale
Non-Repeatability (Maximum)	±0.03 % of full scale
Overload Rating	150 % of full scale
Deflection - Full Scale	0.076 mm (0.003 in)
Force Measurement Accuracy	±1.0 % of full scale
Force Measurement Resolution	±1 kgf (2.2 lbf)

Note: Accuracy is measured at a temperature of 23°C (73°F). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30°C (86°F).

Stroke Transducer

Characteristic	Specification
Type	LVDT
Linear Range	±50 mm (±2.0 in)
Linearity	±0.25 % of full scale
Stroke Measurement Accuracy	±0.5 % of full scale
Stroke Measurement Resolution	0.002 mm (0.0787402 in)

Note: Accuracy is measured at a temperature of 23°C (73°F). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30°C (86°F).

7.2 Thermal Subsystems

The Gleeble 3180 offers a high-speed direct resistance thermal system for heating specimens.

Direct resistance heating provides the ability to reproduce the wide variety of thermal profiles that materials undergo in actual processes. This is critical to the success of thermal-mechanical testing and physical simulation. All Gleeble systems have high-speed heating and cooling rates that can accurately replicate nearly any thermal profile required.

Characteristic	Specification
Heating System Type and Control	Direct resistance with closed-loop control
Temperature Controller	Digital closed-loop control using 18-bit ADC and 32-bit digital processor
Temperature Range	Room Temperature to 1,700℃ (3,092℉)
Response Rate	8,000℃/s (14,400℉/s)
Temperature Monitoring Source	Thermocouple
Thermocouple Sampling Rate	Twice the Power Supply Frequency (100 - 120 Hz)
Resolution	±1℃ or℉
Maximum Number of Simultaneous Thermal Channels	4 thermocouple channels, or 2 thermocouple channels and 1 pyrometer channel
Accuracy of Control	±1℃ (in steady state)
Accuracy of Measurement	±2℃ or ±1% of temperature (whichever is greater) plus the accuracy of the thermocouple wire (in steady state)

Note: As the specimen size, diameter, length, or cross-sectional area increases the effective heating rate will decrease.

7.2.1 Thermocouple Wire Types

Gleeble systems are capable of recording specimen temperature with various thermocouple wire types. The following types of thermocouple wire can be used on any Gleeble system.

Part Number	TC Type	Material	Sold As
Operating Range: 0 - 1,450°C (32 - 2,642°F)			
TC005	R- or S-	Pt 100%	Inch
TC006	R+	Pt 87% - Rh 13%	Inch
TC009	S+	Pt 90% - Rh 10%	Inch
Operating Range: -200 - 1,250°C (-328 - 2,282°F)			
TC014	K-	Alumel	Spool
TC015	K+	Chromel	Spool
Operating Range: 0 - 1,700°C (32 - 3,092°F)			
TC017	B-	Pt 94% - Rh 6%	Inch
TC018	B+	Pt 70% - Rh 30%	Inch
Operating Range: 0 - 750°C (32 - 1,382°F)			
TC030	J+	Fe 100%	Spool
TC031	J-	Constantan	Spool
Operating Range: -200 - 900°C (-328 - 1,652°F)			
TC032A	E+	Chromega	Spool
TC033	E-	Constantan	Spool
Operating Range: 0 - 2,320°C (32 - 4,208°F)			
TC010	C+	W 95% - Re 5%	Inch
	C-	W 74% - Re 26%	

Note: TC wire types C, K, J, and E have a nominal wire diameter of 0.254 mm (0.01 in). TC wire types R, S, and B have a nominal wire diameter of 0.2032 mm (0.008 in).

Note: Gleeble systems can support additional thermocouple wire types not shown. *Contact Dynamic Systems* (page 373) for additional information regarding the use of alternate thermocouple wire types.

7.2.2 Heating Rates

Heating rates are based on using a 480 V / 150 A power supply, full contact copper grips and, plain carbon steel specimens. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

Specimen	Free Span	Drawing Number	Maximum Heating Rate
			°C/s (°F/s)
6 mm dia x 71 mm long	10 mm	SMR002B	8,000 (14,400)
10 mm dia x 71 mm long	10 mm	SMR009B	1,000 (1,800)
10 mm dia x 15 mm long *With non ISO-T Anvils* (page 218)		SMC203B	50 (90)
10 mm dia x 15 mm long *With ISO-T Anvils* (page 216)			5 (9)

7.2.3 Cooling Rates

Free Cooling Rates

The Gleeble system is able to control the specimen cooling rate based on conductive heat transfer. The efficiency and maximum rate of conductive cooling is directly impacted by grip and specimen geometry, material, cleanliness, and system's chilled process fluid flow rate.

The controlled cooling rates are achieved using full contact copper grips on 1018 carbon steel specimens. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

Specimen	Free Span	Drawing Number	Temperature Range	Cooling Rate
			℃ (℉)	℃/s (℉/s)
6 mm dia x 71 mm long	10 mm	SMR002B	950-800 (1,742-1,472)	130 (234)
			800-500 (1,472-932)	68 (122.4)

Quench Cooling Rates

Optional quench systems are available which can use compressed air or inert gas to cool the specimen at high rates. A mixture of compressed air and water can also be used in the quench systems for even higher cooling rates.

Specimen	Free Span	Drawing Number	Temperature Range	Rate
			℃ (℉)	℃/s (℉/s)
1 mm thick x 10 mm wide x 100 mm long	25 mm	SMF002B	1,000 - 600 (1,832 - 1,112)	10,000 (18,000)
6 mm dia x 86 mm long	25 mm	SMR005B	1,000 - 600 (1,832 - 1,112)	2,000 (3,600)

Note: The cooling rates are achieved using full contact copper grips on 1018 carbon steel specimens quenched with water. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

7.2.4 Temperature Uniformity Within the Specimen

The Gleeble system has the unique ability to control the temperature uniformity and thus the thermal gradient within the test specimen. Tests can be performed with very uniform temperature within the specimen work zone, equivalent to a furnace-based test, or with the large thermal gradients needed to accurately simulate welding and other processes.

When using Joule heating, the current density in a Gleeble specimen is uniformly distributed across the entire specimen cross-sectional area, meaning that the Gleeble is able to heat the entire specimen simultaneously, from surface to center. Since the Gleeble grips are cool, the heat generated in the specimen will diffuse into the grips, creating a thermal gradient with the ends of the specimen generally being cooler than the center. The severity of the steady state thermal gradient is defined by the rate of heat generated in the specimen, offset by the heat lost to the grips. This gradient can be controlled by utilizing grips of materials with differing thermal and electrical conductivity and contact area. Thermally and electrically conductive grips with a large specimen contact area will be kept cold more readily with the water-cooled jaws, and will accept significant heat from the specimen, resulting in “cold ends” and a very steep thermal gradient.

Grips with smaller contact area and higher thermal resistance will pull much less heat from the specimen. Grips manufactured from material with higher electrical resistance will, themselves, heat under the same current that is heating the specimen. These factors will result in very little heat being pulled from the specimen and a very flat thermal gradient. In some cases the grips or anvils holding the specimen may reach temperatures equal to or higher than the specimen, creating a “reverse” thermal gradient.

When considering Gleeble thermal gradients, it is also critical to differentiate between the axial thermal gradient (along the length of the specimen), and the transverse thermal gradient (across the diameter or cross section of the specimen). Even in situations where a specimen experiences a very high axial thermal gradient, the transverse, or crosswise thermal gradient will be very small. This ability to generate isothermal planes is a critical benefit of the Gleeble. In contrast to furnace or induction heating methods, where the specimen can only be heated on the surface or to a limited “skin depth”, the center of a Gleeble specimen is heated at the same rate as the surface regardless of the heating rate. This ability to generate isothermal planes allows for the Gleeble platform to perform dilatometry and welding heat affected zone experiments at heating and cooling rates relevant to welding and other processes on specimens that are large enough for subsequent mechanical property or toughness testing. This is not feasible on furnace or inductively-heated systems that rely on thermal conduction to heat the center of the specimen. Axial thermal uniformity within a specimen is reported as the difference between the specimen’s center to edge thermal measurements and is dependent upon:

- Material
- Thermal Resistivity
- Electrical Resistivity
- Grip Contact Surface to Specimen Volume Ratio
- Specimen Length
- Specimen Cross Section
- Free Span
- Grip Selection
- Heating Rate
- Isothermal Holding Time
- Interface Resistance

The following data was obtained using Stainless Steel partial contact grips on 1018 carbon steel specimens. Measurements are taken at steady state temperatures. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

Specimen	Free Span	Drawing Number	Temperature Uniformity
Lengthwise Thermal Gradient			
10 mm dia x 111 mm long	50 mm	SMR023B	±0.5% of T_{avg} for 7 mm of midspan
Crosswise Thermal Gradient			
10 mm dia x 86 mm long	25 mm	SMR012B	±0.5% of T_{avg}

Note: T_{avg} is the average of the specimen cross section temperature at 1,000°C (1,832°F).

Reproducibility

Thermal gradients in resistance-heated specimens are dependent upon on the properties of the specimen. All specimens with the same physical, mechanical, electrical, and chemical properties will have the same gradients within the accuracy of the thermal system, provided that the specimen grips are in good condition.

7.3 Specimen Size Considerations

Gleeble systems are capable of testing a wide variety of material compositions and specimen geometries. Inherent limitations of the system, such as distance between the jaw or anvil faces, the maximum or minimum stroke speed, test temperature, and force limitations for the individual system must be considered when selecting a specific *specimen geometry* (page 378).

The target temperature of a test will also impact the size of a specimen that can safely be tested with a Gleeble system. For example, when considering a standard uniaxial compression specimen, it is possible for a soft material such as aluminum or copper to be tested at ambient temperature. Harder materials, such as steel or titanium alloys, are expected to be tested at elevated temperatures.

The Gleeble 3180's vacuum tank configuration limits the maximum and minimum specimen geometry that can be tested. A specimen with a maximum of 95 mm free span can be tested in the Gleeble 3180. The minimum free span for the system is 10 mm.

Specimen geometry will vary with any specific test. DSI has identified recommended specimen geometries for commonly performed simulation tests. Please contact *Contact Dynamic Systems* (page 373) for assistance identifying a recommended specimen geometry as needed.

Note: To test highly conductive specimens, the system must have adequate water cooling flow per the Site Requirements document. The use of hot grips is recommended for highly conductive specimens. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

7.4 Additional Features

Vacuum Tank

One of the distinguishing features of a Gleeble system is the ability to test materials in a controlled atmosphere. Researchers can simulate processes and test specimens in standard atmosphere, in rough vacuum, in high vacuum or in an inert gas environment. This environmental control is possible due to the large vacuum tank, also referred to as a "test chamber," that is incorporated into every Gleeble. The vacuum tank is fully integrated into the Gleeble system and can be controlled with manual controls or through software controls. A popular approach to atmosphere control in the Gleeble includes "washing cycles" which involve pumping down to a rough vacuum in the tank and then backfilling with an inert gas. This can be conducted multiple times to ensure that the desired atmosphere is achieved.

Most Gleeble vacuum tanks include viewing ports, typically incorporated into the tank doors to allow visual observation of simulations. In some cases, viewing windows are removed or covered to protect users from the light intensity of specimens at elevated temperatures. Depending on the Gleeble model, vacuum tanks may include one or two doors with viewing windows as well as additional ports for measurement devices or equipment feedthroughs.

Feedthroughs are an important feature in the Gleeble vacuum tanks. They allow researchers to install equipment that can measure or interact with the specimen during a test while still controlling the atmosphere. For example, vacuum-sealed electrical feedthroughs allow communication with transducers such as thermocouples, load cells, and strain transducers. Piping feedthroughs enable atmosphere control (e.g. inert gas backfill and vacuum supply) as well as allowing quenching media to be utilized.

Warning: The Gleeble vacuum tank is designed to operate under vacuum or atmospheric pressure, with either air or an inert gas surrounding the specimen. Positive atmospheric pressure, explosive, flammable or corrosive gases, or any mixtures of these gases, should never be used as part of the vacuum tank atmosphere.

Hydraulic Power Unit

The Gleeble 3180 system is equipped with an integrated hydraulic power unit (HPU). The HPU is the primary source of mechanical motion for these Gleeble systems. The HPU is capable of regulating the output pressure of the hydraulic fluid, based on Gleeble system configuration. Typical configurations of the Gleeble allow the user to choose between a high and low output pressure. These pressures can be manually selected with a button on the HMI or through the programming of a Gleeble test. Special configurations of the Gleeble will limit the pressures available for testing. When a low-force load cell is installed, the Gleeble will automatically limit the HPU output to a low pressure. Users will not be able to select a higher hydraulic pressure.

Hydraulic Power Unit Consumables

Reference *Hydraulic Oil* (page 360) for common service parts.

The Gleeble HPU uses one branch of the process fluid chiller for automatic computer control of the hydraulic oil temperature. By automatically regulating the temperature of the hydraulic oil, the Gleeble is capable of maintaining peak performance in a variety of ambient temperature environments. The HPU is protected by a high oil temperature sensor, a high oil level, and a low oil level sensors.

The HPU is enclosed in a self contained cabinet. The cabinet reduces the sound level to approximately 62 dBA with the doors closed. The pump must be located as indicated on the Site Preparation floor plan.

Characteristic		Specification
Pump Motor		10 hp
Variable Pressure Output	Low Pressure	68.94 bar (1000 psi)
	High Pressure	206.84 bar (3000 psi)
Hydraulic Oil Reservoir		113 L (30 gal)

7.5 Gleeble Physical Dimensions

Equipment	Height	Depth	Width	Weight
Control Console	180 cm (71 in)	66 cm (26 in)	61 cm (24 in)	195 kg (430 lb)
3180 Load Unit	162 cm (64 in)	86 cm (34 in)	196 cm (77 in)	1,361 kg (3,000 lb)
Hydraulic Power Unit with Oil	165 cm (65 in)	79 cm (31 in)	94 cm (37 in)	907 kg (2,000 lb)

Section 8

Gleeble 563

Contents

- *Advanced Gleeble Control* (page 106)
- *Hydro-Mechanical* (page 106)
- *Thermal Subsystem* (page 111)
  - *Thermocouple Measurement Assemblies* (page 111)
    - *Thermocouple Wire Types* (page 112)
  - *Heating Rates* (page 112)
  - *Cooling Rates* (page 113)
  - *Temperature Uniformity Within the Specimen* (page 114)
- *Specimen Size Considerations* (page 116)
- *Additional Features* (page 118)
- *Gleeble Physical Dimensions* (page 119)
  - *Frame and Machine Stiffness* (page 119)



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Fig. 8.1: Gleeble 563.

The Gleeble 563 is the preeminent next-generation Gleeble thermal-mechanical simulation system. To keep pace with an ever evolving and developing set of demands and requirements, Dynamic Systems is proud to offer the Gleeble 563. Built on the new Gleeble 500 Series platform, the Gleeble 563 provides the world-class Gleeble performance in a smaller package. The 500 Series of Gleeble systems are tailored to provide a compact, economical solution for researchers while retaining the industry standard capabilities researchers have come to expect.

Material Testing Capabilities of the Gleeble 563

- Hot Ductility and Hot Tensile Testing on a wide variety of specimen geometries
- Strain Induced Crack Opening (SICO) Studies
- Stress vs. Strain Curves Creation
- Melting and Solidification Simulations
- Nil-Strength Testing
- Thermal Cycling/Heat Treatment Simulations
- Weld HAZ Simulations
- Charpy Specimen Heat Treatment Studies
- Study of Local Brittle Zones
- Embrittlement and Crack Susceptibility Studies
- Liquid Metal Embrittlement Studies
- Welding/HAZ Phase Transformation Studies
- Creep/Stress Rupture Simulations
- Low Cycle Thermal-Mechanical Fatigue Simulations
- Hot Compression Testing, including Uniaxial and Plane Strain Studies
- Stress Relaxation Simulations
- Phase Transformations Studies, including CCT/TTT curve development with and without deformation

The low cost and small footprint of the Gleeble 563 allow it to be placed in laboratories or production environments where larger simulators cannot be installed. The space-saving platform also reduces the weight of the entire system, reducing laboratory facility structural requirements.

The Gleeble 563 features a touchscreen-based control system, making the setup and running of tests much faster and easier than traditional control systems. Installation and training are simple processes, allowing new users to begin producing actionable data faster than ever before.

Part Number	Description	Sold As
563	Gleeble 563 Physical Simulation System	System

[22] https://gleeble.com/products/gleeble-systems/gleeble-563-tms-system.html

8.1 Advanced Gleeble Control

Gleeble 500 Series systems are equipped with advanced Gleeble control systems similar to the *Gleeble Touch Control* (page 9) of the 3000 Series systems. The control system of a Gleeble 500 Series system includes an intuitive user display with a large and easy-to-use touchscreen. Advanced software and hardware provide state-of-the-art performance with accuracy and dependability at the heart of the design.

8.2 Hydro-Mechanical

Every Gleeble system derives its power from a servo-controlled hydraulic system. The capabilities of the hydro-mechanical system will vary based on Gleeble options.

Characteristic	Specification
Test Frame	Horizontal aluminum framework and structural vacuum tank
Mechanical System	Closed-loop hydraulic servo control
Maximum Force in Compression	30 kN (3,059 kgf, 6,744 lbf)
Maximum Force in Tension	30 kN (3,059 kgf, 6,744 lbf)
Maximum Stroke Rate	200 mm/s (7.87 in/s)
Minimum Stroke Rate	0.01 mm/s (3.94 x 10^{-4} in/s)
Maximum Stroke Distance	100 mm (3.94 in)

Note: The total number of compression hits possible is dependent upon many test characteristics. These include the number of deformations, the initial position of the hydraulic stroke, and time between deformations.

Note: Accuracy is measured at a temperature of 23°C (73°F). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) $\pm$3 % and an oil temperature of 30°C (86°F).

Maximum Dynamic Force

The maximum dynamic force for the Gleeble 563 is based on the following graph. For a given stroke speed the hydraulic system will provide a corresponding force. All performance figures for the system are based on operating in the region below the Force vs. Stroke curve. System specifications are not valid for tests conducted outside this operating range.

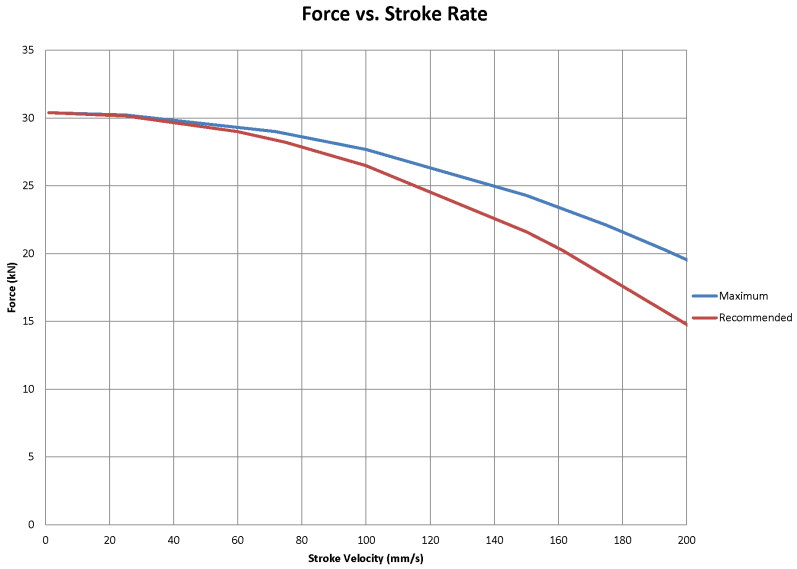


Fig. 8.2: Force vs. Stroke Velocity.

Hydraulic Servo Response

The Gleeble 563's servo systems provide the capability to vary the rate of load application in both tension and compression testing. To achieve the system's rated performance, certain limitations must be observed. For all types of operation, the Stroke rate and Force must be within the operating range as described in the maximum Force vs. Stroke graph.

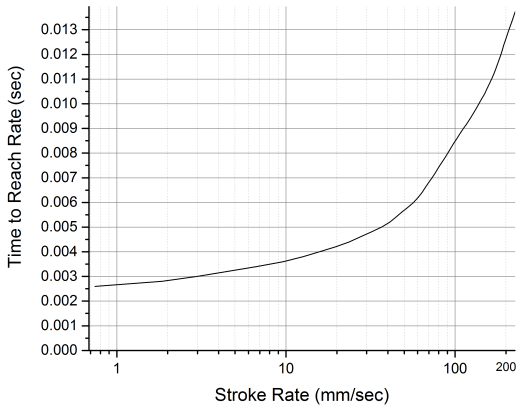


Fig. 8.3: Time to reach programmed rate.

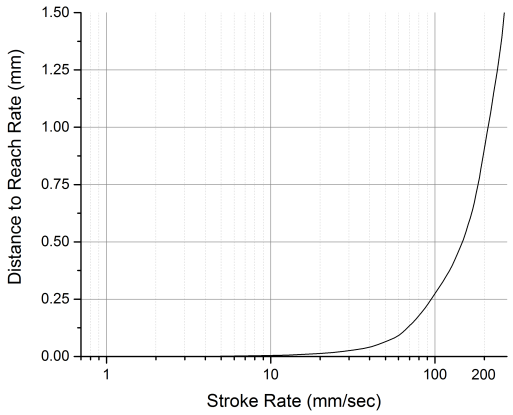


Fig. 8.4: Distance required to reach programmed rate.

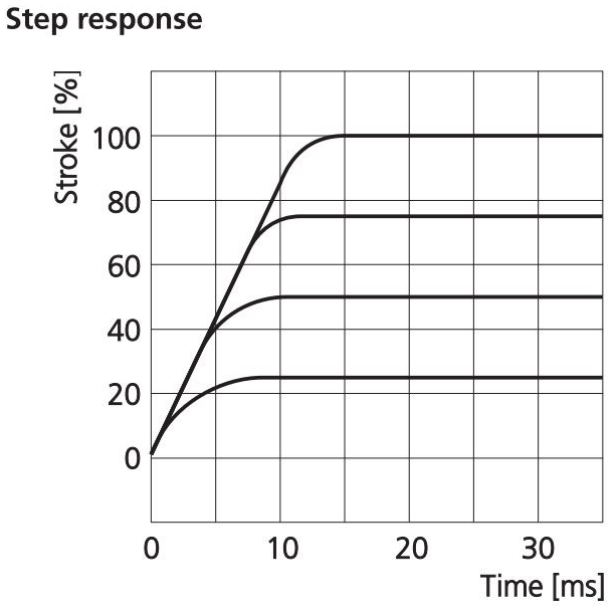


Fig. 8.5: For constant strain rate programs, the duration of the deformation for each hit must be three times the rated response time of the hydraulic servo valve.

Load Cell

The 59002 Load Cell is mounted directly to the stationary jaw. It is used to measure the force exerted on the specimen by the hydraulic system.

Characteristic	Specification
Non-linearity	±0.1 % of full scale
Hysteresis	±0.08 % of full scale
Non-Repeatability (Maximum)	±0.03 % of full scale
Overload Rating	150 % of capacity
Deflection - Full Scale	0.076 mm (0.003 in)
Force Measurement Accuracy	±1.0 % of full scale
Force Measurement Resolution	±0.1 kgf (0.22 lbf)

Note: Accuracy is measured at a temperature of 23°C (73°F). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30°C (86°F).

Stroke Transducer

The 59001 Stroke Transducer is mounted directly to the hydraulic system piston. It is used as the main control transducer for movement of the Pocket Jaws.

Characteristic	Specification
Type	LVDT
Linear Range	±50.8 mm (2 in)
Non-Linearity	±0.25% of full scale
Stroke Measurement Accuracy	0.5 % of full scale
Stroke Measurement Resolution	0.0075 mm (2.95×10^{-4} in)

Note: Accuracy is measured at a temperature of 23°C (73°F). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30°C (86°F).

8.3 Thermal Subsystem

The Gleeble 563 offers a high-speed direct resistance thermal system for heating specimens.

Direct resistance heating provides the ability to reproduce the wide variety of thermal profiles that materials undergo in actual processes. This is critical to the success of thermal-mechanical testing and physical simulation. All Gleeble systems have high-speed heating and cooling rates that can accurately replicate nearly any thermal profile required.

Characteristic	Specification
Heating System Type and Control	Direct resistance with closed-loop control
Temperature Controller	Digital closed-loop control using an 18-bit ADC and a 32-bit digital processor.
Temperature Range	Room temperature to 1,700°C (3,092°F)
Response Rate	10,000°C/s (18,000°F/s)
Temperature Monitoring Source	Thermocouple or Optional *Pyrometer Control Cameras* (page 274)
Thermocouple Sampling Rate	Twice the power line frequency (100 - 120 Hz)
Resolution	±1°C or°F
Maximum Number of Simultaneous Thermal Channels	8 thermocouple channels
Accuracy of Control	±1°C (in steady state)
Accuracy of Measurement	±1 % of temperature plus the accuracy of the thermocouple wire (in steady state)

Note: As the specimen size, diameter, length, or cross-sectional area increases, the effective heating rate will decrease.

8.3.1 Thermocouple Measurement Assemblies

The Dual Channel Thermocouple Input series of modules is designed to add thermocouple input channels to Gleeble 500 Series systems and the HDS-V40. Each module may be connected to any available Gleeble PnP port, providing two thermocouple input channels of a given type.

Part Number	Thermocouple Type	Description
59004	K	Dual Channel Input Box
59005	S	Dual Channel Input Box
59006	R	Dual Channel Input Box
59007	B	Dual Channel Input Box
59008	E	Dual Channel Input Box
59014	J	Dual Channel Input Box

Note: A single K-type Dual Channel Input Box is included standard if required.

Thermocouple Wire Types

Gleeble systems are capable of recording specimen temperature with various thermocouple wire types. The following types of thermocouple wire can be used on any Gleeble system.

Part Number	TC Type	Material	Sold As
Operating Range: 0 - 1,450°C (32 - 2,642°F)			
TC005	R- or S-	Pt 100%	Inch
TC006	R+	Pt 87% - Rh 13%	Inch
TC009	S+	Pt 90% - Rh 10%	Inch
Operating Range: -200 - 1,250°C (-328 - 2,282°F)			
TC014	K-	Alumel	Spool
TC015	K+	Chromel	Spool
Operating Range: 0 - 1,700°C (32 - 3,092°F)			
TC017	B-	Pt 94% - Rh 6%	Inch
TC018	B+	Pt 70% - Rh 30%	Inch
Operating Range: 0 - 750°C (32 - 1,382°F)			
TC030	J+	Fe 100%	Spool
TC031	J-	Constantan	Spool
Operating Range: -200 - 900°C (-328 - 1,652°F)			
TC032A	E+	Chromega	Spool
TC033	E-	Constantan	Spool
Operating Range: 0 - 2,320°C (32 - 4,208°F)			
TC010	C+	W 95% - Re 5%	Inch
	C-	W 74% - Re 26%	

Note: TC wire types C, K, J, and E have a nominal wire diameter of 0.254 mm (0.01 in). TC wire types R, S, and B have a nominal wire diameter of 0.2032 mm (0.008 in).

Note: Gleeble systems can support additional thermocouple wire types not shown. *Contact Dynamic Systems* (page 373) for additional information regarding the use of alternate thermocouple wire types.

Note: Each thermocouple wire type requires a corresponding Dual Channel Thermocouple Input Module for temperature measurement in Gleeble 500 Series systems or the HDS-V40.

8.3.2 Heating Rates

Heating rates are based on using a 480 V / 100 A power supply and full contact copper grips and plain carbon steel specimens. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

Specimen	Free Span	Drawing Number	Maximum Heating Rate
			°C/s (°F/s)
6 mm dia x 58.26 mm long	10 mm	SFR002B	10,000 (18,000)
10 mm dia x 15 mm long (using ISO-T anvils)		SMC203B	5 (9)
10 mm x 15 mm x 20 mm		SMC001B	5 (9)

8.3.3 Cooling Rates

Free Cooling Rates

The Gleeble system is able to control the specimen cooling rate based on conductive heat transfer. The efficiency and maximum rate of conductive cooling is directly impacted by grip and specimen geometry, material, cleanliness, and system's chilled process fluid flow rate.

The free cooling rates are achieved using full contact copper grips on 1018 carbon steel specimens. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

Specimen Type	Free Span	Drawing Number	Temperature Range	Cooling Rate
			℃ (℉)	℃/s (℉/s)
6 mm dia x 58.26 mm long	10 mm	SFR002B	950 - 800 (1,742 - 1,472)	140 (252)
			800 - 500 (1,472 - 932)	78 (140.4)

Quench Cooling Rates

The listed cooling rates were achieved using full contact copper grips on 1018 carbon steel specimens. Specimens were water quenched using a 59013 *Quench Tanks* (page 283) system and 59024 *Standard Quench Nozzle* (page 293) kit. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

Specimen Type	Free Span	Drawing Number	Temperature Range	Cooling Rate
			℃ (℉)	℃/s (℉/s)
6 mm dia x 73.26 mm long	25 mm	SFR006B	1000 - 800 (1,832 - 1,472)	6,000 (10,800)
			800 - 500 (1,472 - 932)	10,000 (18,000)
10 mm dia x 73.26 mm long	25 mm	SFR054B	1000 - 800 (1,832 - 1,472)	6,000 (10,800)
			800 - 500 (1,472 - 932)	5,000 (9,000)
11 mm square x 73.26 mm long	25 mm	SFS024B	1000 - 800 (1,832 - 1,472)	6,000 (10,800)
			800 - 500 (1,472 - 932)	3,300 (5,940)

ISO-Q Quench System

The listed cooling rates were achieved using full contact copper grips on 1018 carbon steel specimens quenched internally with compressed air. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

Specimen Type	Free Span	Drawing Number	Temperature Range	Cooling Rate
			℃ (℉)	℃/s (℉/s)
10 mm dia x 71.37 mm long	10 mm reduced to 6 mm dia x 6 mm long	SFR203B	950 - 800 (1,742 - 1,472)	250 (450)
			800 - 500 (1,472 - 932)	375 (675)
10 mm dia x 71.37 mm long	10 mm reduced to 5 mm dia x 5 mm long	SFR202B	950 - 800 (1,742 - 1,472)	375 (675)
			800 - 500 (1,472 - 932)	375 (675)
10 mm dia x 71.37 mm long	Hollow center - 3 mm dia through hole	SFR202B Modified	800 - 500 (1,472 - 932)	1,500 (2,700)

Note: The cooling rate of 1,500℃/s (2,700℉/s) using a modified SFR202B specimen is achieved using water. The supply and return hoses of the ISO-Q kit must be positioned on the same side of the specimen to enable smooth flow of the quench water through the specimen.

8.3.4 Temperature Uniformity Within the Specimen

The Gleeble system has the unique ability to control the temperature uniformity and thus the thermal gradient within the test specimen. Tests can be performed with very uniform temperature within the specimen work zone, equivalent to a furnace-based test, or with the large thermal gradients needed to accurately simulate welding and other processes.

When using Joule heating, the current density in a Gleeble specimen is uniformly distributed across the entire specimen cross-sectional area, meaning that the Gleeble is able to heat the entire specimen simultaneously, from surface to center. Since the Gleeble grips are cool, the heat generated in the specimen will diffuse into the grips, creating a thermal gradient with the ends of the specimen generally being cooler than the center. The severity of the steady state thermal gradient is defined by the rate of heat generated in the specimen, offset by the heat lost to the grips. This gradient can be controlled by utilizing grips of materials with differing thermal and electrical conductivity and contact area. Thermally and electrically conductive grips with a large specimen contact area will be kept cold more readily with the water-cooled jaws, and will accept significant heat from the specimen, resulting in “cold ends” and a very steep thermal gradient.

Grips with smaller contact area and higher thermal resistance will pull much less heat from the specimen. Grips manufactured from material with higher electrical resistance will, themselves, heat under the same current that is heating the specimen. These factors will result in very little heat being pulled from the specimen and a very flat thermal gradient. In some cases the grips or anvils holding the specimen may reach temperatures equal to or higher than the specimen, creating a “reverse” thermal gradient.

When considering Gleeble thermal gradients, it is also critical to differentiate between the axial thermal gradient (along the length of the specimen), and the transverse thermal gradient (across the diameter or cross section of the specimen). Even in situations where a specimen experiences a very high axial thermal gradient, the transverse, or crosswise thermal gradient will be very small. This ability to generate isothermal

planes is a critical benefit of the Gleeble. In contrast to furnace or induction heating methods, where the specimen can only be heated on the surface or to a limited “skin depth”, the center of a Gleeble specimen is heated at the same rate as the surface regardless of the heating rate. This ability to generate isothermal planes allows for the Gleeble platform to perform dilatometry and welding heat affected zone experiments at heating and cooling rates relevant to welding and other processes on specimens that are large enough for subsequent mechanical property or toughness testing. This is not feasible on furnace or inductively-heated systems that rely on thermal conduction to heat the center of the specimen. Axial thermal uniformity within a specimen is reported as the difference between the specimen’s center to edge thermal measurements and is dependent upon:

- Material
- Thermal Resistivity
- Electrical Resistivity
- Grip Contact Surface to Specimen Volume Ratio
- Specimen Length
- Specimen Cross Section
- Free Span
- Grip Selection
- Heating Rate
- Isothermal Holding Time
- Interface Resistance

Reproducibility

Thermal gradients in resistance-heated specimens are dependent upon on the properties of the specimen. All specimens with the same physical, mechanical, electrical, and chemical properties will have the same gradients within the accuracy of the thermal system, provided that the specimen grips are in good condition.

8.4 Specimen Size Considerations

Gleeble systems are capable of testing a wide variety of material compositions and specimen geometries. Inherent limitations of the system, such as distance between the jaw or anvil faces, the maximum or minimum stroke speed, test temperature, and force limitations for the individual system must be considered when selecting a specific *specimen geometry* (page 378).

The target temperature of a test will also impact the size of a specimen that can safely be tested with a Gleeble system. For example, when considering a standard uniaxial compression specimen, it is possible for a soft material such as aluminum or copper to be tested at ambient temperature. Harder materials, such as steel or titanium alloys, are expected to be tested at elevated temperatures.

The Gleeble 500 Series's vacuum tank configuration limits the maximum and minimum specimen geometry that can be tested. The maximum specimen length for a tensile specimen is 95 mm. The minimum specimen size should have a free span no smaller than 8 mm.

Specimen geometry will vary with by test type. DSI has identified recommended specimen geometries for commonly performed simulation tests. *Contact Dynamic Systems* (page 373) for assistance identifying a recommended specimen geometry as needed.

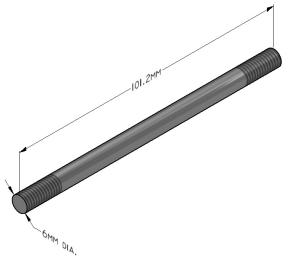


Fig. 8.6: Small-Format Round Specimen - SFR115.

Popular Specimen Sizes			
Specimen Length	**Specimen Width**	**Specimen Thickness**	**Drawing Number**
Specimens			
106.2 mm	10 mm dia	N/A	SFR115
58.26 mm	6 mm dia	N/A	SFR002
101.2 mm	6 mm dia	N/A	SFR106
58.26 mm	11 mm Sq	N/A	SFS002
Flat Specimens			
100 mm	10 mm	1 mm	SMF002

Note: The use of hot grips is recommended for highly conductive specimens. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

Compression Specimens

Popular Specimen Sizes			
Specimen Length	**Specimen Width**	**Specimen Thickness**	**Drawing Number**
Uniaxial Compression			
9 mm	6 mm dia	N/A	SMC206
12 mm	8 mm dia	N/A	SMC200
Plane Strain			
20 mm	15 mm	10 mm	SMC001

8.5 Additional Features

Vacuum Tank

One of the distinguishing features of a Gleeble system is the ability to test materials in a controlled atmosphere. Researchers can simulate processes and test specimens in standard atmosphere, in rough vacuum, in high vacuum or in an inert gas environment. This environmental control is possible due to the large vacuum tank, also referred to as a "test chamber," that is incorporated into every Gleeble. The vacuum tank is fully integrated into the Gleeble system and can be controlled with manual controls or through software controls. A popular approach to atmosphere control in the Gleeble includes "washing cycles" which involve pumping down to a rough vacuum in the tank and then backfilling with an inert gas. This can be conducted multiple times to ensure that the desired atmosphere is achieved.

Gleeble vacuum tanks include a large viewing port incorporated into the tank door to allow visual observation of simulations. In some cases, viewing windows are removed or covered to protect users from the light intensity of specimens at elevated temperatures.

Feedthroughs are an important feature in the Gleeble vacuum tanks. They allow researchers to install equipment that can measure or interact with the specimen during a test while still controlling the atmosphere. For example, vacuum-sealed electrical feedthroughs allow communication with transducers such as thermocouples, load cells, and strain transducers. Piping feedthroughs enable atmosphere control (e.g. inert gas backfill and vacuum supply) as well as allowing quenching media to be utilized.

Warning: The Gleeble vacuum tank is designed to operate under vacuum or atmospheric pressure, with either air or an inert gas surrounding the specimen. Positive atmospheric pressure, explosive, flammable or corrosive gases, or any mixtures of these gases, should never be used as part of the vacuum tank atmosphere.

Hydraulic Power Unit

The Gleeble 500 Series systems are equipped with an integrated hydraulic power unit (HPU). The HPU is the primary source of mechanical motion for these Gleeble systems. The HPU is capable of regulating the output pressure of the hydraulic fluid, based on the Gleeble system configuration. Typical configurations allow the user to choose between a high and low output pressure. These pressures can be manually selected with a button on the HMI or through the programming of a Gleeble test.

Hydraulic Power Unit Consumables

Reference *Hydraulic Oil* (page 360) for common service parts.

The Gleeble HPU is fully integrated into the 500 Series systems. This means that the system uses a single chilled process fluid supply for system temperature regulation and hydraulic oil temperature regulation. By automatically regulating the temperature of the hydraulic oil, the Gleeble is capable of maintaining peak performance in a variety of ambient temperature environments. The HPU is protected by a high oil temperature, high oil level, and low oil level sensors.

Characteristic		Specification
Pump Motor		5 hp
Variable Pressure Output	Low Pressure	68.94 bar (1000 psi)
	High Pressure	206.84 bar (3000 psi)
Hydraulic Oil Reservoir		38 L (10 gal)

8.6 Gleeble Physical Dimensions

The Gleeble 500 Series systems were designed to fit through a standard entryway. With a depth measuring just 87 cm (34 in), with the Lower Console Assembly removed. The system will occupy a space of 3 x 4 m (9.84 x 13.12 ft) for general operation. This does not include the additional space required for options such as a freestanding vacuum system option.

Equipment	Height	Depth	Width	Weight
500 Series System	125 cm (49 in)	97 cm (38 in)	202 cm (80 in)	800 kg (1,800 lb)

8.6.1 Frame and Machine Stiffness

Gleeble 500 Series systems have a frame stiffness of 3.85 x 10^{-8} m/N (6.74 x 10^{-6} lbf).

Section 9

Gleeble 540

Contents

- *Advanced Gleeble Control* (page 122)
- *Hydro-Mechanical* (page 122)
- *Thermal Subsystem* (page 126)
  - *Thermocouple Measurement Assemblies* (page 126)
    - *Thermocouple Wire Types* (page 127)
  - *Heating Rates* (page 128)
  - *Cooling Rates* (page 128)
  - *Temperature Uniformity Within the Specimen* (page 129)
- *Specimen Size Considerations* (page 131)
- *Additional Features* (page 132)
- *Gleeble Physical Dimensions* (page 133)
  - *Frame and Machine Stiffness* (page 133)



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Fig. 9.1: Gleeble 540.

Over 60 years ago, the Gleeble was developed to study weld heat-affected-zone (HAZ). While Gleeble systems have evolved and grown over time, the new Gleeble 540 Welding Simulator continues to focus on applications necessary for welding research. However, the 540 performs much more than just HAZ simulations, adding a wide range of capabilities including studies of ductility, crack susceptibility, nil-strength determination and much more.

The Gleeble 540 Welding Simulator is built on the new Gleeble 500 Series platform. The 500 Series of Gleeble systems are tailored to provide a compact, economical solution for researchers while retaining the world-class capabilities that have made Gleeble systems the industry standard.

Material Testing Capabilities of the Gleeble 540

- Hot Ductility and Hot Tensile Testing on a wide variety of specimen geometries
- Strain Induced Crack Opening (SICO) Studies
- Stress vs. Strain Curves Creation
- Melting and Solidification Simulations
- Nil-Strength Testing
- Thermal Cycling/Heat Treatment Simulations
- Weld HAZ Simulations
- Charpy Specimen Heat Treatment Studies
- Study of Local Brittle Zones
- Embrittlement and Crack Susceptibility Studies
- Liquid Metal Embrittlement Studies
- Welding/HAZ Phase Transformation Studies
- Creep/Stress Rupture Simulations

The low cost and small footprint of the Gleeble 540 allow it to be placed in laboratories or production environments where larger simulators cannot be installed. The space-saving platform also reduces the weight of the entire system, reducing laboratory facility structural requirements.

The Gleeble 540 features a touchscreen based control systems, making setup and running tests much faster and easier than traditional control systems. Installation and training are simple processes so new users can begin producing actionable data faster than ever before.

Part Number	Description	Sold As
540	Gleeble 540 Welding Simulator	System

[23] https://gleeble.com/products/gleeble-systems/welding-simulator.html

9.1 Advanced Gleeble Control

Gleeble 500 Series systems are equipped with advanced Gleeble control systems similar to the *Gleeble Touch Control* (page 9) of the 3000 Series systems. The control system of a Gleeble 500 Series system includes an intuitive user display with a large and easy-to-use touchscreen. Advanced software and hardware provide state-of-the-art performance with accuracy and dependability at the heart of the design.

9.2 Hydro-Mechanical

Every Gleeble system derives its power from a servo-controlled hydraulic system. The capabilities of the hydro-mechanical system will vary based on Gleeble options.

Characteristic	Specification
Test Frame	Horizontal aluminum framework and structural vacuum tank
Mechanical System	Closed-loop hydraulic servo control
Maximum Force in Compression	30 kN (3,059 kgf, 6,744 lbf)
Maximum Force in Tension	30 kN (3,059 kgf, 6,744 lbf)
Maximum Stroke Rate	200 mm/s (7.87 in/s)
Minimum Stroke Rate	0.01 mm/s (3.94 x 10^{-4} in/s)
Maximum Stroke Distance	100 mm (3.94 in)

Note: Accuracy is measured at a temperature of 23℃ (73℉). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30℃ (86℉).

Maximum Dynamic Force

The maximum dynamic force for the Gleeble 540 is based on the following graph. For a given stroke speed the hydraulic system will provide a corresponding force. All performance figures for the system are based on operating in the region below the Force vs. Stroke curve. The specifications are not valid for tests conducted outside this operating range.

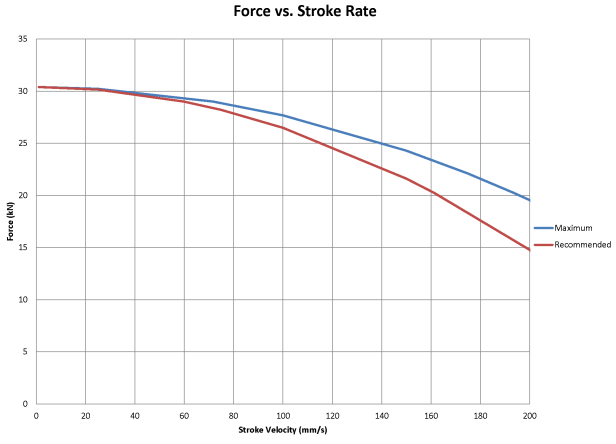


Fig. 9.2: Force vs. Stroke Velocity.

Hydraulic Servo Response

The Gleeble 540's servo systems provide the capability to vary the rate of load application in both tension and compression testing. To achieve the system's rated performance, certain limitations must be observed. For all types of operation, the Stroke rate and Force must be within the operating range as described in the maximum Force vs. Stroke graph.

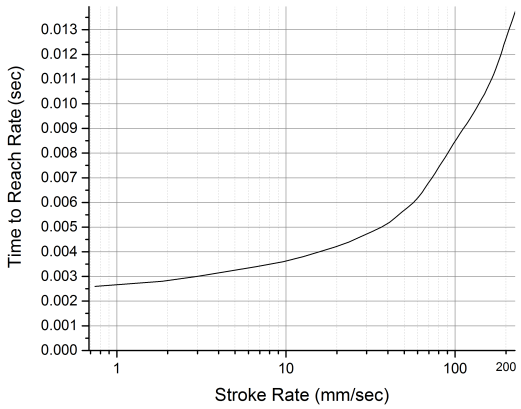


Fig. 9.3: Time to reach programmed rate.

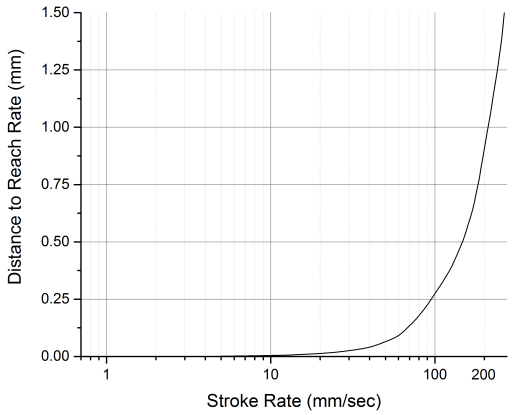


Fig. 9.4: Distance required to reach programmed rate.

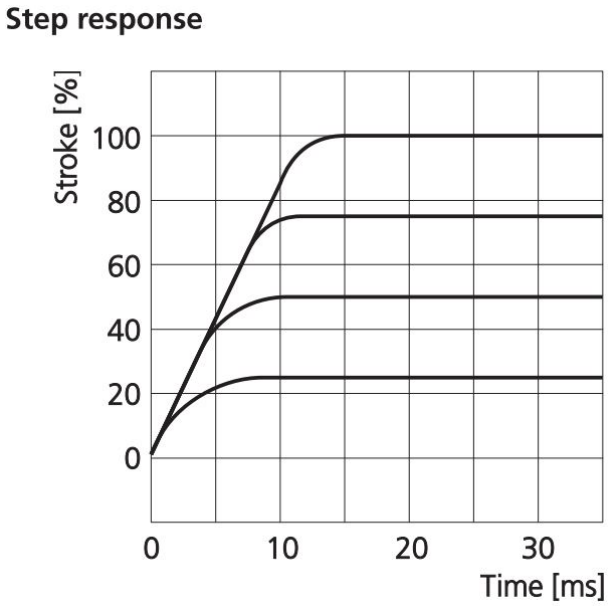


Fig. 9.5: For constant strain rate programs, the duration of the deformation for each hit must be three times the rated response time of the hydraulic servo valve.

Load Cell

The 59002 Load Cell is mounted directly to the stationary jaw. It is used to measure the force exerted on the specimen by the hydraulic system.

Characteristic	Specification
Non-linearity	±0.1 % of full scale
Hysteresis	±0.08 % of full scale
Non-Repeatability (Maximum)	±0.03 % of full scale
Overload Rating	150 % of capacity
Deflection - Full Scale	0.076 mm (0.003 in)
Force Measurement Accuracy	±1.0 % of full scale
Force Measurement Resolution	±0.1 kgf (0.22 lbf)

Note: Accuracy is measured at a temperature of 23°C (73°F). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30°C (86°F).

Stroke Transducer

The 59001 Stroke Transducer is mounted directly to the hydraulic system piston. It is used as the main control transducer for movement of the Pocket Jaws.

Characteristic	Specification
Type	LVDT
Linear Range	±50.8 mm (2 in)
Non-Linearity	±0.25% of full scale
Stroke Measurement Accuracy	0.5 % of full scale
Stroke Measurement Resolution	0.0075 mm (2.95×10^{-4} in)

Note: Accuracy is measured at a temperature of 23°C (73°F). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30°C (86°F).

9.3 Thermal Subsystem

The Gleeble 540 offers a high-speed direct resistance thermal system for heating specimens.

Direct resistance heating provides the ability to reproduce the wide variety of thermal profiles that materials undergo in actual processes. This is critical to the success of thermal-mechanical testing and physical simulation. All Gleeble systems have high-speed heating and cooling rates that can accurately replicate nearly any thermal profile required.

Characteristic	Specification
Heating System Type and Control	Direct resistance with closed-loop control
Temperature Controller	Digital closed-loop control using an 18-bit ADC and a 32-bit digital processor.
Temperature Range	Room temperature to 1,700℃ (3,092℉)
Response Rate	10,000℃/s (18,000℉/s)
Temperature Monitoring Source	Thermocouple or Optional *Pyrometer Control Cameras* (page 274)
Thermocouple Sampling Rate	Twice the power line frequency (100 - 120 Hz)
Resolution	±1℃ or℉
Maximum Number of Simultaneous Thermal Channels	8 thermocouple channels
Accuracy of Control	±1℃ (in steady state)
Accuracy of Measurement	±1 % of temperature plus the accuracy of the thermocouple wire (in steady state)

Note: As the specimen size, diameter, length, or cross-sectional area increases, the effective heating rate will decrease.

9.3.1 Thermocouple Measurement Assemblies

The Dual Channel Thermocouple Input series of modules is designed to add thermocouple input channels to Gleeble 500 Series systems and the HDS-V40. Each module may be connected to any available Gleeble PnP port, providing two thermocouple input channels of a given type.

Part Number	Thermocouple Type	Description
59004	K	Dual Channel Input Box
59005	S	Dual Channel Input Box
59006	R	Dual Channel Input Box
59007	B	Dual Channel Input Box
59008	E	Dual Channel Input Box
59014	J	Dual Channel Input Box

Note: A single K-type Dual Channel Input Box is included standard if required.

Thermocouple Wire Types

Gleeble systems are capable of recording specimen temperature with various thermocouple wire types. The following types of thermocouple wire can be used on any Gleeble system.

Part Number	TC Type	Material	Sold As
Operating Range: 0 - 1,450°C (32 - 2,642°F)			
TC005	R- or S-	Pt 100%	Inch
TC006	R+	Pt 87% - Rh 13%	Inch
TC009	S+	Pt 90% - Rh 10%	Inch
Operating Range: -200 - 1,250°C (-328 - 2,282°F)			
TC014	K-	Alumel	Spool
TC015	K+	Chromel	Spool
Operating Range: 0 - 1,700°C (32 - 3,092°F)			
TC017	B-	Pt 94% - Rh 6%	Inch
TC018	B+	Pt 70% - Rh 30%	Inch
Operating Range: 0 - 750°C (32 - 1,382°F)			
TC030	J+	Fe 100%	Spool
TC031	J-	Constantan	Spool
Operating Range: -200 - 900°C (-328 - 1,652°F)			
TC032A	E+	Chromega	Spool
TC033	E-	Constantan	Spool
Operating Range: 0 - 2,320°C (32 - 4,208°F)			
TC010	C+	W 95% - Re 5%	Inch
	C-	W 74% - Re 26%	

Note: TC wire types C, K, J, and E have a nominal wire diameter of 0.254 mm (0.01 in). TC wire types R, S, and B have a nominal wire diameter of 0.2032 mm (0.008 in).

Note: Gleeble systems can support additional thermocouple wire types not shown. *Contact Dynamic Systems* (page 373) for additional information regarding the use of alternate thermocouple wire types.

Note: Each thermocouple wire type requires a corresponding Dual Channel Thermocouple Input Module for temperature measurement in Gleeble 500 Series systems or the HDS-V40.

9.3.2 Heating Rates

Heating rates are based on using a 480 V / 100 A power supply and full contact copper grips and plain carbon steel specimens. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

Specimen	Free Span	Drawing Number	Maximum Heating Rate
			℃/s (℉/s)
6 mm dia x 58.26 mm long	10 mm	SFR002B	10,000 (18,000)

9.3.3 Cooling Rates

Free Cooling Rates

The Gleeble system is able to control the specimen cooling rate based on conductive heat transfer. The efficiency and maximum rate of conductive cooling is directly impacted by grip and specimen geometry, material, cleanliness, and system's chilled process fluid flow rate.

The free cooling rates are achieved using full contact copper grips on 1018 carbon steel specimens. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

Specimen Type	Free Span	Drawing Number	Temperature Range	Cooling Rate
			℃ (℉)	℃/s (℉/s)
6 mm dia x 58.26 mm long	10 mm	SFR002B	950 - 800 (1,742 - 1,472)	140 (252)
			800 - 500 (1,472 - 932)	78 (140.4)

Quench Cooling Rates

The listed cooling rates were achieved using full contact copper grips on 1018 carbon steel specimens. Specimens were water quenched using a 59013 *Quench Tanks* (page 283) system and 59024 *Standard Quench Nozzle* (page 293) kit. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

Specimen Type	Free Span	Drawing Number	Temperature Range	Cooling Rate
			℃ (℉)	℃/s (℉/s)
6 mm dia x 73.26 mm long	25 mm	SFR006B	1000 - 800 (1,832 - 1,472)	6,000 (10,800)
			800 - 500 (1,472 - 932)	10,000 (18,000)
10 mm dia x 73.26 mm long	25 mm	SFR054B	1000 - 800 (1,832 - 1,472)	6,000 (10,800)
			800 - 500 (1,472 - 932)	5,000 (9,000)
11 mm square x 73.26 mm long	25 mm	SFS024B	1000 - 800 (1,832 - 1,472)	6,000 (10,800)
			800 - 500 (1,472 - 932)	3,300 (5,940)

ISO-Q Quench System

The listed cooling rates were achieved using full contact copper grips on 1018 carbon steel specimens quenched internally with compressed air. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

Specimen Type	Free Span	Drawing Number	Temperature Range	Cooling Rate
			℃ (℉)	℃/s (℉/s)
10 mm dia x 71.37 mm long	10 mm reduced to 6 mm dia x 6 mm long	SFR203B	950 - 800 (1,742 - 1,472)	250 (450)
			800 - 500 (1,472 - 932)	375 (675)
10 mm dia x 71.37 mm long	10 mm reduced to 5 mm dia x 5 mm long	SFR202B	950 - 800 (1,742 - 1,472)	375 (675)
			800 - 500 (1,472 - 932)	375 (675)
10 mm dia x 71.37 mm long	Hollow center - 3 mm dia through hole	SFR202B Modified	800 - 500 (1,472 - 932)	1,500 (2,700)

Note: The cooling rate of 1,500℃/s (2,700℉/s) using a modified SFR202B specimen is achieved using water. The supply and return hoses of the ISO-Q kit must be positioned on the same side of the specimen to enable smooth flow of the quench water through the specimen.

9.3.4 Temperature Uniformity Within the Specimen

The Gleeble system has the unique ability to control the temperature uniformity and thus the thermal gradient within the test specimen. Tests can be performed with very uniform temperature within the specimen work zone, equivalent to a furnace-based test, or with the large thermal gradients needed to accurately simulate welding and other processes.

When using Joule heating, the current density in a Gleeble specimen is uniformly distributed across the entire specimen cross-sectional area, meaning that the Gleeble is able to heat the entire specimen simultaneously, from surface to center. Since the Gleeble grips are cool, the heat generated in the specimen will diffuse into the grips, creating a thermal gradient with the ends of the specimen generally being cooler than the center. The severity of the steady state thermal gradient is defined by the rate of heat generated in the specimen, offset by the heat lost to the grips. This gradient can be controlled by utilizing grips of materials with differing thermal and electrical conductivity and contact area. Thermally and electrically conductive grips with a large specimen contact area will be kept cold more readily with the water-cooled jaws, and will accept significant heat from the specimen, resulting in “cold ends” and a very steep thermal gradient.

Grips with smaller contact area and higher thermal resistance will pull much less heat from the specimen. Grips manufactured from material with higher electrical resistance will, themselves, heat under the same current that is heating the specimen. These factors will result in very little heat being pulled from the specimen and a very flat thermal gradient. In some cases the grips or anvils holding the specimen may reach temperatures equal to or higher than the specimen, creating a “reverse” thermal gradient.

When considering Gleeble thermal gradients, it is also critical to differentiate between the axial thermal gradient (along the length of the specimen), and the transverse thermal gradient (across the diameter or cross section of the specimen). Even in situations where a specimen experiences a very high axial thermal gradient, the transverse, or crosswise thermal gradient will be very small. This ability to generate isothermal

planes is a critical benefit of the Gleeble. In contrast to furnace or induction heating methods, where the specimen can only be heated on the surface or to a limited “skin depth”, the center of a Gleeble specimen is heated at the same rate as the surface regardless of the heating rate. This ability to generate isothermal planes allows for the Gleeble platform to perform dilatometry and welding heat affected zone experiments at heating and cooling rates relevant to welding and other processes on specimens that are large enough for subsequent mechanical property or toughness testing. This is not feasible on furnace or inductively-heated systems that rely on thermal conduction to heat the center of the specimen. Axial thermal uniformity within a specimen is reported as the difference between the specimen’s center to edge thermal measurements and is dependent upon:

- Material
- Thermal Resistivity
- Electrical Resistivity
- Grip Contact Surface to Specimen Volume Ratio
- Specimen Length
- Specimen Cross Section
- Free Span
- Grip Selection
- Heating Rate
- Isothermal Holding Time
- Interface Resistance

Reproducibility

Thermal gradients in resistance-heated specimens are dependent upon on the properties of the specimen. All specimens with the same physical, mechanical, electrical, and chemical properties will have the same gradients within the accuracy of the thermal system, provided that the specimen grips are in good condition.

9.4 Specimen Size Considerations

Gleeble systems are capable of testing a wide variety of material compositions and specimen geometries. Inherent limitations of the system, such as distance between the jaw or anvil faces, the maximum or minimum stroke speed, test temperature, and force limitations for the individual system must be considered when selecting a specific *specimen geometry* (page 378).

The target temperature of a test will also impact the size of a specimen that can safely be tested with a Gleeble system. For example, when considering a standard uniaxial compression specimen, it is possible for a soft material such as aluminum or copper to be tested at ambient temperature. Harder materials, such as steel or titanium alloys, are expected to be tested at elevated temperatures.

The Gleeble 500 Series's vacuum tank configuration limits the maximum and minimum specimen geometry that can be tested. The maximum specimen length for a tensile specimen is 95 mm. The minimum specimen size should have a free span no smaller than 8 mm.

Specimen geometry will vary with by test type. DSI has identified recommended specimen geometries for commonly performed simulation tests. *Contact Dynamic Systems* (page 373) for assistance identifying a recommended specimen geometry as needed.

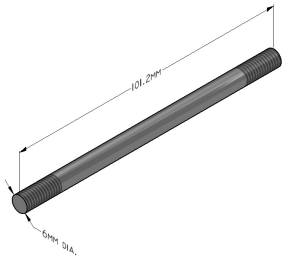


Fig. 9.6: Small-Format Round Specimen - SFR115.

Popular Specimen Sizes			
Specimen Length	**Specimen Width**	**Specimen Thickness**	**Drawing Number**
Specimens			
106.2 mm	10 mm dia	N/A	SFR115
58.26 mm	6 mm dia	N/A	SFR002
101.2 mm	6 mm dia	N/A	SFR106
58.26 mm	11 mm Sq	N/A	SFS002
Flat Specimens			
100 mm	10 mm	1 mm	SMF002

Note: The use of hot grips is recommended for highly conductive specimens. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

9.5 Additional Features

Vacuum Tank

One of the distinguishing features of a Gleeble system is the ability to test materials in a controlled atmosphere. Researchers can simulate processes and test specimens in standard atmosphere, in rough vacuum, in high vacuum or in an inert gas environment. This environmental control is possible due to the large vacuum tank, also referred to as a "test chamber," that is incorporated into every Gleeble. The vacuum tank is fully integrated into the Gleeble system and can be controlled with manual controls or through software controls. A popular approach to atmosphere control in the Gleeble includes "washing cycles" which involve pumping down to a rough vacuum in the tank and then backfilling with an inert gas. This can be conducted multiple times to ensure that the desired atmosphere is achieved.

Gleeble vacuum tanks include a large viewing port incorporated into the tank door to allow visual observation of simulations. In some cases, viewing windows are removed or covered to protect users from the light intensity of specimens at elevated temperatures.

Feedthroughs are an important feature in the Gleeble vacuum tanks. They allow researchers to install equipment that can measure or interact with the specimen during a test while still controlling the atmosphere. For example, vacuum-sealed electrical feedthroughs allow communication with transducers such as thermocouples, load cells, and strain transducers. Piping feedthroughs enable atmosphere control (e.g. inert gas backfill and vacuum supply) as well as allowing quenching media to be utilized.

Warning: The Gleeble vacuum tank is designed to operate under vacuum or atmospheric pressure, with either air or an inert gas surrounding the specimen. Positive atmospheric pressure, explosive, flammable or corrosive gases, or any mixtures of these gases, should never be used as part of the vacuum tank atmosphere.

Hydraulic Power Unit

The Gleeble 500 Series systems are equipped with an integrated hydraulic power unit (HPU). The HPU is the primary source of mechanical motion for these Gleeble systems. The HPU is capable of regulating the output pressure of the hydraulic fluid, based on the Gleeble system configuration. Typical configurations allow the user to choose between a high and low output pressure. These pressures can be manually selected with a button on the HMI or through the programming of a Gleeble test.

Hydraulic Power Unit Consumables

Reference *Hydraulic Oil* (page 360) for common service parts.

The Gleeble HPU is fully integrated into the 500 Series systems. This means that the system uses a single chilled process fluid supply for system temperature regulation and hydraulic oil temperature regulation. By automatically regulating the temperature of the hydraulic oil, the Gleeble is capable of maintaining peak performance in a variety of ambient temperature environments. The HPU is protected by a high oil temperature, high oil level, and low oil level sensors.

Characteristic		Specification
Pump Motor		5 hp
Variable Pressure Output	Low Pressure	68.94 bar (1000 psi)
	High Pressure	206.84 bar (3000 psi)
Hydraulic Oil Reservoir		38 L (10 gal)

9.6 Gleeble Physical Dimensions

The Gleeble 500 Series systems were designed to fit through a standard entryway. With a depth measuring just 87 cm (34 in), with the Lower Console Assembly removed. The system will occupy a space of 3 x 4 m (9.84 x 13.12 ft) for general operation. This does not include the additional space required for options such as a freestanding vacuum system option.

Equipment	Height	Depth	Width	Weight
500 Series System	125 cm (49 in)	97 cm (38 in)	202 cm (80 in)	800 kg (1,800 lb)

9.6.1 Frame and Machine Stiffness

Gleeble 500 Series systems have a frame stiffness of 3.85 x 10^{-8} m/N (6.74 x 10^{-6} lbf).

Section 10

Gleeble 525

Contents

- *Advanced Gleeble Control* (page 137)
- *Pneumatic - Mechanical* (page 138)
- *Thermal Subsystem* (page 139)
  - *Thermocouple Measurement Assemblies* (page 139)
    - *Thermocouple Wire Types* (page 140)
  - *Heating Rates* (page 141)
  - *Cooling Rates* (page 141)
  - *Temperature Uniformity Within the Specimen* (page 143)
- *Specimen Size Considerations* (page 145)
- *Additional Features* (page 146)
- *Gleeble Physical Dimensions* (page 146)
  - *Frame and Machine Stiffness* (page 147)



Fig. 10.1: Gleeble 525.

A Dedicated Simulation System for Optimizing Continuous Annealing, Galvanizing and Coating Lines

The Gleeble 525 Strip Annealing Simulator is a low-cost system built specifically for simulating thermal cycles in sheet specimens, including continuous annealing lines, batch annealing, quenching and tempering (Q+T), quenching and partitioning (Q+P) and other heat treatment processes. The Gleeble 525 is designed to be used on the production floor or in a research lab. This easy-to-use system can quickly run tests and simulations on wide dimension specimens, to help researchers make better processing decisions.

Overview

Gleeble technology makes it easy to reproduce real-world annealing thermal cycles on steel sheet or strip materials. Unlike expensive mill trials, simulations help staff quickly and efficiently optimize annealing procedures to improve profitability, increase production, and reduce waste by rapidly providing the information needed to make better processing decisions.

Build More Efficient Line Schedules

Simulation data help production line metallurgists reduce the number of expensive mill trials they run and provides insight to more efficiently schedule different grades, gauges and specified characteristics. The Gleeble 525 can rapidly and dynamically heat and quench sheet specimens to accurately simulate annealing, galvanizing, and coating line processing. The system can be used to reproduce and evaluate existing processes, experiment with process modifications, or troubleshoot problems.

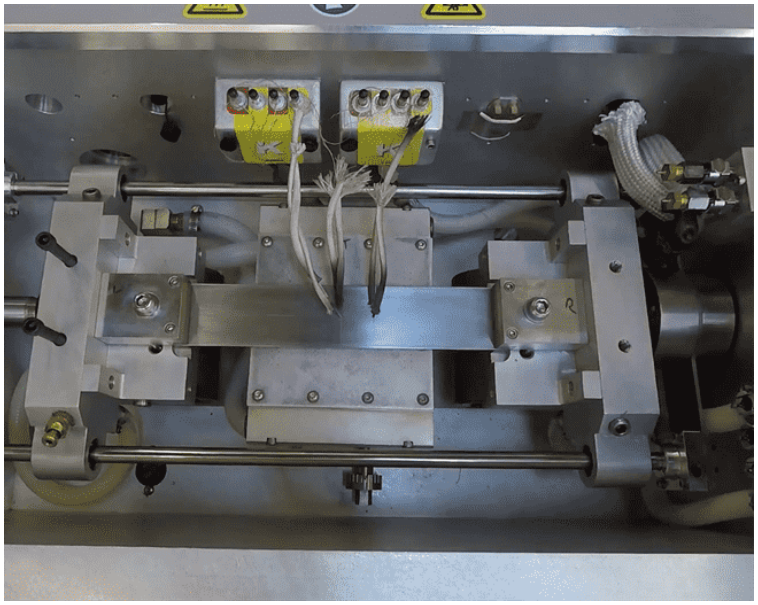


Fig. 10.2: Specimen installed in a Gleeble 525.

Simulation of these processes offers the following benefits:

- Better understanding of the time/temperature relationships and processing window limits for producing desired material characteristics.
- Improved product quality - simulations help determine the conditions needed to optimize material properties and meet the high demanding requirements for advanced high strength steel (AHSS)
- Better process window definition and improved efficiency through reduced use of:
  - Warmer coils
  - Reduce secondary coils

  - Test coils
- Accelerated new product development
- Development of annealing cycles to meet specification and to salvage off-chemistry or misprocessed coils
- Adjustment of processing settings for different alloys and material grades

DSI Strip Annealing Systems Offer the Following Capabilities:

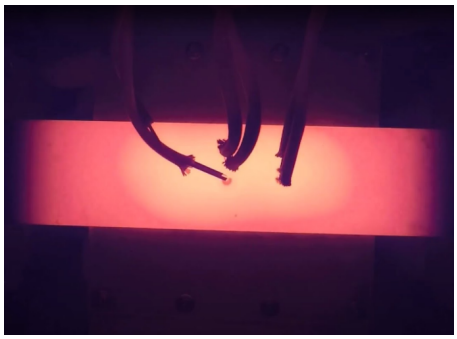


Fig. 10.3: Gleeble 525 specimen's thermal gradient.

Ultra-Fast Heating

All Gleeble strip annealing systems utilize the same ultra-fast direct resistance heating that has made Gleeble systems a staple at the world's leading metals producers.

Proportional Quench

A dynamic cooling system with custom gas-quench spray heads that allows fast yet controlled cooling.

Complex Thermal Cycles

Users can easily program complex temperature profiles, including heating, holding, controlled cooling, reheating and quenching. This allows for accurate simulation of production line processes.

Large Uniform Temperature Zones

Great care has been taken to maximize temperature uniformity in the test specimens, allowing for simulations that are more representative of production processes. This resulting in a more representative post-treatment material condition.

Environmental Control

Specimens can be tested in vacuum, air or inert gas.

Tension Application

Tension can be applied to the specimen to prevent buckling and to simulate roll tension forces.

Part Number	Description	Sold As
525	Gleeble 525 Strip Annealing Simulator	System

10.1 Advanced Gleeble Control

Gleeble 500 Series systems are equipped with advanced Gleeble control systems similar to the *Gleeble Touch Control* (page 9) of the 3000 Series systems. The control system of a Gleeble 500 Series system includes an intuitive user display with a large and easy-to-use touchscreen. Advanced software and hardware provide state-of-the-art performance with accuracy and dependability at the heart of the design.

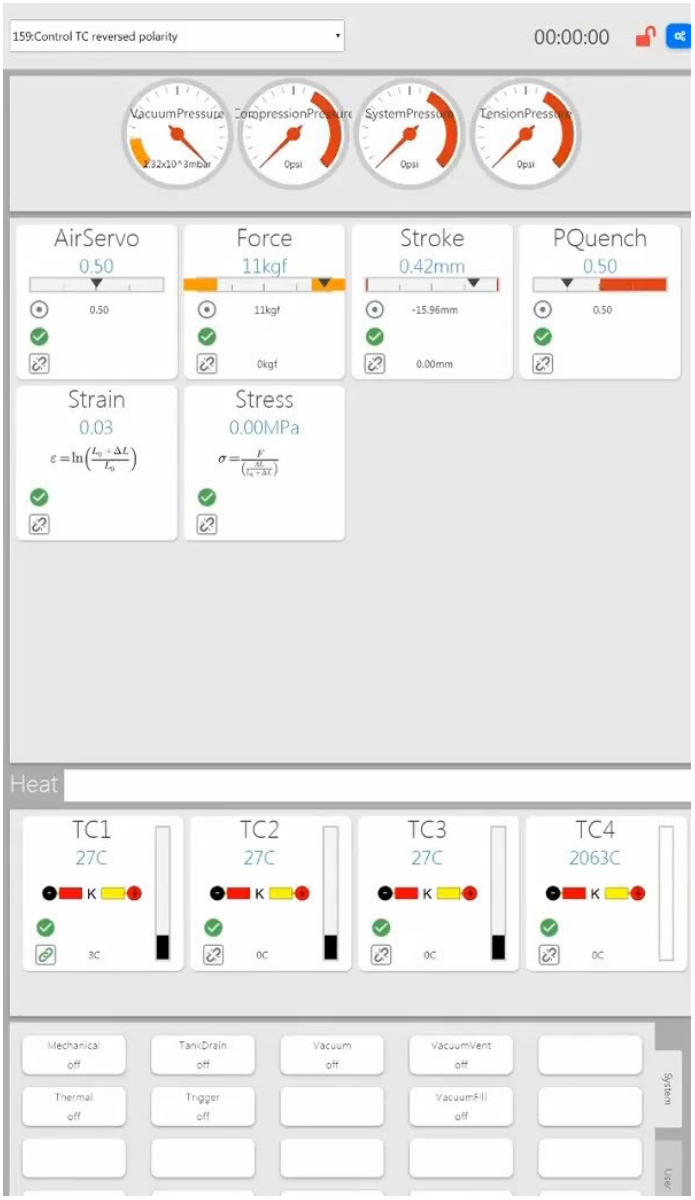


Fig. 10.4: Gleeble 525 User Interface Display.

10.2 Pneumatic - Mechanical

The Gleeble 525 includes a pneumatic system that is used to apply light tension to the specimen. Tension is applied to simulate annealing line tension and to help prevent specimen buckling. The pneumatic system is not intended to conduct deformation or tensile testing. Tension is measured and controlled using a load cell.

Characteristic	Specification
Test Frame	Horizontal framework and structural vacuum tank
Mechanical System	Closed-loop pneumatic servo control
Recommended Force in Tension	50 kgf (110 lbf) (0.49 kN)
Maximum Stroke Distance	50.8 mm (2 in)
Minimum Compressed Air Supply	350 L/min (95.46 gal) for 3 s at 5.5 bar (79.77 psi)
Servo Valve Response Time	4.8 ms

Load Cell

The Gleeble 525's load cell is mounted directly to the stationary jaw. It is used to measure the force exerted on the specimen by the pneumatic system.

Characteristic	Specification
Maximum Force in Tension	225 kgf (496 lbf)
Non-linearity	±0.1 % of full scale
Hysteresis	±0.08 % of full scale
Non-Repeatability (Maximum)	±0.02 % of full scale
Overload Rating	150 % of full scale
Deflection - Full Scale	0.051 mm (0.002 in)

10.3 Thermal Subsystem

The Gleeble 525 offers high-speed heating and dynamic quenching systems to simulate real-world thermal cycles.

Direct resistance heating provides the ability to reproduce the wide variety of thermal profiles that materials undergo in actual processes. This is critical to the success of thermal-mechanical testing and physical simulation. All Gleeble systems have high-speed heating and cooling rates that can accurately replicate nearly any thermal profile required.

Characteristic	Specification
Heating System Type and Control	Direct resistance with closed-loop control
Temperature Control	Digital closed-loop control using an 18-bit ADC and a 32-bit digital processor.
Temperature Range	Room temperature to 1,000℃ (1,832℉)
Time at Maximum Temperature	5 min (When testing with SMF110 specimens)
Temperature Monitoring Source	Thermocouple
Thermocouple Sampling Rate	Twice the Power Supply Frequency (100 - 120 Hz)
Resolution	±1℃ or℉
Maximum Number of Simultaneous Thermal Channels	8 thermocouple channels
Accuracy of Control	±1℃ (in steady state)
Accuracy of Measurement	±1 % of temperature plus the accuracy of the thermocouple wire (in steady state)

Note: As the specimen size, diameter, length, or cross-sectional area increases the effective heating rate will decrease.

10.3.1 Thermocouple Measurement Assemblies

The Dual Channel Thermocouple Input series of modules is designed to add thermocouple input channels to Gleeble 500 Series systems and the HDS-V40. Each module may be connected to any available Gleeble PnP port, providing two thermocouple input channels of a given type.

Part Number	Thermocouple Type	Description
59004	K	Dual Channel Input Box
59005	S	Dual Channel Input Box
59006	R	Dual Channel Input Box
59007	B	Dual Channel Input Box
59008	E	Dual Channel Input Box
59014	J	Dual Channel Input Box

Note: A single K-type Dual Channel Input Box is included standard if required.

Thermocouple Wire Types

Gleeble systems are capable of recording specimen temperature with various thermocouple wire types. The following types of thermocouple wire can be used on any Gleeble system.

Part Number	TC Type	Material	Sold As
Operating Range: 0 - 1,450°C (32 - 2,642°F)			
TC005	R- or S-	Pt 100%	Inch
TC006	R+	Pt 87% - Rh 13%	Inch
TC009	S+	Pt 90% - Rh 10%	Inch
Operating Range: -200 - 1,250°C (-328 - 2,282°F)			
TC014	K-	Alumel	Spool
TC015	K+	Chromel	Spool
Operating Range: 0 - 1,700°C (32 - 3,092°F)			
TC017	B-	Pt 94% - Rh 6%	Inch
TC018	B+	Pt 70% - Rh 30%	Inch
Operating Range: 0 - 750°C (32 - 1,382°F)			
TC030	J+	Fe 100%	Spool
TC031	J-	Constantan	Spool
Operating Range: -200 - 900°C (-328 - 1,652°F)			
TC032A	E+	Chromega	Spool
TC033	E-	Constantan	Spool
Operating Range: 0 - 2,320°C (32 - 4,208°F)			
TC010	C+	W 95% - Re 5%	Inch
	C-	W 74% - Re 26%	

Note: TC wire types C, K, J, and E have a nominal wire diameter of 0.254 mm (0.01 in). TC wire types R, S, and B have a nominal wire diameter of 0.2032 mm (0.008 in).

Note: Gleeble systems can support additional thermocouple wire types not shown. *Contact Dynamic Systems* (page 373) for additional information regarding the use of alternate thermocouple wire types.

Note: Each thermocouple wire type requires a corresponding Dual Channel Thermocouple Input Module for temperature measurement in Gleeble 500 Series systems or the HDS-V40.

10.3.2 Heating Rates

Heating rates are based on using a 480 V / 200 A power supply, standard Stainless Steel top and bottom grips (GN91101B/T), and 1018 carbon steel specimens.

Specimen Type	Maximum Heating Rate	Drawing Number
	°C/s (°F/s)	
1 mm x 50 mm x 260 mm	50 (90)	SMF109B
2 mm x 50 mm x 260 mm	25 (45)	SMF110B

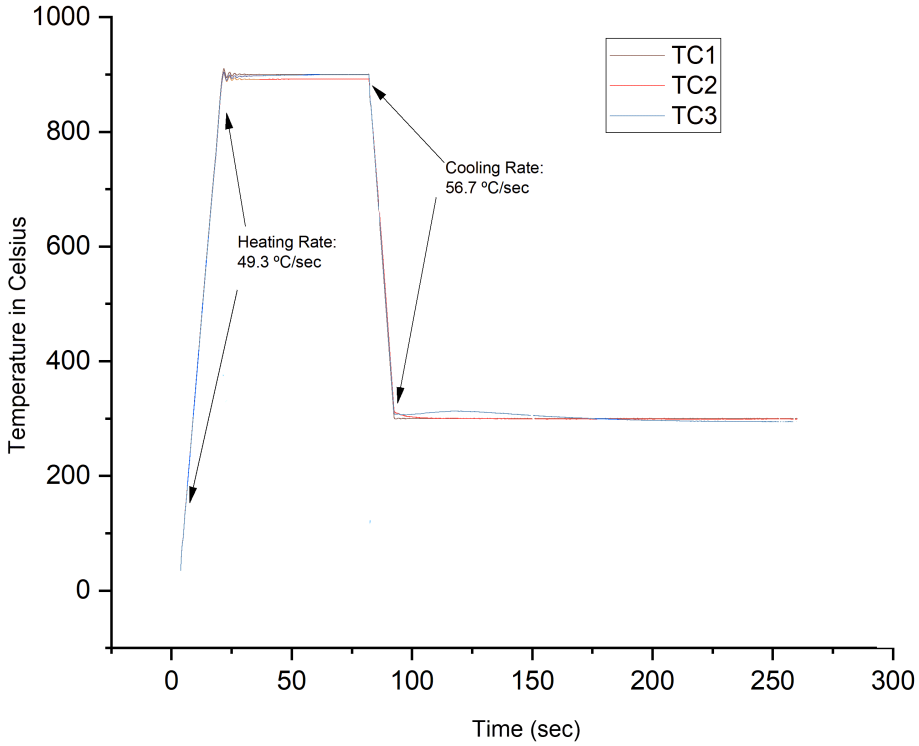


Fig. 10.5: Heating and cooling rates during a Gleeble 525 test.

10.3.3 Cooling Rates

Quench Cooling Rates

The Gleeble 525 includes a proportional quench system which dynamically cools the specimen using a custom-designed quench spray head. The quench system uses a gas supply such as nitrogen, argon, or compressed air.

The free cooling rates are achieved using standard Stainless Steel top and bottom grips (GN91101B/T), 1018 carbon steel specimens, and a *Proportional Quench System* (page 289) valve.

Specimen	Quench Rate	Drawing Number	Quench Medium
	℃/s (℉/s)		
1 mm x 50 mm x 260 mm	57 (102.6)	SMF109B	Nitrogen Gas
2 mm x 50 mm x 260 mm	28 (50.4)	SMF110B	Nitrogen Gas

10.3.4 Temperature Uniformity Within the Specimen

The Gleeble system has the unique ability to control the temperature uniformity and thus the thermal gradient within the test specimen. Tests can be performed with very uniform temperature within the specimen work zone, equivalent to a furnace-based test, or with the large thermal gradients needed to accurately simulate welding and other processes.

When using Joule heating, the current density in a Gleeble specimen is uniformly distributed across the entire specimen cross-sectional area, meaning that the Gleeble is able to heat the entire specimen simultaneously, from surface to center. Since the Gleeble grips are cool, the heat generated in the specimen will diffuse into the grips, creating a thermal gradient with the ends of the specimen generally being cooler than the center. The severity of the steady state thermal gradient is defined by the rate of heat generated in the specimen, offset by the heat lost to the grips. This gradient can be controlled by utilizing grips of materials with differing thermal and electrical conductivity and contact area. Thermally and electrically conductive grips with a large specimen contact area will be kept cold more readily with the water-cooled jaws, and will accept significant heat from the specimen, resulting in “cold ends” and a very steep thermal gradient.

Grips with smaller contact area and higher thermal resistance will pull much less heat from the specimen. Grips manufactured from material with higher electrical resistance will, themselves, heat under the same current that is heating the specimen. These factors will result in very little heat being pulled from the specimen and a very flat thermal gradient. In some cases the grips or anvils holding the specimen may reach temperatures equal to or higher than the specimen, creating a “reverse” thermal gradient.

When considering Gleeble thermal gradients, it is also critical to differentiate between the axial thermal gradient (along the length of the specimen), and the transverse thermal gradient (across the diameter or cross section of the specimen). Even in situations where a specimen experiences a very high axial thermal gradient, the transverse, or crosswise thermal gradient will be very small. This ability to generate isothermal planes is a critical benefit of the Gleeble. In contrast to furnace or induction heating methods, where the specimen can only be heated on the surface or to a limited “skin depth”, the center of a Gleeble specimen is heated at the same rate as the surface regardless of the heating rate. This ability to generate isothermal planes allows for the Gleeble platform to perform dilatometry and welding heat affected zone experiments at heating and cooling rates relevant to welding and other processes on specimens that are large enough for subsequent mechanical property or toughness testing. This is not feasible on furnace or inductively-heated systems that rely on thermal conduction to heat the center of the specimen. Axial thermal uniformity within a specimen is reported as the difference between the specimen’s center to edge thermal measurements and is dependent upon:

- Material
- Thermal Resistivity
- Electrical Resistivity
- Grip Contact Surface to Specimen Volume Ratio
- Specimen Length
- Specimen Cross Section
- Free Span
- Grip Selection
- Heating Rate
- Isothermal Holding Time
- Interface Resistance

Thermal Uniformity

Thermal uniformity within the specimen, the difference between the center-point temperature measurement and the edge temperature measurement, is verified by measuring specimen temperature with thermocouples secured onto the specimen.

Thermocouple Placement

All thermocouple location measurements are indexed from the left and top of the specimen. Secure thermocouples at the following locations:

TC1: Center: 130 mm x 25 mm (5.11 in x 0.984 in)
TC2: 10 mm above TC1: 130 mm x 15 mm (5.11 in x 0.59 in)
TC3: 25 mm right of TC1: 155 mm x 25 mm (6.1 in x 0.984 in)

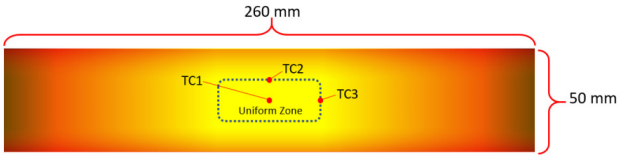


Fig. 10.6: Thermocouple Placement.

Note: All measurements are taken from the left and top of the specimen.

Characteristic	Specification
Uniform Temperature Zone	20 mm x 50 mm area
Steady-State Thermal Gradient	20℃ (68℉)
Thermal Gradient On Heating	20℃ (68℉)
Thermal Gradient On Cooling/Quenching	30℃ (86℉)

Reproducibility

Thermal gradients in resistance-heated specimens are dependent upon on the properties of the specimen. All specimens with the same physical, mechanical, electrical, and chemical properties will have the same gradients within the accuracy of the thermal system, provided that the specimen grips are in good condition.

10.4 Specimen Size Considerations

The Gleeble 525 uses the same *specimen geometries* (page 385) as the *General-Purpose MCU - Strip Annealing Kit* (page 251). This specimen's geometry enables the an ASTM-E8 dog bone-shaped specimen to be cut out of the thermally-uniform center. *Contact Dynamic Systems* (page 373) for assistance identifying a recommended specimen geometry.

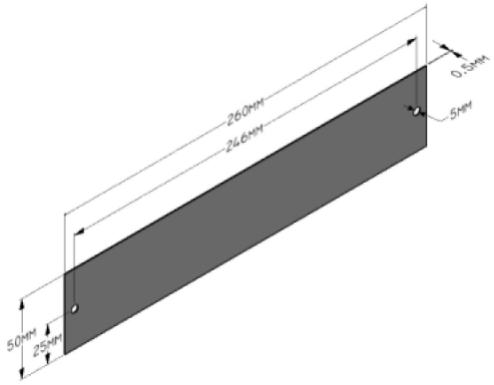


Fig. 10.7: Strip Annealing Specimen - SMF109.

Popular Specimen Sizes			
Length	**Width**	**Thickness**	**Drawing Number**
250 mm	50 mm	0.5 mm	SMF119
250 mm	50 mm	1 mm	SMF109
250 mm	50 mm	2 mm	SMF110

10.5 Additional Features

Additional Strip Annealing Capabilities Available From DSI:

General-Purpose MCU - Strip Annealing Kit **(page 251) -** This jaw set fits within the vacuum tank of a Gleeble 3500C or 3800 General-Purpose Mobile Conversion Unit (MCU), and is used for treatment of specimens up to 50 mm (0.787 in) wide, from which ASTM-E8 dog bone tensile specimens can be produced.

Large-Sample Strip Annealing **(page 77) -** This MCU can be installed on a Gleeble 3500 or 3800, and processes specimens up to 125 mm (4.92 in) wide while maintaining a large uniform temperature zone. This specimen geometry is ideal for conducting post-treatment formability tests such as Limiting Dome Height (LDH) or tensile tests.

Vacuum Tank

One of the distinguishing features of a Gleeble system is the ability to test materials in a controlled atmosphere. Researchers can simulate processes and test specimens in standard atmosphere, in rough vacuum, in high vacuum or in an inert gas environment. This environmental control is possible due to the large vacuum tank, also referred to as a "test chamber," that is incorporated into every Gleeble. The vacuum tank is fully integrated into the Gleeble system and can be controlled with manual controls or through software controls. A popular approach to atmosphere control in the Gleeble includes "washing cycles" which involve pumping down to a rough vacuum in the tank and then backfilling with an inert gas. This can be conducted multiple times to ensure that the desired atmosphere is achieved.

Gleeble vacuum tanks include a large viewing port incorporated into the tank door to allow visual observation of simulations. In some cases, viewing windows are removed or covered to protect users from the light intensity of specimens at elevated temperatures.

Feedthroughs are an important feature in the Gleeble vacuum tanks. They allow researchers to install equipment that can measure or interact with the specimen during a test while still controlling the atmosphere. For example, vacuum-sealed electrical feedthroughs allow communication with transducers such as thermocouples, load cells, and strain transducers. Piping feedthroughs enable atmosphere control (e.g. inert gas backfill and vacuum supply) as well as allowing quenching media to be utilized.

Warning: The Gleeble vacuum tank is designed to operate under vacuum or atmospheric pressure, with either air or an inert gas surrounding the specimen. Positive atmospheric pressure, explosive, flammable or corrosive gases, or any mixtures of these gases, should never be used as part of the vacuum tank atmosphere.

10.6 Gleeble Physical Dimensions

The Gleeble 500 Series systems were designed to fit through a standard entryway. With a depth measuring just 87 cm (34 in), with the Lower Console Assembly removed. The system will occupy a space of 3 x 4 m (9.84 x 13.12 ft) for general operation. This does not include the additional space required for options such as a freestanding vacuum system option.

Equipment	Height	Depth	Width	Weight
500 Series System	125 cm (49 in)	97 cm (38 in)	202 cm (80 in)	800 kg (1,800 lb)

10.6.1 Frame and Machine Stiffness

Gleeble 500 Series systems have a frame stiffness of 3.85 x 10^{-8} m/N (6.74 x 10^{-6} lbf).

Section 11

Specialty Gleeble System Solutions

Contents

- *HDS-V40* (page 149)
  - *Hydro-Mechanical* (page 150)
  - *Thermal Subsystems* (page 153)
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  - *Measurement Gauges and Kits - HDS-V40* (page 158)
    - *HDS-V40 Lengthwise Extensometer - Range: ±50.8 mm* (page 158)
    - *HDS-V40 Uniaxial Compression Anvil Assembly* (page 159)
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    - *HDS-V40 Melting Crucible Retractors and Control Unit* (page 162)
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  - *HDS-V40 Physical Dimensions* (page 166)

11.1 HDS-V40

Unparalleled Technology for Process Development

Continuous casting followed by direct rolling (CC-DR) offers steelmakers the opportunity for substantial energy savings and reduced capital expenditures which, in turn, can lower costs and increase profits.

The HDS-V40 is the only commercially available laboratory system capable of simulating direct rolling, from the continuous caster to the end of the hot rolling process, all in one continuous sequence, using a single specimen. Steelmakers can explore the promise of continuous casting and direct rolling (CC-DR) on an affordable, reproducible, laboratory scale. In addition to direct rolling, this system can be used for simulating semi-solid rolling (liquid metal core reduction), plane strain compression, hot rolling and forging.



[24]

Fig. 11.1: Gleeble HDSV-40.

Thermal and Mechanical Systems

The HDS-V40 uses the Gleeble direct resistance heating method, but expands the technology to permit the use of larger specimens. The larger specimens allow materials properties testing after deformation.An innovative melting containment system features a crucible that holds the molten material in place and can be removed prior to deformation.

Unprecedented Flexibility

No other system offers so much flexibility to perform melting, solidification and deformation simulations in a controlled atmosphere. The HDS-V40 can perform plane strain compression tests on different material conditions including:

- Different parts of the melt zone
- Semi-solid material
- Previously melted material
- Re-solidified material

Additionally, the deformation anvils have separate heating controls. The temperature of the anvils can be adjusted independent of the specimen, simulating an actual rolling mill. An optional optical dilatometer allows collection of transformation data as the specimen cools.

Feedback Control

On the HDS-V40, the user can control the test process using either stroke or strain as the feedback variable to the control software. Strain control is based on the stroke feedback loop. Constant strain rates and non-linear strain rates can be programmed using stroke as the feedback variable within the limits of high-speed testing described in the previous section.

HDS-V40 Capabilities at a Glance

- Continuous Casting–Direct Rolling, liquid metal core reduction, hot rolling and hot forging simulations
- Direct resistance heating for high-speed thermal capability and precise control
- Twin hydraulic systems with exact control of strain and strain rate
- Variable deformation speeds
- Simulations can be run in air, vacuum or inert gas
- Quench in-situ at any time during simulation

[24] https://gleeble.com

- Precise digital control system
- Large sample sizes

Part Number	Description	Sold As
HDS-V40-1.7-150	Gleeble HDS-V40 Direct Rolling Simulator	System

11.1.1 Hydro-Mechanical

The HDS-V40 offers a high-speed mechanical system with unmatched performance. The latest in state-of-the-art hydraulic valves combined with an innovative hydraulic system create a high-speed servo system. The unique, patented Hydrawedge system allows independent control and programming of Strain and Strain Rate. The overall system has eight (8) control axes. Five are servo-hydraulic, three are thermal.

Another feature of this physical simulator is a mechanical system that permits moving the entire specimen and jaw system off the anvil centerline. Normally, the specimen is deformed at the center of the mid-span, where the liquid thickness during solidification is the same on both sides of the anvil. However, as a means of more accurately simulating semi-solid rolling, the specimen can be moved from side to side, enabling sequential compressions to deform the thickest part of the specimen.

Characteristic	Specification
Test Frame	Vertical type with dual 120 mm (4.9 inches) diameter columns
Mechanical System	Closed-loop hydraulic servo control
Data Acquisition Channels	User selectable, up to 16 channels simultaneously, 18-bit ADC
Data Sampling Rate	User selectable, up to 50 kHz.
Maximum Static Force in Compression	40,000 kgf (~ 88,184 lbf) (392 kN)
Maximum Stroke Rate - Both Rams Compressing Simultaneously	1,700 mm/s (66.92 in/s) in compression
Maximum Stroke Rate - Each Ram Compressing Individually	850 mm/s (33.47 in/s) in compression
Minimum Stroke Rate	0.005 mm/s (1.96×10^{-4} in/s) compression
Maximum Combined Stroke Distance	40 mm (1.57 in)
Maximum Number of Compression Hits	No Specific Limit

Note: The total number of compression hits possible is dependent upon many test characteristics. These include the number of deformations, the initial position of the hydraulic stroke, and time between deformations.

Note: Accuracy is measured at a temperature of 23°C (73°F). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30°C (86°F).

Load Cell

Characteristic	Specification
Hysteresis	±0.08 % of full scale
Overload Rating	150 % of capacity
Deflection - Full Scale	0.076 mm (0.003 in)
Force Measurement Accuracy	±0.5 % of full scale
Force Measurement Resolution	±1.5 kgf (3.2 lbf) (0.014 kN)
Force Measurement Response Time	0.1 msec

Note: Accuracy is measured at a temperature of 23°C (73°F). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30°C (86°F).

Stroke Transducer

The opposing anvils of the HDS-V40 system is equipped with a measurement transducer. The stroke transducer serves to control the rate of specimen deformation.

Characteristic	Specification
Type	LVDT
Linear Range	±50.8 mm (±2. in)
Stroke Measurement Accuracy	±0.25 % of full scale
Stroke Measurement Resolution	0.0027 mm (1.063×10^{-4} in)
Stroke Measurement Response Time	0.5 msec

Note: Accuracy is measured at a temperature of 23°C (73°F). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30°C (86°F).

Wedge Transducer

The opposing anvils of the HDS-V40 system is equipped with a measurement transducer. The wedge transducer serves to control the amount of specimen deformation.

Characteristic	Specification
Type	LVDT
Linear Range	±50.8 mm (±2. in)
Wedge Measurement Accuracy	±0.25 % of full scale
Wedge Measurement Resolution	0.0027 mm (1.063×10^{-4} in)
Wedge Measurement Response Time	0.5 msec

Note: Accuracy is measured at a temperature of 23°C (73°F). Maximum stroke rates are at a hydraulic pressure of 203 bar (2,950 psi) ±3 % and an oil temperature of 30°C (86°F).

Maximum Dynamic Force

Maximum Dynamic Force is based on the following graph. For a given stroke speed the hydraulic system will provide a corresponding force. All performance figures for the system are based on operating in the region below the force vs. stroke curve. The specifications are not valid for tests conducted outside this operating range.

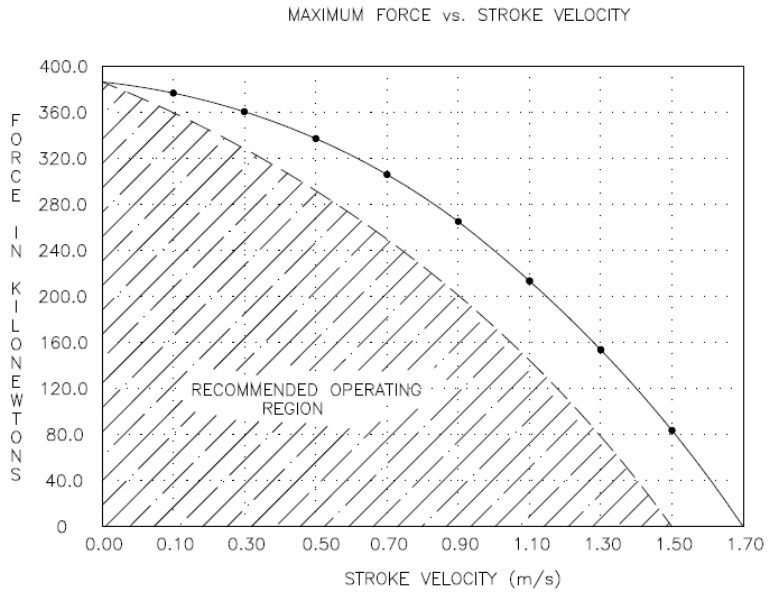


Fig. 11.2: Force vs. Stroke Velocity for HDS-V40.

The above chart shows the optimal performance of the system when both hydraulic rams are operating at full compression speed. The rated performance specification is for the maximum stroke rate with no load, using both rams.

Limits of High-Speed Testing

While the high-speed servo-systems provide the capability for high-speed compression and tension testing, there are certain limitations in the overall system which must be observed.

For all types of operation the Stroke Rate and Force must be within the operating range as described in the Maximum Force vs. Stroke graph.

For constant Strain Rate programs the duration of the deformation for each hit must be ten times the rated response time of the hydraulic servo valve. The Gleeble system uses high-speed valves with a rated response time of 0.006 seconds. Therefore the duration of the actual deformation of the material during the hit must be equal to or greater than 0.060 seconds.

11.1.2 Thermal Subsystems

The mechanical configuration of the HDS-V40 is based on handling a large melt zone. Since the specimen has no strength while in the liquid state, a composite crucible is used to support the melted material. The crucible has an open top an open top, but supports both the sides and the bottom of the specimen. The unique composite crucible permits a cooling medium to be sprayed around the specimen's top, sides, and bottom. The volume of cooling media can be adjusted to provide controlled cooling and any shell formation desired on the cast material. The ends of the specimen are retained in water-cooled grips, preventing the melting from occurring beyond the end of the crucible. The crucible is mounted under the specimen with two retractable arms that provide support for the crucible during the casting process. To ensure efficient melting and to control segregation, the system is designed to provide electromagnetic stirring of the melt pool. Melt superheat may be limited due to the open top of the crucible.

The fragile liquid specimen, with its thin, solidified shell, requires that any deformation be balanced. The specimen should not move in the direction of deformation force while being deformed. To ensure any specimen moment does not occur, two opposing vertical, servo-hydraulic, rams are used. One ram in mounted in the top crosshead of the machine and the other ram is mounted in the bottom crosshead. The rams are synchronized to start and finish deforming the specimen at the same time and velocity.

When the specimen mid-span melts, the level of liquid at the top of the specimen is depressed. The liquid level is brought back to the original height by compressing the specimen. The amount of compression can be programmed into a test manually or automatically. This compression returns the specimen to its original thickness prior to solidification. During solidification the specimen is further compressed to accommodate any shrinkage which may occur as the specimen solidifies.

Characteristic	**Specification**
Heating System Type and Control	Direct resistance with closed-loop control
Temperature Controller	Digital closed-loop control using 18-bit ADC and 32-bit digital processor
Temperature Range	Room Temperature to 1,550℃ (2,822℉)
Temperature Monitoring Source	Thermocouple
Thermocouple Sampling Rate	Twice the Power Supply Frequency (100 - 120 Hz)
Resolution	±1℃ or℉
Maximum Number of Simultaneous Thermal Channels	4 thermocouple channels
Accuracy of Control	±1℃ or℉ (in steady state)
Accuracy of Measurement	±1℃ or℉ or ±1 % of temperature (whichever is greater) plus the accuracy of the thermocouple wire (in steady state)

Heating Rates

Heating rates are based on using a 480 V / 200 A power supply and 1018 carbon steel specimens.

Specimen	Orientation	Drawing Number	Maximum Heating Rate
			℃/s (℉/s)
10 mm dia x 50 mm wide x 165 mm long	Lengthwise	SMF005B	5 (9)
10 mm dia x 15 mm long		SMC203B	1 (1.8)

Note: As the specimen size, diameter, length, or cross-sectional area increases the effective heating rate will decrease.

Cooling Rates

The Gleeble system is able to control the specimen cooling rate based on conductive heat transfer. The efficiency and maximum rate of conductive cooling is directly impacted by grip and specimen geometry, material, cleanliness, and system's chilled process fluid flow rate.

Quenching after specimen melting, prior to complete solidification, can result in undesirable specimen surface conditions. Care should be taken to ensure that the specimen has solidified enough to withstand surface contact with the desired quenching media.

Surface Cooling Rate During Water Quenching

Cooling rates are achieved with a 1018 carbon steel specimen.

Specimen	Free Span	Drawing Number	Temperature Range	Cooling Rate
			℃ (℉)	℃/s (℉/s)
10 mm thick x 50 mm wide x 165 mm long - undeformed	•	SMF005	Max Solid Temp - 800 (Max Solid Temp - 1,472)	50 (90)

Surface Cooling Rate During Gas Quenching

Cooling rates are achieved with a 1018 carbon steel specimen.

Specimen	Free Span	Drawing Number	Temperature Range	Cooling Rate
			℃ (℉)	℃/s (℉/s)
10 mm thick x 50 mm wide x 165 mm long - undeformed	•	SMF005	800 - 500 (1,472 - 932)	5 (9)

Surface Cooling Rate During Gas Quenching for Uniaxial Compression

Cooling rates are achieved with a 1018 carbon steel specimen and *Uniaxial Compression Anvil* (page 159) set and quench spray heads.

Specimen	Free Span	Drawing Number	Temperature Range	Cooling Rate
			℃ (℉)	℃/s (℉/s)
27 mm long x 15 mm dia	•	SMC209	800 - 500 (1,472 - 932)	5 (9)

11.1.3 Thermocouple Measurement Assemblies

The Dual Channel Thermocouple Input series of modules is designed to add thermocouple input channels to Gleeble 500 Series systems and the HDS-V40. Each module may be connected to any available Gleeble PnP port, providing two thermocouple input channels of a given type.

Part Number	Thermocouple Type	Description
59004	K	Dual Channel Input Box
59005	S	Dual Channel Input Box
59006	R	Dual Channel Input Box
59007	B	Dual Channel Input Box
59008	E	Dual Channel Input Box
59014	J	Dual Channel Input Box

Note: A single K-type Dual Channel Input Box is included standard if required.

Thermocouple Wire Types

Gleeble systems are capable of recording specimen temperature with various thermocouple wire types. The following types of thermocouple wire can be used on any Gleeble system.

Part Number	TC Type	Material	Sold As
Operating Range: 0 - 1,450°C (32 - 2,642°F)			
TC005	R- or S-	Pt 100%	Inch
TC006	R+	Pt 87% - Rh 13%	Inch
TC009	S+	Pt 90% - Rh 10%	Inch
Operating Range: -200 - 1,250°C (-328 - 2,282°F)			
TC014	K-	Alumel	Spool
TC015	K+	Chromel	Spool
Operating Range: 0 - 1,700°C (32 - 3,092°F)			
TC017	B-	Pt 94% - Rh 6%	Inch
TC018	B+	Pt 70% - Rh 30%	Inch
Operating Range: 0 - 750°C (32 - 1,382°F)			
TC030	J+	Fe 100%	Spool
TC031	J-	Constantan	Spool
Operating Range: -200 - 900°C (-328 - 1,652°F)			
TC032A	E+	Chromega	Spool
TC033	E-	Constantan	Spool
Operating Range: 0 - 2,320°C (32 - 4,208°F)			
TC010	C+	W 95% - Re 5%	Inch
	C-	W 74% - Re 26%	

Note: TC wire types C, K, J, and E have a nominal wire diameter of 0.254 mm (0.01 in). TC wire types R, S, and B have a nominal wire diameter of 0.2032 mm (0.008 in).

Note: Gleeble systems can support additional thermocouple wire types not shown. *Contact Dynamic*

Systems (page 373) for additional information regarding the use of alternate thermocouple wire types.

Note: Each thermocouple wire type requires a corresponding Dual Channel Thermocouple Input Module for temperature measurement in Gleeble 500 Series systems or the HDS-V40.

11.1.4 Measurement Gauges and Kits - HDS-V40

HDS-V40 Lengthwise Extensometer - Range: ±50.8 mm

The HDS-V40 is supplied with a Lengthwise Strain Gauge Assembly. The L-Strain gauges mounted on the anvil attachment points to provide precise measurement of the anvil movements.

Characteristic	Specification
Type	LVDT
Linear Range	±50.8 mm (2.0 in)
Accuracy	±0.25 % of full scale
Resolution	0.0027 mm (1.063×10^{-4} in)
Response Time	0.5 msec
Gauge Length	0 - 31 mm (0 - 1.22 in)
Maximum Usable Stroke Rate	1, 700 mm/s (66.92 in/s)

Part Number	Description	Sold As
3V924	L-Strain Gauge Assembly - HDS-V40	Kit

HDS-V40 Uniaxial Compression Anvil Assembly

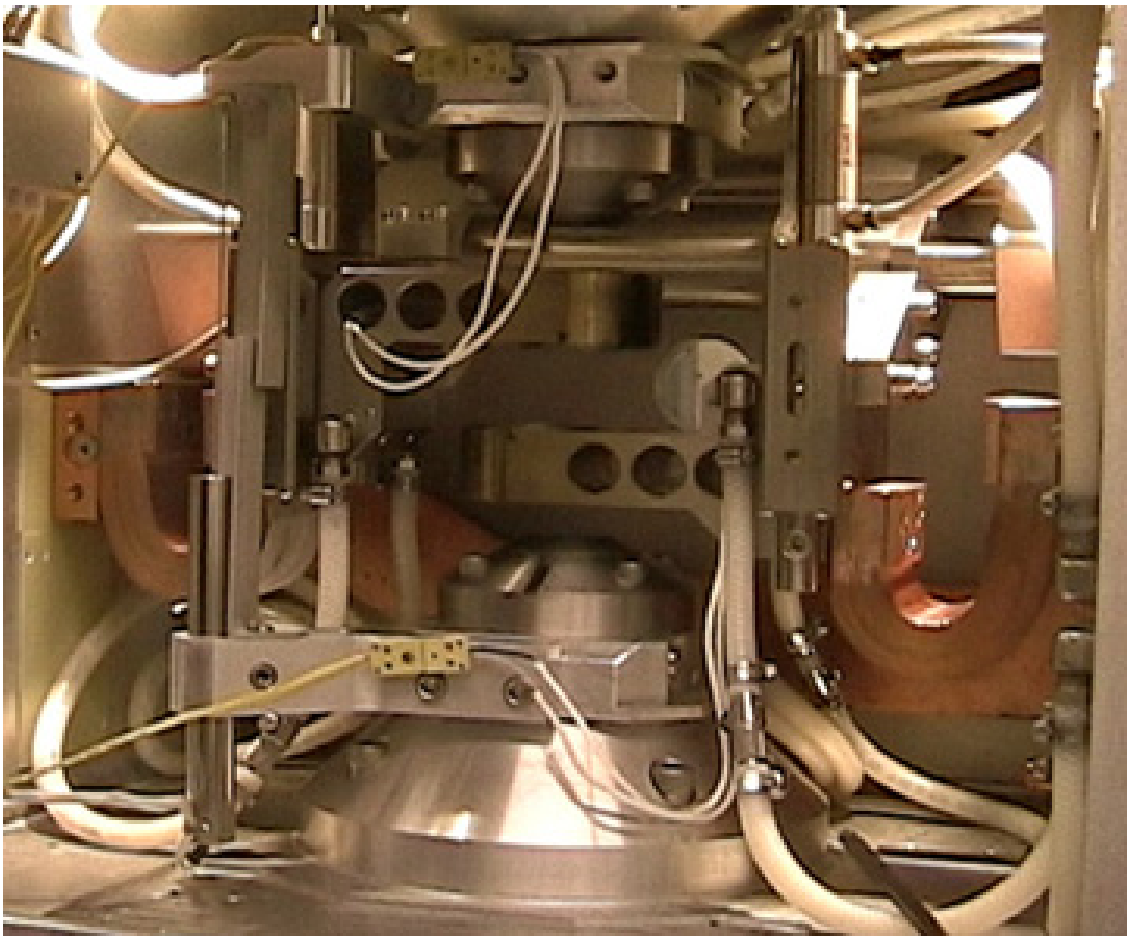


Fig. 11.3: HDS-V40 Uniaxial Compression Anvil Assembly as installed.

The model 3V968 Uniaxial Compression Anvil Assembly is used for uniaxial compression tests. An alternative load cell is included to allow more precise measurements of the forces encountered in uniaxial compression tests. The anvil face size is 25 mm (0.984 in) diameter and uses the ISO-T design developed by DSI to provide uniform temperatures and minimum barreling of the specimen during compression tests.

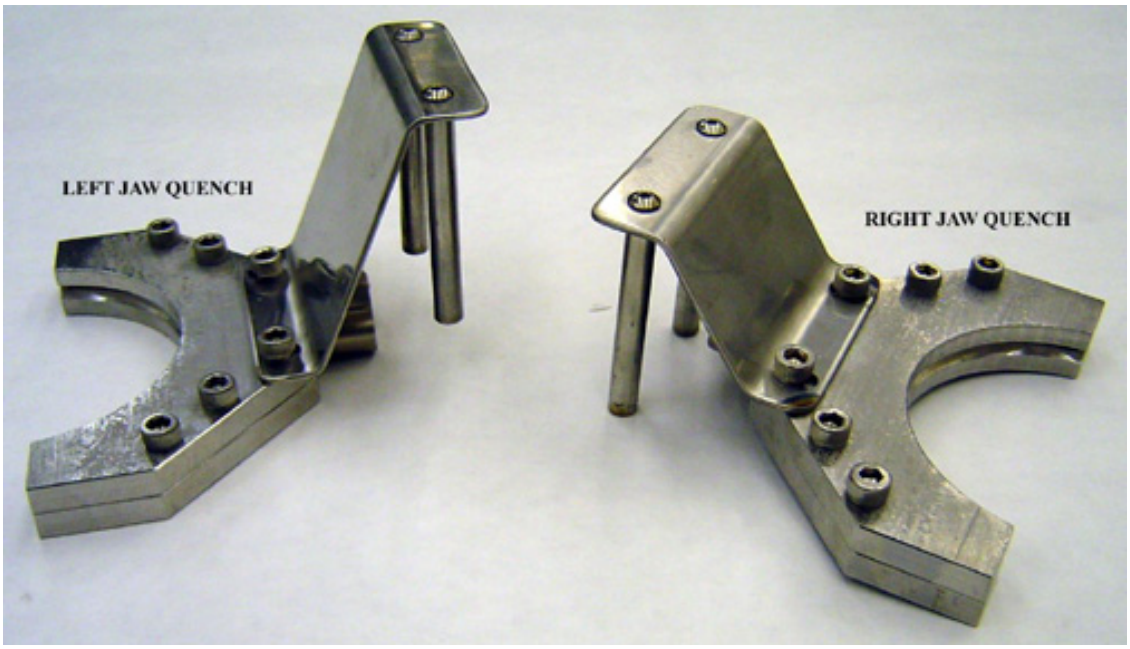


Fig. 11.4: Uniaxial specimen quench spray heads are included with this option.

Part Number	Description	Sold As
3V968	Uniaxial Compression Anvil Assembly - HDS-V40	Kit

HDS-V40 Plane Strain Anvil Assembly

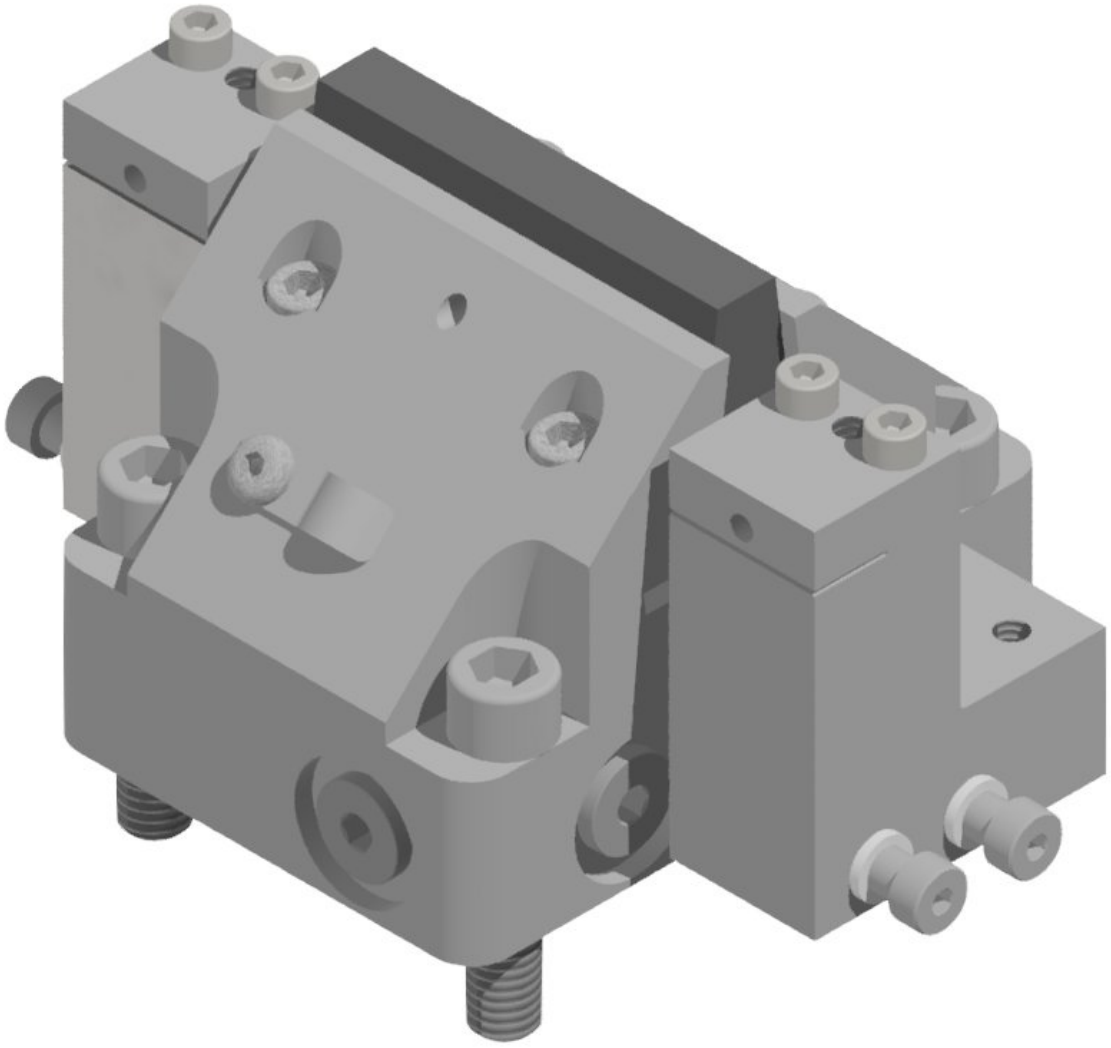


Fig. 11.5: HDS-V40 Plane Strain Heated Mk II Anvil Assembly.

Part Number	Description	Sold As
3V890	Plane Strain Heated Mk II Anvil Assembly - 10 x 70 mm (0.393 x 2.755 in) - HDS-V40	Kit

HDS-V40 Melting Crucible Retractors and Control Unit

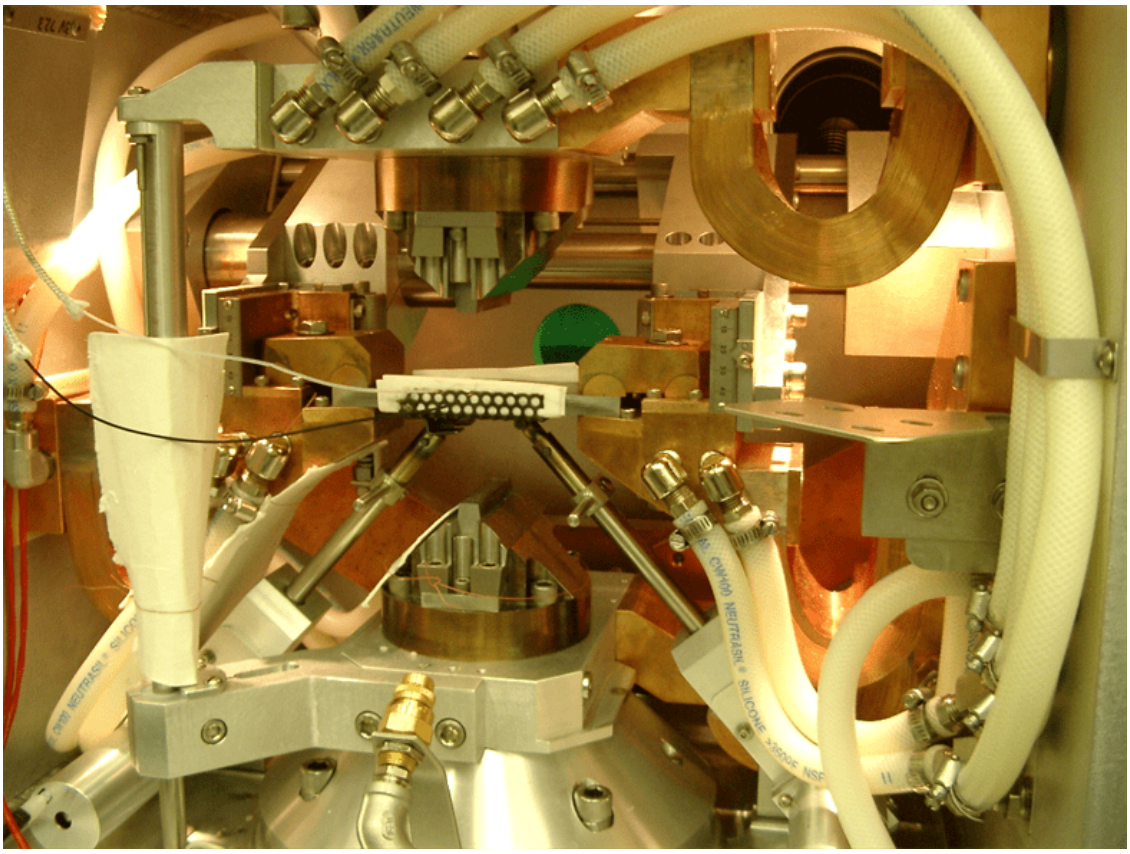


Fig. 11.6: HDS-V40 HDS-V40 Melting Crucible as installed.

Part Number	Description	Sold As
3V905	Melting Crucible Retractors and Control Unit - HDS-V40	Kit

Non-Contact LED Optical Micrometer - Ranges: ±60 mm ±6 mm ±0.6 mm

The 59032 Non-Contact LED Optical Micrometer uses a high-intensity GaN long-life LED combined with an HL-CCD sensor to provide high-speed measurements with no moving parts. Easy-to-use menu-driven setup software is included with the unit to allow configuration of predefined measurement ranges via the Gleeble HMI. Settings can be stored, recalled, and easily changed for a variety of test conditions. The 59032 Non-Contact LED Optical Micrometer can be used to measure in either a crosswise configuration or a lengthwise configuration.

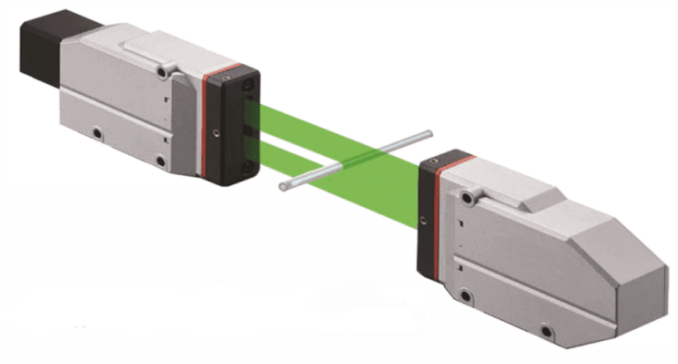


Fig. 11.7: Non-Contact Optical Dilatometer & Extensometer - DSI# 59032.

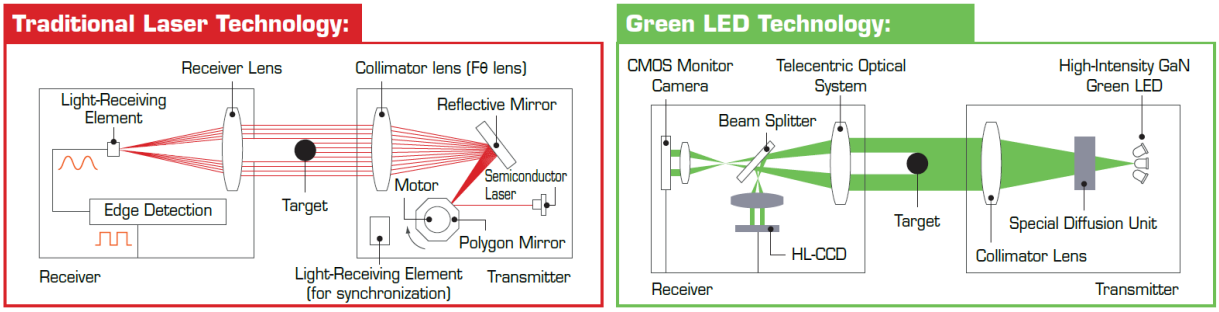


Fig. 11.8: Optical Measurement Comparison.

Green LED Technology

The green LED light is distributed as a
uniform parallel light beam, and is applied to a target. The edge between the bright and dark areas on the HL-CCD sensor is detected and translated into a measured value, such as a specimen's outer diameter.

Traditional Laser Technology

In a conventional laser optical measuring device, the laser beam is projected onto a rotating polygonal mirror. The reflected light scans the measurement range, then reaches the receiving element. To improve speed and accuracy of this laser measuring device, the mirror's rotating motor would need to operate at a faster rate, sacrificing durability and reliability.

Characteristic	Specification		
Range	±60 mm (±2.36 in)	±6 mm (±0.236 in)	±0.6 mm (±0.0236 in)
Resolution	12 μm (4.72 x 10^{-4} in)	1.2 μm (4.72 x 10^{-5} in)	0.3 μm (1.18 x 10^{-5} in)
Accuracy	±68 μm (±2.67 x 10^{-3} in)	±14 μm (±5.51 x 10^{-4} in)	±8.6 μm (±3.33 x 10^{-4} in)
Sampling Rate	16 kHz		
LED Type	InGaN Green		
Ambient Luminescence	3,000 Lux or lower		
Smallest Detectable Object	0.8 mm (0.031 in)		
Serial Communication	RS-232, parity:none, baud:9600		
Analog	Output ±10 VDC		
Output Impedance	~100 ohms		
Supply Power	24 VDC		
Maximum Power Consumption	1.2 amps		
Operating Temperature	0 - 50°C (32 - 122°F)		
Operating Humidity	20 - 85 % RH		
Mounting	Crosswise or Lengthwise		

Note: Measuring range may be limited by vacuum chamber window size.

Danger: Never look directly into the scanning optical system LED transmitting head. Never point the transmitting head away from the vacuum tank while the power is on.

Part Number	Description	Sold As
59032	Non-Contact Optical LED Dilatometer and Extensometer	Ea

11.1.5 Additional Features

Vacuum System

Gleeble vacuum pumping systems are designed to perform as an integral part of the HDS-V40 system. The vacuum pumping system consists of the complete pumping system and its electronic controls. The entire unit is powered and controlled from the HDS-V40 control console. It provides vacuum pressures of 5 x 10^{-4} Torr. The system is equipped with a 350 L/min (92.5 gal/min) roughing pump and a 1,250 L/min (330 gal/min) diffusion pump.

Operation of the Vacuum Pumping Systems is fully automatic. The system status is monitored by the control software and pressure readings are available on the VPM monitor. The system can be used as a roughing pump alone for experiments that do not require extreme vacuum. The tank may be rough pumped and then backfilled with an inert gas such as argon or nitrogen.

Characteristic	Specification
Voltage Rating	380/400 VAC
	460/480 VAC
Roughing Pump	350 L/min (92.5 gal/min)
Diffusion Pump	1,250 L/min (330 gal/min)
Diffusion Pump Size	102 mm (4 in) diameter
Diffusion Pump Cooling	Gleeble chilled process fluid
Lowest Achievable Diffusion Pump Vacuum Pressure	5 x 10^{-4} Torr

Note: The achievable vacuum pressure of the HDS-V40 vacuum tank, 5 x 10^{-4} Torr is only possible in a dry atmosphere (relative humidity less than 60 %) with a clean, dry, and properly sealed vacuum tank.

Warning: The Gleeble vacuum tank is designed to operate under vacuum or atmospheric pressure, with either air or an inert gas surrounding the specimen. Positive atmospheric pressure, explosive, flammable or corrosive gases, or any mixtures of these gases, should never be used as part of the vacuum tank atmosphere.

Hydraulic Power Unit

Gleeble HDS-V40 systems are equipped with an independent hydraulic power unit (HPU). The HPU is the primary source of mechanical motion for these Gleeble systems. The HPU is capable of regulating the output pressure of the hydraulic fluid based on Gleeble system configuration.



Fig. 11.9: Gleeble Hydraulic Power Unit.

Typical configurations allow the user to choose between a high and a low output pressure. These pressures can be manually selected with a button on the HMI or through the programming of a Gleeble test. Special configurations of the Gleeble will limit the pressures available for testing.

The Gleeble HPU uses one branch of the process fluid chiller for automatic computer control of the hydraulic oil temperature. By automatically regulating the temperature of the hydraulic oil, the Gleeble is capable of maintaining peak performance in a variety of ambient temperature environments. The HPU is protected by a high oil temperature sensor, a high oil level sensor, and a low oil level sensor.

Characteristic		Specification
Pump Motor		40 hp
Variable Pressure Output	Low Pressure	68.94 bar (1000 psi)
	High Pressure	206.84 bar (3000 psi)
Hydraulic Oil Reservoir		568 L (150 gal)

11.1.6 HDS-V40 Physical Dimensions

Equipment	Height	Depth	Width	Weight
Control Console	180 cm (71 in)	66 cm (26 in)	61 cm (24 in)	195 kg (430 lb)
Hydraulic Power Unit	63.5 cm (25 in)	121.92 cm (48 in)	91.44 cm (36 in)	•

Section 12

Gleeble Induction Heating System (IHS)

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  - *Reproducibility* (page 171)
- *Specimens* (page 171)
- *Compression Kits* (page 172)
  - *Uniaxial Compression - Induction Anvil Bases* (page 172)
    - *Uniaxial Compression - Induction Anvils* (page 173)
  - *Small Plane Strain - Induction Anvil Bases* (page 174)
    - *Small Plane Strain - Induction Anvils* (page 174)
  - *Large Plane Strain - Induction Anvil Bases* (page 175)
    - *Large Plane Strain -Induction Anvils* (page 175)
- *Quenching Kits* (page 176)
  - *Induction Heating System Quench Kits* (page 176)
    - *Multi-Function Open Quench Spray Nozzle Kit* (page 176)
    - *Hydrawedge II - Multi-Function Open Quench Spray Nozzle Kit* (page 177)
- *Induction Coils* (page 178)

12.1 Induction Heating System

Gleeble systems have historically relied on direct resistance heating to provide extremely fast, uniform and responsive heating. While this method offers considerable advantages over other heating techniques, there are cases where induction heating is preferred. For customers looking to heat via induction, DSI now offers the Induction Heating System (IHS). Developed in partnership with a leading supplier in the induction heating industry, the Gleeble IHS is fully integrated with the Gleeble and allows the user to select either induction or resistance heating for each test. The cooling requirements of the IHS are satisfied through the existing Gleeble cooling loop. It also draws power directly from the Gleeble load unit.

Induction heating is well-suited for use in uniaxial compression testing where it can provide a uniform temperature across the specimen from anvil to anvil. Induction heating can also be used in tensile testing, heat treating applications, and plane strain compression testing. Induction heating is also compatible for custom test setups due to the flexibility it offers.

The integration of the Gleeble Induction Heating System does not impact the functionality of the direct resistance heating capabilities. The Induction Heating System retains the performance standards researchers have come to know and expect from their Gleeble systems. Choosing between standard direct resistance heating and optional induction heating is available through the configuration mode of a GTC system. Only one heating method can be used per test.

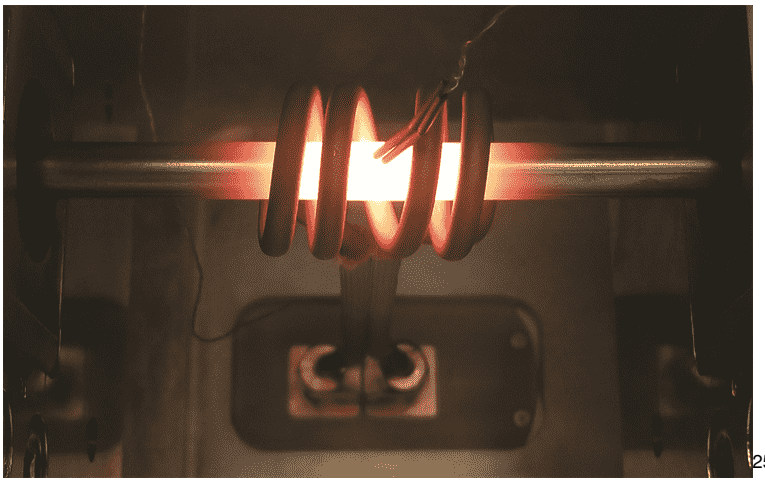
 [25]

Fig. 12.1: Induction Heating Coil.

Part Number	Description	Sold As
37200	Induction Heater Option - Factory Built 3500 or 3800-GTC	Ea.
37201	Induction Heater Option - Series 3 System Equipped with GTC Control - Retrofit	Ea.
Required Accessories		
59025	*Accessory Instrument Module* (page 341) - GTC Systems only	

Note: Series 3 systems must be upgraded to a GTC system to incorporate the Induction Heating System.

12.2 Induction Requirements

Gleeble Induction Equipment Input	
Model	15 kW
AC Voltage	360 - 520 Vrms
Frequency	50 - 60 Hz
AC Line Power	17 kVA max
Power Factor	0.92

[25] https://gleeble.com/products/specialty-systems/induction-heating-system.html

Gleeble Induction Equipment Output	
Frequency	50 - 150 kHz
Voltage	500 Vrms
Power	15 kW
Efficiency (line-coil)	> 90 %

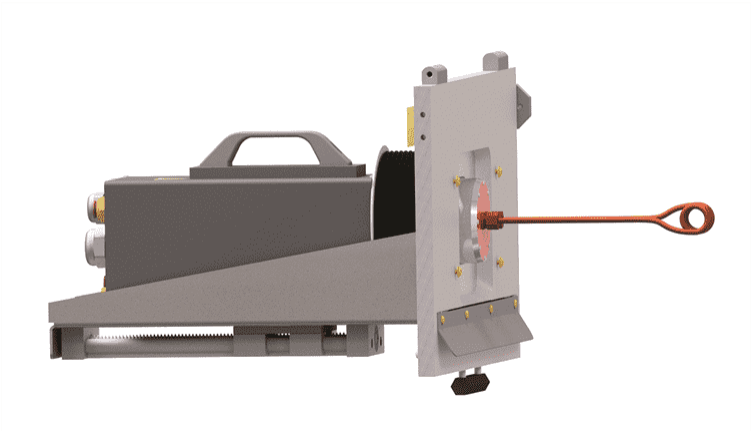


Fig. 12.2: Induction Heating Work Head.

Gleeble Induction Equipment Operating Requirements	
Ambient Temperature	4 - 45℃ (39 - 113℉)
Coolant Temperature	20 - 35℃ (68 - 95℉)
Coolant Flow	10.4 L/min (2.74 gal/min)
Coolant Composition	30 - 50% Propylene Glycol

Gleeble Induction System Performance	
Temperature Range	Room Temperature to 1,700℃
Thermocouple Sampling Rate	Twice the Power Supply Frequency (100 - 120 Hz)
Resolution	±1 (℃ or℉)
Accuracy of Control	±1℃ (steady state)
Accuracy of Measurement	±2℃ or ±1 % of temperature (whichever is greater) plus the accuracy of the thermocouple wire (in steady state)

12.3 Heating Rates

Heating rates are based on 1018 carbon steel uniaxial compression samples at temperatures below the Curie point and held between Si_3N_4 anvils.

Specimen	Drawing Number	Maximum Heating Rate
		℃/s (℉/s)
6 mm dia x 9 mm long	SMC206B	15 (27)
10 mm dia x 15 mm long	SMC203B	15 (27)
15 mm dia x 22 mm long	SMC210B	15 (27)

12.4 Cooling Rates

Free Cooling Rates

The Gleeble system is able to control the specimen cooling rate based on conductive heat transfer. The efficiency and maximum rate of conductive cooling is directly impacted by grip and specimen geometry, material, cleanliness, and system's chilled process fluid flow rate.

The maximum cooling rates listed below are average rates for 1018 carbon steel uniaxial compression specimens, held between Si_3N_4 anvils, and in a rough vacuum atmosphere.

Specimen	Drawing Number	Temperature Range	Cooling Rate
		℃ (℉)	℃/s (℉/s)
6 mm dia x 9 mm long	SMC206B	1,000 - 500 (1,832 - 932)	25 (45)
10 mm dia x 15 mm long	SMC203B	1,000 - 500 (1,832 - 932)	5 (9)
15 mm dia x 22 mm long	SMC210B	1,000 - 500 (1,832 - 932)	2 (1.1)

Quench Cooling Rates

Refer to *Quench Kits* (page 285) for optional quench systems that are available. All quench systems can use compressed air or inert gas to cool the specimen at high rates. A mixture of compressed air and water can also be used in the quench systems for even higher cooling rates.

Air Quenching Rates

Maximum cooling rates listed below are average rates for 1018 carbon steel specimens, held between Si_3N_4 anvils, and air quenched using a *Quench Tank* (page 283) and *Multi-Function Open Quench Spray Nozzle Kit* (page 286) with a maximum of 8.2 bar (120 psi) available air pressure. See *Quench Systems* (page 283) for more information about quench kits and quench tanks.

Specimen	Drawing Number	Cooling Rate
		℃/s (℉/s)
6 mm dia x 9 mm long	SMC206B	250 (450)
10 mm dia x 15 mm long	SMC203B	40 (72)

Water Quenching Rates

Maximum cooling rates listed below are average rates for 1018 carbon steel specimens, held between Si_3N_4 anvils, and water quenched using a *Quench Tank* (page 283) and *Multi-Function Open Quench Spray Nozzle Kit* (page 286) with a maximum of 8.2 bar (120 psi) available air pressure. See *Quench Systems* (page 283) for more information about quench kits and quench tanks.

Specimen	Drawing Number	Temperature Range	Cooling Rate
		℃ (℉)	℃/s (℉/s)
6 mm dia x 9 mm long	SMC206B	1,000 - 300 (1,832 - 572)	500 (900)
10 mm dia x 15 mm long	SMC203B	1,000 - 300 (1,832 - 572)	350 (630)

12.5 Temperature Uniformity Within The Specimen

Temperature uniformity within the specimen is highly dependent on multiple factors, including sample geometry, coil geometry, sample material, and anvil material.

Tests were performed using 1018 carbon steel uniaxial compression specimens, quartz anvils, and the HTR5006 induction coil. Temperature was measured at the center of the sample and 1 mm from each end of the sample. Gradient is reported as the difference from the center measurement to the edge measurement.

Specimen	Drawing Number	Surface Thermal Gradient
6 mm dia x 9 mm long	SMC206B	±30 °C (86 °F)
10 mm dia x 15 mm long	SMC203B	±10 °C (50 °F)
15 mm dia x 22 mm long	SMC210B	±30 °C (86 °F)

12.5.1 Reproducibility

Thermal gradients in resistance and induction-heated specimens are based on the properties of the specimen material being heated. Thermal gradients in induction systems are also influenced by heating coil geometry. All specimens with the same physical, mechanical, electrical and chemical properties will have the same gradients, within the accuracy of the control system, provided that the specimen grips, anvils, and induction coils are in good condition and properly aligned.

12.6 Specimens

The *Gleeble Induction Heating System (IHS)* (page 167) can be used in testing all typical Gleeble *specimen* (page 378) sizes. However, as with direct resistance heating, induction heating rates, cooling rates, and thermal gradients are highly dependent on material properties, sample geometry and experimental setup. Larger specimens will decrease heating and cooling rates, and may reduce the maximum allowable temperature or time at temperature. Higher temperatures may be possible with smaller or specially designed specimens and custom induction coils. Damage caused by the use of non-recommended sample sizes, temperatures, or testing times will not be covered under the warranty.

12.7 Compression Kits

In order to account for the extended anvil length for use with the Induction Heating System, compression anvil base assemblies have been specially modified for use in the Hydrawedge II MCU and the Compression Test Adapter. General-Purpose MCU anvil bases can be used for Induction and Resistive based heating methods. When preforming any compression testing with the Induction Heating System, induction based anvils *must* be used.

12.7.1 Uniaxial Compression - Induction Anvil Bases

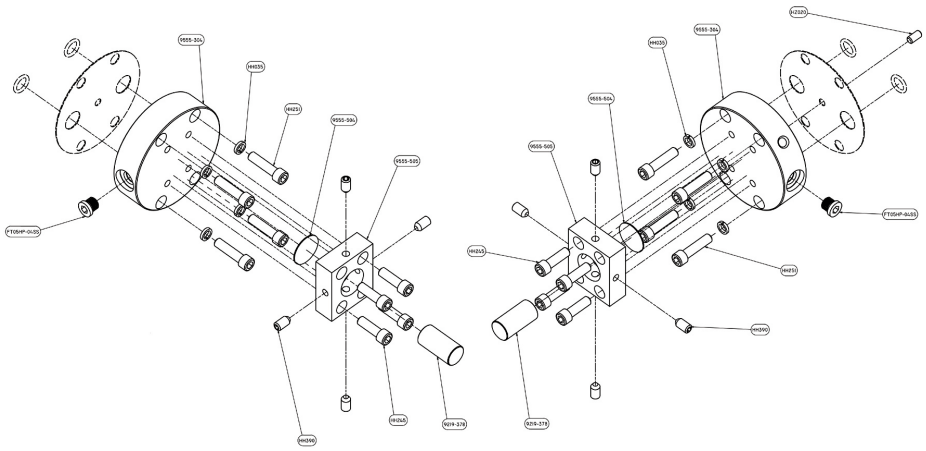


Fig. 12.3: Hydrawedge II Mounted - ISO-T Flow Stress Anvil Assembly - Induction Heating System - DSI# 9555-006.

Part Number	Description	Sold As
9555-006	ISO-T Uniaxial Compression Anvil Assembly - Hydrawedge II MCU or Compression Test Adapter - only used with the Induction Heating System	Kit
9555-100	*ISO-T Uniaxial Compression Anvil Assembly* (page 211) - General-Purpose MCU Pocket Jaws - Requires *Induction Specific Anvils* (page 173) when used with the Induction Heating System	

Uniaxial Compression - Induction Anvils

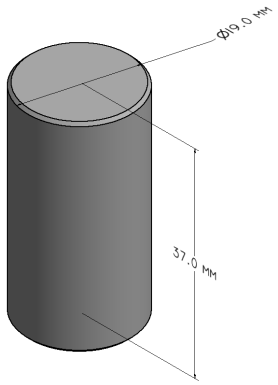


Fig. 12.4: Uniaxial Compression Anvil - Silicon Nitride - DSI# 9219-378.

Part Number	Description	Sold As
9219-375S	Uniaxial Compression Anvil - Quartz - 19.1 mm dia x 37 mm long (0.748 in dia x 1.456 in long) - Induction Heating System only	Ea.
9219-378	Uniaxial Compression Anvil - Silicon Nitride - 19.1 mm dia x 37 mm long (0.748 in dia x 1.456 in long) - Induction Heating System only	Ea.

12.7.2 Small Plane Strain - Induction Anvil Bases

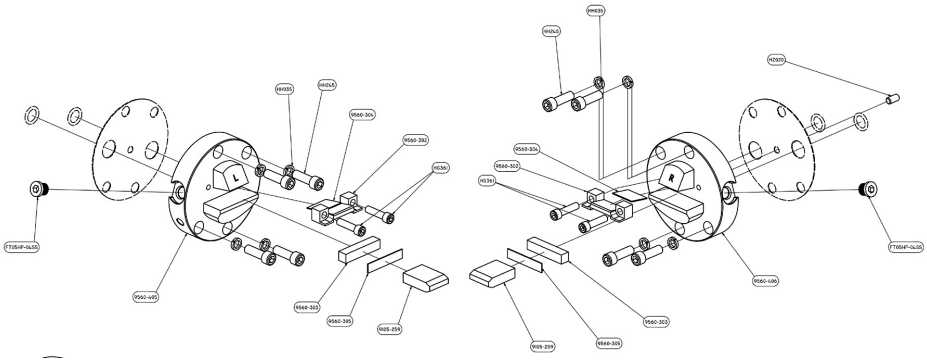


Fig. 12.5: Hydrawedge II Mounted - Small Plane Strain - Induction Heating System - DSI# 9560-112.

Part Number	Description	Sold As
9560-112	Small Plane Stain Anvil Base Assembly - Hydrawedge II Mounted - only used with the Induction Heating System	Kit
9560-113	Small Plane Stain Anvil Base Assembly - Compression Test Adapter Mounted - only used with the Induction Heating System	Kit
9560-001	*Small Plane Strain Anvil Base Assembly* (page 223) - General-Purpose MCU Pocket Jaws - Requires *Induction Specific Anvils* (page 174) when used with the Induction Heating System	

Small Plane Strain - Induction Anvils

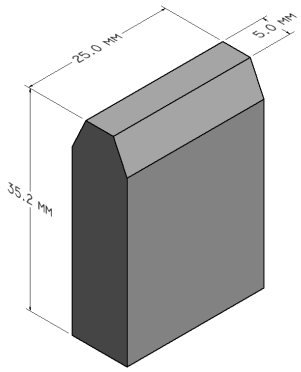


Fig. 12.6: Extended Small Plane Strain Anvil - Silicon Nitride - DSI# 9105-259.

Part Number	Description	Sold As
9105-259	Extended Small Plane Strain Anvil - Silicon Nitride - 5 x 25 x 20 mm (0.196 x 0.984 x 0.787 in) - Induction Heating System only	Ea.
9105-300	Extended Small Plane Strain Anvil - Quartz - 5 x 25 x 20 mm (0.196 x 0.984 x 0.787 in) - Induction Heating System only	Ea.

12.7.3 Large Plane Strain - Induction Anvil Bases

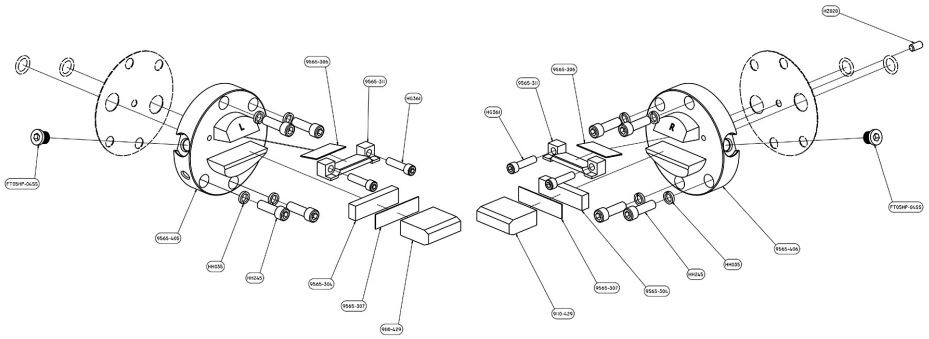


Fig. 12.7: Hydrawedge II Mounted - Large Plane Strain - Induction Heating System - DSI# 9565-110.

Part Number	Description	Sold As
9565-110	Large Plane Stain Anvil Base Assembly - Hydrawedge II Mounted - only used with the Induction Heating System	Kit
9565-111	Large Plane Stain Anvil Base Assembly - Compression Test Adapter Mounted - only used with the Induction Heating System	Kit

Large Plane Strain -Induction Anvils

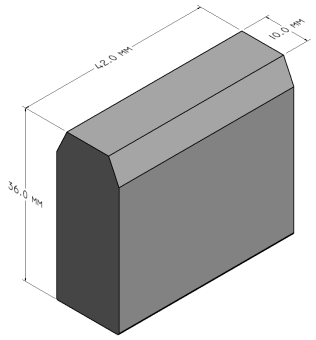


Fig. 12.8: Extended Large Plane Strain Anvil - Silicon Nitride - DSI# 9110-429.

Part Number	Description	Sold As
9110-429	Extended Large Plane Strain Anvil - Silicon Nitride - 10 x 42 x 36 mm (0.393 x 1.653 x 1.417 in) - Induction Heating System only	Ea.
9110-430	Extended Large Plane Strain Anvil - Quartz 10 x 42 x 36 mm - (0.393 x 1.653 x 1.417 in) - Induction Heating System only	Ea.

12.8 Quenching Kits

12.8.1 Induction Heating System Quench Kits

Multi-Function Open Quench Spray Nozzle Kit

The 31733 Multi-Function Open Quench Spray Nozzle Kit features a surface quenching design with sprayer nozzles that quench the specimen by direct contact with the quenching medium. The spray heads are mounted outside the Gleeble's Pocket Jaws, above and below the test specimen. When the Multi-Function Quench Spray Nozzles are used, the quenching medium is sprayed directly on the specimen. If the Gleeble is equipped with a vacuum system, the vacuum is turned off to prevent the quench medium from contaminating the vacuum pump.

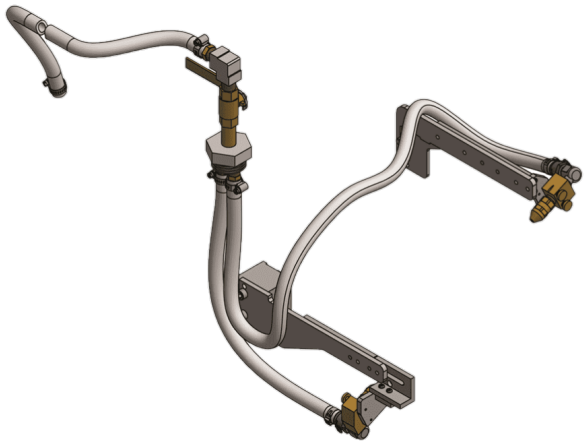


Fig. 12.9: Multi-Function Open Quench Spray Nozzle Kit - DSI# 31733.

This quench spray nozzle kit can be used on the Pocket Jaws of the *General-Purpose Mobile Conversion Unit* (page 49) MCU, the *Low-Force Pocket Jaws* (page 241) for the Gleeble 3500 and 3800, the *Compression Test Adapter* (page 237), and with the *Gleeble Induction Heating System (IHS)* (page 167).

Part Number	Description	Sold As
31733	Multi-Function Open Quench Spray Nozzle Kit	Kit

Hydrawedge II - Multi-Function Open Quench Spray Nozzle Kit

The 31735 Hydrawedge II - Multi-Function Open Quench Spray Nozzle Kit features a surface quenching design with sprayer nozzles that quench the specimen by direct contact with the quenching medium. The spray heads are mounted outside the Gleeble's anvil faces, above and below the test specimen. When the Multi-Function Open Quench Spray Nozzles are used, the quenching medium is sprayed directly on the specimen. If the Gleeble is equipped with a vacuum system, the vacuum is turned off to prevent the quench medium from contaminating the vacuum pump.

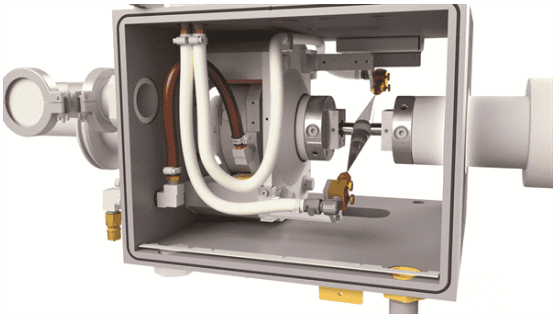


Fig. 12.10: Multi-Function Open Quench Spray Nozzle Kit - Hydrawedge II - DSI# 31735.

The 37135 quench system is only used on the *Hydrawedge II* (page 55) MCU and can be used with the *Gleeble Induction Heating System (IHS)* (page 167).

Part Number	Description	Sold As
31735	Hydrawedge II - Multi-Function Open Quench Spray Nozzle Kit	Kit

12.9 Induction Coils



Fig. 12.11: Induction Coils.

Part Number	Description	Sold As
HTR5007	Round Coil	Ea.
HTR5006A	Uniaxial Compression Coil	Ea.
HTR5009A	Small Plane Strain Coil	Ea.
HTR5008A	Large Plane Strain Coil	Ea.

Section 13

Gleeble Grips

Contents

- *What Are Gleeble Grips?* (page 180)
  - *Grip Selection* (page 180)
- *3000 Series* (page 181)
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    - *Round* (page 182)
    - *Square* (page 184)
    - *Flat* (page 185)
  - *Stainless Steel Grips* (page 187)
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    - *Flat* (page 192)
  - *Backing Nuts* (page 196)
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13.1 What Are Gleeble Grips?

Grips are used to “clamp” specimens while testing. There are many different sizes, materials, and geometries of grips to allow for a wide array of applications. Grips are typically characterized by a few parameters; material, size, geometry, and contact area. For more information about the effects of Gleeble Grips and Specimen geometry on the heating characteristics of a test reference the Grips Section[26] of the Gleeble General Testing Guide.

13.1.1 Grip Selection

Selecting the best grips for a particular application is important for good testing in the Gleeble. There are a number of factors that go into grip selection, careful consideration should go into grip selection for each new application in the machine.

Material

The material of the grips can change the heating and cooling characteristics of the specimen. It also has an effect on the thermal gradient of the specimen. DSI offers Copper and Stainless Steel Grips.

Copper grips have a very high thermal conductivity which allows them to cool the specimen down much faster than Stainless steel due to their ability to transfer heat from the liquid cooled wear plate to the specimen faster than stainless steel grips. Consider using copper grips for applications which require fast cooling rates. Another consideration is the electrical conductivity of the grips. Copper has a much higher electrical conductivity than Stainless Steel and this can allow for faster heating rates. However, copper grips can cause the thermal gradient to be very steep (narrow hot zone). This is desirable in some applications, such as hot ductility, welding, and casting, however other applications may require a more isothermal gradient.

Due to the lower electrical conductivity of Stainless steel, the grips themselves become hotter during the test, which makes the specimen more isothermal. Another way to make the specimen more isothermal is to use partial contact or hot grips. The small contact area on the specimen not only increases the electrical resistance, but also reduces the thermal sink. For the most uniform hot zone, consider using Stainless Steel Hot Grips.

Specimen Size

The size of the grips should be selected to match the size of the specimen. For the best performance the tolerance between the size of the specimen and the corresponding surfaces of the grips must be minimized.

Geometry

The geometry of the grips must match the geometry of the specimen. At the specimen to grip interface a round grip must be used to retain a round specimen. Square grips can be used to retain a square specimen. Flat grips are used for flat specimens.

Contact Area

- Some grips have less contact area than other to change the heating characteristics.
  - Full Contact:

    Full Contact grips provide the largest interface surface area between the specimen and the grips. A Full Contact grip will utilized the entire length of the grip to contact the specimen. These grips provide the most efficient heating and cooling rates possible.
  - Partial Contact:

[26] https://www.gleeble-tech.com/gleebledocs/g3/testing_guide/general.html#grips

Partial Contact grips provide approximately half the contact area when compared to a Full Contact grip. By reducing the contact area between the grips and the specimen the specimen experiences a greater electrical resistance. The increased resistance results in a larger uniform hot zone on the specimen.

- Hot Grips:

  Hot Grips provide the smallest possible contact area between the grips and the specimen. With a minimal contact surface, and maximum electrical resistance, Hot Grips create the largest uniform hot zone of any Gleeble grips.

13.2 3000 Series

Designed to specifically fit a Gleeble 3500, 3800, and 3180; 3000 Series Grips build off nearly a century of design, research, and study. This ensures continued accuracy and consistency of testing.

13.2.1 Copper Grips

Copper grips have a very high thermal and electrical conductivity. This allows them to cool the specimen down much faster than Stainless Steel. Due to Copper's ability to transfer heat from the specimen to the liquid cooled wear plate faster than Stainless Steel grips consider using copper grips for applications which require fast cooling rates.

Another consideration in using Copper grips is the electrical conductivity of the material. Copper has a much higher electrical conductivity than Stainless Steel. This can allow for faster heating rates. However, copper grips can cause the thermal gradient to be very steep (narrow hot zone). This is desirable in some applications, such as hot ductility, welding, and casting, however other applications may require a more isothermal gradient.

Round

Matching the geometry and size of the specimen is important to achieve the best Gleeble performance. Specimens that have a round grip contact area must be tested using Round Grips.

Full Contact Copper - Round

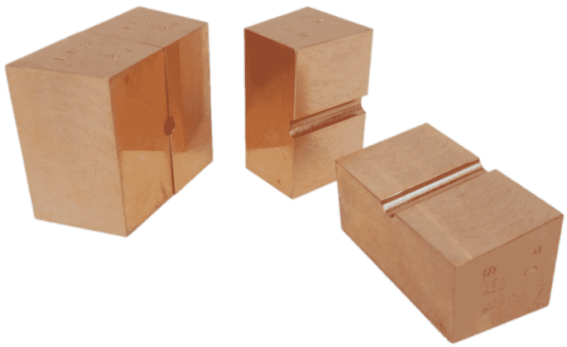


Fig. 13.1: Full Contact Copper Round Grips.

Metric Full Contact Copper Round Grips		
Part Number	**Specimen Size**	**Sold As**
9000-060	6 mm	Set
9000-080	8 mm	Set
9000-100	10 mm	Set
9000-120	12 mm	Set
9000-140	14 mm	Set
9000-160	16 mm	Set
9000-200	20 mm	Set

Imperial Full Contact Copper Round Grips		
Part Number	**Specimen Size**	**Sold As**
9001-040	1/4 in	Set
9001-050	5/16 in	Set
9001-060	3/8 in	Set
9001-070	7/16 in	Set
9001-080	1/2 in	Set
9001-090	9/16 in	Set
9001-100	5/8 in	Set
9001-120	3/4 in	Set

Partial Contact Copper - Round

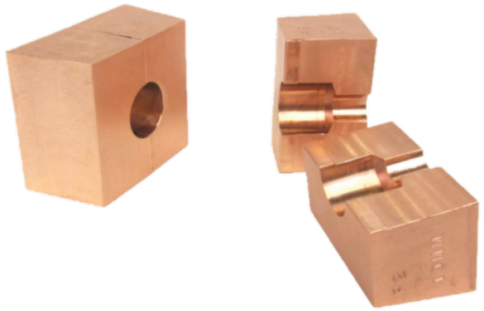


Fig. 13.2: Partial Contact Copper Round Grips.

Metric Partial Contact Copper Round Grips		
Part Number	**Specimen Size**	**Sold As**
9050-045	4.5 mm	Set
9050-060	6 mm	Set
9050-080	8 mm	Set
9050-100	10 mm	Set
9050-120	12 mm	Set
9050-140	14 mm	Set

Square

Matching the geometry and size of the specimen is important to achieve the best Gleeble performance. Specimens that have a square grip contact area must be tested using Square Grips.

Full Contact Copper - Square

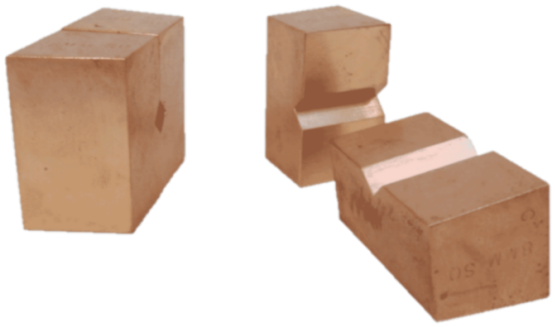


Fig. 13.3: Partial Contact Copper Round Grips.

Metric Full Contact Copper Square Grips		
Part Number	**Specimen Size**	**Sold As**
9002-040	4 mm	Set
9002-060	6 mm	Set
9002-080	8 mm	Set
9002-100	10 mm	Set
9002-110	11 mm	Set
9002-120	12 mm	Set
9002-140	14 mm	Set
9002-160	16 mm	Set
9002-200	20 mm	Set

Imperial Full Contact Copper Square Grips		
Part Number	**Specimen Size**	**Sold As**
9003-040	1/4 in	Set
9003-050	5/16 in	Set
9003-060	3/8 in	Set
9003-070	7/16 in	Set
9003-080	1/2 in	Set
9003-090	9/16 in	Set
9003-100	5/8 in	Set
9003-120	3/4 in	Set

Flat

Flat grips are used to secure flat, sheet, or strip specimens within the Gleeble system. These grips use a pin to retain the specimen between the grips, enabling tension forces to be applied to the specimen during testing.

		
Grips with a 5mm Spring Pin are used for forces up to 18 kN in tension.	Grips with a 3/16 inch Tension Pin are used for forces up to 17 kN in tension.	Grips with a 10 mm Tension Pin are used for all other tests.

Full Contact Copper - Flat - 5 mm Spring Pin

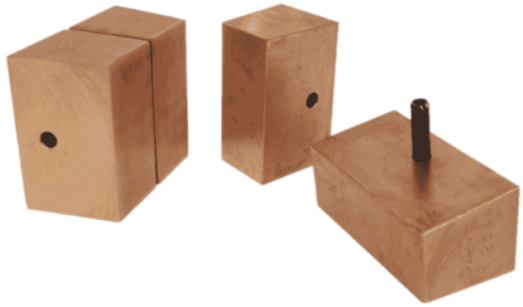


Fig. 13.4: Full Contact Copper Flat Grips with 5 mm Spring Pin.

Metric Full Contact Copper Flat Grips 5 mm Spring Pin		
Part Number	**Specimen Size Range**	**Sold As**
9006-000	0.00 mm - 1.25 mm	Set
9006-010	1.00 mm - 2.25 mm	Set
9006-020	2.00 mm - 3.25 mm	Set
9006-030	3.00 mm - 4.25 mm	Set
9006-040	4.00 mm - 5.25 mm	Set
9006-050	5.00 mm - 6.25 mm	Set
9006-060	6.00 mm - 7.25 mm	Set
9006-070	7.00 mm - 8.25 mm	Set
9006-080	8.00 mm - 9.25 mm	Set
9006-090	9.00 mm - 10.25 mm	Set
9006-100	10.00 mm - 11.25 mm	Set
9006-110	11.00 mm - 12.25 mm	Set
9006-120	12.00 mm - 13.25 mm	Set

Full Contact Copper - Flat - 10 mm Tension Pin

Metric Full Contact Copper Flat Grips 10 mm Tension Pin		
Part Number	**Specimen Size Range**	**Sold As**
9006-500	0.00 mm - 1.25 mm	Set
9006-510	1.00 mm - 2.25 mm	Set
9006-520	2.00 mm - 3.25 mm	Set
9006-530	3.00 mm - 4.25 mm	Set
9006-540	4.00 mm - 5.25 mm	Set
9006-550	5.00 mm - 6.25 mm	Set
9006-560	6.00 mm - 7.25 mm	Set
9006-570	7.00 mm - 8.25 mm	Set
9006-580	8.00 mm - 9.25 mm	Set
9006-590	9.00 mm - 10.25 mm	Set
9006-600	10.00 mm - 11.25 mm	Set
9006-610	11.00 mm - 12.25 mm	Set
9006-620	12.00 mm - 13.25 mm	Set

13.2.2 Stainless Steel Grips

Due to the lower electrical conductivity of Stainless steel, the grips themselves become hotter during the test, which makes the specimen more isothermal. Another way to make the specimen more isothermal is to use partial contact or hot grips. The small contact area on the specimen not only increases the electrical resistance, but also reduces the thermal sink. For the most uniform hot zone, consider using Stainless Steel Hot Grips.

Round

Matching the geometry and size of the specimen is important to achieve the best Gleeble performance. Specimens that have a round grip contact area must be tested using Round Grips.

Full Contact Stainless Steel - Round

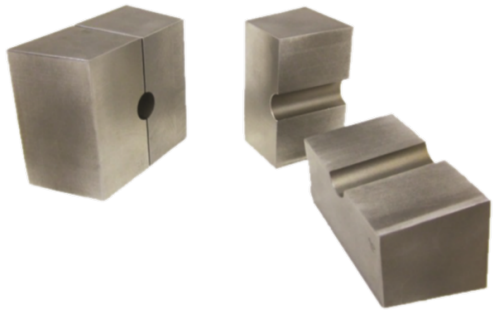


Fig. 13.5: Full Contact Stainless Steel Round Grips.

Metric Full Contact Stainless Steel Round Grips		
Part Number	**Specimen Size**	**Sold As**
9065-060	6 mm	Set
9065-080	8 mm	Set
9065-100	10 mm	Set
9065-110	11 mm	Set
9065-120	12 mm	Set
9065-140	14 mm	Set
9065-160	16 mm	Set
9065-200	20 mm	Set

Imperial Full Contact Stainless Steel Round Grips		
Part Number	**Specimen Size**	**Sold As**
9066-040	1/4 in	Set
9066-050	5/16 in	Set
9066-060	3/8 in	Set
9066-070	7/16 in	Set
9066-080	1/2 in	Set
9066-090	9/16 in	Set
9066-100	5/8 in	Set
9066-120	3/4 in	Set
9066-160	1.0 in	Set

Partial Contact Stainless Steel - Round

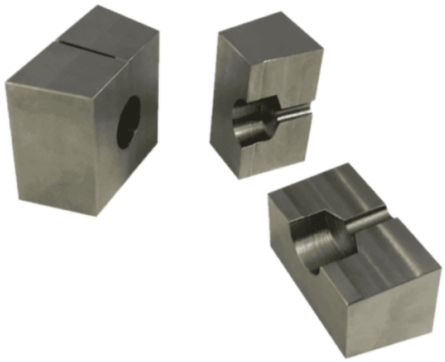


Fig. 13.6: Partial Contact Stainless Steel Round Grips.

Metric Partial Contact Stainless Steel Round Grips		
Part Number	**Specimen Size**	**Sold As**
9060-100	10 mm	Set
9060-200	20 mm	Set

Hot Grips Stainless Steel - Round

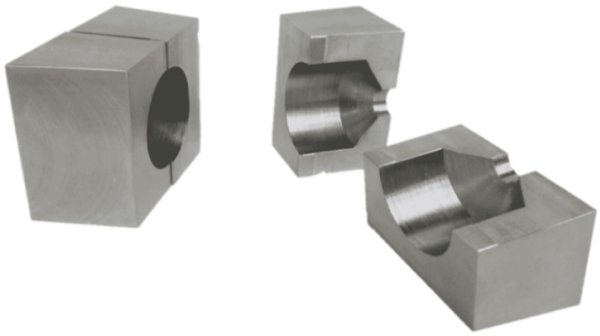


Fig. 13.7: Hot Grip Stainless Steel Round Grips.

Metric Hot Grip Stainless Steel Round Grips		
Part Number	**Specimen Size**	**Sold As**
9010-040	4 mm	Set
9010-060	6 mm	Set
9010-080	8 mm	Set
9010-100	10 mm	Set
9010-110	11 mm	Set
9010-120	12 mm	Set
9010-140	14 mm	Set
9010-160	16 mm	Set
9010-200	20 mm	Set

Imperial Hot Grip Stainless Steel Round Grips		
Part Number	**Specimen Size**	**Sold As**
9011-040	1/4 in	Set
9011-050	5/16 in	Set
9011-060	3/8 in	Set
9011-070	7/16 in	Set
9011-080	1/2 in	Set
9011-090	9/16 in	Set
9011-100	5/8 in	Set
9011-120	3/4 in	Set

Square

Matching the geometry and size of the specimen is important to achieve the best Gleeble performance. Specimens that have a square grip contact area must be tested using Square Grips.

Full Contact Stainless Steel - Square

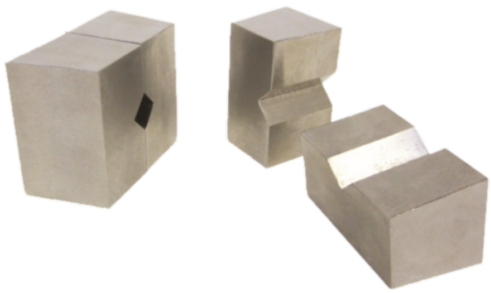


Fig. 13.8: Full Contact Stainless Steel Round Grips.

Metric Full Contact Stainless Steel Square Grips		
Part Number	**Specimen Size**	**Sold As**
9067-100	10 mm	Set
9067-110	11 mm	Set

Partial Contact Stainless Steel - Square

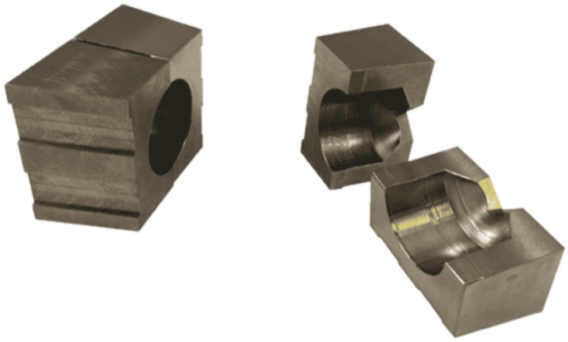


Fig. 13.9: Partial Contact Stainless Steel Square Grips.

Metric Partial Contact Stainless Steel Square Grips		
Part Number	**Specimen Size**	**Sold As**
9012-060	6 mm	Set
9012-080	8 mm	Set
9012-100	10 mm	Set
9012-120	12 mm	Set
9012-140	14 mm	Set
9012-160	16 mm	Set
9012-200	20 mm	Set

Imperial Partial Contact Stainless Steel Square Grips		
Part Number	**Specimen Size**	**Sold As**
9013-040	1/4 in	Set
9013-050	5/16 in	Set
9013-060	3/8 in	Set
9013-070	7/16 in	Set
9013-080	1/2 in	Set
9013-090	9/16 in	Set
9013-100	5/8 in	Set
9013-120	3/4 in	Set

Flat

Flat grips are used to secure flat, sheet, or strip specimens within the Gleeble system. These grips use a pin to retain the specimen between the grips, enabling tension forces to be applied to the specimen during testing.

		
Grips with a 5mm Spring Pin are used for forces up to 18 kN in tension.	Grips with a 3/16 inch Tension Pin are used for forces up to 17 kN in tension.	Grips with a 10 mm Tension Pin are used for all other tests.

Full Contact Stainless Steel - Flat - 5 mm Spring Pin

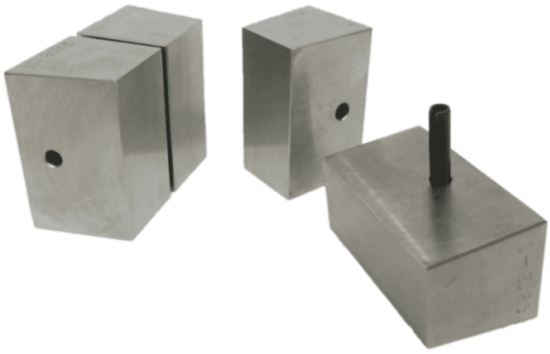


Fig. 13.10: Full Contact Stainless Steel Flat Grips with 5 mm Spring Pin.

Metric Full Contact Stainless Steel Flat Grips 5 mm Spring Pin		
Part Number	**Specimen Size Range**	**Sold As**
9007-000	0.00 mm - 1.25 mm	Set
9007-010	1.00 mm - 2.25 mm	Set
9007-020	2.00 mm - 3.25 mm	Set
9007-030	3.00 mm - 4.25 mm	Set
9007-040	4.00 mm - 5.25 mm	Set
9007-050	5.00 mm - 6.25 mm	Set
9007-060	6.00 mm - 7.25 mm	Set
9007-070	7.00 mm - 8.25 mm	Set
9007-080	8.00 mm - 9.25 mm	Set
9007-090	9.00 mm - 10.25 mm	Set
9007-100	10.00 mm - 11.25 mm	Set
9007-110	11.00 mm - 12.25 mm	Set
9007-120	12.00 mm - 13.25 mm	Set

Full Contact Stainless Steel - Flat - 10 mm Tension Pin

Metric Full Contact Stainless Steel Flat Grips 10 mm Tension Pin		
Part Number	**Specimen Size Range**	**Sold As**
9007-500	0.00 mm - 1.25 mm	Set
9007-510	1.00 mm - 2.25 mm	Set
9007-520	2.00 mm - 3.25 mm	Set
9007-530	3.00 mm - 4.25 mm	Set
9007-540	4.00 mm - 5.25 mm	Set
9007-550	5.00 mm - 6.25 mm	Set
9007-560	6.00 mm - 7.25 mm	Set
9007-570	7.00 mm - 8.25 mm	Set
9007-580	8.00 mm - 9.25 mm	Set
9007-590	9.00 mm - 10.25 mm	Set
9007-600	10.00 mm - 11.25 mm	Set
9007-610	11.00 mm - 12.25 mm	Set
9007-620	12.00 mm - 13.25 mm	Set

Partial Contact Stainless Steel - Flat - 5 mm Spring Pin



Fig. 13.11: Partial Contact Stainless Steel Flat Grips with 5 mm Spring Pin.

Metric Partial Contact Stainless Steel Flat Grips 5 mm Spring Pin		
Part Number	**Specimen Size Range**	**Sold As**
9017-000	0.00 mm - 1.25 mm	Set
9017-010	1.00 mm - 2.25 mm	Set
9017-020	2.00 mm - 3.25 mm	Set
9017-030	3.00 mm - 4.25 mm	Set
9017-040	4.00 mm - 5.25 mm	Set
9017-050	5.00 mm - 6.25 mm	Set
9017-060	6.00 mm - 7.25 mm	Set
9017-070	7.00 mm - 8.25 mm	Set
9017-080	8.00 mm - 9.25 mm	Set
9017-090	9.00 mm - 10.25 mm	Set
9017-100	10.00 mm - 11.25 mm	Set
9017-110	11.00 mm - 12.25 mm	Set
9017-120	12.00 mm - 13.25 mm	Set

Hot Grips Stainless Steel - Flat

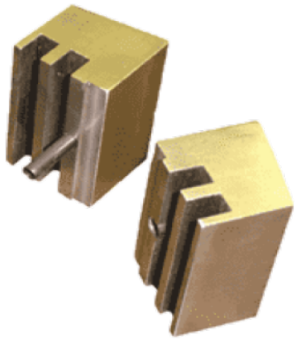


Fig. 13.12: Hot Grip Stainless Steel Flat Grips with 5 mm Spring Pin.

Metric Hot Grip Stainless Steel Flat Grips 5 mm Spring Pin		
Part Number	**Specimen Size Range**	**Sold As**
9016-000	0.00 mm - 1.25 mm	Set
9016-010	1.00 mm - 2.25 mm	Set
9016-020	2.00 mm - 3.25 mm	Set
9016-030	3.00 mm - 4.25 mm	Set
9016-040	4.00 mm - 5.25 mm	Set
9016-050	5.00 mm - 6.25 mm	Set
9016-060	6.00 mm - 7.25 mm	Set
9016-070	7.00 mm - 8.25 mm	Set
9016-080	8.00 mm - 9.25 mm	Set
9016-090	9.00 mm - 10.25 mm	Set
9016-100	10.00 mm - 11.25 mm	Set
9016-110	11.00 mm - 12.25 mm	Set
9016-120	12.00 mm - 13.25 mm	Set

13.2.3 Backing Nuts

To best secure a specimen in the Gleeble Pocket Jaws for tension and basic compression tests, Backing Nuts are used. Threaded onto the ends of the specimen these Nuts provide safe and secure tension within the Grips and Jaw assemblies. Backing Nuts are threaded for round samples with a specified thread diameter and pitch.

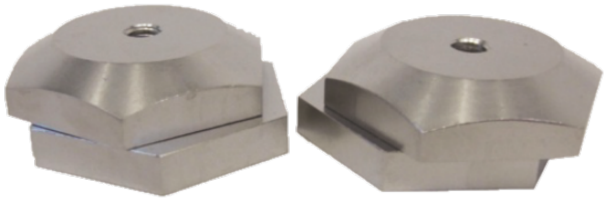


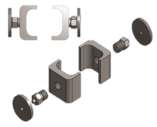
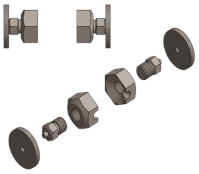
Fig. 13.13: Backing Nuts.

Metric Backing Nuts		
Part Number	**Description**	**Sold As**
9020-060	6 mm dia (thread size: 6 mm x 1.0)	Set of 4
9020-080	8 mm dia (thread size: 8 mm x 1.25)	Set of 4
9020-100	10 mm dia (thread size: 10 mm x 1.5)	Set of 4
9020-120	12 mm dia (thread size: 12 mm x 1.75)	Set of 4
9020-140	14 mm dia (thread size: 14 mm x 2.0)	Set of 2
9020-160	16 mm dia (thread size: 16 mm x 2.0)	Set of 2
9020-180	18 mm dia (thread size: 18 mm x 2.5)	Set of 2
9020-200	20 mm dia (thread size: 20 mm x 2.5)	Set of 2

Imperial Backing Nuts		
Part Number	**Description**	**Sold As**
9026-040	1/4 in dia (thread size: 1/4 in x 20)	Set of 4
9026-050	5/16 in dia (thread size: 5/16 in x 18)	Set of 4
9026-060	3/8 in dia (thread size: 3/8 in x 16)	Set of 4
9026-070	7/16 in dia (thread size: 7/16 in x 14)	Set of 4
9026-080	1/2 in dia (thread size: 1/2 in x 13)	Set of 4
9026-090	9/16 in dia (thread size: 9/16 in x 12)	Set of 2
9026-100	5/8 in dia (thread size: 5/8 in x 11)	Set of 2
9026-120	3/4 in dia (thread size: 3/4 in x 10)	Set of 2
9026-160	1.00 in dia (thread size: 1.00 in x 10)	Set of 2

13.2.4 Jaw Jacks

Jaw Jacks are used in the Gleeble 3500, 3800, and 3180 to secure the specimen and grip assembly within the General-Purpose Pocket Jaws. Jaw Jacks come in three different styles. Standard U-Jacks can be used for low speed or low-force tension however they are best suited for thermal only tests. Conical Jacks are used in conjunction with Backing Nuts. These jacks are well suited for tension, compression, or thermal only tests of threaded specimens. Heavy Duty Jacks are best suited for compression testing.

		
Standard U-Jacks	Conical Jacks	Heavy Duty Jacks

U-Jacks		
Part Number	**Description**	**Sold As**
GA00175A	Standard U-Jacks with plates - 2 per kit	Kit
GA00173A	Round Jaw Plate for standard U-shaped Jaw Jacks	Ea.
GA00174C	Long Screw Jaw Jack for standard U-shaped Jaw Jacks	Ea.
GA00175AD	Jaw Jack U-Clamp for standard U-shaped Jaw Jacks	Ea.

Conical Jacks		
Part Number	**Description**	**Sold As**
GA00175B	Conical Jacks with plates - 2 per kit	Ea.
GA00173A	Round Jaw Plate - Standard U-shaped Jaw Jacks	Ea.
GA00174A	Jaw Cone Jack	Ea.
GA00174C	Long Screw Jaw Jack - Standard U-shaped Jaw Jacks	Ea.

Heavy Duty Jacks		
Part Number	**Description**	**Sold As**
GA00197CA	Heavy Duty Jacks - 2 per kit	Kit
GA00197B	Heavy Duty Jaw Jack Base	Ea.
GA00197D	Heavy Duty Jaw Jack Screw	Ea.
GA00197E	Heavy Duty Jaw Jack Washer	Ea.
GA00197F	Heavy Duty Jaw Jack Handle	Ea.
GA00197G	Heavy Duty Jaw Jack Plate	Ea.
HE210	10-32 x 3/9 in LG. P.H.M.S SS Screw	Ea.

13.3 500 Series

Resized and redesigned specifically for the smaller platform of a Gleeble 500 Series systems these grips retain the exceptional performance of traditional Gleeble grips while increasing use-ability.

13.3.1 Copper Grips

Copper grips have a very high thermal and electrical conductivity. This allows them to cool the specimen down much faster than Stainless Steel. Due to Copper's ability to transfer heat from the specimen to the liquid cooled wear plate faster than Stainless Steel grips consider using copper grips for applications which require fast cooling rates.

Another consideration in using Copper grips is the electrical conductivity of the material. Copper has a much higher electrical conductivity than Stainless Steel. This can allow for faster heating rates. However, copper grips can cause the thermal gradient to be very steep (narrow hot zone). This is desirable in some applications, such as hot ductility, welding, and casting, however other applications may require a more isothermal gradient.

Round

Matching the geometry and size of the specimen is important to achieve the best Gleeble performance. Specimens that have a round grip contact area must be tested using Round Grips.

Full Contact Copper - Round

Metric Full Contact Copper Round Grips		
Part Number	**Specimen Size**	**Sold As**
9300-040	4 mm	Set
9300-050	5 mm	Set
9300-060	6 mm	Set
9300-070	7 mm	Set
9300-080	8 mm	Set
9300-090	9 mm	Set
9300-100	10 mm	Set

Imperial Full Contact Copper Round Grips		
Part Number	**Specimen Size**	**Sold As**
9300-520	1/8 in	Set
9300-530	3/16 in	Set
9300-540	1/4 in	Set
9300-550	5/16 in	Set
9300-560	3/8 in	Set

Partial Contact Copper - Round

Metric Partial Contact Copper Round Grips		
Part Number	**Specimen Size**	**Sold As**
9308-040	4 mm	Set
9308-050	5 mm	Set
9308-060	6 mm	Set
9308-070	7 mm	Set
9308-080	8 mm	Set
9308-090	9 mm	Set
9308-100	10 mm	Set

Imperial Partial Contact Copper Round Grips		
Part Number	**Specimen Size**	**Sold As**
9308-520	1/8 in	Set
9308-530	3/16 in	Set
9308-540	1/4 in	Set
9308-550	5/16 in	Set
9308-560	3/8 in	Set

Square

Matching the geometry and size of the specimen is important to achieve the best Gleeble performance. Specimens that have a square grip contact area must be tested using Square Grips.

Full Contact Copper - Square

Metric Full Contact Copper Square Grips		
Part Number	**Specimen Size**	**Sold As**
9301-040	4 mm	Set
9301-050	5 mm	Set
9301-060	6 mm	Set
9301-070	7 mm	Set
9301-080	8 mm	Set
9301-090	9 mm	Set
9301-100	10 mm	Set
9301-110	11 mm	Set

Imperial Full Contact Copper Square Grips		
Part Number	**Specimen Size**	**Sold As**
9301-520	1/8 in	Set
9301-530	3/16 in	Set
9301-540	1/4 in	Set
9301-550	5/16 in	Set
9301-560	3/8 in	Set

Partial Contact Copper - Square

Metric Partial Contact Copper Square Grips		
Part Number	**Specimen Size**	**Sold As**
9309-040	4 mm	Set
9309-050	5 mm	Set
9309-060	6 mm	Set
9309-070	7 mm	Set
9309-080	8 mm	Set
9309-090	9 mm	Set
9309-100	10 mm	Set
9309-110	11 mm	Set

Imperial Partial Contact Copper Square Grips		
Part Number	**Specimen Size**	**Sold As**
9309-520	1/8 in	Set
9309-530	3/16 in	Set
9309-540	1/4 in	Set
9309-550	5/16 in	Set
9309-560	3/8 in	Set

Flat

Flat grips are used to secure flat, sheet, or strip specimens within the Gleeble system. These grips use a pin to retain the specimen between the grips, enabling tension forces to be applied to the specimen during testing.

		
Grips with a 5mm Spring Pin are used for forces up to 18 kN in tension.	Grips with a 3/16 inch Tension Pin are used for forces up to 17 kN in tension.	Grips with a 10 mm Tension Pin are used for all other tests.

Full Contact Copper - Flat - 3/16 in Or 10 mm Pins

Metric Full Contact Copper Flat Grips 3/16 in Pin		
Part Number	**Specimen Size Range**	**Sold As**
9302-000	0.00 mm - 1.25 mm	Set
9302-010	1.00 mm - 2.25 mm	Set
9302-020	2.00 mm - 3.25 mm	Set
9302-030	3.00 mm - 4.25 mm	Set
9302-040	4.00 mm - 5.25 mm	Set

Metric Full Contact Copper Flat Grips 10 mm Pin		
Part Number	**Specimen Size Range**	**Sold As**
9302-500	0.00 mm - 1.25 mm	Set
9302-510	1.00 mm - 2.25 mm	Set
9302-520	2.00 mm - 3.25 mm	Set
9302-530	3.00 mm - 4.25 mm	Set
9302-540	4.00 mm - 5.25 mm	Set

13.3.2 Stainless Steel Grips

Due to the lower electrical conductivity of Stainless steel, the grips themselves become hotter during the test, which makes the specimen more isothermal. Another way to make the specimen more isothermal is to use partial contact or hot grips. The small contact area on the specimen not only increases the electrical resistance, but also reduces the thermal sink. For the most uniform hot zone, consider using Stainless Steel Hot Grips.

Round

Matching the geometry and size of the specimen is important to achieve the best Gleeble performance. Specimens that have a round grip contact area must be tested using Round Grips.

Full Contact Stainless Steel - Round

Metric Full Contact Stainless Steel Round Grips		
Part Number	**Specimen Size**	**Sold As**
9311-040	4 mm	Set
9311-050	5 mm	Set
9311-060	6 mm	Set
9311-070	7 mm	Set
9311-080	8 mm	Set
9311-090	9 mm	Set
9311-100	10 mm	Set

Imperial Full Contact Stainless Steel Round Grips		
Part Number	**Specimen Size**	**Sold As**
9311-520	1/8 in	Set
9311-530	3/16 in	Set
9311-540	1/4 in	Set
9311-550	5/16 in	Set
9311-560	3/8 in	Set

Partial Contact Stainless Steel - Round

Metric Partial Contact Stainless Steel Round Grips		
Part Number	**Specimen Size**	**Sold As**
9310-040	4 mm	Set
9310-050	5 mm	Set
9310-060	6 mm	Set
9310-070	7 mm	Set
9310-080	8 mm	Set
9310-090	9 mm	Set
9310-100	10 mm	Set

Imperial Partial Contact Stainless Steel Round Grips		
Part Number	**Specimen Size**	**Sold As**
9310-520	1/8 in	Set
9310-530	3/16 in	Set
9310-540	1/4 in	Set
9310-550	5/16 in	Set
9310-560	3/8 in	Set

Hot Grip Stainless Steel - Round

Metric Hot Grip Stainless Steel Round Grips		
Part Number	**Specimen Size**	**Sold As**
9304-040	4 mm	Set
9304-050	5 mm	Set
9304-060	6 mm	Set
9304-070	7 mm	Set
9304-080	8 mm	Set
9304-090	9 mm	Set
9304-100	10 mm	Set

Imperial Hot Grip Stainless Steel Round Grips		
Part Number	**Specimen Size**	**Sold As**
9304-520	1/8 in	Set
9304-530	3/16 in	Set
9304-540	1/4 in	Set
9304-550	5/16 in	Set
9304-560	3/8 in	Set

Square

Matching the geometry and size of the specimen is important to achieve the best Gleeble performance. Specimens that have a square grip contact area must be tested using Square Grips.

Full Contact Stainless Steel - Square

Metric Full Contact Stainless Steel Square Grips		
Part Number	**Specimen Size**	**Sold As**
9312-040	4 mm	Set
9312-050	5 mm	Set
9312-060	6 mm	Set
9312-070	7 mm	Set
9312-080	8 mm	Set
9312-090	9 mm	Set
9312-100	10 mm	Set
9312-110	11 mm	Set

Imperial Full Contact Stainless Steel Square Grips		
Part Number	**Specimen Size**	**Sold As**
9312-520	1/8 in	Set
9312-530	3/16 in	Set
9312-540	1/4 in	Set
9312-550	5/16 in	Set
9312-560	3/8 in	Set

Partial Contact Stainless Steel - Square

Metric Partial Contact Stainless Steel Square Grips		
Part Number	**Specimen Size**	**Sold As**
9305-040	4 mm	Set
9305-050	5 mm	Set
9305-060	6 mm	Set
9305-070	7 mm	Set
9305-080	8 mm	Set
9305-090	9 mm	Set
9305-100	10 mm	Set
9305-110	11 mm	Set

Imperial Partial Contact Stainless Steel Square Grips		
Part Number	**Specimen Size**	**Sold As**
9305-520	1/8 in	Set
9305-530	3/16 in	Set
9305-540	1/4 in	Set
9305-550	5/16 in	Set
9305-560	3/8 in	Set

Hot Grip Stainless Steel - Square

Metric Hot Grip Stainless Steel Square Grips		
Part Number	**Specimen Size**	**Sold As**
9313-040	4 mm	Set
9313-050	5 mm	Set
9313-060	6 mm	Set
9313-070	7 mm	Set
9313-080	8 mm	Set
9313-090	9 mm	Set
9313-100	10 mm	Set

Imperial Hot Grip Stainless Steel Square Grips		
Part Number	**Specimen Size**	**Sold As**
9313-520	1/8 in	Set
9313-530	3/16 in	Set
9313-540	1/4 in	Set
9313-550	5/16 in	Set

Flat

Flat grips are used to secure flat, sheet, or strip specimens within the Gleeble system. These grips use a pin to retain the specimen between the grips, enabling tension forces to be applied to the specimen during testing.

		
Grips with a 5mm Spring Pin are used for forces up to 18 kN in tension.	Grips with a 3/16 inch Tension Pin are used for forces up to 17 kN in tension.	Grips with a 10 mm Tension Pin are used for all other tests.

Full Contact Stainless Steel - Flat - 3/16 in Or 10 mm Pin

Metric Full Contact Stainless Steel Flat Grips 3/16 in Pin		
Part Number	**Specimen Size Range**	**Sold As**
9303-000	0.00 mm - 1.25 mm	Set
9303-010	1.00 mm - 2.25 mm	Set
9303-020	2.00 mm - 3.25 mm	Set
9303-030	3.00 mm - 4.25 mm	Set
9303-040	4.00 mm - 5.25 mm	Set

Metric Full Contact Stainless Steel Flat Grips 10 mm Pin		
Part Number	**Specimen Size Range**	**Sold As**
9303-500	0.00 mm - 1.25 mm	Set
9303-510	1.00 mm - 2.25 mm	Set
9303-520	2.00 mm - 3.25 mm	Set
9303-530	3.00 mm - 4.25 mm	Set
9303-540	4.00 mm - 5.25 mm	Set

Full Contact Stainless Steel - Flat - 3/16 in Pin

Metric Full Contact Stainless Steel Flat Grips 3/16 in Pin		
Part Number	**Specimen Size Range**	**Sold As**
9306-000	0.00 mm - 1.25 mm	Set
9306-010	1.00 mm - 2.25 mm	Set
9306-020	2.00 mm - 3.25 mm	Set
9306-030	3.00 mm - 4.25 mm	Set
9306-040	4.00 mm - 5.25 mm	Set

Partial Contact Stainless Steel - Flat - 3/16 in Pin

Metric Partial Contact Stainless Steel Flat Grips 3/16 in Pin		
Part Number	**Specimen Size Range**	**Sold As**
9307-000	0.00 mm - 1.25 mm	Set
9307-010	1.00 mm - 2.25 mm	Set
9307-020	2.00 mm - 3.25 mm	Set
9307-030	3.00 mm - 4.25 mm	Set
9307-040	4.00 mm - 5.25 mm	Set

13.3.3 Backing Nuts

To best secure a specimen in the Gleeble Pocket Jaws for tension and basic compression tests, Backing Nuts are used. Threaded onto the ends of the specimen these Nuts provide safe and secure tension within the Grips and Jaw assemblies. Backing Nuts are threaded for round samples with a specified thread diameter and pitch.

Metric Backing Nuts		
Part Number	**Description**	**Sold As**
9320-040	4.0 mm dia threaded specimens	Set of 4
9320-050	5.0 mm dia threaded specimens	Set of 4
9320-060	6.0 mm dia threaded specimens	Set of 4
9320-070	7.0 mm dia threaded specimens	Set of 4
9320-080	8.0 mm dia threaded specimens	Set of 4
9320-090	9.0 mm dia threaded specimens	Set of 4
9320-100	10.0 mm dia threaded specimens	Set of 4

Imperial Backing Nuts		
Part Number	**Description**	**Sold As**
9321-020	1/8 in dia threaded specimens	Set of 4
9321-030	3/16 in dia threaded specimens	Set of 4
9321-040	1/4 in dia threaded specimens	Set of 4
9321-050	5/16 in dia threaded specimens	Set of 4
9321-060	3/8 in dia threaded specimens	Set of 4

13.4 Specialty Grips

Special order or custom grips are available. If you require custom grips please contact a *Sales Representative* (page 373).

13.4.1 Torsion Grips

For Hot Torsion MCU collet grips see *Collet Grips* (page 69) .

13.4.2 Nil-Strength Grips

For Nil-Strength grips see *Nil-Strength Grips* (page 247).

Section 14

Uniaxial Compression Studies

Contents

- *Asymmetric Uniaxial Compression Testing Using ISO-T Anvils* (page 210)
- *Uniaxial Compression Anvil Assemblies* (page 211)
  - *ISO-T Anvil Base Kits* (page 211)
  - *ISO-T Anvil Assemblies* (page 214)
- *Uniaxial Compression Anvils* (page 216)
  - *ISO-T Anvils* (page 216)
  - *Non-ISO-T Anvils* (page 218)
- *Specimen Loading Tools and Clips* (page 219)
- *Uniaxial Compression Testing Consumables Kits* (page 220)
  - *Hot Compression Starter Kit - DSI# 9570-000* (page 220)
  - *Uniaxial Compression Consumables - DSI# Kit 9570-001* (page 220)

14.1 Asymmetric Uniaxial Compression Testing Using ISO-T Anvils

Uniaxial compression testing is widely used for uniaxial compression expansion measurement of metals and alloys. To keep the deformation uniform during compression, temperature within the volume of the specimen must be uniform. Thermal uniformity can be achieved by furnace heating or induction heating. These methods require slow heating rates, and the material is allowed to soak for a long period of time, ensuring that an equilibrium temperature is reached.

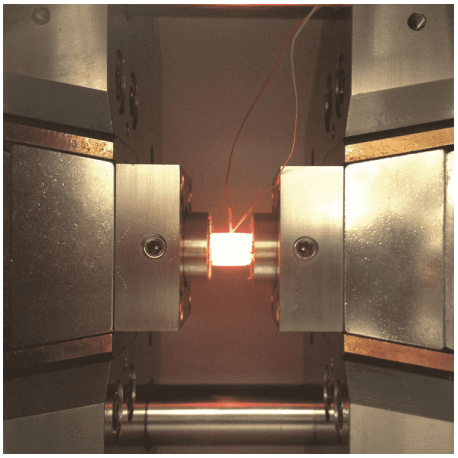


Fig. 14.1: Uniaxial Compression Test.

he unique DSI direct resistance heating system can also provide uniform heating, but can do it much faster. In resistance heating, an isothermal plane across the diameter of a cylindrical specimen is always maintained during heating or cooling. The ISO-T anvil system developed at Dynamic Systems Inc. also eliminates the axial temperature gradient. This provides a uniform temperature throughout the entire volume of the specimen. Thus, the best features of resistance heating including, faster heating and cooling rates, easy specimen access, short soaking times, and direct fast quenching, are combined with the uniformity of temperature distribution found in furnace heating. This provide an excellent method for uniaxial compression testing at elevated temperatures.

Conducting Tests Using Gleeble's Uniaxial Compression Testing Assemblies

To prevent barreling of the specimen, the application of suitable *Diffusion Barriers* (page 368) at the interface between the anvils and the *specimen* (page 381) is recommended. The diffusion barrier prevents diffusion bonding. This creates near frictionless contact between the specimen and the anvils. Allowing the specimen free movement against the anvils prevents any barreling.

Hot Deformation Software (HDS) (page 336) can be used to perform a uniaxial compression test in conjunction with a *Hydrawedge II* (page 55).

14.2 Uniaxial Compression Anvil Assemblies

Uniaxial compression tests involve the compression of a specimen held between two anvil faces. Each anvil base kit below includes all components needed to perform simple uniaxial compression tests.

14.2.1 ISO-T Anvil Base Kits

General-Purpose MCU - Pocket Jaw Mounted

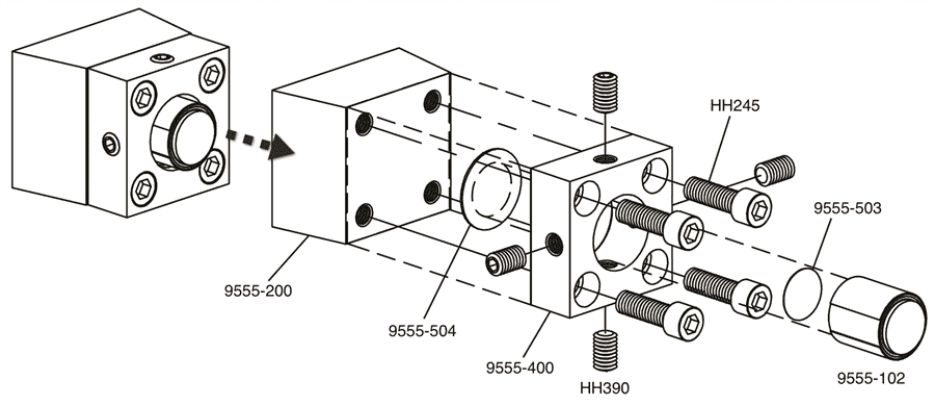


Fig. 14.2: Pocket Jaw Mounted - ISO-T Flow Stress Anvil Assembly - DSI# 9555-100.

Part Number	Description	Sold As
9555-100	ISO-T Uniaxial Compression Anvil Assembly - General-Purpose MCU Pocket Jaws	Kit
9555-110	ISO-T Uniaxial Compression Anvil Assembly - Gleeble 3180	Kit
9555-200	ISO-T Uniaxial Compression - Pocket Jaw Wedge Mount - General-Purpose MCU Pocket Jaws	Ea.
9555-400	ISO-T Uniaxial Compression - Anvil Mounting Block - General-Purpose MCU Pocket Jaws	Ea.
Used With All Uniaxial Compression Anvil Assemblies		
9555-504	ISO-T Copper Backup Plate - 28.575 mm (1.125 in) dia	Ea.
9555-503	Graphite Disk - 10 mil thick	Ea.
HH390	Set Screw - Secures Anvil Assembly into Mounting Block	Ea.
HH245	Bolt - Secures Anvil Mounting Block	Ea.

Hydrawedge II or Compression Tester Adapter Mounted

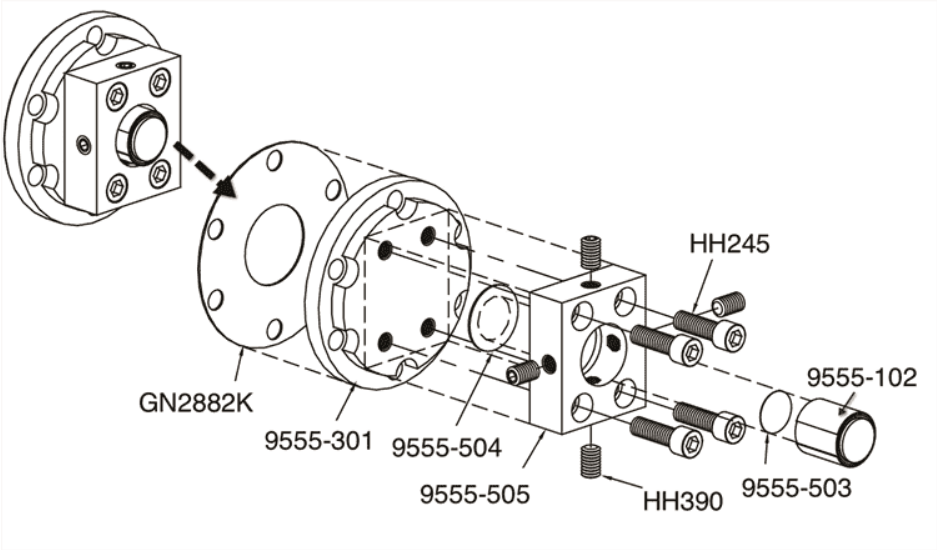


Fig. 14.3: Hydrawedge II Mounted - ISO-T Flow Stress Anvil Assembly - DSI# 9555-101.

Part Number	Description	Sold As
9555-101	ISO-T Uniaxial Compression Anvil Assembly - Hydrawedge II and Compression Testing Kit	Kit
9555-303	Uniaxial Compression Anvil Mount - Hydrawedge II and Compression Test Adapter Set	Ea.
GN2882K	Copper Backup Plate - Hydrawedge II and Compression Test Adapter Set	Ea.
9555-301	Uniaxial Compression Mounting Plate	Ea.
9555-505	ISO-T Anvil Mounting Block - Hydrawedge II	Ea.

563 Pocket Jaw

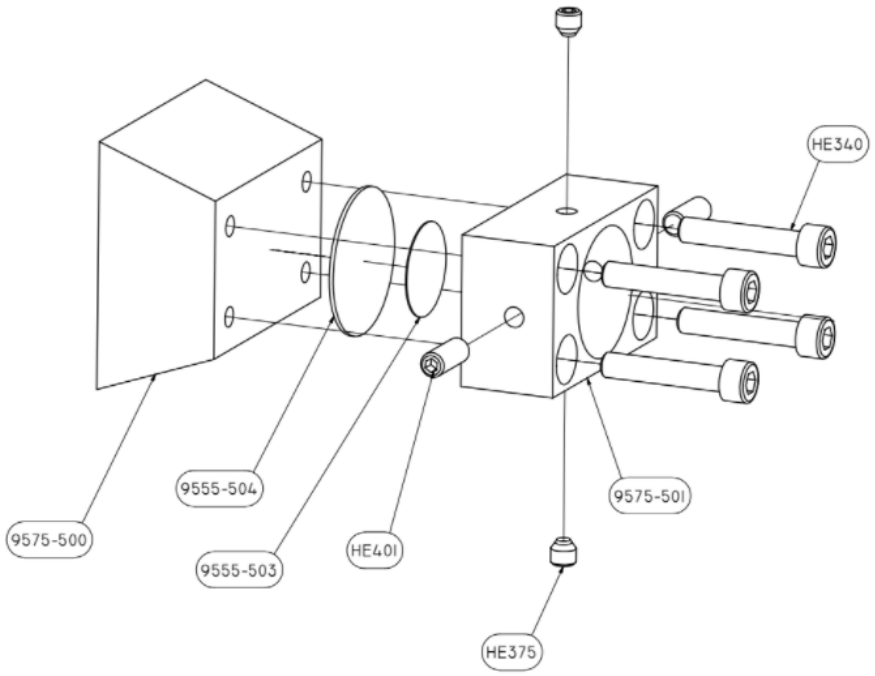


Fig. 14.4: ISO-T Anvil Assembly - 563 - DSI# 9575-100.

Part Number	Description	Sold As
9575-100	ISO-T Uniaxial Compression Anvil Assembly - 500 Series	Kit
9575-500	Compression Mounting Base	Ea.
9575-501	ISO-T Anvil Mounting Block	Ea.

14.2.2 ISO-T Anvil Assemblies

ISO-T anvil assemblies require anvil caps, anvil bases, and interstitial conducting media typically graphite disks.

Standard ISO-T Anvil Assembly

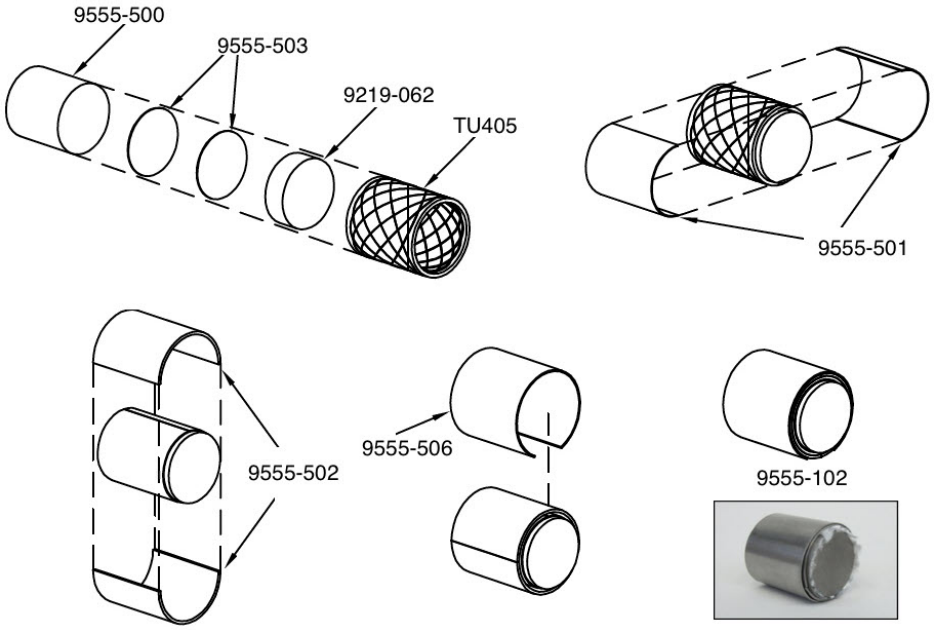


Fig. 14.5: ISO-T Uniaxial Compression Anvil Assembly - DSI# 9555-102.

Part Number	Description	Sold As
9555-102	ISO-T Tungsten Carbide Anvil Assembly	Ea.
9555-501	ISO-T Inner Containment Sleeve	Ea.
9555-502	ISO-T Outer Containment Sleeve	Ea.
9555-506	ISO-T Anvil Spring Clip	Ea.

ISO-T Anvil Assembly - 6 mm Specimens

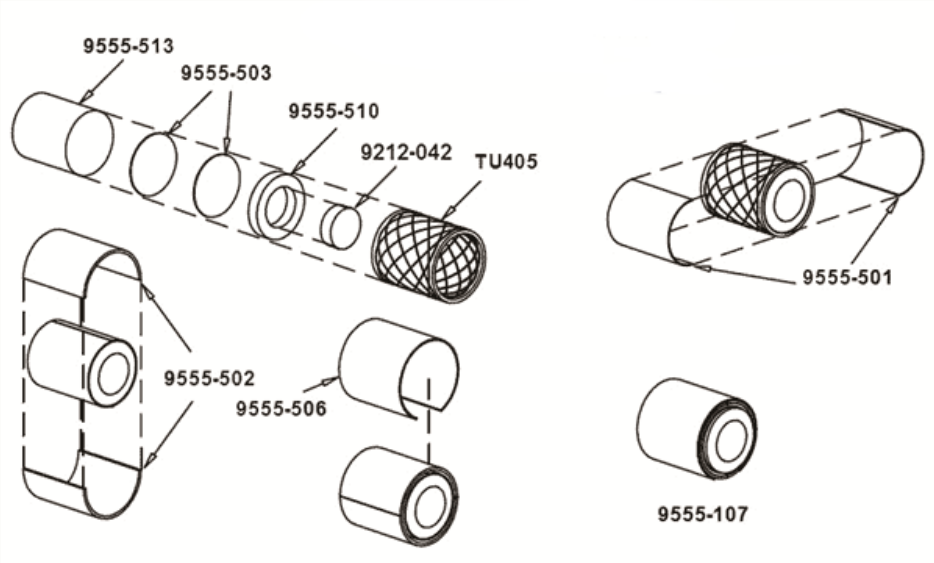


Fig. 14.6: ISO-T Uniaxial Compression Anvil Assembly - 6 mm - DSI# 9555-107.

Part Number	Description	Sold As
9555-107	ISO-T Anvil Assembly - 6 mm dia specimens	Ea.

14.3 Uniaxial Compression Anvils

DSI's ISO-T anvils utilize interior layers of thermal and electrical resistance material to allow the user to adjust the anvil assembly temperature. Matching the anvil temperature to the specimen temperature will reduced the thermal gradient in the specimen.

For large samples, tests with less stringent thermal gradient requirements, or where the additional compliance of the resistance layers may be problematic, the multi-piece anvil stack can be replaced with a solid one piece, Non-ISO-T anvil.

Recommended Maximum Operating Temperatures for Compression Anvils	
Tungsten Carbide	1,200℃ (2,192℉)
Pure Tungsten	1,400℃ (2,552℉)
Tungsten Composite	1,700℃ (3,092℉)
Quartz	•
Silicon Nitride	•

14.3.1 ISO-T Anvils

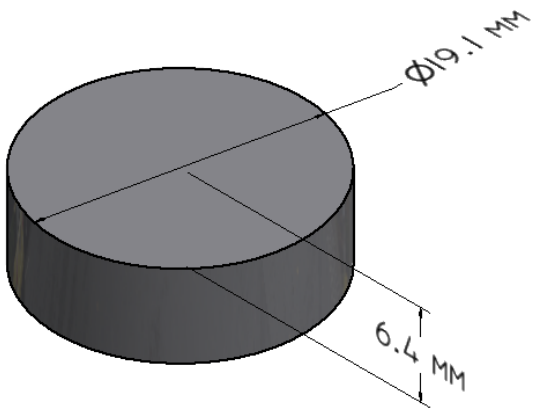


Fig. 14.7: ISO-T Tungsten Carbide Anvil Cap - Uniaxial Compression - DSI# 9219-062.

Part Number	Description	Sold As
Anvils For Use With Standard 10 mm dia x 15 mm Uniaxial Compression Specimens		
9219-062	ISO-T Tungsten Carbide Anvil Cap - Uniaxial Compression - 19.1 mm dia x 6.35 mm (0.75 in dia x 0.25 in)	Pack of 5
9555-500	ISO-T Tungsten Carbide Anvil Base - Uniaxial Compression - 19.1 mm dia x 19.1 mm (0.75 in dia x 0.75 in)	Pack of 2
Anvils For High-Temperature Studies		
9219-066	ISO-T Uniaxial Compression Anvil Cap - High-Temperature - Pure Tungsten - 19.1 mm dia x 6.35 mm (0.75 in dia x 0.25 in)	Ea.
9555-515	ISO-T Uniaxial Compression Anvil Base - High-Temperature - Pure Tungsten - 19.1 mm dia x 19.1 mm (0.75 in dia x 0.75 in)	Ea.
9220-069	ISO-T Uniaxial Compression Anvil Cap - High-Temperature - Tungsten Composite - 20 mm dia x 6.5 mm (0.787 in dia x 0.255 in)	Ea.
Anvils For Use With 6 mm dia x 9 mm Uniaxial Compression Specimens		
9212-042	Uniaxial Compression Anvil - 12 mm dia x 4 mm (0.472 in dia x 0.157 in)	Pack of 10
9555-510	ISO-T Anvil Adapter Ring - 12 mm dia x 4 mm (0.472 in dia x 0.157 in)	Ea.
9555-513	ISO-T Uniaxial Compression Anvil Base - 12 mm dia x 4 mm (0.472 in dia x 0.157 in)	Ea.

14.3.2 Non-ISO-T Anvils

Non-ISO-T anvils are are made as a single unit and do not require an anvil base or interstitial conducting medium.

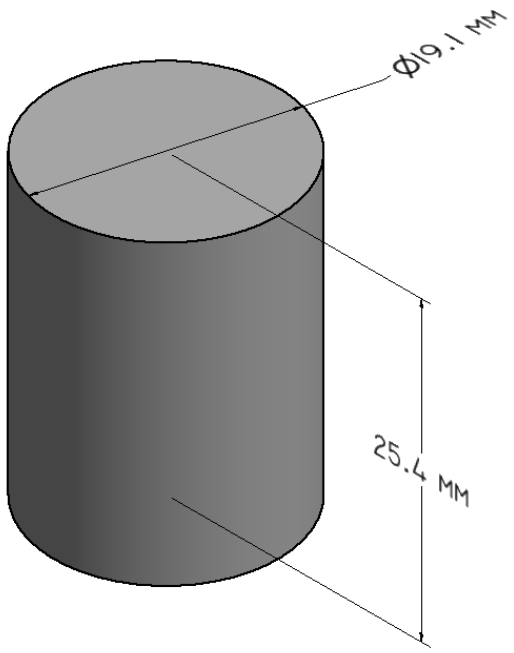


Fig. 14.8: Non-ISO-T Tungsten Carbide Anvil - DSI# 9219-252.

Part Number	Description	Sold As
9219-252	Tungsten Carbide Uniaxial Compression Anvil - 19.1 mm dia x 25.4 mm (0.75 in dia x 1.0 in)	Pack of 2
9219-253	Stainless Steel Uniaxial Compression Anvil - 19.1 mm dia x 25.4 mm (0.75 in dia x 1.0 in)	Pack of 2

14.4 Specimen Loading Tools and Clips

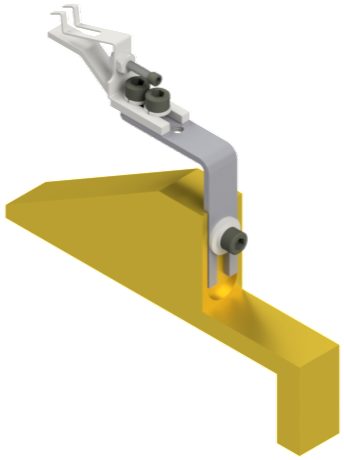


Fig. 14.9: Specimen Loading Tool

For more information on Specimen Loading Tools and Clips can be found *here* (page 348).

14.5 Uniaxial Compression Testing Consumables Kits

Uniaxial Compression Consumables Kits contain many of the most commonly used consumables for the various compression testing methods.

14.5.1 Hot Compression Starter Kit - DSI# 9570-000

Kit 9570-000 contains the following parts:

Part Number	Description
RMX005SB	5 mil thick Graphite Foil
RMX004S	4 mil thick Tantalum Sheet
RMX010SA	10 mil thick Graphite Foil
HW008	Super Bonder Glue
HW008A	Omega Bond Thermocouple Cement
HW014	Anti-seize Compound - Nickel Paste
HW510	Superlube

14.5.2 Uniaxial Compression Consumables - DSI# Kit 9570-001

Kit 9570-001 contains the following parts:

Part Number	Description
9219-062	ISO-T Tungsten Carbide Anvil Cap - Uniaxial Compression - 19 mm dia x 6.35 mm (0.75 in dia x 0.25 in)
9555-102	ISO-T Tungsten Carbide Anvil Assembly
9555-504	ISO-T Copper Backup Plate - 1.125 in dia
9555-500	ISO-T Tungsten Carbide Anvil Base - Uniaxial Compression - 19 mm dia x 19 mm (0.75 in dia x 0.75 in)
9555-501	ISO-T Anvil Inner Containment Sleeve
9555-502	ISO-T Anvil Outer Containment Sleeve
9555-506	ISO-T Spring Clip
9555-503	Graphite Disk - 10 mil
TU405	Nextel Sleeving

For additional consumable items see *Gleeble Consumables* (page 359).

Section 15

Plane Strain Studies

Contents

- *Plane Strain Compression Testing* (page 222)
- *Plane Strain Anvil Assemblies* (page 223)
  - *Small Plane Strain* (page 223)
  - *Large Plane Strain* (page 226)
  - *MAXStrain* (page 227)
- *Plane Strain Anvils* (page 229)
  - *Small Plane Strain* (page 229)
  - *Large Plane Strain* (page 231)
  - *MAXStrain* (page 232)
- *Plane Strain Anvil Alignment Tool* (page 234)
- *Specimen Loading Tools and Clips* (page 235)
- *Plane Strain Compression Testing Consumables Kits* (page 236)
  - *Hot Compression Starter Kit - DSI# 9570-000* (page 236)
  - *Small Plane Strain Compression Kit - DSI# 9570-002* (page 236)
  - *Large Plane Strain Compression Kit - DSI# 9570-003* (page 236)

15.1 Plane Strain Compression Testing

In plane strain compression testing, a plate-shaped specimen is subjected to primary compression in the thickness (h) direction, which subsequently results in positive strain deformation of the plate normal to the width of the plate (w direction). In order to minimize the amount of material spread in the length direction of the specimen (t), it is necessary that t > w. When the spread in the length direction is minimized, plane strain conditions are achieved. When relatively large values of the ratio of the plate breadth to the specimen thickness (w > h) are studied, essentially homogeneous deformation occurs between the plates. When the w:h ratio is small, a greater amount of non-homogeneous deformation occurs. During plane strain compression, the w : h ratio will increase and may cause a transition from homogeneous deformation to heterogeneous deformation.

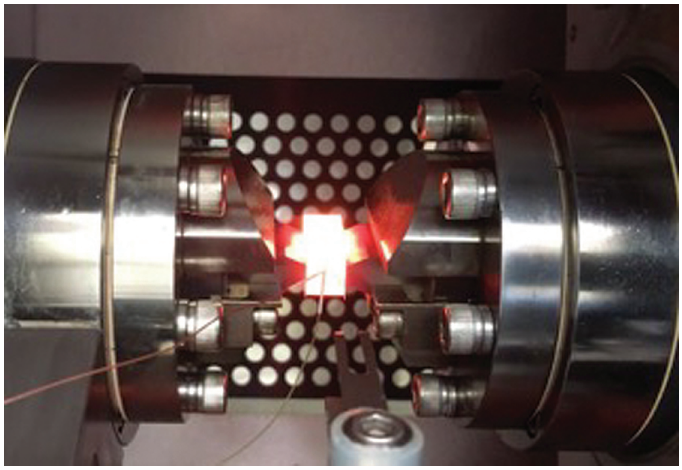


Fig. 15.1: Plane Strain Compression Test.

Because of the stress and strain conditions found in plane strain compression test, higher anvil pressure values, and lower strain values are theoretically recorded when compared to stress/strain values measured in the uniaxial compression tests.

When the direct resistance heating current is applied to the specimen, bulk heating, and hence nominally uniform temperatures, are noted in the volume of material between the anvil contact surfaces. The edge material outside of the anvil faces is not heated by the heating current to the same extent as the material between the anvils. This heating method provides for heating of the entire specimen over a relatively short period of time. However, uniform temperatures are not always preferred. Cooler ends help to constrain the material from deformation in the “t” direction. The cooler ends act as heat sinks. This simulates a rolling mill’s inter-pass cooling profiles, between or during deformation steps.

Plane strain compression testing is primarily used to study and simulate the types of stress states and flow patterns associated with rolling mill metal working conditions. However, plane strain compression testing can also be useful when conducting other complex simulations in which plane strain conditions are expected.

Conducting Tests Using Gleeble’s Plane Strain Testing Assemblies

To prevent barreling of the specimen, the application of suitable *Diffusion Barriers* (page 368) at the interface between the anvils and the *specimen* (page 381) is recommended. The diffusion barrier prevents diffusion bonding. This creates near frictionless contact between the specimen and the anvils. Allowing the specimen free movement against the anvils.

Hot Deformation Software (HDS) (page 336) can be used to perform a plane strain compression test in conjunction with a *Hydrawedge II* (page 55).

15.2 Plane Strain Anvil Assemblies

Gleeble systems use unique anvil assemblies to conduct Plane Strain simulations. The anvil assemblies are designed to fit seamlessly into the jaws of the General-Purpose MCU, or bolt directly to the moving shafts of the Hydrawedge of MaxStrain MCUs.

15.2.1 Small Plane Strain

Small Plane Strain Anvil Assemblies use 5 x 25 x 10 mm (0.196 x 0.984 x 0.393 in) anvils.

General-Purpose MCU - Pocket Jaw Mounted

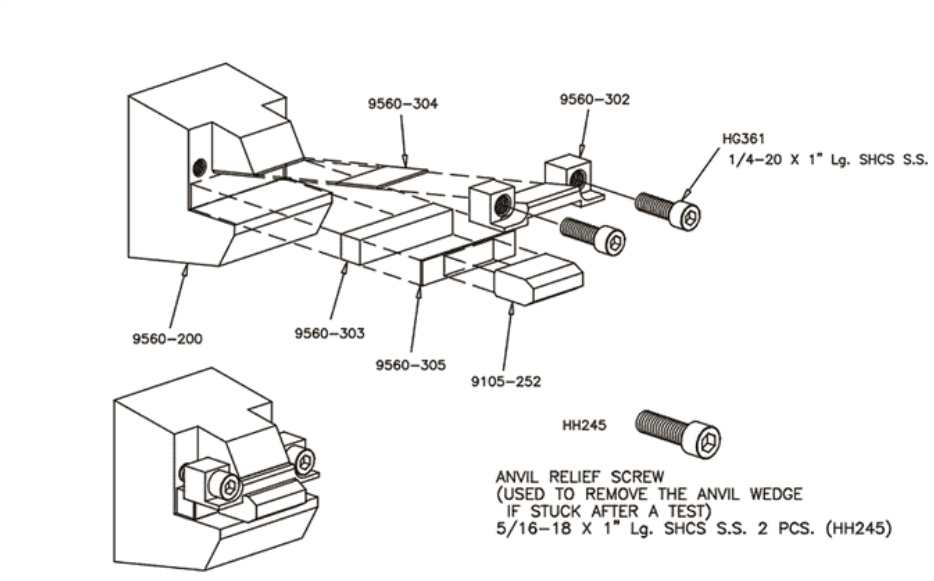


Fig. 15.2: Pocket Jaw Mounted - Small Plane Strain Assembly - DSI# 9560-001.

Part Number	Description	Sold As
9560-001	Small Plane Strain Jaw System Assembly - General-Purpose MCU	Kit
9560-003	Small Plane Strain Jaw System - 3180	Kit
9560-200	Pocket Jaw Wedge Mount - Small Plane Strain	Ea.
Parts Used With Pocket Jaw, 563, Hydrawedge II, and Compression Tester Adapter Assemblies		
9560-304	Side Conductor Plate - Small Plane Strain	Ea.
9560-305	Bottom Conductor Plate - Small Plane Strain	Ea.
9560-302	Wedge Block - Small Plane Strain	Ea.
9560-303	Backing Block - Small Plane Strain	Pack of 2
HH245	Anvil Relief Screw - Small Plane Strain	Ea.
HG361	Wedge Block Retention Screw - Small Plane Strain - 1/4-20 x 1.00 Stainless Steel	Ea.
9555-516	4 mm High-Temperature Mica Sheet - 24 x 39 in	Sheet

Hydrawedge II or Compression Tester Adapter Mounted

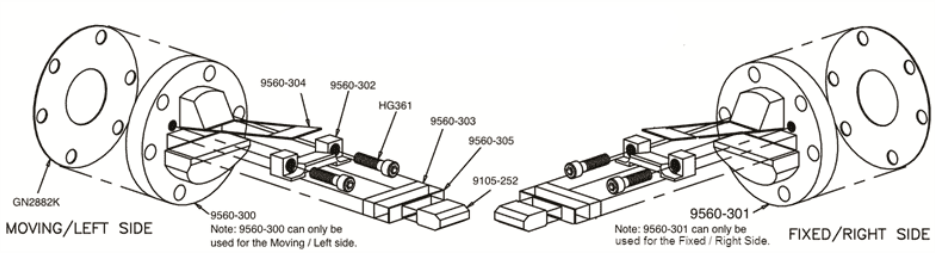


Fig. 15.3: Hydrawedge II Mounted - Small Plane Strain Anvil Assembly - DSI# 9560-100.

Part Number	Description	Sold As
9560-100	Small Plane Strain Anvil Assembly - Hydrawedge II	Kit
9560-103	Small Plane Strain Anvil Assembly - Compression Test Adapter	Kit
9560-300	Left Side Anvil Base - Small Plane Strain	Ea.
9560-301	Right Side Anvil Base - Small Plane Strain	Ea.
GN2882K	Copper Backup Plate - Hydrawedge II and Compression Test Adapter Set	Ea.
GN2876GA	Plane Strain Anvil Mount - Small Plane Strain - Mounts Anvil Assembly to Moving Shafts	Ea.

563 Pocket Jaw

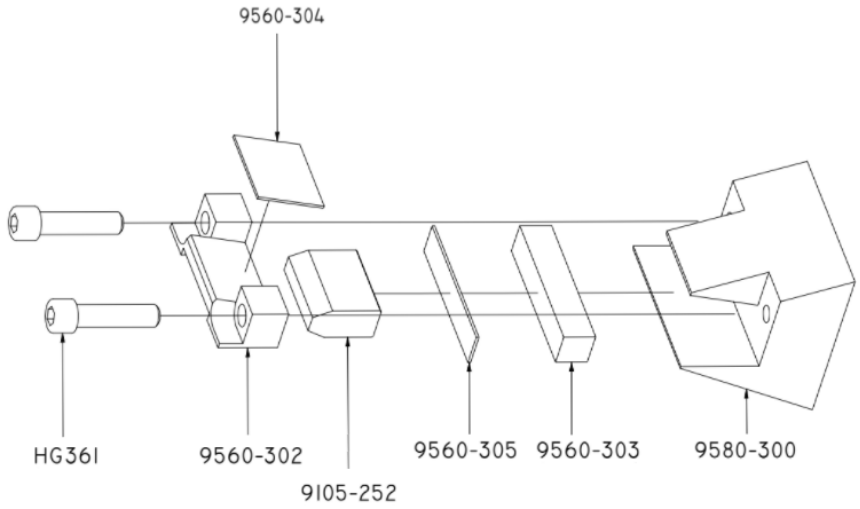


Fig. 15.4: 563 Mounted - Small Plane Strain Anvil Assembly - DSI# 9580-100.

Part Number	Description	Sold As
9580-100	Small Plane Strain Anvil Assembly - 563	Kit
9580-300	Pocket Jaw Wedge Mount - Small Plane Strain - 563	Ea.

15.2.2 Large Plane Strain

Large Plane Strain Anvil Assemblies use 10 x 42 x 20 mm (0.393 x 1.653 x 0.787 in) anvils.

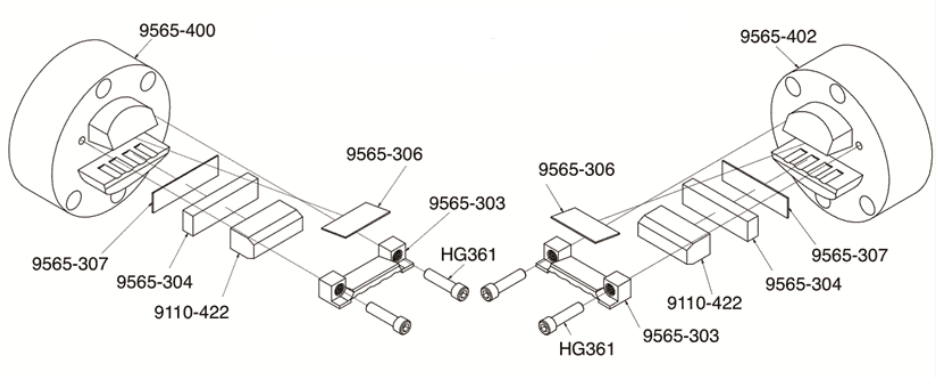


Fig. 15.5: Hydrawedge II Mounted - Large Plane Strain Anvil Assembly - DSI# 9565-107.

Part Number	Description	Sold As
9565-107	Large Plane Strain Anvil Assembly - Hydrawedge II	Kit
9565-108	Large Plane Strain Anvil Assembly - Compression Test Adapter	Kit
9565-303	Wedge Block - Large Plane Strain	Ea.
9565-304	Backing Block - Large Plane Strain	Ea.
9565-306	Side Conductor Plate - Large Plane Strain	Ea.
9565-307	Bottom Conductor Plate - Large Plane Strain	Ea.
GN2876LA	Copper Conducting Disk - Large Plane Strain	Ea.
9565-400	Left Side Anvil Base - Large Plane Strain - Water-Cooled	Ea.
9565-402	Right Side Anvil Base - Large Plane Strain - Water-Cooled	Ea.

15.2.3 MAXStrain

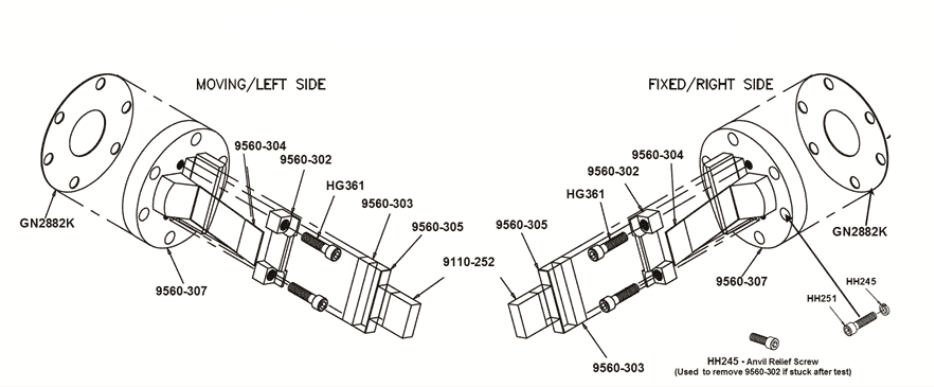


Fig. 15.6: MAXStrain II Mounted -Plane Strain Anvil Assembly - DSI# 9560-108.

Part Number	Description	Sold As
9560-108	Plane Strain Anvil Assembly - MAXStrain 10 x 25 x 10 mm (0.393 x 0.984 x 0.393 in)	Kit
9560-307	Plane Strain Base - MAXStrain	Ea.
9560-304	Side Conductor Plate - MAXStrain	Ea.
9560-302	Wedge Block - MAXStrain	Ea.
9560-303	Bottom Conductor Plate -MAXStrain	Ea.
9560-305	Backing Block - MAXStrain	Ea.

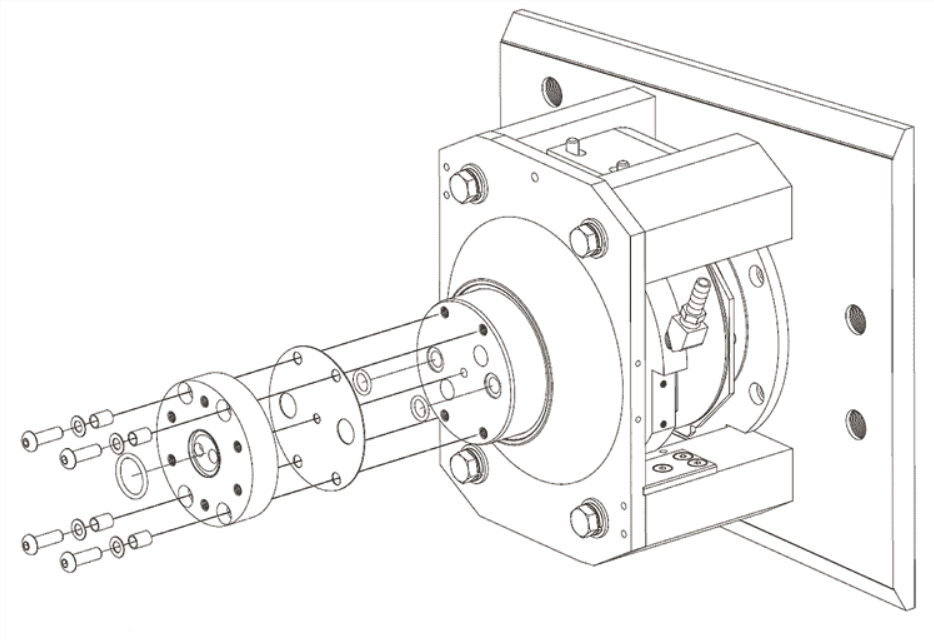


Fig. 15.7: MAXStrain Anvil Bases - DSI# 3M954.

Part Number	Description	Sold As
3M954	Anvil Bases - MAXStrain	Kit
3M263	Insulating Disk - Anvil Base to Moving Shaft - MAXStrain	Ea.
3M303	Insulating Washer - MAXStrain	Ea.
3M304	Insulating Bushing - MAXStrain	Ea.
9560-307	Plane Strain Base - MAXStrain	Ea.
ORS112	O-Ring	Ea.

15.3 Plane Strain Anvils

Plane strain tests are frequently used in the simulation of rolling. Fig. 15.8 shows the basis for this, where the deformation forces, strain and heat flow are all in the same direction as those found in rolling.

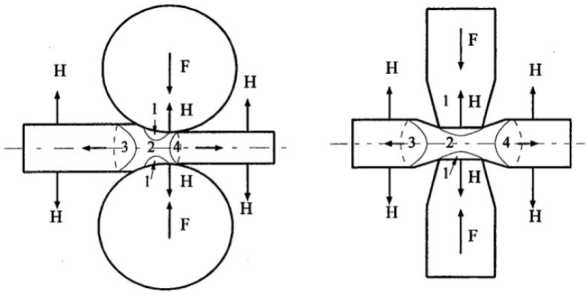


Fig. 15.8: Hot Rolling Process Simulation.

Recommended Maximum Operating Temperatures for Compression Anvils	
Tungsten Carbide	1,200°C (2,192°F)
Pure Tungsten	1,400°C (2,552°F)
Tungsten Composite	1,700°C (3,092°F)
Quartz	•
Silicon Nitride	•

15.3.1 Small Plane Strain

Small Plane Strain Anvil Assemblies use 5 x 25 x 20 mm (0.196 x 0.984 x 0.787 in) anvils.

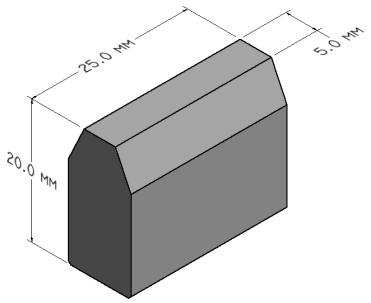


Fig. 15.9: Small Plane Strain Anvils - DSI# 9105-252

Part Number	Description	Sold As
Small Plane Strain Anvils		
9105-252	Small Plane Strain Anvil - Tungsten Carbide - 5 x 25 x 20 mm (0.196 x 0.984 x 0.787 in)	Pack of 10
9105-352	Small Plane Strain Anvil - Tungsten Carbide - 5 x 35 x 20 mm (0.196 x 1.377 x 0.787 in)	Pack of 10
Anvils For High-Temperature Studies		
9105-256	Small Plane Strain Anvil - Pure Tungsten - 5 x 25 x 20 mm (0.196 x 0.984 x 0.787 in)	Ea.

15.3.2 Large Plane Strain

Large Plane Strain Anvil Assemblies use 10 x 42 x 20 mm (0.393 x 1.653 x 0.787 in) anvils.

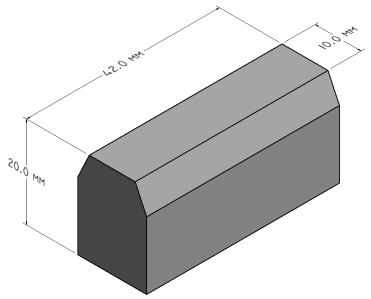


Fig. 15.10: Large Plane Strain Anvils - DSI# 9110-422

Part Number	Description	Sold As
9110-422	Large Plane Strain Anvil - Tungsten Carbide - Straight Sides - 10 x 42 x 20 mm (0.393 x 1.653 x 0.787 in)	Pack of 2

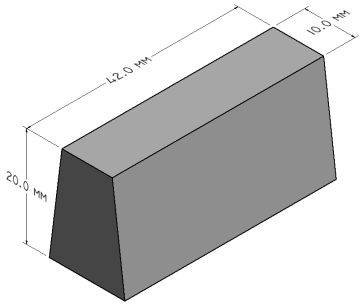


Fig. 15.11: Plane Strain Anvils - DSI# 9110-432.

Part Number	Description	Sold As
9110-432	Large Plane Strain Anvil - Tungsten Carbide - Tapered Sides - 10 x 42 x 20 mm (0.393 x 1.653 x 0.787 in) with	Pack of 2

15.3.3 MAXStrain

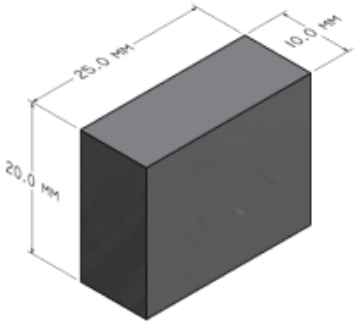


Fig. 15.12: MAXStrain Anvils - DSI# 9110-252.

Part Number	Description	Sold As
9110-252	MAXStrain - Punch-Style Plane Strain Anvil - Tungsten Carbide - 10 x 25 x 20 mm (0.393 x 0.984 x 0.787 in)	Pack of 10

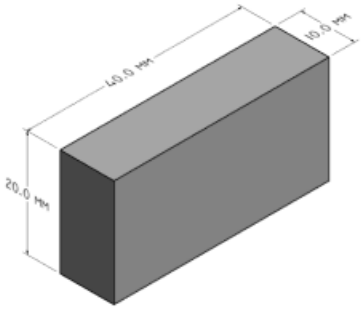


Fig. 15.13: MAXStrain Anvils - DSI# 9110-402.

Part Number	Description	Sold As
9110-402	MAXStrain - Punch-Style Plane Strain Anvil - Tungsten Carbide - 10 x 40 x 20 mm (0.393 x 1.574 x 0.787 in)	Pack of 2

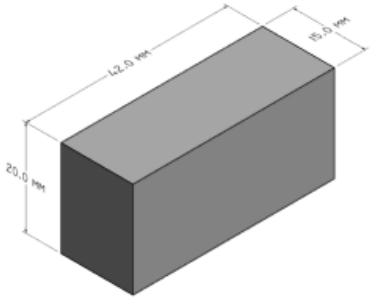


Fig. 15.14: MAXStrain Anvils - DSI# 9115-422.

Part Number	Description	Sold As
9115-422	MAXStrain - Punch-Style Plane Strain Anvil - Tungsten Carbide - 15 x 42 x 20 mm (0.590 x 1.653 x 0.787 in)	Pack of 2

15.4 Plane Strain Anvil Alignment Tool

Alignment of the Plane Strain Anvils is crucial to a successful simulation. The Plane Strain Anvil Alignment Tool provides the ability to properly position the anvils, relative to each other, while protecting the operator from hazardous pinch points.

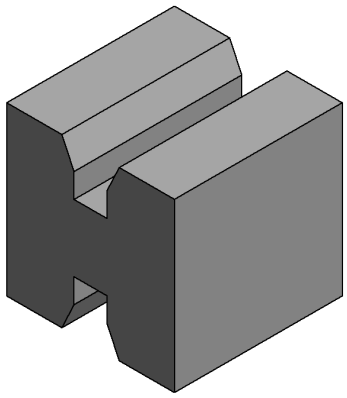


Fig. 15.15: Plane Strain Anvil Alignment Tool - DSI# GN2885K

Part Number	Description	Sold As
MAXStrain		
3M131	Anvil Base Alignment Tool	Ea.
3M963	Specialized Tools and Fixtures Kit - MaxStrain II	Ea.
All Other Plane Strain Fixtures		
9565-900	Alignment Fixture - 10 mm Plane Strain Anvil	Ea.
GN2885K	Alignment Fixture - 5 mm Plane Strain Anvil	Ea.

15.5 Specimen Loading Tools and Clips

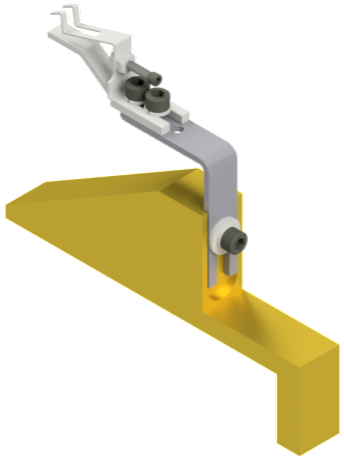


Fig. 15.16: Specimen Loading Tool

For more information on Specimen Loading Tools and Clips can be found *here* (page 348).

15.6 Plane Strain Compression Testing Consumables Kits

Plane Strain consumable kits contain many of the most commonly used consumables for differing Plane Strain testing methodologies.

15.6.1 Hot Compression Starter Kit - DSI# 9570-000

Kit 9570-000 contains the following parts:

Part Number	Description
RMX005SB	5 mil thick Graphite Foil
RMX004S	4 mil thick Tantalum Sheet
RMX010SA	10 mil thick Graphite Foil
HW008	Super Bonder Glue
HW008A	Omega Bond Thermocouple Cement
HW014	Anti-seize Compound - Nickel Paste
HW510	Superlube

15.6.2 Small Plane Strain Compression Kit - DSI# 9570-002

Kit 9570-002 contains the following parts:

Part Number	Description
9105-252	Small Plane Strain Anvil - Tungsten Carbide - 5 x 25 x 10 mm (0.196 x 0.984 x 0.393 in)
9560-303	Backing Block - Small Plane Strain
9560-304	Side Conductor Plate - Small Plane Strain
9560-305	Bottom Conductor Plate - Small Plane Strain

15.6.3 Large Plane Strain Compression Kit - DSI# 9570-003

Kit 9570-003 contains the following parts:

Part Number	Description
9110-422	Large Plane Strain Anvil - Tungsten Carbide - Straight Sides - 10 x 42 x 15 mm (0.393 x 1.653 x 0.59 in)
9565-304	Backing Block - Large Plane Strain
9565-306	Side Conductor Plate - Large Plane Strain
9565-307	Bottom Conductor Plate - Large Plane Strain

For additional consumable items see *Gleeble Consumables* (page 359).

Section 16

Compression Test Adapter

16.1 Compression Test Adapter

The Compression Test Adapter, CTA, is an optional jaw assembly for the *General-Purpose Mobile Conversion Unit* (page 49) MCU. The Compression Test Adapter (CTA) is used for uniaxial compression or plane strain compression studies. It allows for high strain-rate deformation while eliminating overshoot on the final deformation. The addition of *spacer shims* (page 238) alters the hard stop location of the CTA. By over programming the compressive stroke the CTA is forced into the hard stop. This eliminates and ramp down, overshooting, or oscillations in the stroke movement

The CTA utilizes the *Jaw to Jaw L-Gauge* (page 263) to measure the amount and rate of compression.

Current Gleeble Users

Current Gleeble users can access the Compression Test Adapter operator's manual here.[27]

For anvil assemblies and consumables see *Plane Strain Studies* (page 221) or *Uniaxial Compression Studies* (page 209).

Characteristic	Specification	Specimen Drawing Number
Maximum Strain Rate	30/s	
Recommended Uniaxial Flow Stress Specimen	10 mm dia x 15 mm long	SMC203B
Recommended Plane Strain Specimen	10 mm x 15 mm x 20 mm	SMC001B

[27] https://support.gleeble.com/portal/en/kb/articles/series-3-gtc-9520-020-compression-test-adapter-user-manual

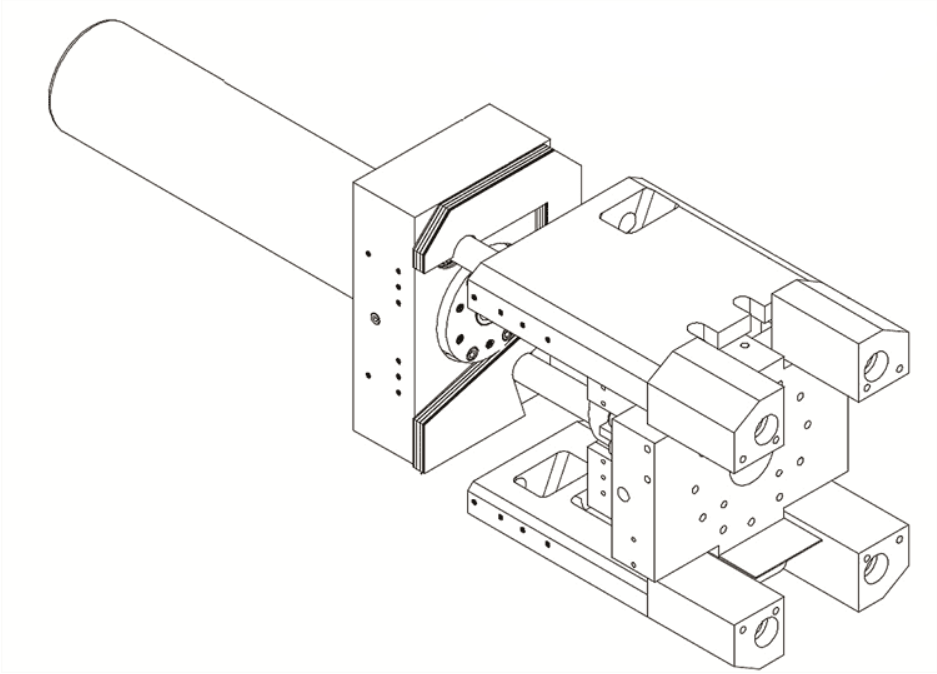


Fig. 16.1: Compression Testing Adapter Set - DSI# 9520-020.

Part Number	Description	Sold As
9520-020	Compression Testing Adapter Set with Fixed-End Hard Stops and Spacer Set	Kit

Space Shims

Part Number	Thickness (inches)	Material	Quantity
9520-604A	0.125	Aluminum	6
9520-604B	0.0625	Aluminum	3
9520-604C	0.032125	Aluminum	3
9520-604D	0.020	Stainless	1
9520-604E	0.015	Stainless	1
9520-604F	0.010	Stainless	1

Section 17

Low-Force Testing Systems

Contents

- *Low-Force Carrier* (page 240)
- *Low-Force Pocket Jaws* (page 241)
  - *Jaw Rotation Kit* (page 241)
  - *Low-Force Pocket Jaws - Heating Rate* (page 243)
  - *Specimen Size Considerations* (page 244)
- *Nil-Strength Jaws* (page 245)
  - *Nil-Strength Jaws - Heating Rate* (page 246)
  - *Specimen Size Considerations* (page 246)
  - *Nil-Strength Grips* (page 247)
- *Low-Force Load Cells* (page 248)
- *Low-Force Assemblies - Replacement Parts* (page 249)

Materials developers are often faced with the task of eliminating cracking during rolling, casting, continuous casting, and welding processes. The possibility of cracking is greatly reduced if the range between the material's nil-strength and nil-ductility temperatures are minimized. However, standard thermal-mechanical testing machines are often unable to control and apply the very small tensile forces required for nil-strength temperature (NST) testing. The Gleeble Low-Force Testing System, available for most Gleeble systems, create the conditions necessary for achieving accurate and reproducible NST values. Gleeble low-force systems are also capable of measuring low-forces in tension or compression.

The Low-Force Pocket Jaws are also useful for certain types of unrestrained thermal fatigue testing as they reduce the frictional resistance of the hydraulic system during thermal expansion on the specimen. *CCT testing* (page 335), with a *crosswise dilatometer* (page 258) is commonly performed with the low-force testing system.

Current Gleeble Users

Current Gleeble users can access the Gleeble Low-Force Testing System Operator's Manual here.[28]

The Gleeble Low-Force Testing System consists of the Low-Force Carrier, Low-Force Pocket Jaws or Nil-Strength Jaws, and an optional Low-Force Load Cell.

[28] https://support.gleeble.com/portal/en/kb/articles/series-3-gtc-low-force-testing-user-manual

17.1 Low-Force Carrier

The 9510-002 Low-Force Jaw Carrier is for use with all low-force testing configurations in the Gleeble 3500 and 3800 systems. The Jaw Carrier is the assembly upon which the Nil-Strength Jaws or Low-Force Pocket Jaws are mounted. The Jaw Carrier must be installed to use either jaw sets. sets. The Jaw Carrier must also be installed to mount the Low-Force Load Cell.

The low friction coefficient derived by the bearing system used in the Low-Force Jaw Carrier significantly reduces any external mechanical force experienced by a specimen during thermal expansion. The reduction in external mechanical forces ensures that the specimen can thermally expand free from any resistance of the hydraulic system.

Warning: Operating the Low-Force Carrier assembly with a specimen larger than recommended, or at a heating rate faster than recommended, can cause damage to the carrier's heating cables. See *Low-Force Pocket Jaws - Heating Rate* (page 243) or *Nil-Strength Jaws - Heating Rate* (page 246) for heating specifications.

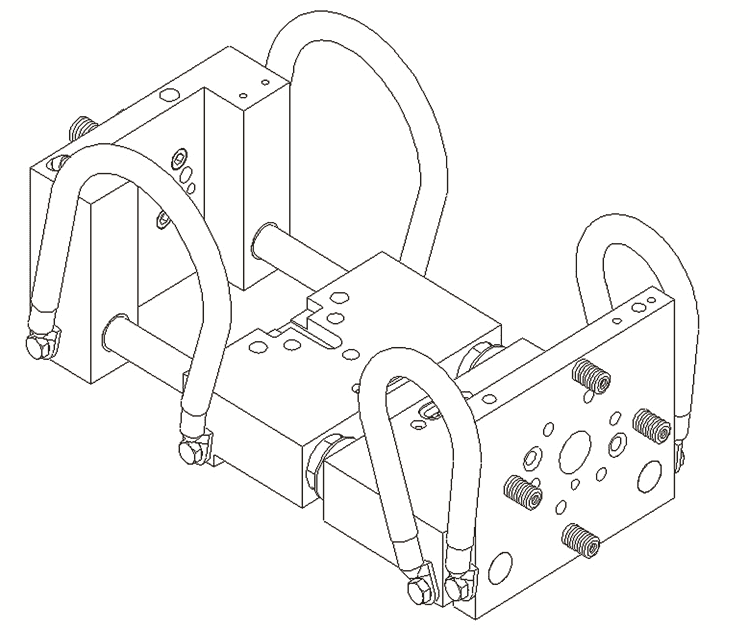


Fig. 17.1: Low-Force Carrier - DSI# 9510-002.

Part Number	Description	Sold As
9510-002	Jaw Carrier Kit - Gleeble 3500 and 3800	Kit

17.2 Low-Force Pocket Jaws

The 9510-101 Low-Force Pocket Jaws can be used for *low-force* (page 248) tension and compression testing. CCT dilatometery testing is also conducted with the Low-Force Pocket Jaws. The Pocket Jaw assemblies must be installed on the *Low-Force Carrier* (page 240) and, are used with *Gleeble Grips* (page 179). The Low-Force Pocket Jaws are only available for Gleeble 3500 and 3800 systems.

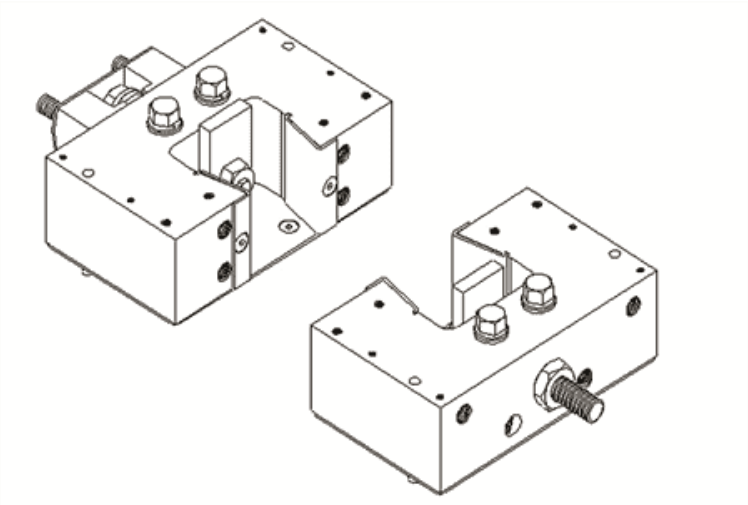


Fig. 17.2: Low-Force Pocket Jaws - DSI# 9510-101.

Part Number	Description	Sold As
9510-101	Low-Force Pocket Jaw Assembly	Kit

17.2.1 Jaw Rotation Kit

Low-Force Pocket Jaw Rotation Kit

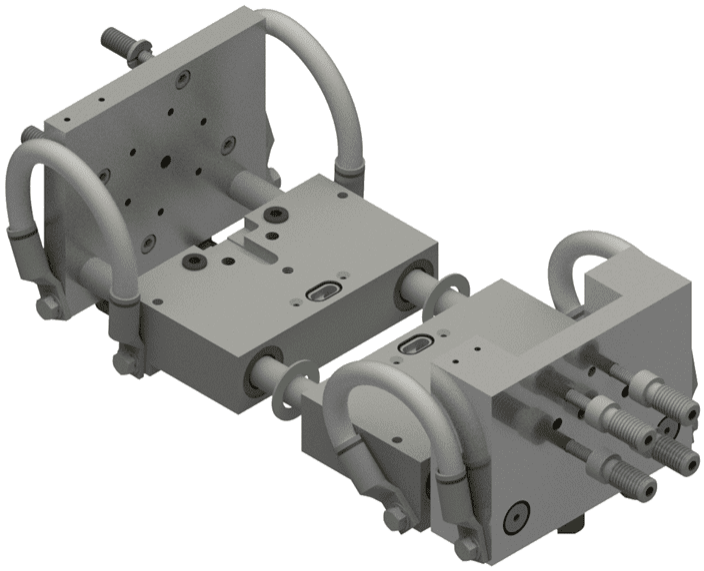


Fig. 17.3: Low-Force Pocket Jaws Rotation Kit - DSI# 9510-005.

The 9510-005 Low-Force Pocket Jaws Rotation Kit contains the parts necessary to rotate the pocket jaws 90 degrees. Specimens will now be mounted parallel to the vacuum tank doors. When used with standard grips devices such as *DIC cameras* (page 299), *optical micrometers* (page 269), *pyrometers* (page 274), or lasers will have a direct line of sight to the flat plane of the specimen. Viewing angles can be from either the front or back door vacuum tank windows.

Part Number	Description	Sold As
9510-005	Low-Force Pocket Jaws - Jaw Rotation Kit	Ea.

17.2.2 Low-Force Pocket Jaws - Heating Rate

Heating rates are based on using full contact copper grips and 1018 carbon steel or 6061 aluminum specimens in the Low-Force Pocket Jaws. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

Material	Specimen Size	Drawing Number	Maximum Heating Rate
			℃/s (℉/s)
Steel Bar	10 mm dia x 71 mm long	SMR009B	25 (45)
Steel Bar	10 mm square x 71 mm long	SMS004B	25 (45)
Aluminum Bar	6 mm dia x 71 mm long	SMR002A	15 (27)
Steel Sheet	1 mm thick x 25 mm wide x 26 mm long	SMF128B	25 (45)
Aluminum Sheet	1 mm thick x 25 mm wide x 26 mm long	SMF128A	15 (27)

17.2.3 Specimen Size Considerations

Gleeble systems are capable of testing a wide variety of material compositions and specimen geometries. Inherent limitations of the system, such as distance between the jaw or anvil faces, the maximum or minimum stroke speed, test temperature, and force limitations for the individual system must be considered when selecting a specific *specimen geometry* (page 378).

The target temperature of a test will also impact the size of a specimen that can safely be tested with a Gleeble system. For example, when considering a standard uniaxial compression specimen, it is possible for a soft material such as aluminum or copper to be tested at ambient temperature. Harder materials, such as steel or titanium alloys, are expected to be tested at elevated temperatures.

Popular Specimen Sizes		
Specimen Length	**Specimen Width**	**Drawing Number**
Bar Specimens		
116 mm	6 mm dia	SMR104
71 mm	10 mm dia	SMR009
71 mm	10 mm^2	SMS004

To achieve the best thermal control, flat specimens should have a cross-sectional area between 25 mm^2 and 400 mm^2 (0.0387 in^2 and 0.620 in^2).

Warning: Operating the Low-Force Carrier assembly with a specimen larger than recommended, or at a heating rate faster than recommended, can cause damage to the carrier's heating cables. See *Low-Force Pocket Jaws - Heating Rate* (page 243) or *Nil-Strength Jaws - Heating Rate* (page 246) for heating specifications.

17.3 Nil-Strength Jaws

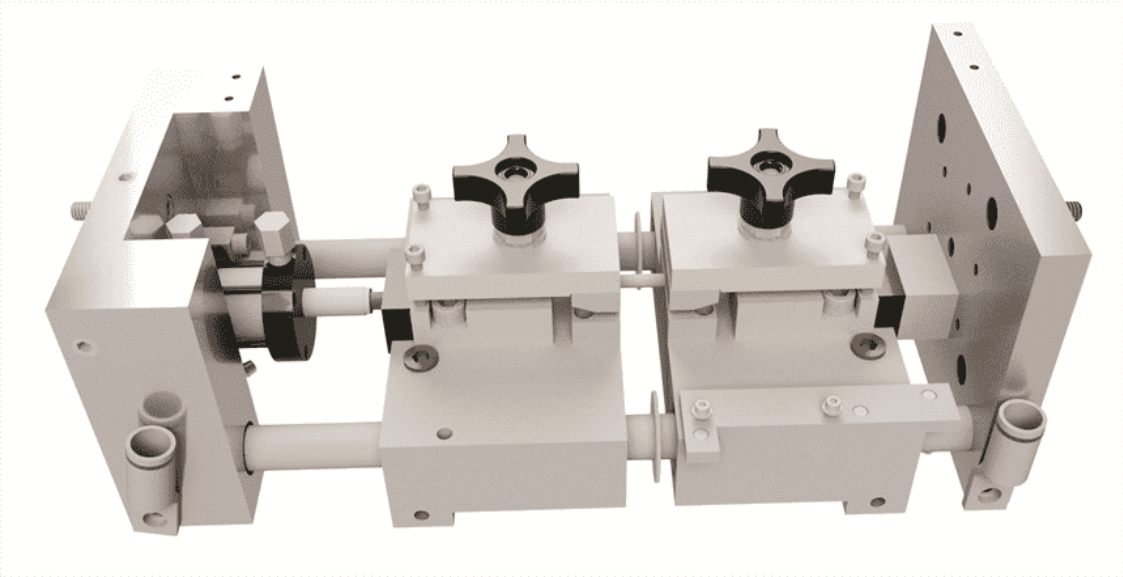


Fig. 17.4: Nil-Strength Jaw Configuration - DSI# 9510-051.

The Nil-Strength Jaw Set includes the grip mounting assembly and a pneumatic cylinder for applying static low-force loads. In the Nil-Strength Jaw Set, a pneumatic pneumatic cylinder provides the tensile force instead of the more powerful hydraulic system, thus allowing the application of small loads. Only a single load value can be applied during each test. This jaw configuration is intended for static force testing only.

Characteristic	Specification
Air Cylinder Travel Range	±25 mm (±0.98 in)
Air Cylinder Stroke-Rate Control	None

Part Number	Description	Sold As
9510-051	Nil-Strength Testing Assembly - 3500 and 3800	Kit
9510-052	Nil-Strength Testing Assembly - 3180	Kit

17.3.1 Nil-Strength Jaws - Heating Rate

Heating rates are based on using full contact copper grips, and 1018 carbon steel specimens or 6061/T6 aluminum in the Nil-Strength Jaws. See *Gleeble Grips* (page 179) for more information regarding the selection of grips.

Material	Specimen Size	Drawing Number	Maximum Heating Rate
			℃/s (℉/s)
Steel Bar	6 mm dia x 81 mm long	SMR004B	30 (54)
Aluminum Bar	6 mm dia x 81 mm long	SMR004A	15 (27)
Steel Sheet	1 mm thick x 25 mm wide x 26 mm long	SMF128B	25 (45)
Aluminum Sheet	1 mm thick x 25 mm wide x 26 mm long	SMF128A	15 (27)

17.3.2 Specimen Size Considerations

Gleeble systems are capable of testing a wide variety of material compositions and specimen geometries. Inherent limitations of the system, such as distance between the jaw or anvil faces, the maximum or minimum stroke speed, test temperature, and force limitations for the individual system must be considered when selecting a specific *specimen geometry* (page 378).

The target temperature of a test will also impact the size of a specimen that can safely be tested with a Gleeble system. For example, when considering a standard uniaxial compression specimen, it is possible for a soft material such as aluminum or copper to be tested at ambient temperature. Harder materials, such as steel or titanium alloys, are expected to be tested at elevated temperatures.

Popular Specimen Sizes			
Specimen Length	**Specimen Width**	**Specimen Thickness**	**Drawing Number**
Bar Specimens			
81 mm	6 mm dia	N/A	SMR004
26 mm	25 mm	1 mm	SMF128

Warning: Operating the Low-Force Carrier assembly with a specimen larger than recommended, or at a heating rate faster than recommended, can cause damage to the carrier's heating cables. See *Low-Force Pocket Jaws - Heating Rate* (page 243) or *Nil-Strength Jaws - Heating Rate* (page 246) for heating specifications.

17.3.3 Nil-Strength Grips

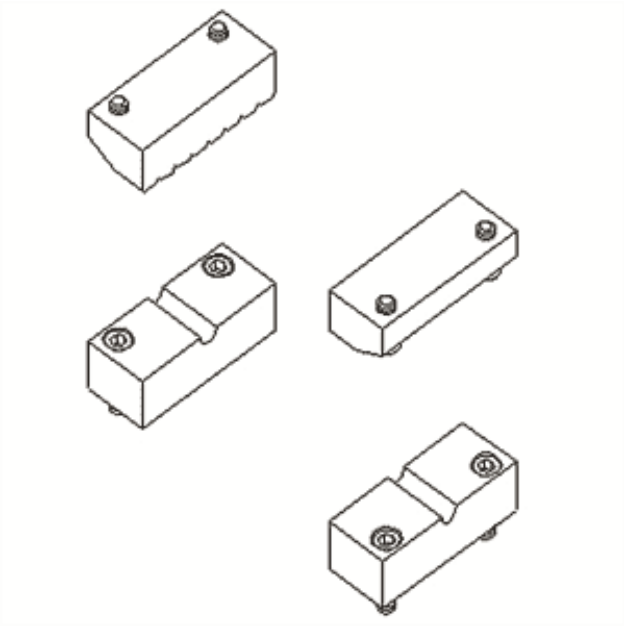


Fig. 17.5: Nil-Strength Grips - DSI# 9510-051.

The Nil-Strength Jaw set requires at least one set of grips. Each grip set contains two stainless steel top grips and two copper bottom grips.

Part Number	Description	Sold As
9510-063	Nil-Strength Grip Set - 6 mm square specimens	Set
9510-060	Nil-Strength Grip Set - 6 mm dia round specimens	Set
9510-061	Nil-Strength Grip Set - 1/4 in dia round specimens	Set
9510-062	Nil-Strength Grip Set - flat specimens	Set

17.4 Low-Force Load Cells

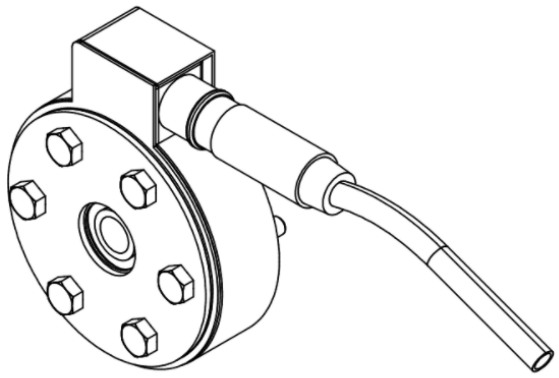


Fig. 17.6: Low-Force Load Cell - 3500 - DSI# 9510-120.

When mounted to the Low-Force Jaw Carrier, a Gleeble Low-Force Load Cell will provide improved accuracy at low-forces. There is no mechanical overload protection for these load cells. Due to the high-speed of the hydro-mechanical capabilities of a Gleeble system, these load cells can inadvertently be damaged. This damage can occur even when utilizing the software load-limiting capabilities of *QuikSim2* (page 333). Each load cell is supplied as an assembly that includes the mounting hardware, a magnetic shield, and a load cell signal conditioner.

Characteristic	Specification
Maximum Load	2,268 kgf (5,000 lbf) 22.24 kN
Non-linearity	±0.1 % of full scale
Hysteresis	±0.08 % of full scale
Non-Repeatability	±0.03 % of full scale
Overload rating	150 % of capacity
Deflection - Full Scale	0.0508 mm (0.002 in)
Force Measurement Accuracy	±1.0 % of full scale
Force Measurement Resolution	±1 kgf (2.2 lbf)

Part Number	Description	Sold As
3500 Low-Force Load Cell		
9510-120	500 to 5,000 lbf Load Cell - Gleeble 3500	Kit
LC05000	Replacement 3500 Low-Force Load Cell - Load Cell Only	Ea.
3800 Low-Force Load Cell		
9510-121	500 to 5,000 lbf Load Cell - Gleeble 3800	Kit
LC05000B	Replacement 3800 Low-Force Load Cell - Load Cell Only	Ea.

17.5 Low-Force Assemblies - Replacement Parts

Low-Force Carrier

Part Number	Description	Sold As
HH251	Moving-Side Mounting Hardware - 5/16-18 x 1 1/4 in SHCS S.S.	Ea.
9510-228	Moving-Side Bolt-Adapter - 1/2-13 to 5/16-18	Ea.
HH245	Fixed-Side Mounting Hardware - 5/16-18 x 1 in SHCS S.S.	Ea.
9510-229	Fixed-Side Bolt-Adapter - 1/2-13 to 5/16-18	Ea.
ORS014	Fixed-Side O-Rings	Ea.
OR7017	Jaw Mount O-Ring	Ea.
9510-010	Carrier Heating Cable - 14.0 inch length	Ea.
9510-011	Carrier Heating Cable - 10.4 inch length	Ea.

Low-Force Pocket Jaws

Part Number	Description	Sold As
9510-407	Wear Plate - Copper	Ea.
HE115	Wear Plate Installation Hardware - 10-32 x 3/8 in FHSHCS S.S.	
9510-416	Jaw-Jack Bolt	Ea.
HE305A	Jaw-Jack Bolt Extension 10-32 x 1/4 in SHCS S.S.	Ea.
9510-428	Pocket Jaw 3/8 in Jack-Plate	Ea.
HY069	Repair Helicoil - Jack Bolt Threading	Ea.
9510-414	Water Stop Plug	Ea.
OR7016	Jaw-Plate O-Rings	Ea.

Low-Force Load Cells

Part Number	Description	Sold As
HG135	Load Cell Mounting Hardware - 1/4-20 x 1 3/4 in HHB S.S.	Ea.
HK595	1/2-20 x 2 in Load Cell to Jaws Bolt	Ea.
BRS0250D	5/16 in OD IGUS Sleeve Bearing	Ea.
HG042	1/2 in OD Plastic Spacer	Ea.

Nil-Strength Jaws

Part Number	Description	Sold As
9510-205	Cylinder Mounting Blocks	Ea.
HG361	Cylinder Mounting Block Installation Hardware - 1/2-20 x 1/2 in SHCS S.S.	Ea.

Section 18

Strip Annealing

Contents

- *Strip Annealing Solutions* (page 250)
- *General-Purpose MCU - Strip Annealing Kit* (page 251)
  - *Specimen Size Considerations* (page 252)
  - *General-Purpose MCU - Strip Annealing Kit Replacement Grips* (page 254)
  - *General-Purpose MCU - Strip Annealing Kit Additional Parts* (page 255)

18.1 Strip Annealing Solutions

Annealing and coating lines are large, complex systems that require tight process control and optimization to maintain efficiency and product quality. Simulation data provides insights that enable more efficient scheduling of different material grades, gauges and specifications. This data can be used to reproduce and evaluate existing processes, experiment with process modifications, or troubleshoot problems. Gleeble systems can rapidly and dynamically heat and quench sheet specimens to accurately simulate annealing or galvanizing coating line processing. Simulations and experiments are a safer and less costly method of producing data for optimization. Production line trials risk damaging the mill, take up valuable production time, and often result in wasted material. Unlike expensive mill trials, simulations help staff quickly and efficiently optimize annealing procedures to improve profitability, increase production, and reduce waste by quickly providing the information needed to make better processing decisions.

Annealing simulations offer substantial benefits:

- Better understand the time/temperature relationship of materials, and processing windows
- Improved product quality
- Simulations help optimize material properties and meet the high demands of advanced high-strength steel (AHSS)
- Minimize scrap at transitions and warmer coils and reduce the use of secondary coils or test coils
- Accelerate new product development
- Improve efficiency by defining process windows to allow better transitions
- Develop annealing cycles to meet specifications and salvage off-chemistry or misprocessed coils
- Adjust processing settings for different alloys and grades

Each Gleeble Strip Annealing Simulation Solution includes the following features:

- All Gleeble strip annealing systems utilize an ultra-fast and responsive direct resistance heating system

- *Proportional Quench* (page 289)
- A dynamic cooling system with custom gas-quench spray heads that allows fast, yet controlled, cooling
- Complex thermal cycles
- Users can easily program complex temperature profiles, including heating, holding, controlled cooling, reheating and quenching, allowing for accurate process simulation

Large Uniform Temperature Zones - Great care has been taken to maximize the uniformity within the specimen which allows for a more representative post treatment analysis

Environmental Control - Tests can be run in vacuum, air or inert gas

Tension Application - Tension can be applied to the specimen to prevent buckling and simulate roll tension forces

Wide Surface Quenching - Custom designed quench spray heads for air or gas minimize thermal gradients in the test specimen during cooling

DSI offers a range of Strip Annealing Simulation Solutions

General-Purpose MCU - Strip Annealing Kit

The *General-Purpose MCU - Strip Annealing Kit* (page 251) fits within the vacuum tank of a Gleeble 3500 or 3800 and is used for heat treatment simulation of specimens. Dynamic temperature control and quenching capabilities enable higher cooling rates with minimal undershoot and a small thermal gradient.

Large-Sample Strip Annealing MCU

The *Large-Sample Strip Annealing* (page 77), available for Gleeble 3500 and 3800 systems, achieves controlled heating and cooling cycles on large sheet specimens with large uniform temperature zones. The sample size is large enough to provide subsequent properties testing of the material, including LDH and tensile test coupons.

Gleeble 525 Strip Annealing System

The *Gleeble 525 Strip Annealing Simulator's* (page 134) low cost, simplicity of operation and small footprint make it an ideal fit for line technicians to use. It can be placed near each annealing line for quick implementation of results. Simple to use, the system can be used to quickly run tests and simulations to help staff quickly make better processing decisions.

18.2 General-Purpose MCU - Strip Annealing Kit

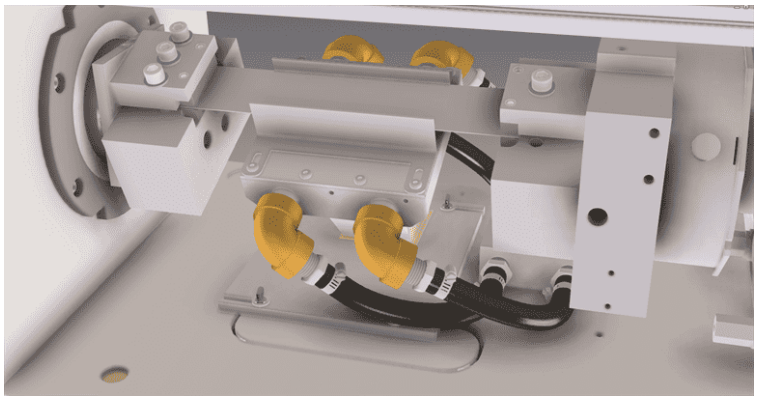


Fig. 18.1: General-Purpose MCU - Strip Annealing Kit - DSI# 9505-052.

The General-Purpose MCU - Strip Annealing Kit provides unique methods for physical simulation of strip annealing processes, including continuous annealing and transverse flux annealing.

Current Gleeble Users

Current Gleeble users can access the General-Purpose MCU - Strip Annealing Kit operator's manual here.[29]

A *Proportional Quench System* (page 289) allows easy programming of cooling rates using only air or inert gas as the cooling medium. The proportional control valve adjusts the cooling gas flow as needed to maintain a linear cooling rate during the annealing simulation. This is the newest method for annealing specimens. It provides simpler programming requirements and more accurate temperature control during cooling. The spray patterns and cooling spray settings must be carefully considered and planned in designing the annealing simulation.

Characteristic	Specification
Maximum Heating Rate	50 °C/s (90 °F/s)
Maximum Cooling Rate	400 °C/s (720 °F/s) with Helium quenching medium and high flow regulator
Maximum Temperature	900 °C (1,620 °F)
Thermally Uniform Hot Zone	20 mm x 50 mm (0.787 in x 1.968 in)
Hot Zone Thermal Gradient	±15 °C (±27 °F)

Note: The maximum heating rate was measured with a 1 mm x 50 mm x 260 mm 1018 carbon steel specimen.

Note: The hot zone thermal gradient is measured at a steady state temperature.

Part Number	Description	Sold As
9505-052	General-Purpose MCU - Strip Annealing Kit	Kit
Optional Accessories		
59046	*Proportional Quench* (page 289) - 3500 and 3800 GTC systems	Kit

Note: The General-Purpose MCU - Strip Annealing Kit supports the new *Proportional Quench System* (page 289) for better dynamic control of cooling using air or inert gas.

18.2.1 Specimen Size Considerations

The *specimen* (page 385) used with the *General-Purpose MCU - Strip Annealing Kit* (page 251) enables the creation of an ASTM-E8 dog bone shaped sample to be cut out of the thermally uniform center. *Contact Dynamic Systems* (page 373) for assistance identifying a recommended specimen geometry.

[29] https://support.gleeble.com/portal/en/kb/articles/series-3-gtc-9505-052-2-inch-strip-annealing-system-user-manual

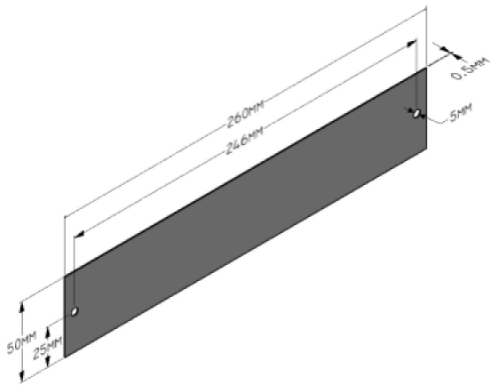


Fig. 18.2: Strip Annealing Specimen - SMF109.

Popular Specimen Sizes			
Length	**Width**	**Thickness**	**Drawing Number**
250 mm	50 mm	0.5 mm	SMF119
250 mm	50 mm	1 mm	SMF109
250 mm	50 mm	2 mm	SMF110

Thermal Uniformity

Thermal uniformity within the specimen, the difference between the center-point temperature measurement and the edge temperature measurement, is verified by measuring specimen temperature with thermocouples secured onto the specimen.

Thermocouple Placement

All thermocouple location measurements are indexed from the left and top of the specimen. Secure thermocouples at the following locations:

TC1: Center: 130 mm x 25 mm (5.11 in x 0.984 in)
TC2: 10 mm above TC1: 130 mm x 15 mm (5.11 in x 0.59 in)
TC3: 25 mm right of TC1: 155 mm x 25 mm (6.1 in x 0.984 in)

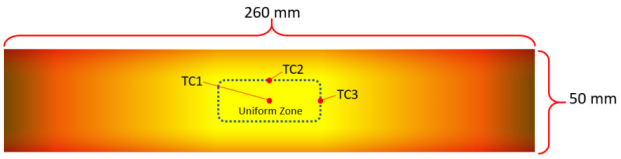


Fig. 18.3: Thermocouple Placement.

Note: All measurements are taken from the left and top of the specimen.

18.2.2 General-Purpose MCU - Strip Annealing Kit Replacement Grips

A variety of grips and spray heads have been developed over many years to accommodate the different heating and cooling cycles of different annealing processes. Because of the wide variety of heating and cooling cycles possible in the Gleeble, there is no single grip set which applies to all simulations.



Fig. 18.4: General-Purpose MCU - Strip Annealing Copper Alloy Grips - DSI# GN91101A.

Part Number	Description	Sold As
GN9110IAB	Strip Annealing Jaw - Bottom Grip - Copper	Ea.
GN9110IAT	Strip Annealing Jaw - Top Grip - Copper	Ea.
GN9110IA	Replacement General-Purpose MCU - Strip Annealing Copper Alloy Grips - includes two GN9110AB bottom grips, two GN9110AT top grips, and four spring pins	Set



Fig. 18.5: General-Purpose MCU - Strip Annealing Stainless Steel Grips - DSI# GN91101.

Part Number	Description	Sold As
GN9110IB	Strip Annealing Jaw - Bottom Grip - Stainless Steel	Ea.
GN9110IT	Strip Annealing Jaw - Top Grip - Stainless Steel	Ea.
GN9110I	Replacement General-Purpose MCU - Strip Annealing Stainless Steel Grips - includes two GN9110B bottom grips, two GN9110T top grips, and four spring pins	Set

18.2.3 General-Purpose MCU - Strip Annealing Kit Additional Parts

Part Number	Description	Sold As
33917	Moving-Shaft Bolt-Adapter - 5/8-11 in to 3/8-16 in	Ea.
31347	Moving Shaft Conductor Plate	Ea.
OR7025	Large Moving-Shaft Side O-Ring	Ea.
ORS013	Small Moving-Shaft Side O-Rings	Ea.
HZ014	Specimen Retention Dowel Pin - 3/16 x 5/8 Dowel Pin S.S.	Ea.
HI595	Moving-Shaft Mounting Hardware - 3/8-16 x 2 1/2 in SHCS S.S.	Ea.
OR7111	Fixed-Side O-Rings	Ea.
HK361	Fixed-Side Mounting Hardware - 1/2-13 x 2 1/2 in SHCS S.S.	Ea.
HH252	Hard Stop Mounting Hardware - 5/16-18 x 1 1/2 in SHCS S.S.	Ea.

Section 19

Crosswise Gauges

Contents

- *3000 Series Gauges* (page 257)
  - *Standard Crosswise Gauge - Range: ±6.25 mm* (page 257)
  - *High-Resolution Crosswise Dilatometer - Range: ±2.54 mm* (page 258)
- *500 Series Gauges* (page 260)
  - *Crosswise Gauge for Gleeble 500 Series - Range: ±6.35 mm* (page 260)
  - *High-Resolution Crosswise Dilatometer for Gleeble 500 Series - Range: ±2.54 mm* (page 261)

Crosswise gauges, also known as C-Gauges, measure the changes in the diameter or thickness of a specimen. These gauges are typically attached directly to the specimen. These gauges can be used to calculate or, if applicable, control the Gleeble mechanical system using the calculated deformation, stress or strain experienced by the specimen.

19.1 3000 Series Gauges

19.1.1 Standard Crosswise Gauge - Range: ±6.25 mm

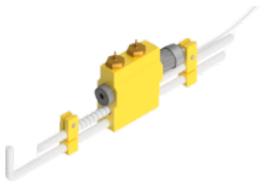


Fig. 19.1: Crosswise Gauge - DSI# 39010.

The 39010 Crosswise Gauge, also known as a C-Gauge, is the standard measurement gauge supplied with all 3000 Series Gleeble systems with a range of ±6.25 mm. This C-Gauge attaches directly to the specimen through quartz rods and can be used to control the Gleeble's mechanical movements through crosswise deformation, stress, or strain feedback. The main body of the gauge must be cooled to maintain proper function and measurement accuracy. This gauge can be used on the Gleeble 3800 and 3500 systems.

Current Gleeble Users

Current Gleeble users can access the 39010 Crosswise Gauge Operator's Manual here.[30]

Characteristic	Specification
Type	LVDT
Linear Range	±6.25 mm (±0.246 in)
Linearity	±0.25 % of full scale
Resolution	0.3 μm (1.18 x 10^{-5} in)
Response Time	0.32 ms
Gauge Length	0 - 12 mm (0 - 0.472 in)
Control Modes	Crosswise Measurement, Stress, Strain
Main Body Cooling	Compressed Air or Helium at 0.34 bar (5 psi)

Note: *Quartz contact rods* (page 345) are rated for continuous operation between 11 - 1,300°C (50 - 2,372°F) and limited (30 second) operation up to 1,400°C (2,552°F).

Part Number	Description	Sold As
39010	Crosswise Gauge - Kit and Module included	Ea.
Replacement Parts		
39011	Replacement Crosswise Gauge and Kit - (Module not included)	Ea.
GA000090	Replacement Crosswise Gauge - (Kit and Module not included)	Ea.

For additional parts, accessories and consumables, reference *Measurement Gauge Parts and Accessories* (page 345).

[30] https://support.gleeble.com/portal/en/kb/articles/series-3-gtc-39010-c-strain-gauge-user-manual

19.1.2 High-Resolution Crosswise Dilatometer - Range: ±2.54 mm

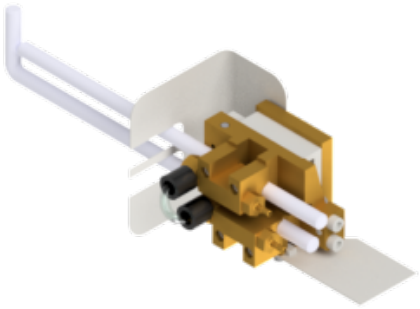


Fig. 19.2: High-Resolution Crosswise Dilatometer - DSI# 39018.

The 39018 High-Resolution Crosswise Dilatometer[31] is an LVDT-based gauge designed for accurate measurements of material transformations. The data collected by the dilatometer can be used by Gleeble's *Continuous Cooling Transformation (CCT) Software Package* (page 335) to create CCT or TTT plots.

This transducer can be used for measuring transformations after deformation on a variety of materials and specimen sizes within the limits of the gauge. No mechanical control is possible with this gauge. This dilatometer can be used on the Gleeble 3500 and 3800 systems.

The dilatometer attaches directly to the specimen through quartz rods. The main body of the gauge must be cooled to maintain proper function and measurement accuracy. Main body cooling is achieved through heat shields and active gas cooling.

Current Gleeble Users

Current Gleeble users can access the 39018 High-Resolution Crosswise Strain Gauge: Dilatometer Operator's Manual here.[32]

Characteristic	Specification
Linear Range	±2.54 mm (0.099 in)
Linearity	±0.25 % of full scale
Resolution	±0.4 μm (1.57 x 10^{-5} in)
Recommended Usable Deformation Rate	< 10 mm/s (0.394 in/s)
Control Modes	None - Measurement Recording Only
Heat Shields	Required
Main Body Cooling	Compressed Air or Helium at 0.34 bar (5 psi)

Note: Specimen size is limited by the length of the quartz rods. The standard configuration of the gauge can accept a 5 - 12 mm diameter specimen.

Note: The main body of the High-Resolution Crosswise Dilatometer is rated to a temperature of 150°C (302°F). To protect the gauge, heat shields must always be used.

Note: *Quartz contact rods* (page 345) are rated for continuous operation between 11 - 1,300°C (50 - 2,372°F) and limited (30 second) operation up to 1,400°C (2,552°F).

[31] https://support.gleeble.com/portal/en/kb/articles/series-3-gtc-39018-cct-dilatometer-user-manual
[32] https://support.gleeble.com/portal/en/kb/articles/series-3-gtc-39018-cct-dilatometer-user-manual

Part Number	Description	Sold As
39018	High-Resolution Crosswise Dilatometer - Kit and Module included	Kit
Replacement Parts		
9655-001	Replacement CCT Dilatometer Assembly - (Kit and module not included)	Ea.

For additional parts, accessories and consumables, reference *Measurement Gauge Parts and Accessories* (page 345).

19.2 500 Series Gauges

19.2.1 Crosswise Gauge for Gleeble 500 Series - Range: ±6.35 mm

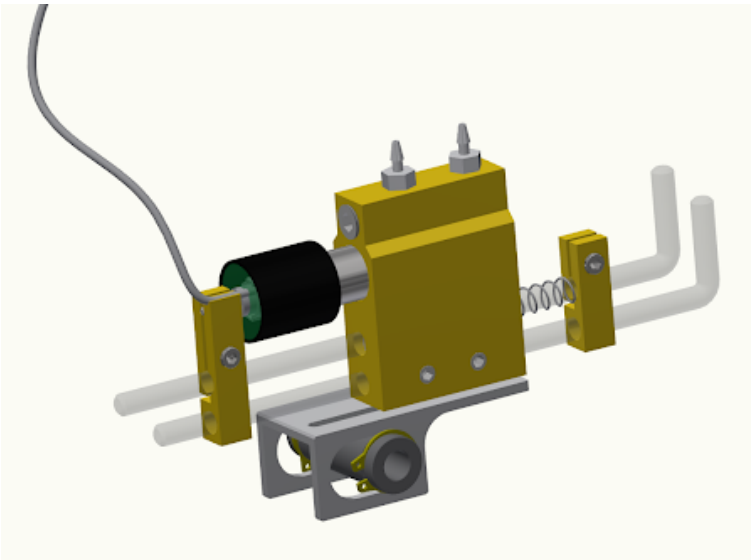


Fig. 19.3: Crosswise Gauge for Gleeble 500 Series - DSI# 59012.

The 59012 Crosswise Gauge is mounted on the specimen in a Gleeble System. It can be used to provide precise measurements of the crosswise deformation of the specimen within the hot zone. This gauge attaches directly to the specimen through quartz rods and can be used to control the Gleeble's mechanical movements through crosswise deformation, stress, or strain feedback. The main body of the gauge must be cooled to maintain proper function and measurement accuracy.

Characteristic	Specification
Type	LVDT
Linear Range	±6.35 mm (±0.25 in)
Accuracy	±0.1 % of full scale
Resolution	0.3 μm (1.18 x10^{-6} in)
Response Time	0.32 ms
Gauge Length	0 - 12 mm (0 - 0.47 in)
Control Modes	Crosswise Measurement, Stress, Strain
Main Body Cooling	Compressed Air or Helium at 0.5 bar (7.25 psi)

Note: *Quartz contact rods* (page 345) are rated for continuous operation between 11 - 1,300℃ (50 - 2,372℉) and limited (30 second) operation up to 1,400℃ (2,552℉).

Part Number	Description	Sold As
59012	Crosswise Gauge for Gleeble 500 Series - Kit and Module included	Kit

For additional parts, accessories and consumables, reference *Measurement Gauge Parts and Accessories* (page 345).

19.2.2 High-Resolution Crosswise Dilatometer for Gleeble 500 Series - Range: ±2.54 mm

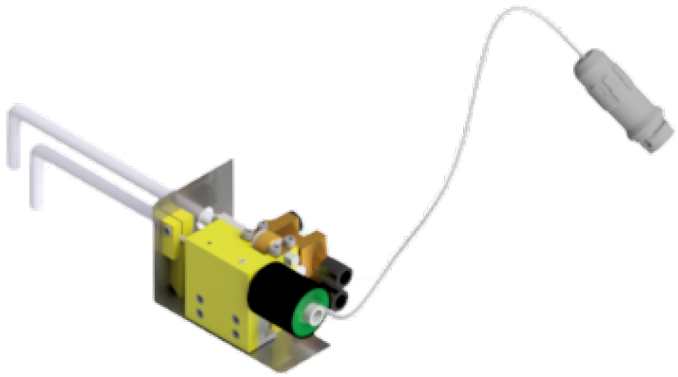


Fig. 19.4: High-Resolution Crosswise Dilatometer for Gleeble 500 Series - DSI# 59021.

The 59021 High-Resolution Crosswise Dilatometer is mounted on the specimen in a Gleeble System. It can be used to provide precise diameter measurements of the specimen within the hot zone. This gauge attaches directly to the specimen through quartz rods and can be used to control the Gleeble's mechanical movements through crosswise deformation, stress, or strain feedback.

The main body of the gauge must be cooled to maintain proper function and measurement accuracy. Main body cooling is achieved through heat shields and active gas cooling.

Characteristic	Specification
Type	LVDT
Linear Range	±2.54 mm (±-0.1 in)
Accuracy	±0.2 % of full scale
Resolution	0.15 μm (5.905 x 10^{-6} in)
Response Time	1.59 ms
Gauge Length	0 - 5 mm (0 - 0.2 in)
Control Modes	Crosswise Measurement, Stress, Strain
Heat Shields	Required
Main Body Cooling	Compressed Air or Helium at 0.5 bar (7.25 psi)

Note: *Quartz contact rods* (page 345) are rated for continuous operation between 11 - 1,300°C (50 - 2,372°F) and limited (30 second) operation up to 1,400°C (2,552°F).

Part Number	Description	Sold As
59021	High-Resolution Crosswise Dilatometer for Gleeble 500 Series - Kit and Module included	Kit

For additional parts, accessories and consumables, reference *Measurement Gauge Parts and Accessories* (page 345).

Section 20

Lengthwise Gauges

Contents

- *3000 Series Gauges* (page 263)
  - *Jaw-to-Jaw Lengthwise Extensometer - Range: ±12.7 mm* (page 263)
  - *High-Resolution Jaw-to-Jaw Lengthwise Extensometer - Range: ±2.54 mm* (page 264)
  - *Hot Zone Lengthwise Extensometer - Range: ±12.5 mm* (page 264)
  - *Hot Zone Lengthwise Strain Gauges* (page 265)
  - *Hydrawedge II Lengthwise Strain Gauge - Range: ±25.4 mm* (page 267)
- *500 Series Gauges* (page 268)
  - *Jaw-to-Jaw Lengthwise Strain Gauge for Gleeble 500 Series - Range: ±12.7 mm* (page 268)

Lengthwise gauges, commonly referred to as L-Gauges, measure a change in the length of a specimen. These gauges can be secured directly to the specimen or to the jaw assembly. These gauges can be used to calculate the strain experienced by the specimen and can be used to control mechanical movements.

20.1 3000 Series Gauges

20.1.1 Jaw-to-Jaw Lengthwise Extensometer - Range: ±12.7 mm

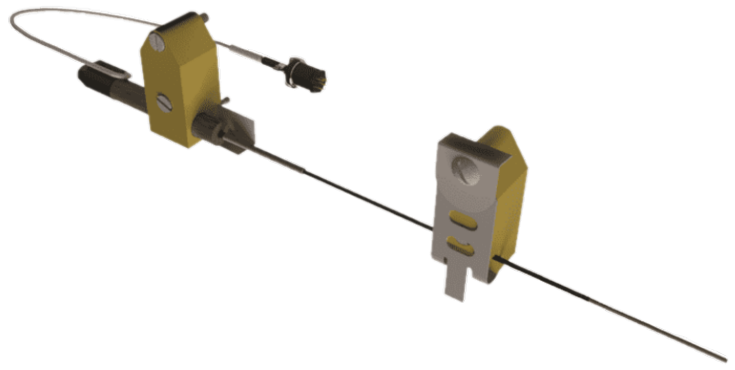


Fig. 20.1: Jaw-to-Jaw Lengthwise Extensometer - DSI# 39050.

The 39050 Jaw-to-Jaw Lengthwise Extensometer is mounted on the Pocket Jaws of the *General-Purpose Mobile Conversion Unit* (page 49) for the Gleeble *3500* (page 28), *3800* (page 11), and the *Compression Test Adapter* (page 237). Gleeble *3180* (page 90) systems utilize a 39052 Jaw-to-Jaw Lengthwise Extensometer. Each can be used to provide precise measurement of the movement of the jaws.

Current Gleeble Users

Current Gleeble users can access the 39050 Jaw-to-Jaw Lengthwise Extensometer operator's manual here.[33]

Characteristic	Specification
Type	LVDT
Linear Range	±12.7 mm (0.5 in)
Linearity	±0.25 % of full scale
Resolution	±2 μm (7.87 x 10^{-5} in)
Gauge Length	0 - 31 mm (0 - 1.22 in)
Maximum Usable Stroke Rate	500 mm/s (19.68 in/s)
Maximum Deformation Rate With L-Gauge Control	50 mm/s (1.969 in/s)
Control Modes	Length Measurement, Stress, Strain, Deformation

Part Number	Description	Sold As
39050	Jaw-to-Jaw Lengthwise Extensometer - Kit and Module included - 3500 and 3800	Ea.
39052	Jaw-to-Jaw Lengthwise Extensometer - Kit and Module included - 3180	Ea.
Replacement Parts		
39051	Jaw-to-Jaw Lengthwise Extensometer and Kit - (Module not included) - 3500 and 3800	Ea.

[33] https://support.gleeble.com/portal/en/kb/articles/series-3-gtc-39050-jaw-to-jaw-lgauge-user-manual

For additional parts, accessories and consumables, reference *Measurement Gauge Parts and Accessories* (page 345).

20.1.2 High-Resolution Jaw-to-Jaw Lengthwise Extensometer - Range: ±2.54 mm

The 39053 High-Resolution Jaw-to-Jaw Lengthwise Extensometer is similar to the standard 39050 Extensometer. Although the 39053 has a smaller linear range, the higher resolution makes this extensometer invaluable when measuring minute and subtle changes in a specimen.

Characteristic	Specification
Linear Range	±2.54 mm (0.099 in)
Linearity	±0.25 % of full scale
Resolution	±0.4 μm (1.57 x 10^{-5} in)
Maximum Usable Stroke Rate	500 mm/s (19.68 in/s)
Maximum Deformation Rate With L-Gauge Control	50 mm/s (1.969 in/s)
Control Modes	Length Measurement, Stress, Strain, Deformation

For additional parts, accessories and consumables, reference *Measurement Gauge Parts and Accessories* (page 345).

Part Number	Description	Sold As
39053	High-Resolution Jaw-to-Jaw Lengthwise Extensometer - Kit and Module included - 3500 and 3800	Ea.

20.1.3 Hot Zone Lengthwise Extensometer - Range: ±12.5 mm

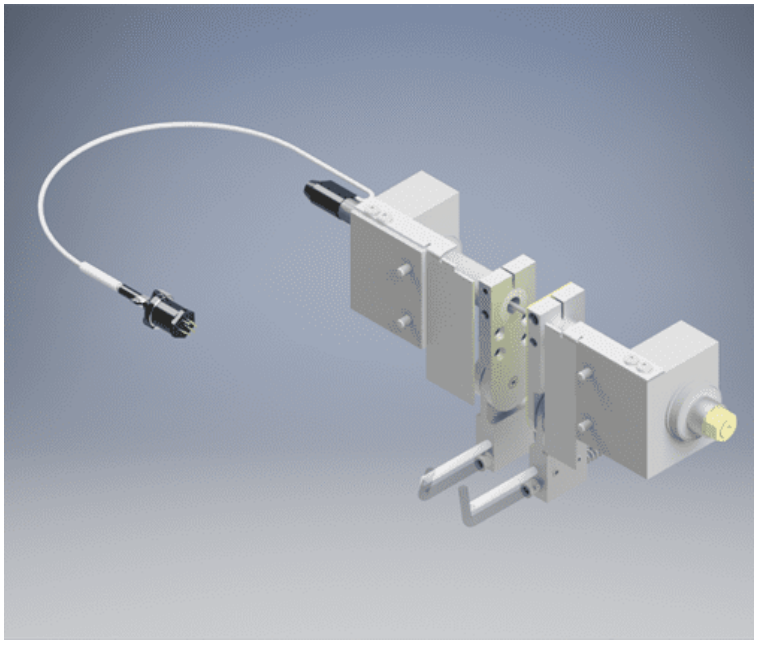


Fig. 20.2: Hot Zone Lengthwise Extensometer - DSI# 39061.

The 39061 Hot Zone Lengthwise Extensometer is an LVDT-based measuring device. The 39061 HZT gauge is a design improvement for the popular 39060 Hot Zone Gauge. Both devices utilize the same LVDT and specimen contact methodologies. However this is where the similarities end. The new 39061's improved design enables easier gauge installation. The redesign also allows for more consistent gauge placement test to test. Just like the traditional 39060, the new 39061 HZT measures lengthwise strain using alumina and quartz rods in contact with the hot zone of the specimen. The 39061 is equipped with two spacer blocks used to set a defined starting gauge length.

Characteristic	Specification
Type	LVDT
Defined Gauge Spacer Blocks	10 mm and 25 mm
Linear Range	±12.5 mm (1.0 in)
Linearity	±0.25 % of full scale
Resolution	±2 μm (7.87 x 10^{-5} in)
Gauge Length	0 - 25.4 mm (0 - 1.00 in)
Maximum Usable Stroke Rate	500 mm/s (19.68 in/s)
Maximum Deformation Rate With L-Gauge Control	50 mm/s (1.969 in/s)
Control Modes	Length Measurement, Stress, Strain, Deformation

Note: *Alumina contact rods* (page 347) are rated for continuous operation between 0 - 1,200℃ (32 - 2,192℉) and a limited time (30 seconds) up to 1,300℃ (2,372℉).

Note: *Quartz contact rods* (page 345) are rated for continuous operation between 11 - 1,300℃ (50 - 2,372℉) and limited (30 second) operation up to 1,400℃ (2,552℉).

Part Number	Description	Sold As
39061	Hot Zone Lengthwise Extensometer - Kit and Module included	Ea.

20.1.4 Hot Zone Lengthwise Strain Gauges

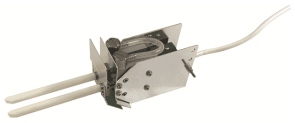


Fig. 20.3: Hot Zone Lengthwise Strain Gauge.

The Gleeble Hot Zone L-Strain Gauges are full-bridge strain gauges equipped with alumina rods that contact the specimen in the hot zone for lengthwise measurement of strain. DSI offers three different Hot Zone Gauges with varying measurement ranges and initial set points.

These gauges feature a unique mounting design. The measurement gauge is held onto the specimen by light, flexible, ceramic fiber cords. These ceramic fiber cords make the gauge nearly self-supporting and eliminate the need for bulky mounting brackets.

Current Gleeble Users

Current Gleeble users can access the Gleeble Hot Zone L-Strain Gauge operator's manual here.[34]

[34] https://support.gleeble.com/portal/en/kb/articles/series-3-gtc-39070-39071-39072-hot-zone-lgauge-user-manual

The light weight of the gauge combined with the self-supporting design virtually eliminates side loading on the specimen. The combination of radiant heat shields and convection cooling fins allows use of the gauges at elevated specimen temperatures for short periods of time without additional cooling. A valve, regulator, vacuum tank feedthroughs and hoses for additional gas cooling of the gauge are included with the kit. For typical operation, compressed air is used to provide additional cooling to the gauges.

Characteristic	Specification		
DSI Part Number	**39070**	**39071**	**39072**
System Identification Number	HZT070	HZT071	HZT072
Linear Range	+0.5/-0.2 in (+12.7/-5.08 mm)	+5/-2 mm (+0.197/-0.079 in)	+12.5/-5 mm (+0.492/-0.196 in)
Gauge Length	1.0 in (25.4 mm)	10 mm (0.394 in)	25 mm (0.984 in)
Maximum Tension Range	0.5 in (12.7 mm)	5 mm (0.197 in)	12.5 mm (0.492 in)
Maximum Compression Range	0.2 in (5.08 mm)	2 mm (0.079 in)	5 mm (0.197 in)
Type	Full-Bridge Strain Gauge		
Linearity	±0.15 % of full scale		
Resolution	±2 μm (7.87 x 10^{-5} in)		
Maximum Usable Rate	10 mm/s (0.394 in/s)		
Main Body Cooling	Compressed Air or Helium at 0.34 bar (5 psi)		
Control Modes	Measurement Only		

Note: *Alumina contact rods* (page 347) are rated for continuous operation between 0 - 1,200°C (32 - 2,192°F) and a limited time (30 seconds) up to 1,300°C (2,372°F).

Part Number	Description	Sold As
39070	Hot Zone Lengthwise Strain Gauge - Range: +0.5/-0.2 in	Ea.
39071	Hot Zone Lengthwise Strain Gauge - Range: +5/-2 mm	Ea.
39072	Hot Zone Lengthwise Strain Gauge - Range: +12.5/-5 mm	Ea.

For additional parts, accessories and consumables, reference *Measurement Gauge Parts and Accessories* (page 345).

20.1.5 Hydrawedge II Lengthwise Strain Gauge - Range: ±25.4 mm

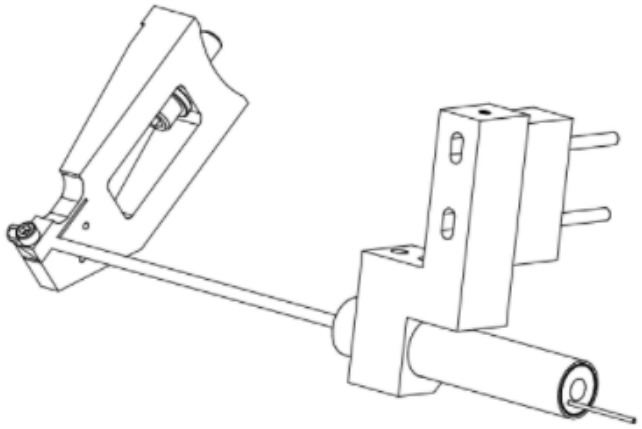


Fig. 20.4: Hydrawedge II Lengthwise Strain Gauge - DSI# 39057.

The 39055 Hydrawedge L-Strain System is designed specifically to be mounted in the *Hydrawedge II* (page 55) MCU.

Current Gleeble Users

Current Gleeble users can access the 39055 Hydrawedge L-Strain System operator's manual here.[35]

Characteristic	Specification
Type	LVDT
Linear Range	±25.4 mm (1.0 in)
Linearity	±0.25 % of full scale over ±25.4 mm (±1.0 in)
Resolution	±2 μm (7.87 x 10^{-5} in)
Gauge Length	0 to 31 mm (0 to 1.22 in)
Maximum Usable Stroke Rate	2,000 mm/s (78.74 in/s)
Maximum Recommended Strain Rate	50/s

Note: The effective maximum strain rate is dependent on the specimen material, size, and test temperature.

Part Number	Description	Sold As
39057	Hydrawedge II Lengthwise Strain Gauge - Kit and Module included	Kit
Replacement Parts		
TRN006	6 inch LVDT Stroke Transducer	Ea.
TRN006A	Measurement Core for TRN006	Ea.
TRN006B	Measurement Core Bushing for TRN006	Ea.

[35] https://support.gleeble.com/portal/en/kb/articles/series-3-gtc-series-partnumber-part-description-users-manual

20.2 500 Series Gauges

20.2.1 Jaw-to-Jaw Lengthwise Strain Gauge for Gleeble 500 Series - Range: ±12.7 mm

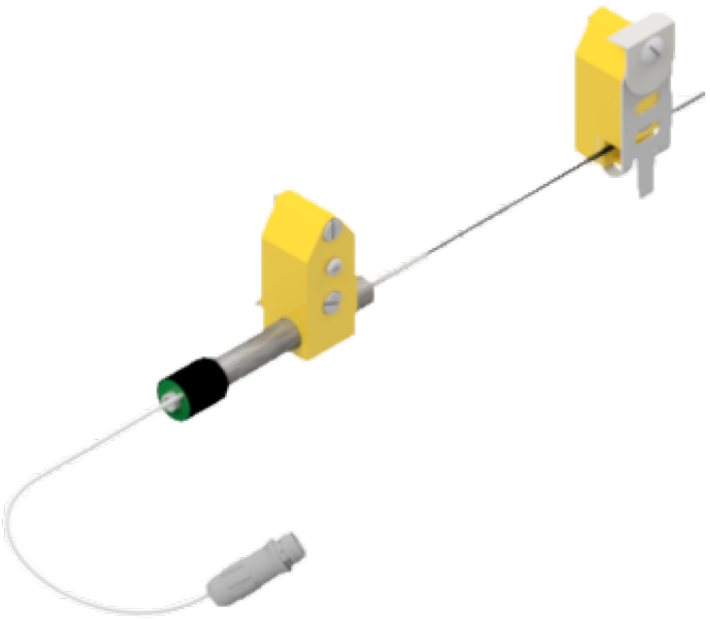


Fig. 20.5: Jaw-to-Jaw Lengthwise Strain Gauge for Gleeble 500 Series - DSI# 59011.

The 59011 Jaw-to-Jaw Lengthwise Strain System is mounted on the Pocket Jaws in the Gleeble system. It can be used to provide precise measurements of the movement of the jaws without being affected by compliance in the rest of the load train.

Characteristic	Specification
Type	LVDT
Linear Range	±12.7 mm (0.5 in)
Accuracy	±0.1 % of full scale
Resolution	0.6 μm (2.36 x 10^{-5} in)
Response Time	0.5 ms
Gauge Length	0 - 31 mm (0 - 1.22 in)
Control Modes	Lengthwise Measurement, Stress, Strain

Part Number	Description	Sold As
59011	Jaw-to-Jaw Lengthwise Strain Gauge for Gleeble 500 Series - Kit and Module included	Ea.

For additional parts, accessories and consumables, reference *Measurement Gauge Parts and Accessories* (page 345).

Section 21

Non-Contact Optical Micrometer

Contents

- *Non-Contact LED Optical Micrometer - Ranges: ±60 mm / ±6 mm / ±0.6 mm* (page 271)
- *Non-Contact Optical Dilatometer - Range: ±20 mm* (page 273)

New & Improved Optical System Can Achieve High Speed, High Accuracy, and High Durability

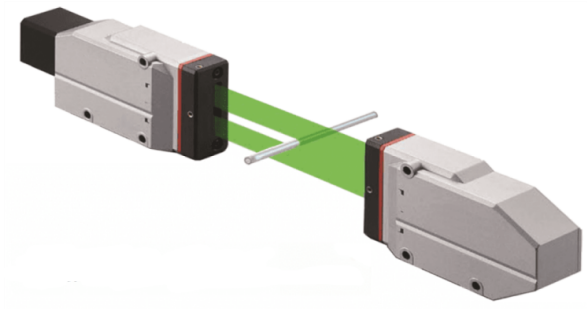


Fig. 21.1: Non-Contact LED Optical Micrometer - DSI# 59063.

The Non-Contact LED Optical Micrometer, uses a high-intensity GaN long-life green LED combined with an HL-CCD sensor to provide high-speed measurements with no moving parts. This unit is much faster and has higher resolution than conventional, laser-based measuring devices. Easy-to-use, menu-driven setup software is included with the unit to allow configuration of the controller on the desktop PC. Settings can be stored, recalled, and easily changed for a variety of test conditions. The measurement system includes a controller unit, transmitter unit, receiver unit, two optical-coated window ports for use with the Gleeble vacuum tank, and all necessary mounting brackets and cables to operate the system.

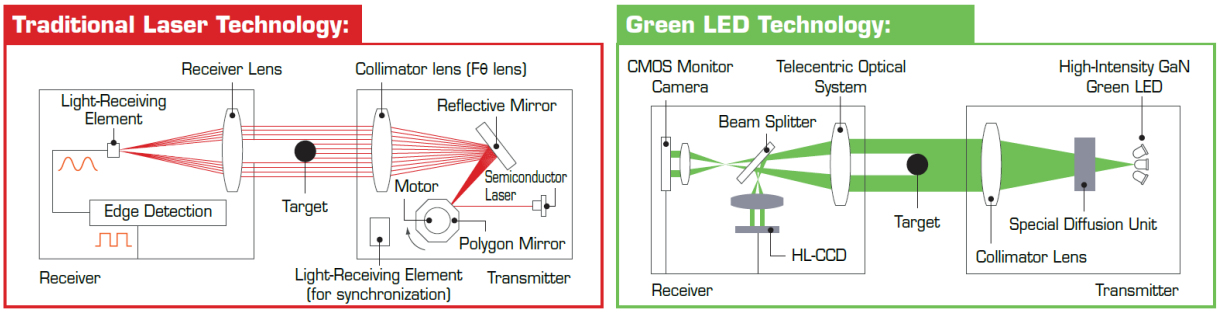


Fig. 21.2: Optical Measurement Comparison.

Green LED Technology

The green LED light is distributed as a uniform parallel light beam, and is applied to a target. The edge between the bright and dark areas on the HL-CCD sensor is detected and translated into a measured value, such as a specimen's outer diameter.

Traditional Laser Technology

In a conventional laser optical measuring device, the laser beam is projected onto a rotating polygonal mirror. The reflected light scans the measurement range, then reaches the receiving element. To improve speed and accuracy of this laser measuring device, the mirror's rotating motor would need to operate at a faster rate, sacrificing durability and reliability.

DSI offers two models of optical extensometers. The 39112 *Non-Contact Optical Dilatometer - Range: ±20 mm* (page 273) is used with Gleeble systems equipped with a Series 3 control system. The 39112 offers a vast improvement over traditional laser based extensometers.

The 59063 *Non-Contact LED Optical Micrometer* (page 271) is used on *Gleeble Touch Control* (page 9) enabled systems. It offers many improvements over other optical measurement devices offered by DSI. The 59063's higher sampling rate, combined with a wider ranging focal distance, results in lower noise and more accurate measurements.

The controller unit is an electronic system which controls the transmitter and receiver units and converts the optical measurement to usable electronic signals. The Gleeble work station displays a real-time camera image of the specimen target. This makes it easy to align the transmitter and receiver units. In addition, the user can see the exact location of the measurement beam in relation to the specimen and thermocouple locations. Common settings are selectable and configurable directly from the *Gleeble HMI* (page 6).

The 59063's transmitter unit contains a high-intensity GaN green LED and a special diffusion unit with collimator lens to shape the LED beam. The receiver unit contains an HL-CCD sensor for measurement; a telecentric optical system to provide only parallel light for imaging; and a CMOS camera monitor to provide images of the specimen during setup. The components are housed in a dustproof and waterproof IP64 enclosure, and mounted outside the vacuum tank. The system uses no motors or spinning mirrors. This results in longer life and higher reliability.

21.1 Non-Contact LED Optical Micrometer - Ranges: ±60 mm / ±6 mm / ±0.6 mm

The 59063 Non-Contact LED Optical Micrometer uses a high-intensity GaN long-life green LED combined with an HL-CCD sensor to provide high-speed measurements with no moving parts. Easy-to-use, menu-driven setup software is included with the unit to allow configuration of predefined measurement ranges via the Gleeble HMI. Settings can be stored, recalled, and easily changed for a variety of test conditions. The 59063 Non-Contact LED Optical Micrometer can be used to measure in either a crosswise configuration or a lengthwise configuration.

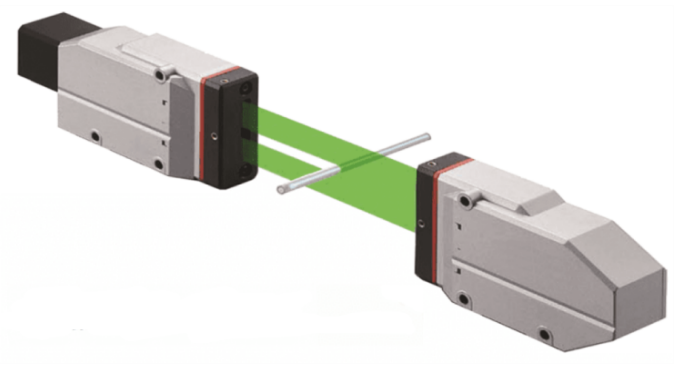


Fig. 21.3: Non-Contact LED Optical Micrometer - DSI# 59063.

Current Gleeble Users

Current Gleeble users can access the 59063 Non-Contact LED Optical Micrometer System operator's manual here.[36]

Danger: Never look directly into the scanning optical system LED transmitting head. Never point the transmitting head away from the vacuum tank while the power is on.

[36] https://support.gleeble.com/portal/en/kb/articles/gtc-59063-led-micrometer-user-manual

Characteristic	Specification		
Range	±60 mm (±2.36 in)	±6 mm (±0.236 in)	±0.6 mm (±0.0236 in)
Resolution	12 μm (4.72 x 10^{-4} in)	1.2 μm (4.72 x 10^{-5} in)	0.3 μm (1.18 x 10^{-5} in)
Accuracy	±68 μm (±2.67 x 10^{-3} in)	±14 μm (±5.51 x 10^{-4} in)	±8.6 μm (±3.33 x 10^{-4} in)
Sampling Rate	16 kHz		
LED Type	InGaN Green		
Ambient Luminescence	3,000 Lux or lower		
Smallest Detectable Object	0.8 mm (0.031 in)		
Serial Communication	RS-232, parity:none, baud:9600		
Analog	Output ±10 VDC		
Output Impedance	~100 ohms		
Supply Power	24 VDC		
Maximum Power Consumption	1.2 amps		
Operating Temperature	0 - 50°C (32 - 122°F)		
Operating Humidity	20 - 85 % RH		
Mounting	Crosswise or Lengthwise		

Note: Measuring range may be limited by vacuum chamber window size.

Part Number	Description	Sold As
59063	Non-Contact LED Optical Micrometer	Ea
Required Mounting Kits		
32851	3500 or 3800 Mounting Kit - 59063 Non-Contact LED Optical Micrometer	Ea
32855	3180 Mounting Kit - 59063 Non-Contact LED Optical Micrometer	Ea
Required Accessories		
59025	*Accessory Instrument Module* (page 341) - GTC Systems only	

Note: The 59063 Non-Contact LED Optical Micrometer is only available on GTC equipped systems.

Note: The 59063 Non-Contact LED Optical Micrometer requires an *Accessory Instrument Module* (page 341) and *Non-Contact Optical Measuring Device Window Feedthrough* (page 342).

21.2 Non-Contact Optical Dilatometer - Range: ±20 mm

The 39112 Scanning Non-Contact Optical Dilatometer and Extensometer is only available for 3000 Series systems without Gleeble Touch Control (GTC). Specifications, including measurement range, sampling rate, and resolution, vary from those of the new 59063 system. Contact the DSI Engineering Team for details.

Danger: Never look directly into the scanning optical system LED transmitting head. Never point the transmitting head away from the vacuum tank while the power is on.

Characteristic	Specification
Sampling Rate	2,400 Hz
Measurement Range	±20 mm (0.787 in)
Resolution	0.01 μm (3.93^{-7} in)
Mounting	Crosswise or Lengthwise
Maximum Specimen Temperature	1,300°C/s (2,372°F/s)

Part Number	Description	Sold As
39112	Scanning Non-Contact Optical Dilatometer and Extensometer	Ea
Required Mounting Kits		
32844	3500 or 3800 Mounting Kit - 39112 Optical Dilatometer and Extensometer System	Ea

Note: The 39112 Scanning Non-Contact Optical Dilatometer and Extensometer requires *Non-Contact Optical Measuring Device Window Feedthrough* (page 342).

Section 22

Pyrometer Control Cameras

Contents

- *3000 Series* (page 274)
  - *Silicon Two-Color Pyrometer* (page 275)
  - *InGaAs Two-Color Pyrometer* (page 276)
- *500 Series* (page 277)
  - *Silicon Two-Color Pyrometer for Gleeble 500 Series* (page 277)
  - *InGaAs Two-Color Pyrometer for Gleeble 500 Series* (page 278)
  - *500 Series Pyrometer Mounting Kit* (page 279)

22.1 3000 Series



Fig. 22.1: Pyrometer Control Camera System for 3000 Series Systems.

22.1.1 Silicon Two-Color Pyrometer

The 37015 Pyrometer series of two-color pyrometers provide a method for non-contact temperature measurement and control on Gleeble systems. The 37015 series pyrometers use two silicon detectors in the pyrometer camera. The camera features an optical laser for easy alignment and sighting of the measurement location on the specimen. The camera can be switched to one-color mode for operation as a standard radiation pyrometer.

Each model of the 37015 series pyrometer includes all required mounting brackets and hardware.

Current Gleeble Users

Current Gleeble users can access the 37015 Pyrometer operator's manual here.[37]

Characteristic	Specification
Accuracy of Camera	±0.5 % of measured value in ℃ + 1 ℃
Repeatability of Camera	Within ±0.25 % of measured value in ℃ + 1 ℃
Response Time of Camera	< 20 ms, Adjustable up to 10 s
Response Accuracy	±2 % at 1,000 ℃/s
	±4 % at 2,000 ℃/s
Resolution	1 ℃
Focal Length	25 - 36 cm (10 - 14 in)
Focus	Variable-focus optics with laser-aim sighting
Mounting	Mounting arm for direct specimen view and vacuum tank use
Housing	Housing rating – IP 65 (according to DIN 40050)

Part Number	Detector Type	Temperature Range	Sold As
		℃ (℉)	
37015-14C	Silicon	600 - 1,400 (1,112 - 2,552)	Ea.
37015-15C		650 - 1,500 (1,202 - 2,732)	Ea.
37015-18C		750 - 1,800 (1,382 - 3272)	Ea.
37015-25C		900 - 2,500 (1,652 - 4,532)	Ea.
37015-30C		1,000 - 3,000 (1,832 - 5,432)	Ea.

[37] https://support.gleeble.com/portal/en/kb/gtc-series-3-kits-and-accessories/37015-37080-pyrometer-systems

22.1.2 InGaAs Two-Color Pyrometer

The 37017 Pyrometer series of two-color pyrometers provide a method for non-contact temperature measurement and control on Gleeble systems. By using 2 InGaAs detectors, the 37017 series provides a wider operating range than pyrometers equipped with silicon detectors. The camera features an optical laser for easy alignment and sighting of the measurement location on the specimen. The camera can be switched to one-color mode for operation as a standard radiation pyrometer.

Each model of the 37017 series pyrometer includes all required mounting brackets and hardware.

Current Gleeble Users

Current Gleeble users can access the 37017 Pyrometer operator's manual here.[38]

Characteristic	Specification
Accuracy of Camera	±0.5 % of measured value in ℃ + 1 ℃
Repeatability of Camera	Within ±0.25 % of measured value in ℃ + 1 ℃
Response Time of Camera	< 20 ms, Adjustable up to 10 s
Response Accuracy	±2 % at 1,000 ℃/s
	±4 % at 2,000 ℃/s
Resolution	1 ℃
Focal Length	25 - 36 cm (10-14 in)
Focus	Variable-focus optics with laser-aim sighting
Mounting	Mounting arm for direct specimen view and vacuum tank use
Housing	Housing rating – IP 65 (according to DIN 40050)

Part Number	Detector Type	Temperature Range	Sold As
		℃ (℉)	
37017-10C	InGaAs	350 - 1,000 (662 - 1,832)	Ea.
37017-13C		350 - 1,300 (662 - 2,372)	Ea.
37017-16C		400 - 1,600 (752 - 2,912)	Ea.
37017-18C		500 - 1,800 (932 - 3,272)	Ea.
37017-30C		800 - 3,000 (1,472 - 5,432)	Ea.

[38] https://support.gleeble.com/portal/en/kb/gtc-series-3-kits-and-accessories/37015-37080-pyrometer-systems

22.2 500 Series

22.2.1 Silicon Two-Color Pyrometer for Gleeble 500 Series

The 500 Series Silicon Two-Color Pyrometers provide a method for non-contact temperature measurement and control on Gleeble 563 and 540 systems. These pyrometers use two silicon detectors in the pyrometer camera. The camera features an optical laser for easy alignment and sighting of the measurement location on the specimen. All programming of the pyrometer can be achieved through the integrated Gleeble Tech Support web page of every Gleeble System. Emissivity changes, selecting color modes, and creation of unique emissivity profiles are all achievable with the new Gleeble control environment.

Characteristic	Specification
Accuracy of Camera	±0.5 % of measured value in ℃ + 1 ℃
Repeatability of Camera	Within ±0.25 % of measured value in ℃ + 1 ℃
Response Time of Camera	< 20 ms, Adjustable up to 10 s
Response Accuracy	±2 % at 1,000 ℃/s
	±4 % at 2,000 ℃/s
Resolution	1 ℃
Focal Length	25 - 36 cm (10 - 14 in)
Focus	Variable-focus optics with laser-aim sighting
Mounting	Mounting arm for direct specimen view and vacuum tank use
Housing	Housing rating – IP 65 (according to DIN 40050)

Part Number	Detector Type	Temperature Range	Sold As
		℃ (℉)	Ea.
59078	Silicon	600-1,400 (1,112-2,552)	Ea.
59079		650-1,500 (1,202-2,732)	Ea.
59080		750-1,800 (1,382-3272)	Ea.
Required Mounting Kits			
57001	*500 Series Pyrometer Mounting Kit* (page 279)		

22.2.2 InGaAs Two-Color Pyrometer for Gleeble 500 Series

The 500 Series InGaAs Two-Color Pyrometers provide a method for non-contact temperature measurement and control on Gleeble 563 and 540 systems. These pyrometers use two InGaAs detectors in the pyrometer camera. The camera features an optical laser for easy alignment and sighting of the measurement location on the specimen. All programming of the pyrometer can be achieved through the integrated Gleeble Tech Support web page of every Gleeble System. Emissivity changes, selecting color modes, and creation of unique emissivity profiles are all achievable with the new Gleeble control environment.

Characteristic	Specification
Accuracy of Camera	±0.5 % of measured value in ℃ + 1 ℃
Repeatability of Camera	Within ±0.25 % of measured value in ℃ + 1 ℃
Response Time of Camera	< 20 ms, Adjustable up to 10 s
Response Accuracy	±2 % at 1,000 ℃/s
	±4 % at 2,000 ℃/s
Resolution	1 ℃
Focal Length	25 - 36 cm (10 - 14 in)
Focus	Variable-focus optics with laser-aim sighting
Mounting	Mounting arm for direct specimen view and vacuum tank use
Housing	Housing rating – IP 65 (according to DIN 40050)

Part Number	Detector Type	Temperature Range	Sold As
		℃ (℉)	Ea.
59084	InGaAs	350-1,000 (662-1,832)	Ea.
59085		350-1,300 (662-2,372)	Ea.
59086		400-1,600 (752-2,912)	Ea.
59087		500-1,800 (932-3,272)	Ea.
Required Mounting Kits			
57001	*500 Series Pyrometer Mounting Kit* (page 279)		

22.2.3 500 Series Pyrometer Mounting Kit

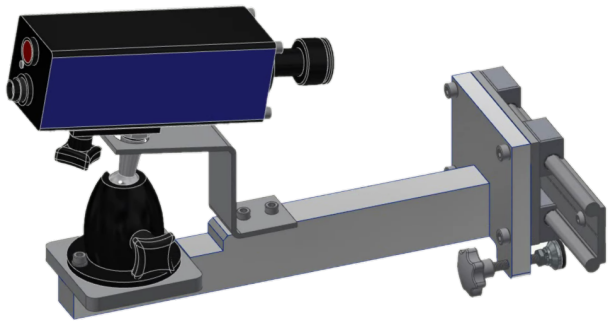


Fig. 22.2: Pyrometer Control Camera Mount for 500 Series Systems - DSI# 57001.

The 57001 Pyrometer Mounting Kit is designed specifically for use on Gleeble 563 and 540 systems. This kit includes all mounting and installation hardware needed to correctly install a 500 Series *Silicon Two-Color Pyrometer for Gleeble 500 Series* (page 277) or *InGaAs Two-Color Pyrometer for Gleeble 500 Series* (page 278). A Pyrometer is not included in the 57001 kit.

Part Number	Description	Sold As
57001	Pyrometer Mounting Kit - 563 and 540 only	Kit

Section 23

Melting and Solidification

Contents

- *Gleeble Remote Control Pendant* (page 281)
- *Melt Enhancer* (page 281)
- *Quartz Crucibles* (page 282)



Fig. 23.1: Melted and Solidified Specimen.

Materials researchers have come to rely on the multi-functionality of Gleeble systems. The unique horizontal specimen mounting of a Gleeble General-Purpose MCU provides the unmatched ability to conduct melting and solidification testing. The full hydraulic capabilities of the Gleeble system remain intact during a melting test. This provides researchers the ability to conduct continuous casting characterization tests, from melting to controlled solidification and deformation.

The liquefied specimen is contained within a quartz crucible by the cooler specimen ends. Once allowed to cool, the specimen solidifies into a single piece, enabling mechanical deformation testing to be conducted.

Current Gleeble Users

Current Gleeble users can access the Continuous Casting Process Simulation[39] application notes in the Gleeble Application Quick Start Guide.

[39] https://support.gleeble.com/portal/en/kb/articles/series-3-gtc-gleeble-general-testing-guide-user-manual

23.1 Gleeble Remote Control Pendant

The Gleeble Remote Control Pendant is a hardwired remote control for the Gleeble 3000 Series systems. The pendant contains the primary control features available on the Control Console/HMI in a portable option. The pendant gives the Gleeble operator the ability to focus on the specimen view, while keeping the Gleeble controls within easy reach.



Fig. 23.2: Gleeble Pendant - DSI# 35205.

Part Number	Description	Sold As
35205	Gleeble Remote Control Pendant Mark II Design	Ea.

23.2 Melt Enhancer

The Melt Enhancer aids in the melting of a specimen by altering the magnetic field in the Gleeble chamber. It prevents excessive electromagnetic stirring of the melt pool which, could cause molten metal to splash out of the crucible.

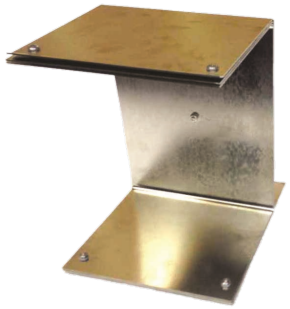


Fig. 23.3: Melt Enhancer - DSI# 35320.

Part Number	Description	Sold As
35320	Melt Enhancer (Magnetic Field Guide)	Ea.

23.3 Quartz Crucibles

Quartz crucibles are used to contain the liquefied metal during the melt phase of the solidification simulation. Selecting an appropriately sized crucible is important to the success of each test. A crucible that is either two large or too small could cause difficulties during melting. When the inside diameter is too large, the molten metal sinks, and the specimen would be out of shape along the specimen axis. During sinking the thermocouple tends to be detached, which results in a failure of temperature control. If the inside diameter is too small, the tube will break when the specimen is expanding. With the right size of the quartz tube, it is easy to control the melting and solidification. DSI has identified the correct quartz crucible for the most commonly used specimen geometries.

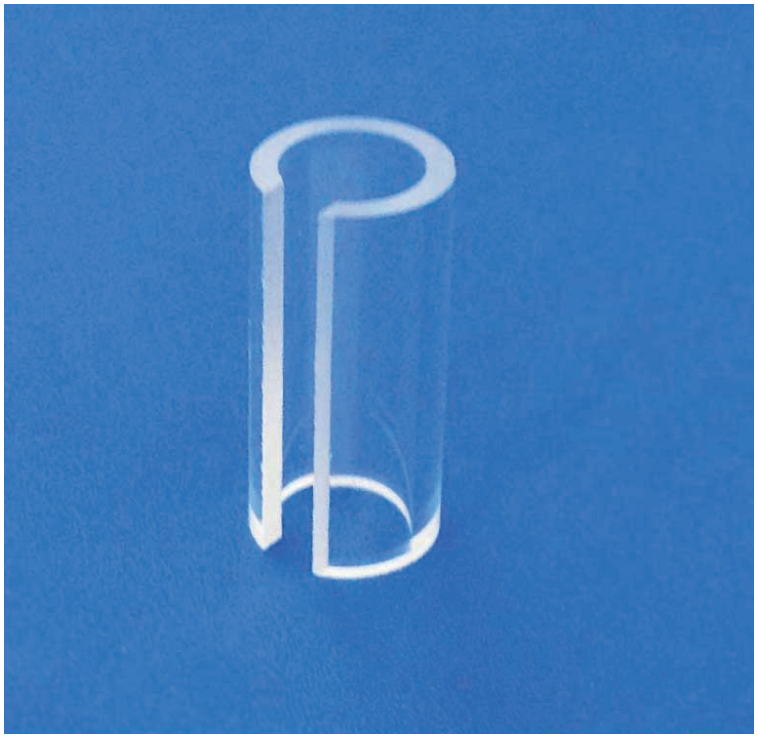


Fig. 23.4: Quartz Crucible - DSI# G414B.

Part Number	Description	Quantity Per Package	Sold As
G414B	For 10 mm dia specimens	30	Package
G414E	For 6 mm dia specimens	10	Package

Note: *Contact Dynamic Systems* (page 373) for crucible options for specimens not listed above.

Section 24

Quench Systems

Contents

- *Quench Tanks* (page 283)
- *Quench Kits* (page 285)
  - *3000 Series Quench Spray Nozzle Kits* (page 285)
    - *Open Quench Spray Nozzle Kit* (page 285)
    - *Multi-Function Open Quench Spray Nozzle Kit* (page 286)
    - *Hydrawedge II - Multi-Function Open Quench Spray Nozzle Kit* (page 286)
    - *Closed ISO-Q Quench Kits* (page 288)
    - *Proportional Quench System* (page 289)
    - *Cryogenic Quench System* (page 291)
  - *500 Series Quench Nozzle Kits* (page 293)
    - *500 Series Standard Quench Nozzle* (page 293)
    - *500 Series ISO-Q Adapter* (page 293)
- *Gleeble System Quench Cooling Rates* (page 293)

24.1 Quench Tanks

The Gleeble Quench Tank Systems are designed to increase the cooling capability of the Gleeble platform. DSI offers two standard Quench Tank System options, the 59013 High Flow and the 59038 Extended High Flow quench systems. Each option includes two independent quench medium tanks. These tanks can be used independently or simultaneously.

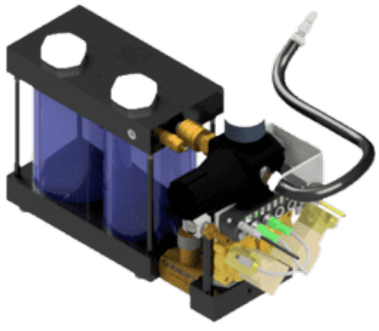


Fig. 24.1: High Flow Quench - DSI# 59013.

The quench system uses a gas or liquid cooling medium to remove thermal energy from the test specimen. The quench directly interfaces with the high-speed EtherCAT bus on all GTC and 500 Series systems. Spray heads are not included and must be purchased separately.

Current Gleeble Users

Current Gleeble users can access the Quench Tank Systems operator's manual here.[40]

Characteristic	Specification	
	High Flow	**Extended High Flow**
Volume of Quench Tanks	1 liter (0.26 gal) per tank	3 liters (0.792 gal) per tank
Number of Quench Tanks per System	2 tanks	
Quench Medium Flow Control	One multi-turn needle valve per tank	
Maximum Air or Gas Output Pressure	0 - 6.89 bar (0 - 100 psi)	

Part Number	Description	Sold As
59013	High-Flow Quench	Ea.
59038	Extended High-Flow Quench	Ea.

Warning: Gleeble Quench Tanks are not designed to be used with flammable gases or liquids, including hydrogen gas. The maximum water temperature the Quench Tank can withstand is 38°C (86°F).

[40] https://support.gleeble.com/portal/en/kb/articles/gtc-series-5-59013-59038-dual-channel-quench-user-manual

24.2 Quench Kits

24.2.1 3000 Series Quench Spray Nozzle Kits

Open Quench Spray Nozzle Kit

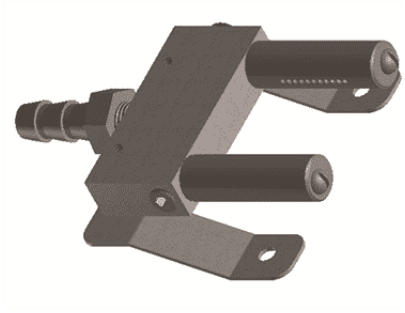


Fig. 24.2: Quench Spray Nozzle - DSI# GN9300AS1.

The GN9300AS1 Open Quench Spray Nozzle Kit features spray head designed to quench through specimen surface contact. The spray heads are mounted between the Gleeble's Pocket Jaws, above and below the test specimen. Each kit includes specific spray nozzles for flat and round specimens. When the quench valves are turned on, the quenching medium flows through the spray heads toward the specimen. If the Gleeble is equipped with a vacuum system, the vacuum is turned off to prevent the quench medium from contaminating the vacuum pump. This quench spray nozzle kit can be used on the Pocket Jaws of the *General-Purpose Mobile Conversion Unit* (page 49) MCU and the *Low-Force Pocket Jaws* (page 241) for the Gleeble 3500 and 3800.

Note: The GN9300AS1 Open Quench Spray Nozzle Kit is not compatible with the *Gleeble Induction Heating System (IHS)* (page 167) or *Compression Test Adapter* (page 237).

Part Number	Description	Sold As
GN9300AS1	Open Quench Spray Nozzle Kit - 3500 and 3800	Kit
GN9300AS3	Open Quench Spray Nozzle Kit - 3180	Kit
Optional Accessories		
GN9300B	Flat Spray Pattern - 1 Row - Quench Spray Nozzle (Included in GN9300AS3)	Ea.
GN9300C	Round Spray Pattern - 1 Row - Quench Spray Nozzle (Included in GN9300AS3)	Ea.
GN9300M	Flat Spray Pattern - 3-Row - Quench Spray Nozzle	Ea.
GN9300L	Round Spray Pattern - 3 Row - Quench Spray Nozzle	Ea.

Multi-Function Open Quench Spray Nozzle Kit

The 31733 Multi-Function Open Quench Spray Nozzle Kit features a surface quenching design with sprayer nozzles that quench the specimen by direct contact with the quenching medium. The spray heads are mounted outside the Gleeble's Pocket Jaws, above and below the test specimen. When the Multi-Function Quench Spray Nozzles are used, the quenching medium is sprayed directly on the specimen. If the Gleeble is equipped with a vacuum system, the vacuum is turned off to prevent the quench medium from contaminating the vacuum pump.

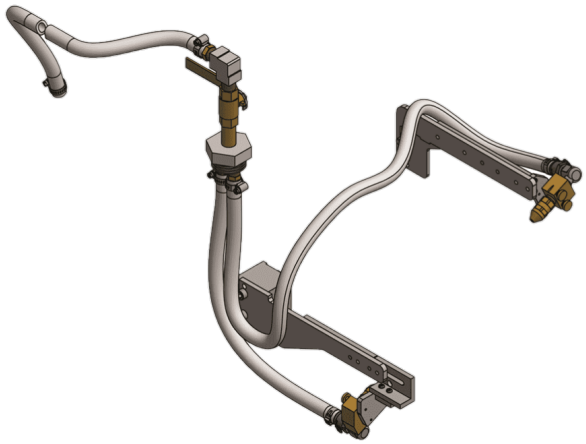


Fig. 24.3: Multi-Function Open Quench Spray Nozzle Kit - DSI# 31733.

This quench spray nozzle kit can be used on the Pocket Jaws of the *General-Purpose Mobile Conversion Unit* (page 49) MCU, the *Low-Force Pocket Jaws* (page 241) for the Gleeble 3500 and 3800, the *Compression Test Adapter* (page 237), and with the *Gleeble Induction Heating System (IHS)* (page 167).

Part Number	Description	Sold As
31733	Multi-Function Open Quench Spray Nozzle Kit	Kit

Hydrawedge II - Multi-Function Open Quench Spray Nozzle Kit

The 31735 Hydrawedge II - Multi-Function Open Quench Spray Nozzle Kit features a surface quenching design with sprayer nozzles that quench the specimen by direct contact with the quenching medium. The spray heads are mounted outside the Gleeble's anvil faces, above and below the test specimen. When the Multi-Function Open Quench Spray Nozzles are used, the quenching medium is sprayed directly on the specimen. If the Gleeble is equipped with a vacuum system, the vacuum is turned off to prevent the quench medium from contaminating the vacuum pump.

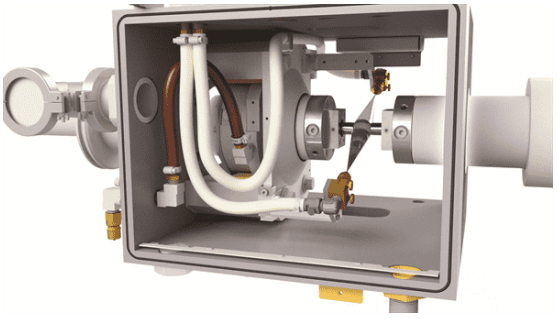


Fig. 24.4: Multi-Function Open Quench Spray Nozzle Kit - Hydrawedge II - DSI# 31735.

The 37135 quench system is only used on the *Hydrawedge II* (page 55) MCU and can be used with the *Gleeble Induction Heating System (IHS)* (page 167).

Part Number	Description	Sold As
31735	Hydrawedge II - Multi-Function Open Quench Spray Nozzle Kit	Kit

Closed ISO-Q Quench Kits

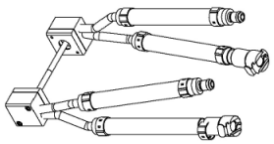


Fig. 24.5: ISO-Q Quench Heads - DSI# 38520.

The ISO-Q Closed Quench Spray Nozzle Kit provides a quenching method that does not compromise the vacuum in the chamber when quenching. The ISO-Q Quench System works with both the high-flow and extended high-flow quench systems on the 3500, 3800, and the 3180. The specimens for use with the ISO-Q quench system have holes in each end to accommodate the ISO-Q Quench Nozzles. This allows the quench medium to contact the specimen internally. When using this method of quenching, a vacuum or inert gas atmosphere can be maintained. This quench kit is typically used for Continuous Cooling Transformation (CCT) and Heat Affected Zone (HAZ) studies. The ISO-Q Quench System is sometimes referred to as a “closed quench” system.

Part Number	Description	Sold As
3500 and 3800		
38520	ISO-Q Quench Fixture Kit for 10 mm dia specimens	Kit
38524	ISO-Q Quench Fixture Kit for 10, 11, and 12 mm square HAZ Specimens	Kit
Replacement Parts - 3500 and 3800		
31726	Replacement ISO-Q Quench Head Assembly with Quench Tube for 10 mm dia specimens - 38520 kit	Ea
31728	Replacement ISO-Q Quench Head Assembly for 10, 11, and 12 mm Square HAZ Specimens - 38524 kit	Ea
33707	Quench Cap Replacement	Ea
3180		
38523	ISO-Q Quench Fixture Kit for 10 mm specimens - 3180	Kit
MAXStrain MCU		
38521	ISO-Q Quench Fixture Kit for MAXStrain	Kit

Proportional Quench System

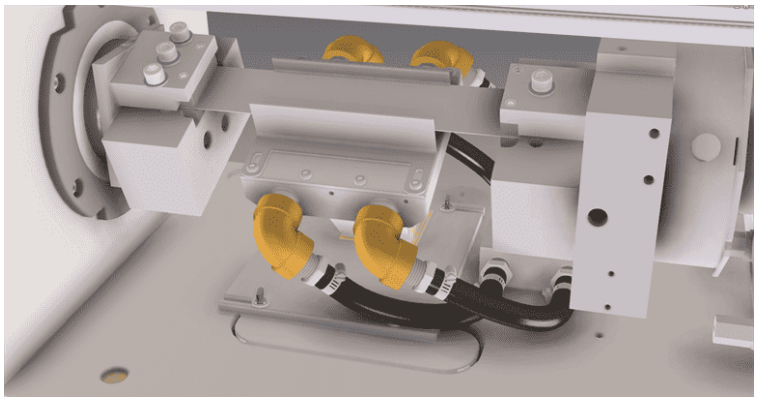


Fig. 24.6: High Density Gas Quench Head Assembly and Proportional Quench - DSI# 31730 and 59046.

The 59046 Proportional Quench is a variable flow rate quench system for use with the *General-Purpose MCU - Strip Annealing Kit* (page 251) and uses a gas quench medium. This device allows for automatic flow rate adjustment based on the error between a user-programmed temperature profile and the actual specimen temperature.

Current Gleeble Users

Current Gleeble users can access the 59046 Proportional Quench operator's manual here.[41]

Characteristic	Specification
Type	Proportional Control Quenching Valve
Control Mode	Temperature Feedback with Programmable Gain
Quenching Medium	Independent Compressed Air or Inert Gas Source
Maximum Supply Pressure	10 bar (145 psi)
Supply Line Size Minimum Diameter	19 mm (0.75 in)
Supply Flow Rate Minimum	4,000 L/min (1,057 gal/min)
Flow Range	0 - 4,000 L/min (0 - 1,057 gal/min)

[41] https://support.gleeble.com/portal/en/kb/articles/series-3-31731-proportional-quench-users-manual



Fig. 24.7: Regulator - High Flow - DSI# 38525-TX.

Part Number	Description	Sold As
59046	Proportional Quench - 3500 and 3800 GTC systems	Kit
31731	Proportional Quench - Series 3 systems	Kit
Required Accessories		
31730	High-Density Gas Quench Head Assembly	Kit
59025	*Accessory Instrument Module* (page 341) - GTC Systems only	
Optional Accessories		
38525-TX	Regulator - High Flow with Adapter Fittings - Country Specific	Ea.

Note: Contact a DSI *Sales Representative* (page 373) for specific part numbers for Regulator- High Flow - Adapter Fittings information.

Cryogenic Quench System

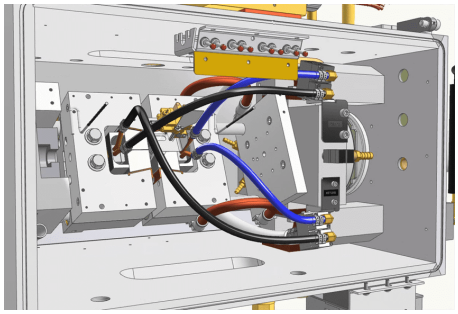


Fig. 24.8: Cryogenic Quench System - DSI# 59074.

The 59074 Cryogenic Quench System is designed to cool specimens to a cryogenic temperature range. This is typically achieved by using liquid nitrogen, although the system can also use liquid argon or other cryogenic gases. The system can also utilize an inert gas stream cooled in a bath of cryogenic fluid. In typical operation, the liquid nitrogen contacts the sample internally, similar to the action of the *Closed ISO-Q Quench Kits* (page 288). This quench medium delivery method ensures that an isothermal plane is maintained in the center of the specimen so that thermal gradients do not adversely affect dilatometry or microstructure analysis. The goal of the sub-zero quench is not to accelerate the quench rate, but rather to provide a means to reach cryogenic end-of-quench temperatures. Such endpoint temperatures are not achievable with DSI's standard quenching systems.

Any temperature between the lowest achievable cryogenic temperature and room temperature can be achieved by using the Cryogenic Quench. Through control of the cryogenic quenching medium, plus the use of a technique called "back heating," the Gleeble system is able to reach and maintain the programmed temperature. Back heating is the combined use of direct resistance heating and active quenching of a specimen at the same time.

Cooling specimens into a cryogenic temperature range is useful for studies evaluating the properties of materials at low temperatures, and for the evaluation of transformations that may occur below room temperature, such as evaluating the volume fraction and stability of retained austenite in highly alloyed tool steels, or retained austenite steels such as TRIP or Q and P steels.

Performance

Maximum (average) cooling rates listed below are for a 1018 carbon steel ISO-Q specimen SMR201B. The specimen was pre-chilled by flowing LN_2 through the sample at a delivery pressure of 22 psi for 5 minutes. The specimen was held in Stainless Steel Hot Grips in a Low-Force Pocket Jaw Assembly.

Specimen Type	Free Span	Drawing Number	Temperature Range	Cooling Rate
			℃ (℉)	℃/s (℉/s)
10 mm dia x 84 mm long with reduced center	5 mm dia x 5 mm long	SMR201B	1,000 to 600 (1,832 to 1,112)	60 (108)
			600 to 400 (1,112 to 752)	60 (108)
			400 to 25 (752 to 77)	40 (72)
			25 to -150 (77 to -238)	10 (18)

Note: Vacuum seals may be adversely affected by cryogenic temperatures.

System Recommendations

Characteristic	Specification
Required Minimum Liquid Nitrogen Delivery Pressure	1.51 bar (22 psi)
Maximum Liquid Nitrogen Delivery Pressure	3.45 bar (50 psi)
Recommended Liquid Nitrogen Tank Volume	230 L (60.75 gal)
Recommended System Pre-chill Recommended Duration for Maximum Cooling Rate	5 min
Supplied Liquid Nitrogen Transfer Hose	2 m (6 ft) long, female to female CGA-295

Note: The required fitting (connection) on a customer-supplied Cryogenic Liquid Container (CLC) must be a male CGA-295 (3/4-16 in UNF-2A-RH-EXT) (1/2 in SAE Flare). This fitting will enable the DSI-supplied Liquid Nitrogen Transfer Hose to connect to the CLC.

Note: Liquid nitrogen tank (Cryogenic Liquid Container, CLC) pressure is set with a pressure relief valve on the CLC. Note: A CLC setup with a 1.51 bar (22 psi) pressure relief valve has a set point for a maximum of 1.51 bar (22 psi)

Note: When pre-chilling the system while holding a sample at an elevated temperature, a 6-minute pre-chill is recommended.

Note: 3.45 bar (50 psi) is not required for usage.

Part Number	Description	Sold As
59074	Cryogenic Quench System	Kit
Required Accessories		
59025	*Accessory Instrument Module* (page 341) - GTC Systems only	

24.2.2 500 Series Quench Nozzle Kits

500 Series Standard Quench Nozzle

The 59024 Standard Quench Nozzle provides the Gleeble 500 Series system with the ability to spray a quench medium directly onto the surface of a specimen for an increased cooling rates.

Part Number	Description	Sold As
59024	Standard Quench Nozzle - 563 and 540	Kit

500 Series ISO-Q Adapter

The 59023 500 Series ISO-Q Adapter provides the Gleeble system with the ability to quench a specimen internally, in a closed quench-fluid loop that never enters the testing chamber. The ISO-Q Adapter therefore allows for rapid cooling rates while the desired vacuum atmosphere is maintained. The ISO-Q Quench Nozzles are embedded in the specimen, and quench the specimen by direct contact. The specimens for use with the ISO-Q quench system have holes in each end to accommodate the ISO-Q Quench Nozzles. This allows the quench medium to contact the specimen internally. When using this method of quenching a vacuum or inert gas atmosphere can be maintained. This quench kit is typically used for Continuous Cooling Transformation (CCT) and Heat Affected Zone (HAZ) studies. The ISO-Q Quench System is sometimes referred to as a “closed quench” system.

Part Number	Description	Sold As
59023	ISO-Q Quench Adapter - 563 and 540	Kit

24.3 Gleeble System Quench Cooling Rates

Quench cooling rates can be found in each system’s specifications section.

- *Gleeble 3800-GTC* (page 11)
- *Gleeble 3500-GTC* (page 28)
- *Gleeble 3180-GTC* (page 90)
- *Gleeble 563* (page 104)
- *Gleeble 540* (page 120)
- *Gleeble 525* (page 134)

Section 25

Laser-Ultrasonic Sensor for In-Situ Metallurgy - LUMet

Contents

- *LUMet* (page 295)
  - *How LUMet Works* (page 296)
- *LUMet Specifications* (page 296)
  - *Generation Laser* (page 296)
  - *Detection Laser* (page 297)
- *Specimen Size Considerations* (page 297)
- *LUMet Dimensions* (page 298)

25.1 LUMet



[42]

Fig. 25.1: LUMet System - DSI# 35203.

It is now possible to monitor metal microstructures in real time, in situ, at high-temperatures and high heating and cooling rates, while conducting physical simulations. The LUMet system provides unprecedented capabilities by allowing observation of the internal physical state of a specimen during Gleeble tests. Laser-ultrasonics is a technology that enables non-contact ultrasonic measurements, using lasers to generate and detect ultrasound pulses. Unlike other ultrasonic technologies, it can be used on hot materials, because the sensor is not in physical contact with the specimen. This-one-of a kind ability makes the LUMet uniquely capable of in situ studies of solid metallic materials up to their melting points. In the field of metallurgy and metallurgical processing, ultrasonics is a sensitive technique for measurements of elasticity, internal microstructure, phase transitions, crystallographic texture, grain size, and more. When used with the Gleeble 3500 or 3800, these measurements can be done in situ, in real time, during thermo-mechanical processing.

Researchers can gather in situ information on:

- Recrystallization
- Phase transformations
- Grain growth
- Elastic constants
- Grain size
- Texture

Danger: Never operate the LUMet with any safety interlocks bypassed. Bypassing a safety interlock can expose the operator to Class 4 lasers.

Part Number	Description	Sold As
35203	LUMet System	Ea.
Required Accessories		
59025	*Accessory Instrument Module* (page 341) - GTC Systems only	
TCNR-LUM	3 days on-site installation, commissioning and training by a Tecnar specialist. Cost includes all travel expenses.	3 Days

[42] https://gleeble.com/products/specialty-systems/laser-ultrasonic-measurement-system-lumet.html

25.1.1 How LUMet Works



Fig. 25.2: LUMet Laser Probe.

The LUMet system uses lasers to generate and detect ultrasound pulses in a sample under test. To generate the ultrasound pulse in the sample, a high-power, short-pulse laser produces light pulses about 10 ns in duration. Each pulse causes intense pressure on the surface of the sample, and sends an ultrasonic pressure pulse through it.

A laser interferometer measures surface displacement caused by the pulse laser and its subsequent reflections, with sub-nanometer resolution, as it echoes through the sample. Based on the measured velocity and attenuation of sound in the medium, researchers can determine texture, modulus, grain size and phase mixtures.

25.2 LUMet Specifications

Characteristics	Specification
Laser Class	Class 1
Round Specimen Diameter	10 - 12 mm
Flat Specimen Thickness	1 - 15 mm
Maximum Heating Rate	100 °C/s (180 °F/s
Maximum Temperature	1,300 °C (2,372 °F)
Maximum Stroke Rate	4 mm/s (0.157 in/sec)
Recommended Stroke Rate	2 mm/s (0.0787 in/sec)
LUMet Power	240 VAC supplied from Gleeble load unit
LUMet Cooling Process Fluid Rate	18.9 L/min ±1 L/min (5 gpm ±1 gpm)
LUMet Cooling Process Fluid Temperature	20 - 23.9 °C (68 - 75 °F)
LUMet Cooling Process Fluid Pressure	1.5 bar (21.75 psi)
Safety Goggles Rating	Optical Densities (OD): OD 7+ 532 nm and OD 7+ 1064 nm

Note: Round Specimens should have a length-to-diameter ratio between 1 and 1.5.

25.2.1 Generation Laser

The Generation Laser System contains a pulsed, frequency-doubled industrial Nd:YAG laser. Although the generation laser always operates at 50 pulses per second, it can be configured to release a pulse only every *n* cycles, where *n* is an integer from 1 to 50. Its purpose is to send a non-contact ultrasonic pulse though the test specimen. The pulse and its echoes are then collected by the LUMet Pulse Detection Laser System. The Generation Laser System and the Pulse Detection Laser System are mounted on a motorized, horizontal slide which tracks the deformation of the sample, allowing the measurement point to be maintained during thermal expansion and contraction, or during mechanical deformation.

Laser System	Generation Laser
Laser Type	Nd:YAG
Wavelength	532 nm
Pulse Frequency	1 - 50 Hz
Pulse Width	9 ns
Nominal Spot Size	1 mm
Output Power	70 mJ

25.2.2 Detection Laser

The Pulse Detection Laser System contains a pulsed Nd:YAG. The Pulse Detection Laser System operates in synchronization with the Generation Laser System at up to 50 pulses per second. The purpose of the Pulse Detection Laser System is to provide a means of tracking the ultrasonic pulse generated by the Generation Laser System.

Laser System	Detection Laser
Laser Type	Nd:YAG
Wavelength	1064 nm
Pulse Frequency	Synchronized with the G-Laser
Pulse Width	90 μs
Nominal Spot Size	1.3 mm
Output Power	50 mJ

25.3 Specimen Size Considerations

Gleeble systems are capable of testing a wide variety of material compositions and specimen geometries. Inherent limitations of the system, such as distance between the jaw or anvil faces, the maximum or minimum stroke speed, test temperature, and force limitations for the individual system must be considered when selecting a specific *specimen geometry* (page 378).

The target temperature of a test will also impact the size of a specimen that can safely be tested with a Gleeble system. For example, when considering a standard uniaxial compression specimen, it is possible for a soft material such as aluminum or copper to be tested at ambient temperature. Harder materials, such as steel or titanium alloys, are expected to be tested at elevated temperatures.

Popular Specimen Sizes			
Specimen Length	**Specimen Width | Specimen Thickness | Drawing Number**		
60 mm	10 mm dia	3 mm	SMF121

LUMet Specimen Mounting Hardware

Part Number	Description	Sold As
34362	LUMet Specimen Installation Fixture	Ea.
HE205	Specimen Mounting Bolt	Ea.

25.4 LUMet Dimensions

Equipment	Height	Depth	Width
LUMet Control Console	190.4 cm (74.96 in)	90.6 cm (35.67 in)	180 cm (70.86 in)
LUMet Laser Probe	134.8 cm (53.07 in)	74.6 cm (29.37 in)	62.1 cm (24.45 in)

Section 26

Digital Image Correlation

Contents

- *Digital Image Correlation* (page 299)
- *Compatible DIC Systems* (page 300)
- *DIC Integration Package* (page 306)

26.1 Digital Image Correlation

Digital Image Correlation (DIC) can be used in conjunction with a Gleeble system for 3D non-contact optical measurements of deformation and strain. DSI has developed a successful combination of high-performance cameras, lighting, fixturing, and licensed software to produce accurate results, even at elevated temperatures.

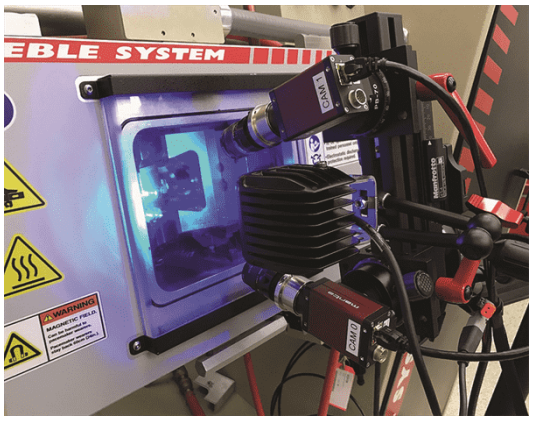


Fig. 26.1: DIC System Installed on a General-Purpose MCU.

Digital Image Correlation can be used on a number of standard Gleeble tests, including tensile tests, Strain Induced Crack Opening (SICO) and, uniaxial compression.

High-resolution cameras and intense blue LED lighting are focused on specimens through the front or rear windows of the Gleeble. DIC systems provide thousands of strain measurements across a specimen, allowing characterization of strain fields in an entire test region. Traditional contact measurement systems provide only 2-point strain measurements – from one point to another point.

Key Features:

- Non-contact measurement
- No mechanical interaction with the sample
- No need for precise placement
- Enables testing of complex shapes and geometries
- Numerical deformation of your experimental images with finite element displacements fields
- Eliminates strain gages and displacement sensors
- Performance Analysis

- Flexibility to set various DIC parameters with automated tools to determine optimum DIC settings for each test
- Parallel processing of various DIC settings: Subset, Step, Interpolation, Strain Windows, etc.
- Virtual Fields Method (VFM) technique for processing full-field kinematic measurements to extract parameters driving the mechanical behavior of materials
- Materials Properties & Identification with VFM
- Reconstruction of stress fields at the surface of the specimen
- Applicable to horizontal axial, horizontal shear, vertical axial, and vertical shear loading conditions
- Intelligent optimization with flexible boundary conditions
- Isotropic linear elasticity
- Orthotropic linear elasticity
- Hardening laws: Bilinear, Swift, Voce, Ludwik
- FEA Validation
- Allows for a thorough comparison between DIC and FEA
- Establish a one-to-one relationship between model and experiment by adopting identical filtering

26.2 Compatible DIC Systems

DSI has successfully integrated Digital Image Correlation systems from a variety of manufacturers into Gleeble equipment. If you have an existing DIC system, please contact the *Gleeble Service Team* (page 373) to confirm compatibility and create an integration plan.

We are now able to offer new DIC systems that have been optimized for Gleeble experiments while also enabling the DIC system to be used on other equipment in your laboratory. DSI has worked extensively to develop a customized suite of equipment including cameras, software, lighting, specimen mounting rotational kits, and specimen preparation solutions.

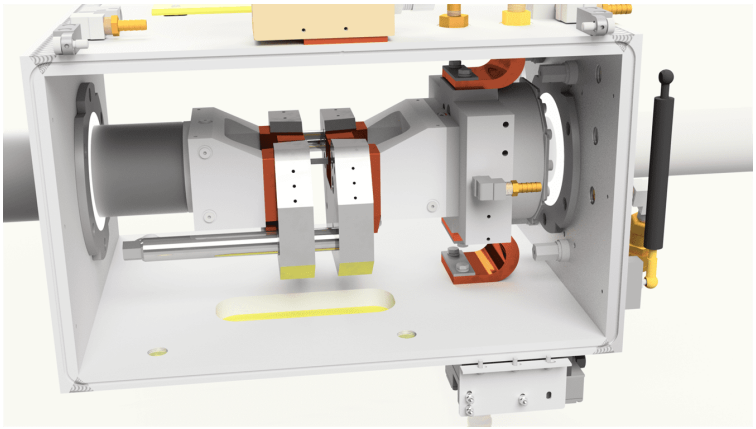


Fig. 26.2: *General-Purpose MCU Pocket Jaw Rotation Kit - DSI# 37500.* (page 343)

DSI has partnered with Trilion USA, a GOM / Aramis Certified Partner, to configure an affordable DIC solution ideal for a wide range of Gleeble simulations.

This package includes the primary hardware and software required to add DIC capability to your Gleeble platform. This technology is highly accurate and provides robust data across a specimen, instead of point-to-point measurements.

Part Number	Description	Sold As
TRIL001	**Gleeble SNAP Digital Image Correlation System (DIC):** • 12 megapixel camera pair with 30 frames per second (fps) at full resolution (100 fps or higher available at a reduced resolution) This package includes the primary hardware and software required to add DIC capability to your Gleeble platform. This technology is highly accurate and provides robust data across a specimen, instead of point-to-point measurements. **System includes:** • Trilion Snap Sensor Setup • Two 12-megapixel, 30 fps cameras at full 4,096 x 3,000 pixels resolution. • Optics: 35 mm metal lenses with locking screws. • Trilion Basics camera bar, 300 mm length with studio stand. • Custom lighting solution for high-temperature applications, including mounting and accessories. **Trilion Snap 3D Software:** • Data Acquisition (DAQ) Module. • Multi-camera software module. • DAQ software module with sync cables and USB DAQ. **GOM Correlate Professional:** • Single license for measurement, analysis and reporting. • Creates calibration file and project file. • Process automation capabilities with scripting and Gleeble-based project templates. • Automated calculation and reporting of material testing results. • Use on any Windows 7/10 PC with USB license. • 1 year of software updates included. **GOM Correlate:** • Free evaluation software for 2D DIC. • Complete 2D DIC acquisition and processing. • Serves as a viewer for all measured results (2D and 3D) created with ARAMIS. • Unlimited licenses with yearly updates. **Includes:** • Calibration Cube. • Training. • Two days of on-site training by DIC expert. • 1-Year Limited Warranty.	Ea.

DSI has partnered with Trilion USA, a GOM / Aramis Certified Partner, to configure an affordable DIC solution ideal for a wide range of Gleeble simulations.

This package includes the primary hardware and software required to add DIC capability to your Gleeble platform. This technology is highly accurate and provides robust data across a specimen, instead of point-to-point measurements.

Part Number	Description	Sold As
TRIL002	**Gleeble SNAP High-Speed Digital Image Correlation System (DIC)** • 12-megapixel camera pair with 187 frames per second (fps) at full resolution (1,000 fps or higher available at a reduced resolution) This package includes the primary hardware and software required to add DIC capability to your Gleeble platform. This technology is highly accurate and provides robust data across a specimen, instead of point-to-point measurements. **System includes:** • Trilion Snap Sensor Setup. • Two 12-megapixel, 187 fps cameras at full 4,096 x 3,000 pixels resolution. • Higher speed (fps) available at a reduced resolutions, for example, 1,000 fps can be achieved at 2,048 x 1,000 pixels resolution. • Optics: 35 mm metal lenses with locking screws. • Trilion Basics camera bar, 300 mm length with studio stand. • Custom lighting solution for high-temperature applications, including mounting and accessories. **Trilion Snap 3D Software:** • Data Acquisition (DAQ) Module. • Multi camera software module. • DAQ software module with sync cables and USB DAQ. **GOM Correlate Professional:** • Single license for measurement, analysis and reporting . • Creates calibration file and project file. • Process automation capabilities with scripting and Gleeble-based project templates. • Automated calculation and reporting of material testing results. • Use on any Windows 7/10 PC with USB license. • 1 year of software updates included. **GOM Correlate:** • Free evaluation software for 2D DIC. • Complete 2D DIC acquisition and processing. • Serves as a viewer for all measured results (2D and 3D) created with ARAMIS. • Unlimited licenses with yearly updates. **Includes:** • Calibration Cube. • Training. • Two days of on-site training by DIC expert. • 1-Year Limited Warranty.	Ea.

Part Number	Description	Sold As
ARA-2.3	**ARAMIS 2.3 Megapixel Digital Image Correlation System** • 2.3 megapixel 3D camera pair. • 1,936 x 1,216 pixels. • Frame rate up to 130 fps at full resolution. • Up to 450fps with GOM Testing controller (included). **System includes:** • ARAMIS Professional software for image acquisition, data analysis and live processing. • GOM Testing controller (8-channel data logger). • High precision lenses. • Factory certified calibration panels. • 150 mm frame with 350 mm working distance. • 55, 90 and 140 mm fields of view. **LED lighting:** • Stable studio stand to hold the sensor. • Standard image processing workstation. **Includes:** • 1-year Warranty . • Trilion Gold support.	Ea.

Part Number	Description	Sold As
ARA-12	**ARAMIS 12 Megapixel Digital Image Correlation System:** • 12 megapixel 3D camera pair. • 4,096 x 3,068 pixels. • Frame rate up to 25 fps at full resolution. • 75 fps at 4,096 x 1,000 pixels (1/3 image). • 100 fps at reduced resolution (binning). **System includes:** • ARAMIS Professional software for image acquisition, data analysis and live processing. • GOM Testing Controller (8-channel data logger). • High-precision lenses. • Factory certified calibration panels. • 150 mm frame with 350 mm working distance. • 120 mm field of view. **LED lighting:** • Stable studio stand to hold the sensor. • Standard image processing workstation. **Includes:** • 1-year Warranty and Trilion Gold support.	Ea.

Part Number	Description	Sold As
ARA-SRX	**Aramis SRX Digital Image Correlation System:** • ARAMIS SRX Professional. • 12 megapixel camera pair (4,096 x 3,068 pixels). • Frame rate with PC configuration: 75 fps at full resolution and up to 490 fps at reduced resolution. **System includes:** • ARAMIS Professional software for image acquisition, data analysis and live processing (1 license/seat). • GOM Testing Controller (8-channel data logger). • High-precision lenses. • Factory-certified calibration panels. **LED Lighting:** • Custom lighting solution for high-temperature applications, including mounting and accessories. • Includes a high performance computer workstation due to increased performance requirements. • 180 mm frame, 130 mm measuring volume. (Recommended for specimens with gauge length less than 130mm, including standard tensile tests). **Includes:** • 1-year Warranty and Gold support.	Ea.

Part Number	Description	Sold As
ARA-SRX-TRBO	**Aramis SRX Turbo Digital Image Correlation System:** • ARAMIS SRX Turbo Professional. • 12 megapixel camera pair 335 fps at full resolution and up to 1,000 fps at reduced resolution (1,920 x 1,000). **System includes:** • ARAMIS Professional software for image acquisition, data analysis and live processing (1 license/seat). • GOM Testing Controller (8-channel data logger). • Factory certified measuring volumes. • High-precision lenses. • Factory-certified calibration Panels. • Custom lighting solution for high-temperature applications, including mounting and accessories. • Includes a high-performance computer workstation due to increased performance requirements. • 180 mm frame, 130 mm measuring volume. (Recommended for specimens with gauge length less than 130 mm, including standard tensile tests). **Includes:** • 1-year Warranty and Gold support.	Ea.

26.2.1 DIC Correlation Software and Accessories

Part Number	Description	Sold As
GOM-CP-ST	Seat License - GOM Correlate Professional. Portable license resides on USB. Additional license(s) are recommended when data analysis is required away from the Gleeble workstation.	Ea.
GOM-CP-N	Network License for Single User - GOM Correlate Professional. License is managed via network access - no USB required. Additional license(s) are recommended when data analysis is required away from the Gleeble workstation.	Ea.
SNAP-LNS-12	12 mm lenses - SNAP -DIC Lens for 12 Megapixel USB Cameras (30 fps) with calibration panel - Recommended for large specimens - *Strip Annealing Simulations* (page 250)	Ea.
SNAP-LNS-35	35 mm lenses - SNAP -DIC Lens: 12 Megapixel USB Cameras (30 fps) with calibration panel - Recommended for specimens with gauge length less than 100mm - Tensile testing - Included in TRIL001 and TRIL002	Ea.
SNAP-LNS-50	50 mm lenses - SNAP -DIC Lens: 12 Megapixel USB Cameras (30 fps) with calibration panel	Ea.
SNAP-LNS-100	100 mm lenses - SNAP -DIC Lens: 12 Megapixel USB Cameras (30 fps) with calibration panel - Recommended for specimens with gauge length of less than 25mm - *Uniaxial Compression Testing* (page 209)	Ea.
ARA-LNS-70	70 mm Measuring Volume lens and calibration cube - Aramis Pro - Recommended for specimens with gauge length of less than 25 mm - *Uniaxial Compression Testing* (page 209)	Ea.
ARA-LNS-200	200 mm Measuring Volume lens and calibration cube - Aramis Pro Recommended for large specimens - *Strip Annealing Simulations* (page 250)	Ea.

Note: Additional lenses for different measuring volumes can be purchased at a later date.

26.3 DIC Integration Package

The 59045 Digital Image Correlation (DIC) Integration Package is designed to better integrate a DIC system with the Gleeble. The package includes a small module (shown below) as well as BNC cables to facilitate a simple and easy-to-use interface between the Gleeble and a compatible DIC system. The 59045 Digital Image Correlation (DIC) Integration Package features the following:

- A single ±10 VDC output BNC connection for data transmission from the Gleeble to a DIC system.
- Two ±10 VDC analog input BNC connections for data transmission from a compatible DIC system to the Gleeble.
- 5 VDC ground referenced pulse trigger for data acquisition synchronization between the Gleeble and a compatible DIC system.
- Support for multiple modules.



Fig. 26.3: DIC Integration Package - DSI# 59045.

Current Gleeble Users

Current Gleeble users can access the 59045 Digital Image Correlation (DIC) Integration Package operator's manual here.[43]

[43] https://support.gleeble.com/portal/en/kb/articles/gtc-59045-digital-image-correlation-dic-integration-package-user-manual

Part Number	Description	Sold As
59045	Digital Image Correlation (DIC) Integration Package - GTC Systems only	Ea.
39150	**DIC Data Integration Package - Series 3 Systems.** • Integrates Gleeble data with DIC data providing synchronization between the two devices. • Configurable to any two DIC system variables and two Gleeble data variables. • Analog +/-10 VAC full scale. • Data received at frame-rate of the DIC system. • General-Purpose High-Speed Trigger. • 5VDC (compatible with 5V TTL). • Used to synchronize data collection between the two systems.	Ea.

DIC Integration-Required Accessories

Part Number	Description	Sold As
DIC-TRAIN-ADV	**Advanced On-Site DIC Software and Technique Training:** • Training to be conducted by DIC representative, expert, or certified DSI Service Engineer. • Includes 2 days on site. • Charge includes travel costs.	Ea.
59025	*Accessory Instrument Module* (page 341) - GTC Systems only	
39152	**Mounting Equipment for Digital Image Correlation (DIC) System.** • This package provides all brackets needed to mount cameras and light fixtures to the Gleeble. • It provides a position locator for the devices, allowing easier loading and unloading of specimens. • The mounting equipment allows the user to set up the cameras at appropriate locations for various specimen geometries. • This assembly may be used in place of the standard tripod mounting used with standard DIC systems. • *This package does not include DIC cameras or lighting.*	Ea.

DIC Integration Optional Accessories

Part Number	Description	Sold As
37500	*Pocket Jaw Rotation Kit* (page 343)	
9510-005	*Low Force Pocket Jaw Rotation Kit* (page 343)	
39151	**Camera Lighting Integration Package:** • Includes the additional lighting and fixtures required for operating Digital Imaging Correlation systems at temperatures up to 1,100℃ (2,012℉). • Recommended for any testing above 200℃ (392℉).	Ea.
DIC036	**DIC Speckling Kit for High-Temperature Applications.** • Paint Spray Gun with connections to Gleeble compressed air system. • High-Temperature Black Marker (DIC032). • Alumina Powder. • Accessories, including sanding belt, bottles, hose, and solvent.	Ea.
DIC031	Gravity Paint Spray Gun	Ea.
DIC032	High-Temp Black Marker - Oil Based - Rated to 1,093℃ (1,902℉)	Ea.

Section 27

Vacuum Pumping Systems

Contents

- *3000 Series Vacuum Pumping Systems* (page 311)
- *500 Series Vacuum Pumping Systems* (page 312)
- *Common Service Parts* (page 313)
  - *Vacuum Pump Parts* (page 313)
  - *Vacuum Pump Oil* (page 313)
  - *Diffusion Pump Quick Cool Retrofit* (page 314)

The vacuum pumping systems incorporated into a Gleeble thermal-mechanical testing system provide a controlled atmosphere resulting in minimal oxidation of a specimen during elevated temperature tests.

The Gleeble vacuum systems can be customized to provide either a rough vacuum, or high vacuum. Most options of Gleeble vacuum systems can also create an inert gas environment. Supplemented by external compressed inert gas, the vacuum system can remove the existing atmosphere within the vacuum tank then fill the vacuum tank with the inert gas. This backfill process is semi-automated and needs to be repeated any time the vacuum tank door is opened.

Gleeble vacuum systems are controlled, powered, and cooled, as needed, from the Gleeble system. All wire and hose connections come standard with each vacuum system.



Fig. 27.1: Vacuum Pumping System.

27.1 3000 Series Vacuum Pumping Systems

The Gleeble Vacuum Pumping Systems are designed to perform as an integral part of any Gleeble system. The typical vacuum system contains one diffusion vacuum pump and one rough vacuum pump. The entire unit is controlled from the Gleeble console. The lowest vacuum pressure achievable by the diffusion pump integrated into the 38045 and 38046 systems is 5 x 10^{-5} Torr. The rough vacuum pump, as part of the 38045 or 38046 systems, or 38050 Standalone Rough Pump can reach a lowest achievable vacuum pressure of 5 x 10^{-2} Torr. Once activated, the 38045 and 38046 Vacuum Pump systems can automatically transition from rough vacuum to high vacuum operation.

Characteristic	Specification	Vacuum Pump System
Voltage Rating	380/400 VAC	38045 or 38050
	460/480 VAC	38046 or 38050
Roughing pump	350 L/min (92.5 gal/min)	All systems
Diffusion pump	1,250 L/min (330 gal/min)	38045 or 38046
Diffusion pump size	102 mm (4 in) diameter	38045 or 38046
Diffusion pump cooling	Gleeble chilled process fluid	38045 or 38046
Lowest Achievable Diffusion Pump Vacuum Pressure	5 x 10^{-5} Torr	38045 or 38046
Lowest Achievable Rough Pump Vacuum Pressure	5 x 10^{-2} Torr	All systems

Note: A clean vacuum tank and dry vacuum tank atmosphere (relative humidity less than 60%) are required to achieve the maximum vacuum pressure within 15 minuets.

Part Number	Description	Sold As
38045	Vacuum Pumping System - Includes Rough Pump and Diffusion Pump (460/480 Volt)	Ea.
38046	Vacuum Pumping System - Includes Rough Pump and Diffusion Pump (380/400/415 Volt)	Ea.
38050	Vacuum Rough Pump System (All voltages) - Rough Pump Only with Frame	Ea.
38047	Vacuum Rough Pump System (All voltages) - Rough Pump Only, No Frame	Ea.

27.2 500 Series Vacuum Pumping Systems

The Gleeble Vacuum Pumping Systems are designed to perform as an integral part of any Gleeble system. The typical vacuum system contains one diffusion vacuum pump and one rough vacuum pump. The entire unit is controlled from the Gleeble console. The diffusion pump integrated into the 55310 and 55311 systems can reach a lowest achievable vacuum pressure of 5 x 10^{-5} Torr. The rough vacuum pump, as part of the 55310 or 55311 systems, and 55312 or 55313 Integrated Rough Pump systems can reach a lowest achievable vacuum pressure of 5 x 10^{-2} Torr. Once activated the 55310 and 55311 Vacuum Pump systems can automatically transition from rough vacuum to high vacuum operation with pneumatically controlled valves.

> The 55312 and 55313 vacuum options are built into the Gleeble 500 Series frame and do not add to the Gleeble system's overall footprint. These options are a rough pump vacuum only and do not include a diffusion pump or High Vacuum capability.

Characteristic	Specification	Vacuum Pump System
Voltage Rating	380/400 VAC	55310, 55312, 55313
	460/480 VAC	55311, 55312, 55313
Roughing pump	350 L/min (92.5 gal/min)	All systems
Diffusion pump	1,250 L/min (330 gal/min)	55310 or 55311
Diffusion pump size	102 mm (4 in) diameter	55310 or 55311
Diffusion pump cooling	Gleeble chilled process fluid	55310 or 55311
Lowest Achievable Diffusion Pump Vacuum Pressure	5 x 10^{-5} Torr	55310 or 55311
Lowest Achievable Rough Pump Vacuum Pressure	5 x 10^{-2} Torr	All systems

Note: A clean vacuum tank and dry vacuum tank atmosphere (relative humidity less than 60%) are required to achieve the maximum vacuum pressure within 15 minuets.

Part Number	Description	Sold As
55310	Vacuum Pumping System - Includes Rough Pump and Diffusion Pump - 380/400 Volt	Ea.
55311	Vacuum Pumping System - Includes Rough Pump and Diffusion Pump - 460/480 Volt	Ea.
55312	Integrated Rough Vacuum Pumping System - All voltages	Ea.
55313	G5 Control Integrated Rough Vacuum Pumping System - All voltages	Ea.

27.3 Common Service Parts

27.3.1 Vacuum Pump Parts

Part Number	Description	Sold As
38040	Vapor Removal System Option for 38045 or 38046 Vacuum Pumping Systems	Ea.
31619	Replacement Water Flow Switch for Vacuum Pump	Ea.
HTR480B	Replacement Diffusion Pump Heater Kit - 460/480 volt	Kit
HTR400B	Replacement Diffusion Pump Heater Kit - 380/400/415 volt	Kit
GAUGE101	Active Pirani Rough Vacuum Gauge	Ea.
GAUGE101A	Active Pirani Gauge Replacement Tube	Ea.
GAUGE102	Active Magnetron High-Vacuum Gauge	Ea.
HTR-WIRE-REPAIR	Diffusion Pump wire repair - #14 AWG High Temp Heater Wire (454°C (849°F) rated) including high-temperature lugs	Kit

27.3.2 Vacuum Pump Oil

Pfeiffer is phasing out the Adixen rough pump and replacing it with the Duovane rough pump. Your vacuum system may contain either pump. Refer to the images below to identify which pump is installed. PV400 is compatible only with the Adixen pump, while PV402 is compatible only with the Duovane pump.

Part Number	Description	Sold As
PV400	Adixen Vacuum Rough Pump Oil - 2 liter	Ea.
PV402	Duovane Vacuum Rough Pump Oil – 1 liter	Ea.
PV410	Vacuum Diffusion Pump Oil - 500 ml	Ea.

Adixen Rough Pump	Duovane Rough Pump
	

27.3.3 Diffusion Pump Quick Cool Retrofit

This option accelerates cooling of the diffusion pump to reduce shutdown time and extend the life of the diffusion pump heating element. The Quick Cool circuit is included standard as part of all new Gleeble systems equipped with a diffusion pump. Contact a DSI *Service* (page 373) representative for assistance in determining if your vacuum system has the Quick Cool circuit.

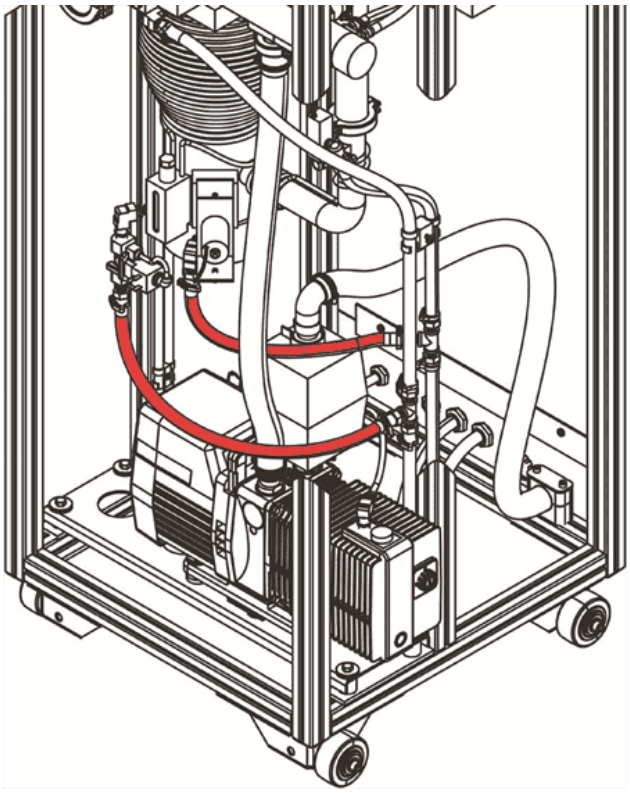


Fig. 27.2: Diffusion Pump Quick Cool Retrofit - DSI# 32015.

Part Number	Description	Sold As
32015	Varian Diffusion Pump Quick Cool Retrofit	Ea.

Section 28

Gleeble Chillers

Contents

- *Selecting the Correct Process Fluid Chiller* (page 317)
- *Air-Cooled Process Fluid Chillers* (page 318)
  - *Standard Air-to-Process-Fluid Chiller* (page 318)
  - *High Ambient Temperature - Air-to-Process-Fluid Chiller* (page 319)
- *Water-Cooled Process Fluid Chillers* (page 320)
  - *Water-to-Process-Fluid Chiller* (page 320)
  - *Heat Exchanger* (page 321)
- *Common Service Parts* (page 322)

DSI offers several types of process fluid chillers to provide cooling for the Gleeble system and its equipment. DSI strongly recommends a dedicated closed-loop system for circulation of chilled process fluid inside the Gleeble and its peripheral equipment. This provides the best thermal stability in order to achieve the best results from the Gleeble system.

A DSI Sales representative can identify the correct chiller for any installation based on location, building requirements, and Gleeble Labratory configuration.

Due to the design of the Gleeble and the process fluid chillers, the chiller must be located at or below the level of the Gleeble, and within 15 m (50 ft) of it. DSI may be able to configure a chiller system that does not meet these requirements, but additional engineering costs may be incurred. A DSI Engineer will need to approve chiller installations more than 3 m (9.8 ft) below the Gleeble system components.

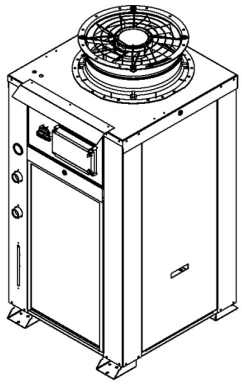


Fig. 28.1: Air-to-Process Fluid Chiller.

Selecting A Process Fluid Chiller

A DSI Sales representative is uniquely capable of identifying the correct Process Fluid Chiller for each customer's needs.

 [44]

28.1 Selecting the Correct Process Fluid Chiller

The process fluid chiller is an important part of every Gleeble system. Making the right choice of process fluid chiller is vital. Multiple factors must be considered when selecting a process fluid chiller. If the laboratory that is going to house the Gleeble system contains a building-supplied coolant loop, a *Water-Cooled Process Fluid Chillers* (page 320) may be appropriate. If no building coolant loop is available an, *Air-Cooled Process Fluid Chillers* (page 318) will be required. For Gleeble systems that will be located in an environment that commonly experiences high heat and humidity, a *High Ambient Temperature - Air-to-Process-Fluid Chiller* (page 319) may be required. It is important to ensure that the process fluid chiller can cool the Gleeble system efficiently. A DSI Sales representative is uniquely capable of identifying the correct Process Fluid Chiller for any situation.

Chiller Requirements

Reference the Gleeble Site Preparation Checklist[45] for plumbing requirements for all chiller systems.

[44] https://drive.google.com/file/d/1f12AHxZG2ipP6ql4fmaqDPcUN-78herR/view?usp=sharing
[45] https://www.gleeble-tech.com/gleebledocs/g3/3800_site_prep/index.html

28.2 Air-Cooled Process Fluid Chillers

28.2.1 Standard Air-to-Process-Fluid Chiller

The Air-Cooled Process Fluid Chiller uses a refrigeration loop to chill a reservoir of process fluid. Chilled process fluid from this reservoir is then pumped to the Gleeble and its equipment by means of a pump located inside the process fluid chiller. The heat that is removed from the chilled process fluid is passed directly into the air around the Air-Cooled Process Fluid Chiller by cooling fans. DSI recommends the Air-Cooled Process Fluid Chiller be placed outdoors on a concrete pad or other suitable structure. The Air-Cooled Process Fluid Chiller can be used indoors, but removing the heat from the area around the Air-Cooled Process Fluid Chiller can be a facilities challenge. If the temperature around the Air-Cooled Process Fluid Chiller gets too high, the process fluid chiller will become ineffective.

Characteristic	Specification
Ambient Temperature Maximum	35°C (95°F)
Ambient Temperature Minimum	-28°C (-20°F)
Noise Rating	77 dBa
Electrical Power Requirements	380 VAC / 3 Phase / 50 Hz / 15 amp
	460 VAC / 3 Phase / 60 Hz / 15 amp
Process Fluid Reservoir Capacity	136 liter (36 gal)
Cooling Capacity at 50 Hz power	50,000 BTU
Cooling Capacity at 60 Hz power	60,000 BTU

Danger: The Air-Cooled Process Fluid Chiller is loud and must be isolated from the laboratory area where the Gleeble will be placed. If the decision is made to locate an Air-Cooled Process Fluid Chiller indoors, it is most frequently located in the same sound isolation room as the Gleeble hydraulic power unit.

Part Number	Description	System	Sold As
35118-DXCE	Air-to-Process-Fluid Chiller	All Systems	Ea.
35116-(X)	Air-to-Process-Fluid Chiller - China Only	All Systems	Ea.

28.2.2 High Ambient Temperature - Air-to-Process-Fluid Chiller

DSI also offers a high ambient temperature Air-Cooled Process Fluid Chiller for operation in climates where ambient air temperatures are frequently over 35°C (95°F) when the Gleeble will be operating. Locations such as India, South America or Africa require a High Ambient Temperature Air-to-Process-Fluid Chiller. This process fluid chiller is larger than the standard unit.

Characteristic	Specification
Ambient Temperature Maximum	> 35°C (95°F)
Ambient Temperature Minimum	-25°C (-10°F)
Electrical Power Requirements	380 VAC / 40 Amp / 3 Phase / 50 Hz / 30 FLA
	460 VAC / 40 Amp / 3 Phase / 60 Hz / 30 FLA
Process Fluid Reservoir Capacity	227 liter (60 gal)
Cooling Capacity With 50 Hz Power	87,500 BTU
Cooling Capacity With 60 Hz Power	105,000 BTU

Note: Specifications are for the 35125-DX50 High Ambient Temperature Air-to-Process-Fluid Chiller only.

Danger: The Air-Cooled Process Fluid Chiller is loud and must be isolated from the laboratory area where the Gleeble will be placed. If the decision is made to locate an Air-Cooled Process Fluid Chiller indoors, it is most frequently located in the same sound isolation room as the Gleeble hydraulic power unit.

Part Number	Description	System	Sold As
35125-DX50	High Ambient Temperature Air -to-Process Fluid Chiller	3500 - 3800	Ea.
35150-WF50	High Ambient Temperature Air -to-Process Fluid Chiller - India Only	3500 - 3800	Ea.
35145-WF50	High Ambient Temperature Air -to-Process Fluid Chiller - India Only	3180 - 500 Series	Ea.
35125-DXCE	High Ambient Temperature Air -to-Process Fluid Chiller - CE Mark	All Systems	Ea.
35125-DXKR	High Ambient Temperature Air -to-Process Fluid Chiller - S. Korea, Japan, or Canada only	All Systems	Ea.

28.3 Water-Cooled Process Fluid Chillers

28.3.1 Water-to-Process-Fluid Chiller

If the facility where the Gleeble will be located has an existing building supplied process water loop, the Water-Cooled Process Fluid Chiller may be a better solution than the Air-Cooled Process Fluid Chiller. The Water-Cooled Process Fluid Chiller is similar to the Air-Cooled Process Fluid Chiller in that it uses a refrigeration loop to chill the reservoir of process fluid circulated to the Gleeble and its equipment. However, instead of passing heat to the surrounding air, it passes the heat into the water in the building process water loop.

If the facility where the Gleeble will be located has a building process water loop with a flow rate and temperature of 57 L/min at 29.45°C (15 gal/min at 85°F) or 28.4 L/min at 18.9°C (7.5 gal/min at 66°F) and a **differential pressure** (between the supply and return) of 1.72 bar (25 psi) or greater then the Water-Cooled Process Fluid Chiller is the best water chiller choice.

Characteristic	Specification
Building Fluid Flow Rate and Temperature	57 L/min at 29.45°C (15 gal/min at 85°F)
	28.4 L/min at 18.9°C (7.5 gal/min at 66°F)
Building Fluid Supply/Return Pressure Difference Minimum	1.72 bar (25 psi)
Ambient Air Temperature Maximum	35°C (95°F)
Ambient Air Temperature Minimum	10°C (50°F)
Noise Rating	72 dBa
Electrical Power Requirements	380 VAC / 20 Amp / 3 Phase / 50 Hz
	460 VAC / 20 Amp / 3 Phase / 60 Hz
Process Fluid Reservoir Capacity	136 L (36 gal)
Cooling Capacity With 50 Hz Power	50,000 BTU
Cooling Capacity With 60 Hz Power	60,000 BTU

Part Number	Description	System	Sold As
35122-DXCE	Water to Process Fluid Chiller	All Systems	Ea.

28.3.2 Heat Exchanger

If the facility where the Gleeble will be located has a chilled water loop, a DSI Heat Exchanger might be the best solution. The DSI Heat Exchanger requires access to a chilled water loop with a temperature of 14.5°C (58°F) or lower, a **differential pressure** (between the supply and return) of 1.72 bar (25 psi) or greater, and a flow rate of at least 38 L/min (10 gal/min).

The heat exchanger is a direct heat transfer device and contains no refrigeration equipment. It relies on a high efficiency heat exchanger to remove heat directly from the Gleeble cooling process fluid system to the customer supplied chilled water.

The Heat Exchanger is a more economical solution than either the Air-Cooled Process Fluid Chiller or the Water-Cooled Process Fluid Chiller and is the best choice for a facility that has access to chilled water. DSI heat exchangers are very quiet; the only noise emitted is flow noise of the fluid through the Heat Exchanger and the pump that circulates the process fluid to the Gleeble system.

Characteristic	**Specification**
Building Fluid Temperature Maximum	14.5°C (58°F)
Building Fluid Pressure Difference Minimum	1.72 bar (25 psi)
Building Fluid Flow Rate Minimum	38 L/min (10 gal/min)
Noise Rating	69 dBa
Process Fluid Reservoir Capacity	83 liter (22 gal)
Electrical Power Requirements	
35142-DXCE	230 VAC / 1 Phase / 50 Hz
35142-DX60	115 VAC / 1 Phase / 60 Hz

Part Number	**Description**	**System**	**Sold As**
35142-DXCE	230 VAC / 50 Hz Heat Exchanger - CE Mark	All Systems	Ea.
35142-DX60	120 VAC / 60 Hz Heat Exchanger	All Systems	Ea.

28.4 Common Service Parts

Part Number	Description	Sold As
G471JB	Propylene Glycol, 18.92 L (5 gal)	Ea.
35009	Water Chiller Power Transformer Package - boost or buck voltage. Consult with *DSI Engineering* (page 373) to specify the correct voltage specifications.	Ea.

For filters and replacement parts see *Water Filters* (page 363).

Note: The Water Chiller Power Transformer Package is most commonly used in South Korea and Canada, or other locations with 380 VAC 60 Hz power supply.

Section 29

Air Compressors

Contents

- *Compressed Air Requirements* (page 324)
- *Dirt & Moisture* (page 324)
- *Air Compressors* (page 325)

All Gleeble systems require compressed air to operate correctly. For optimal performance, the compressed air source should be dedicated to the Gleeble system. Dynamic Systems Inc. offers a full line of air compressors specifically selected to provide the best performance for a Gleeble system. An air compressor sold by DSI can be supplied from the manufacturing facility in the United States, or locally from within a customer's region. Optionally, facility, building, or house compressed air can adequately supply a Gleeble system if the existing compressed air system can meet the minimum requirements for Gleeble operation.



Fig. 29.1: Air Compressor - DSI# 35167.

29.1 Compressed Air Requirements

Compressed air is required to operate the Air Ram. It is also required for the optional *Quench Systems* (page 283), *Vacuum Pumping Systems* (page 309), and *Large-Sample Strip Annealing* (page 77) MCU.

Gleeble System Requirements	
Pressure	5.6 to 8.4 kg/cm^2 (80 to 120 psi)
Flow Rate	29 L/s (1 cfs) for 6 seconds
Quench System Requirements	
Pressure	Up to 7.03 kg/cm^2 (Up to 100 psi)
Flow Rate	29 L/s (1 cfs) for 6 seconds
Large-Sample Strip Annealing MCU	
Pressure	5.6 to 8.4 kg/cm^2 (80 to 120 psi)
Flow Rate	71 L/s (1.2 cfs) for 6 seconds
Additional Compressed Air Storage	455 L (120 gal) within 3 m (10 ft) of the Gleeble

Note: Any additional compressed air storage tank must have a 19 mm (0.75 in) outlet which is connected to the Large-Sample Strip Annealing MCU by a 19 mm (0.75 in) inside diameter hose.

A single air supply may be used to supply the needs of the Gleeble System (including strip annealing simulations) if it meets all the above requirements. If a single air supply is used, it should have two compressed air outlets. One outlet will be connected to the Gleeble air distribution manifold, which will then be used to supply the air ram, vacuum system, and quench options. The second compressed air outlet, supplying the Large-Sample Strip Annealing MCU, must be of sufficient size (including hose and fittings) to prevent excessive pressure loss and provide the flow rates listed above. For use with the Large-Sample Strip Annealing MCU the minimum connection size is 19 mm (0.75 in) inside-diameter hose.

29.2 Dirt & Moisture

Compressed air or other quench gas media of quality class 2 are preferred (as defined by ANSI/ISA-7.0.01-1996). This corresponds to roughly < 1 μm filtering, < -40 °C dew point, and oil content of < 0.1 mg/m^3. Compressed air qualities that do not meet these requirements may void the warranty.

29.3 Air Compressors

Part Number	Description	Sold As
35160	Air Compressor - 5 hp, 189 L (80 gal) 230 VAC to 460 VAC, 60 Hz	Ea.
35161	Air Compressor - 5 hp, 189 L (80 gal) 190 VAC to 400 VAC, 50 Hz	Ea.
35167	Air Compressor - 10 hp, 455 L (120 gal) 400 VAC, 50 Hz	Ea.
35170	455 L (120 gal) Compressed Gas Storage Tank	Ea.
35180	Parts and accessories to use an existing air compressor with all Gleeble Systems	Pack

Note: 35170 Storage Tank is only available in the United States. Other regions may require locally sourced equipment that meets local safety requirements. Consult with a *Sales* (page 373) representative for more information.

Section 30

Thermocouple Welder and Wire

Contents

- *Thermocouple Welder* (page 327)
- *Thermocouple Wire* (page 328)
- *Thermocouple Measurement Assemblies* (page 329)
- *Thermocouple Consumables* (page 329)
  - *Thermocouple Welder Starter Kit - DSI# 35200A* (page 329)
  - *Thermocouple Welder Rebuild Kit - DSI# 35202* (page 330)



Fig. 30.1: Fine Wire Thermocouple Welder - DSI# 35200.

30.1 Thermocouple Welder

The 35200 Thermocouple Welder is used to attach individual thermocouple wires to Gleeble specimens for the purpose of temperature measurement and control. The unit consists of an integrated welding jig and controller. The jig holds the specimen and feeds the thermocouple wire during the weld. A movable guard is lowered over the jig prior to the weld to protect the operator from sparks, flash, and electric shock. The controller allows the operator to set the desired weld voltage manually, or through the use of four pre-programmed presets, and to initiate the weld itself.

Current Gleeble Users

Current Gleeble users can access the 35200 Thermocouple Welder operator's manual here.[46]

Part Number	Description	Sold As
35200	Fine Wire Thermocouple Welder Kit [CE Mark]	Kit
Optional Accessories		
35200A	*Thermocouple Welder Starter Kit - DSI# 35200A* (page 329)	Kit
35202	*Thermocouple Welder Rebuild Kit - DSI# 35202* (page 330)	Kit

[46] https://support.gleeble.com/portal/en/kb/articles/series-3-gtc-35200-thermocouple-welder-users-manual

30.2 Thermocouple Wire

There are many types of thermocouples which can be used for testing. Depending on the temperature range, different thermocouple types can be chosen. The most commonly used thermocouples in Gleeble testing are Type K and Pt Rh-Pt types such as Type S, R, and B. Gleeble GTC and 500 series systems can support additional thermocouple wire types not shown below. *Contact Dynamic Systems* (page 373) for additional information regarding the use of alternate thermocouple wire types.

Non-contact temperature measurement is available with an optional *Pyrometer Control Camera* (page 274).

Gleeble systems are capable of recording specimen temperature with various thermocouple wire types. The following types of thermocouple wire can be used on any Gleeble system.

Part Number	TC Type	Material	Sold As
Operating Range: 0 - 1,450°C (32 - 2,642°F)			
TC005	R- or S-	Pt 100%	Inch
TC006	R+	Pt 87% - Rh 13%	Inch
TC009	S+	Pt 90% - Rh 10%	Inch
Operating Range: -200 - 1,250°C (-328 - 2,282°F)			
TC014	K-	Alumel	Spool
TC015	K+	Chromel	Spool
Operating Range: 0 - 1,700°C (32 - 3,092°F)			
TC017	B-	Pt 94% - Rh 6%	Inch
TC018	B+	Pt 70% - Rh 30%	Inch
Operating Range: 0 - 750°C (32 - 1,382°F)			
TC030	J+	Fe 100%	Spool
TC031	J-	Constantan	Spool
Operating Range: -200 - 900°C (-328 - 1,652°F)			
TC032A	E+	Chromega	Spool
TC033	E-	Constantan	Spool
Operating Range: 0 - 2,320°C (32 - 4,208°F)			
TC010	C+	W 95% - Re 5%	Inch
	C-	W 74% - Re 26%	

Note: TC wire types C, K, J, and E have a nominal wire diameter of 0.254 mm (0.01 in). TC wire types R, S, and B have a nominal wire diameter of 0.2032 mm (0.008 in).

Note: Gleeble systems can support additional thermocouple wire types not shown. *Contact Dynamic Systems* (page 373) for additional information regarding the use of alternate thermocouple wire types.

30.3 Thermocouple Measurement Assemblies

The Dual Channel Thermocouple Input series of modules is designed to add thermocouple input channels to Gleeble 500 Series systems and the HDS-V40. Each module may be connected to any available Gleeble PnP port, providing two thermocouple input channels of a given type.

Part Number	Thermocouple Type	Description
59004	K	Dual Channel Input Box
59005	S	Dual Channel Input Box
59006	R	Dual Channel Input Box
59007	B	Dual Channel Input Box
59008	E	Dual Channel Input Box
59014	J	Dual Channel Input Box

Note: A single K-type Dual Channel Input Box is included standard if required.

30.4 Thermocouple Consumables

Part Number	Description	Sold As
TC007	Single-Hole Ceramic Insulating Tubes 0.020 ID	Package
TC008	Two-Hole Ceramic Insulating Tubes 0.020 ID	Package
TC011	Single-Hole Ceramic Insulating Tubes 0.031 ID	Package
TC026	Double-Hole Round Ceramic Insulating Tubes 0.032 ID	Ea.
TU010	Clear Teflon TC Insulator Tubing	Foot
TU011	Black Teflon TC Insulator Tubing	Foot
G176B	Red Thermocouple Push Post	Ea.
G176C	Black Thermocouple Push Post	Ea.

30.4.1 Thermocouple Welder Starter Kit - DSI# 35200A

The Thermocouple Welder Starter Kit includes consumables and tools used by many researchers to fully utilize the Gleeble Thermocouple Welder.

Part Number	Description	Sold As
35200A	Thermocouple Welder Starter Kit	Kit
35200A Kit Includes		
TC014	K- Thermocouple wire	
TC015	K+ Thermocouple wire	
HW017	Acid Brush	
HW008A	High-Temperature Air Set	
G420F	Wire Cutters	
G420H	Ceramic Disc Magnet	
TC007	0.020 ID Single-Hole TC Ceramic Tube	
TC011	1/32 ID Single-Hole TC Ceramic Tube	

30.4.2 Thermocouple Welder Rebuild Kit - DSI# 35202

The Thermocouple Welder Rebuild Kit includes all the hardware and assemblies to repair a welding head that becomes worn from use.

Part Number	Description	Sold As
35202	Thermocouple Welder Rebuild Kit	Kit
35202 Kit Includes		
GA00402A	TC Welder Wire Jaw	
GA00402B	TC Welder Wire Jaw SS Clip	
GA00402F	TC Welder Retainer Bushing	
All required installation screws and washers		

Section 31

Gleeble Computer Control and Software

Contents

- *Computer Control and Data Acquisition* (page 332)
  - *Standard Gleeble Workstation* (page 332)
    - *QuikSim2* (page 333)
    - *Origin* (page 333)
- *Additional Gleeble Software* (page 334)
  - *Gleeble Script Language (GSL)* (page 334)
  - *Continuous Cooling Transformation (CCT) Software Package* (page 335)
  - *Hot Deformation Software (HDS)* (page 336)
  - *Heat Affected Zone (HAZ) Software* (page 338)
  - *CTOME - LUMet Analysis Software* (page 338)
  - *LUSGenCtrl - LUMet Control Software* (page 338)

31.1 Computer Control and Data Acquisition

All Gleeble systems are equipped with a Windows-based workstation and powerful embedded processor for testing control. The workstation and embedded testing control processor are linked by a high-speed data connection.

The Windows workstation offers a flexible industry-standard multi-tasking Graphical User Interface for creating simulation programs and analyzing the resulting data, as well as creating reports and presentations.

The embedded processor executes test and simulation programs and collects data under the control of the Windows program. This division of labor offers the full power of the workstation to the user while tests are running, enabling the operator to create new tests and analyze data while the machine is actively executing tests or physical simulations.

31.1.1 Standard Gleeble Workstation

Desktop Workstation

Each Gleeble system is supplied with a powerful workstation computer. The default workstation that is supplied is routinely updated to maintain the current features and capabilities. Each workstation will generally include the following capabilities.

Intel i7 8 Core Processor PC Computer:

- High capacity hard drive
- High speed data processing capability
- Flat panel display monitor
- USB communication ports
- Windows operating system
- Internal Wi-Fi for connectivity to the Gleeble system

The standard Gleeble workstation is supplied with:

- Microsoft Windows
- QuikSim2
- Origin

QuikSim2

QuikSim2 Software Features:



- Programs the GTC Digital Control System
- Independent Workstation
- Windows Based
- User Friendly
- Highly Flexible
- Password Protection
- Arbitrary Waveform Generation
- Table Form Software - Just fill in the blanks (standard)
- Provides full Windows multi-tasking during testing

Note: Current Gleeble users can access the QuikSim2 Operator's Manual here.[47]

Origin

Origin Software[48] Features:



- Supports Laser Printers and Color Ink Jet Printers
- Creates Publication-Ready Data Plots
- Windows Based
- Powerful and Flexible
- Built-in Mathematical Functions
- Automatic Data File Loading After a Test is Run
- LabTalk Templates for Repetitive Plotting

[47] https://support.gleeble.com/portal/en/kb/articles/series-3-gtc-series-5-quiksim-2-user-manual
[48] https://www.originlab.com/

31.2 Additional Gleeble Software

31.2.1 Gleeble Script Language (GSL)



The digital control system executes user programs written in a proprietary script language designed for real-time control in the materials testing environment. Programs are written in an English-like `verb-argument` or `preposition-argument` format, stored in an ASCII plain text file. Formatting is not critical. Each command is written on a separate line. Each line may be optionally commented. The statements contained within a file are executed sequentially, unless they are flagged with a concurrent execution operator, or are part of a structured code segment (such as a subroutine). Command verbs are designed to be control system independent. The desired control axis is specified as an argument.

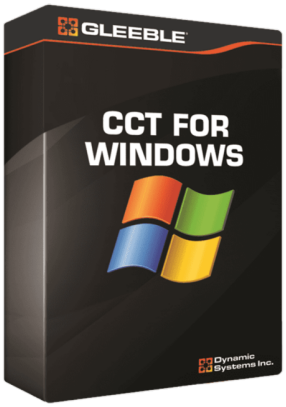
A script file is always the final control program that is sent to the digital control system at run time. However, because the script programming method is more difficult, Table programming, *Hot Deformation Software (HDS)* (page 336), and *Heat Affected Zone (HAZ) Software* (page 338) programming methods offer a simple graphical interface that the user can understand intuitively. By placing inputs in the graphical interface, the user creates a detailed outline of the test. Then, QuikSim2 automatically generates the appropriate Script program to control the Gleeble at run time.

Note: Additional guidance on GSL coding, commands, and features can be found in the QuikSim2 operator's manual here.[49]

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[49] https://support.gleeble.com/portal/en/kb/articles/series-3-gtc-series-5-quiksim-2-user-manual

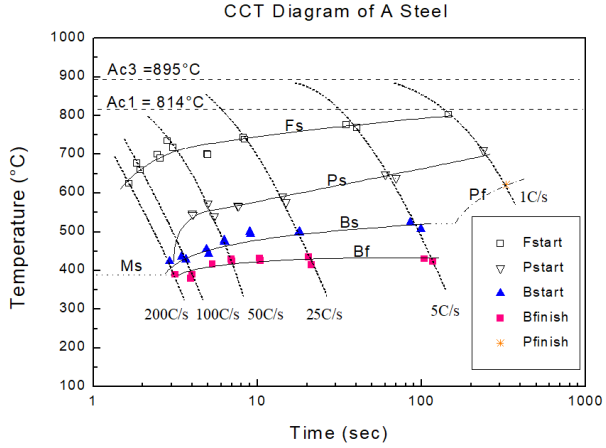
31.2.2 Continuous Cooling Transformation (CCT) Software Package



DSI has developed a software package written for Origin that allows the user to generate continuous cooling transformation curves. This program is referred to as the Continuous Cooling Transformation Curve Generation Software (CCT/TTT)[50]. The program allows for up to ten transformations from each of up to 45 acquired cooling curve files.

The typical method used to measure the start and finish of phase transformations is to plot a dilation versus temperature curve for a given cooling rate. A straight edge is then used to determine the temperature and time at which the transformation(s) starts and finishes. The basis of the evaluation is the rate of change of the slope of the dilation vs temperature curve. A number of curves at different cooling rates are used to obtain data for the complete continuous cooling transformation diagram. The specimen can be rapidly quenched from representative temperatures to freeze the micro-structure and determine the products of the phase change through metallography.

A graphical method of analysis is the basis for the Continuous Cooling Transformation Curve Generation Software (CCT/ TTT). However, rather than performing the graphical analysis on paper, the analysis of the transformation is performed on the video display terminal. The keyboard or mouse is used to move a line along the dilation versus temperature curve and to vary the slope of the curve. When the transformation point is selected, the time and temperature of the point can be stored for analysis. The data is automatically plotted and can be modified to take into account subsequent metallographic analysis.



To help the user determine the transformation points, there are two computer software aids. One method is the use of a linear approximation to the dilation curve equation before and after transformation. A more precise method of analysis is to use a curve calculated from the equation for the thermal contraction curve instead of a straight edge. However, this curve is different for every material and crystal structure so it does not lend itself readily to analysis for many materials. Thus, the linear approximation to the cooling curve which provides a high level of accuracy is used since it is both versatile and convenient. As a second method , a numerical derivative method is available to help the user determine the phase transformation points. The second derivative of the dilation versus temperature can be plotted on the same dilation vs. temperature graph. The deviation points from and to a near constant line represent the start and finish points, respectively, of phase transformation.

The Gleeble provides accurate measurement of phase transformations. The CCT dilatometer or *Laser*

[50] https://support.gleeble.com/portal/en/kb/articles/series-3-gtc-series-5-35530-cct-software-tutorial-tech-tip

(page 269) dilatometer measures the change in diameter of the specimen. Since direct resistance heating is used in the Gleeble, the dilatometer and temperature measurement are taken on an isothermal plane. This means that the temperature at the surface of the specimen is the same as the temperature at the core of the specimen. Since the surface and the core of the specimen are at the same temperature, the transformation starts and finishes at the same time for all points in the isothermal plane. This results in accurate transformation data. The isothermal plane is maintained even during heating and cooling of the specimen.

The copper grips of the Gleeble allow for rapid cooling of the specimen without quenching. (Cooling rates depend on specimen geometry, grip material, conductivity of specimen and the condition of the grip system.) The excellent heating control of the Gleeble also makes it possible to program controlled linear cooling rates in the specimen. Newtonian cooling can also be used if desired.

31.2.3 Hot Deformation Software (HDS)



The Hot Deformation Software (HDS) is used to program the Gleeble and Hydrawedge for single or multi-hit deformations. The software uses a very intuitive user interface that graphically represents the steps of a multiple deformation simulation. The user can set all the parameters to control the thermal and mechanical aspects of the simulation from within HDS. After setting the parameters for each step of the process simulation, the HDS software creates a Gleeble Scripting Language (GSL) program that can be run directly or further modified to optimize the simulation program.

Note: Additional guidance on performing an HDS test can be found in the QuikSim2 operator's manual here.[51]

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[51] https://support.gleeble.com/portal/en/kb/articles/series-3-gtc-series-5-quiksim-2-user-manual

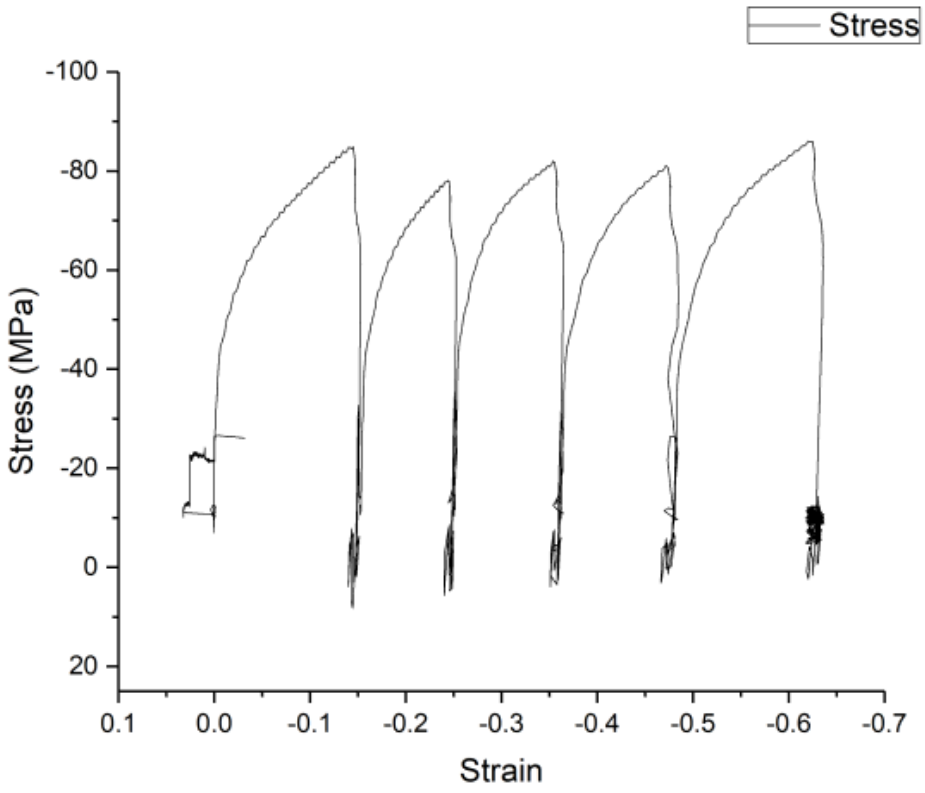


Fig. 31.1: Stress vs Strain curve created with HDS software

31.2.4 Heat Affected Zone (HAZ) Software



The optional HAZ software can generate single and multi-pass weld curves for use in weld simulation on the Gleeble. Below is a list of some of the major features of the HAZ software:

-6 curve generation methods

-Preview temperature program curve in Origin

-Single and multi-pass welds (up to 10 weld passes per program)

-Run HAZ programs directly, or output to a Gleeble Script Language file for further customization

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Note: Additional guidance on performing an HAZ test can be found in the QuikSim2 operator's manual here.[52]

31.2.5 CTOME - LUMet Analysis Software

CTOME is computer software equipped with a Graphical User Interface. The user interacts with the data using a mouse and keyboard. Keyboard entries are used to input values or text in the readers. The operator uses buttons and drop-down menus to facilitate the data processing. Results are output as figures, as a pdf report, and as an ASCII data file that can be used for further manual processing. The software is dedicated to the processing of data in metallurgy. CTOME has been developed to be a powerful software for the metallurgical scientist that requires a fast access and treatment to large amount of data.

31.2.6 LUSGenCtrl - LUMet Control Software

LUSGenCtrl is the software created by Tecnar to control the firing and detection of the LUMet lasers.

[52] https://support.gleeble.com/portal/en/kb/articles/series-3-gtc-series-5-quiksim-2-user-manual

Part Number	Description	Sold As
COMO016	*QuikSim2* (page 333)	Ea.
COMO14(X)	*Origin* (page 333)	Ea.
35515	*Hot Deformation Software (HDS)* (page 336)	Ea.
35520	*Gleeble Script Language (GSL)* (page 334)	Ea.
35525	*Heat Affected Zone (HAZ) Software* (page 338)	Ea.
35530	*Continuous Cooling Transformation (CCT) Software Package* (page 335)	Ea.
CTOME-SOFT	*CTOME - LUMet Analysis Software* (page 338)	Ea.

Section 32

Measurement Gauge Accessories & Gleeble Repair Parts

Contents

- *Accessory Instrument Module* (page 341)
- *Non-Contact Optical Measuring Device Window Feedthrough* (page 342)
- *Pocket Jaw Rotation Kits* (page 343)
- *Heating Modification for a Highly Conductive Specimen* (page 344)
- *Measurement Gauge Parts and Accessories* (page 345)
  - *Measurement Gauge Quartz Rods* (page 345)
  - *Measurement Gauge Universal Accessories* (page 346)
  - *Measurement Transducer Parts* (page 346)
  - *Hot Zone L-Strain Consumable Parts* (page 347)
- *Specimen Loading Tools* (page 348)
  - *Manual Specimen Loaders* (page 348)
  - *Automatic Specimen Loader* (page 350)
  - *Plane Strain Specimen Loading Clips* (page 351)
  - *Uniaxial Compression Specimen Loading Clips* (page 352)
- *Mobile Conversion Units - Replacement Parts* (page 354)
  - *O-Ring Sets* (page 354)
  - *Vacuum Tank Door Piston - Replacement Parts* (page 354)
- *Chilled Process Fluid Systems - Replacement Parts* (page 355)
- *Hydraulic Systems - Replacement Parts* (page 356)

32.1 Accessory Instrument Module

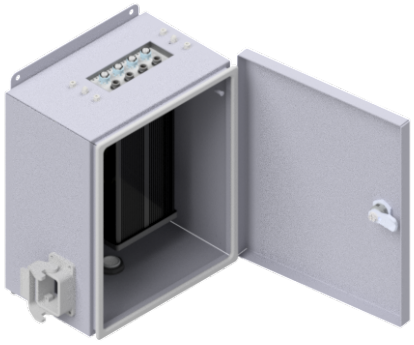


Fig. 32.1: Accessory Instrument Module - DSI# 59025.

The Instrumentation Expansion Module is used in a variety of Gleeble accessory applications. This module integrates options such as the *LED Micrometer* (page 269) or *Digital Image Correlation System* (page 299) with the Gleeble for input and output of data.

Part Number	Description	Sold As
59025	Accessory Instrument Module	Ea.

32.2 Non-Contact Optical Measuring Device Window Feedthrough

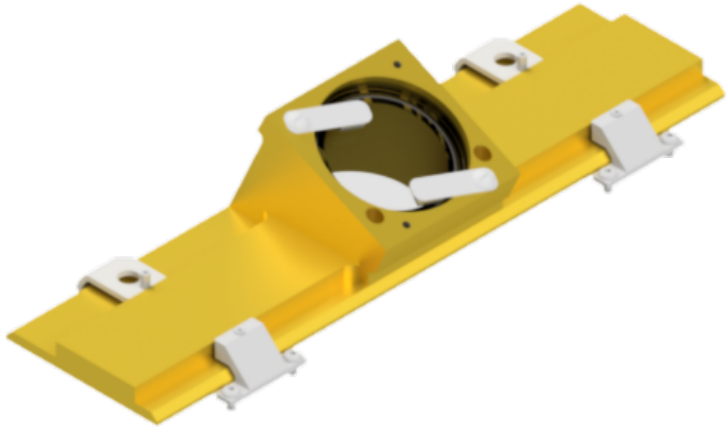


Fig. 32.2: General-Purpose MCU Window Feedthrough - DSI# 32846.

Part Number	Description	Sold As
32845	3180 Mounting Kit - 59063 or 39112 Optical Dilatometer and Extensometer Systems	Kit
32846	General-Purpose MCU Window Feedthrough Mounting Assembly - 59063 or 39112 Optical Dilatometer and Extensometer Systems	Kit
32847	Hydrawedge II Window Feedthrough Mounting Assembly - 59063 or 39112 Optical Dilatometer and Extensometer Systems	Kit
WIND003	3 in dia Laser Window Glass	Ea.
WIND006	3 in dia Borosilicate Laser Window Glass	Ea.

32.3 Pocket Jaw Rotation Kits

General-Purpose MCU Pocket Jaw Rotation Kit

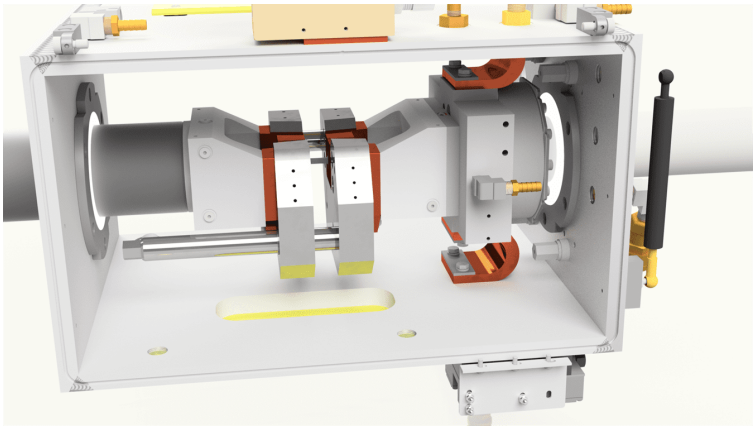


Fig. 32.3: General-Purpose MCU Pocket Jaw Rotation Kit - DSI# 37500.

The 37500 General-Purpose MCU - Pocket Jaw Rotation Kit contains the parts necessary to rotate the pocket jaws 90 degrees. After rotating the specimens, the face of the specimen will now be parallel to the vacuum tank doors. When used with standard grips devices such as *DIC cameras* (page 299), *optical micrometers* (page 269), *pyrometers* (page 274), or lasers will have a direct line of sight to the flat plane of the specimen. Viewing angles can be from either the front or back door vacuum tank windows.

Part Number	Description	Sold As
37500	General-Purpose MCU - Pocket Jaw Rotation Kit	Ea.

Low-Force Pocket Jaw Rotation Kit

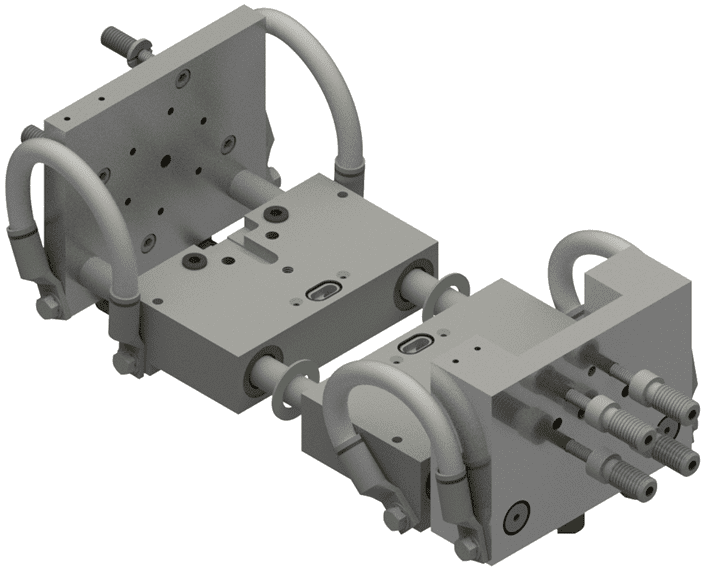


Fig. 32.4: Low-Force Pocket Jaws Rotation Kit - DSI# 9510-005.

The 9510-005 Low-Force Pocket Jaws Rotation Kit contains the parts necessary to rotate the pocket jaws 90 degrees. Specimens will now be mounted parallel to the vacuum tank doors. When used with standard grips devices such as *DIC cameras* (page 299), *optical micrometers* (page 269), *pyrometers* (page 274), or lasers will have a direct line of sight to the flat plane of the specimen. Viewing angles can be from either the front or back door vacuum tank windows.

Part Number	Description	Sold As
9510-005	Low-Force Pocket Jaws - Jaw Rotation Kit	Ea.

32.4 Heating Modification for a Highly Conductive Specimen

To successfully heat aluminum, copper, or other highly conductive materials, additional grounding modifications must be added to the General-Purpose MCU.

Part Number	Description	Sold As
35220	Heating Modification for a Highly Conductive Specimen	Ea.

32.5 Measurement Gauge Parts and Accessories

32.5.1 Measurement Gauge Quartz Rods



Fig. 32.5: L-Shaped Quartz Rod - DSI# G417B.

Part Number	Description	Sold As
G417B	39010 C-Strain and 39060 L-Strain - L-Shaped Quartz Rod - 5 mm dia	Ea.
9655-805	39018 Dilatometer - L-Shaped Quartz Rod - 5 mm dia	Ea.



Fig. 32.6: Straight Chisel-Point Quartz Rod - DSI# G417C.

Part Number	Description	Sold As
G417C	39010 C-Strain - Straight Chisel-Point Quartz Rod - 5 mm dia	Ea.
9655-804	39018 Dilatometer - Straight Chisel-Point Quartz Rod - 5 mm dia	Ea.

32.5.2 Measurement Gauge Universal Accessories

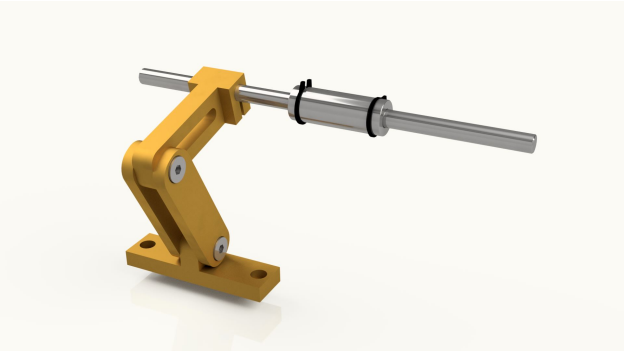


Fig. 32.7: Universal Extensometer Mount - DSI# 9655-100.

Part Number	Description	Sold As
9655-100	Universal Extensometer Mount - Mounting Hardware Not Included	Ea.
Mounting Hardware - 3800, 3500 or 3180		
34658	Pocket Jaw Mounting Arm for 9655-100	Ea.
HE306	Thumb Screw for installing 34658 - 10-32 x 1/2 in	Ea.
GA00412M	Rubber Band Mounting Rod	Ea.
G412L	Rubber Band for Extensometer	Ea.
Mounting Hardware - 563 or 540		
M3S108	Mounting Screws for 9655-100 M3 x .5 x 6 mm	Ea.

32.5.3 Measurement Transducer Parts

Part Number	Description	Sold As
Used with 39053 and 39010		
SC0250A	Replacement 39053 High-Resolution L- Strain and 39010 C-Strain Transducer Core - Core Only	Ea.
32398	Replacement transducer assembly for 39053 High-Resolution L-Strain and 39010 C-Strain - includes transducer and core	Ea.
Used With 39050		
GA000192	Replacement Transducer assembly - 39050 includes transducer and core	Ea.
SC0500	Standard 500 MHR Transducer - 39050 - includes transducer and SC0500A transducer core	Ea.
SC0500A	Replacement 39050 Transducer Core - core only	Ea.
SC0500B	Replacement 39050 Transducer Core with Insulated Extension Rod	Ea.

32.5.4 Hot Zone L-Strain Consumable Parts

Part Number	Description	Parts Per Set	Sold As
Used with 39071			
9660-851	Alumina Rod, Chisel-Point End - 0.188 in dia	2	Set
9660-852	Alumina Rod, Inverted Chisel-Point End - 0.138 in dia	2	Set
9660-850	Alumina Rod, Chisel-Point End - 0.138 in dia	2	Set
GAUGE001	Ceramic Fiber Cord - 6 in	2	Set
Used with 39070, 39071 & 39072			
9660-853	Alumina Rod, Chisel-Point End - 0.188 in dia	2	Set
GAUGE003	Ceramic Fiber Cord - 10 in	8	Set
GAUGE002	Spring Tabs for Ceramic Fiber Cords	2	Set

32.6 Specimen Loading Tools

32.6.1 Manual Specimen Loaders

Uniaxial Compression - Pocket Jaws

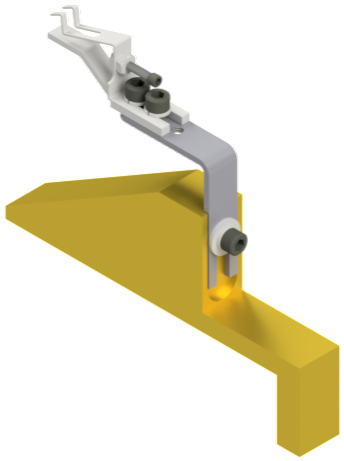


Fig. 32.8: Manual Specimen Loading Tool - DSI# 9555-104.

Part Number	Description	Sold As
9555-104	Manual Specimen Loading Tool - Included in 9555-100 *Uniaxial Compression Kit* (page 211)	Ea.

Plane Strain Compression - Pocket Jaws

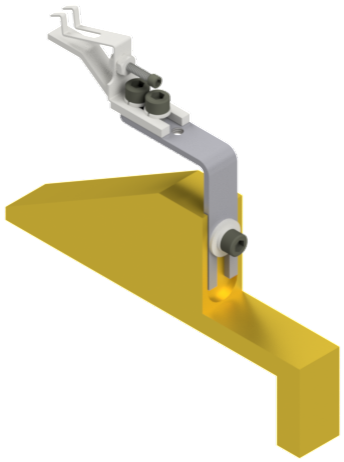


Fig. 32.9: Manual Specimen Loading Tool - DSI# 9560-109.

Part Number	Description	Sold As
9560-109	Manual Specimen Loading Tool - Included in 9560-001 *Plane Strain Compression Kit* (page 223)	Ea.

Compression Test Adapter

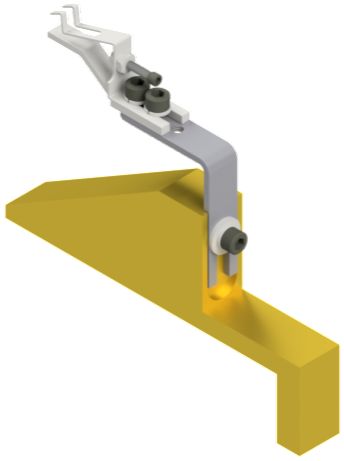


Fig. 32.10: Manual Specimen Loading Tool - DSI# 9520-115.

Part Number	Description	Sold As
9520-115	Manual Specimen Loading Tool	Ea.

32.6.2 Automatic Specimen Loader

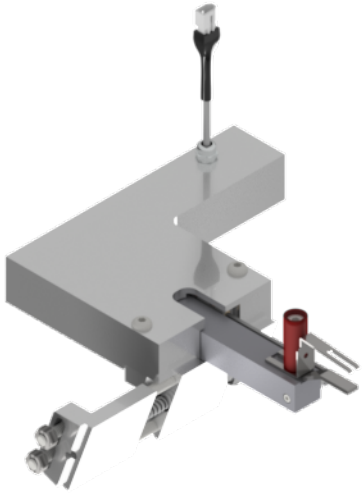


Fig. 32.11: Specimen Auto-Loader Assembly - DSI# 32782.

Part Number	Description	Sold As
32782	Specimen Auto-Loader Assembly	Ea.

32.6.3 Plane Strain Specimen Loading Clips

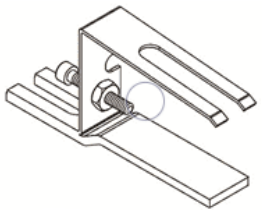


Fig. 32.12: Specimen Loading Clip - DSI# 33781.

Part Number	Description	Sold As
33781	Specimen Loading Clip for Plane Strain Specimens - 20 mm x 25 mm x 35 mm	Ea.

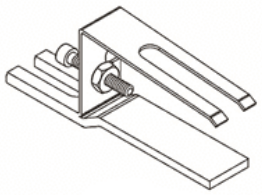


Fig. 32.13: Specimen Loading Clip - DSI# 33785.

Part Number	Description	Sold As
33785	Specimen Loading Clip for Plane Strain Specimens - 15 mm x 20 mm x 35 mm	Ea.

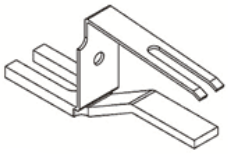


Fig. 32.14: Specimen Loading Clip - DSI# 33780.

Part Number	Description	Sold As
33780	Specimen Loading Clip for Plane Strain Specimens - 10 mm x 15 mm x 20 mm	Ea.

32.6.4 Uniaxial Compression Specimen Loading Clips

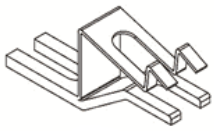


Fig. 32.15: Specimen Loading Clip - DSI# 33783.

Part Number	Description	Sold As
33783	Specimen Loading Clip for Uniaxial Compression Specimens with C-Strain Dilatometer - 10 mm dia x 15 mm long	Ea.

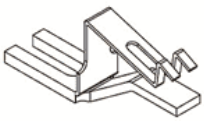


Fig. 32.16: Specimen Loading Clip - DSI# 33782.

Part Number	Description	Sold As
33782	Specimen Loading Clip for Uniaxial Compression Specimens - 10 mm dia x 15 mm long	Ea.

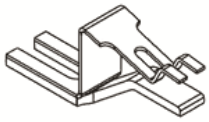


Fig. 32.17: Specimen Loading Clip - DSI# 33795.

Part Number	Description	Sold As
33795	Specimen Loading Clip for Uniaxial Compression Specimens - 8 mm dia x 10 mm long	Ea.

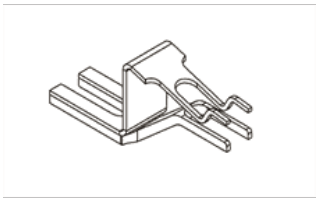


Fig. 32.18: Specimen Loading Clip - DSI# 33797.

Part Number	Description	Sold As
33797	Specimen Loading Clip for Uniaxial Compression Specimens with C-Strain Dilatometer - 6 mm dia x 9 mm long	Ea.

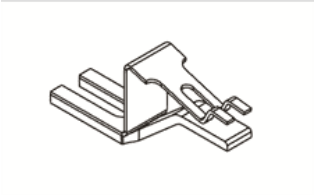


Fig. 32.19: Specimen Loading Clip - DSI# 33796.

Part Number	Description	Sold As
33796	Specimen Loading Clip for Uniaxial Compression Specimens - 6 mm dia x 9 mm long	Ea.

32.7 Mobile Conversion Units - Replacement Parts

32.7.1 O-Ring Sets

Part Number	Description	Sold As
OR007	Replacement O-Ring Set - General-Purpose MCU and Hydrawedge I Vacuum Tank	Kit
OR010	Replacement O-Ring Set - Hydrawedge II Vacuum Tank	Kit
OR011	Replacement O-Ring Set - MAXStrain I Vacuum Tank	Kit
OR014	Replacement O-Ring Set - Torsion Vacuum Tank	Kit
OR015	Replacement O-Ring Set - MAXStrain II Vacuum Tank	Kit
OR019	Replacement O-Ring Set - 3180 Vacuum Tank	Kit

32.7.2 Vacuum Tank Door Piston - Replacement Parts



Fig. 32.20: Vacuum Tank Gas Piston

Every Gleeble system (or each MCU supplied) includes at least one vacuum tank door piston. The size of the vacuum tank piston will vary depending on the type of Gleeble System or MCU. New designs have been introduced, improving performance and ease of use. These new designs are included in the model numbers below:

Model 32752: A new design with improved damping and longer durability, these replace the existing door springs on the following vacuum tanks: General Purpose MCU, Hydrawedge MCU, MAXStrain MCU, and 3180. Must have new spring mounts. (See 32753 and 32754 for upgrade kits)

Model 32753: Upgrade Kit for Damped Vacuum Tank Front Door Spring: Kit includes one (1) spring with mounts for the vacuum tank front door on the following vacuum tanks: General Purpose MCU, Hydrawedge MCU, MAXStrain MCU, and 3180.

Model 32754: Upgrade Kit for Damped Vacuum Tank Back Door Spring: Kit includes one (1) spring with mounts for the vacuum tank back door on the following vacuum tanks: General Purpose MCU, Hydrawedge MCU, and 3180. (Not applicable on MAXStrain MCU)

Part Number	Description	Sold As
32752	Replacement Damped Vacuum Tank Door Spring	Ea.
32753	Upgrade Kit for Damped Vacuum Tank Front Door Spring Assembly	Kit
32754	Upgrade Kit for Damped Vacuum Tank Back Door Spring Assembly	Kit

32.8 Chilled Process Fluid Systems - Replacement Parts

Part Number	Description	Sold As
31622	Load Unit Water Distribution Manifold	Ea.
31604	Load Unit Air and Water Manifold - 3180, 3500, 3800	Ea.
31620	Water Flow Switch/Load Unit Water Distribution Manifold - All Systems	Ea.
31615	2 GPM Flow Meter Circuit - Load Unit Water Distribution Manifold - All Systems	Ea.
31616	Grounded 2 GPM Flow Meter Circuit - Load Unit Water Distribution Manifold - All Systems	Ea.
31617	5 GPM Flow Meter Circuit - Load Unit Water Distribution Manifold - All Systems	Ea.
31621	Water Flow Valve for Load Unit - 3180, 3500, 3800	Kit
31612	Load Unit Column End Plumbing - 3500 and 3800 with MCUs	Kit

32.9 Hydraulic Systems - Replacement Parts



Fig. 32.21: Schrader Valve Fill Connector - DSI# ACM9979F





Schrader Valve Assembly for Parker Ac-
- DSI# ACM9982C

Part Number	Description	Sold As
35333	3500 Dual Hydraulic Valve System Upgrade	Ea.
35334	3800 Dual Hydraulic Valve System Upgrade	Ea.
35341	3500 Dual Hydraulic Valve System Upgrade - For machines with existing dual valve upper hydraulic blocks	Ea.
35342	3800 Dual Hydraulic Valve System Upgrade - For machines with existing dual valve upper hydraulic blocks	Ea.
GAUGE004	Gleeble Branded Oil Pressure Gauge - Load Unit and MCU	Ea.
ACM00043	1 Pint Pilot Accumulator - 3180	Ea.
32496	1 Pint Pilot Accumulator - Hydrawedge I MCU Pilot Accumulator	Ea.
ACM00251	1 Quart Pilot Accumulator - All 3500 & 3800 Load Units, Hydrawedge II MCU, MAXStrain I & II MCU	Ea.
ACM01001	1 Gal Accumulator - 3180	Ea.
ACM02502	2.5 Gallon Accumulator - Split Flange Mount - 60 GPM - 3500 Load Unit - Serial # 304 - 329	Ea.
ACM02503	2.5 Gallon Accumulator - SAE Thread Mount - 60 GPM - 3500 Load Unit - Serial # 304 - 329	Ea.
ACM05005	5 Gallon Accumulator - Split Flange Mount - 100 GPM - 3500 & All 3800 Load Units, Hydrawedge II MCU, MAXStrain I & II MCU - Serial # 330 - Present	Ea.
ACM05006	5 Gallon Accumulator - SAE Thread Mount - 100 GPM - 3500 & All 3800 Load Units, Hydrawedge II MCU, MAXStrain I & II MCU - Serial # 330 - Present	Ea.
ACM9982C	Schrader Valve Assembly for Parker Accumulators - All sizes	Ea.
ACM9979F	Schrader Valve Fill Connector for all Accumulator Charging Kits	Ea.
ACM99###	Accumulator Charging Kits (Country Specific - See below)	Ea.

- ACM9990A - South Africa

- ACM9991A - Brazil
- ACM9992A - Argentina, Australia, India
- ACM9993A - Belgium, France, Slovenia, Spain
- ACM9994A - Germany, Austria, Holland
- ACM9995A - Italy
- ACM9984A - South Korea
- ACM9985A - China
- ACM9986A - Taiwan
- ACM9987A - Japan
- ACM9988A - Russia, Venezuela
- ACM9989A - United States, Canada

Note: If your country is not listed above, please contact *DSI* (page 373) for assistance.

Section 33

Gleeble Consumables

Contents

- *Common Gleeble Consumables and Tools* (page 360)
  - *Hydraulic Oil* (page 360)
  - *Oil Filters* (page 360)
  - *Air Filters* (page 363)
  - *Water Filters* (page 363)
  - *Copper Cleaner* (page 364)
  - *Glue and Cement* (page 364)
  - *Heat Shield Cloth and Sleeve* (page 365)
  - *Lubricant* (page 365)
- *Compression Test Consumables Kits* (page 366)
  - *Hot Compression Starter Kit - DSI# 9570-000* (page 366)
  - *Uniaxial Compression Consumables Kit - DSI# 9570-001* (page 366)
  - *Small Plane Strain Compression Kit - DSI# 9570-002* (page 366)
  - *Large Plane Strain Compression Kit - DSI# 9570-003* (page 367)
- *Diffusion Barriers* (page 368)
  - *Graphite Foil* (page 368)
  - *Tantalum Foil* (page 369)

33.1 Common Gleeble Consumables and Tools

33.1.1 Hydraulic Oil

Part Number	Description	Sold As
G200A	Hydraulic Oil - 18.9 L (5 gal) - Can	Ea
G200AA	Hydraulic Oil - 208.19 L (55 gal) - Drum	Ea

Note: Details for alternative hydraulic oil can be found here.[53]

33.1.2 Oil Filters

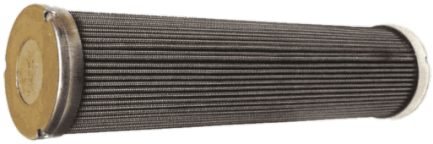


Fig. 33.1: High Pressure Oil Filter DSI# FIL526.

Part Number	Description	Sold As
FIL526	Load Unit and MCU Oil Filter (3 Micron Filtration, 8 in long)	Ea.



Fig. 33.2: Hydraulic Filter Element - DSI# FIL522.

Part Number	Description	Sold As
FIL522	Hydraulic Power Unit Oil Filter - 35343 RWE 20 hp HPU	Ea.

[53] https://www.gleeble-tech.com/gleebledocs/g3/3800_site_prep/appendix_a.html#hydraulic-oil-for-use-in-all-gleeble-systems



Fig. 33.3: Parker Oil Filter - DSI# FIL513.

Part Number	Description	Sold As
FIL513	Parker Oil Filter - top of hydraulic pump	Ea.

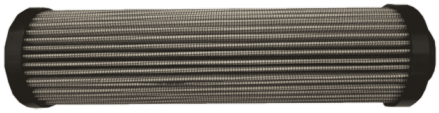


Fig. 33.4: Hydraulic Oil Filter - DSI# FIL514.

Part Number	Description	Sold As
FIL514	Hydraulic Oil Filter - Mitten Pump	Ea.



Fig. 33.5: Hydraulic Filter for Ralph Earl Pump DSI# FIL520.

Part Number	Description	Sold As
FIL520	Hydraulic Filter for Ralph Earl Pump - 40 hp	Ea.



Fig. 33.6: Hydraulic Filter Element for Hydraulic Pump - DSI# FIL523.

Part Number	Description	Sold As
FIL523	Hydraulic Filter Element for Hydraulic Pump - HDS-V40	Ea.

33.1.3 Air Filters



Fig. 33.7: Load Unit Air Filter and Housing - DSI# 32435 and FIL540A.

Part Number	Description	Sold As
32435	Load Unit Air Filter Housing	Ea.
FIL540A	Replacement Filter Element	Ea.
FIL518	Air Filter for Hydraulic Pump - RWE 20 hp HPU	Ea.

33.1.4 Water Filters



Fig. 33.8: Replacement Water Filter - DSI# FILW750D.

Part Number	Description	Sold As
FILWKIT	Load Unit Water Filter Kit	Kit
FILW750B	Replacement Mounting Nut Gasket - Load Unit Water Filter Kit	Ea.
FILW750C	Replacement Shell Gasket - Load Unit Water Filter Kit	Ea.
FILW750D	Replacement Water Filter Cartridge - Load Unit Water Filter Kit	Ea.

33.1.5 Copper Cleaner



Fig. 33.9: Copper and Stainless Steel Cleaner - DSI# HW001A.

Part Number	Description	Sold As
HW001A	Copper and Stainless Steel Cleaner	Can

33.1.6 Glue and Cement



Fig. 33.10: Supper Bonder Glue - DSI# HW008.

Part Number	Description	Sold As
HW008	Super Bonder Glue (0.7 oz tube)	Ea.
HW008A	Omega Bond Thermocouple Cement (8 oz)	Can

33.1.7 Heat Shield Cloth and Sleeve

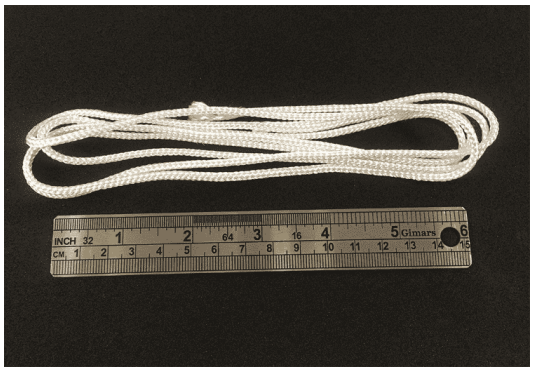


Fig. 33.11: Nextel 440 Heat Treated Wire Sleeve - DSI# TU403.

Part Number	Description	Sold As
TU403	0.0615 in Nextel 440 Heat Treated Wire Sleeve	Foot
TU405	ISO-T High-Temperature Nextel Insulating Sleeving - 5 ft minimum	Foot
RMX100P	Ceramic Cloth Heat Shield	Square Inch

33.1.8 Lubricant

Part Number	Description	Sold As
HW510	Superlube - 14.1 oz	Can
G327A	High-Vacuum Grease - 5.3 oz tube	Ea.
HW014	Anti-Seize Compound - Nickel Paste - 4 oz tube	Ea.

33.2 Compression Test Consumables Kits

Compression Tests and Studies include *Uniaxial Compression Studies* (page 209) and *Plane Strain Studies* (page 221). Uniaxial Compression and Plane Strain tests use many of the same consumables and accessories.

33.2.1 Hot Compression Starter Kit - DSI# 9570-000

Kit 9570-000 contains the following parts:

Part Number	Description
RMX005SB	5 mil thick Graphite Foil
RMX004S	4 mil thick Tantalum Sheet
RMX010SA	10 mil thick Graphite Foil
HW008	Super Bonder Glue
HW008A	Omega Bond Thermocouple Cement
HW014	Anti-seize Compound - Nickel Paste
HW510	Superlube

33.2.2 Uniaxial Compression Consumables Kit - DSI# 9570-001

Kit 9570-001 contains the following parts:

Part Number	Description
9219-062	ISO-T Tungsten Carbide Anvil Cap - Uniaxial Compression - 19 mm dia x 6.35 mm (0.75 in dia x 0.25 in)
9555-102	ISO-T Tungsten Carbide Anvil Assembly
9555-504	ISO-T Copper Backup Plate - 1.125 in dia
9555-500	ISO-T Tungsten Carbide Anvil Base - Uniaxial Compression - 19 mm dia x 19 mm (0.75 in dia x 0.75 in)
9555-501	ISO-T Anvil Inner Containment Sleeve
9555-502	ISO-T Anvil Outer Containment Sleeve
9555-506	ISO-T Spring Clip
9555-503	Graphite Disk - 10 mil
TU405	Nextel Sleeving

33.2.3 Small Plane Strain Compression Kit - DSI# 9570-002

Kit 9570-002 contains the following parts:

Part Number	Description
9105-252	Small Plane Strain Anvil - Tungsten Carbide - 5 x 25 x 10 mm (0.196 x 0.984 x 0.393 in)
9560-303	Backing Block - Small Plane Strain
9560-304	Side Conductor Plate - Small Plane Strain
9560-305	Bottom Conductor Plate - Small Plane Strain

33.2.4 Large Plane Strain Compression Kit - DSI# 9570-003

Kit 9570-003 contains the following parts:

Part Number	Description
9110-422	Large Plane Strain Anvil - Tungsten Carbide - Straight Sides - 10 x 42 x 15 mm (0.393 x 1.653 x 0.59 in)
9565-304	Backing Block - Large Plane Strain
9565-306	Side Conductor Plate - Large Plane Strain
9565-307	Bottom Conductor Plate - Large Plane Strain

33.3 Diffusion Barriers

33.3.1 Graphite Foil

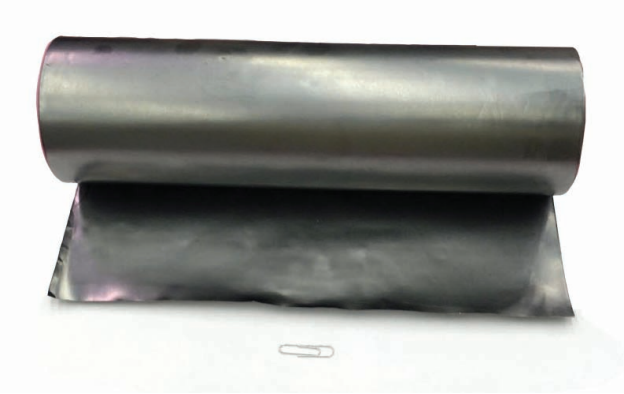


Fig. 33.12: Graphite Foil - 5 mil thick - DSI# RMX005SB.

Part Number	Description	Sold As
9555-509	ISO-T Conductive Graphite Disk, 5 mil thick - minimum 50	Ea.
9555-503	ISO-T Conductive Graphite Disk, 10 mil thick - minimum 50	Ea.
RMX005SB	5 mil thick Graphite Foil (12 in. x 50 ft)	Roll
RMX010SA	10 mil thick Graphite Foil (12 in. x 50 ft)	Roll



Fig. 33.13: Graphite Punch - DSI# Tool012.

Part Number	Description	Sold As
TOOL012	Graphite Foil Punch – 3/4 in dia	Ea.
TOOL011	Punch Pad for Foil Punch	Ea.

33.3.2 Tantalum Foil

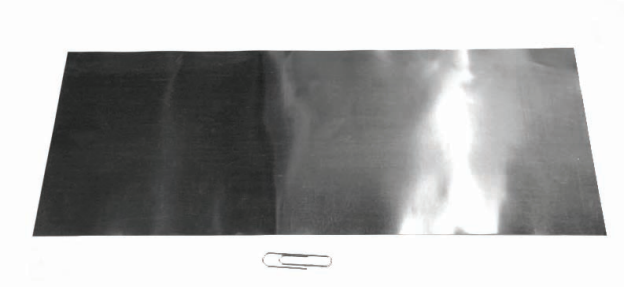


Fig. 33.14: Tantalum Foil - 4 mil thick - DSI# RMX004S.

Part Number	Description	Sold As
RMX004S	4 mil thick Tantalum Foil - 250 cm^2 (40 in^2)	Sheet

Section 34

System Service

Contents

- *System Upgrades* (page 370)
- *Training* (page 371)
- *Calibration* (page 371)
- *Extended Warranty* (page 371)
- *Spare or Replacement Parts and Consumables* (page 371)

Explore programs and options to maximize system performance and ensure your Gleeble continues to deliver world-class research.

Gleeble systems are powerful and highly precise scientific instruments. With proper maintenance and care, a Gleeble will provide researchers with decades of reliable service. DSI's Global Service Organization is dedicated to providing customers with the support needed to keep their equipment running at peak performance.

To discuss maintenance, parts and enhancements for your system, please contact our *Parts* (page 373) or *Service* (page 373) teams.

34.1 System Upgrades

A wide range of options and accessories are available to customize and add capability to your Gleeble system, including:

Software Upgrades Software updates can be made to the Gleeble workstation, including QuikSim and Origin. Updates to the GTC and 500 Series HMI touchscreen software are provided at no cost in connection with annual service and calibration.

Hardware Upgrades Upgrades can range from simple purchases of additional gauges to advanced improvement such as *Hydraulic Crosshead Locks* (page 86) for *Mobile Conversion Units* (page 46).

Integration of Digital Image Correlation Technology (DIC) See *Digital Image Correlation* (page 299) for more information.

LED Optical Extensometer and Dilatometer See *Non-Contact Optical Micrometer* (page 269) for more information.

Gleeble Touch Control (GTC) This significant software and hardware upgrade includes a range of enhancements, including improved usability and performance. See *Gleeble Touch Control* (page 9) for more information.

34.2 Training

The most important part of any Gleeble research program is the human component. Knowledgeable, well-trained users ensure simulations are designed and executed correctly. Various levels of training are offered by DSI, including general operating instructions, advanced training, and application-specific training. Training is available at the DSI facility in Poestenkill, NY, at user sites, or at Regional Demonstration Centers around the world.

34.3 Calibration

Gleeble systems are complex, high-performance machines that should be calibrated at least once a year by a Certified Gleeble Service Engineer. The DSI Global Service organization offers calibration as a standalone service or as part of an Annual Maintenance Contract.

34.3.1 Annual Maintenance Contract (AMC)

Like any complex instrument, a Gleeble systems require periodic maintenance. AMCs are a great way to proactively ensure regular service and calibration for your equipment. By purchasing an AMC, organizations can schedule service visits during dates that are convenient for them. Regular maintenance minimizes the risk of failures and downtime. Service visits typically last 2-3 days on site, depending on the features and accessories installed on each system.

34.4 Extended Warranty

Each new Gleeble system must pass extensive acceptance tests, both in the DSI factory, and again at the installation site. During installation, the system is calibrated by a Certified Service Engineer. The system comes with a comprehensive one (1) year warranty covering defects in materials and workmanship. The standard warranty can be extended to cover additional years via the purchase of an extended warranty. Older systems that are beyond their initial manufacturer's warranty period may be eligible for extended warranty protection. Please *Contact Dynamic Systems* (page 373) to learn more.

34.5 Spare or Replacement Parts and Consumables

Common spare parts and consumable parts are listed in *Gleeble Consumables* (page 359). Contact DSI's Parts and Service team for replacement items or to replenish your supply of consumables. Only DSI and our affiliated partners sell certified components. Use of components supplied by unauthorized dealers may damage equipment and void the system's warranty.

Section 35

Contract Testing

Access to Gleeble data is a true competitive advantage for many organizations. Experts in industry and academia alike understand the value of simulation data. Unfortunately, not every research lab has access to a Gleeble system, or their system may be fully utilized. In these cases DSI can offer several solutions to help provide provide Gleeble research results.

Academic Collaborations The Gleeble community consists of world-renowned researchers at leading research institutions around the globe. DSI is able to connect you with university partners that have the equipment and expertise necessary to support your research goals.

Contract Testing at DSI DSI offers contract testing as a service. DSI staff has expertise on Gleeble's applications to support a wide range of metallurgical investigations. Our staff works with customers to evaluate their needs, design an experimental matrix, and execute physical simulations on the client's material. DSI has access to most of the equipment listed in this catalog, plus access to cutting edge pre-commercial testing kits. DSI limits contract testing services to Gleeble testing with minimal post-test analyses such as microscopy.

Partner Laboratories For customers that require deeper investigations, where Gleeble testing is only a portion of the analysis required, we can suggest partnering with a research laboratory that can provide additional services. The DSI team will work with the customer and the research lab to deliver actionable results. In these cases, Gleeble testing may be conducted by DSI at our facility and then specimens and data are shared with the team for analysis.

Section 36

Contact Dynamic Systems

- *Sales* (page 373)
- *System Service and Support* (page 373)
- *Parts and Consumables* (page 373)
- *General Inquiries* (page 374)
- *Global Customer Support* (page 374)

To better serve the growing numbers of Gleeble users, we have continued to make improvements to our customer service process. Our goal is to connect you as quickly as possible to the staff at DSI that can best meet your needs.

36.1 Sales

For sales inquiries please e-mail Sales@gleeble.com.

> For over 60 years, Dynamic Systems has been providing solutions to the materials industry. Our thermal-mechanical simulation systems have evolved over the decades to provide unsurpassed performance and reliability. DSI has developed a simulation system for every need. Solutions range from systems with small footprints to high-performance work horse systems. Contact a DSI Sales representative to discover what solution DSI has for you.

36.2 System Service and Support

For service inquiries please e-mail Support@gleeble.com.

> Gleeble thermal-mechanical simulators have been designed and built to provide long-lasting and reliable performance. Even a well-oiled machine needs occasional maintenance. Self-guided troubleshooting support and trouble ticket requests can be found on our support website, Support.Gleeble.com.[54] For advanced system service or additional training, a DSI System Service Engineer can address your unique needs.

36.3 Parts and Consumables

For parts inquiries please e-mail Parts@gleeble.com.

[54] https://support.gleeble.com/portal/en/home

The Parts and Consumables Department at Dynamic Systems is uniquely positioned to provide superior service. Whether your system has withstood the test of time, or has recently been installed, only Dynamic Systems and their affiliated global partners can provide genuine consumables or replacement parts for your Gleeble system. To receive faster and more efficient service, please provide your system serial number, part number and quantity, or a photo of thr part in question when contacting DSI.

36.4 General Inquiries

For general inquiries please e-mail Info@gleeble.com.

For any questions or concerns that do not fall into a category listed above, you can contact the Dynamic Systems General Inquiry Help Desk by visiting our website at Gleeble.com.[55]

Mailing Address:

Dynamic Systems Inc.
323 New York Route 355
Poestenkill, New York 12140
USA

Time Zone: Eastern Time (UTC/GMT -5 hours)

Office Hours: 0730 - 1700 Monday - Friday

Contact Phone Number: +1 (518) 283-5350

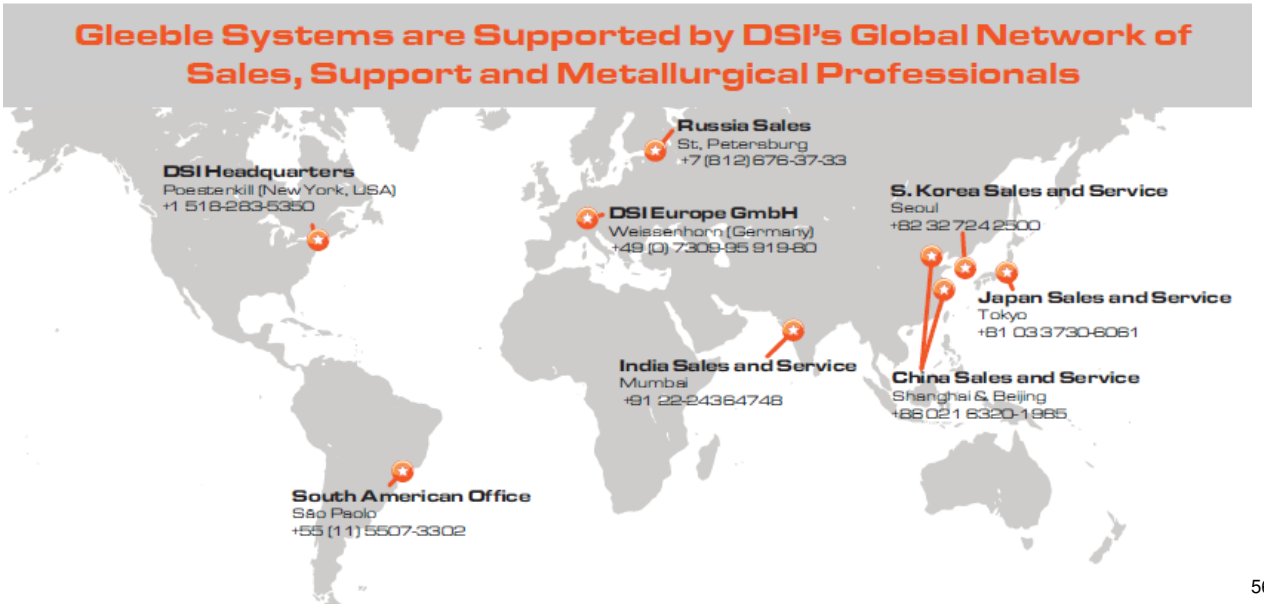
General Contact Email: Info@gleeble.com

36.5 Global Customer Support

Dynamic Systems works with partners around the world to offer the world's most advanced line of thermal-mechanical physical simulators and testing equipment.

Our regional partners are an important resource for providing local expertise and support. For more information about any of our products or services, please contact the appropriate representative listed below.

[55] https://gleeble.com/



[56]

China

Shanghai Sales and Service Office
Room 1006, Jintiandi Building, 998 Renmin Road
Huang Pu District
Shanghai, P.R. China 200021

Phone: +86 021 6320-1985
Email: China@Gleeble.com

Europe

DSI Europe GmbH[57]
Tatschenweg 1
D-74078
Heilbronn Germany

Phone: +49 (0) 7131-39099-231
Email: EU@Gleeble.com

South America

Technical Contact:
Dr. Fulvio Siciliano
São Paulo, Brazil

Phone: +55 (11) 98455-8845
Email: SouthAmerica@Gleeble.com or Fulvio@Gleeble.com

South Korea

Korea Kiyon LTD.

[56] https://gleeble.com/contact-us/contact-the-dsi-team.html
[57] https://gleeble.com/contact-us/contact-the-dsi-europe-office.html

486, Seobusaet-gil
Geumcheon-gu
Seoul (08588)
Republic of Korea

Phone: +82-2-2087-3527
Fax: +82-2087-3535
Email: SouthKorea@gleeble.com or jefflee@glovebox.co.kr

India

Dynamic Technology Systems
101, New Udyog Mandir #2,
Mogul Lane, Mahim (West)
Mumbai - 400016. India

Phone: +91 22-24464748
Email: India@Gleeble.com or info@dts-india.com

Japan

Japan Machinery Company
JMC Hightech Center
2-4-12 Higashi Rokugo, Ota-Ku
Tokyo 144-0046, Japan

Phone: +81 03 3730-6061
Email: Japan@Gleeble.com or kameyamam@jmc.asia

Russia

OM-Trading
Raevskogo Street, 4, 1st floor, room N55
Moscow 121151, Russian Federation

Phone: +7 495 783 88 12
Email: Russia@Gleeble.com

Section 37

Appendix A

37.1 Additional Gleeble Documentation

The following sections provide links or downloads for helpful and peripheral documents, sites, and documents.

Site Preparation Checklist[58] This checklist is used to ensure that the customer's facility is prepared for a DSI System Service Engineer to travel there, and install the new Gleeble system.

Gleeble System Comparison Chart[59] The Gleeble System Comparison Chart is a available on the Gleeble website and highlights key features, benefits, and differences among all main Gleeble systems.

General Testing Guide[60] The Gleeble General Testing Guide provides in-depth details on basic operational considerations for all Gleeble tests and simulations.

Application Notes[61] The Gleeble Application Notes contain test or application-specific information.

Gleeble Chiller Selection Guide[62] The Chiller Selection Guide is used by DSI Sales representatives to identify the correct *Process Fluid Chiller* (page 316) for each customer's unique needs.

[58] https://www.gleeble-tech.com/gleebledocs/g3/3800_site_prep/index.html
[59] https://gleeble.com/products/gleeble-systems/comparison-chart.html
[60] https://support.gleeble.com/portal/en/kb/articles/series-3-gtc-gleeble-general-testing-guide-user-manual
[61] https://support.gleeble.com/portal/en/kb/articles/series-3-gtc-gleeble-application-notes-application-note
[62] https://drive.google.com/file/d/1f12AHxZG2ipP6ql4fmaqDPcUN-78herR/view?usp=sharing

Section 38

Appendix B

38.1 Specimen Drawings

Gleeble systems are capable of testing a wide variety of material compositions and specimen geometries. Inherent limitations of the system, such as distance between the jaw or anvil faces, the maximum or minimum stroke speed, test temperature, and force limitations for the individual system must be considered when selecting a specific *specimen geometry* (page 378).

The target temperature of a test will also impact the size of a specimen that can safely be tested with a Gleeble system. For example, when considering a standard uniaxial compression specimen, it is possible for a soft material such as aluminum or copper to be tested at ambient temperature. Harder materials, such as steel or titanium alloys, are expected to be tested at elevated temperatures.

38.1.1 Round Bar Specimens

Round bar specimens can be used for tension, compression, or thermal-based tests.

Specimens for Gleeble 3500 and 3800 Systems

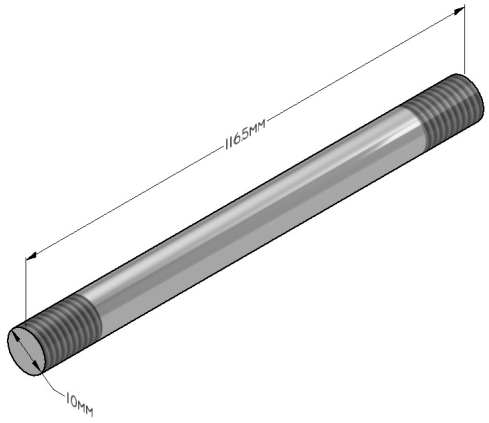


Fig. 38.1: Round Bar Specimen - SMR111.

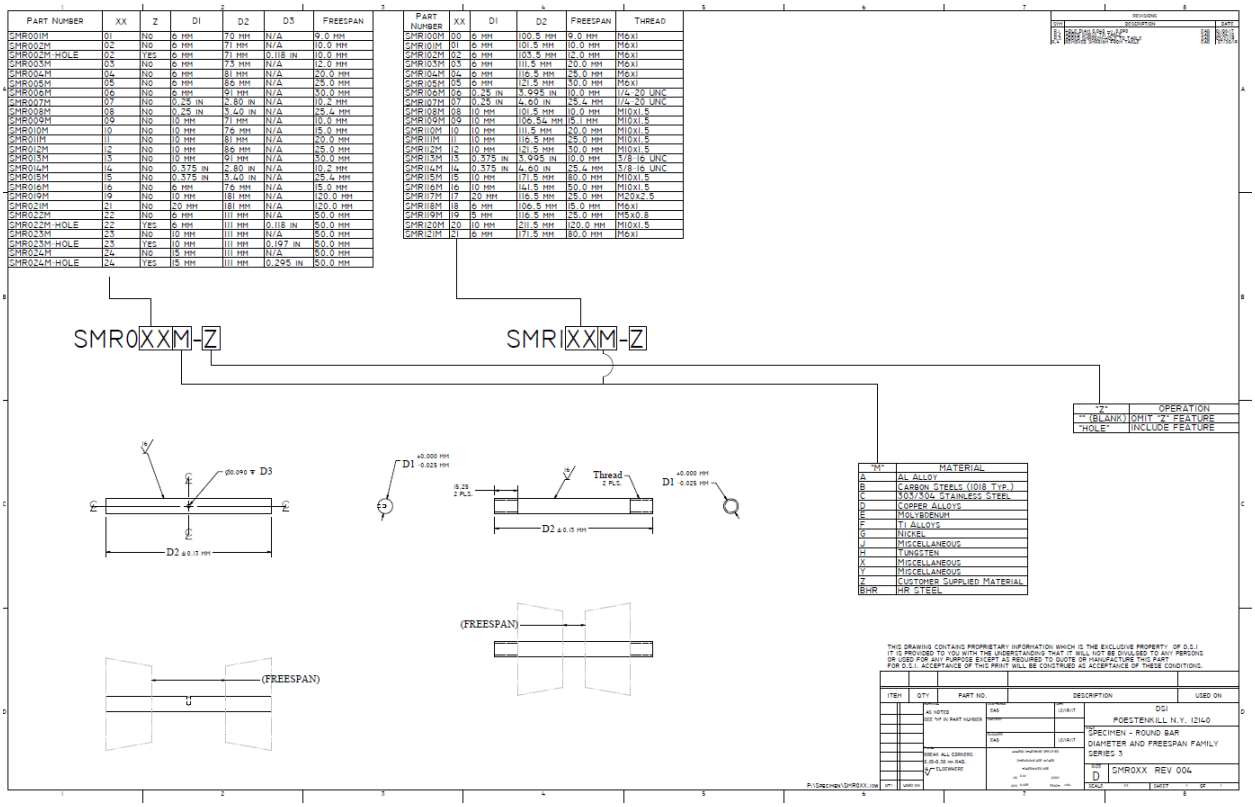


Fig. 38.2: Round Bar Specimen Mechanical Drawing.

Specimens for 500 Series Systems

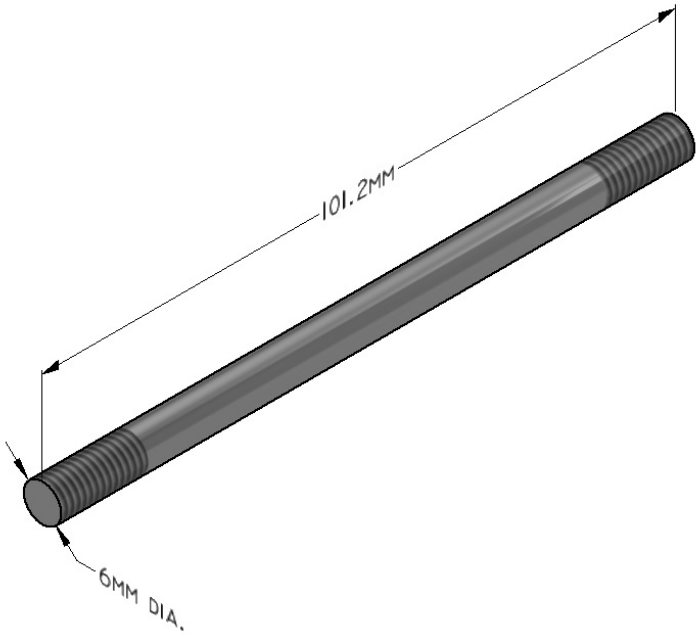


Fig. 38.3: 500 Series Round Bar Specimen - SMR115.

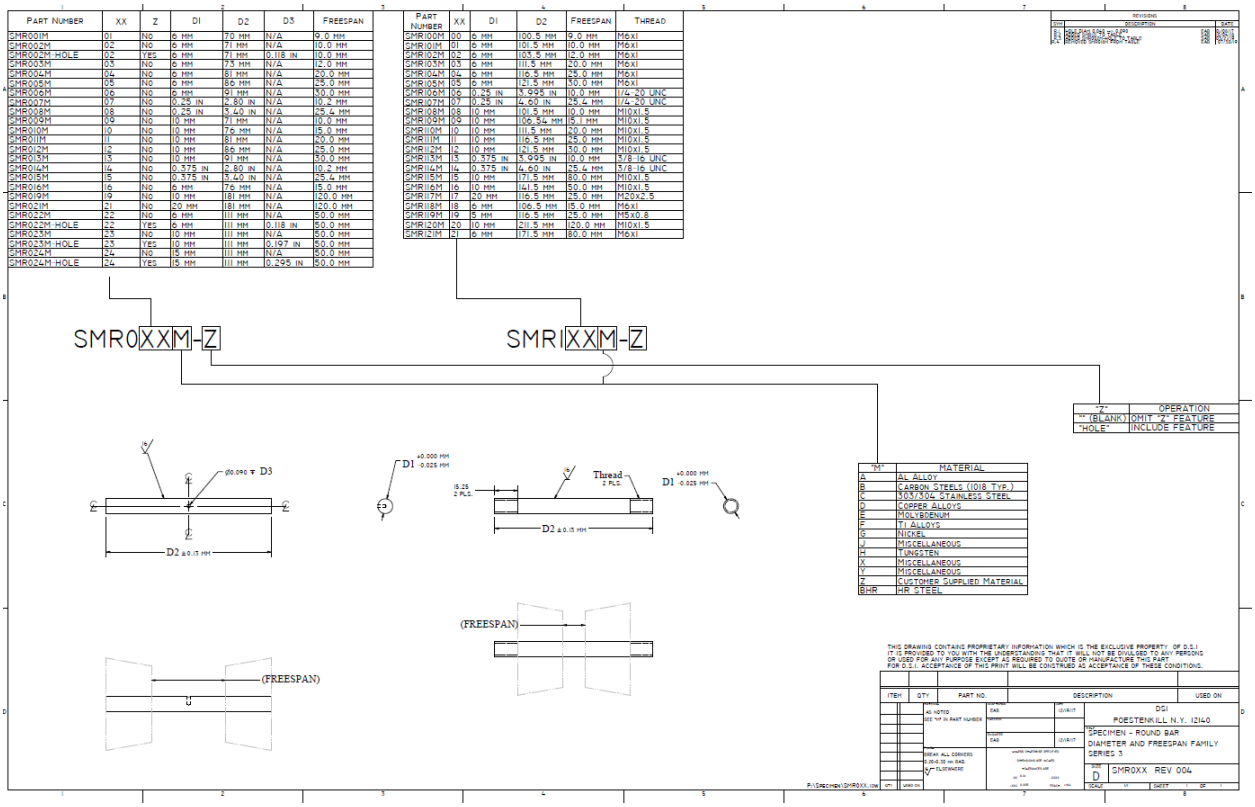


Fig. 38.4: 500 Series Round Bar Specimen Mechanical Drawing.

38.1.2 Compression Specimens

Compression specimens are used for *Uniaxial Compression Studies* (page 209) and *Plane Strain Studies* (page 221) . These specimens can be used in any Gleeble system rated for compression testing.

Uniaxial Compression Specimens

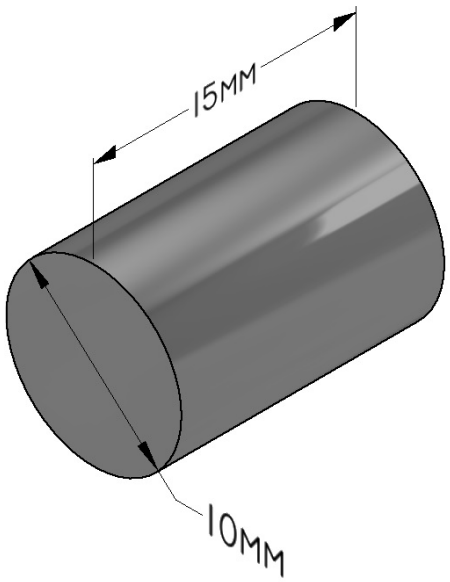


Fig. 38.5: Uniaxial Compression Specimen - SMC203.

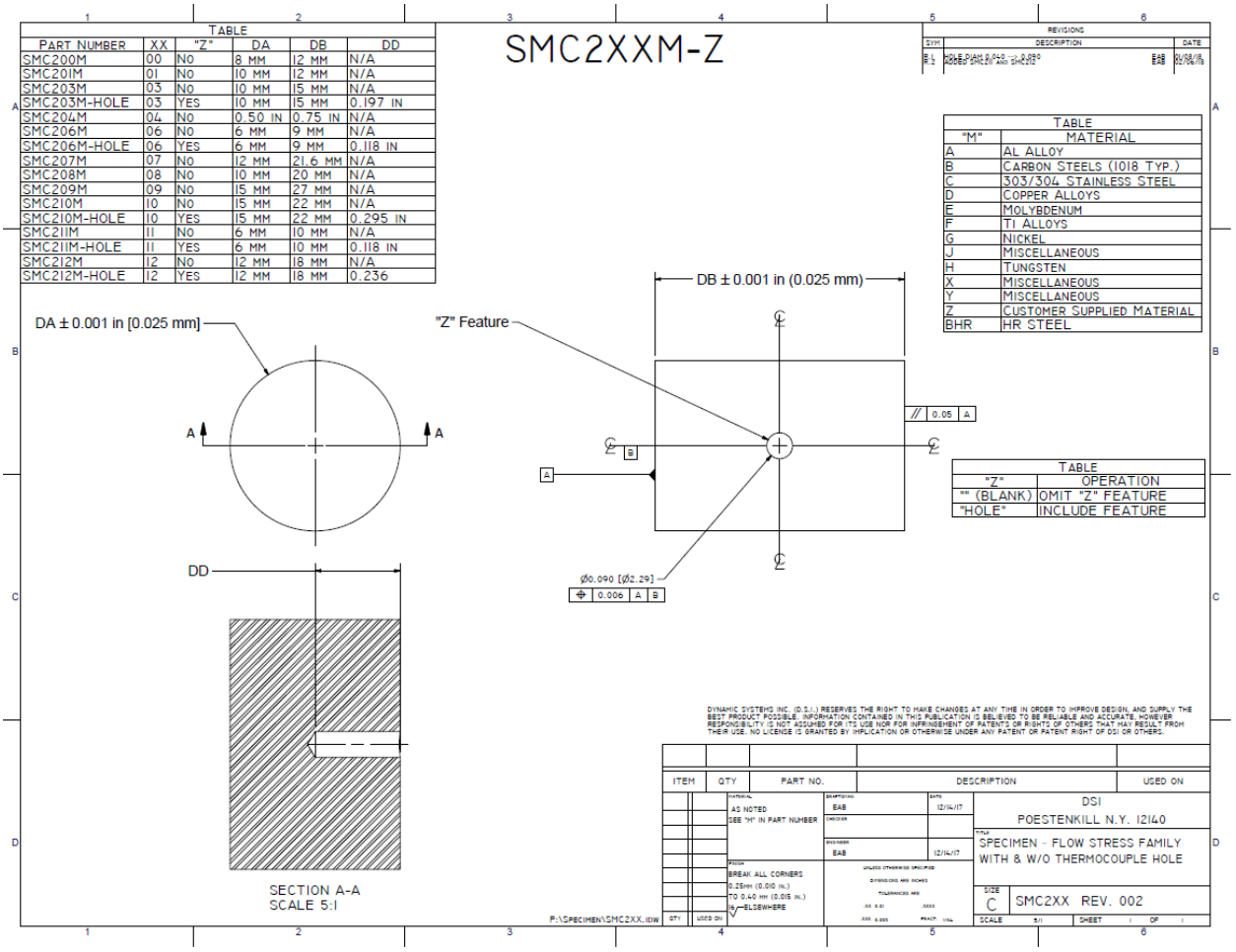


Fig. 38.6: Uniaxial Compression Specimen Mechanical Drawing.

Plane Strain Compression Specimens

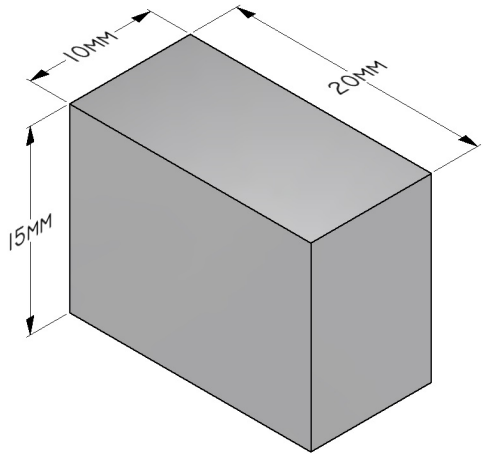


Fig. 38.7: Plane Strain Compression Specimen - SMC001.

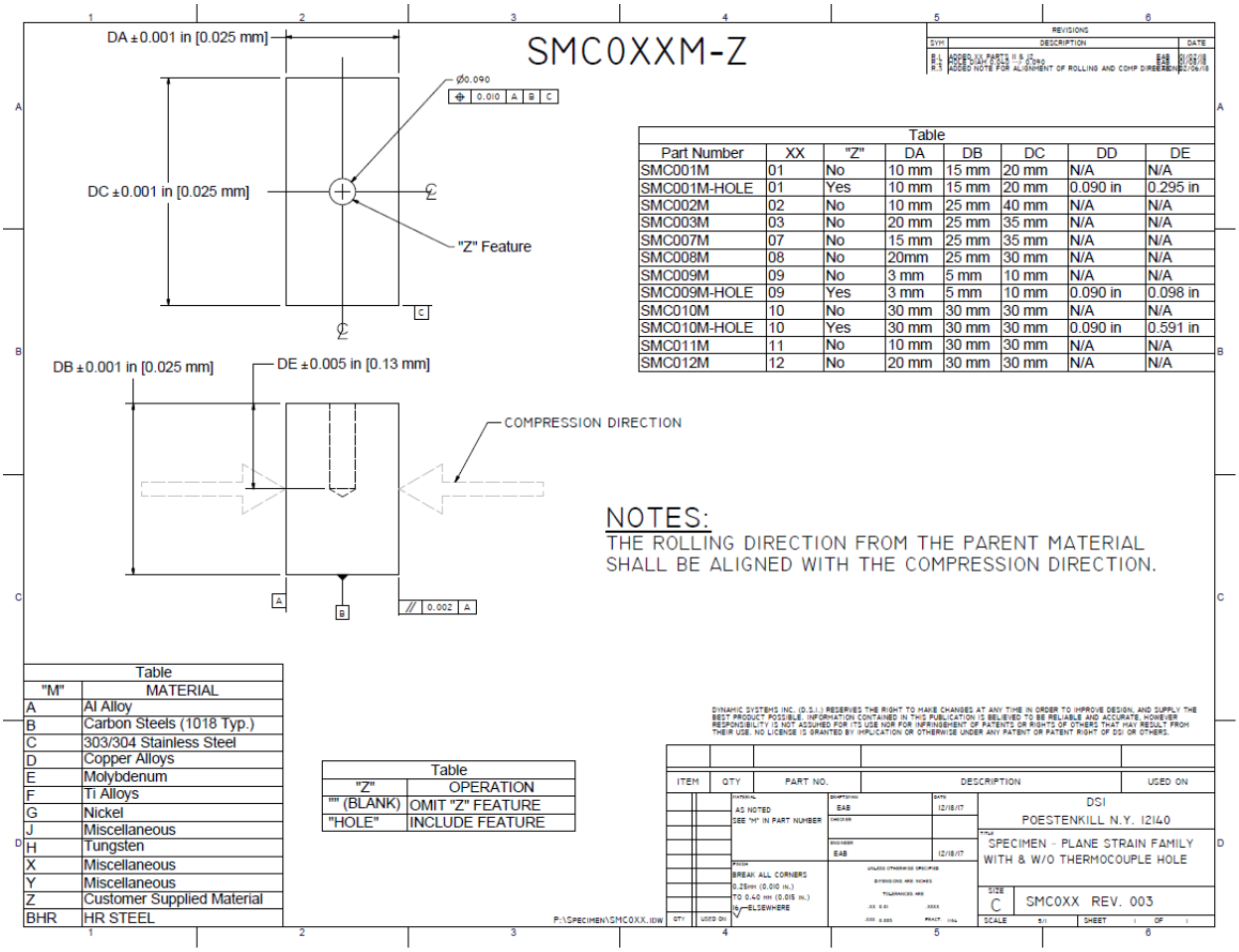


Fig. 38.8: Plane Strain Compression Specimen Mechanical Drawing.

38.1.3 Square Specimens

Square specimens can be used for all thermal cycle testing, including HAZ studies.

Square Specimens for All Systems

A drawing of a square bar specimen, SMS006 is provided as an example. For other specimen geometries, or assistance in identifying the correct specimen geometry, please contact a *Service Engineer* (page 373).

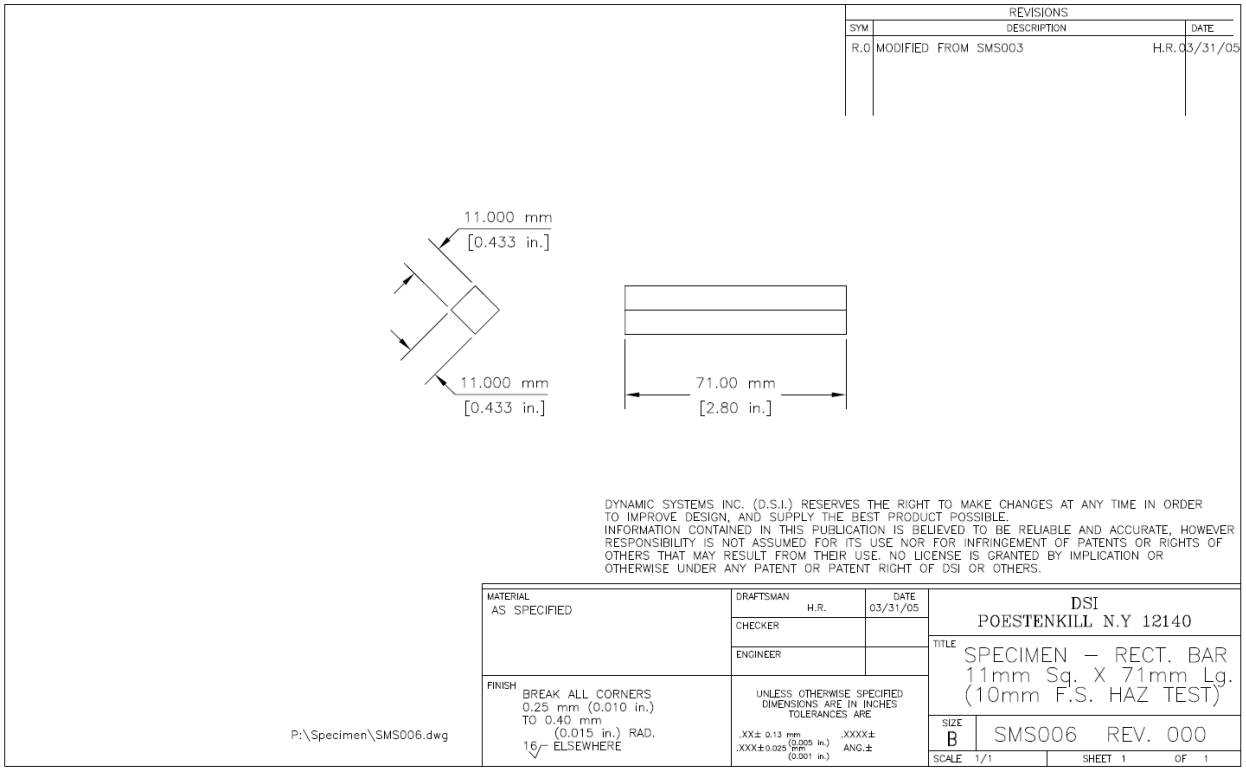


Fig. 38.9: Square Specimen Mechanical Drawing.

38.1.4 Flat Specimens

Flat specimens are used in tension and thermal-based studies.

Flat Specimens for All Gleeble Systems

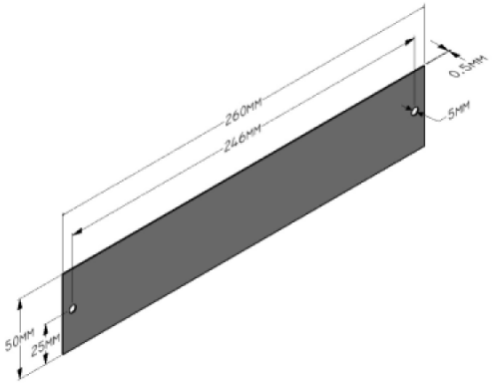


Fig. 38.10: Flat Specimen - SMF109.

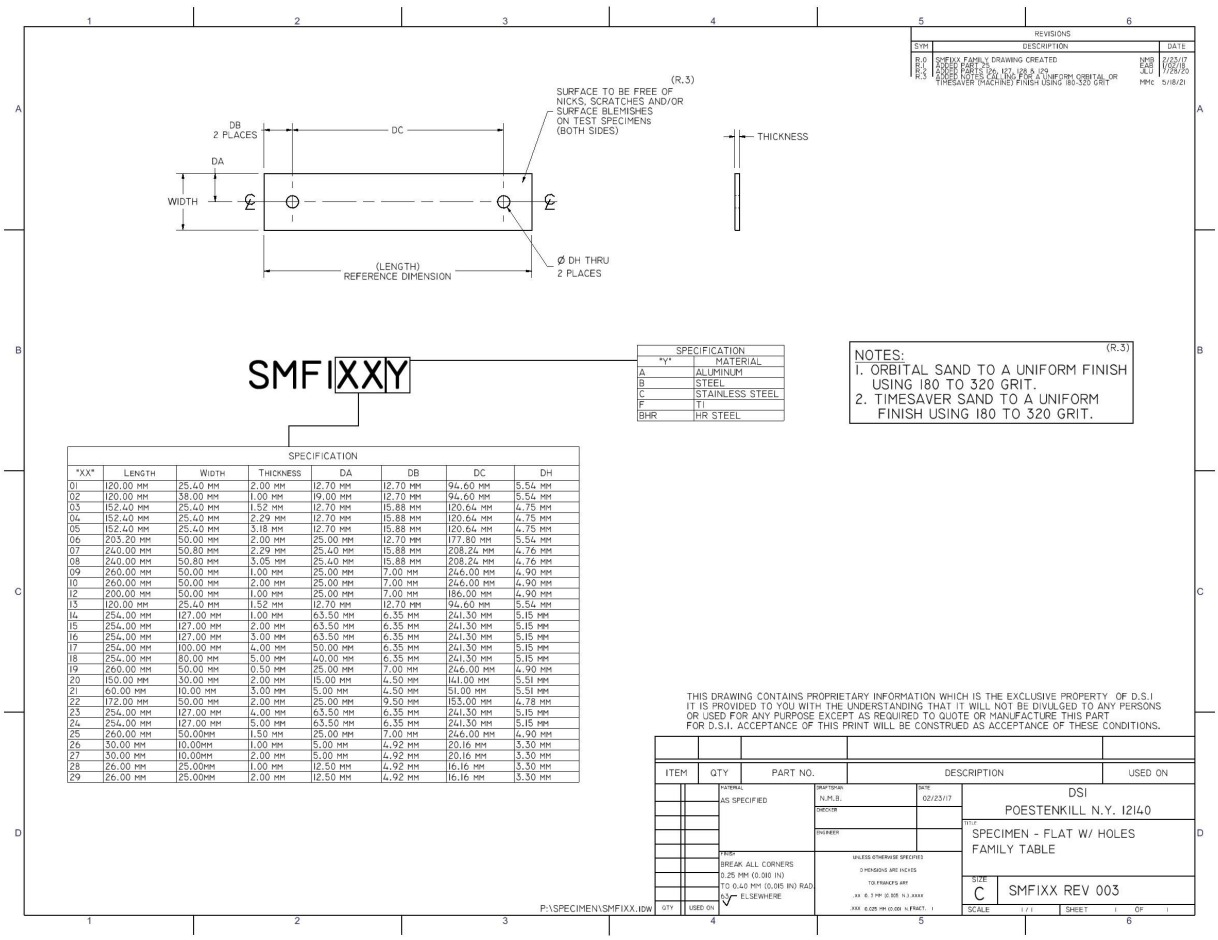


Fig. 38.11: Flat Specimen Mechanical Drawing.

38.1.5 Hot Torsion Specimens

A drawing of the Hot Torsion specimen SMT001 is provided as an example. For other specimen geometries or assistance, in identifying the correct specimen geometry please, contact a *Service Engineer* (page 373).

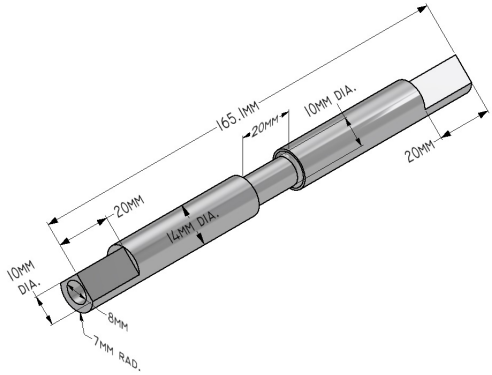


Fig. 38.12: Hot Torsion Specimen - SMT001.

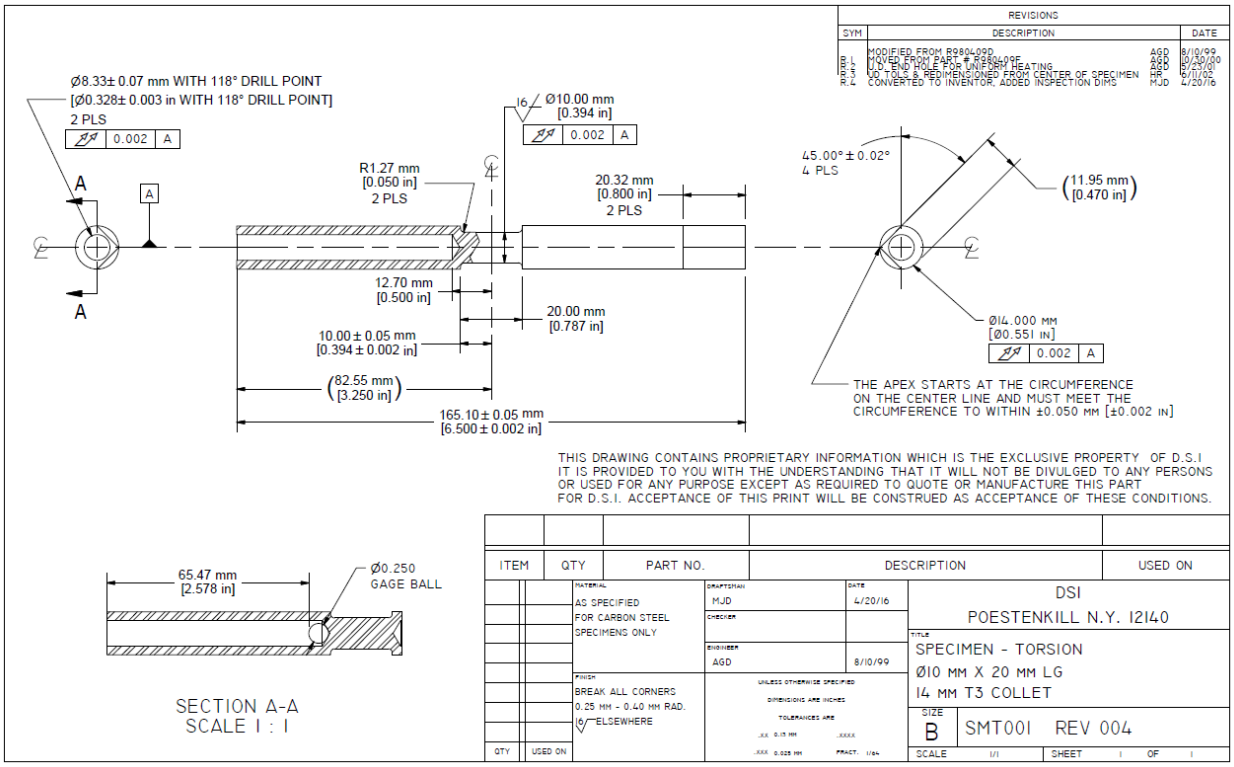


Fig. 38.13: Hot Torsion Specimen Mechanical Drawing.

38.1.6 MAXStrain Specimens

A drawing of the MAXStrain specimen SMC408 is provided as an example. For other specimen geometries or assistance, in identifying the correct specimen geometry please, contact a *Service Engineer* (page 373).

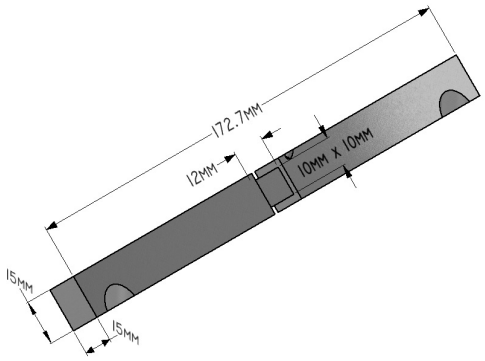


Fig. 38.14: MAXStrain Specimen - SMC408.

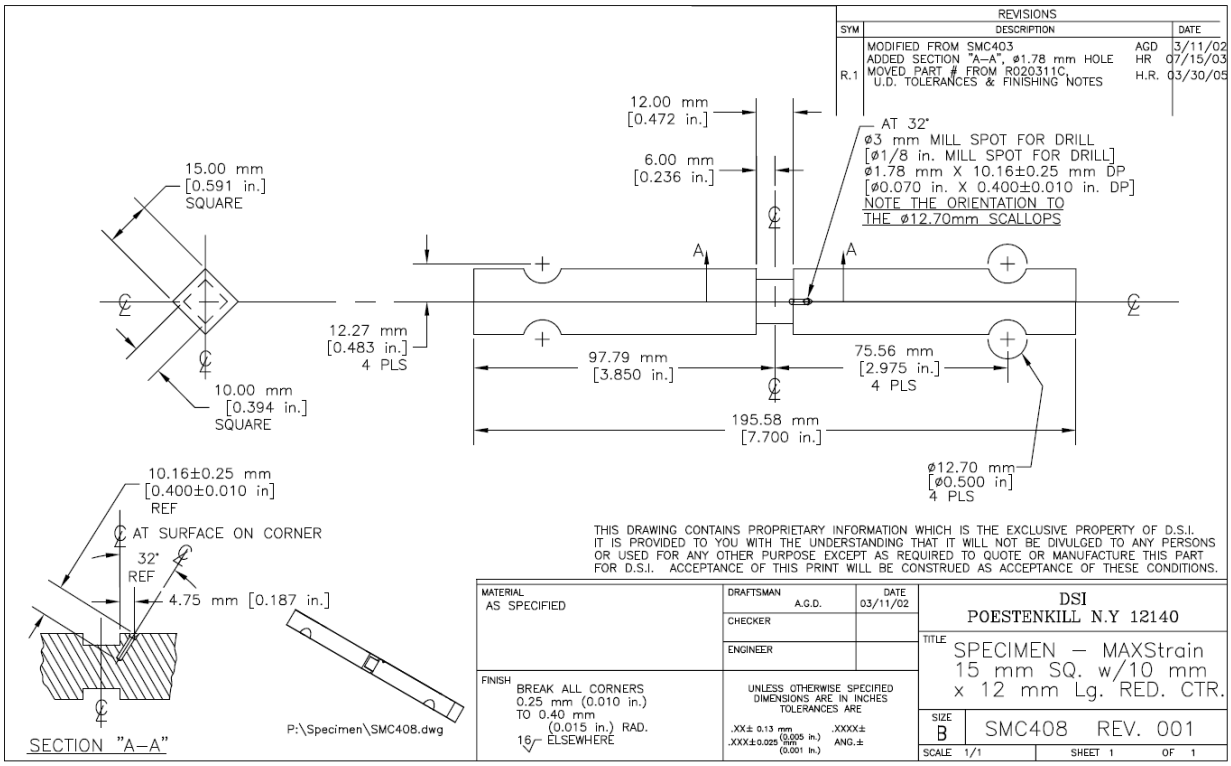


Fig. 38.15: MAXStrain Specimen Mechanical Drawing.

Section 39

Appendix C

39.1 Abbreviations and Units of Measure

Length

Abbreviation	Long Name	Example
μm	micrometer	0.15 μm
mm	millimeter	$\pm$18 mm
cm	centimeter	15 cm
m	meter	2 m
mil, thou	thousandths of an inch	5 mil, 5 thou
in	inch	1.5 in
ft	foot	4 ft

Volume

Abbreviation	Long Name	Example
L	liters	350 L
oz	ounce	0.7 oz
gal	gallons	92.5 gal
cfs	cubic feet per second	1 cfs

Time

Abbreviation	Long Name	Example
ms	millisecond	0.32 ms
s	seconds	30 s
min	minutes	15 min
hr	hours	1 hr

Temperature

Abbreviation	Long Name	Example
℃	Celsius	1,000℃
℉	Fahrenheit	1,832℉
T_{avg}	average temperature	T_{avg} for 50 mm

Weight

Abbreviation	Long Name	Example
g	grams	166 g
kg	kilograms	20,000 kg
N	Newtons	50 N
kN	kilo-newtons	196 kN
lb	pounds	44,000 lb

Force and Torque

Abbreviation	Long Name	Example
kgf	kilogram force	225 kgf
Nm	Newton meter	10 Nm
lbf-in	inch pound	175 lbf-in
lbf-ft	foot pound	45 lbf-ft
lbf	pound feet	496 lbf

Electricity

Abbreviation	Long Name	Example
Hz	Hertz	2 Hz
kHz	kilohertz	50 kHz
VDC	volts direct current	24 VDC
VAC	volts alternating current	400 VAC
kVA	kilovolt amps	75 kVA
A, amp	amperes	40 amp, 40 A
kW	kilowatt	15 kW
V_{rms}	root mean square voltage	500 V_{rms}

Pressure

Abbreviation	Long Name	Example
mmHg	millimeters of mercury	-0.10 mmHg
psi	pounds per square inch	80 psi
bar	bar	1.9 bar
Torr	Torr	5 x 10^{-5} Torr

Material

Abbreviation	Long Name	Example
Cu	Copper	Cu backup plate
SS	Stainless Steel	SS grips
Ta	Tantalum	Ta foil
Pt	Platinum	Pt 100 %
Rh	Rhodium	Rh 13 %
Fe	Iron	Fe 100 %
Re	Rhenium	Re 5 %
W	Tungsten	W 95 %
Si_3N_4	Silicon Nitride	Si_3N_4 anvils

Other

Abbreviation	Long Name	Example
pcs	pieces	2 pcs
Ea.	Each	Ea.
dia	diameter	10 mm dia
hp	horsepower	20 hp
dBA	weighted decibel	67 to 70 dBA
ISO-T	Iso-Thermal	ISO-T Anvils
ISO-Q	Iso-Thermal Quench	ISO-Q Quench Head
MCU	Mobile Conversion Unit	General-Purpose MCU
HWII	Hydrawedge II	HWII MCU
HPU	Hydraulic Power Unit	20 hp HPU
CTA	Compression Test Adapter	CTA Assembly
PnP	Plug and Play	PnP port
IM	Instrument Module	IM inside console
VPM	Virtual Panel Meters	Stroke VPM
RH	Relative Humidity	20-85 % RH
ADC	Analog to Digital Converter	18-bit ADC
rpm	Revolution per Minute	1,500 rpm
LVDT	Linear Variable Differential Transducer	Gauge Type: LVDT

Section 40

Warranty

Dynamic Systems Inc. (“DSI”) hardware products are warranted against defects in materials and workmanship for one year. If DSI receives notice of such defects during the warranty period, DSI shall, at its option, either repair or replace hardware products which prove to be defective.

DSI’s software and firmware products which are designated by DSI for use with a hardware product, when properly installed on that hardware product, are warranted not to fail to execute their programming instructions due to defects in materials and workmanship. If DSI receives notice of such defects during the warranty period, DSI shall repair or replace software media and firmware which do not execute their programming instructions due to such defects. DSI does not warrant that the operation of the software, firmware or hardware shall be uninterrupted or error free.

DURATION AND COMMENCEMENT OF WARRANTY PERIOD: The warranty period for Gleeble Systems and accessories is one year. The warranty period begins either on the date of shipment or, where the purchase price includes installation by DSI, on the date of installation. If Buyer schedules or delays installation more than thirty (30) days after shipment, the warranty period begins on the thirty-first (31st) day from the date of shipment.

PLACE OF PERFORMANCE: Within DSI’s service travel areas, warranty and installation services for products installed by DSI and certain other products designated by DSI will be performed at Buyers facility and Buyer shall pay DSI round-trip travel expenses for such service.

On-site warranty services are provided only at the initial installation point. If products eligible for on-site warranty and installation services are moved from the initial installation point, the warranty will remain in effect only if Buyer purchases additional inspection or installation services at the new site.

Supervision of installation and on-site warranty services are available outside the country of initial purchase only if Buyer pays DSI’s international prices. If Buyer transports a product from the country of initial purchase without having paid DSI’s international prices, any remaining warranty covers parts and labor only, and applies only if the product is returned to DSI. However, Buyer may obtain on-site warranty service if the location is one where DSI can normally provide on-site service for the product and Buyer pays DSI’s established travel charges. Service outside the country of initial purchase is subject to the conditions regarding DSI’s service travel areas and initial installation point described above.

For product warranties requiring return to DSI, products must be returned to a service facility designated by DSI. Warranties requiring return to DSI are not limited to the country of purchase. Buyer shall prepay shipping charges (and shall pay all duties and taxes) for products returned to DSI for warranty service.

LIMITATION OF WARRANTY: The foregoing warranty shall not apply to defects resulting from -

1. Improper or inadequate maintenance by Buyer;
2. Buyer-supplied software or interfacing;
3. Unauthorized modification or misuse;
4. Operation outside of the environmental specifications for the product;
5. Improper site preparation and maintenance;
6. Operation using electrical power which does not meet specification.

THE WARRANTY SET FORTH ABOVE IS EXCLUSIVE AND NO OTHER WARRANTY, WHETHER WRITTEN OR ORAL, IS EXPRESSED OR IMPLIED. DSI SPECIFICALLY DISCLAIMS THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

Section 41

Privacy Policy and Terms and Conditions

41.1 Privacy Policy

To view a current version of the DSI Privacy Policy[63] please visit Gleeble.com.[64]

41.2 Terms and Conditions

TERMS AND CONDITIONS OF SALE

1. PRICE QUOTATIONS

a. Unless otherwise agreed to in writing by Dynamic Systems Inc. (DSI), all quotations expire thirty (30) days after the date of the quotation or, if earlier, the end of the ordering period of any purchase agreement against which the quotation is issued. All prices quoted are valid only if Buyer's requested delivery date (including any change orders) is within six (6) months of the date on which the original order is placed.

b. Unless otherwise agreed to in writing by DSI, all prices quoted are exclusive of insurance costs and all taxes (except taxes levied against DSI's income) including state and local use, sales, property (ad valoram) and similar taxes. Buyer agrees to pay such taxes unless Buyer has provided DSI with an exemption resale certificate in the appropriate form for the jurisdiction of DSI's place of business and any jurisdiction to which equipment is to be directly shipped hereunder or unless such sale is otherwise exempt from such taxes. When applicable, such taxes shall appear as a separate item on DSI's invoice. All prices are EXW (EX-Works), Poestenkill, New York USA unless otherwise stated in writing.

2. PAYMENT AND SECURITY TERMS- Payments shall be made in accordance with the terms of the quotation.

a. Should Buyer become delinquent in the payment of any sum due DSI, after ten (10) days from the date of written notice to Buyer, DSI shall not be obligated to continue performance under any agreement with Buyer. In addition, the Buyer agrees to pay a late payment penalty charge of one and one half (1-1/2) percent of the unpaid amount per month for each 30 days delay in payment with the first penalty occurring 40 days after the invoice date.

Buyer hereby grants and DSI reserves a purchase money security interest in each product purchased hereunder, and in any proceeds thereof, for the amount of its purchase price. Upon request by DSI, Buyer shall sign any document required to perfect such security interest. Payment in full of the purchase price of any product purchased hereunder shall release the security interest on that product.

3. DELIVERY DATES

[63] https://gleeble.com/about-us1/dsi-privacy-policy.html
[64] https://gleeble.com

Shipments of any products purchased are subject to DSI's availability schedule. DSI shall make every reasonable effort to meet any delivery date(s) quoted or acknowledged. However, DSI will not be liable in any way for its failure to meet such delivery date(s).

4. DELAYS IN PERFORMANCE

DSI shall not be liable for any delay in performance hereunder due to unforeseen circumstances, or due to causes beyond its control including, but not limited to, acts of nature, acts of government, labor disputes, delays in transportation, and delays in delivery or inability to deliver by DSI's suppliers.

5. SHIPMENT, RISK OF LOSS AND PACKING

a. Standard prices are based on EXW (EX-Works) Poestenkill, New York USA per Incoterms 2020. For quotations provided with other shipment terms, Items 5.b. and 5.d. below may not apply.

b. Unless otherwise stated in writing, prices do not include transportation and routing costs. Such costs must be paid by customer and will appear as a separate item on invoice.

c. DSI shall ship in accordance with DSI's standard practices. Buyer specified shipping instructions different than DSI's standard practices, are subject to agreement by DSI, and Buyer shall be subject to an additional charge. Shipments moving under Buyer instructions shall be freight collect unless otherwise agreed to by DSI.

d. Unless otherwise stated in writing, title to the products and risk of loss and damage shall pass to Buyer when loaded into the shipping container or truck at the DSI factory in the case of EXW (EX-Works) Poestenkill, New York.

e. Unless otherwise agreed to in writing by DSI, all products shall be packed, if appropriate, for shipment and storage in accordance with standard commercial practices. All packing shall conform to requirements of carrier's tariffs.

f. All shipments of Gleeble Systems of more than 300 miles overland must be in a full air ride enclosed van. Failure to ship by air ride transport van will void the warranty.

6. ORDER OF PRECEDENCE

a. These Terms and Conditions of Sale and any attachments from DSI take precedence over Buyer's additional or different terms and conditions, to which notice of objection is hereby given. Acceptance by Buyer is limited to these Terms and Conditions. Neither DSI's commencement of performance nor delivery shall be deemed or construed as acceptance of Buyer's additional or different terms and conditions.

b. Buyer's purchase of DSI's products hereunder represents acceptance of these Terms and Conditions of Sale and any attachments, which together constitute the entire understanding between the parties and supersede any previous communications, representations, or agreements by either party whether verbal or written. No change or modification of any of the terms or conditions herein shall be valid or binding on either party unless in writing and signed by an authorized representative of each party.

7. CHANGES AND CANCELLATIONS

a. If Buyer issues a change order causing a delivery delay or cancels an order less than one hundred twenty (120) days prior to scheduled shipment, Buyer shall be subject to up to a 20% cancellation charge based on the list price of the affected products. In addition, Buyer agrees to pay DSI for any non-recoverable costs incurred by DSI in the process of designing or construction or supplying equipment or services.

b. In addition, any such change in delivery dates caused by Buyer establishing a delivery date greater than four (4) months from Buyer's original scheduled shipping date shall constitute a new order for the affected products in determining the appropriate list price.

c. If Buyer cancels an order for special equipment or services any time after the order is received by DSI, Buyer may be subject to an additional charge. Special equipment or services are those items not set forth in DSI's current price list.

8. INSTALLATION OF PRODUCTS

Installation of equipment refers to supervision of installation by DSI's personnel where required. See installation and site preparation manual for details.

9. ACCEPTANCE OF PRODUCTS

Acceptance shall be accomplished by using applicable test procedures or programs established by DSI. If installation by DSI is not included in the purchase price, acceptance shall be at the time of completion of final tests at DSI's plant. If in Buyer's order Buyer has indicated its intention to witness final tests, DSI shall give Buyer at least ten (10) days advance notice of the date of such tests. DSI shall notify Buyer of any additional charges that may be associated with witnessing such tests. If installation by DSI is included in the purchase price, acceptance shall occur at the installation site when DSI demonstrates that the applicable acceptance test programs work properly or the product is otherwise demonstrated to be in normal operating condition. If installation is scheduled or delayed by Buyer more than thirty (30) days after delivery, Buyer shall be deemed to have accepted the products on the thirty-first (31st) day from the date of delivery.

10. COPYRIGHTED MATERIALS

Unless otherwise agreed to in writing by DSI, DSI's copyrighted materials (software and printed documentation) may not be copied except for archive purposes, to replace a defective copy, or for program error verification.

11. LICENSED PRODUCTS

With respect to those products which DSI licenses and which are supplied hereunder, the word "purchase" or similar or derivative words is understood to mean "license" and "Buyer" or similar or derivative words is understood to mean "Licensee". Title to licensed products shall remain with DSI, notwithstanding anything to the contrary herein.

12. WARRANTY

Please see *Warranty* (page 391) for DSI's warranty policy.

13. NUCLEAR, MEDICAL AND AVIATION APPLICATIONS

DSI's products are not specifically designed, manufactured or intended for sale as parts, components or assemblies for the planning, construction, maintenance, operation or use of any nuclear or medical facility nor for the flight, navigation or communication of aircraft or ground support equipment. Any Buyer using DSI's products for these applications agrees that, except as otherwise provided herein, DSI is not liable, in whole or in part, for any claims or damages arising from such use. If Buyer uses DSI's products for these applications, Buyer agrees to indemnify and hold DSI harmless from any claims for loss, cost, damage, expense or liability arising out of or in connection with the use or performance of DSI's products in such nuclear or aviation applications. Test equipment used in a static application which is not a functional part, component or assembly of an aircraft and is not attached to or utilized in the flight of an aircraft is not subject to this paragraph.

14. FORCE MAJEURE

Neither party shall be liable for any delay in delivery or in the performing of any obligation hereunder due to a cause or causes which are beyond its reasonable control, such as, but not limited to, acts of God, acts of DSI's vendors, rules or regulations of any governmental authority, fires, strikes or labor interruptions, flood, global or regional pandemics, war, riot, delays in transportation, lack of adequate fuel, power, raw materials, labor or containers, or breakage or failure of machinery or apparatus.

15. MISCELLANEOUS

a. Except as may be prohibited by the U.S. bankruptcy laws, in the event of any insolvency or inability to pay debts as they become due by a party hereto, or voluntary or involuntary bankruptcy proceeding by or against a party hereto, or appointment of a receiver or assignee for the benefit of creditors, the other party may elect to cancel any unfulfilled obligations hereunder.

b. Any required notices shall be given in writing at the address of each party set forth in the attachments hereto, or to such other address as either party may substitute by written notice to the other.

c. Neither party may assign or transfer any of the rights, duties, or obligations herein, without the prior written consent of the other, and any purported attempt to do so shall be null and void.

d. DSI's failure to exercise any of its rights hereunder shall not constitute or be deemed a waiver or forfeiture of such rights.

e. Should any part of this warranty be ruled invalid by a competent court of jurisdiction, all other parts of the warranty shall remain valid.

f. Stenographic, typographic and clerical errors are subject to correction.

g. Buyer agrees not to export or re-export the product or technical data in any manner contrary to U. S. law unless properly authorized by the U. S. Government.

h. Any dispute regarding the interpretation or validity hereof shall be governed by the laws of the State of New York, United States of America. The parties hereby agree that any dispute relating to the products sold hereunder shall be subject to the jurisdiction of the courts within the State of New York, United States of America.