MTS Damper Testing Solutions

A complete portfolio of systems for quality assurance, performance, NVH and durability testing

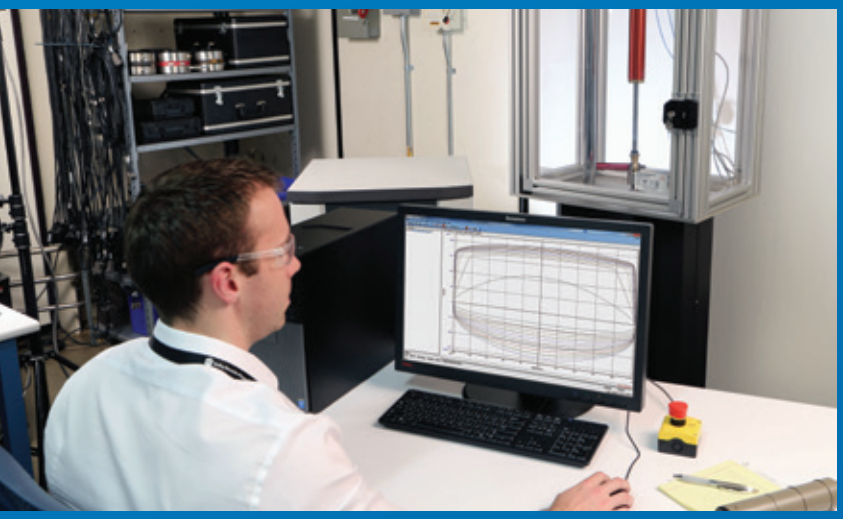
THE **MTS DAMPER TESTING PORTFOLIO** COMPRISES A PROVEN ARRAY OF ELECTRIC AND SERVOHYDRAULIC TESTING SOLUTIONS FOR CONDUCTING ACCURATE AND REPEATABLE DAMPER QUALITY ASSURANCE, PERFORMANCE, NVH AND DURABILITY TESTING ACROSS A DIVERSE RANGE OF VEHICLES, INCLUDING MOTORCYCLES, ALL-TERRAIN VEHICLES, PASSENGER CARS, RACING CARS AND TRUCKS.

TEST APPLICATIONS:

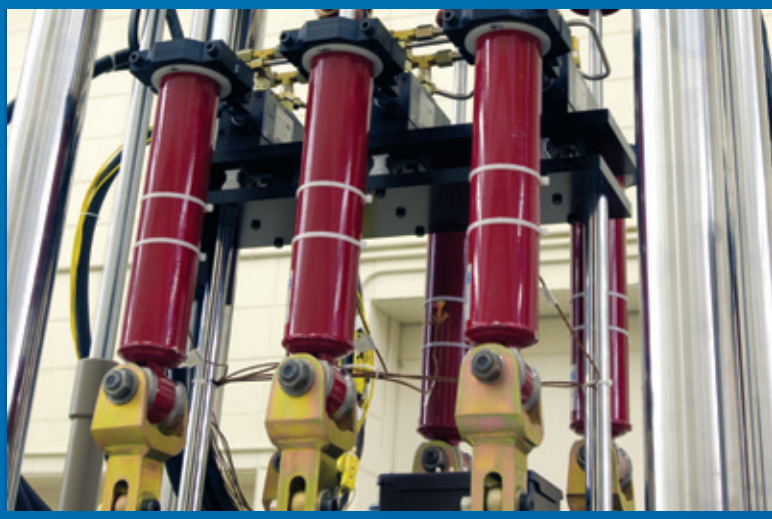
- Quality
- Characterization
- Friction force
- Noise, Vibration & Harshness (NVH)
- Durability

DAMPER TYPES:

- Motorcycle
- All-Terrain Vehicle (ATV)
- Passenger car
- Racing car
- Light & heavy truck
- Off-road vehicle - agriculture, construction, mining, forestry



Performance Testing: EMA System



Durability Testing: Model 852 System

The Evolving MTS Damper Testing Portfolio

The MTS damper testing portfolio has evolved dramatically in recent years, adapting to meet increasingly complex test challenges posed by the rise of active and semi-active vehicle suspensions, the advent of electric and autonomous vehicles, and growing demands for improved test system efficiency.

Once exclusively servohydraulic, the redefined MTS damper portfolio now comprises a full complement of high-performance electric and servohydraulic load frames to address a complete spectrum of test applications across a diverse range of damper types in a variety of test environments, including manufacturing facilities, test laboratories, proving grounds and race tracks.

The MTS damper portfolio employs versatile FlexTest® digital controls and easy-to-use, full-featured MTS Damper Software, providing the versatility needed to adapt readily to changing test requirements.

The portfolio also features a host of ancillary hardware, including innovative add-on environments to enhance test fidelity, multi-specimen fixtures to boost system productivity and safety enclosures to protect personnel. Additionally, advanced MTS hybrid simulation techniques can extend system utility into the early stages of vehicle development, while custom solutions can be engineered to meet unique, non-standard testing needs.

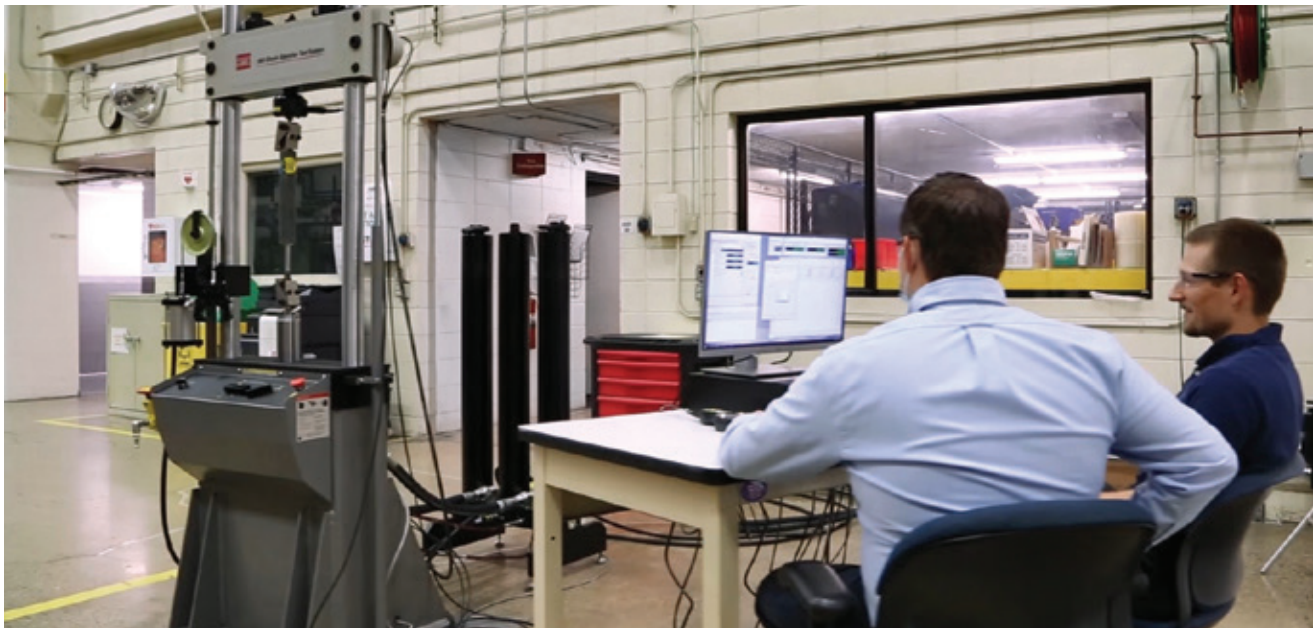
All MTS damper testing solutions are backed by the unmatched MTS global service and support organization, dedicated to maximizing test system uptime and efficiency with local technical support, calibration services, rebuild and repair services, and spare parts.

Contact MTS today to learn how the diverse MTS damper testing portfolio can help you meet your unique quality, performance and durability testing requirements with ease, efficiency and confidence.

The MTS damper portfolio comprises a full complement of high-performance load frames to address a complete spectrum of test applications.

Performance Testing

The MTS damper testing portfolio features a selection of compact and portable electric and hydraulic solutions that are ideal for evaluating the vehicle dynamics of prototypes at the proving ground or tuning race car dampers at the track. MTS solutions provide the quick, precise and repeatable single specimen performance characterization required in both environments. To optimize test environment efficiency, MTS can also provide custom designed trailer-mounted solutions upon request.



Model 849 System

One of the original MTS damper test systems, the servohydraulic Model 849 is engineered to measure the damping characteristics and service life of a broad range of test specimens with unsurpassed accuracy and consistency. The system features a stiff, self-supporting base for long life and a selectable servo valve for delivering a high level of single specimen performance and durability testing flexibility.

Actuation	Linear Servohydraulic
Application(s)	» Performance Characterization (Programmable) » Durability
Force (kN)	15.0 – 25.0
Specimens	Single
Software	MTS Damper

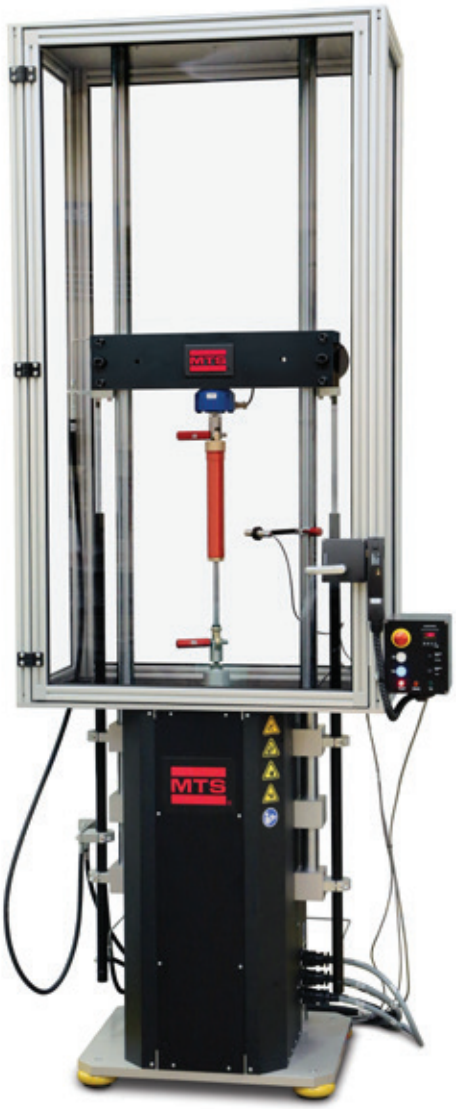
Refer to page 21 for complete performance specifications.

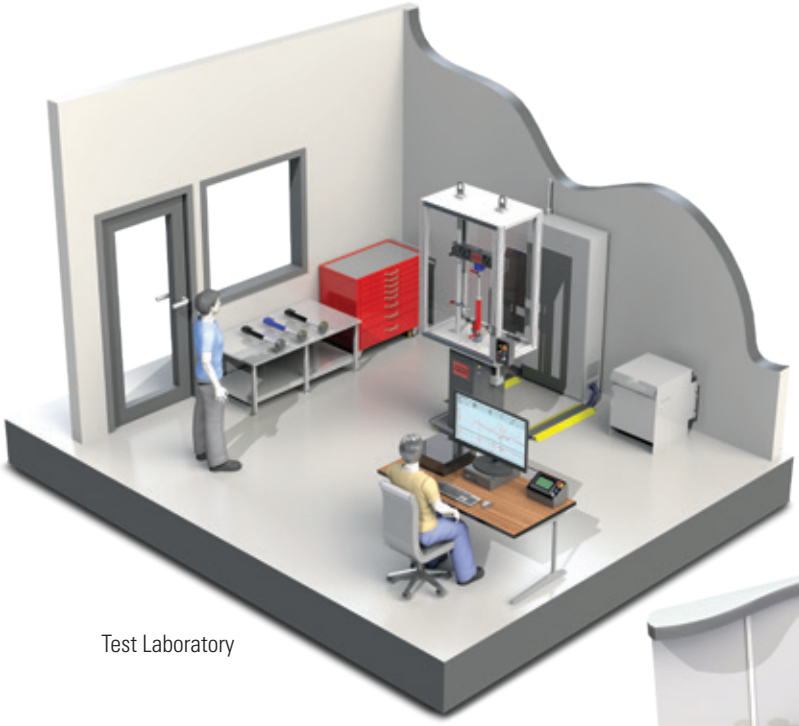
EMA (Electro-Magnetic Actuation) System

MTS EMA Damper Test Systems comprise a complete family of compact, cost-effective linear electric load frames for performing a broad range of single specimen damper testing applications. These high-performance systems are deployed worldwide for damper characterization and in-line production quality testing, as well as custom applications such as NVH, high-velocity testing and road profile playback. EMA systems are renowned among product R&D engineers, leading damper manufacturers and race team engineers alike for their high frequency response, programmability and unmatched operational efficiency. Electrically actuated EMA systems also deliver clean and quiet operation, easy setup and relatively simple maintenance and repair.

Actuation	Linear Electric (Aircore)
Application(s)	Performance Characterization (Programmable)
Force (kN)	8.9 – 26.7
Specimens	Single
Software	MTS Damper

Refer to page 19 for complete performance specifications.





Test Laboratory

Proving Ground Trailer

Mechanical Hardware-in-the-Loop (mHIL™)

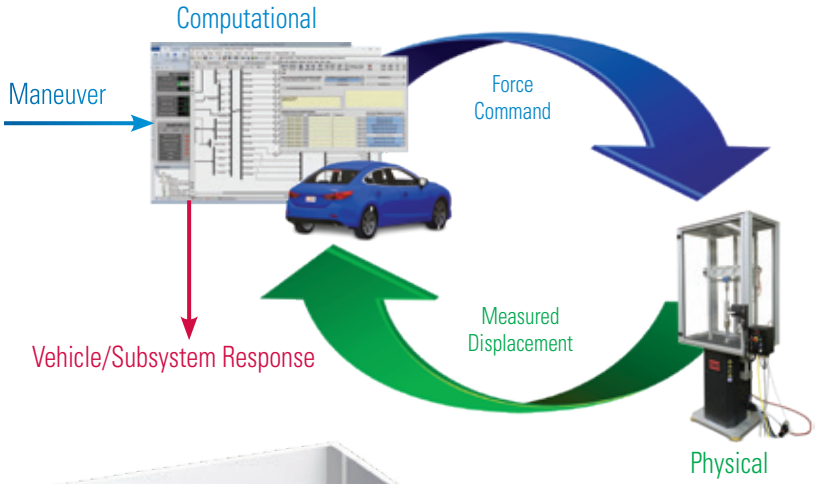
MTS is pioneering the use of advanced simulation methods and technologies throughout vehicle development to realize new efficiencies and reduce costs and time to market. An industry leader in hybrid simulation, MTS continues to explore new ways of integrating physical components and virtual models to streamline and accelerate analysis and testing. MTS has proven both iterative and real-time hybrid simulation techniques for use in vehicle development simulation.

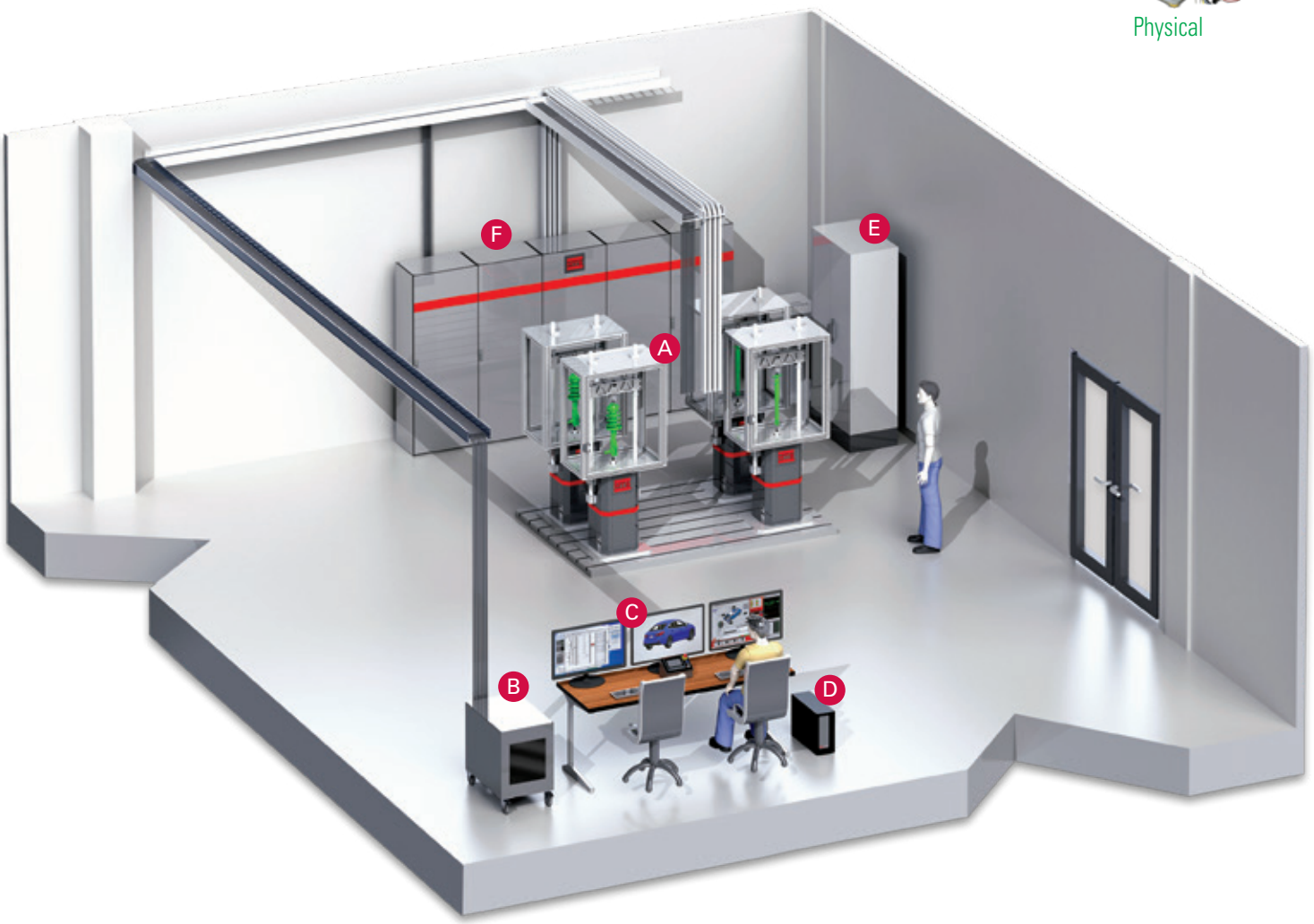
Mechanical Hardware-in-the-Loop (mHIL) employs a real-time, closed loop process to introduce physical components under test into a virtual simulation; for example, using actual vehicle dampers as part of a virtual handling simulation. This approach replaces a vehicle model's virtual dampers with four real ones in test rigs. As the virtual handling simulation plays out, data is exchanged in real-time. The vehicle model and the damper rigs act on new data with each clock tick, with the physical response of the dampers affecting the behavior of the model and vice versa.

For manufacturers under pressure to bring new products to market faster, mHIL delivers important advantages. By allowing physical inputs from hard-to-model damper systems and the subsequent simulation of their complex interactions with other vehicle systems, it generates high-fidelity vehicle, system and component behavior data much faster and more cost-effectively than physical testing or computational analysis alone. Validation and optimization of designs can occur earlier in the development process – with fewer and faster iterations – well before the first prototype hits the track.

4-Corner mHIL Damper System

A. 4 x EMA Systems
B. HIL Simulator
C. Integration & User Application Interface
D. FlexTest Controller
E. Pneumatic supply
F. Electrical supply





Accelerate Active System Development

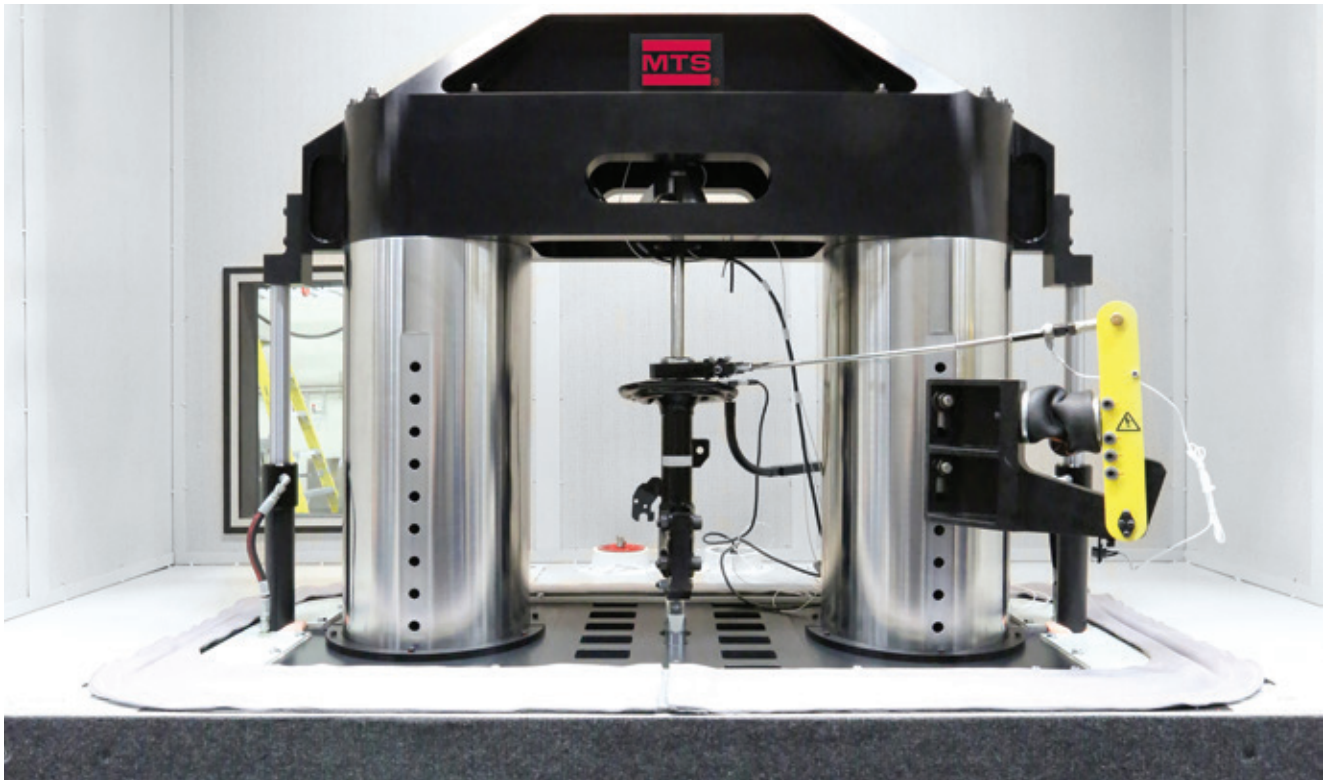
The mHIL Damper Test System combines a physical sub-system of components with a vehicle model adapted or damper and spring inputs to create a real-time, vehicle-level simulation environment for testing semi-active or active damper, suspension, and body control systems. This environment can be employed throughout the vehicle development process for:

» Damping control development & evaluation
» Full objective handling/target setting and optimization
» Ride metric optimization
» Four poster simulation
» Fault and limit handling events
» Track program support
» Warranty and production support

Noise, Vibration & Harshness (NVH) Testing

Structure-borne noise testing to meet evolving consumer demands

The first-of-its-kind Model 853 Damper NVH System is purpose-engineered for analyzing a broad spectrum of damper noise and vibration phenomena, including elusive, structure-borne "chuckle" noises that can prove especially degrading to the ride comfort and quality of electric and autonomous vehicles.



Chuckle originates as a mechanical vibration in the body of a shock absorber. Impedance coupling in the upper mount transforms the vibration to acoustic noise in the vehicle cab. As such, chuckle is model- or platform-dependent, making it very difficult to identify and resolve at the component level. Meaningful analysis requires an exceptionally high-performance test bench featuring:

A. High-bandwidth measurement accelerometers and transducers

B. High-fidelity actuator Input, characterized by clean sinusoidal input and low THD

C. High-stiffness Load Frame that exhibits no mechanical vibration

Model 853 NVH Damper System

The innovative Model 853 draws from both MTS damper and elastomer testing technologies to address the complete range of damper noise phenomena. The system employs high-bandwidth transducers – typically used in high-frequency elastomer testing – to perform damper NVH measurements with fidelity and accuracy up to 800 Hz. It also features an elastomer system's high-stiffness load frame, along with larger diameter columns, a thicker crosshead, and a more robust base to avoid the resonant modes that can corrupt measurements. Linear electromagnetic actuation technology provides the clean sinusoidal input and low total harmonic distortion (THD) the system requires for effective chuckle testing. The Model 853 employs full-featured MTS Damper software and is driven by a versatile FlexTest® controller capable of reproducing virtually any type of signal, making it suitable for basic damper characterization, and even elastomer testing.

Total Harmonic Distortion (THD):	<1% up to 200 Hz excitation frequency
Measurement bandwidth for vibration testing:	≤ 800 Hz
27 kN actuator:	20 kN at 3 m/s
18 kN actuator:	15 kN at 3 m/s
Noise Level (typical):	< 60 dBA without acoustic chamber < 42 dBA with acoustic chamber

Refer to page 20 for complete performance specifications.

Low-Noise EMA System

MTS also offers a low-noise version of its electric EMA system to measure air- and structure-born damper noises in quieter electric and hybrid vehicles. Like standard EMA damper test systems, the low-noise solution features linear electromagnetic actuation technology, which provides clean sinusoidal input and low total harmonic distortion. Low-Noise EMA systems, however, employ higher resolution encoders than the standard EMA, further minimizing signal noise and enhancing damper test performance and repeatability. Other Low-Noise EMA options include sound dampening insulation, as well as a more massive load frame with larger columns to increase frame resonance.

Actuation	Linear Electric (Aircore)
Application(s)	» NVH » Performance Characterization
Force (kN)	8.9 – 26.7
Specimens	Single
Software	Shock 6 (SID) or MTS Damper

Refer to page 19 for complete performance specifications

** System noise level is dependent on a variety of factors. Consult an MTS Applications Engineer to identify noise levels for specific applications.*

Durability Testing

To meet a full spectrum of damper durability testing requirements, the MTS portfolio features a selection of high-force test platforms. These solutions combine a large, self-supporting base mass to withstand high inertial loading and a selectable three-stage servovalve to perform high velocity durability testing on even the largest dampers and struts. Highly reliable and robust, these systems are engineered to subject single or multiple specimens to millions of durability cycles, or run short bursts of high-performing cycles to measure damping characteristics.

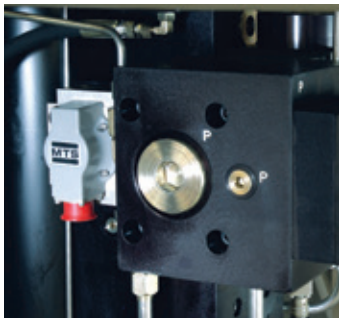
Model 850 System

MTS' original high-force damper testing platform, the model 850 was purpose built for conducting durability testing on a broad range of dampers. The MTS Model 850 can accommodate multiple specimen damper testing or single specimen performance characterization when higher forces and velocities are required for larger vehicles.

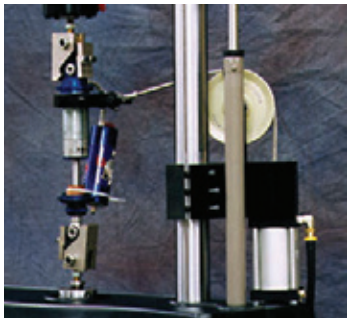
Actuation	Linear Servohydraulic
Application(s)	» Durability » Performance Characterization
Force (kN)	25.0 – 67.0
Specimens	Multiple (1 - 6)
Software	MTS Damper

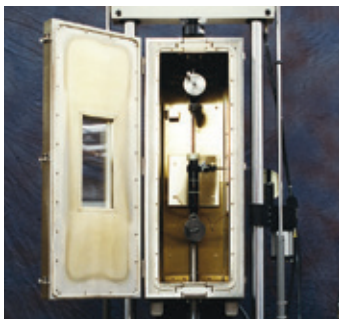
Refer to page 22 for complete performance specifications.

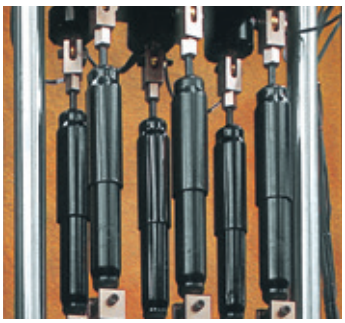
Hardware Options

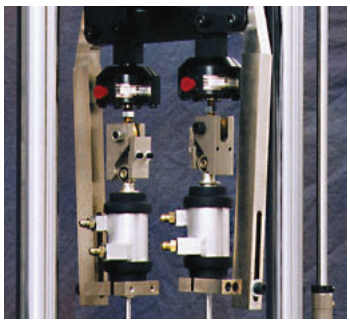

Servovalves (high, medium or low-velocity)


Custom Accumulation


Side-loading


Environmental Simulation


Multi-specimen Fixtures


Water-cooling

Model 852 System

Engineered for optimal damper testing flexibility, the highly capable Model 852 delivers the force required for multi-specimen durability testing while supporting an array of optional hardware for conducting a wide variety of performance testing. The standard Model 852 system is capable of applying up to 150 kN on up to eight dampers simultaneously. To support testing of independent specimens and small subassemblies, the system features a standard T-slot table for mounting the fixtures and reaction brackets needed to support a variety of optional hardware. Additionally, the system's columns, crosshead and actuator can be positioned at the table's end or center point, further enhancing test flexibility.

Actuation	Linear Servohydraulic
Application(s)	» Durability » Performance Characterization
Force (kN)	25.0 – 150.0
Specimens	Multiple (1 - 8)
Software	MTS Damper

Refer to page 23 for complete performance specifications.

The Model 852 mud/slurry add-on provides a precise, clean and efficient means for conducting damper seal tests in the presence of dry powders, particulate/liquid volumes or particulate/liquid sprays.

Custom Solutions

MTS has the custom engineering capabilities and expertise to pursue the development of systems for unique or highly specific damper testing applications. Over the years, MTS has designed and built or upgraded numerous damper testing solutions for a wide range of custom applications, including:

» Production quality testing

» High-velocity testing

» Testing in the presence of mud and slurry

» Magneto-Rheological (MR) damper testing

» Inverted or angled specimens

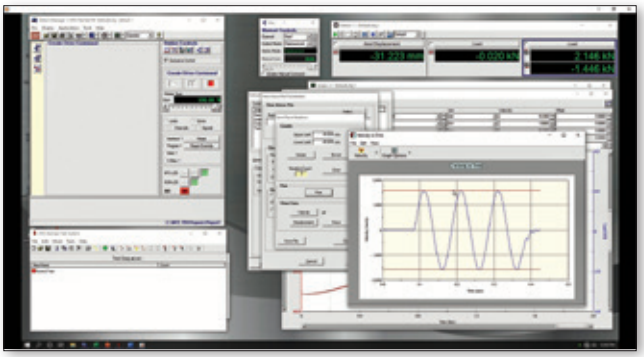
» and more

Mud & Slurry

Test Application Software

MTS Damper Software

MTS Damper Software meets a full spectrum of performance, durability, and quality assurance testing needs. It facilitates testing with up to four user-programmable channels simultaneously, including axial, lateral, rotational/torsional, and active damper. Tests can be set up easily and stored for use at any time. Data acquisition is flexible and comprehensive, and test data reports can be automated to support numerous methods of presentation and analysis. MTS Damper Software is deployed on Models 849, 850 and 852 systems, and EMA systems with FlexTest controllers.

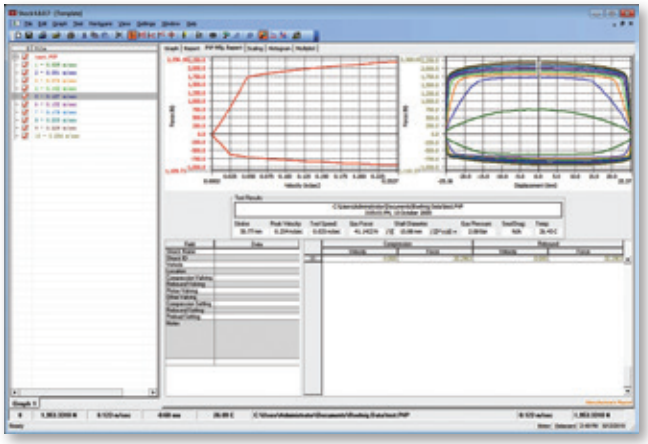


Capabilities

- Conduct temperature-dependent performance tests, position-dependent gas force evaluation, noise characterization (NVH), and friction force testing.
- Make simple predefined durability cycle counts that ensure components meet their required fatigue life, as well as more complex specimen-failure characterizations.
- Generate sine, ramp, square, sine-on-sine, sine sweep, dual-rate sine, dual-rate ramp, as well as user-defined block cyclic waveforms and RPC® time history playback.
- Create easy-to-use operator interfaces for efficient Pass/Fail quality auditing.

Shock 6 Software

Designed primarily for damper performance testing, easy-to-use Shock 6 Software offers an array of pre-programmed test options and a wizard-based interface with integrated analysis tools. It is typically deployed on SYD (Crank Dyno) and EMA systems.



Capabilities

- Temperature or time-based warm-up
- Static gas tests
- Friction testing
- Velocity Plots (constant, peak velocity, multiple constant)
- Pass/Fail validation
- Variable wave form generation for conducting square wave, sine on sine, variable sine, triangle and frequency sweeps with EMA Systems
- The ability to import custom waveforms or playback track data to simulate real world conditions with EMA Systems

Versatile FlexTest Controls

MTS damper testing solutions are supported by a selection of versatile system servo controllers to provide the flexibility you need to address a full spectrum of testing needs and adapt readily to evolving standards. The standard system servo controller has a sample rate of 8 kHz; while an alternative servo controller with a 20 kHz sample rate is also available.

Scalable and easy-to-use, FlexTest controllers provide the high-speed closed-loop control, data acquisition, function generation and transducer conditioning required to conduct reliable single and multi-channel testing. These controllers integrate seamlessly with MTS Damper software to generate a wide variety of control waveforms.

Damper System Safety

Test lab safety can be enhanced with state-of-the-art Series 295 Isolation Hydraulic Service Manifolds (ISHM) and MTS SafeGuard™ technology. The 295 ISHM provides smooth, controlled transitions of hydraulic pressure between the hydraulic power unit (HPU) and the test rig to enhance safety and predictable control of the hydraulic system. The 295 ISHM meets Performance Level c (PLc) requirements for human safety and integrates MTS SafeGuard to meet the highest performance levels - PLd and PLe.

Safety-rated Programmable Logic Controller (PLC):

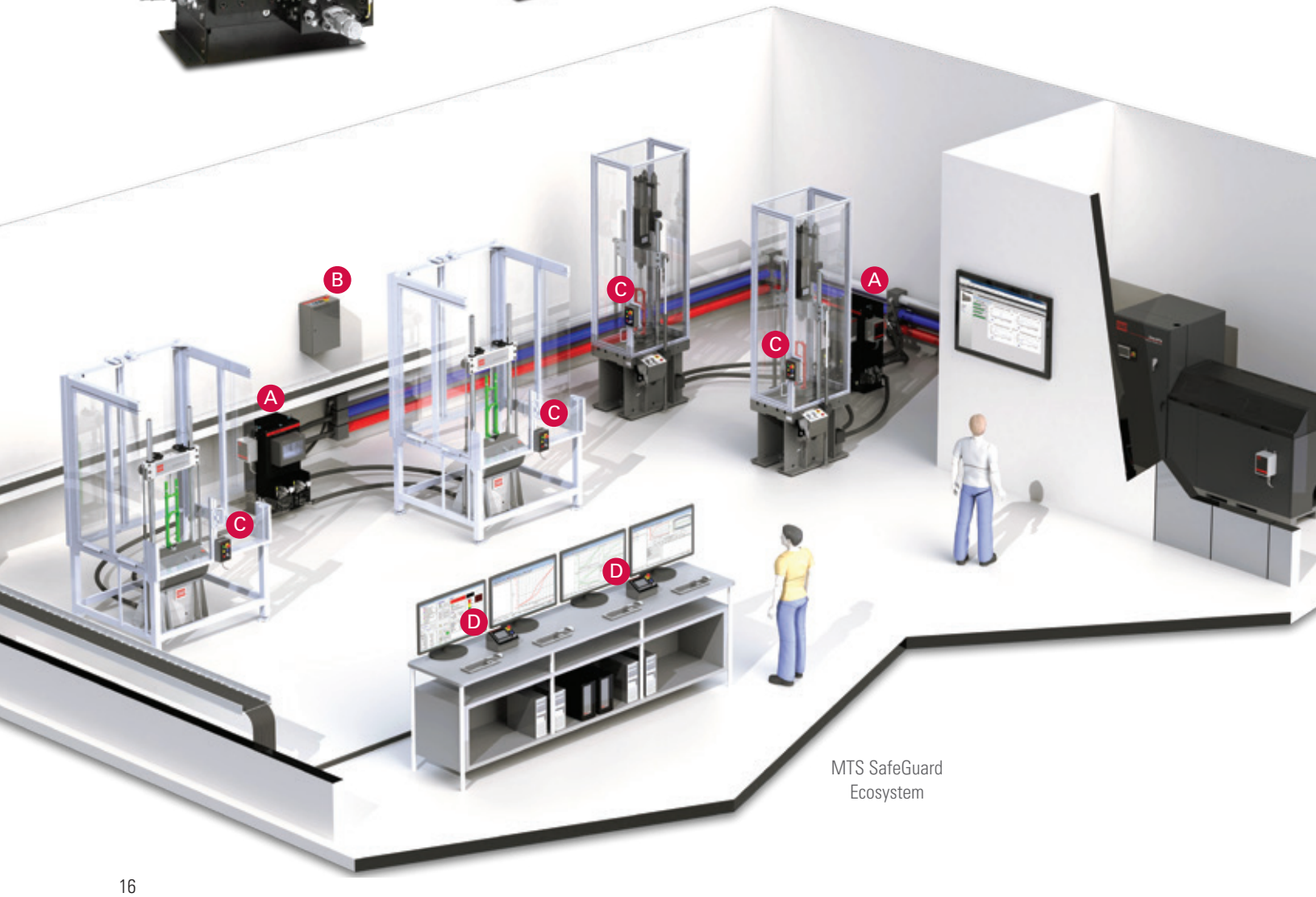
- Safe Speed
- Safe Isolation / Safe Power Off
- Three-position mode switch (Off / Low / High)
- Safety-rated valves
- Test area enclosures
- E-stops & Station stops

A
295 IHSM/MTS SafeGuard
275 Machine Interface

B
MTS SafeGuard
273 Processor

C
E-stops &
Station Stops

D
MTS SafeGuard
274 User Interface



MTS SafeGuard
Ecosystem

MTS Global Service & Support

MTS fields the most experienced service, support and consulting staff of any testing solution provider. This global team provides local technical support, calibration services, rebuild & repair services and spare parts to maximize the uptime and efficiency of your MTS damper testing investment and help you meet your exact test requirements as quickly as possible.

Onsite services

MTS field service engineers have a worldwide reputation for applications expertise and will respond to requests for support or repair quickly and efficiently.

Engineering services

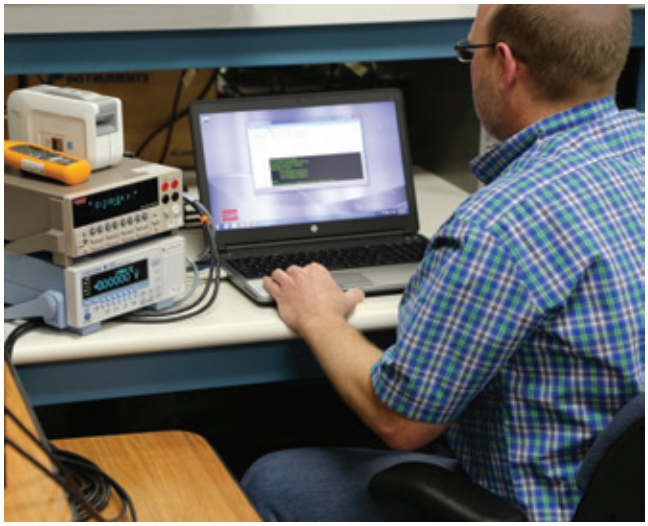
MTS offers a complete set of professional engineering services, including systems engineering, test consulting and facilities design services.

Training

MTS training programs are designed to improve operator efficiency and optimize system performance. Expertly led and completely customizable, these courses provide engaging hands-on learning experiences.

Calibration & alignment

All test labs must calibrate their testing equipment to help ensure data accuracy. MTS provides top-quality, accredited calibration services and load frame alignment services to minimize data variance.

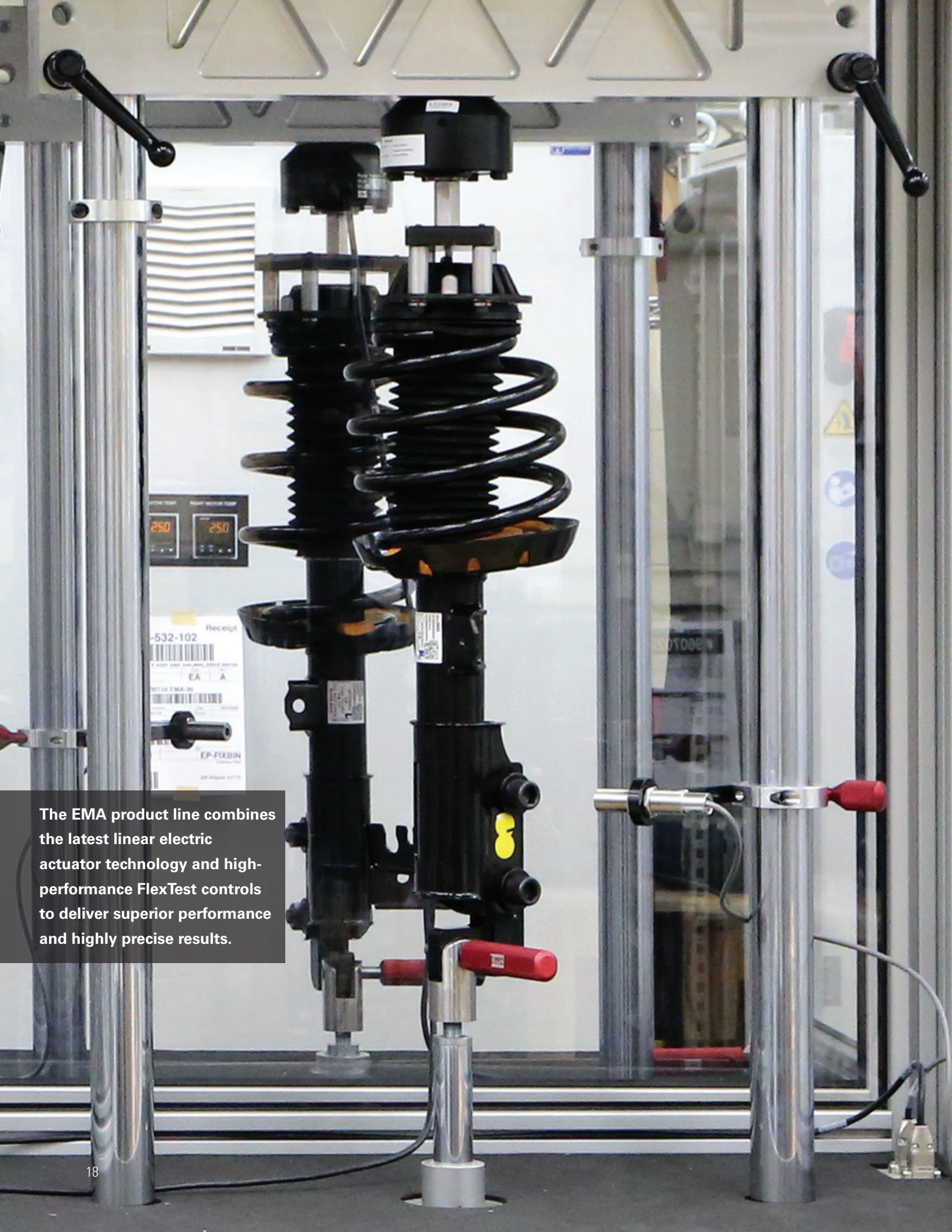


Maintenance & monitoring

Based on decades of service experience, MTS has developed a set of well-defined routine maintenance offerings tailored for specific systems and components, to help extend equipment life.

Upgrade solutions

As technology improves, an upgrade is often the most economical way of expanding lab capabilities and extending the life of existing test equipment. MTS offers upgrades and replacements for mechanical components, controllers and software.



The EMA product line combines the latest linear electric actuator technology and high-performance FlexTest controls to deliver superior performance and highly precise results.

EMA System Performance Specifications

EMA Specification[1]	Units	EMA-9kN	EMA-18kN	EMA-27kN
Dynamic Force	kN lbf	8.9 2000	17.8 4000	26.7 6000
Static Force	kN lbf	2.1 475	4.2 950	6.2 1400
Static Force with Static Load Compensation	kN lbf	7 1475	13 2950	20 4400
Peak Velocity	m/sec in/sec	4 157	4 157	4 157
Maximum Force @ 3 m/s (480V)	kN lbs	6 1,350	12 2,700	18 4,050
Stroke	mm in	203 8	203 8	203 8
Frequency Response	Hz	100	100	100
Temperature Monitoring	Specimen Motor	Non-contacting IR with software monitoring Non-contacting IR with process meter monitoring		
Digital Encoder Accuracy	µ	0.5	0.5	0.5
Noise Level – Typical	dbA	65	65	65
Load Cell	kN lbf	10kN 2,200	35kN 5,500	50kN 11,000
Waveforms Supported	Type Software	Sine, Triangle, Square, Frequency Sweep, Sine-on-Sine, Custom Profile, RPC Playout Damper Analysis Software		
Bearing Material	Type	Dry Linear Bearing – Maintenance Free Replacement Interval: 2-5 yrs		
Facility Requirements[2]	Vac kVA	 135	380-480, 50/60 hz 135	 270
Air Supply	SM^3/min SCFM	0.65 23	1.3 45	1.9 68

[1] *Specifications subject to change.*

[2] *Maximum performance achieved at 480 Vac.*

MTS 853 Damper NVH Specifications

Model 853 Damper NVH	Units	Model 853.18	Model 853.27
Dynamic Force	kN lbf	17.8 42000	26.7 6000
Peak Velocity	m/sec in/sec	4 157	
Velocity at Peak Force	m/sec in/sec	2.5 98	
Stroke	mm in	200 8.7	
Frequency Response (real time close loop control)	Hz	100	
Measurement bandwidth for vibration testing (i.e. “chuckle”, “clatter”, “rumble”)[1]	Hz	≤800	
Total Harmonic Distortion (THD)	–	< 1% up to 200 Hz command /response frequency	
Temperature Monitoring	Specimen Motor	Non-contacting IR Non-contacting IR	
Digital Encoder resolution	nm	10	
Noise Level – Typical	dbA	<60	
Noise Level, with integrated Acoustic Chamber - Typical	dBA	<42	
Load Cell	kN lbf	25 5600	
Waveforms Supported	Type Software	Sine, Triangle, Square, Frequency Sweep, Custom Profile 793 MPT, MTS Damper, RPC Connect	
Facility Requirements[2]	V A	240 (3-phase) 90	 125
Air Supply	PSI BAR CFM	100 7 35	
Testing with optional Elastomer package	Hz K* ° (Phase Accuracy)	400 5% 0.5	
Testing with optional sideload actuator	N lbf	1000 225	

Specifications subject to change.

[1] *Measurement Bandwidth is typical for a passenger car sized damper or strut.*

[2] *MTS can supply transformers for voltages other than 240V 3-Phase.*

MTS 849 System Specifications

Description	Model 849.15		Model 849.25	
Actuator Maximum Dynamic Force	15 kN (3.3 kip)		25 kN (5.5 kip)	
Actuator Rod Diameter	70 mm			
Actuator Stroke	250 mm			
Actuator Hydrostatic Bearing	Standard			
Actuator Anti-Rotate	Standard			
Servovalve	126 lpm (33 gpm)		188 lpm (50 gpm)	
Friction Force Servovalve	3.8 lpm (1 gpm)		3.8 lpm (1 gpm)	
Servovalve Shutoff	Manual			
Hydraulic Low Flow	Standard, limits actuator to 10 mm/s			
Friction Force Load Cell	7 kN (1500 lbs.)			
Sideload	Hydraulic, dynamic (optional) Pneumatic, static (optional)			
Accumulators	8 liters		15 liters	
Test Space	1200 mm			
HSM	Integral to accumulator manifold			
Performance: *For 3 cycles at 100 mm stroke sine wave command*	3.2 m/s 2.3 0.7	0 kN 5 10	2.9 m/s 2.5 2.0 1.4 0.6	0 kN 5 10 15 18

MTS 850 Specifications

MTS Model 850.xx Damper Test Machine Specifications

Description		
Actuator Rod Diameter		80 mm (3.15 in.)
Test Space, Actuator Face to Load Cell	850.25	max. 1560 mm min. 160 mm
	850.50	max. 1540 mm min. 132 mm
Frame Dynamic Load Rating		50 kN (11 kip)
Floor Mount		Frame Bolted to Concrete (optional vibration isolation system available)
HSM		Integral to Accumulator manifold, 300 lpm max
Actuator Hydrostatic Bearing		Yes
Actuator Stroke		250 mm (10 in.)
Heavy Duty Anti-Rotate		Yes
Safety Low Flow		Yes
Accumulator		19 Liter Pressure and Return

Performance Testing Specifications

Maximum peak velocity for 3 cycles of 100 mm stroke (peak to peak), sine wave command

Model 850.25		Model 850.50	
4.0 m/s	No Load	5.0 m/s	No Load
3.5 m/s	5 000 N Load	4.5 m/s	5 000 N Load
2.8 m/s	10 000 N Load	4.0 m/s	10 000 N Load
1.8 m/s	15 000 N Load	3.0 m/s	20 000 N Load
1.0 m/s	18 000 N Load	1.2 m/s	30 000 N Load

Durability Testing Specifications

Maximum continuous peak velocity of 100 mm stroke (peak to peak) and 12.5 kN load sine wave command

Maximum continuous peak velocity of 100 mm stroke (peak to peak) and 25 kN load sine wave command

Model 850.25			Model 850.50		
HPU	HZ POWER	M/S	HPU	HZ POWER	M/S
505.20	60	0.9	505.20	60	0.4
505.20	50	0.7	505.20	50	0.3
505.30	60	1.5	505.30	60	0.8
505.30	50	1.2	505.30	50	0.6
505.60	60	3.5	505.60	60	1.9
505.60	50	2.8	505.60	50	1.6
505.90*	60	3.6	505.90	60	3
505.90	50	3.6	505.90	50	2.4
			505.180*	60	4
			505.180*	50	4

**HSM on frame limits flow to 300 Lpm (80 gpm). Add MTS Model 293 HSM for HPUs with output greater than 300 Lpm.*

MTS 852 Specifications

MTS Model 852.xx Damper Test Machine Specifications

Description		
Actuator Rod Diameter		80 mm (3.15 in.)
Test Space, Actuator Face to Load Cell		1575 mm maximum 180 mm maximum
Frame Dynamic Load Rating		67 kN (15 kip)
Floor Mount		Frame Bolted to Concrete (optional vibration isolation system available)
HSM		Integral to Accumulator Manifold, 284 lpm max
Actuator Hydrostatic Bearing		Yes
Actuator Stroke		250 mm (10 in.)
Heavy Duty Anti-Rotate		Yes
Safety Low Flow		Yes
Accumulation	852.25 & 852.50 852.67	19 Liter Pressure and Return 38 Liter Pressure and Return

Performance Testing Specifications

Maximum velocity, sine wave, for 3 cycles of 100 mm stroke (peak to peak), 45 kg moving mass, sine wave command

Model 852.25		Model 852.50		Model 852.67	
No Load	No Load	5.0 m/s	No Load	3.8 m/s	No Load
3.6 m/s	5 000 N load	4.5 m/s	5 000 N load	3.6 m/s	10 kN load
3.0 m/s	10 000 N load	4.0 m/s	10 000 N load	3.1 m/s	20 kN load
2.2 m/s	15 000 N load	3.0 m/s	20 000 N load	2.5 m/s	30 kN load
1.5 m/s	18 000 N load	1.2 m/s	30 000 N load	1.7 m/s	40 kN load

Durability Testing Specifications

Maximum sine wave continuous peak velocity for durability testing

Model 852.25			Model 852.50			Model 852.67		
HPU	HZ POWER	M/S	HPU	HZ POWER	M/S	HPU	HZ POWER	M/S
505.20	60	0.9	505.20	60	0.5	505.20, 60 Hz	60	0.3 (33.5 kN of load)
505.20	50	0.7	505.20	50	0.4	505.20, 50 Hz	60	0.2 (33.5 kN of load)
505.30	60	1.6	505.30	60	0.9	505.30	60	0.6 (33.5 kN of load)
505.30	50	1.3	505.30	50	0.7	505.30	50	0.4 (33.5 kN of load)
505.60	60	3.2	505.60	60	2	505.60	60	1.4 (33.5 kN of load)
505.60	50	2.9	505.60	50	1.7	505.60	50	1.1 (33.5 kN of load)
505.90*, #	60	3.2	505.90*	60	3.2	505.90*	60	2.2 (33.5 kN of load)
505.90*, #	50	3.2	505.90	50	2.6	505.90	50	1.7 (33.5 kN of load)
			505.180*, #	60	3.6	505.180*, #	60	2.9 (33.5 kN of load)
			505.180*, #	50	3.6	505.180*, #	50	2.9 (33.5 kN of load)

** Due to a flow limit of 284 lpm with the standard on/off HSM, an optional 293 HSM is required to meet this performance.*

 # Maximum velocity limited at this specimen load.

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