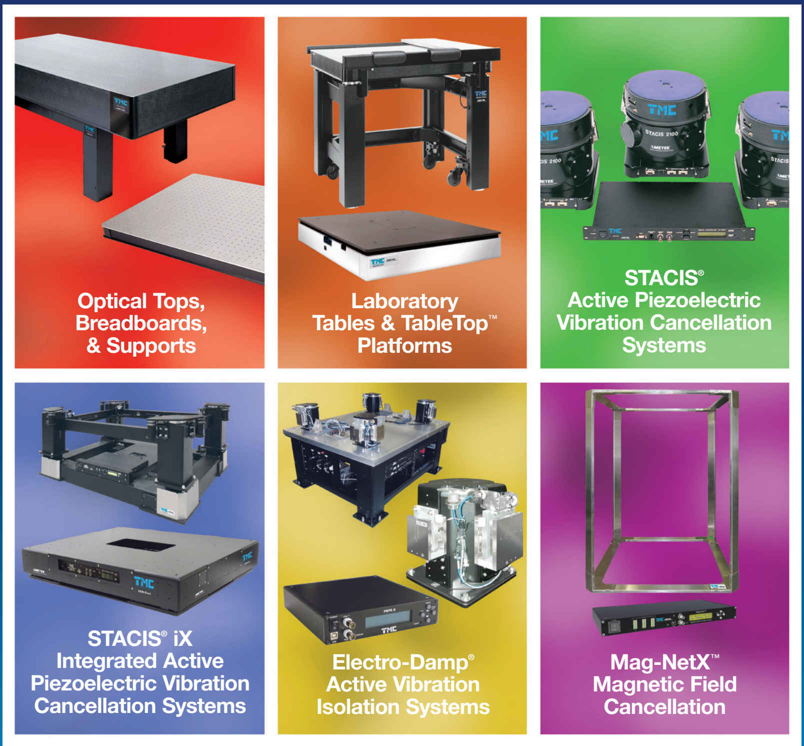
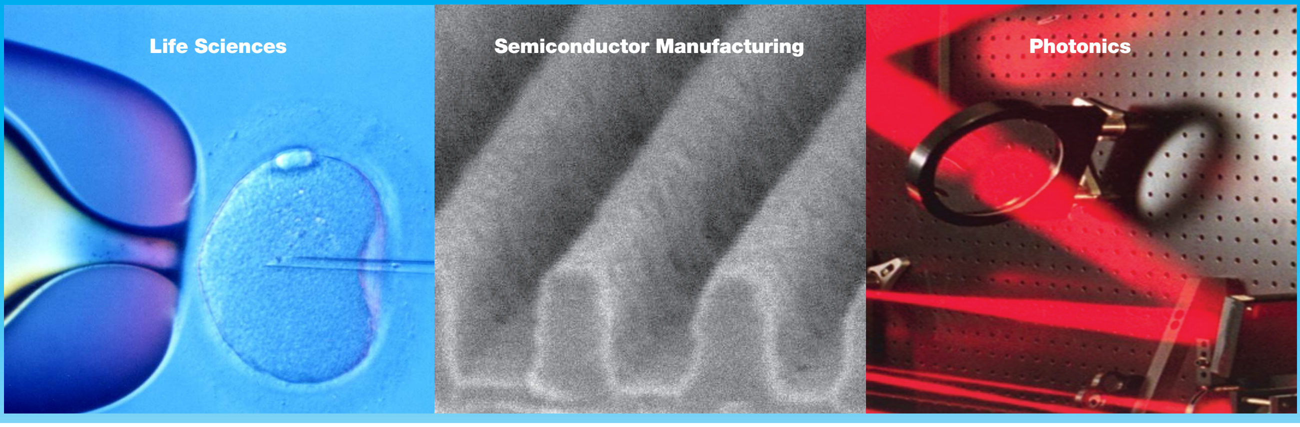
GMP
GENERAL MICROTECHNOLOGY & PHOTONICS

# TMC™
VIBRATION CONTROL™




AMETEK®
ULTRA PRECISION TECHNOLOGIES




www.gmp.ch

GMP SA Siège principale: Avenue des Baumettes 17 CH-1020 Renens +41 21 633 21 21 Fax. +41 21 633 21 29 info@gmp.ch
GMP SA Büro Zürich: Dübendorfstrasse 11a CH-8117 Fällanden +41 44 825 34 00 Fax. +41 44 825 34 01 so@gmp.ch

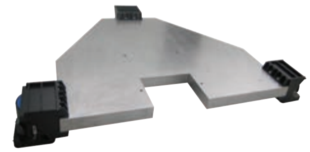
## Section 1 Page 1

**STACIS®**

***Active Piezoelectric Vibration Cancellation Systems***

**STACIS® 2100**
**Active Piezoelectric Vibration Cancellation System**
*page 2*

**Quiet Island® with STACIS®**
**Active Piezoelectric Vibration Cancellation System**
*page 4*



**65 SERIES**
**Floor Platform with STACIS®**
*page 7*

## Section 2 Page 11

**STACIS® iX**

***Integrated Active Piezoelectric Vibration Cancellation Systems***

**STACIS® iX SEM-Base™**
**Active Piezoelectric Vibration Cancellation Floor Platform for Scanning Electron Microscopes**
*page 12*

**STACIS® iX LaserTable-Base™**
**Hybrid Piezoelectric/Air Active Vibration Cancellation System**
*page 16*

**STACIS® iX Stage-Base™**
**Frame Mountable Active Hard-Mount Piezoelectric Vibration Cancellation System**
*page 18*

## Section 3 Page 19

**Optical Tops, Breadboards, & Supports**

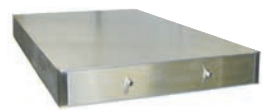
**784 Performance Series**
**Research Grade CleanTop® Optical Top**
*page 30*

**783 Performance Series**
**Scientific Grade CleanTop® Optical Top**
*page 31*

**781 Performance Series**
**Laboratory Grade CleanTop® Optical Top**
*page 32*

**790 Specialty Series**
**ClassOne™ CleanTop® Optical Top**
*page 33*

**710 Specialty Series**
**Non-Magnetic CleanTop® Optical Top**
*page 34*



**730 Specialty Series**
**Vacuum Compatible CleanTop® Optical Top**
*page 35*

**78 Series**
**CleanTop® Breadboard**
**2 and 4 in. Thick (50, 100 mm)**
**Skin (3/16 in., 5mm)**
*page 36*

**77 Series**
**CleanTop® Breadboard**
**2 and 4 in. Thick (50, 100 mm)**
**Skin (1/8 in., 3mm)**
*page 36*

**75 Lightweigt Series**
**CleanTop® Breadboard**
**2 in. Thick (50 mm)**
**Skin (0.075 in., 2mm)**
*page 37*

**Micro-g®**
**System 1 4-Post System with Tiebars**
*page 40*

**Micro-g®**
**System 1 Free-Standing Individual Posts**
*page 42*

VIBRATION CONTROL

TMC designs and manufactures advanced active and passive floor vibration cancellation systems. We continue to lead the industry with sophisticated active, inertial vibration cancellation systems featuring piezo-electric actuators and digital controllers. Our passive products range from simple, desktop isolated microscope bases, to virtually any size optical table systems.

*TMC's 80,000 sq ft (7,450 m2) corporate headquarters and manufacturing facility are located in Peabody, MA US.*

Our products are designed and manufactured at our state-of-the-art, vertically integrated manufacturing facility and are backed by a customer commitment to provide superior global service.

TMC is a unit of AMETEK, Inc. a leading global manufacturer of electronic instruments and electro-mechanical devices. AMETEK has nearly 14,000 colleagues at over 120 manufacturing facilities around the world. Supporting those operations are more than 100 sales and service locations across the United States and in more than 30 other countries around the world.

TMC products enable ultra-precision research, measurements, and manufacturing in fields of photonics, semiconductor manufacturing, life sciences, drug discovery, and nanotechnology.

AMETEK®
ULTRA PRECISION TECHNOLOGIES

## TMC: ISO 9001 Certified

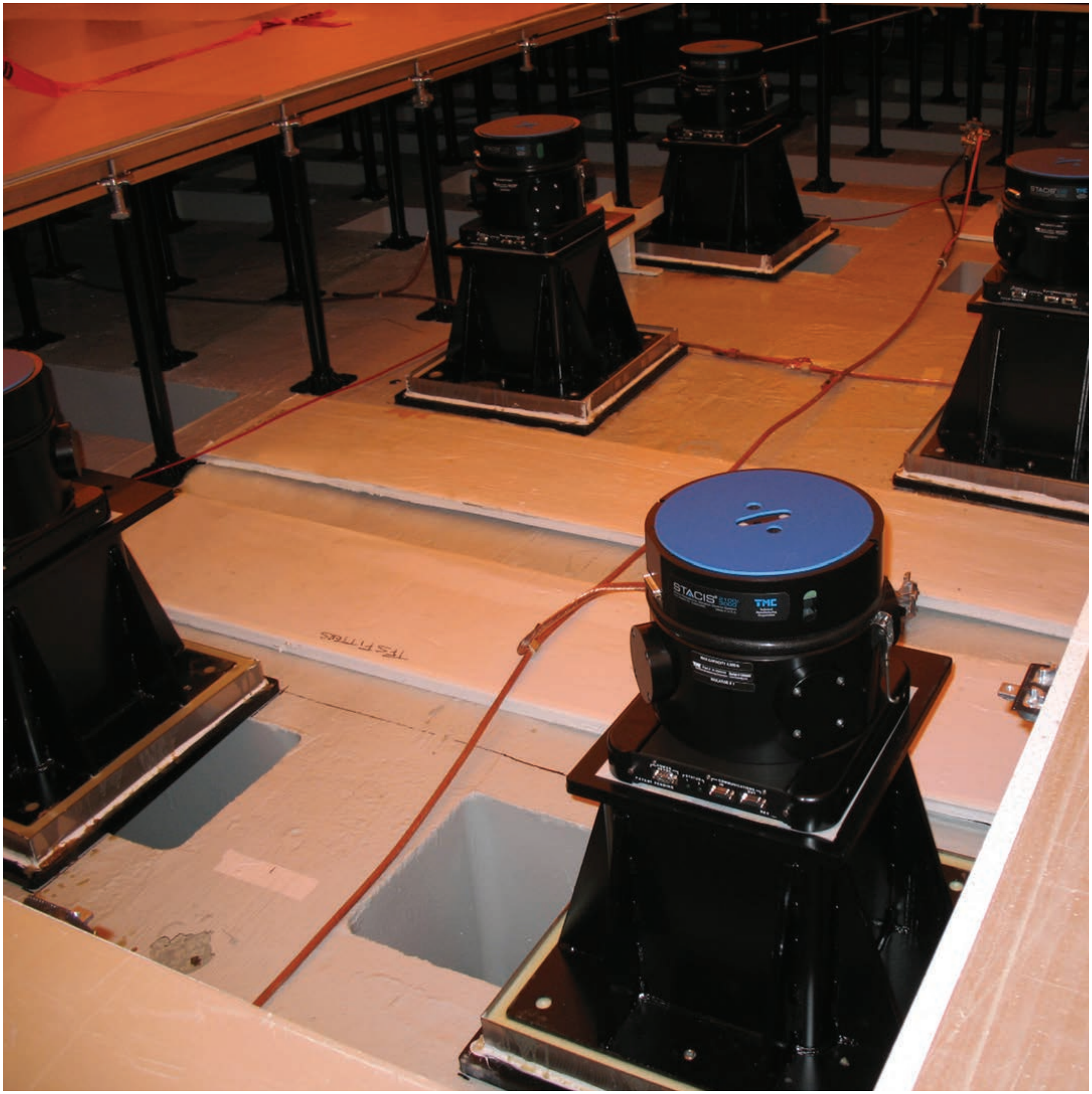
ISO 9001:2008 TÜV SÜD ISO 9001 CERTIFIED

*TMC is ISO 9001:2008 certified, the most comprehensive of the ISO standards. TMC passed its registration audit with no findings, an acknowledgement of a quality philosophy we have had since our founding. Our program of continuous product improvement is based on the fundamental operating premise to exceed the expectations of our customers.*

# STACIS®

## Active Piezoelectric Vibration Cancellation





# STACIS® 2100

## Active Piezoelectric Vibration Cancellation System

STACIS® is the world's most advanced active vibration cancellation system. Employing advanced inertial vibration sensors and state-of-the-art piezoelectric actuators, STACIS cancels vibration in real time by sensing floor vibration, then expanding and contracting piezoelectric actuators to filter out floor motion.

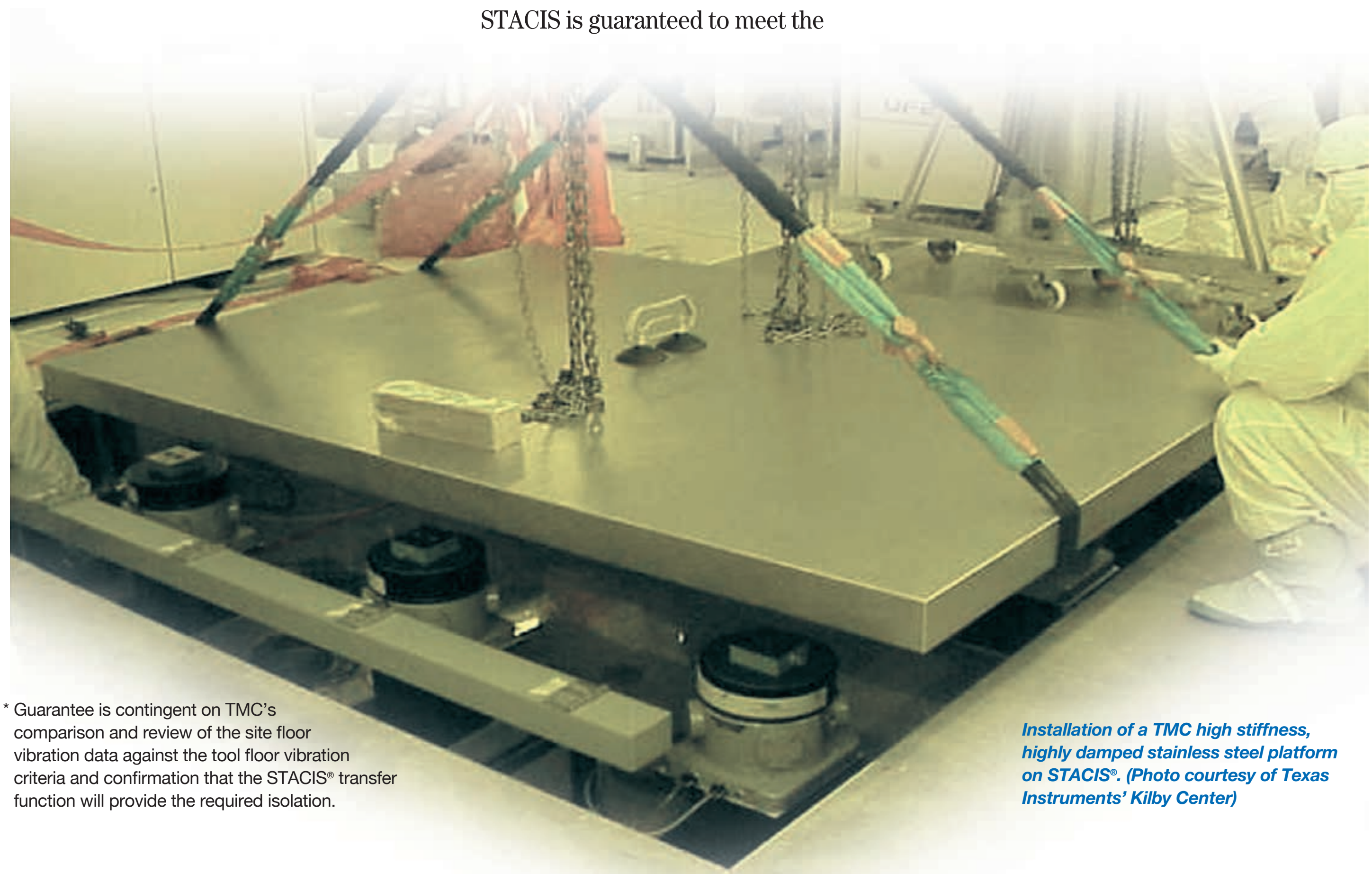
Primarily designed to isolate precision microlithography, metrology, and inspection equipment in advanced semiconductor factories, STACIS is now the industry standard solution for the most sensitive instruments in noisy environments.


CE Marked

Hundreds of times stiffer than air isolators, STACIS suffers from none of the limitations of air systems. There is no "soft" suspension and, unlike active air systems, STACIS can be "stacked" (placed beneath a tool with an internal active air isolation system).

In addition to facilitating optimal tool performance and resolution in noisy fabs, STACIS is guaranteed to meet the floor vibration specifications of wafer inspection, metrology and microlithography tools.*

With many hundreds of successful installations worldwide, STACIS is the ideal vibration isolation system for the most vibration-sensitive instruments.



*Installation of a TMC high stiffness, highly damped stainless steel platform on STACIS®. (Photo courtesy of Texas Instruments' Kilby Center)*

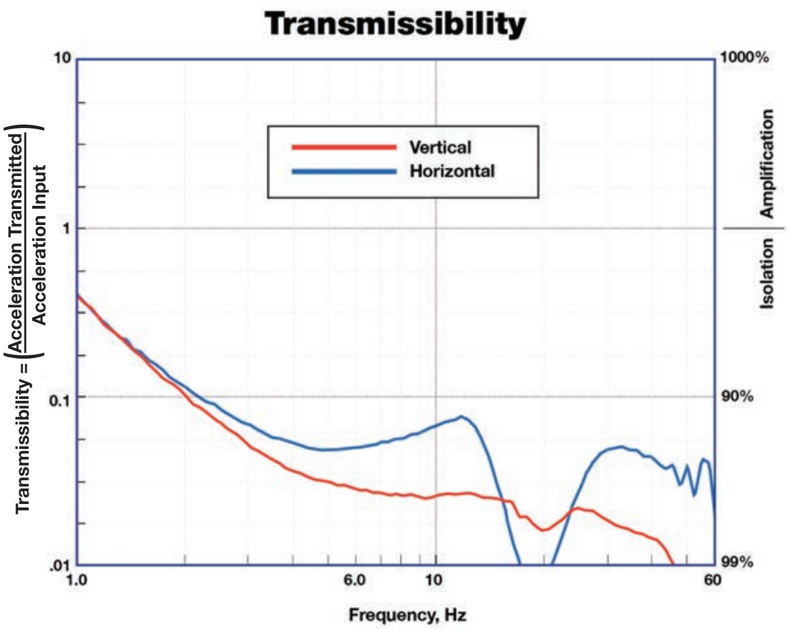
* Guarantee is contingent on TMC's comparison and review of the site floor vibration data against the tool floor vibration criteria and confirmation that the STACIS® transfer function will provide the required isolation.

## Features & Benefits

- Vibration isolation starts at 0.6 Hz, with 40% to 70% isolation at 1 Hz
- Provides greater than 90% isolation at frequencies 2 Hz and higher, vertical and horizontal
- Reduces fab floor construction costs, allows tools to be installed in higher vibration environments
- Active bandwidth, 0.6 Hz to 150 Hz
- Recommended by many tool manufacturers
- 6 degree-of-freedom active hard mount design, no soft air suspension
- Installs easily, robust control system requires minimal or no on-site compensation
- A point-of-use solution that is compatible with all internal tool vibration isolation systems
- Ensures tool vibration criteria will be met as vibration levels increase over time
- Uses TMC's patented STACIS® technology to cancel vibration using piezoelectric actuators
- Enables older and noisier floors to accommodate state-of-the-art tools
- Compatible with various floor heights and sub-floor geometries in fabs
- Increases throughput, quality and yield

### STACIS® Ordering Chart

| Catalog Number | Description |
|---|---|
| 21-301-01 | STACIS, 3-mount, low capacity |
| 21-301-02 | STACIS, 3-mount, medium capacity |
| 21-301-03 | STACIS, 3-mount, high capacity |
| 21-401-01 | STACIS, 4-mount, low capacity |
| 21-401-02 | STACIS, 4-mount, medium capacity |
| 21-401-03 | STACIS, 4-mount, high capacity |




*STACIS® 2100 on a "riser" installed under a TMC platform in a 36" tall raised floor*

## General Specification (may vary depending on configuration)

### DC-2000 Digital Controller

| | |
|---|---|
| Analog inputs/outputs | 16 channels (16/14 bit) |
| Digital inputs/outputs | 16 |
| Sampling rate | 6.5 KHz nominal |
| Front panel | Two-line LCD with soft menu keys |
| | BNC input and output for signal monitoring |
| | Two RS-232 communication ports (second port on rear) |
| | Tri-color system status lamp |
| Physical | Single RETMA rack unit height x 15 in. deep |
| Power | 90-240 VAC, 50-60 Hz, 600 watts max. |
| Other | Power connector for support of external devices |

### Performance Specifications

| | |
|---|---|
| Active degrees of freedom | 6 |
| Active bandwidth | 0.6 to 150 Hz |
| Natural frequency | Passive elastomer: 18 Hz |
| | Effective active resonant frequency: 0.5 Hz |
| Isolation at 1.0 Hz | 40% - 70% |
| Isolation at 2.0 Hz and above | 90% or better |
| Settling time after a 10 lb (4.5 kg) step input (10:1 reduction) | 0.3 sec |
| Internal noise | <0.1 nm RMS |
| Operating load range per isolator (different passive mounts required) | 400 - 4,500 lb (182 - 2,045 kg) |
| Isolator overload safety factor | > 2:1 |
| Number of isolators | 3 or 4 typical |
| Stiffness (1,000 lb/454 kg mass) (typical middle capacity isolator) | 40,000 lb/in. ($73 \times 10^5$ N/m) |
| Magnetic field emitted | < 0.02 micro-gauss broadband RMS |

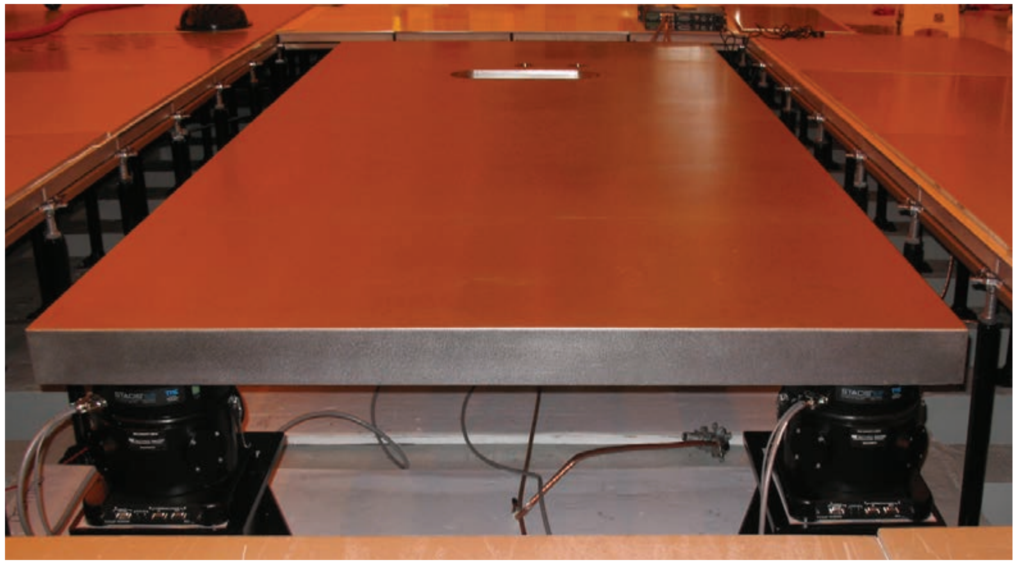
### Dimensions, Environmental & Utility Requirements

| | |
|---|---|
| Isolator size | 11.75 in. (w) x 12.5 in. (d) x 10.8 in. (h) (300 x 320 x 275 mm) |
| Isolator weight | 75 lb (34 kg) |
| Controller size | 19 in. (w) x 15 in. (d) x 1.75 in. (h) (483 x 381 x 44 mm) |
| Temp., operating | 50° to +90°F (10 to 32°C) |
| Temp., storage | -40° to 255°F (-40 to 125°C) |
| Humidity, operating | 30 - 60% |
| Power required | 100, 120, 230 or 240 volts; 50/60 Hz; < 600 watts, CE compliant |
| Floor displacement | < 480 μ in. (12 μm) below 10 Hz |

Options: TMC laminated, stainless steel platforms, frames, and "risers," leveling devices, earthquake restraints, and lifthoods

# Quiet Island®

## Sub-Floor Platforms and Supports



Semiconductor manufacturing factories (fabs) incorporate a system of raised false floors to accommodate complex facilities requirements (plumbing, electrical cables, gas piping, etc.) and to maintain strict cleanliness standards. Such floors present a challenge to the installation of extremely vibration-sensitive production, inspection, and metrology equipment. The raised floors cannot provide the necessary quiet vibration environment for such tools.

TMC's Quiet Island® is an innovative solution that replaces a section of the raised floor area with a "Quiet Island" anchored to the sub-floor below. The Quiet Island consists of a special platform combined with a dedicated support structure, the nature of which depends upon the application.

### Platform

The platform is a TMC designed and manufactured 4 inch (100 mm) thick lamination of steel plates sandwiched around a lightweight, incompressible, damped core material. The layering effect of rigid steel plates and core, epoxy bonded into a stainless steel pan provides an extremely high level of stiffness and structural damping. The large cross-section and steel content yield a very high level of overall rigidity. The top and sides are a continuous, one-piece, stainless steel shell to preserve cleanliness, appearance and integrity.

### Platform Supports

Depending on the specific application requirements, the platform supports are either a rigid, non-resonant support stand or a STACIS® 2100 Active Vibration Cancellation System. If the sub-floor meets the vibration criteria of the tool in question by a reasonable margin, simply supporting the tool with a support that does not amplify vibration is sufficient. To achieve this, TMC has designed a family of ultra-rigid support stands for a range of floor heights and sub-floor access hole requirements. Typically tripods, quad-stands or square cross-section stands, these attach directly to the sub-floor and platform.

However, if the sub-floor does not meet, or in the future may not meet, the tool vibration criteria, a "point-of-use" vibration isolation system must be employed. STACIS 2100 is the ideal choice. STACIS 2100 is compatible with all tool internal vibration isolation systems (ask for our *Stacking Active on Active* white paper). In addition, it provides the most vibration isolation across the widest frequency range commercially available.

*Rigid-Damped Tripod (no platform required)*

And, the "hard-mount" design is extremely stiff so that there is no stability concern for tall, top-heavy tools.

The rigid stands and STACIS 2100 supports are interchangeable and field upgradable. Together, they provide the complete solution for supporting sensitive tools in a fab raised-floor environment.

### Other Quiet Island Configurations

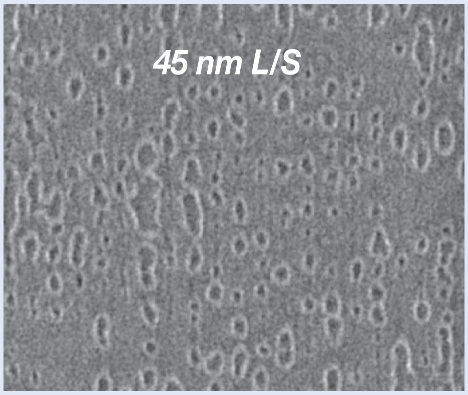
The many types of raised floors and installation challenges has led TMC to develop a number of innovative and unusual solutions. Among these are TMC's patented Rigid-Damped Tripod. If you have an unusual raised-floor challenge, chances are we already have a proven solution. Please contact one of our Application Engineers to learn more.

*A version of our Rigid Quiet Island® meets the most stringent water scanner floor stiffness specifications.*

# APPLICATION NOTE

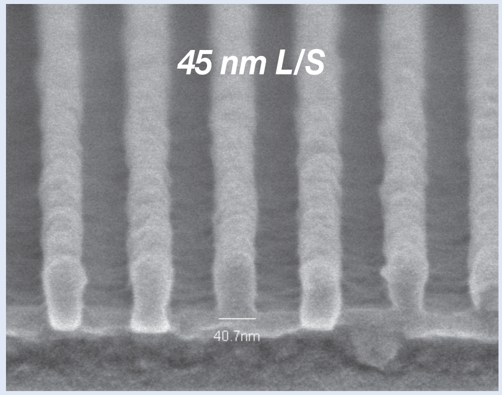
## Impact of Vibration on Advanced Immersion Lithography (actual customer supplied data)

*The 45 nanometer line-width test patterns shown were produced with an advanced Immersion Lithography System manufactured by Amphibian Systems and installed at SEMATECH in Austin, Texas. Variation between the images is due to the effect of seismic vibration on the photolithography process. The images shown were obtained using a scanning electron microscope.*




**Without STACIS®...**

*Best pattern obtained on either the elastomer or rigid version of original pedestal.*

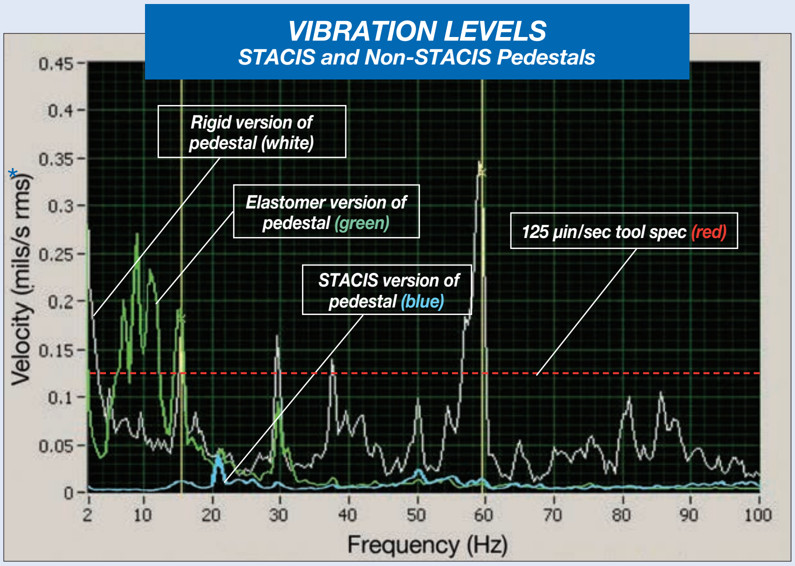



**With STACIS®...**

*Pattern achieved with STACIS active vibration isolation.*

The tool was initially installed on a steel and concrete plinth with a steel support structure which incorporated commercial elastomer vibration isolation pads. This pedestal did not achieve the tool's specified vibration criteria and pattern quality was poor.

In an attempt to reduce vibration, the elastomer pads were effectively shorted out with metal shims leading to a more rigid, non-resonant structure but this resulted in little improvement. The vibration criteria were not met with either version of the pedestal and pattern quality remained poor.




*Vertical Axis Data shown

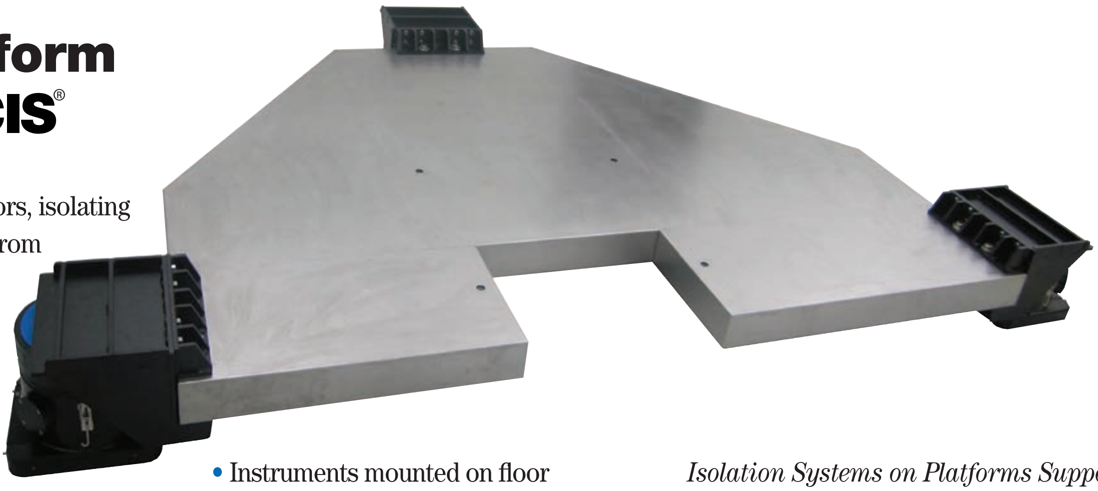
The plinth support structure was removed and retrofitted with a STACIS® Active Piezoelectric Vibration Cancellation System. The STACIS mounts were placed directly beneath the existing plinth. Supporting the tool on STACIS resulted in a dramatic reduction of overall seismic vibration levels and achievement of the manufacturer's floor vibration specification. More importantly, STACIS provided a dramatic improvement in pattern quality.

Photos, images, and vibration data courtesy of SEMATECH.

*65 Series STACIS® Floor Platform supporting an Omicron Multiprobe Scanning Tunneling Microscope (STM) with nanometer scale resolution at the Max Planck Institute in Dresden, Germany.*

## 65 Series

# Floor Platform with STACIS®



For conventional lab floors, isolating building floor vibration from large, tall tools presents an ergonomic challenge. Placing the isolators directly beneath the tool may raise the tool to an impractical height. Furthermore, conventional air isolators are unstable when placed close together under a tall, top-heavy payload.

TMC's 65 Series Floor Platforms solve this dilemma. By combining our Stainless Steel Platforms (see page 4 discussion) with a unique "lifthood" design, our isolators "cradle" the platform allowing the tool to be lifted a minimal distance above the floor. And, because the isolators are not integrated into the platform, the platform may be custom designed to match the tool footprint or any desired shape.

TMC floor platforms are configured with our STACIS® Active Piezoelectric Isolators. The advantages of STACIS include:

- STACIS piezoelectric isolators suffer no ill effects from tall, top-heavy payloads. There's no danger of gravitational instability.
- Instruments mounted on floor platforms (TEMs, STEMs, STMs, SPMs, etc.) are among the most vibration-sensitive tools made. STACIS provides the best vibration isolation commercially available with no low-frequency amplification.
- Instruments requiring isolation typically incorporate an internal, built-in vibration isolation system. This system is generally a low-frequency air isolator which, in general, should not be supported by another low-frequency air isolation system. STACIS can be being "stacked" beneath any tool's internal isolation system (ask for our *Stacking Pneumatic Isolators* and *Supporting Active Electro-Pneumatic Vibration Isolation Systems on Platforms Supported by STACIS® 'Hard-Mount' Piezoelectric Isolation Systems* white papers).

TMC works closely with instrument manufacturers to ensure that our platform design meets the instrument's footprint, structural, and utility requirements.

We have successfully isolated hundreds of different instruments and are often already familiar with the tool requirements. In most instances, you need only provide the tool manufacturer and model for us to recommend a solution.

**Note:** For Scanning Electron Microscopes (SEMs), TMC has developed a dedicated version of our STACIS Floor Platform. See STACIS® iX SEM-Base™ on page 12.

### How to Order:

1. Identify the equipment or instrument model and configuration.
2. Confirm the type of floor you have – conventional tiled lab floor, wooden beam and planks, etc.
3. Tell us if the instrument manufacturer has made a pre-installation site survey of the vibration level. In most cases, a standard floor platform will be recommended. We may recommend taking our own site vibration measurements and look at the special conditions involved. (see Room Environmental Surveys, page 86.)

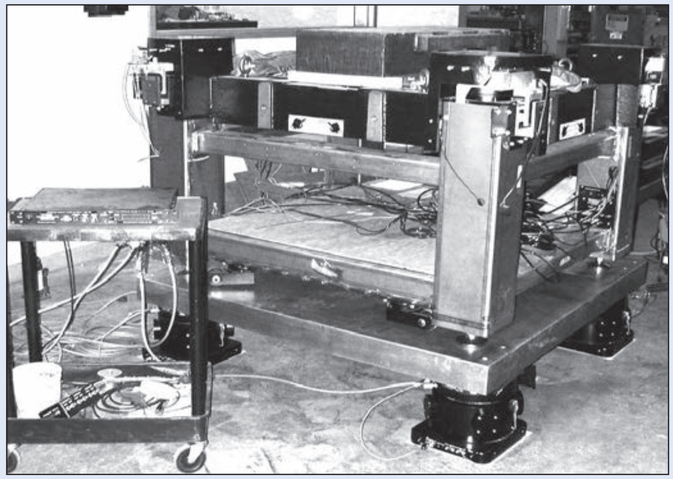
*STACIS® 65 Series Floor Platform supporting a JEOL JEM-2100F Transmission Electron Microscrope (TEM).*

*A Cameca NanoSIMS 50L on a TMC 65 Series Floor Platform supported by STACIS® isolators.*
*This tool is a 5,000-pound secondary ion mass spectrometer with a spatial resolution of 50 nanometers.*
*Photo courtesy of the Planetary and Space Sciences Research Institute (PSSRI) at The Open University, Milton Keynes, U.K.*

# APPLICATION NOTE

## STACIS® as a Microseismic Shaker

***Equipment manufacturers can use STACIS® to generate micron-level floor vibration simulating real world floor activity to develop tool vibration criteria.***



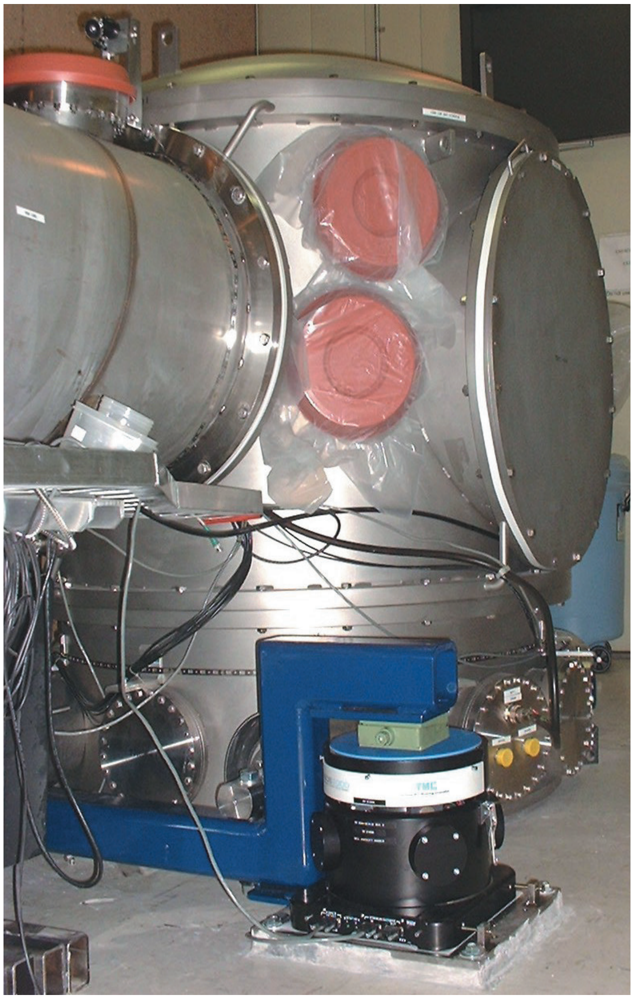
*STACIS® 2100 is used as an isolation system/micron-level shaker within TMC's own factory to test performance of other TMC vibration isolation products.*

***Semiconductor equipment makers, electron microscope manufacturers, and other precision tool makers struggle to develop meaningful floor vibration criteria for their instruments. These criteria can be derived either theoretically or empirically. Theoretical calculations are extremely complex and are often impractical or do not reflect actual tool sensitivity because of the many variables that cannot be easily modeled. Floor vibration criteria arrived at empirically are typically based on gathering tool performance information from a wide range of installations represented by various floor vibration levels. These floor vibration levels and the corresponding tool performance are used to create an upper limit of vibration amplitudes over a frequency spectrum that represents floor vibration levels that will result in acceptable tool performance. Both of these approaches are extremely difficult, time consuming, and do not result in a precise vibration specification for the tool.***

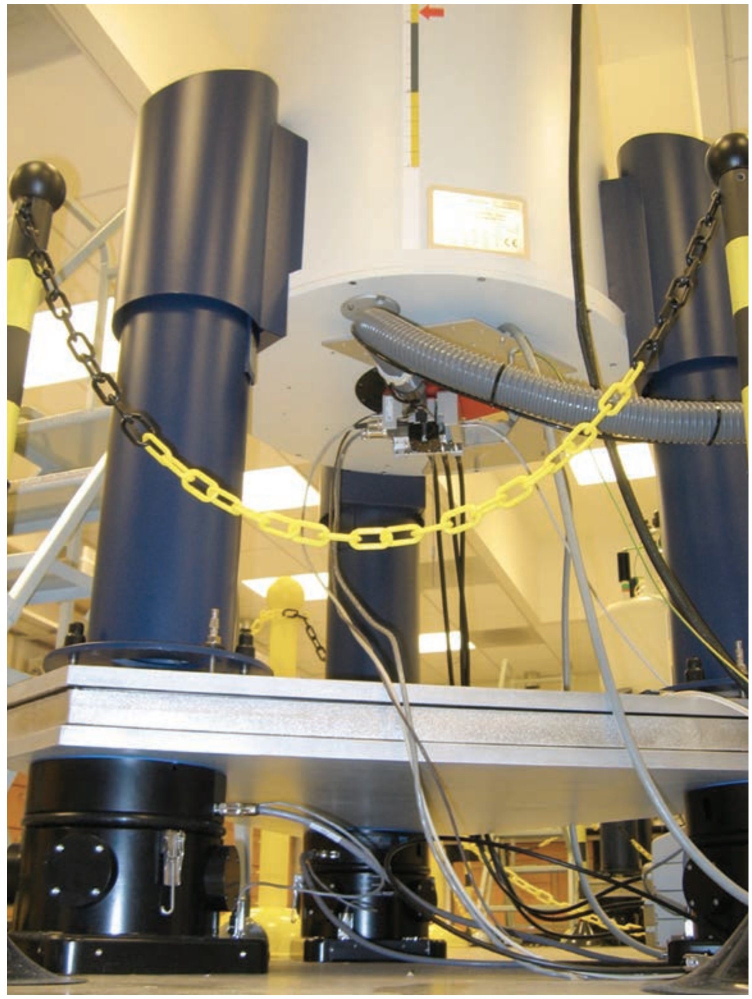

STACIS® 2100 offers a completely unique and novel way to approach the development of tool vibration criteria. STACIS, which is normally operated as a floor vibration isolation/cancellation system, can also be operated to provide micron-level shaker input. This shaker signal can be white noise, discrete frequency, or a sine-swept wave-form. STACIS can provide independent or combined X, Y and Z axis vibration input. As a shaker, STACIS can be run to simultaneously cancel building floor vibrations providing a quiet foundation while superimposing on this the desired frequency and amplitude vibration spectrum required to test tool performance. No other shaker system can control inputs down to such small amplitudes. No other shaker system can isolate ambient floor vibration while *simultaneously* providing a controlled vibration frequency spectrum. The vibration generated at the STACIS digital controller at extremely low amplitudes is not corrupted by ambient building floor vibrations at the test site.

Complete working tools can be mounted on a STACIS isolation/shaker system, and the STACIS vibration amplitudes can be adjusted as overall tool performance is evaluated. The tool can be excited at given frequencies or given bands of frequencies to determine the exact amplitude/frequency relationship of vibration input that limits overall tool performance. The result is an overall tool vibration criteria level that corresponds to the exact vibration level at which the tool can provide optimal performance. This testing can be completed relatively quickly and easily – without shipping tools to customer sites and waiting for large amounts of field data or relying on questionable modeling information.

Contact TMC or your local sales representative to acquire a STACIS® 2100 system for use as a shaker for testing your sensitive equipment in a controlled vibration environment.



*STACIS® supporting the end chambers of a prototype LIGO interferometer at the California Institute of Technology. These are the most precise instruments ever made – capable of measuring distances of less than $10^{-18}$ meters.*



*A STACIS® System, incorporating a non-ferromagnetic, highly damped, aluminum platform, provides a second stage of vibration isolation for a Bruker BioSpin 600 MHz NMR Spectrometer. Photo courtesy of Buker BioSpin and Memorial Sloan Kettering Cancer Center.*


*The Nikon FX-21S LCD Stepper incorporates an advanced version of TMC's STACIS® for the ultimate in vibration cancellation. The rigid mounts yield faster settling times in response to motion resulting in higher throughput.*


www.techmfg.com • 978-532-6330 • 800-542-9725 (Toll Free) • Fax: 978-531-8682 • sales@techmfg.com

# Integrated Active Piezoelectric Vibration Cancellation



*STACIS® iX SEM-Base™*


*STACIS® iX LaserTable-Base™*


*STACIS® iX Stage-Base™*

# STACIS® iX SEM-Base™

## Active Piezoelectric Vibration Cancellation Floor Platform for Scanning Electron Microscopes


STACIS® iX SEM-Base™ active vibration cancellation floor platform system is designed for use with scanning electron microscopes (SEMs). SEMs are among the most vibration sensitive tools made, and these precision instruments typically incorporate an internal vibration isolation system. SEM-Base is compatible with all internal SEM vibration isolation systems.

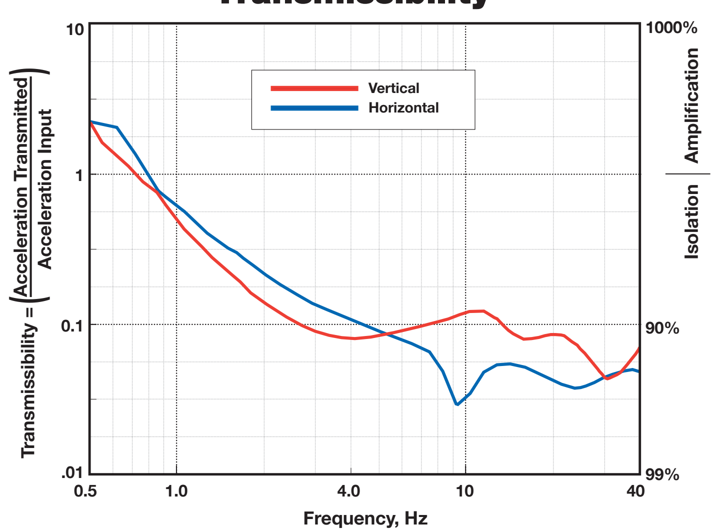
SEM-Base is a compact, cost-effective alternative to our 65 Series STACIS® 2100 Floor Platform (page 7). It incorporates STACIS technology but has a much smaller footprint and installs easily with minimal tuning.

With vibration cancellation starting below 1 Hz, SEM-Base features extended stroke piezoelectric actuators and damped, powder-coated steel plates that sandwich four isolators and TMC's DC 2000 digital controller. The system is only 6.5 in. tall, measures 35.5 in. x 44.5 in., weighs approximately 650 pounds, can support 900 to 2,500 pounds, and has no soft air suspension.

## Features

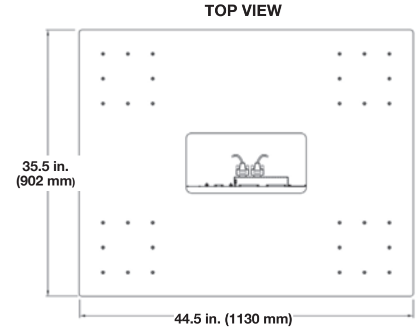
- Incorporates patented STACIS® technology
- Active inertial vibration cancellation system
- 35.5 in. x 44.5 in. x 6.5 in., fits most commercial SEMs
- Load capacity: 900 - 2,500 lb.
- Vibration cancellation starts below 1 Hz
- 6 active degrees-of-freedom
- Installs easily, minimal or no tuning required
- Compatible with all internal tool vibration isolation systems
- No soft air suspension
- Simple, robust, and cost-effective
- Optional casters allow easy portability, no lifting required
- Ask about our SEM-Lift™ System for installation

### Transmissibility*

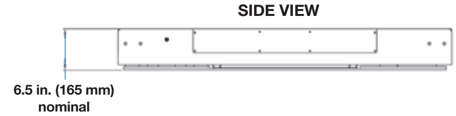



* 2,150 lb. (980 kg) payload with simulated floor vibration at VC-C (500 micro-inches per second, 12.5 microns per second)

TOP VIEW



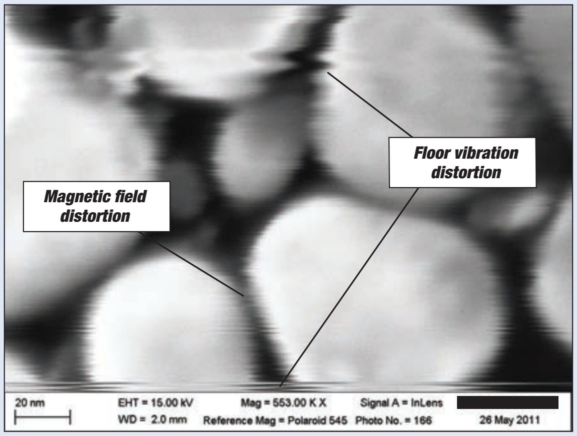

SIDE VIEW



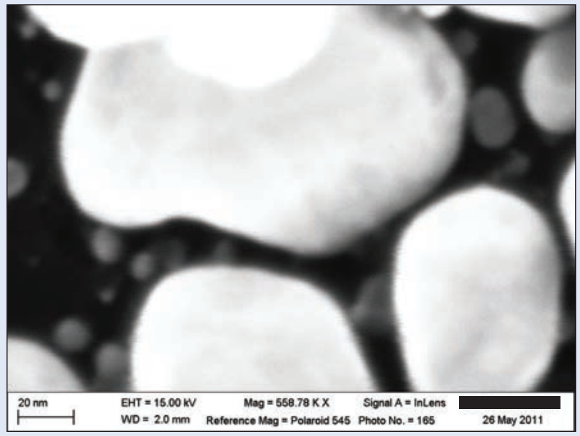
# APPLICATION NOTE

**Before and After Images, Zeiss Auriga FIB-SEM on STACIS® iX SEM-Base™ with Mag-NetX™ (actual customer supplied data)**

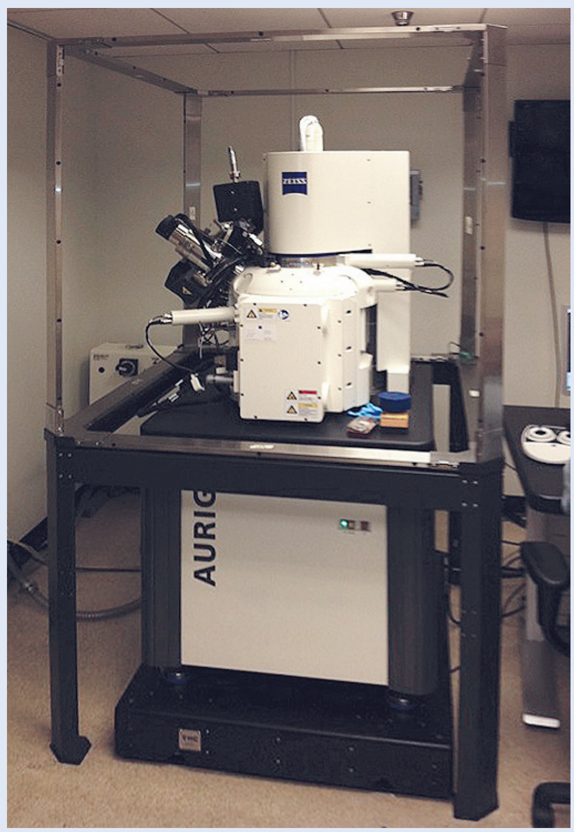
***Before***




***After***




The before and after photos above are actual images taken from a Zeiss Auriga FIB-SEM installed in a non-ideal environment. The image on the left was taken with the newly installed TMC STACIS® iX SEM-Base™ Floor Platform and Mag-NetX™ Magnetic Field Cancellation (see page 78) systems powered-off. The image on the right was taken immediately after both active systems were powered-on.

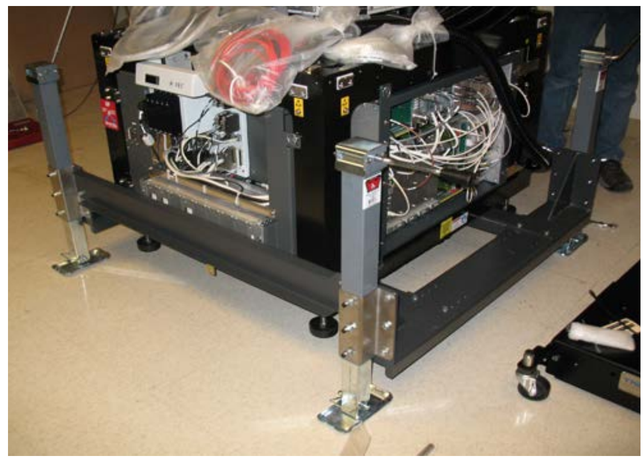


# Ask about helpful options that will ensure a smooth SEM-Base™ installation.

**SEM-Lift™**

**Convertible Roll-Off Crate**

*SEM-Base™ (shown with optional retractable casters) may be provided with a convertible roll-off crate. The crate cover converts to a sturdy ramp and the cover slats form a guide for the wheels.*



*SEM-Lift™ is a safe and sturdy lifting device for scanning electron microscope (SEM) columns. It simplifies and speeds SEM-Base™ installation on a previously installed SEM column. SEM-Lift raises the column several inches allowing SEM-Base™ to be rolled into place.*


*STACIS® iX SEM-Base™ Floor Platform isolating an FEI Helios NanoLab DualBeam SEM/FIB (top left), a JEOL JSM-6700F Field Emission Scanning Electron Microscope (top right), an Hitachi S-3400N SEM (bottom left), and a Field Emission Scanning Electron Microscope (bottom right).*

# STACIS® iX
# LaserTable-Base™

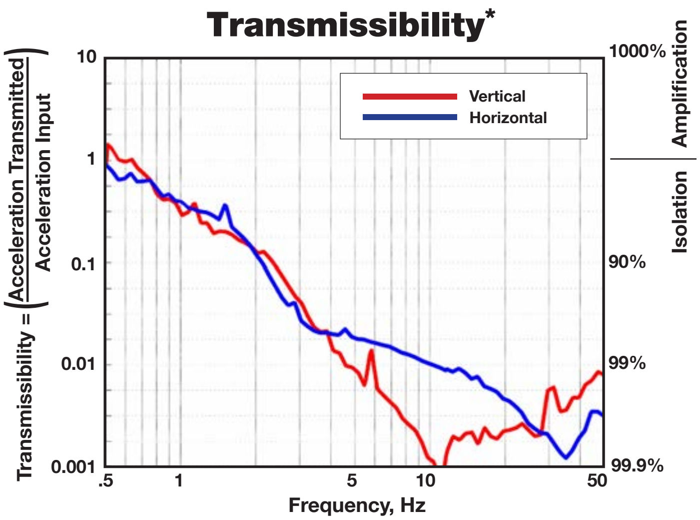
### Hybrid Piezoelectric/Air Active Vibration Cancellation System

CE Marked

STACIS® iX Laser-Table-Base™ is TMC's latest addition to our STACIS® iX line of piezoelectric active vibration cancellation systems. LaserTable-Base offers an extraordinary level of improvement over existing technology in the amount of vibration isolation attainable with an Optical Table.

Typically, Optical Tables are supported by low-frequency pneumatic vibration isolation systems. Though very effective at isolating high frequencies, these passive systems actually amplify vibration in the critical 1 to 3 Hz range.

TMC's STACIS® technology overcomes these limitations through a patented technology which incorporates piezoelectric actuators and inertial vibration sensors to cancel, not amplify, very low-frequency vibration.




* 4,000 lb (1,800 kg) capacity LaserTable-Base™ with MaxDamp® Isolation System. Payload of 2,000 lbs (907 kg), tested with simulated floor vibration at VC-C (500 micro-inches per second, 12.5 microns per second).

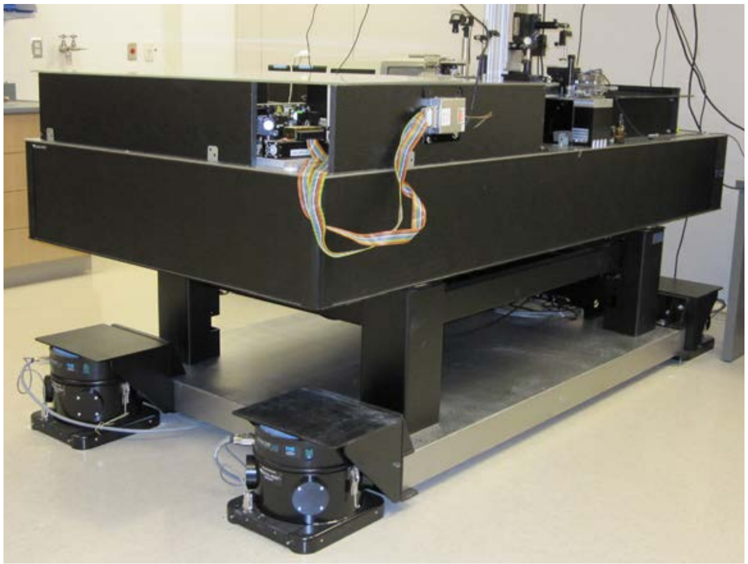
## Features

- Incorporates patented STACIS® technology
- Active inertial vibration cancellation system
- Vibration cancellation starts below 1 Hz
- 6 active degrees-of-freedom
- Consists of two isolation systems in series for maximum vibration cancellation
- Incorporates patented MaxDamp® Air Isolators
- Simple, robust, and cost-effective
- Installs easily, minimal tuning required
- Optional shelves for mounting equipment under the table
- Includes TMC's DC-2000 Digital Controller

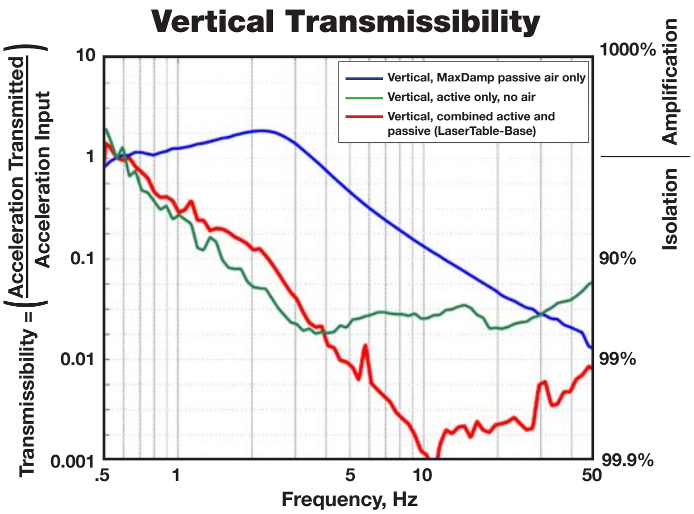
LaserTable-Base™ combines these two technologies, air and STACIS®, into one integrated cancellation system. The result is vibration cancellation at very low frequencies and unprecedented levels of high-frequency isolation due to the combined effect of two isolation systems in series.

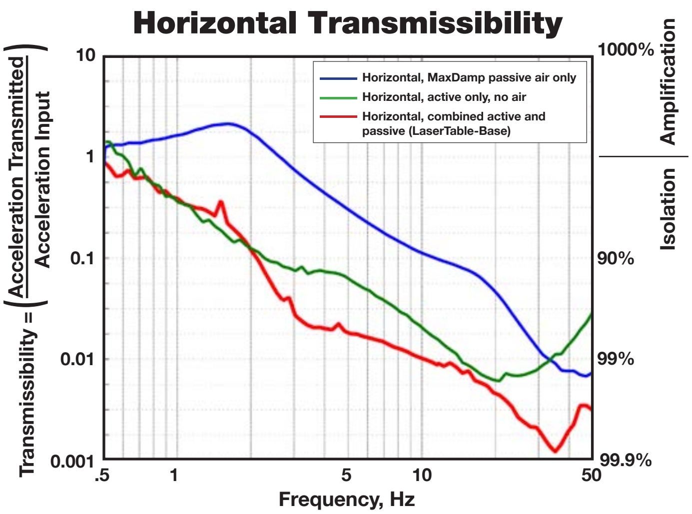
Furthermore, STACIS® iX improves upon the original STACIS technology by the addition of extended travel piezoelectric actuators (to accommodate even the worst floors) and an updated design that significantly lowers total cost.

The upper pneumatic portion of LaserTable-Base consists of patented MaxDamp® Air Isolators. The modular design allows for customizing the air sub-system for specific application requirements.



*Until recently, researchers desiring the quietest possible vibration environment in a lab combined two independent products into a two-stage isolation system. This photo shows a 784 Series CleanTop® Optical Top supported by Gimbal Piston™ Air Isolators. This air isolation system is, in turn, supported on a 65 Series Floor Platform cradled with STACIS® 2100 Isolators. LaserTable-Base™ now combines these two independent isolators into one integrated system, with improved overall performance in a smaller footprint.*




*Combining the low frequency, passive MaxDamp® Air Isolators with a Piezoelectric Active Vibration Cancellation System in series results in an overall transmissibility curve that is the sum of the two individual transmissibility curves. The resultant vibration isolation performance is so dramatic that over some frequency ranges, we are limited by measurement instrumentation noise-floors and unable to measure and demonstrate the full isolation performance. That is, above 10 to 12 Hz, the actual performance of the combined system is expected to exceed that shown since the combined isolation is theoretically the sum of the isolation provided by the two sub-systems.*

## STACIS® iX
# Stage-Base™

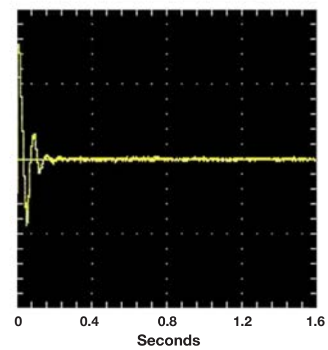
### Frame Mountable Active Hard-Mount Piezoelectric Vibration Cancellation System

STACIS® iX Stage-Base™ is specifically designed to be built into advanced semiconductor tools which incorporate high precision motorized X-Y stages. Such tools require extremely efficient vibration isolation. But, just as critical, these tools require that payload motion induced by the stage settle very quickly so as not to adversely impact tool throughput.

Stage-Base incorporates TMC's patented STACIS® technology to achieve extremely efficient vibration isolation using piezo-electric actuators and a stiff suspension.

TMC continues to apply advancing tech-nology to develop new solutions to the challenging demands that semiconductor tools place on their vibration isolation systems. Stage-Base provides vibration isolation comparable to our STACIS active piezoelectric vibration cancellation systems but is specifically designed to be the primary isolation system incorporated inside the tool. Stage-Base features extended stroke piezoelectric actuators, fast settling time in response to stage motion, and a hard-mount suspension with no soft air springs. It is available in 6 degrees-of-freedom and starts to isolate well below 1 Hz.

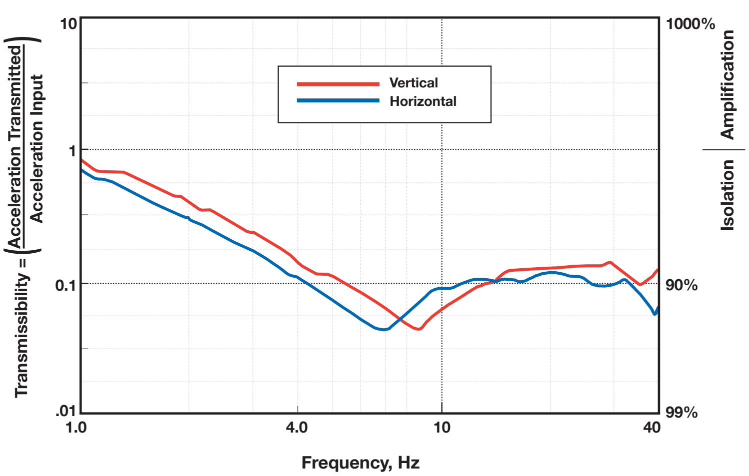
**Settling Time**




## Features

- Incorporates patented STACIS® technology
- Position repeatability of payload to within microns
- Frame-mountable design
- 6 active degrees-of-freedom
- No feedforward required
- Active inertial vibration cancellation system
- Fast settling time in response to stage motion
- No soft air suspension
- Simple, robust, and cost-effective

**Transmissibility***




* 2,150 lb. (980 kg) payload with simulated floor vibration at VC-C (500 micro-inches per second, 12.5 microns per second)

# CleanTop® Optical Tops, Breadboards, & System 1 Supports



*Top photo courtesy of MetroLaser; bottom, NASA Goddard's Advanced Interferometer and Metrology Lab (AIM) incorporates two 5 ft. x 16 ft. x 2 ft. Invar CleanTop® Optical Tops, each supported on a six-mount STACIS® active piezoelectric vibration cancellation system.*

# CleanTop® Optical Table

## With System 1 Supports

Optical Tops and Isolation Systems from TMC are the industry standard. The optical tops provide the highest core density and smallest honeycomb cell area in an all-steel construction with the first, and still best, spill-proof tapped hole design. The small honeycomb cell size results in a more rigid structure, a heavier structure, and a table with the highest inertia. The greater the moment of inertia, the lower the compliance curve and the smaller the effect of applied forces.

TMC optical tops use a symmetrical dry damping method preferable to other dampers. TMC utilizes broadband damping that does not need careful tuning and therefore is less susceptible to mass loading of the table that can change the table's resonant frequency.

We offer three different levels of *Performance*: Research, Scientific or Laboratory grade, as well as Specialty Tables for environmental considerations.

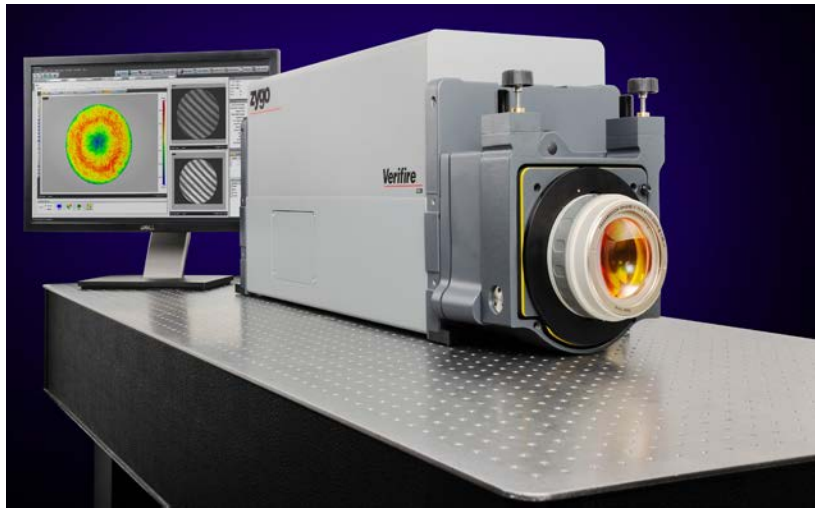



*Photo courtesy of Zygo Corporation*

TMC's Optical Tops with Micro-g® System 1 Vibration Isolation Legs feature patented Gimbal Piston™ Isolators which provide unparalleled isolation efficiency in both horizontal and vertical directions. The Gimbal Piston is widely renowned as the solution of choice. No competing isolator design has ever rivaled this unique and innovative mechanism. Combined with its highly tuned, non-linear damping response, the Gimbal Piston provides the most stable experimental working environments for advanced research in the world.

TMC's Micro-g® System 1 isolators are available in a variety of different configurations. There are different capacity legs depending on the mass of the optical top and payload. The legs can be configured with or without horizontal tie bars. TMC also offers leveling baseplates for large table setups where the floor may not be perfectly level. The system can be constructed using 6 legs attached with tie bars. Internal retractable casters are available on some sizes. Several height options are also available. Many vibration isolation/ cancellation options are manufactured by TMC, allowing the end user to overcome just about any vibration problem.

Perhaps no single characteristic of an optical top is as crucial as its structural damping. TMC's R&D Department is constantly evaluating new techniques and materials to maximize structural damping performance. We are able to offer various levels of performance and added flexibility in specifying a TMC top.

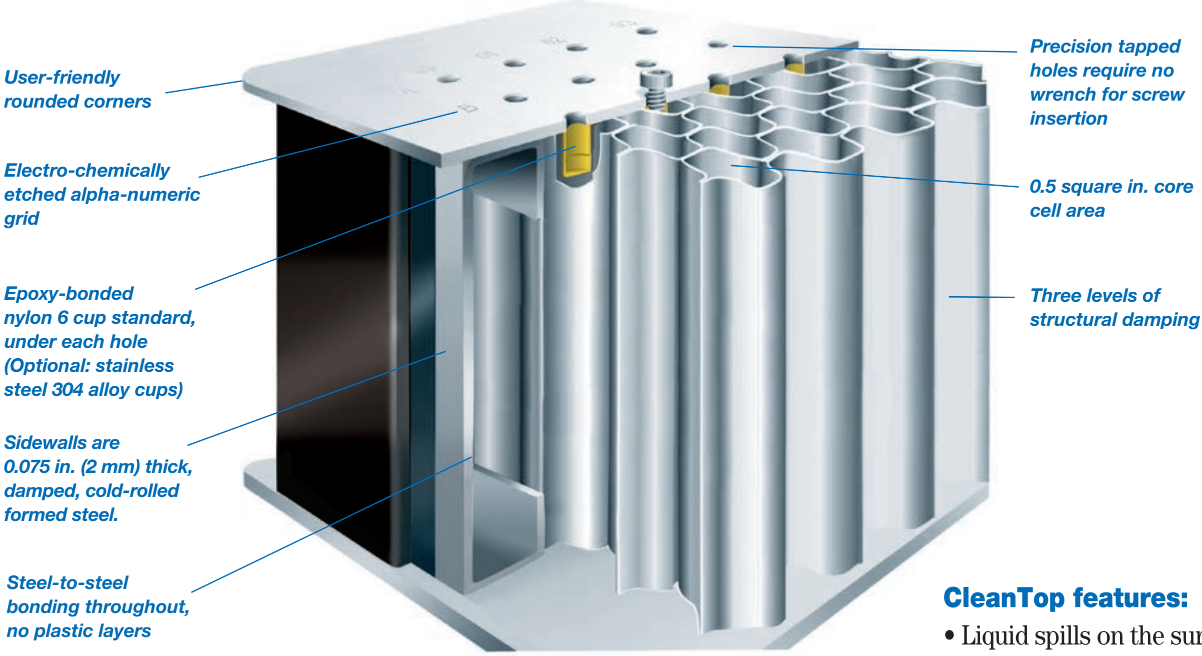
| **Performance Series Tops** |
|---|
| Research Grade |
| Scientific Grade |
| Laboratory Grade |
| **Specialty Series Tops** |
| ClassOne™ CleanTop® |
| Non-Magnetic CleanTop® |
| Vacuum Compatible |

*See Page 30 - 35*

| **System 1 Supports** |
|---|
| Gimbal Piston™ Vibration Isolators |
| Rigid Supports |

*See Page 38*

# CleanTop® Optical Top






TMC's CleanTop Optical Top is the best method yet for providing a spill-proof, clean, precise, and corrosion resistant optical top with unmatched structural performance. CleanTop is now a standard feature of all TMC optical tops.

Individual CleanTop cups are epoxy-bonded under each tapped hole after it is tapped and cleaned. Cups are made from chemically resistant nylon 6, and stainless steel (304 alloy) cups are available. Holes are now tapped and countersunk prior to adding the cups to allow the machined top sheet to be thoroughly cleaned with open, rather than blind, holes prior to bonding. The top plate is processed through a custom TMC industrial cleaning center where a high pressure, high temperature cleaning solution is forced through each threaded hole, completely clearing any machining or tapping debris. Several rinse and dry cycles ensure an essentially "sterilized" top surface prior to bonding the cups.

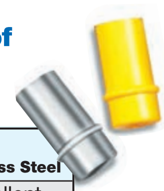
CleanTop represents another innovation in TMC's long optical top tradition of industry "firsts" including:

- First spill-proof optical top (CleanTop).
- First all-steel optical top.
- First oil-free optical top.
- First honeycomb core registered to the tapped hole array.
- First lightweight breadboard with formed rather than drilled holes.
- First vacuum compatible optical top.

## CleanTop features:

- Liquid spills on the surface are contained and cannot reach the top's honeycomb core.
- The core is completely clean and dry with no residual thread-cutting oils to out-gas.
- Extremely clean tapped holes make screw insertion smooth and simple.
- Easy retrieval of small parts dropped into the holes is assured.
- Since no penetration of the core is possible when dangerous chemicals are used on the top's surface, health hazards will not occur by chemicals reaching the core unnoticed.

## General Chemical Resistance of the Nylon 6 and Stainless Steel 304 Alloy Cups (optional)

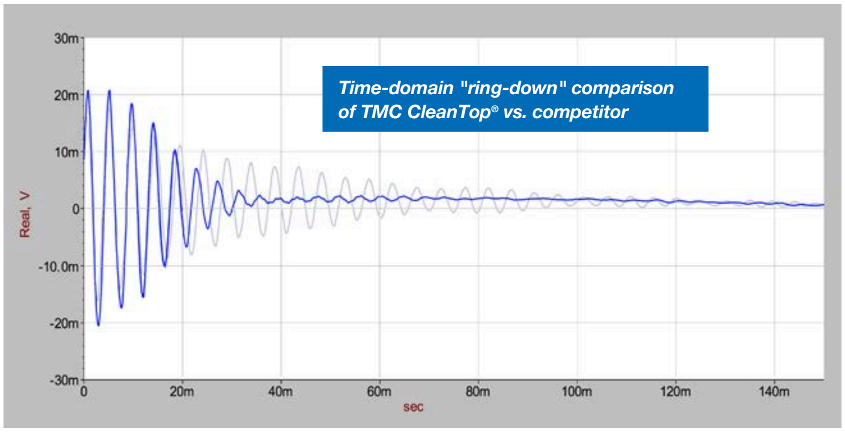


| | Nylon 6 | 304 Stainless Steel |
|---|---|---|
| Aromatic Solvents | Excellent | Excellent |
| Aliphatic Solvents | Excellent | Excellent |
| Hydrocarbons | Excellent | Excellent |
| Gasoline & Oils | Excellent | Excellent |
| Refrigerants | Excellent | Excellent |
| Chlorinated Solvents | Fair | Excellent |
| Weak Acids | Good | Excellent |
| Strong Acids | Attacked | Excellent |
| Weak Alkalines | Excellent | Excellent |
| Strong Alkalines | Good | Excellent |
| Oxidizing Agents | Attacked | Excellent |

# Structural Damping

TMC has long adhered to the philosophy that dry damping of an optical top is preferable to oil-based dampers. Oil's characteristics can change over time and hidden oil reservoirs are always in danger of being pierced by an end-user customizing his system.

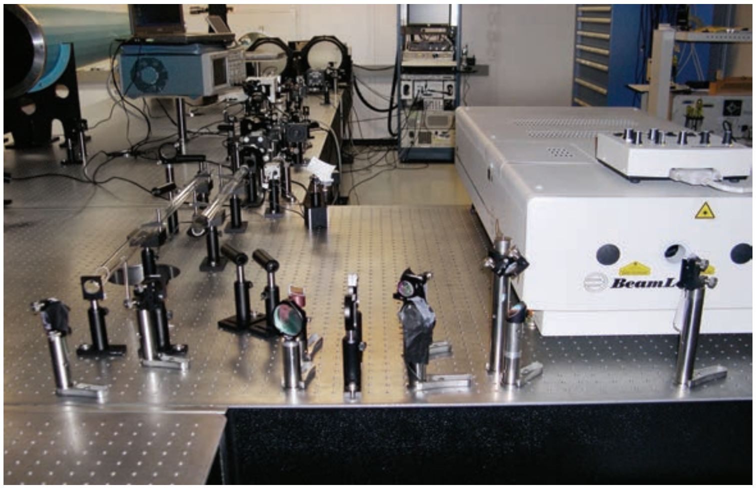
Our approach to damping of structural resonances has consistently been based on a "broadband damping" approach. "Tuned damping," or using a tuned mass-damper to resonate out-of-phase with a top's bending mode, is a risky approach. First, it assumes the damper can be set to exactly coincide with the resonant frequency of the top. An optical top's resonant frequency will vary based on load, distribution of load, temperature, and even the presence of the dampers themselves. Therefore, in practice, it is difficult to tune the dampers to the top's resonance. Furthermore, it assumes that only the lowest resonant frequency requires damping when many secondary bending and twisting modes require attention.




*Time-domain response measured at identical corner locations on the top surface in response to calibrated hammer strike. The faster ring-down time measured on the CleanTop® indicates superior damping.*

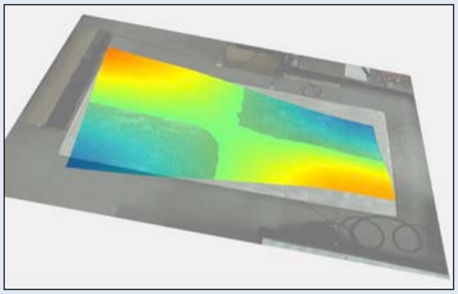
More importantly, the notion of incorporating a tuned mass-damper to suppress a structural resonance is a flawed one. Tuned damping is only effective in damping discrete resonances and is misapplied when used to damp a broadband structural resonance. In simple terms, a tuned damper "splits" a structural resonance into two resonances by creating a coupled mass system.

TMC's proprietary broadband damping techniques are the most effective way to damp an optical top. This approach works over the entire frequency range of interest, dissipating energy at the top's primary, secondary, and higher resonant frequencies. In addition, performance will not be compromised by adding weight to the top.



*Multiple CleanTop® Optical Tables rigidly coupled in a "T" shaped configuration. This table system is part of the Texas Petawatt Laser at the University of Texas Austin (photo courtesy of the Texas Center for High Intensity Laser Science).*

## Laser Scanning Vibrometry



TMC's CleanTops are engineered using the most advanced methods for structural analysis and design. The Operational Deflection Shape shown above was measured using a technique called Laser Scanning Vibrometry (LSV). LSV is among the most sensitive and most accurate non-contact vibration measurement techniques commercially available. It uses the laser doppler effect to measure the behavior of the entire table rather than the behavior one discrete point.

# Structural Damping Performance Summary

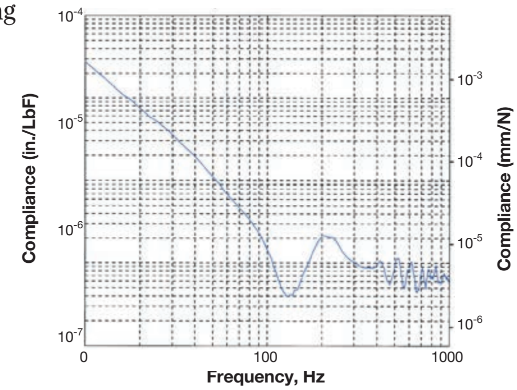
TMC optical tops have guaranteed performance levels which are unsurpassed. In addition, with three levels of broadband damping and three environmental choices, TMC offers the most flexibility in choosing a performance level.

Guaranteed maximum compliance levels for the maximum damping level are tabulated in the plots below. The standard damping level offers compliance levels a factor of four times higher than those tabulated. The minimum damping level is only recommended for non-sensitive applications.

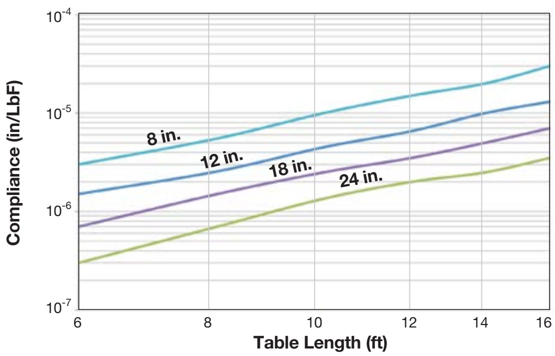
The curves summarize the guaranteed performance levels of TMC optical tops. In addition, table top corner compliance data are presented for the three damping levels available. Data were acquired by impact testing, using a one-pound calibrated hammer, accelerometer, and dual-channel spectrum analyzer. As these examples demonstrate, actual measured performance is often considerably better than our guaranteed performance. For a more complete discussion of optical top performance, see pages 102-105.



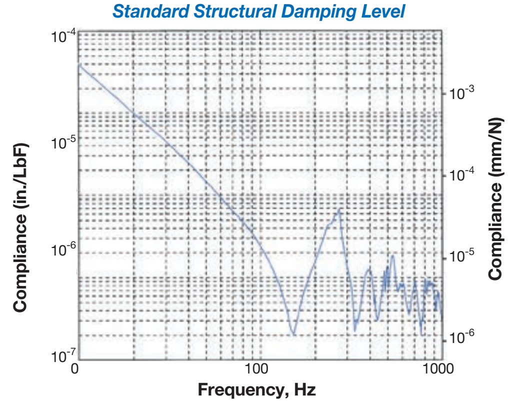
***Maximum Structural Damping Level***



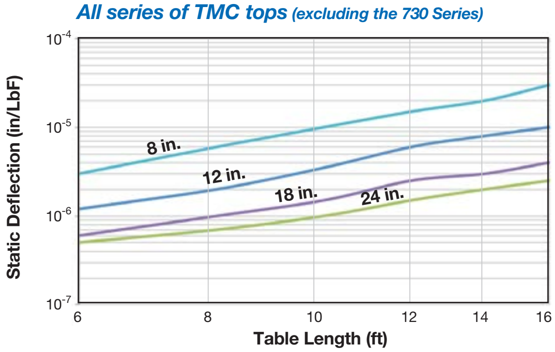

***Guaranteed maximum compliance levels — Tops with maximum fixed damping level (micro-in./lb force input)***



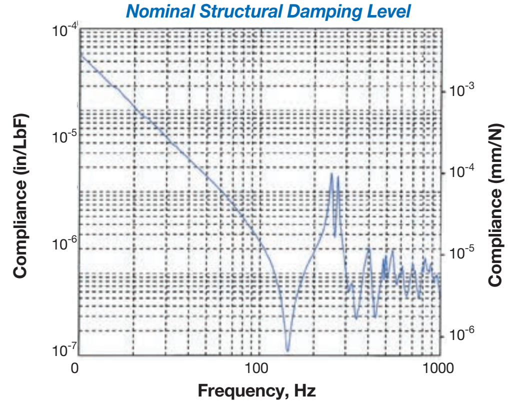

***Standard Structural Damping Level***



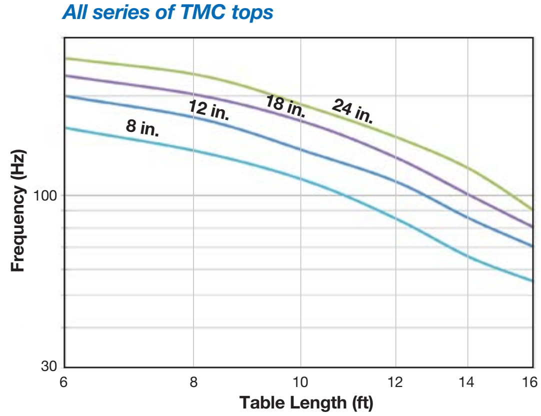

***Guaranteed maximum static deflection — All series of TMC tops** (excluding the 730 Series)*




***Nominal Structural Damping Level***

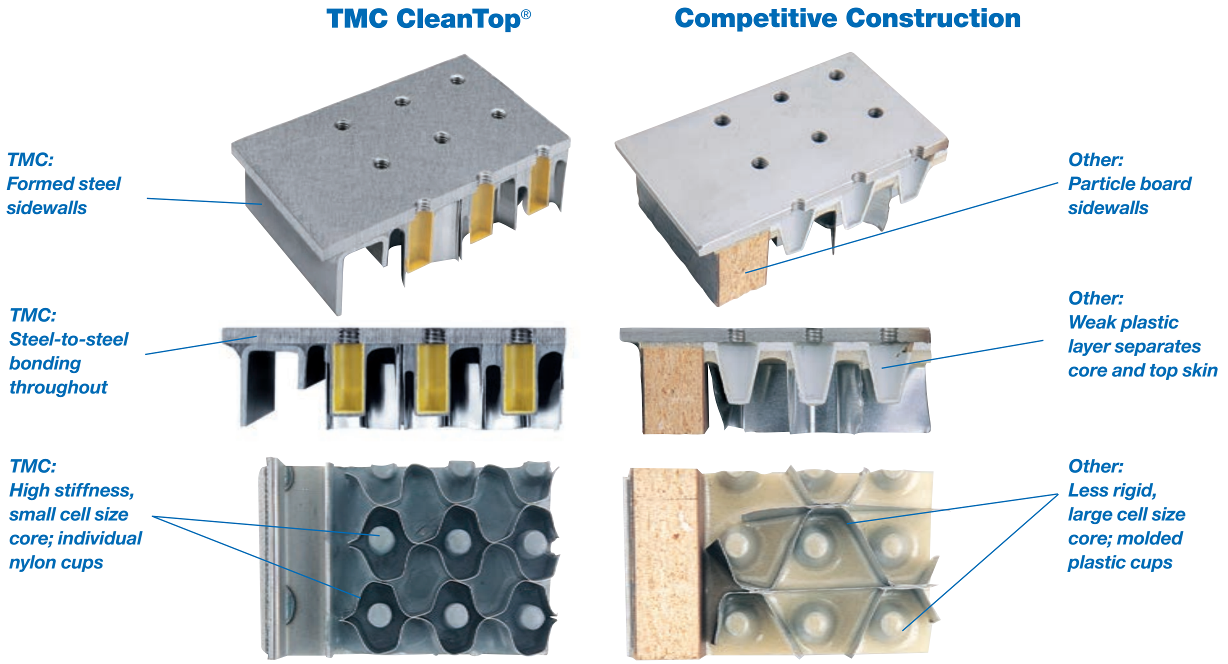



***Guaranteed minimum resonant frequency (Hz) — All series of TMC tops***




To convert from in./lb to mm/N, multiply by a factor of 5.7.
Example: $10^{-6}$ in./lb x 5.7 = 5.7 x $10^{-6}$ mm/N

# 20 Reasons for Choosing a CleanTop® Optical Top




**1.** Sidewalls of TMC ferromagnetic tops are 0.075 in. (2 mm) thick, damped, cold-rolled formed steel (see center CleanTop® photo, above), unlike the moisture-absorbing particle board favored by other manufacturers, presumably for its low cost. In addition, steel provides structural integrity unattainable with particle board sidewalls.

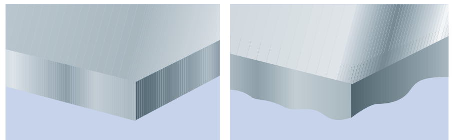
**2.** TMC's CleanTop design does not require enlarging core cell size because CleanTop cups are cylindrical, not conical like molded plastic membrane cavities. Our average cell size of 0.5 $in.^2$ (3 $cm^2$) is at least 50% smaller than molded cavity top designs, assuring the highest stiffness and greatest core-to-skin bonding contact area.

**3.** CleanTop achieves a spill-proof core with only two bonding layers: top skin to core and core to bottom skin. Imitations must add a third bonding layer, which severely weakens the structure: top skin to plastic layer, plastic layer to core, and core to bottom skin.

**4.** Additionally, to avoid excessive epoxy being squeezed into the plastic cups, imitative designs use only the thinnest layer of epoxy between the top skin and plastic layer. The thinness of this layer can produce "voids" when the top is bonded by trapping air, significantly weakening the bond.

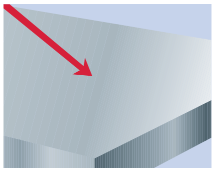
**5.** TMC employs a proprietary process to clean our machined skins to a level that is virtually "sterilized." This ensures the cleanest threaded holes and superb epoxy bonding. Furthermore, the cleaning station is in an entranceway to a clean, finishing building, so that the cleaned top never sees a heavy, industrial machining environment. In the CleanTop design, no machining, grinding, or sanding of any kind is performed subsequent to this cleaning process.

**6.** TMC top skins are stretcher-leveled, stress-relieved, and pressure-bonded against a precision-lapped granite plate, without subsequent grinding – avoiding heat and stress. The finished top is flat within $\mp 0.005$ in. (0.13 mm) within the normal hole pattern area, guaranteed.

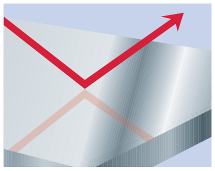


*TMC top skin (left) and competitive design top skin after grinding (right)*

**7.** Top surfaces of TMC tops are lightly sanded with an orbital pattern to remove burrs and provide a non-glare, non-reflecting finish, without inducing internal stress.



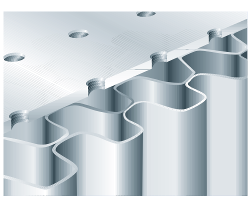
*TMC no-glare surface.*



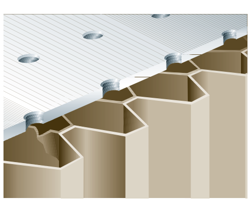
*Ground surface of competitive design creates reflection and glare.*

**8.** Standard mounting holes in TMC tops are tapped, either 1/4-20 on 1 in. centers or M6 on 25 mm centers. Imperial 1/4-20 tapped holes on 1 in. staggered centers and metric M6 on 25 mm staggered centers are available at a nominal additional fee. Custom patterns, including large through-holes for cables, etc., are easily accomplished with our multiple 2,000-watt laser machining centers.

**9.** All TMC mounting holes are in register with open cells in the honeycomb core (a given with CleanTop® but not necessarily with other designs). This assures that the core is not damaged by subsequent drilling and tapping during manufacture, that the structural integrity of the assembly is maintained, and that all mounting screws can be inserted to full depth without obstruction.



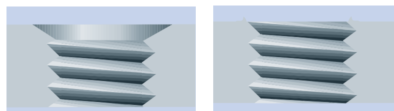
*TMC-registered holes (shown without CleanTop® cups)*



*Competitive non-registered holes*

**10.** Every hole in a TMC top is lead-screw-tapped, the most precise method known, and there are no inserts. Inserts can loosen, and top skins can be distorted when inserts are pressed into undersized holes.

**11.** TMC mounting holes are slightly countersunk to remove ridges and burrs. Every TMC mounting screw can be finger tightened at first insertion – no wrench is needed.



*TMC-countersunk holes (left) vs. non-countersunk holes in competitive design (right)*

**12.** TMC's broadband dry damping approach is the only logical one for an optical top. Others use "tuned" dampers which only work on a discrete frequency. Structural resonances are not discrete and therefore not eliminated but rather "split" into two resonances by tuned dampers.

**13.** TMC's honeycomb core is made of 0.010 in. (0.25 mm) thick steel, work-hardened and plated to prevent corrosion and assure years of service. Steel honeycomb is the ideal material for optical tops since the Young's modulus of steel is three times that of aluminum.

**14.** TMC's honeycomb core is a closed-cell structure with basic cell size of 0.5 in.$^2$ (3 cm$^2$), giving a core density of 13-14 lb/ft$^3$ (300 kg/m$^3$), significantly greater than others on the market. The effective core density is 18-20 (16 lb/ft$^3$) including sidewalls and dampers.

**15.** Our honeycomb structures are totally TMC-manufactured, assuring reduced manufacturing cost, top quality, and dimensional precision.

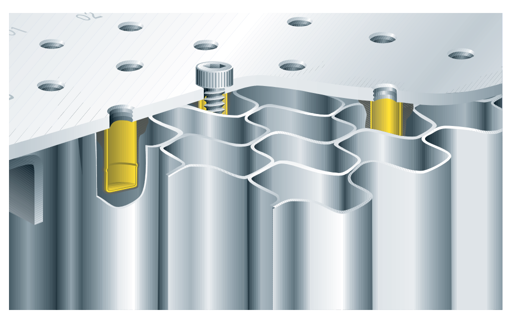
**16.** The core, skins, and sidewalls of TMC tops are rigidly and permanently bonded with specially formulated high-strength epoxy, which has no viscoelastic creep or hysteresis. The overall shear modulus of TMC's finished, bonded core is 275,000 psi (19,300 kg/cm$^2$).

**17.** The stainless steel version of TMC's CleanTop cups offers the ultimate in an unbroken stainless steel barrier. This design renders the top immune to even repeated spills of the most corrosive liquids.

**18.** Structural damping of TMC tops is accomplished using broadband mass dampers which are separate from the core, do not permit hysteresis or creep of the top, and do not detract from the top's stiffness.

**19.** Our unique, direct core-to-top bonding improves the thermal conductivity of the core to the outside environment, reducing the "thermal relaxation time" for the top.

**20.** Our skins, core, sidewalls, and dampers are all made of steel and therefore have the same coefficient of thermal expansion. Thus, even in situations with repeated temperature cycling, a TMC top expands and contracts as a whole, assuring structural integrity and preventing long-term internal stress buildup.



*TMC's honeycomb core*

# How to Select a CleanTop® Optical Top

*Support stand specified separately*

## 1. Select Performance Series

TMC offers three levels of structural damping, though not all levels are available in each construction. Because the damping mechanisms are expensive to manufacture, it is prudent to specify only the level of damping required.

All TMC damping levels incorporate broadband dry damping. For a complete description of broadband vs. tuned damping, see page 104.

| Series | Damping Level |
|---|---|
| 784 | Maximum structural damping – Research Grade |
| 783 | Standard structural damping – Scientific Grade |
| 781 | Nominal structural damping – Laboratory Grade |

### Maximum Structural Damping – Research Grade

TMC's maximum structural damping provides a level of performance unsurpassed in the industry. It is recommended for the most demanding applications.

### Standard Structural Damping – Scientific Grade

An economical alternative for less sensitive applications incorporates our broadband standard dry damping level.

### Nominal Structural Damping – Laboratory Grade

The nominal broadband damping level is appropriate for general lab work when the main consideration is a rigid, flat mounting surface.

## Select Specialty Series

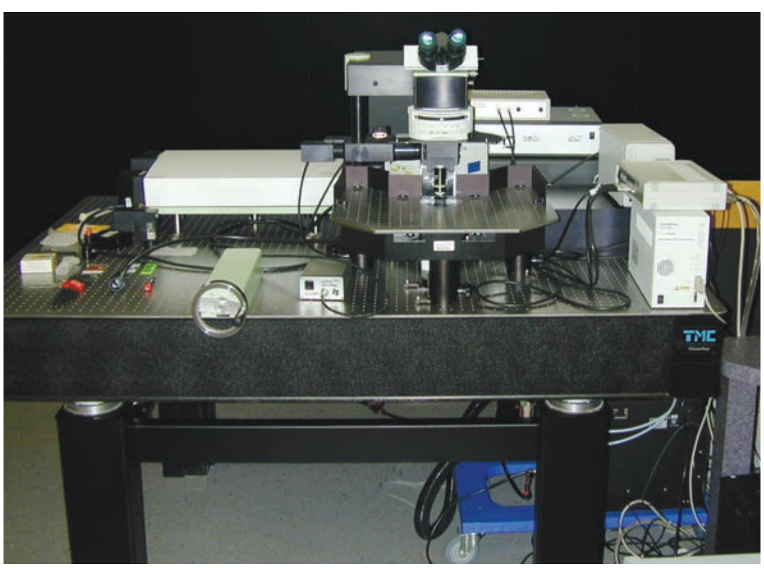
### ClassOne™ CleanTop®

The ClassOne™ version takes CleanTop® one step further. Designed for maximum cleanroom compatibility, the ClassOne CleanTop has not only a stainless steel top skin but stainless steel sides and a stainless steel bottom skin as well. Nylon 6 CleanTop cups are standard and 304 alloy stainless steel cups are available as an option.

Wiped down with a lint-free cloth, the ClassOne is wrapped in plastic prior to shipping and may be brought directly into a clean environment with minimal cleaning.

### Non-Magnetic CleanTop®

For work in a highly magnetic environment, we offer non-magnetic construction. This table is made from 304 alloy stainless steel rather than the conventional ferromagnetic 430 alloy.



*784 Series CleanTop® Optical Top on Micro-g® Post Mount Support with Gimbal Piston™ Isolators at the Yale Microscopy Workshop.*

Though the skins, sides, dampers, and core are a 304 alloy, no stainless steel top can be said to be "100%" non-ferromagnetic. In some cases, 316 L alloy is preferable and this material is available.

### Vacuum Compatible

TMC has combined our CleanTop® design with several new proprietary design features, cleaning methods, and a vacuum pump-down procedure to attain a level of vacuum compatibility previously unattainable.

## 2. Select Table Dimensions

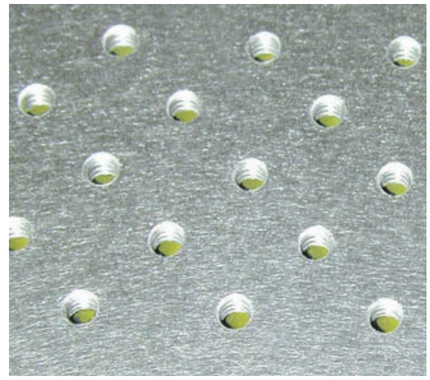
Overall table length and width should be determined based on the best suitability at your location. Consider the space available, the size and mass of the items being placed on top of the table, as well as the overall mass of the entire system for installation purposes. Standard dimensions are available up to 5 ft. wide and 16 ft. long. Please contact TMC if a custom size is required.

### Overall Top Thickness

A top length-to-thickness ratio of 10:1 is a safe rule of thumb for most applications, although for very sensitive work in severe environments, a ratio of 7:1 may be justified. It should also be kept in mind that while top thickness is proportional to top static rigidity and dynamic natural frequency, it does not directly affect compliance, which is primarily controlled by structural damping. Standard optical tops are available in 8 in., 12 in., 18 in. and 24 in.

Small, 2 in. (50 mm) thick tops should be supported on uniform flat surfaces, not post mounts. Our 4 in. (100 mm) thick tops may be supported on post mounts, but they do not incorporate the same proprietary damping techniques used on our thicker tops.

We recommend that all sensitive work be done on tops at least 8 in. (200 mm) thick.



## 3. Tapped Holes

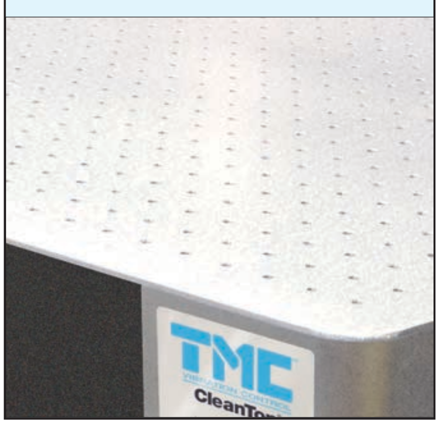
TMC offers both imperial 1/4-20 tapped holes on 1 in. centers and metric M6 tapped holes on 25 mm centers. Though there is no price difference between tops, imperial tops have imperial overall dimensions while metric tops have metric overall dimensions. The suffix designation determines the type of tapped hole, imperial or metric.

In addition, we now offer both imperial 1/4-20 tapped holes on 1 in. staggered centers and metric M6 on 25 mm staggered centers, doubling the number of tapped holes on conventional 1 in. or 25 mm grids. The DoubleDensity™ construction is available with any version of our CleanTop® at a nominal additional fee. For more information on DoubleDensity tops, see page 44.

| Surface Dimensions | | |
|---|---|---|
| **in.** | **ft.** | **m** |
| 30 x 60 | | 0.75 x 1.5 |
| 30 x 72 | | 0.75 x 1.8 |
| 30 x 96 | | 0.75 x 2.4 |
| 30 x 120 | | 0.75 x 3.0 |
| 36 x 60 | 3 x 5 | 0.9 x 1.5 |
| 36 x 72 | 3 x 6 | 0.9 x 1.8 |
| 36 x 96 | 3 x 8 | 0.9 x 2.4 |
| 36 x 120 | 3 x 10 | 0.9 x 3.0 |
| 40 x 60 | | 1.0 x 1.5 |
| 40 x 80 | | 1.0 x 2.0 |
| 40 x 120 | | 1.0 x 3.0 |
| 48 x 48 | 4 x 4 | 1.2 x 1.2 |
| 48 x 60 | 4 x 5 | 1.2 x 1.5 |
| 48 x 72 | 4 x 6 | 1.2 x 1.8 |
| 48 x 96 | 4 x 8 | 1.2 x 2.4 |
| 48 x 120 | 4 x 10 | 1.2 x 3.0 |
| 48 x 144 | 4 x 12 | 1.2 x 3.6 |
| 48 x 168 | 4 x 14 | 1.2 x 4.2 |
| 48 x 192 | 4 x 16 | 1.2 x 4.8 |
| 59 x 60 | 5 x 5 | 1.5 x 1.5 |
| 59 x 72 | 5 x 6 | 1.5 x 1.8 |
| 59 x 80 | | 1.5 x 2.0 |
| 59 x 96 | 5 x 8 | 1.5 x 2.4 |
| 59 x 120 | 5 x 10 | 1.5 x 3.0 |
| 59 x 144 | 5 x 12 | 1.5 x 3.6 |
| 59 x 168 | 5 x 14 | 1.5 x 4.2 |
| 59 x 192 | 5 x 16 | 1.5 x 4.8 |

**Radius Corners**

TMC tops now include a user-friendly 1 in. radius corner as a standard feature at no extra charge. These "hip-savers" are especially appreciated in darkened rooms. This feature does not impact overall dimensions or the hole pattern.



# How to configure your CleanTop® Optical Top part number

1. Select a performance level or specialty type code from the Prefix Chart.
2. Select a size code for any one the thicknesses indicated from the Size Chart.
3. Select a suffix code indicating hole pattern/laser ports requirements from the Suffix Chart.

## Model Number Examples

**784 — 455 — 02R**

| 1 Prefix Code | 2 Size Code | 3 Suffix Code |
|---|---|---|
| Performance/ Damping Level | Basic Part Size code | Hole Pattern/ Laser Ports |
| Research Performance Level | 48 in. x 96 in. x 8 in. | 1 in. centers - 1/4-20 |

**714 — 675 — 12DR**

| 1 Prefix Code | 2 Size Code | 3 Suffix Code |
|---|---|---|
| Performance/ Damping Level | Basic Part Size code | Hole Pattern/ Laser Ports |
| Non-Magnetic Specialty Type | 1.5 m x 3.0 m x 12 | M6 25mm staggered centers double density holes |

## 1. Prefix Chart

| Code | CleanTop® Performance Level | Damping Level |
|---|---|---|
| 784 | Research Grade | Maximum structural damping |
| 783 | Scientific Grade | Standard structural damping |
| 781 | Laboratory Grade | Nominal structural damping |
| **Code** | **CleanTop® Specialty Type** | |
| 794 | ClassOne™ (cleanroom compatible) | Maximum structural damping |
| 794ss | ClassOne™ (cleanroom compatible) | Maximum structural damping (stainless steel cups) |
| 793 | ClassOne™ (cleanroom compatible) | Standard structural damping |
| 793ss | ClassOne™ (cleanroom compatible) | Standard structural damping (stainless steel cups) |
| 714 | Non-Magnetic | Maximum structural damping (304 Alloy) |
| 714L | Non-Magnetic 316L | Maximum structural damping (316 Alloy) |
| 730 | Vacuum Compatible | n/a |

## 2. Size Chart

| Surface Dimensions | | | Code | | | |
|---|---|---|---|---|---|---|
| in. | ft | m | 8 in. Thick (200 mm) | 12 in.Thick (300 mm) | 18 in.Thick (450 mm) | 24 in.Thick (600 mm) |
| 30 x 60 | | 0.75 x 1.5 | – 432 – | – 632 – | | |
| 30 x 72 | | 0.75 x 1.8 | – 491 – | – 691 – | | |
| 30 x 96 | | 0.75 x 2.4 | – 492 – | – 692 – | | |
| 30 x 120 | | 0.75 x 3.0 | – 493 – | – 693 – | | |
| 36 x 60 | 3 x 5 | 0.9 x 1.5 | – 436 – | – 636 – | | |
| 36 x 72 | 3 x 6 | 0.9 x 1.8 | – 439 – | – 639 – | | |
| 36 x 96 | 3 x 8 | 0.9 x 2.4 | – 440 – | – 640 – | – 740 – | – 840 – |
| 36 x 120 | 3 x 10 | 0.9 x 3.0 | – 494 – | – 694 – | – 794 – | – 894 – |
| 40 x 60 | | 1.0 x 1.5 | – 443 – | – 643 – | | |
| 40 x 80 | | 1.0 x 2.0 | – 444 – | – 644 – | – 744 – | – 844 – |
| 40 x 120 | | 1.0 x 3.0 | – 445 – | – 645 – | – 745 – | – 845 – |
| 48 x 48 | 4 x 4 | 1.2 x 1.2 | – 447 – | – 647 – | | |
| 48 x 60 | 4 x 5 | 1.2 x 1.5 | – 449 – | – 649 – | | |
| 48 x 72 | 4 x 6 | 1.2 x 1.8 | – 451 – | – 651 – | – 751 – | – 851 – |
| 48 x 96 | 4 x 8 | 1.2 x 2.4 | – 455 – | – 655 – | – 755 – | – 855 – |
| 48 x 120 | 4 x 10 | 1.2 x 3.0 | – 459 – | – 659 – | – 759 – | – 859 – |
| 48 x 144 | 4 x 12 | 1.2 x 3.6 | – 463 – | – 663 – | – 763 – | – 863 – |
| 48 x 168 | 4 x 14 | 1.2 x 4.2 | – 465 – | – 665 – | – 765 – | – 865 – |
| 48 x 192 | 4 x 16 | 1.2 x 4.8 | – 467 – | – 667 – | – 767 – | – 867 – |
| 59 x 60 | 5 x 5 | 1.5 x 1.5 | – 470 – | – 670 – | – 770 – | – 870 – |
| 59 x 72 | 5 x 6 | 1.5 x 1.8 | – 471 – | – 671 – | – 771 – | – 871 – |
| 59 x 80 | | 1.5 x 2.0 | – 472 – | – 672 – | – 772 – | – 872 – |
| 59 x 96 | 5 x 8 | 1.5 x 2.4 | – 473 – | – 673 – | – 773 – | – 873 – |
| 59 x 120 | 5 x 10 | 1.5 x 3.0 | – 475 – | – 675 – | – 775 – | – 875 – |
| 59 x 144 | 5 x 12 | 1.5 x 3.6 | – 476 – | – 676 – | – 776 – | – 876 – |
| 59 x 168 | 5 x 14 | 1.5 x 4.2 | – 477 – | – 677 – | – 777 – | – 877 – |
| 59 x 192 | 5 x 16 | 1.5 x 4.8 | – 478 – | – 678 – | – 778 – | – 878 – |
| Weight Factor (WF) (approx.); Area x WF = Total Weight | | | 0.225 lb/in.$^2$ (0.016 kg/cm$^2$) | 0.265 lb/in.$^2$ (0.019 kg/cm$^2$) | 0.420 lb/in.$^2$ (0.030 kg/cm$^2$) | 0.475 lb/in.$^2$ (0.033 kg/cm$^2$) |

**(Migro-g® Supports Specified Separately)**

## 3. Suffix Chart

| Code | Hole Pattern - Threads | Double Density* | Laser Port** |
|---|---|---|---|
| 00R | No Holes | no | no |
| 01R | 1 in. centers - 1/4-20 | no | yes |
| 02R | 1 in. centers - 1/4-20 | no | no |
| 11R | 25 mm centers - M6 | no | yes |
| 12R | 25 mm centers - M6 | no | no |
| 01DR | 1 in. staggered centers - 1/4-20 | yes | yes |
| 02DR | 1 in. staggered centers - 1/4-20 | yes | no |
| 11DR | 25 mm staggered centers - M6 | yes | yes |
| 12DR | 25 mm staggered centers - M6 | yes | no |

* see page 44 ** see page 47

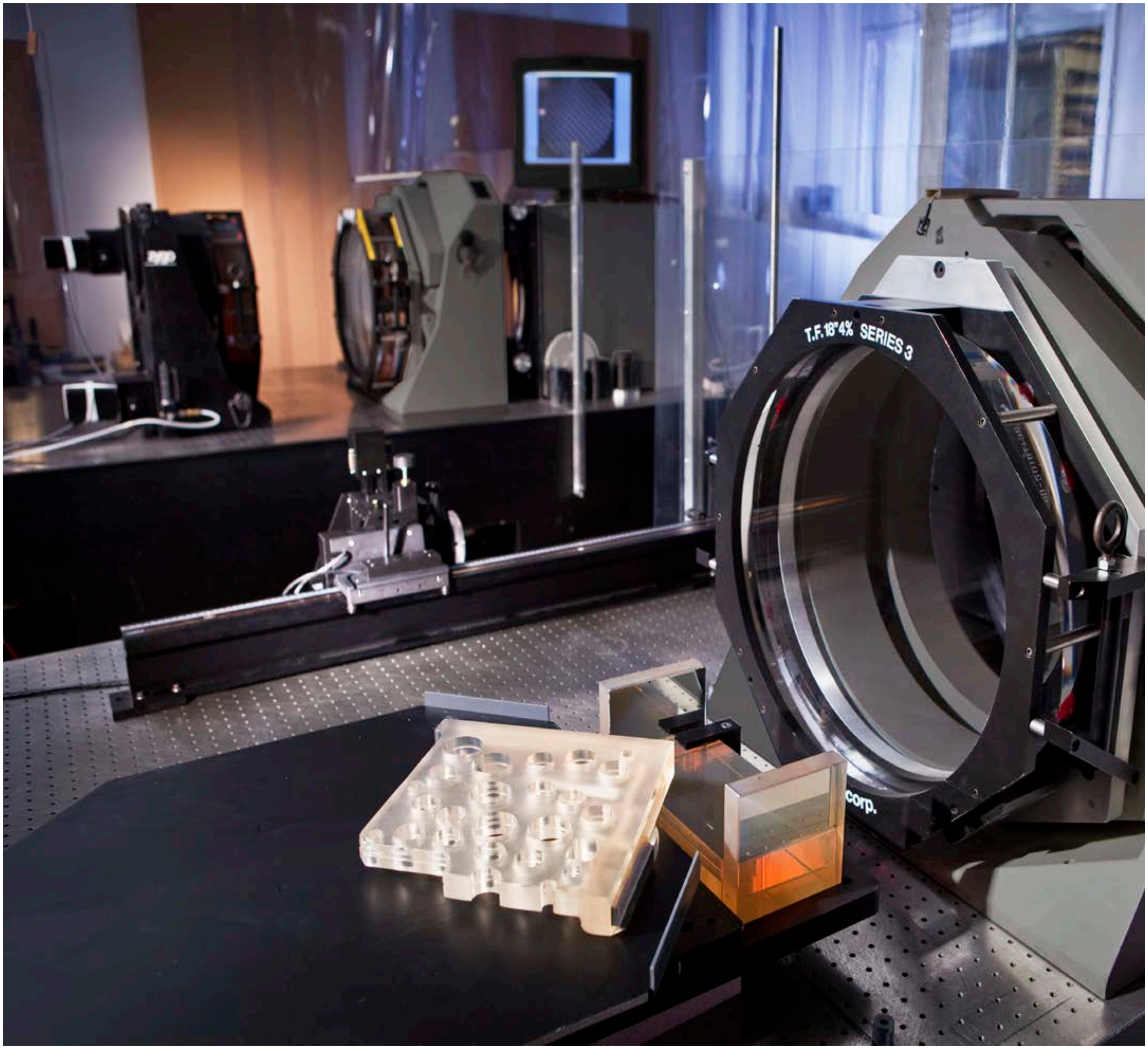



*Photo courtesy of Zygo Corporation*

### 784 Performance Series

# Research Grade CleanTop® Optical Top

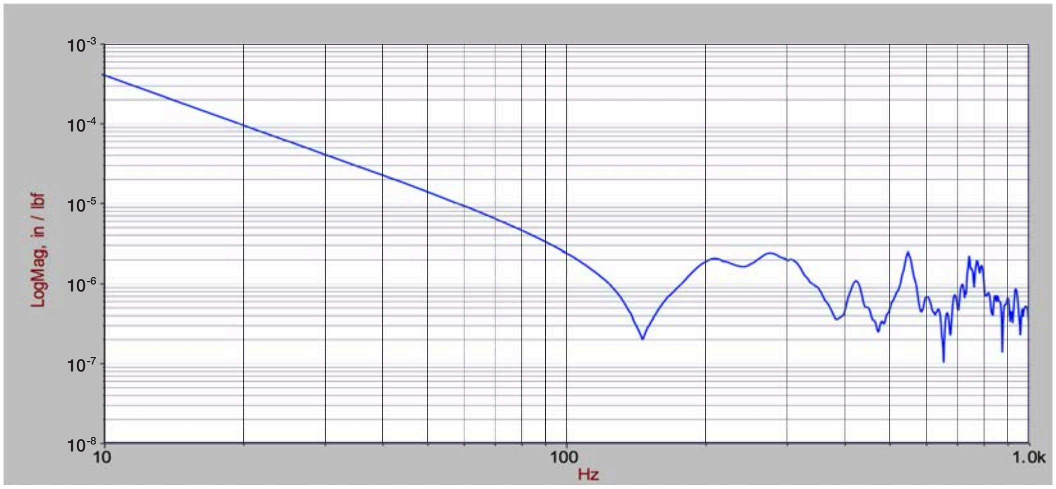

## Features

- Maximum Structural Damping – Research Grade
- CleanTop individual nylon cups under each tapped hole are airtight (25mm)

## General Specifications

**Core:** Steel honeycomb, closed-cell, 0.010 in. thick foil
**Core shear modulus:** 275,000 psi
**Core cell size:** <0.5 in.$^2$
**Core density:** 13.3 lb/ft$^3$ (230 kg/m$^3$)
**Flatness:** ∓ 0.005 in. (0.13 mm)
**Top skin:** 430 series ferromagnetic stainless steel, 3/16 in. thick (5 mm)
**Sidewalls:** Damped, formed steel channel, vinyl covered
**Tapped holes:** Backed by 1 in. (25 mm) long CleanTop nylon cups

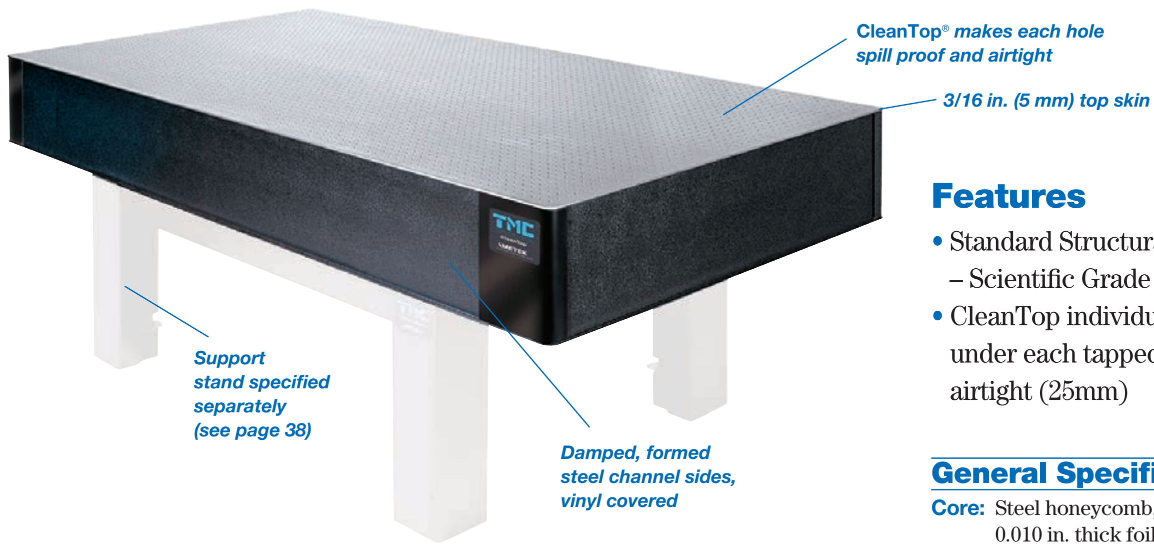
Research Grade CleanTop® provides the ultimate in optical top performance. Unmatched in the industry, Research Grade performance combines the smallest cell-size and highest core density with the unique CleanTop® design, all-steel construction, and the highest level of structural damping commercially available. Research Grade CleanTops are recommended for the most demanding applications including interferometers, holography, and ultra-fast lasers, as well as the most severe floor vibration environments. For the best overall vibration control, consider combining this top with a STACIS® iX support, a hybrid air/piezoelectric, 2-stage vibration cancellation system (page 39).




*Corner Compliance data measures the displacement of the top in response to impact by a calibrated hammer. The lack of response below 300 Hz is indicative of extremely high damping and excellent overall structural performance. Compliance was measured on a 48 in. x 96 in. x 12 in. top.*

### 783 Performance Series

# Scientific Grade CleanTop® Optical Top



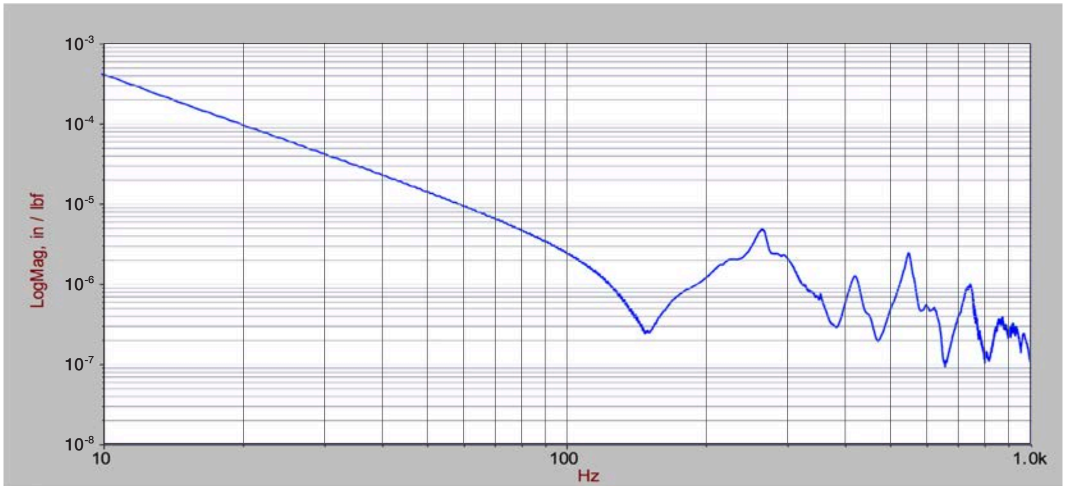

Scientific Grade CleanTop® provides a high level of optical top performance with reduced structural damping. Scientific Grade has the same design features as Research Grade including core size and density, CleanTop cups, and all-steel construction with reduced damping. Peak compliance levels for Scientific Grade damping exceed peak compliance levels of Research Grade damping by a factor of 4.

## Features

- Standard Structural Damping – Scientific Grade
- CleanTop individual nylon cups under each tapped hole are airtight (25mm)

## General Specifications

**Core:** Steel honeycomb, closed-cell, 0.010 in. thick foil
**Core shear modulus:** 275,000 psi
**Core cell size:** <0.5 in.$^2$
**Core density:** 13.3 lb/ft$^3$ (230 kg/m$^3$)
**Flatness:** ∓ 0.005 in. (0.13 mm)
**Top skin:** 430 series ferromagnetic stainless steel, 3/16 in. thick (5 mm)
**Sidewalls:** Damped, formed steel channel, vinyl covered
**Tapped holes:** Backed by 1 in. (25 mm) long CleanTop nylon cups

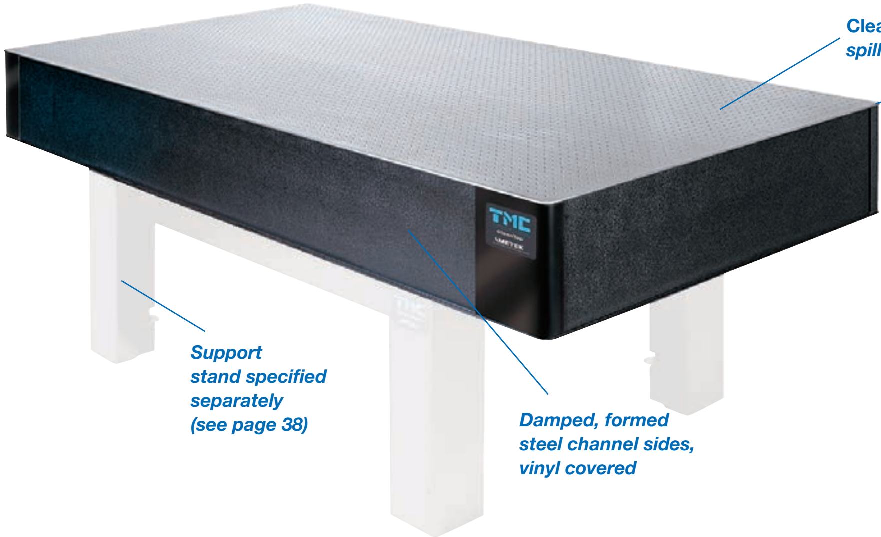



*Corner Compliance data measured on the Scientific Grade demonstrates a higher peak compliance value than the Research Grade. Compliance was measured on a 48 in. x 96 in. x 12 in. top.*

3

## 781 Performance Series

# Laboratory Grade CleanTop® Optical Top



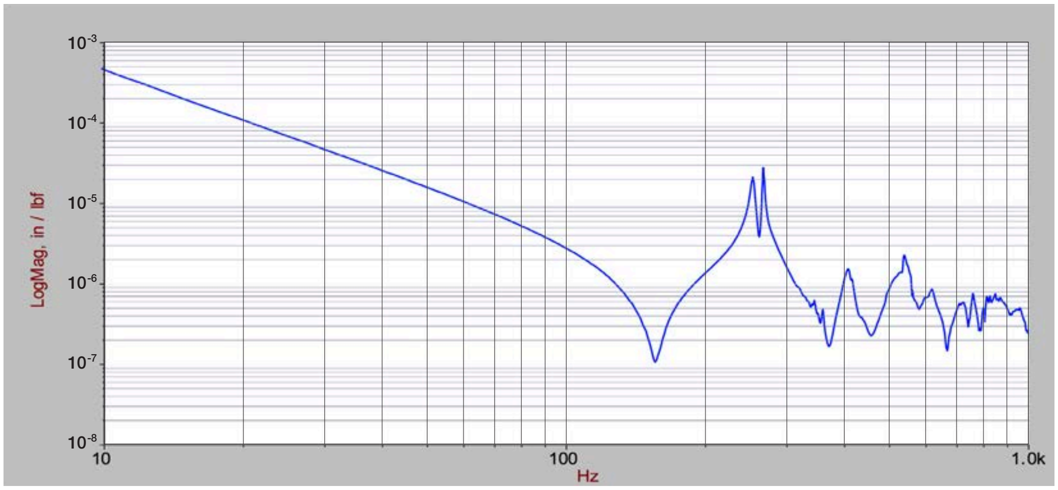

Laboratory Grade CleanTop® provides an economical performance level for the least sensitive applications in less severe floor vibration environments. The Laboratory Grade is appropriate for general lab applications where the primary requirement is for a rigid, flat mounting surface.

## Features

- Nominal Structural Damping – Laboratory Grade
- CleanTop individual nylon cups under each tapped hole are airtight (25mm)

## General Specifications

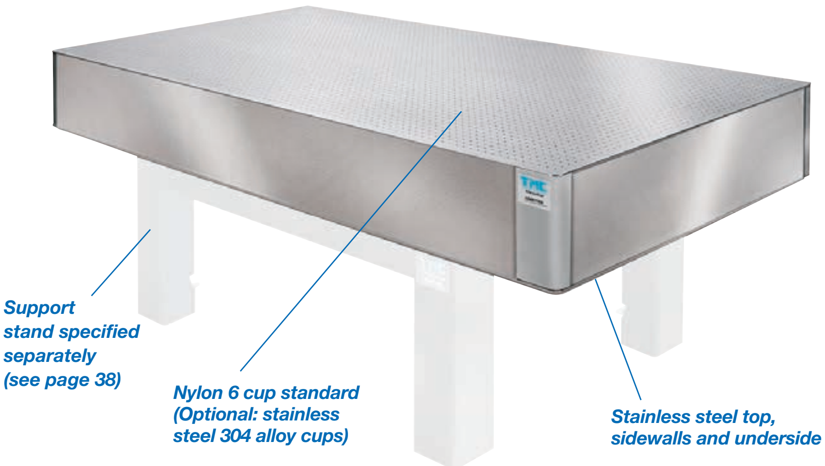
**Core:** Steel honeycomb, closed-cell, 0.010 in. thick foil
**Core shear modulus:** 275,000 psi
**Core cell size:** <0.5 in.$^2$
**Core density:** 13.3 lb/ft$^3$ (230 kg/m$^3$)
**Flatness:** ∓ 0.005 in. (0.13 mm)
**Top skin:** 430 series ferromagnetic stainless steel, 3/16 in. thick (5 mm)
**Sidewalls:** Damped, formed steel channel, vinyl covered
**Tapped holes:** Backed by 1 in. (25 mm) long CleanTop nylon cups




*Corner Compliance data measured on the Laboratory Grade shows higher amplification at the table's resonant frequency. Compliance was measured on a 48 in. x 96 in. x 12 in. top.*

## 790 Specialty Series

# ClassOne™ CleanTop® Optical Top




Our 790 Series, ClassOne™ CleanTop® optical top design is an extension of the original CleanTop adapted for cleanrooms. It is Class 100 cleanroom compatible with an all-stainless steel construction. Maximum and standard damping levels are available as well as stainless CleanTop cups, if preferred.

## Features

- 3/16 in. (5 mm) thick top skin
- Two levels of fixed damping
- Individual cups under each tapped hole are airtight
- Stainless steel top, bottom, sides
- Cleanroom-compatible design and packaging

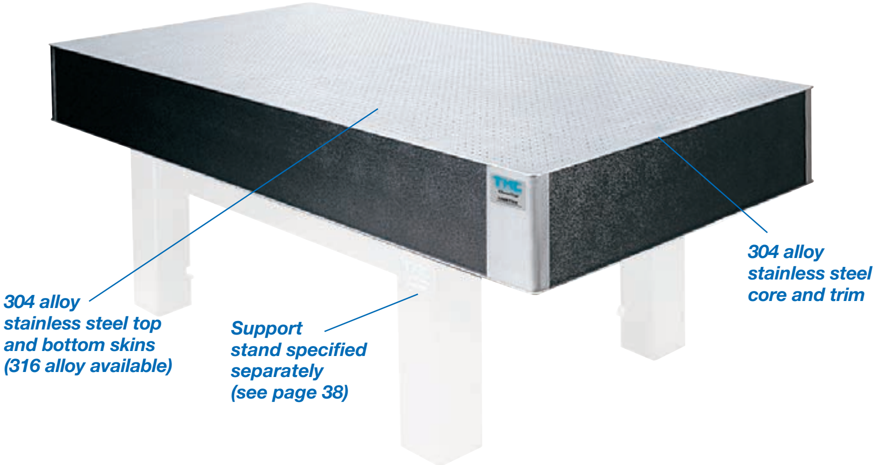
## General Specifications

**Core:** Steel honeycomb, closed-cell, 0.010 in. thick foil
**Core shear modulus:** 275,000 psi
**Core cell size:** <0.5 $in.^2$
**Core density:** 13.3 $lbs/ft^3$ (230 $kg/m^3$)
**Flatness:** $\mp$ 0.005 in. (0.13 mm)
**Top and bottom skins:** 430 series ferromagnetic stainless steel
**Sidewalls:** Stainless steel with damped interior surface
**Tapped holes:** Backed by 1 in. (25 mm) long nylon (optional stainless steel 304 alloy) cups


*TMC ClassOne™ CleanTop® Optical Top in a 36 in. thick custom configuration featuring stainless steel top and bottom skins and sidewalls, as well as custom mounted vertical tapped surfaces inside a large cutout. We can provide many custom shapes and sizes to meet the most unusual applications. Please contact TMC if you are unable to locate a product that suits your needs.*

### 710 Specialty Series

# Non-Magnetic CleanTop® Optical Top




## Features

- 100% constructed from 304 alloy, 316 stainless steel skin available (non-magnetic).
- 0.165 in. thick top and bottom skins.
- CleanTop proprietary spill-proof tapped hole design.

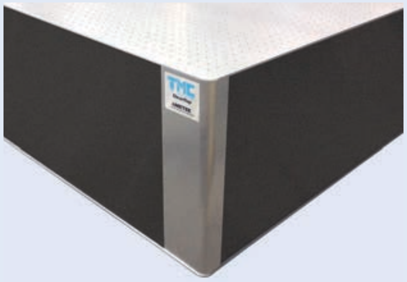
## General Specifications

**Core:** 304 alloy stainless steel honeycomb, closed-cell, 0.010 in. thick foil
**Core shear modulus:** 275,000 psi
**Core cell size:** <0.5 in.$^2$
**Core density:** 13.3 lb/ft$^3$ (230 kg/m$^3$)
**Flatness:** $\mp$ 0.005 in. (0.13 mm)
**Skins:** 304 alloy stainless steel
**Sidewalls:** Vinyl covered composite side with damped interior surface
**Tapped holes:** Backed by 1 in. (25 mm) long nylon cups

TMC's CleanTop® Optical Top, available in a "non-magnetic" construction, is recommended for applications requiring the support of a high-strength magnet or the maintenance of a homogenous magnetic field.

Though no alloy of stainless steel can be 100% non-magnetic, the lower carbon content of the 300 series alloys offers a dramatic reduction in ferromagnetic properties. Alloys are available with even less ferromagnetism than 304 alloy such as 316. For more information on the 316 stainless steel top, contact TMC.

*TMC routinely designs and manufactures complex vibration isolation systems to support high strength superconducting magnets. TMC has become expert in the non-ferromagnetic material requirements for these high magnetic field environments.*



## 730 Specialty Series

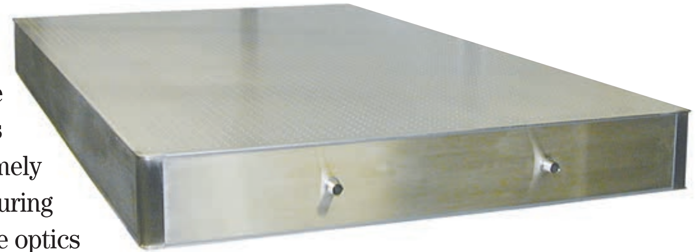
# Vacuum Compatible CleanTop® Optical Top

Historically, it has been extremely difficult if not impossible to adapt steel honeycomb optical tops to meet the rigorous requirements of vacuum chamber applications. Engineers have sacrificed the rigidity, flatness, damping, and convenience of optical tops for baked, vacuum compatible machined structures of aluminum and stainless steel. Until now.

TMC has combined our inherently clean CleanTop® design with several new proprietary design features, cleaning methods, and a vacuum pump-down procedure developed for the University of Texas' Petawatt Laser Project to achieve a level of vacuum compatibility previously unattainable. Though this new design does not require baking (and is incompatible with baking), engineers at University of Texas' Petawatt Laser have achieved 8 x $10^{-7}$ torr in a 7-foot diameter, 380 cubic foot chamber containing a 14-foot long CleanTop Optical Top.

Closely correlated with their vacuum compatibility is the fact that these tops only out-gas extremely small amounts ensuring they do not damage optics (because attaining the target vacuum level would be of little value if the top emitted enough contamination to damage optics). The top for the Petawatt Laser application was demonstrated to cause less than a 0.1% loss in optical transmission of a test optic.

We cannot guarantee precisely what level of vacuum you will achieve or what ratio of optical transmission you will maintain. But, we can guarantee that we will provide you with the same design features, cleaning methods, and recommended pumping procedures that assisted the University of Texas' Petawatt Laser in attaining a vacuum level of 8 x $10^{-7}$ torr and less than 0.1% transmission loss.



*The table shown is TMC catalog number 730-455-02R. This is a 48 in. x 96 in. x 8 in. CleanTop® Optical Top adapted for vacuum chamber installation.*

## Features

- Proprietary CleanTop clean optical top design
- Stainless steel honeycomb core
- Stainless steel CleanTop cups
- Vacuum compatible core geometry
- Vent fittings on table end-wall
- Special cleaning of process materials
- Cleaning and packing in accordance with strict standards of NIF Project (National Ignition Facility at Lawrence Livermore National Labs)
- Special pump-down procedure used in conjunction
- Developed in cooperation with the University of Texas Petawatt Laser Project (though not officially endorsed by U.T.)

### How to Order

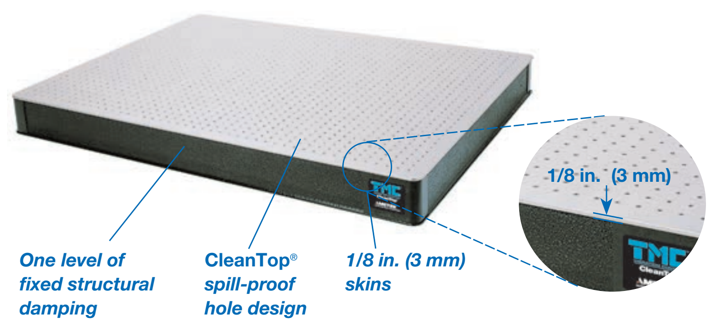
Contact a TMC Applications Engineer for part numbers and pricing as well as vacuum pump-down procedures, details, and instructions.

*A 14-foot long TMC vacuum compatible CleanTop® Optical Top mounted in a 7-foot diameter, 380 cubic foot vacuum chamber (shown with Siskiyou large, vacuum compatible, round-optics mounts). Photo courtesy of Texas Center for High Intensity Laser Science (The Texas Petawatt Laser) at the The University of Texas - Austin*

# CleanTop® Breadboards 2 and 4 in. Thick (50, 100 mm)

## 78 Series — 3/16 in. Skins (5 mm)


## 77 Series — 1/8 in. Skins (3 mm)




TMC's 78 and 77 Series CleanTop® Breadboards provide the ultimate in rigidity and damping for smaller tops. Available in both 2 and 4 in. thicknesses (50, 100 mm), these tops include the same proprietary CleanTop spill-proof hole technology and small cell, high-density steel honeycomb core as our largest tops. These tops can be readily designed to meet custom requirements including custom mounting hole patterns, through-holes, special shapes and custom materials. TMC's 78 and 77 Series CleanTop Breadboards are recommended for virtually all demanding breadboard applications.

### Model Number Example

| 78 or 77 | — 219 — | 02R |
|---|---|---|
| **Prefix** | **Size** | **Suffix** |
| CleanTop 1/8 in. or 3/16 in. skins | 24 in. x 48 in. x 4 in. | 1/4 in.- 20 holes on 1 centers Radius corners |

### General Specifications

**Core:** Steel honeycomb, closed-cell, 0.010 in. (0.2 mm) thick foil
**Core shear modulus:** 275,000 psi (19,300 kg/cm²)
**Core cell size:** <0.5 in.² (3 cm²)
**Core density:** 13.3 lb/ft³ (230 kg/m³)
**Flatness:** ∓ 0.005 in. (0.13 mm)
**Top skin:** 430 series ferromagnetic stainless steel, 1/8 in. or 3/16 in. thick
**Sidewalls:** Damped, formed steel channel, vinyl covered
**Tapped holes:** Backed by 1 in. (25 mm) long CleanTop nylon cups

## 1. Prefix Chart

| Skin Thickness | Prefix |
|---|---|
| 1/8 in. (3 mm) | 77 |
| 3/16 in. (5 mm) | 78 |

## 2. Size Chart

| Surface Dimensions | | | 78 Series | | 77 Series | |
|---|---|---|---|---|---|---|
| in. | ft | m | 2 in. (50 mm) | 4in. (100 mm) | 2 in. (50 mm) | 4 in. (100 mm) |
| 12 x 12 | 1 x 1 | 0.3 x 0.3 | – 105 – | – 205 – | – 105 – | – 205 – |
| 12 x 24 | 1 x 2 | 0.3 x 0.6 | – 107 – | – 207 – | – 107 – | – 207 – |
| 12 x 36 | 1 x 3 | 0.3 x 0.9 | – 108 – | – 208 – | – 108 – | – 208 – |
| 12 x 48 | 1 x 4 | 0.3 x 1.2 | – 109 – | – 209 – | – 109 – | – 209 – |
| 12 x 72 | 1 x 6 | 0.3 x 1.8 | – 110 – | – 210 – | – 110 – | – 210 – |
| 20 x 30 | | 0.5 x 0.75 | – 111 – | – 211 – | – 111 – | – 211 – |
| 20 x 40 | | 0.5 x 1.0 | – 112 – | – 212 – | – 112 – | – 212 – |
| 24 x 24 | 2 x 2 | 0.6 x 0.6 | – 113 – | – 213 – | – 113 – | – 213 – |
| 24 x 36 | 2 x 3 | 0.6 x 0.9 | – 115 – | – 215 – | – 115 – | – 215 – |
| 24 x 48 | 2 x 4 | 0.6 x 1.2 | – 119 – | – 219 – | – 119 – | – 219 – |
| 24 x 60 | 2 x 5 | 0.6 x 1.5 | – 121 – | – 221 – | – 121 – | – 221 – |
| 24 x 72 | 2 x 6 | 0.6 x 1.8 | – 123 – | – 223 – | – 123 – | – 223 – |
| 24 x 96 | 2 x 8 | 0.6 x 2.4 | – 124 – | – 224 – | – 124 – | – 224 – |
| 30 x 30 | | 0.75 x 0.75 | – 125 – | – 225 – | – 125 – | – 225 – |
| 30 x 36 | | 0.75 x 0.9 | – 127 – | – 227 – | – 127 – | – 227 – |
| 30 x 40 | | 0.75 x 1.0 | – 129 – | – 229 – | – 129 – | – 229 – |
| 30 x 48 | | 0.75 x 1.2 | – 131 – | – 231 – | – 131 – | – 231 – |
| 30 x 60 | | 0.75 x 1.5 | – 132 – | – 232 – | – 132 – | – 232 – |
| 30 x 72 | | 0.75 x 1.8 | – 191 – | – 291 – | – 191 – | – 291 – |
| 30 x 96 | | 0.75 x 2.4 | – 192 – | – 292 – | – 192 – | – 292 – |
| 36 x 36 | 3 x 3 | 0.9 x 0.9 | – 133 – | – 233 – | – 133 – | – 233 – |
| 36 x 48 | 3 x 4 | 0.9 x 1.2 | – 135 – | – 235 – | – 135 – | – 235 – |
| 36 x 60 | 3 x 5 | 0.9 x 1.5 | – 136 – | – 236 – | – 136 – | – 236 – |
| 36 x 72 | 3 x 6 | 0.9 x 1.8 | – 139 – | – 239 – | – 139 – | – 239 – |
| 36 x 96 | 3 x 8 | 0.9 x 2.4 | – 140 – | – 240 – | – 140 – | – 240 – |
| 40 x 40 | | 1.0 x 1.0 | – 141 – | – 241 – | – 141 – | – 241 – |
| 40 x 60 | | 1.0 x 1.5 | – 143 – | – 243 – | – 143 – | – 243 – |
| 40 x 80 | | 1.0 x 2.0 | – 144 – | – 244 – | – 144 – | – 244 – |
| 48 x 48 | 4 x 4 | 1.2 x 1.2 | – 147 – | – 247 – | – 147 – | – 247 – |
| 48 x 60 | 4 x 5 | 1.2 x 1.5 | – 149 – | – 249 – | – 149 – | – 249 – |
| 48 x 72 | 4 x 6 | 1.2 x 1.8 | – 151 – | – 251 – | – 151 – | – 251 – |
| 48 x 96 | 4 x 8 | 1.2 x 2.4 | – 155 – | – 255 – | – 155 – | – 255 – |
| Weight Factor (WF) | | lb/in.² | 0.135 | 0.195 | .100 | 0.150 |
| Area x WF = Total Weight | | kg/cm² | 0.01 | 0.014 | 0.007 | 0.011 |

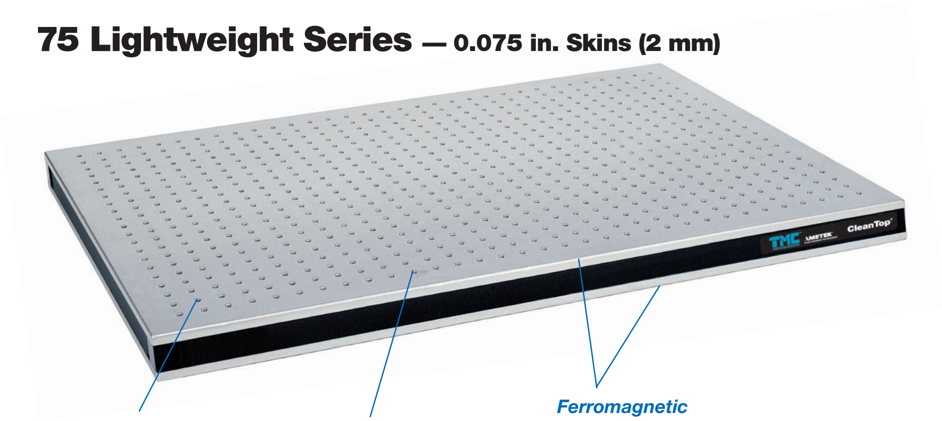
## 3. Suffix Chart

| Suffix | Hole Pattern - -Threads | Double Density* | Laser Port** |
|---|---|---|---|
| 00R | No Holes | no | no |
| 01R | 1 in. centers - 1/4-20 | no | yes |
| 02R | 1 in.centers - 1/4-20 | no | no |
| 11R | 25 mm centers - M6 | no | yes |
| 12R | 25 mm centers - M6 | no | no |
| 01DR | 1 in. staggered centers - 1/4-20 | yes | yes |
| 02DR | 1 in. staggered centers - 1/4-20 | yes | no |
| 11DR | 25 mm staggered centers - M6 | yes | yes |
| 12DR | 25 mm staggered centers - M6 | yes | no |

* see page 44 ** see page 47

# CleanTop® Breadboards 2 in. Thick (50 mm)

## 75 Lightweight Series — 0.075 in. Skins (2 mm)




Another in a long line of TMC innovations, our 75 Series Breadboards minimize both weight and cost. A patented manufacturing technique allows us to form countersunk, tapped holes in a thin top skin of stainless steel. The holes are not drilled or punched, but fabricated in a way that effectively "thickens" the skin in a small ring around the threads. No inserts are used and the tapped holes are three threads deep.

These tops have relatively high levels of rigidity, as they utilize our standard steel core. However, with their thin top and bottom skins, they cannot have the rigidity and damping properties of our 78 and 77 CleanTop® Breadboards. They are ideal when light loads are anticipated and low weight and/or cost are the most crucial factors.

The weight savings – 50% less than our 78 Series Breadboards – is derived only from the lighter gauge skins.

This lightweight design is available from stock in the sizes listed below. A full range of sizes and materials is available on a custom basis. Contact TMC for pricing and delivery for custom configurations.

## General Specifications

**Core:** Steel honeycomb, closed-cell, 0.010 in. (0.2 mm) thick foil

**Core shear modulus:** 275,000 psi (19,300 kg/cm²)

**Core cell size:** <0.5 in.² (3 cm²)

**Core density:** 13.3 lb/ft³ (230 kg/m³)

**Flatness:** ∓ 0.005 in. (0.13 mm)

**Top skin:** 430 series stainless steel, 0.075 in. (2 mm) thick

**Bottom skin:** 400 series stainless steel, 0.075 in. (2 mm) thick

**Sidewalls:** High-pressure laminate

**Tapped holes:** Backed by individual, CleanTop cups; 3 threads

## Features

- Ultra-lightweight design – weighs less than 9 lbs/ft² (44 kg/m²).
- Stainless steel top and bottom skins.
- Aluminum and carbon steel versions available.
- Very low prices, even in low quantity.
- Formed holes are countersunk and tapped three threads.
- Formed holes in top skin add to rigidity.
- CleanTop individual cups under each hole make the core spill proof.

## Ordering Chart — Model Number

| Surface Dimensions | | Model Number | | Weight | |
|---|---|---|---|---|---|
| in. | mm | 1/4 - 20 holes on 1 in. centers | M6 holes on 25 mm centers | lbs | kg |
| 19 x 23 | 450 x 600 | 75SSC – 103 – 02 | 75SSC – 103 – 12 | 31 | 14 |
| 19 x 47 | 450 x 1200 | 75SSC – 104 – 02 | 75SSC – 104 – 12 | 62 | 28 |
| 23 x 23 | 600 x 600 | 75SSC – 113 – 02 | 75SSC – 113 – 12 | 37 | 17 |
| 23 x 35 | 600 x 900 | 75SSC – 115 – 02 | 75SSC – 115 – 12 | 56 | 25 |
| 23 x 47 | 600 x 1200 | 75SSC – 119 – 02 | 75SSC – 119 – 12 | 74 | 34 |
| 35 x 47 | 900 x 1200 | 75SSC – 135 – 02 | 75SSC – 135 – 12 | 111 | 50 |

**Note:** Only the most common, stocked sizes are listed.
Contact TMC for more details.

3

## Micro-g®

# How to Select System 1 Post-Mount Supports

*Choose from Gimbal Piston™ isolators or rigid supports*


## Features

- Modular design for upgradability, maximum convenience
- Choose rigid support or Gimbal Piston™ air vibration isolation
- Retractable casters
- Safety tiebars
- A range of heights and capacities

## General Specifications

**Isolator natural frequency:**

**High Input**
Vertical = 1.0 Hz
Horizontal = 0.8 Hz
**Low Input**
Vertical = 1.2-1.7 Hz
Horizontal = 1.0-1.5 Hz

**Isolation efficiency @ 5 Hz:**
Vertical = 80-90%
Horizontal = 80-90%

**Isolation efficiency @ 10 Hz:**
Vertical = 90-99%
Horizontal = 90-99%

**Finish:** Medium texture black powder coat paint

**Facilities required:**
80 psi nitrogen or air

**Height control valves:**
repeatability standard valve
+/- 0.050 in. 1.3mm
**Precision valve:** +/- 0.005 in. (.13mm)
(Page 57)

Micro-g® gives you superior convenience and economy in acquiring precisely the equipment you need for supporting optical tables or other large work surfaces. The unique Micro-g design lets you customize basic features and still have off-the-shelf prices and speedy delivery.

There are six categories of options, and the convenient selection charts help you construct a part number for ordering. Systems can also be easily upgraded – whether to convert from a leveling stand to an isolator or add casters – whenever required.

## Options

### Isolators/Leveling Posts

If you need vibration isolation now, the choice is our Gimbal Piston™ isolators, which are unsurpassed in the industry for passive vertical and horizontal vibration attenuation – especially as demonstrated at realistic, low levels of input.

If a rigid stand will suffice for the present, Micro-g offers an economical leveling mount option with rugged, adjustable jack screws that provide +2 1/2 and -0 in. (+62 and -0 mm) of travel. Later, you can upgrade the system to full vibration isolation performance, with a total cost only slightly more than if you had opted for this feature originally.

### Load Capacities

Depending on the weight of your table and onboard equipment, you can select support systems with capacities of 1,400, 4,000, 6,000, 10,000, or 15,000 lb (600, 2,000, 3,000, 4,500, or 7,000 kg, respectively). Customized systems can be configured from standard components to support virtually any structure.

### Height

Seven post heights are available as standard: 12, 16, 18, 22, 24, 28, and 32 in. (300, 400, 450, 550, 600, 700, and 800 mm, respectively) – though not all sizes are available in all capacities. Taking into account the table thickness and height of equipment components, select the post size that provides the working height you need. Ergonomic convention would dictate 36 in. (900 mm) from floor to table top surface.

### Tiebars

For safety reasons, tiebars are recommended. They are mandatory when you choose casters or anticipate upgrading to them. If you require constant access to the area under the table, free-standing support bases will provide more than adequate stability.

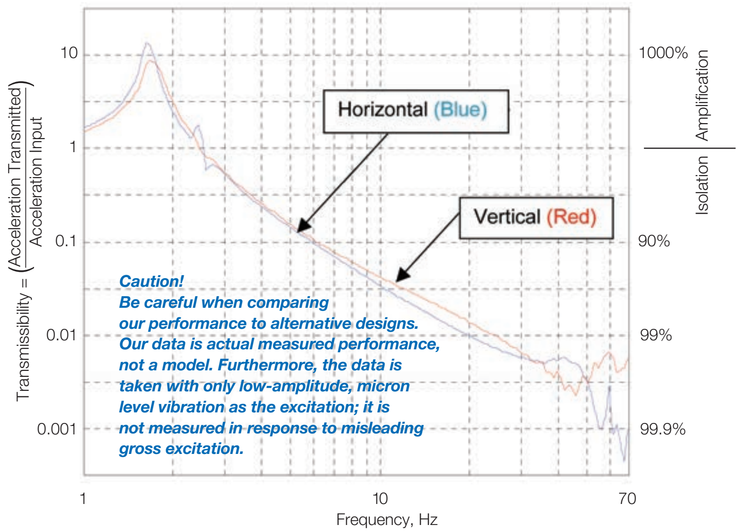
## Casters

Micro-g®'s optional casters are of a rugged, heavy-duty design making an installed table easily movable when they are engaged. Once the table is positioned, the casters retract to establish solid floor contact during equipment operation. Like other Micro-g features, they can be integrated at the outset or purchased later if you choose to upgrade. Casters retract externally on the smallest capacity posts, internally on the intermediate, and are not available for the highest capacity. They are not available on posts less than 18 in. tall.

## Configurations

A simple four-post frame configuration is the most common; however, depending on the size and shape of the supported structure and on the weight and position of onboard equipment, another multiple support system may be preferred. For unusual size tops or if you have any doubt as to your approach, please call us.

***System 1 Vibration Isolation Performance (actual measured data)***



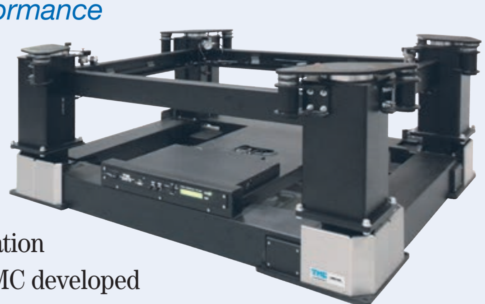

***Measured performance of TMC 14 Series Micro-g® System 1 Gimbal Piston™ Isolators***



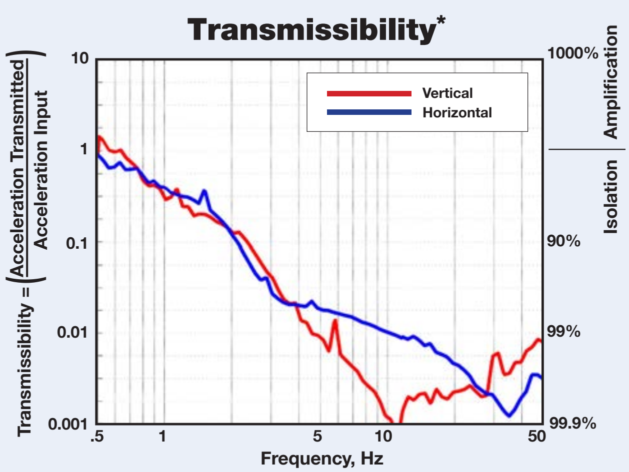
# STACIS® iX LaserTable-Base™

**Hybrid Piezoelectric/Air Active Vibration Cancellation System**

*New two-stage hybrid active/passive system achieves breakthrough vibration isolation performance*



For the ultimate in vibration isolation performance, TMC developed STACIS® iX LaserTable-Base™, a new, hybrid active/passive two-stage isolation system. Though low frequency air isolators provide excellent high frequency isolation, passive mass-spring-dampers actually amplify vibration at their resonant frequency, typically 1 to 3 Hz. LaserTable-Base combines the patented STACIS® piezoelectric vibration cancellation system achieving almost 20 dB of isolation at 2 Hz with TMC's MaxDamp® Gimbal Piston™ Isolators to provide unprecedented overall vibration isolation performance. LaserTable-Base is ideal for the most demanding, vibration-sensitive applications including atomic force microscopy, single molecule biophysics, laser trapping, and interferometry.




** 4,000 lb (1,800 kg) capacity LaserTable-Base™ with MaxDamp® Isolation System. Payload of 2,000 lbs (907 kg), tested with simulated floor vibration at VC-C (500 micro-inches per second, 12.5 microns per second).*

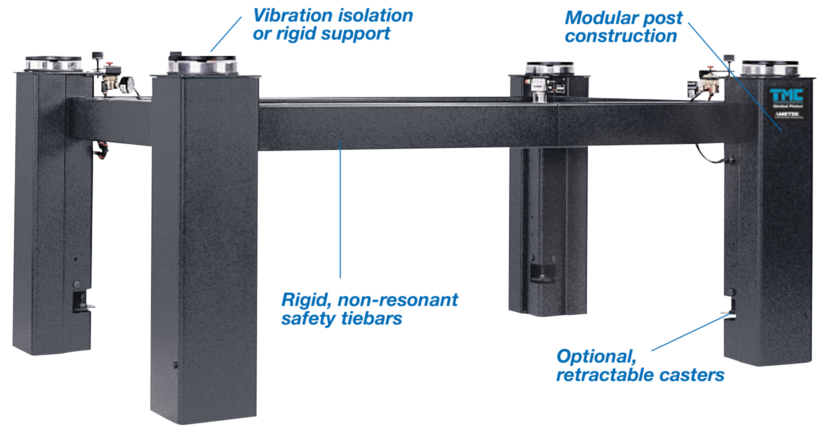
## Features

- Incorporates patented STACIS® technology
- Active inertial vibration cancellation system
- Vibration cancellation starts below 1 Hz
- 6 active degrees-of-freedom
- Consists of two isolation systems in series for maximum vibration cancellation
- Incorporates patented MaxDamp Air Isolators
- Simple, robust, and cost-effective
- Installs easily, minimal tuning required
- Optional shelves for mounting equipment under the table
- Includes TMC's DC-2000 Digital Controller

**Micro-g®**

# System 1 4-Post with Tiebars

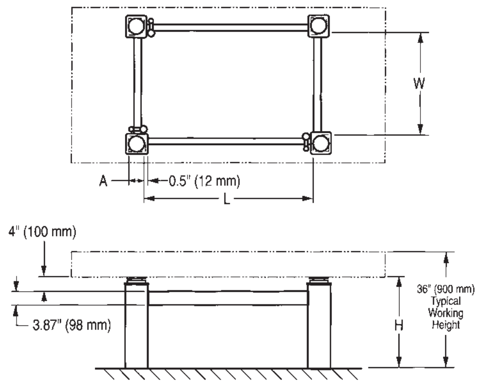
## Gimbal Piston™ Isolators or Rigid Supports





The preferred choice for supporting most optical tops is the 4-Post System with safety tiebars. Choose from vibration isolation or rigid support, with or without casters* from a range of heights and capacities. Baseplates or leveling baseplates can be added so the system can be fastened to the floor.

How to Order: See instructions on Page 41.




### Height Code Ordering Chart

| Height Code H | Height in. | Height mm | Standard Heights Available Prefix 11 & 12 | Standard Heights Available Prefix 13 & 14 |
|---|---|---|---|---|
| 2 | 12 | 300 | | • |
| 3 | 16 | 400 | | • |
| 4 | 18 | 450 | | • |
| 5 | 22 | 550 | | • |
| 6 | 24 | 600 | | • |
| 7 | 28 | 700 | • | • |
| 8 | 32 | 800 | • | • |

### 4-Post System Ordering Chart

| Application: Typical Size of Optical Top in. | Application: Typical Size of Optical Top mm | Gimbal Piston™ Isolators w/casters | Gimbal Piston™ Isolators w/o casters | Rigid Leveling Stand w/casters | Rigid Leveling Stand w/o casters | H Height: Specify Height Code | A Cross-Section in. | A Cross-Section mm | W Width in. | W Width mm | L Length in. | L Length mm | Capacity** lbs | Capacity** kg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 30 x 30 | 750 x 750 | 12 – 42H – 22 | 12 – 41H – 23 | 11 – 42H – 24 | 11 – 41H – 25 | See Height Code Ordering Chart | 4 | 100 | 20 | 500 | 20 | 500 | 1400 | 600 |
| 30 x 36 | 750 x 900 | 12 – 42H – 28 | 12 – 41H – 28 | 11 – 42H – 28 | 11 – 41H – 28 | | 4 | 100 | 20 | 500 | 26 | 650 | 1400 | 600 |
| 30 x 48 | 750 x 1200 | 12 – 42H – 29 | 12 – 41H – 29 | 11 – 42H – 29 | 11 – 41H – 29 | | 4 | 100 | 20 | 500 | 35 | 875 | 1400 | 600 |
| 30 x 60 | 750 x 1500 | 12 – 42H – 24 | 12 – 41H – 24 | 11 – 42H – 24 | 11 – 41H – 24 | | 4 | 100 | 20 | 500 | 40 | 1000 | 1400 | 600 |
| 30 x 72 | 750 x 1800 | 14 – 42H – 14 | 14 – 41H – 14 | 13 – 42H – 14 | 13 – 41H – 14 | | 6 | 150 | 15 | 375 | 40 | 1000 | 4000 | 2000 |
| 30 x 96 | 750 x 2400 | 14 – 42H – 15 | 14 – 41H – 15 | 13 – 42H – 15 | 13 – 41H – 15 | | 6 | 150 | 15 | 375 | 50 | 1250 | 4000 | 2000 |
| 30 x 120 | 750 x 3000 | 14 – 42H – 16 | 14 – 41H – 16 | 13 – 42H – 16 | 13 – 41H – 16 | | 6 | 150 | 15 | 375 | 60 | 1500 | 4000 | 2000 |
| 36 x 36 | 900 x 900 | 12 – 42H – 88 | 12 – 41H – 88 | 11 – 42H – 88 | 11 – 41H – 88 | | 4 | 100 | 26 | 650 | 26 | 650 | 1400 | 600 |
| 36 x 48 | 900 x 1200 | 12 – 42H – 89 | 12 – 41H – 89 | 11 – 42H – 89 | 11 – 41H – 89 | | 4 | 100 | 26 | 650 | 35 | 875 | 1400 | 600 |
| 36 x 60 | 900 x 1500 | 12 – 42H – 84 | 12 – 41H – 84 | 11 – 42H – 84 | 11 – 41H – 84 | | 4 | 100 | 26 | 650 | 40 | 1000 | 1400 | 600 |
| 36 x 72 | 900 x 1800 | 14 – 42H – 24 | 14 – 41H – 24 | 13 – 42H – 24 | 13 – 41H – 24 | | 6 | 150 | 20 | 500 | 40 | 1000 | 4000 | 2000 |
| 36 x 96 | 900 x 2400 | 14 – 42H – 25 | 14 – 41H – 25 | 13 – 42H – 25 | 13 – 41H – 25 | | 6 | 150 | 20 | 500 | 50 | 1250 | 4000 | 2000 |
| 36 x 120 | 900 x 3000 | 14 – 42H – 26 | 14 – 41H – 26 | 13 – 42H – 26 | 13 – 41H – 26 | | 6 | 150 | 20 | 500 | 60 | 1500 | 4000 | 2000 |
| 40 x 40 | 1000 x 1000 | 12 – 42H – 33 | 12 – 41H – 33 | 11 – 42H – 33 | 11 – 41H – 33 | | 4 | 100 | 30 | 750 | 30 | 750 | 1400 | 600 |
| 40 x 60 | 1000 x 1500 | 14 – 42H – 89 | 14 – 41H – 89 | 13 – 42H – 89 | 13 – 41H – 89 | | 6 | 150 | 26 | 650 | 35 | 875 | 4000 | 2000 |
| 40 x 80 | 1000 x 2000 | 14 – 42H – 84 | 14 – 41H – 84 | 13 – 42H – 84 | 13 – 41H – 84 | | 6 | 150 | 26 | 650 | 40 | 1000 | 4000 | 2000 |
| 40 x 120 | 1000 x 3000 | 14 – 42H – 86 | 14 – 41H – 86 | 13 – 42H – 86 | 13 – 41H – 86 | | 6 | 150 | 26 | 650 | 60 | 1500 | 4000 | 2000 |
| 48 x 48 | 1200 x 1200 | 14 – 42H – 33 | 14 – 41H – 33 | 13 – 42H – 33 | 13 – 41H – 33 | | 6 | 150 | 30 | 650 | 30 | 650 | 4000 | 2000 |
| 48 x 60 | 1200 x 1500 | 14 – 42H – 39 | 14 – 41H – 39 | 13 – 42H – 39 | 13 – 41H – 39 | | 6 | 150 | 30 | 750 | 35 | 875 | 4000 | 2000 |
| 48 x 72 | 1200 x 1800 | 14 – 42H – 34 | 14 – 41H – 34 | 13 – 42H – 34 | 13 – 41H – 34 | | 6 | 150 | 30 | 750 | 40 | 1000 | 4000 | 2000 |
| 48 x 96 | 1200 x 2400 | 14 – 42H – 35 | 14 – 41H – 35 | 13 – 42H – 35 | 13 – 41H – 35 | | 6 | 150 | 30 | 750 | 50 | 1250 | 4000 | 2000 |
| 48 x 120 | 1200 x 3000 | 14 – 42H – 36 | 14 – 41H – 36 | 13 – 42H – 36 | 13 – 41H – 36 | | 6 | 150 | 30 | 750 | 60 | 1500 | 4000 | 2000 |
| 48 x 144 | 1200 x 3600 | 14 – 42H – 37 | 14 – 41H – 37 | 13 – 42H – 37 | 13 – 41H – 37 | | 6 | 150 | 30 | 750 | 70 | 1750 | 4000 | 2000 |
| 59 x 60 | 1500 x 1500 | 14 – 42H – 49 | 14 – 41H – 49 | 13 – 42H – 49 | 13 – 41H – 49 | | 6 | 150 | 40 | 1000 | 35 | 875 | 4000 | 2000 |
| 59 x 72 | 1500 x 1800 | 14 – 42H – 44 | 14 – 41H – 44 | 13 – 42H – 44 | 13 – 41H – 44 | | 6 | 150 | 40 | 1000 | 40 | 1000 | 4000 | 2000 |
| 59 x 80 | 1500 x 2000 | 14 – 42H – 44 | 14 – 41H – 44 | 13 – 42H – 44 | 13 – 41H – 44 | | 6 | 150 | 40 | 1000 | 40 | 1000 | 4000 | 2000 |
| 59 x 96 | 1500 x 2400 | 14 – 42H – 45 | 14 – 41H – 45 | 13 – 42H – 45 | 13 – 41H – 45 | | 6 | 150 | 40 | 1000 | 50 | 1250 | 4000 | 2000 |
| 59 x 120 | 1500 x 3000 | 14 – 42H – 46 | 14 – 41H – 46 | 13 – 42H – 46 | 13 – 41H – 46 | | 6 | 150 | 40 | 1000 | 60 | 1500 | 4000 | 2000 |
| 59 x 144 | 1500 x 3600 | 14 – 42H – 47 | 14 – 41H – 47 | 13 – 42H – 47 | 13 – 41H – 47 | | 6 | 150 | 40 | 1000 | 70 | 1750 | 4000 | 2000 |

* Casters can only be used with post height of 18 in. and taller.
** These capacities are guidelines. Consider table mass and payload when choosing isolation legs. Contact TMC for more information.

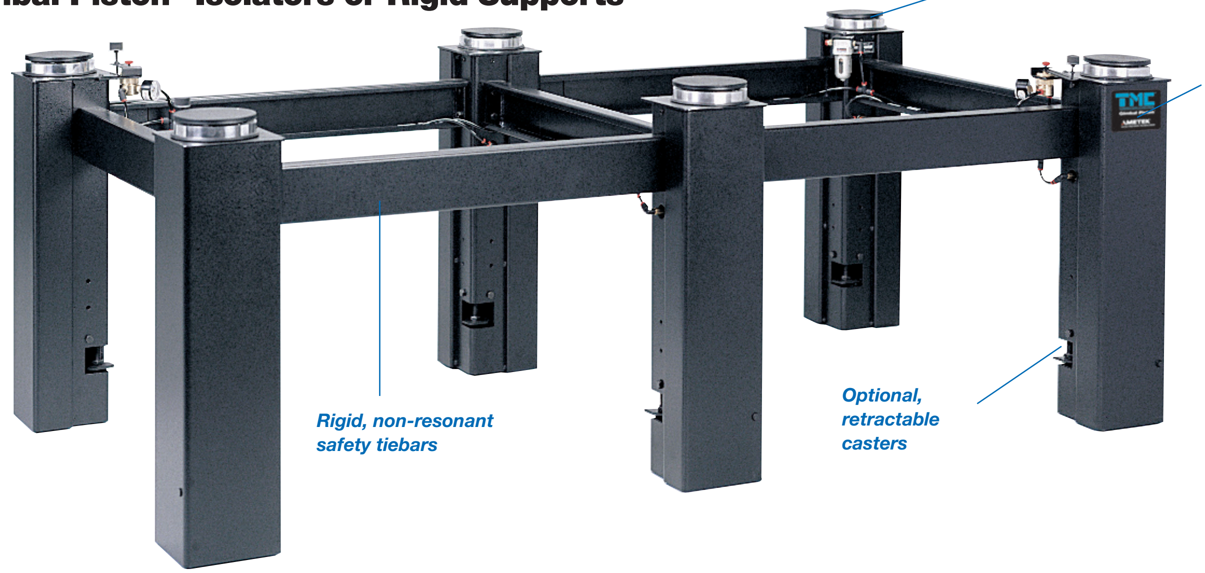


www.techmfg.com • 978-532-6330 • 800-542-9725 (Toll Free) • Fax: 978-531-8682 • sales@techmfg.com

Micro-g®

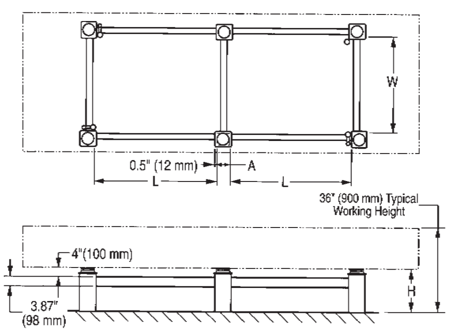
# System 1 6-Post with Tiebars

## Gimbal Piston™ Isolators or Rigid Supports




Most tops more than 10 ft (3 m) long are best supported by the 6-Post System with Tiebars. In addition to the higher weight capacity, the structural characteristics of the top are enhanced by the additional support points.

How to Order: See instructions below.




### Height Code Ordering Chart

| Height Code H | Height in. | Height mm | Standard Heights Available Prefix 13 & 14 |
|---|---|---|---|
| 2 | 12 | 300 | • |
| 3 | 16 | 400 | • |
| 4 | 18 | 450 | • |
| 5 | 22 | 550 | • |
| 6 | 24 | 600 | • |
| 7 | 28 | 700 | • |
| 8 | 32 | 800 | • |

### 6–Post System Ordering Chart

| Application: Typical Size of Optical Top | | Recommended Model Number | | | | H Height: Specify Height Code | A Cross-Section | | W Width | | L Length | | Capacity | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Gimbal Piston™ Isolators | | Rigid Leveling Stand | | | | | | | | | | |
| in. | mm | w/casters | w/o casters | w/casters | w/o casters | | in. | mm | in. | mm | in. | mm | lbs | kg |
| 48 x 120 | 1200 x 3000 | 14 – 62H – 33 | 14 – 61H – 33 | 13 – 62H – 33 | 13 – 61H – 33 | See Height Code Ordering Chart | 6 | 150 | 30 | 750 | 30 | 750 | 6000 | 3000 |
| 48 x 144 | 1200 x 3600 | 14 – 62H – 34 | 14 – 61H – 34 | 13 – 62H – 34 | 13 – 61H – 34 | | 6 | 150 | 30 | 750 | 40 | 1000 | 6000 | 3000 |
| 48 x 168 | 1200 x 4200 | 14 – 62H – 35 | 14 – 61H – 35 | 13 – 62H – 35 | 13 – 61H – 35 | | 6 | 150 | 30 | 750 | 50 | 1250 | 6000 | 3000 |
| 48 x 192 | 1200 x 4800 | 14 – 62H – 36 | 14 – 61H – 36 | 13 – 62H – 36 | 13 – 61H – 36 | | 6 | 150 | 30 | 750 | 60 | 1500 | 6000 | 3000 |
| 59 x 120 | 1500 x 3000 | 14 – 62H – 43 | 14 – 61H – 43 | 13 – 62H – 43 | 13 – 61H – 43 | | 6 | 150 | 40 | 1000 | 30 | 750 | 6000 | 3000 |
| 59 x 144 | 1500 x 3600 | 14 – 62H – 44 | 14 – 61H – 44 | 13 – 62H – 44 | 13 – 61H – 44 | | 6 | 150 | 40 | 1000 | 40 | 1000 | 6000 | 3000 |
| 59 x 168 | 1500 x 4200 | 14 – 62H – 45 | 14 – 61H – 45 | 13 – 62H – 45 | 13 – 61H – 45 | | 6 | 150 | 40 | 1000 | 50 | 1250 | 6000 | 3000 |
| 59 x 192 | 1500 x 4800 | 14 – 62H – 46 | 14 – 61H – 46 | 13 – 62H – 46 | 13 – 61H – 46 | | 6 | 150 | 40 | 1000 | 60 | 1500 | 6000 | 3000 |

### How to Order:

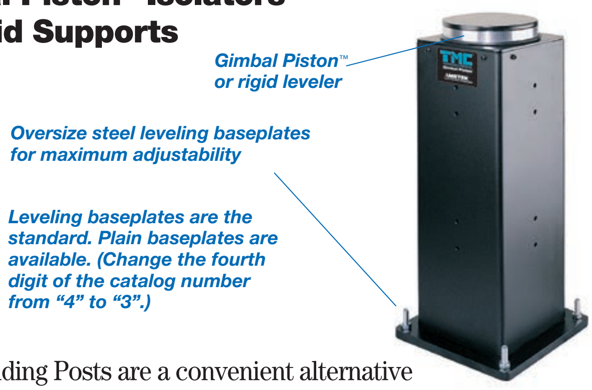
1. Determine whether vibration isolation is required or whether rigid, non-resonant support is adequate.
2. Choose whether or not the caster option is desired.*
3. Find the size of the optical top to be supported in the left column of the ordering chart.
4. Pick the model number from the appropriate column.
5. Assign the height code (H) to the catalog number based on the desired height of the table surface and thickness of the optical top.
6. Ensure that the support has adequate capacity by comparing the capacity to the optical top weight plus equipment load. Top weight is equal to the top area times the weight factor from the bottom of the optical top size charts. The isolator capacity should be at least double the total load.
7. Contact TMC when in doubt and for unusually sized tops.

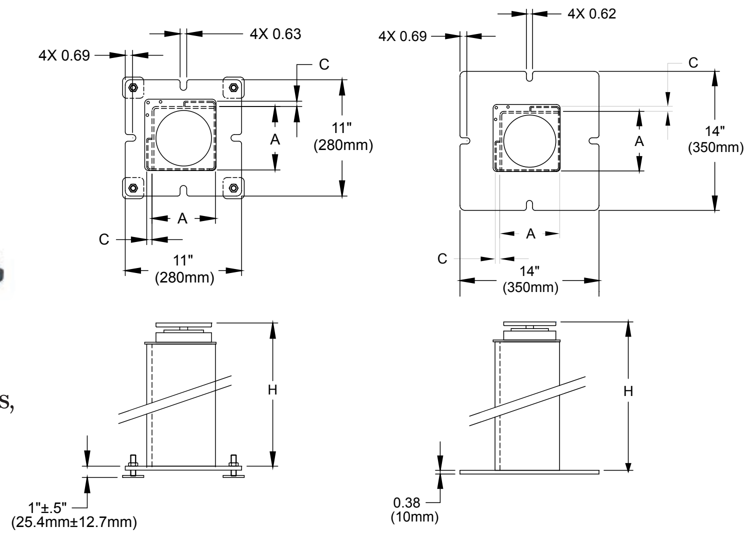
*Casters can only be used with post heights of 18 in. and taller.

## Micro-g®

# System 1 Free-Standing Individual Posts

### Gimbal Piston™ Isolators or Rigid Supports




*Baseplate with levelers*     *Plain baseplate*

Free-Standing Posts are a convenient alternative to posts with tiebars when open access between the posts is necessary. Though generally configured in sets of four and six legs, other configurations include three and five legs. The independent posts offer the maximum flexibility in post positioning with respect to the optical top. Free-Standing Posts are especially convenient for supporting large coupled table systems.

## How to Order:

1. Determine whether vibration isolation is required or whether rigid, non-resonant support is adequate.
2. Calculate the required capacity by adding the equipment load to the optical top weight. Top weight is equal to top area times the weight factor from the bottom of the optical top selection charts. Generally, 8 in. (200 mm) and 12 in. (300 mm) tops require 13 and 14 prefix legs.
3. Choose the indicated catalog number from the ordering chart.
4. 4-Post Systems are recommended for most applications. Other configurations require that total capacity exceeds optical top mass plus equipment load by a factor of 2. Choose the desired number of posts.
5. Leveling baseplates and wear plates come standard with individual posts. This can be of great assistance on larger tables and in labs with uneven floors. Plain baseplates are available. To specify, change the fourth digit of the catalog number from "4" to "3" (for example 16-143-00 becomes 16-133-00).
6. Height control valve kits (included with 4-Post and 6-Post Systems) must be specified when ordering individual posts. Choose valve kit from the bottom of the chart corresponding to the chosen posts. Note that if more than 4 posts are combined, a suffix must be added to the valve kit corresponding to the number of posts (e.g., for 8 of 14-134-00, the correct valve kit is SV14-8).
7. Contact TMC when in doubt and for unusual configurations.


## Single-Post System Ordering Chart

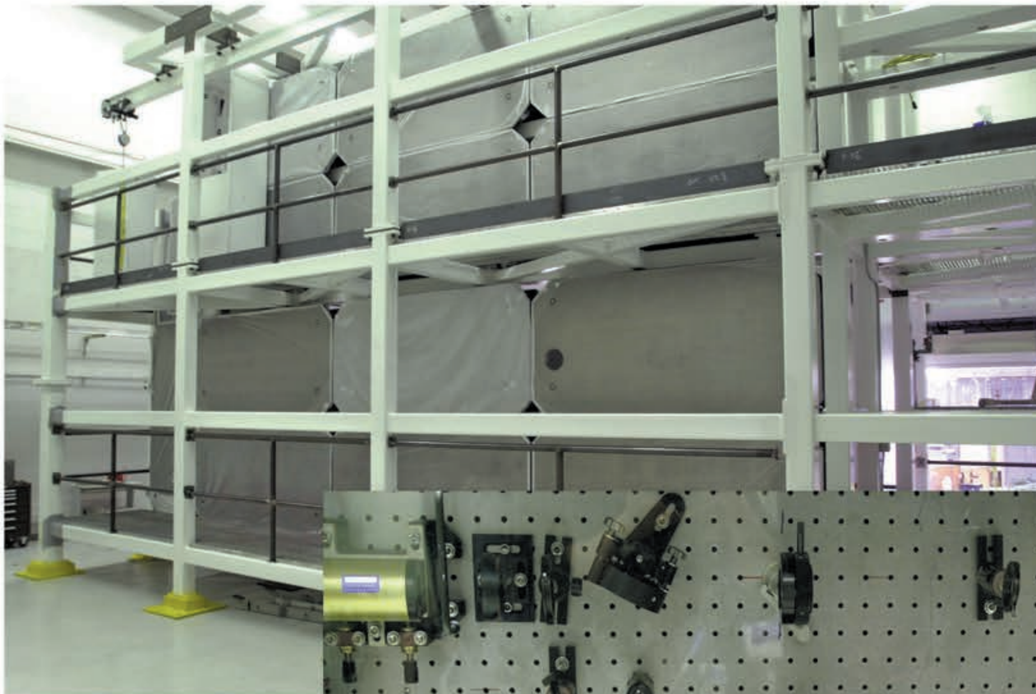
| Catalog Number | | H | | A | | C | | Capacity Per Post | |
|---|---|---|---|---|---|---|---|---|---|
| Gimbal Piston Isolator | Rigid Post | in. | mm | in. | mm | in. | mm | lbs | kg |
| 14-142-00 | 13-142-00 | 12 | 300 | 6 | 150 | 1/2 | 13 | 1000 | 500 |
| 14-143-00 | 13-143-00 | 16 | 400 | 6 | 150 | 1/2 | 13 | 1000 | 500 |
| 14-144-00 | 13-144-00 | 18 | 450 | 6 | 150 | 1/2 | 13 | 1000 | 500 |
| 14-145-00 | 13-145-00 | 22 | 550 | 6 | 150 | 1/2 | 13 | 1000 | 500 |
| 14-146-00 | 13-146-00 | 24 | 600 | 6 | 150 | 1/2 | 13 | 1000 | 500 |
| 14-147-00 | 13-147-00 | 28 | 700 | 6 | 150 | 1/2 | 13 | 1000 | 500 |
| 14-148-00 | 13-148-00 | 32 | 800 | 6 | 150 | 1/2 | 13 | 1000 | 500 |
| 16-143-00 | Contact TMC for 2500 lb (1100 kg) Rigid Post details | 16 | 400 | 8 | 200 | 0 | 0 | 2500 | 1000 |
| 16-145-00 | | 22 | 550 | 8 | 200 | 0 | 0 | 2500 | 1000 |
| 16-147-00 | | 28 | 700 | 8 | 200 | 0 | 0 | 2500 | 1000 |

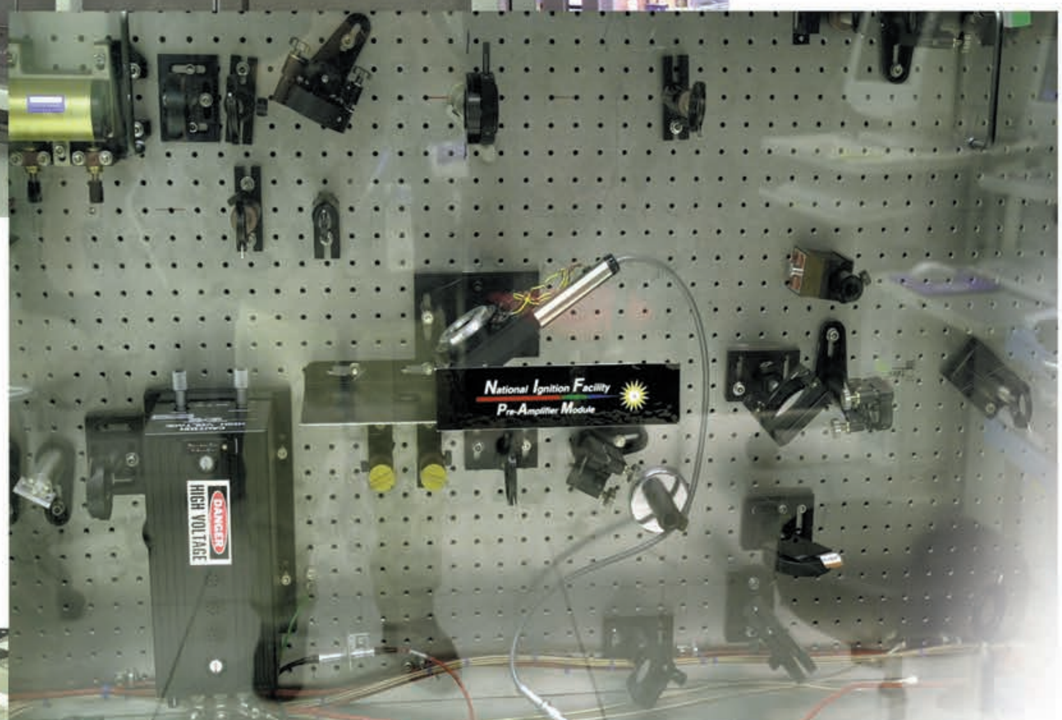
**Note:** Free-Standing Individual Posts are incompatible with retractable casters.
12 in. tall posts do not incorporate baseplates.

## Height Control Valve Kit Ordering Chart

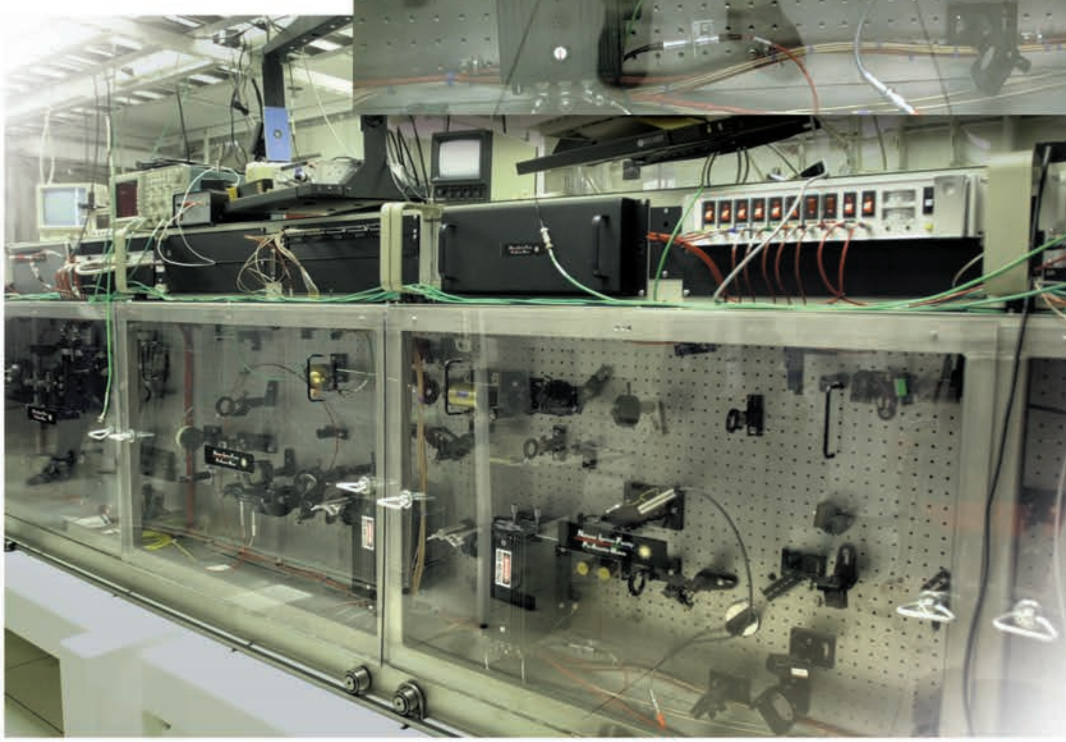
| Catalog Number | Valve Kit |
|---|---|
| SV12 | Standard Valve Kit (4) 12-Series Posts |
| SV14 | Standard Valve Kit (4) 14-Series Posts |
| SV16 | Standard Valve Kit (4) 16-Series Posts |


www.techmfg.com • 978-532-6330 • 800-542-9725 (Toll Free) • Fax: 978-531-8682 • sales@techmfg.com





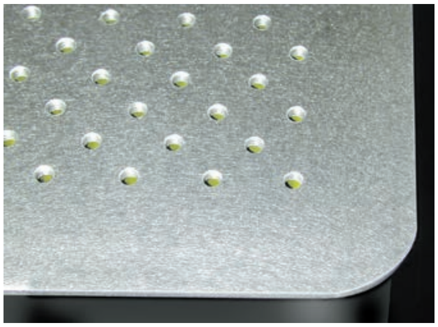

*In 2000, TMC was awarded a contract for over 500 eight-ft long CleanTop® Optical Tops to support optics in the PABST Assemblies, part of the National Ignition Facility. This was likely the largest single order for Optical Tops ever successfully completed.*



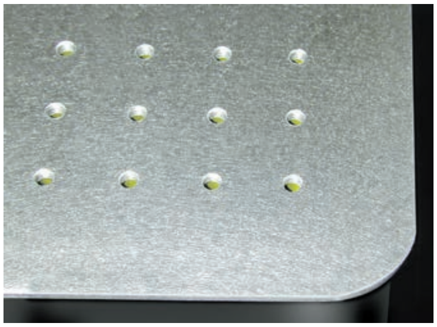
*Photos courtesy of Lawrence Livermore National Labs*

# Options & Accessories

*TMC offers a comprehensive line of options and accessories to help you obtain maximum utility from TMC optical tables, breadboards, and supports. We also provide unequaled expertise and fast turnaround in designing and building custom configurations to your specifications. Requirements for joined tables, tables made of special materials, and for custom through-hole patterns and ports are readily accommodated.*



*CleanTop® DoubleDensity™ construction (288 holes per ft²)*



*Standard TMC CleanTop® construction (144 holes per ft²)*

## Benefits

- Allows more precise location of positioning equipment
- Translation stages require less travel
- Compatible with existing 1/4-20 on 1 in. and M6 on 25 mm patterns

## How to Order

After choosing your optical top, simply specify the corresponding suffix from the chart below by adding the letter "D" to the suffix.

## CleanTop® DoubleDensity™

### Double the number of tapped holes

CleanTop® Double-Density™ is another TMC innovation to the optical table industry. By combining our existing uniquely small honeycomb cell size (0.50 in.²) with our proprietary CleanTop® individual sealed hole technology, we are now able to offer twice the number of tapped holes. Because we use our existing honeycomb core design, which is twice the cell density as our nearest competitor, there are absolutely no changes to any performance specifications. No alterations to the core design were necessary to accommodate the additional CleanTop cups.

## Features

- Twice as many tapped holes as conventional 1 in. or 25 mm grids.
- 288 holes per ft², 3,200 holes per m².
- Twice the number of honeycomb cells (0.50 in.²) as our nearest competitor.
- Core density unchanged, the highest in the industry (13.3 lb per ft³).
- Hole pattern is 1/4-20 on 1 in. staggered centers or M6 on 25 mm staggered centers.
- Available with any version of TMC's CleanTop at a nominal additional fee.
- No change to any performance specifications.

### Suffix Chart Hole Patterns/Laser Ports

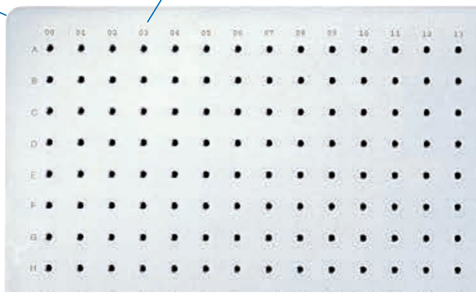
| Suffix | Hole Pattern - -Threads | Double Density | Laser Port |
|---|---|---|---|
| 00R | No Holes | no | no |
| 01R | 1 in. centers - 1/4-20 | no | yes |
| 02R | 1 in. centers - 1/4-20 | no | no |
| 11R | 25 mm centers - M6 | no | yes |
| 12R | 25 mm centers - M6 | no | no |
| 01DR | 1 in. staggered centers - 1/4-20 | yes | yes |
| 02DR | 1 in. staggered centers - 1/4-20 | yes | no |
| 11DR | 25 mm staggered centers - M6 | yes | yes |
| 12DR | 25 mm staggered centers - M6 | yes | no |

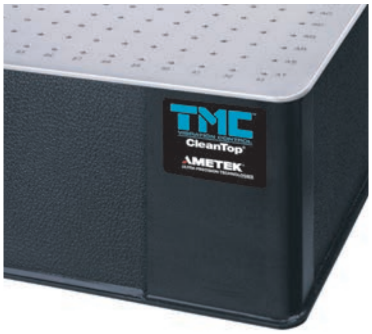
## Alpha-Numeric Grid

A handy option to ease replicating an optical setup is our Alpha-Numeric Grid pattern. By electro-chemically etching a coordinate pattern on the top surface, each tapped hole has an address. This is also helpful in documenting a setup for OEM applications.

## How to Order:

**Alpha-Numeric Grid**
To specify the Alpha-Numeric Grid, add the suffix G to the TMC model number (for instance, 784-455-02GR).





## Rounded Corners

CleanTop® Tops now include user-friendly rounded corners as a standard feature. We laser-cut a generous, 1-in. radius at each corner of the top.

Conventional top construction produces a 90° bend which is subsequently "dulled" by grinding or filing. Though dull, this right angle often leads to painful hip bruises for those logging long hours in the lab. The rounded corner feature eliminates this inconvenience.

If required, conventional square corners are available at no extra charge.



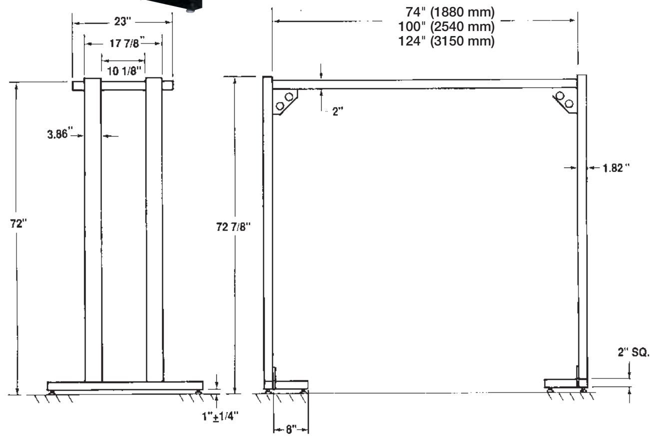
## Overhead Shelf

An overhead shelf is an ideal storage rack for equipment and instrumentation used in conjunction with an optical table. Spanning the long axis of the table, the overhead shelf is adjustable in height and free standing, so vibration isolation will not be compromised. It includes a UL-approved electrical strip with two eight-grounded outlet strips in the 6-ft shelf and four eight-grounded outlets in the 8- and 10-ft shelves. (125 V, 60 Hz, 15 A).

Optional accessories include a second tier shelf. The shelf includes two rows of holes on a 2 in. (50 mm) spacing to facilitate mounting of fixtures.

Built to the same rugged standards you have come to expect from TMC, the structure is formed steel with a non-resonant design, black powder coat finish, and leveling feet for uneven floors. Capacity is 200 lb (90 kg).

For custom requirements such as non-U.S. format outlet strips, contact TMC.

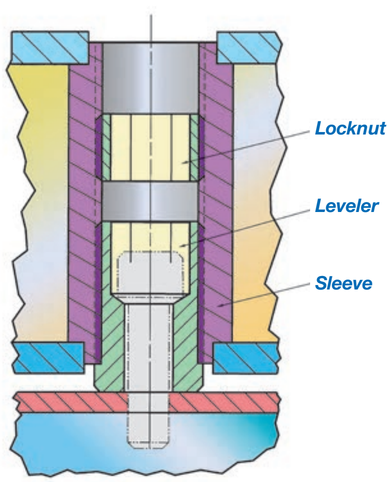




### Overhead Shelf Ordering Chart

| Shelf Model | Description | L in. | L mm |
|---|---|---|---|
| 81-231-01 | Complete shelf system | 74 | 1880 |
| 81-232-01 | Complete shelf system | 100 | 2540 |
| 81-233-01 | Complete shelf system | 124 | 3150 |
| 81-236-01 | Second shelf tier | 74 | 1880 |
| 81-237-01 | Second shelf tier | 100 | 2540 |
| 81-238-01 | Second shelf tier | 124 | 3150 |

## Breadboard Leveler

As an option on 2 in. (50 mm) thick breadboards with 1/8 in. (3 mm) or 3/16 in. (5 mm) skins, TMC provides a breadboard leveler mechanism (see page 36). The leveler consists of a threaded sleeve bonded into the top, a bushing leveler, and a locknut. An M6 or 1/4-20 bolt may then be used to fasten the breadboard to another top. The leveler is adjusted and locked with a simple Allen wrench.




### How to Order

Specify the number of levelers required at the end of the breadboard model number suffix. For instance, if 4 levelers are desired, 77-119-02R becomes 77-119-024R.

# Options & Accessories (continued)

## Earthquake Restraint System

TMC's earthquake restraint bracket system provides increased safety and stability for optical tables in high-risk earthquake areas without affecting table performance.

The TMC earthquake restraint system relies on top brackets and upper tiebars to control motion of the table top and, where severe occurrences are anticipated, floor brackets with lower tiebars to secure the support structure to the floor. Under normal conditions, there is no contact between the top brackets and the support structure, so that performance of the optical top and the vibration isolation system are not affected. Clearances are large and brackets are lightweight, stiff, well-damped, unobtrusive and encapsulated with soft elastomer to provide gradual snubbing.

Our earthquake restraint bracket system can be retrofitted to an installed TMC optical table or specified with a new order.

Inferior, competitive designs may depend on large, pendulum-like structures that hang below the table top and connect to the floor. Since pendulums characteristically have low resonant frequencies, these add-on structures lower the resonant frequency of the table top and degrade compliance and damping. In addition, the floor connection creates a potential rigid coupling between table top and floor, which can compromise vibration isolation if it drifts out of calibration.

### Top Restraint Brackets

Top brackets encircle the upper tiebar and bolt to the underside of the top. They mount within a few inches of a support post and restrict the motion of the top (see illustration). Normally, four brackets are required for a typical table. Specify brackets individually. On new table orders, the top will be supplied with mounting holes. For retrofitting tables, contact TMC for recommendations.

### Top Restraint Bracket Ordering Chart

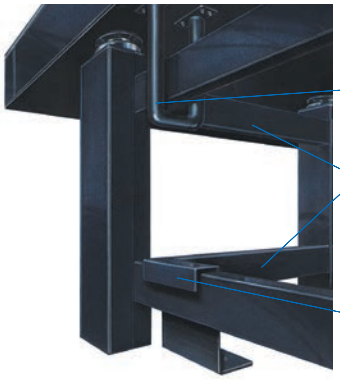
**One top restraint bracket (bolts included)**
**No. 83-102-01** (8 1/4-20 bolts)
**No. 83-102-11** (8 M6 metric bolts)

### Floor Restraint Brackets

Floor brackets are recommended where quakes are anticipated. They encircle the lower tiebars close to the support posts and bolt to the floor (see illustration). Four brackets are usually recommended. Since standard TMC post-mount support systems are supplied with only upper tiebars, an additional set of four lower tiebars must be specified for both new and retrofitted orders. Specify both floor brackets and tiebars individually. Note that for posts less than 22 in. tall, a special Floor Restraint Bracket is required. Contact TMC for information.

### Floor Restraint Bracket Ordering Chart

**One floor restraint bracket (no bolts)**
**No. 83-103-01** (for TMC 11 and 12 Series posts)
**No. 83-103-02** (for TMC 13 and 14 Series posts)
**No. 83-103-03** (for TMC 63-500 Series posts)




### Upper and Lower Tiebars

Standard post-mount support systems are supplied only with upper tiebars. An additional set of lower tiebars is required when floor restraint brackets are used; or, you may want an additional row of tiebars for extra strength. Tiebars must be specified individually – see ordering chart.

### Tiebar Ordering Chart (Including Bolts)

| Tiebar Length | | Model No. |
|---|---|---|
| in. | mm | |
| 15 | 380 | 83-101-15 |
| 20 | 510 | 83-101-20 |
| 26 | 660 | 83-101-26 |
| 30 | 760 | 83-101-30 |
| 35 | 890 | 83-101-35 |
| 40 | 1015 | 83-101-40 |
| 50 | 1270 | 83-101-50 |
| 60 | 1525 | 83-101-60 |
| 70 | 1780 | 83-101-70 |

## Laser Shelf

TMC tables larger than 36 in. x 72 in. (900 mm x 1,800 mm) and supported at least 18 in. (450 mm) above the floor can be fitted with a laser shelf. The shelf consists of an additional undrilled 2 in. (50 mm) thick breadboard attached to the bottom plate of the table. Though such a support system will not match the performance of direct mounting of equipment to the table's top surface, for less sensitive applications this arrangement can save valuable working space on the top.

In some cases, our tiebars may interfere with shelf mounting. Contact us if you are in doubt.

### Laser Shelf Ordering Chart

| Model | Description | W | L |
|---|---|---|---|
| 81-172-01 | Shelf-imperial hardware | 24 in. | 48 in. |
| 81-172-02 | Shelf-metric hardware | 600 mm | 1200 mm |
| 81-173-01 | Shelf-imperial hardware | 24 in. | 72 in. |
| 81-173-02 | Shelf-metric hardware | 600 mm | 1800 mm |

*Order as a complete set or order the breadboard separately.*

# Custom Configurations

*TMC's complete manufacturing facility can readily provide custom configurations to meet your special requirements.*

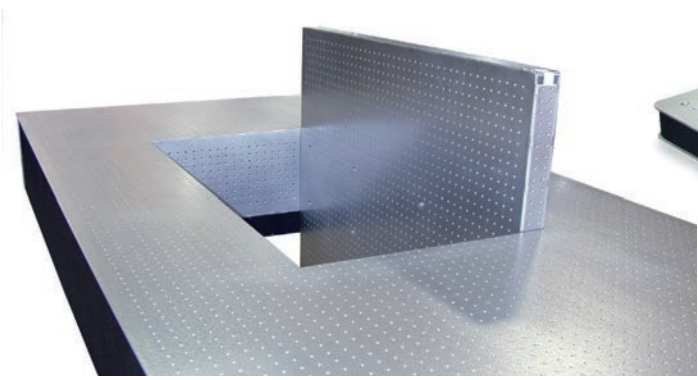


## Special Materials

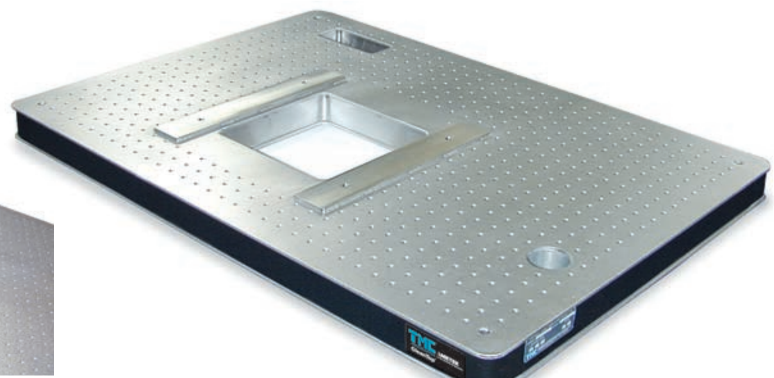
Tables made of any commercially available metallic materials are readily manufactured by TMC. Aluminum, non-ferromagnetic 300 series stainless steel, and thermally stable Invar Alloys are among the most frequent requests.

## Special Through-Holes and Ports

Our multiple new 2,000-watt laser machining centers coupled with our capacity to punch, drill, shear, form, and weld steel makes inclusion of custom hole patterns readily available. Common patterns include notches, rectangular through-holes, laser ports, and threaded bosses.



***TMC designed and manufactured this custom three-dimensional, 11-sided optical table system built entirely of non-ferromagnetic 304 alloy stainless steel to support the 500-pound quantum gas microscope housed in the Department of Physics at Harvard University.***

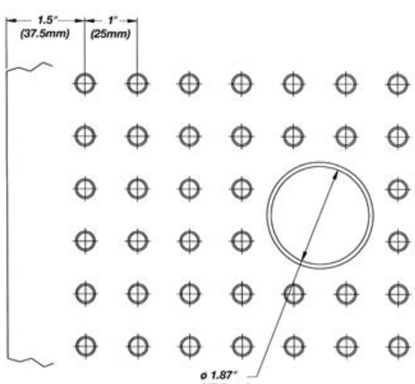


***78 Series CleanTop® Breadboard with custom hole and precision machined plate interface.***

## Laser Ports

All TMC optical tops can be supplied with a laser port, as noted in the laser port and hole pattern suffix chart. The laser port is a 1 7/8 in. (47 mm) diameter stainless steel tube running through the table, bonded to the top and bottom skins.

Provisions for mounting a laser shelf underneath the table top are included with this option. See drawing and chart at right.




### Suffix Chart
### Hole Patterns/Laser Ports

| Suffix | Hole Pattern-Threads | Double Density | Laser Port |
|---|---|---|---|
| 00R | No Holes | no | no |
| 01R | 1 in. centers – 1/4-20 | no | yes |
| 02R | 1 in. centers – 1/4-20 | no | no |
| 11R | 25 mm centers – M6 | no | yes |
| 12R | 25 mm centers – M6 | no | no |
| 01DR | 1 in. staggered centers – 1/4-20 | yes | yes |
| 02DR | 1 in. staggered centers – 1/4-20 | yes | no |
| 11DR | 25 mm staggered centers – M6 | yes | yes |
| 12DR | 25 mm staggered centers – M6 | yes | no |

# Custom Configurations (continued)

## Joined Tables

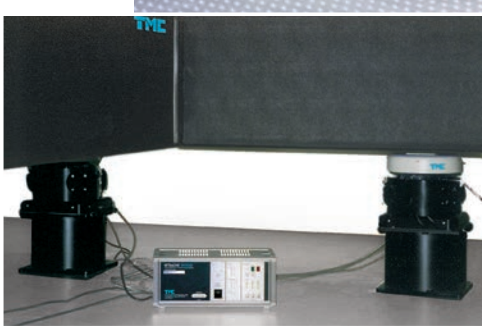
By welding a precision ground and aligned joiner plate system to the table skins, TMC can provide a rigid coupling between optical tables. In addition to tables coupled end-to-end, we can easily join them in "L" or "T" shapes. (Even relatively small tables are sometimes made in sections to allow rigging in elevators, etc.)

In addition, we can provide configurations with two working heights on one table by coupling tables of differing thicknesses.

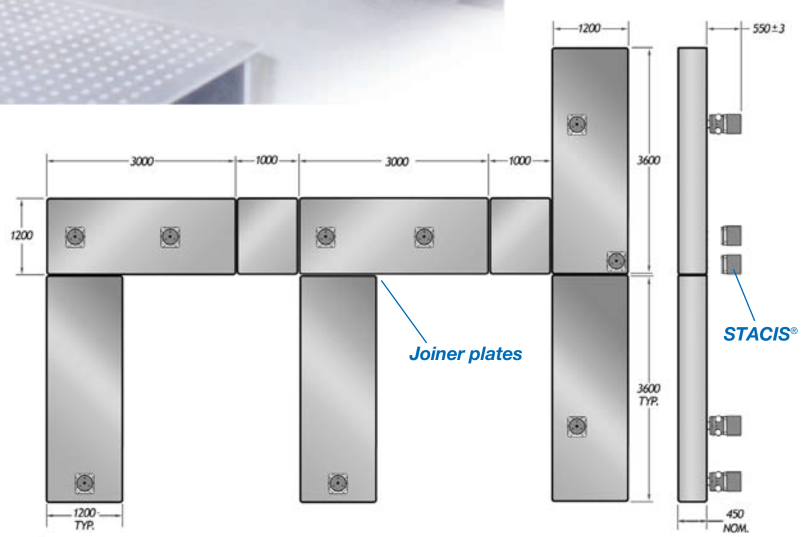
All joined tables are assembled and tested in our factory, shipped separately, and reassembled on site.

The tables can, at any time, be separated and supported individually or rejoined.


*Precision-machined steel mating joiner plates are aligned and welded to multiple tops*



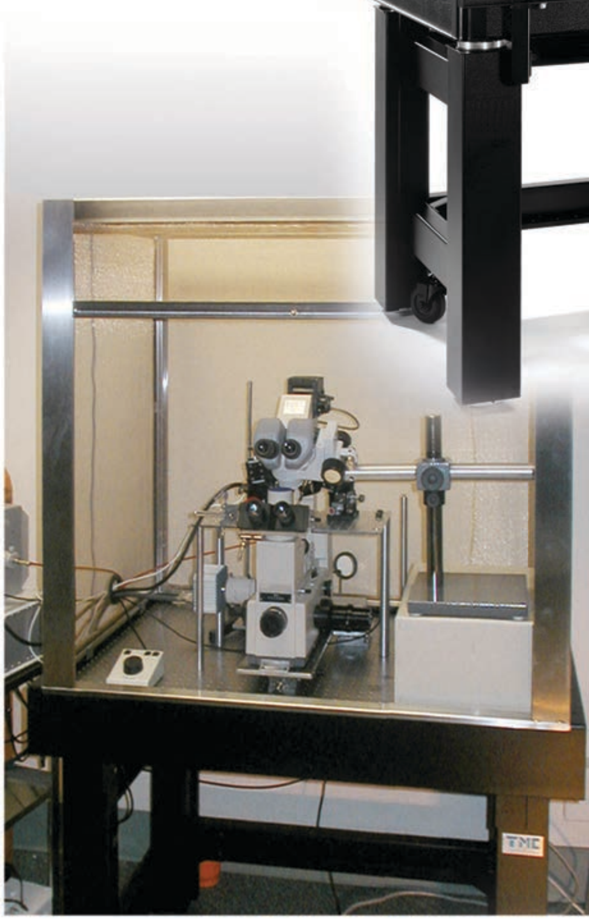
*This eight-piece CleanTop® Optical Table System is installed at the Max Planck Institute in Heidelberg, Germany. The system may be configured as one entire assembly or smaller assemblies of one or more table units. The entire system is installed on a STACIS® Active Piezoelectric Vibration Cancellation System.*



# Laboratory Tables & TableTop™ Platforms



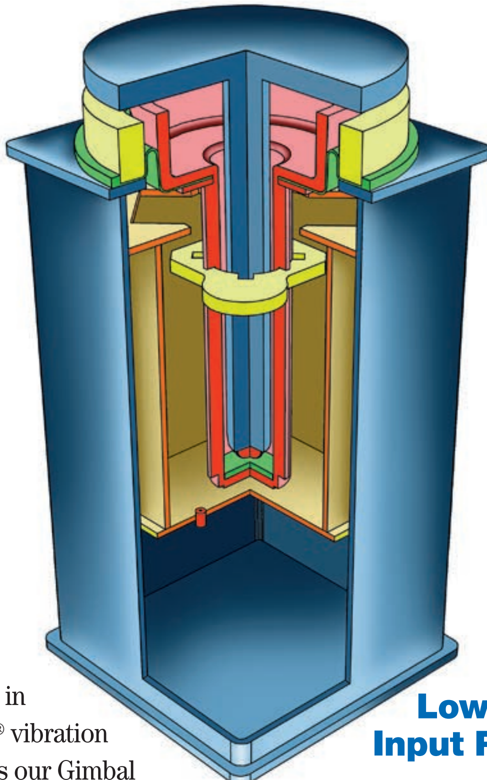
*Leica Microsystems*



*University of Nevada, Reno, School of Medicine*

*Probing Solutions*

# Gimbal Piston™ Isolator



The key element in all TMC Micro-g® vibration isolation tables is our Gimbal Piston™ Air Isolator. These assemblies have repeatedly proven, in independent tests, to provide outstanding isolation in all directions for even the lowest input levels.

The Gimbal Piston utilizes proprietary pneumatic damping techniques, which include air flow restrictors and a unique geometry. It is lightly damped and highly responsive to typical, low-amplitude ambient floor vibrations, yet achieves very high damping for gross transient disturbances, such as sudden load changes or bumping the top plate. The result is that Gimbal Piston Isolators provide superior isolation yet will virtually eliminate any gross disturbance within a few seconds.

The Gimbal Piston can also stabilize isolated systems with relatively high centers of gravity without compromising isolation.

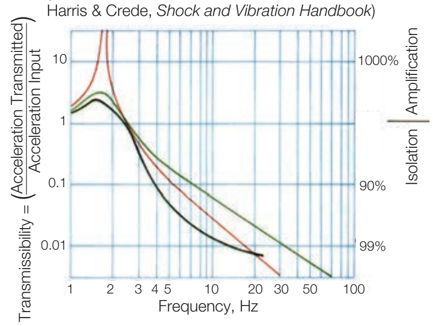
## Low-Amplitude Input Response

The greatest challenge in designing an effective isolator is to maintain good performance at the low vibration amplitude inputs typical of ambient building floor vibration. Isolator specifications are often based on measurements done with the isolator placed on a “shaker table” with very high amplitude input levels. Such testing, with input amplitudes on the order of millimeters, yields unrealistic performance expectations and is misleading as results will not reflect the actual performance in use. The Gimbal Piston Isolator design is unique in its ability to maintain its stated resonant frequency and high level of attenuation in even the most quiet, real, floor environments. The performance is linear to such low amplitudes because the design is virtually free of friction and therefore able to avoid rolling friction to static friction transitions.

Every other system that we have tested at levels typical for floor vibration exhibits either a higher resonant frequency than claimed or a substantial increase in transmission through the isolator mount.

**Vibration Isolation vs. Pneumatic Damping**

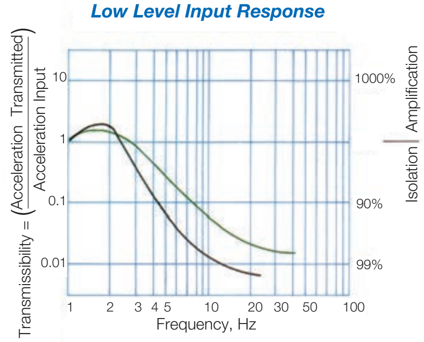
(source for theoretical curves: Harris & Crede, *Shock and Vibration Handbook*)




■ Theoretical 1.5 Hz isolator with no damping
■ Theoretical 1.5 Hz isolator with 0.2 damping coefficient
■ Measured Gimbal Piston™ Isolators with 40-microinch floor inputs (vertical)

We stress the importance of performance specifications at low levels because we have repeatedly observed, in our own testing and in many as-used installations, that better performance is much easier to achieve at greater amplitudes and higher frequencies.

**Low Level Input Response**



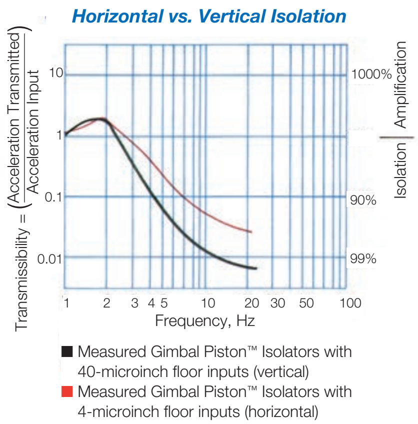

■ Measured Gimbal Piston™ Isolators with 40-microinch floor inputs (vertical)
■ Measured Gimbal Piston™ Isolators with 4-microinch floor inputs (vertical)

## Horizontal vs. Vertical Inputs

Our innovative Isolator allows a thin-wall, rolling diaphragm seal to accommodate horizontal displacement by acting as a gimbal. Instead of using a cable-type pendulum suspension, the Gimbal Piston™ Isolator carries the load on a separate top plate that has a rigid rod extending down into a well in the main piston. The bottom of the rod has a ball-end that bears on a hard, flat seat.

The result is an inherently flexible coupling which allows horizontal flexure in the isolator as the ball simply rocks (without sliding or rolling) very slightly on the seat.

The approach works extremely well, even with sub-microinch levels of input displacement, because the fiction is virtually the same as the rolling friction. Horizontal motion is simply converted to the usual vertical diaphragm flexure but out of phase: one side of the piston up, the other down, in a gimbal-like motion.

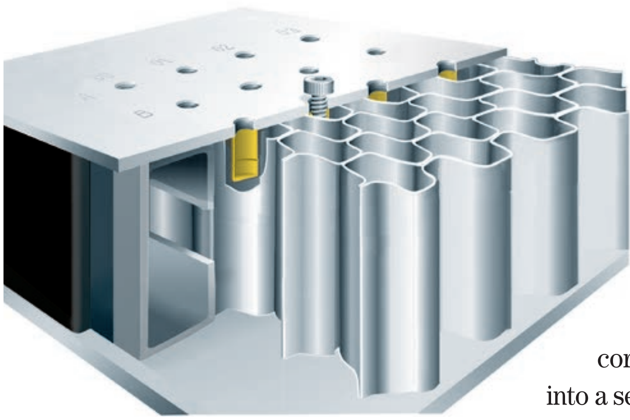



4


*The Gimbal Piston™ isolator is standard in all TMC 63-500 series lab tables. The modular isolator is also featured in the Micro-g® post-mount supports. There are a variety of different load ratings available, suitable for the largest CleanTop® or a custom OEM application.*

# Top Plate Design Alternatives

## Small Lab Tables & TableTop™ Isolators



*TMC Steel Honeycomb CleanTop®*

An effective table top design must incorporate three critical factors: mass, stiffness, and damping. Mass ensures that forces applied to the table top will cause minimal displacements. Stiffness raises the table top's lowest resonance out of the working range and provides a more stable work surface. Damping decays the higher frequency vibration that reaches the top.

TMC provides three basic versions of table tops: stainless steel laminate, CleanTop® steel honeycomb, and granite.

### Stainless Steel Laminate

The standard TMC top plate is a 2 to 4 in. thick, highly damped, high stiffness lamination of steel plates sandwiched around a lightweight damped core, rigid epoxy-bonded into a seamless stainless steel pan with rounded edges and corners. With their combinations of structural epoxies and visco-elastic adhesives, these tops will not delaminate due to heat, humidity, or aging. TMC laminated tops are recommended for most applications not requiring mounting holes.

Laminated tops are standard on 64 Series TableTop™ Platforms, , and 63-500 and 68-500 Series Lab Tables, 63-600 ClassOne™ Workstations, and Quiet Island® Sub-Floor Platforms. They can also be supplied with a plastic top skin laminated onto the stainless steel to make an even more easily cleanable surface. Plastic skins do, however, detract from the ferromagnetic properties of the top and are unsatisfactory for magnetic hold-downs.

### Steel Honeycomb CleanTop®

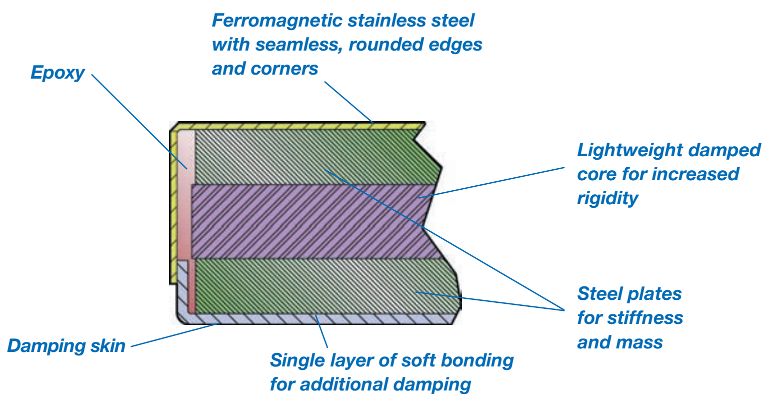
Researchers requiring bolt down mounting of their equipment to a flat and stable worksurface should use steel honeycomb spill proof cleantop breadboards.

For a complete discussion of CleanTop Optical Tops, see Section 3.

### Granite Tops

Granite surfaces are standard with 64 Series TableTop Platforms. The advantages of a granite top are its relatively high mass and stiffness and the potential for being lapped to a precise surface flatness. Granite's non-magnetic nature is useful in some applications.

For small tops, granite is an inexpensive, moderate performance material. In larger sizes, however, granite is more expensive than standard TMC top plates, sacrifices damping, and is more difficult to customize.




*TMC stainless steel laminate cross section*

# Performance Summary

## Small Tops for Lab Tables

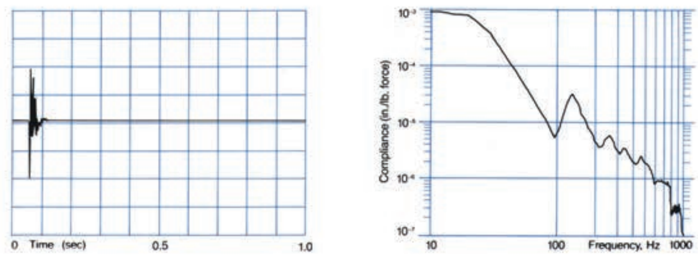
### Damping

Structural damping determines how quickly an excited resonance in a table top decays. The simplest way to measure damping is to hit the table top with a hammer and measure the decay with an accelerometer and oscilloscope or spectrum analyzer. The height of a resonance peak in the "compliance curve" also measures damping.

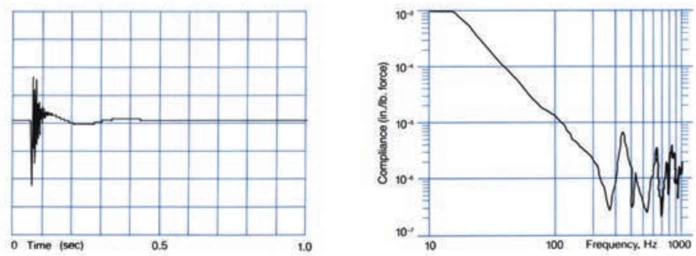
### Compliance

Compliance is a reciprocal measurement of the dynamic stiffness of a table top. The data are obtained by inputting a measured force to the table top with a calibrated hammer and measuring the resultant acceleration (or displacement) with an accelerometer. Compliance is the ratio of displacement to force expressed as a function of frequency.

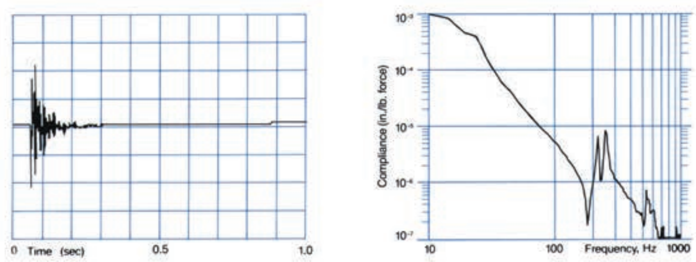
**Damping** **Compliance**



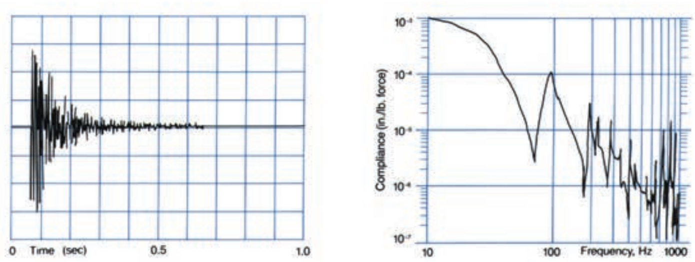

*TMC Laminated Steel Top — 30 x 48 x 2 in. (750 x 1200 x 50 mm)*



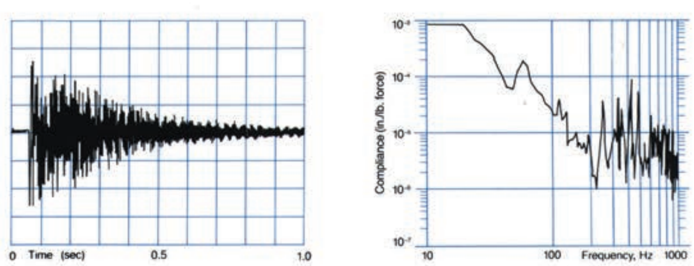

*TMC CleanTop® — 30 x 48 x 4 in. (750 x 1200 x 100 mm)*




*Granite Top — 30 x 48 x 4 in. (750 x 1200 x 100 mm)*




*Damped Steel Plate — 30 x 48 x 3/4 in. (750 x 1200 x 19 mm)*

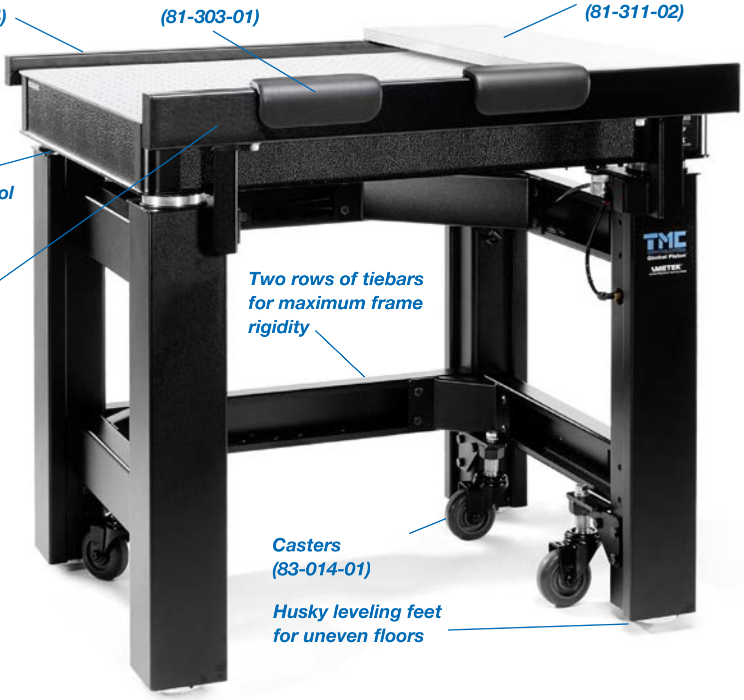



*Undamped Steel Plate — 30 x 48 x 3/4 in. (750 x 1200 x 19 mm)*

## 63-500 Series

# Micro-g® Lab Table

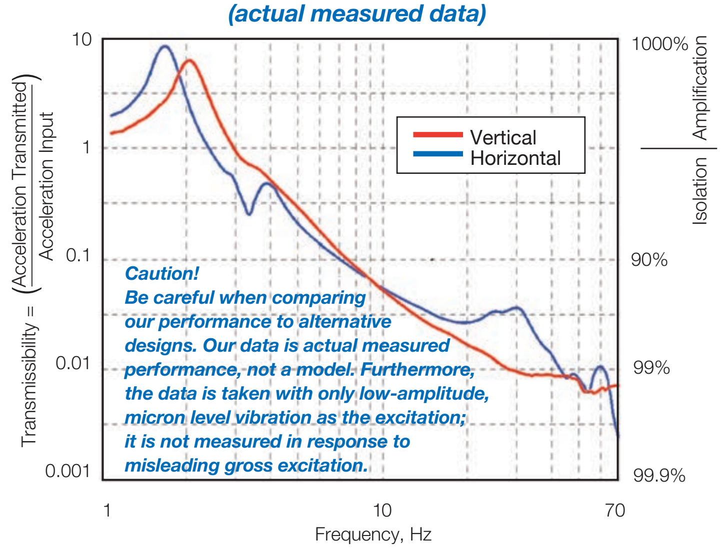
### Gimbal Piston™ Isolators




*Shown above is a Micro-g® Lab Table (63-533) with CleanTop® Optical Top and accessories. At right is a Micro-g® Lab Table (63-541) featuring a stainless steel laminate top with listed accessories.*

TMC's Micro-g® Lab Table provides an excellent vibration-free working surface for loads up to 350 lb (160 kg). Now with modular construction, these tables are recommended for use in such diverse applications as electrophysiology, cell injection, ultramicrotomy, photomicroscopy, scanning tunnel microscopy, and confocal laser scanning microscopy.

### 63-531 Vibration Isolation Performance (actual measured data)




## General Specifications

**Isolator natural frequency:**

**High Input**
Vertical = 1.2 Hz
Horizontal = 1.0 Hz

**Low Input**
Vertical = 1.5 - 2.0 Hz
Horizontal = 1.2 - 1.7 Hz

**Isolation efficiency @ 5 Hz:**
Vertical = 70 - 85%
Horizontal = 75 - 90%

**Isolation efficiency @ 10 Hz:**
Vertical = 90 - 97%
Horizontal = 90 - 97%

**Recommended load capacity:**
350 lb (160 kg)

**Finish:** Medium texture black powder coat frame, stainless steel top

**Facilities required:**
80 psi nitrogen or air

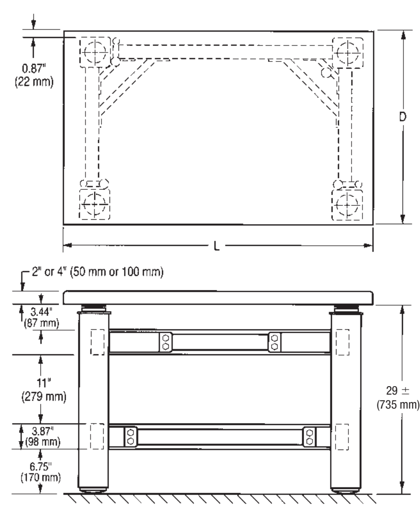
**Shipping weight:**
Approximately 600 lb (272 kg)

**Height control valves:**
repeatability standard valve +/- 0.050 in. (1.3 mm)
**Precision valve:** +/- 0.005in. (.13mm)

*Micro-g Lab Table (63-541) with the following accessories:*

| | | |
|---|---|---|
| (1) | 81-301-022 | Front support bar-48 in., 2 in. tops |
| (1) | 81-302-022 | Rear support bar-48 in., 2 in. tops |
| (2) | 81-303-01 | Armrest pads |
| (2) | 81-312-02 | 10 in. x 32 1/2 in. Sliding shelf |
| (1) | 83-014-01 | Retractable Casters |

*Accessories for 63-500 Lab Tables are specified separately and listed in the Ordering Chart on page 55.*



## Which top is best for you?

**CleanTop®** features TMC's proprietary spill-proof, drilled and tapped mounting hole array. Tops are 4 in. (100 mm) thick and have 1/4–20 holes on 1 in. spacing or M6 holes on 25 mm spacing. The small cell-size steel honeycomb design is even stiffer than our stainless steel laminate. Guaranteed flat to ∓0.005 in. (∓0.13 mm).

**Stainless Steel Laminate,** our least expensive 63-500 Series top, is recommended for applications that require a strong magnetic attachment and will not involve repeated exposure of the top to corrosive liquids. However, stains from such liquids can be removed with an industrial strength stainless steel cleaner. This top does not have the precision flatness of our CleanTop honeycomb top. Flatness is ∓ 0.030 in. (∓ 0.8 mm).

**Formica® Layer on Stainless Steel laminate** is an easy-to-clean alternative to stainless steel, without sacrificing structural performance. A plastic layer is added to the top surface, which reduces ferromagnetic attachment strength.


*Photo courtesy of Leica Microsystems Inc.*

4

## Table and Accessory Ordering Chart *(see page 56)*

| TABLE MODEL (D x L) | 25 in. x 36 in. 625 x 900 mm | 30 in. x 30 in. 750 x 750 mm | 30 in. x 36 in. 750 x 900 mm | 30 in. x 48 in. 750 x 1200 mm | 30 in. x 60 in. 750 x 1500 mm | 36 in. x 48 in. 900 x 1200 mm | 36 in. x 60 in. 900 x 1500 mm |
|---|---|---|---|---|---|---|---|
| Isolator frame only (no top) | 63-510 | 63-520 | 63-530 | 63-540 | 63-540 | 63-560 | 63-560 |
| Isolator with 2 in. stainless steel laminate | 63-511 | 63-521 | 63-531 | 63-541 | 63-551 | 63-561 | 63-571 |
| Isolator with 2 in. Formica® layer on stainless steel laminate | 63-512 | 63-522 | 63-532 | 63-542 | 63-552 | 63-562 | 63-572 |
| Isolator with 4 in. CleanTop®, 1/4-20 on 1 in. spacing | | | 63-533 | 63-543 | 63-553 | 63-563 | 63-573 |
| Isolator with 100 mm CleanTop, M6 on 25 mm | | | 63-534 | 63-544 | 63-554 | 63-564 | 63-574 |
| **ACCESSORY** *(see page 56)* | | | | | | | |
| Front support bar, 2 in. (50mm) tops | 81-301-012 | 81-301-002 | 81-301-012 | 81-301-022 | 81-301-032 | 81-301-022 | 81-301-032 |
| Front support bar, 4 in. (100mm) tops | 81-301-014 | 81-301-004 | 81-301-014 | 81-301-024 | 81-301-034 | 81-301-024 | 81-301-034 |
| Rear support bar, 2 in. (50mm) tops | 81-302-012 | 81-302-002 | 81-302-012 | 81-302-022 | 81-302-032 | 81-302-022 | 81-302-032 |
| Rear support bar, 4 in. (100mm) tops | 81-302-014 | 81-302-004 | 81-302-014 | 81-302-024 | 81-302-034 | 81-302-024 | 81-302-034 |
| Armrest pads (front support bar) | 81-303-01 for all tables (order 2) | | | | | | |
| Armrest pads (perimeter enclosure and Faraday Cage) | 81-303-02 for all tables (order 2) | | | | | | |
| Sliding shelf, 6 in.(150 mm) wide | 81-311-01 | 81-311-02 | 81-311-02 | 81-311-02 | 81-311-02 | 81-311-03 | 81-311-03 |
| Sliding shelf, 10 in. (250 mm) wide | 81-312-01 | 81-312-02 | 81-312-02 | 81-312-02 | 81-312-02 | 81-312-03 | 81-312-03 |
| Sliding shelf, 14 in. (350 mm) wide | 81-313-01 | 81-313-02 | 81-313-02 | 81-313-02 | 81-313-02 | 81-313-03 | 81-313-03 |
| Sliding shelf, 20 in. (500 mm) wide | 81-314-01 | 81-314-02 | 81-314-02 | 81-314-02 | 81-314-02 | 81-314-03 | 81-314-03 |
| Full perimeter enclosure, 2 in. (50 mm) tops | 81-321-01 | 81-321-02 | 81-321-03 | 81-321-04 | | 81-321-06 | |
| Full perimeter enclosure, 4 in. (100 mm) tops | | | 81-322-03 | 81-322-04 | | 81-322-06 | |
| Raised rear shelf | 81-324-01 | 81-324-02 | 81-324-01 | 81-324-04 | | 81-324-04 | |
| Subshelf | 81-325-01 | 81-325-02 | 81-325-03 | 81-325-04 | 81-325-04 | 81-325-04 | 81-325-04 |
| Sliding shelf for perimeter enclosure | 81-327-03 | 81-327-04 | 81-327-04 | 81-327-04 | | 81-327-06 | |
| Acrylic enclosure | | | 81-328-03 | 81-328-04 | | 81-328-06 | |
| Casters, set of 4 | 83-014-01 for all tables | | | | | | |

# Micro-g® Lab Table Features

### Superior TableTops™

Our standard laminated tops provide an attractive stainless steel ferromagnetic working surface with highly damped, high stiffness construction at low cost. For applications requiring the ultimate stiffness or mounting holes, specify our proprietary CleanTop® honeycomb top.

### Gimbal Piston™ Isolators

Our Gimbal Piston™ Isolator has been proven by independent tests to consistently outperform the competition. It achieves both horizontal and vertical isolation down to very low input levels.

### Thin-Wall Rolling Diaphragms

An integral part of the Gimbal Piston, the thin-wall, dacron-reinforced, rolling diaphragm air seals are only 0.020 in. (0.5 mm) thick and extremely flexible. They do not stiffen the spring as thicker rubber diaphragms do.

### Aluminum Height Control Valves

All systems are equipped with rugged aluminum height control valves. Virtually unbreakable, they are finger adjustable with no need for tools.

### Internal Piston Travel Restraint

Unique in the industry, TMC provides husky, tamper-proof, built-in piston travel restraints. The restraints are completely independent of the table valves and have been ram-tested at forces above those produced by the pistons operating at full pressure. They cannot be decoupled accidentally and do not interfere with setting up and using the table, but simply protect against overtravel without the use of external bars that create hazardous pinch points. Heavy loads, including the top plate, can be safely removed from a table in full operation.

### Tiebar Gussets

Exclusive TMC tiebar gussets increase table frame rigidity. They compensate for the elimination of the front tiebar in order to provide kneewell space.

### Rugged Built-in Leveling Feet

Table legs include built-in fine-thread 3 in. (75 mm) diameter screw jack levelers with 1/2 in. (13 mm) travel, provision for external adjustment, and a handy adjustment wrench. The base is a solid, slightly domed shape to assure solid, wobble-free contact with sloping or irregular floors.

# Accessories

### Front Support Bar*

This adjustable steel rail mounts on the table's front legs. It has a slot in which the shelves mount and is normally ordered with the armrest pads. The bar may be centered along the length of the table or cantilevered off to either side, allowing for a wider sliding shelf to suit your application.

* NOTE: The bars can be retrofitted but cannot be used with the Full Perimeter Enclosure or Faraday Cage.

### Rear Support Bar*

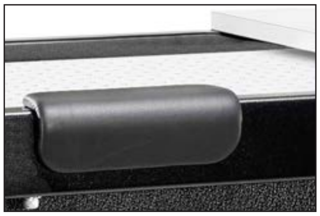
This adjustable rail mounts on the rear table legs and supports the rear end of the sliding shelves. It may also be cantilevered off to either side, allowing for a wider sliding shelf.

### Casters

A set of four retractable casters with a total weight capacity of 1,000 lb (450 kg) can be mounted to the base of the table legs. Casters are required when using the OnTrak™ feature.

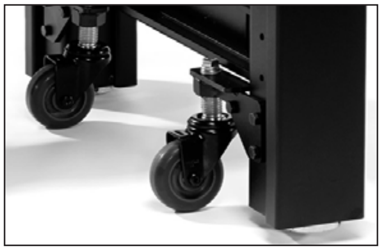
### Armrest Pads

Adjustable leather forearm rests which fasten to the front support bar. Also available is an armrest pad that attaches to the Full Perimeter Enclosure.



### Sliding Shelf

Shelves are made of wood with white plastic laminate covering all sides. A metal bracket on the front edge of the shelf fits into the slot in the front support bar. Shelves slide freely from side to side



**NEW From TMC!**

# OnTrak™

An easy-to-use, roll-off option for 63-500 Tables that dramatically simplifies table rigging and installation.

## Features & Benefits

- No heavy lifting required
- Table ships pre-installed on isolator frame
- Casters required
- Reduces set-up time
- Simply roll table off skid and into final destination

## How to Order

1. Simply specify the "OnTrak" part number from the chart at right.
2. Contact TMC for pricing.
3. Be sure your table configuration includes caster set No. 83-014-01.

## OnTrak Ordering Chart

| Order Number | Nominal Table Size |
|---|---|
| 90-510 | 25 in. x 36 in. |
| 90-530 | 30 in. x 36 in. |
| 90-540 | 30 in. x 48 in. |
| 90-550 | 30 in. x 60 in. |
| 90-560 | 36 in. x 48 in. |

and are easily lifted off the support bars. Built-in stops prevent shelves from sliding out of slots. When ordering sliding shelves, you must order front and rear support bars.

## Subshelf

For additional storage space, a shelf mounted beneath the isolated table top is available and may be retrofitted at any time.

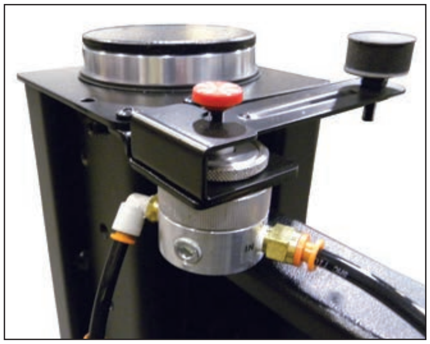
## Fixed Full-Perimeter Enclosure*

A fixed, welded-steel structure that completely surrounds the table top to provide non-isolated support for Faraday cages, or other special fixtures. It cannot be used with sliding shelves or support bars. There is an 8 in. wide sliding shelf specifically for the Full Perimeter Enclosure.

* Required for use with a Faraday Cage

## Precision Height Control Valves

To minimize bottled air supply usage, standard TMC height control valves have a small "dead band," resulting in a height return accuracy of ∓0.05 in. (∓1.3 mm). Precision valves control height to within +/- 0.005 in. but exhaust continuously. To specify precision height control valves with a table, add the letter "P" after the basic table model number. (ie.: 63P-533) Precision valves may also be retrofitted to installed tables.



# How to order

See Ordering Chart on page 55.
(See following example.)

**Example:** To order a 30 in. x 48 in. (750 mm x 1,200 mm) table with a 2 in. (50 mm) thick stainless steel laminate top, front and rear support bars, two 10 in. (250 mm) wide shelves, and armrest pads, the following numbers are specified:

| | | |
|---|---|---|
| 1 each | 63-541 | table |
| 1 each | 81-301-022 | front support bar |
| 1 each | 81-302-022 | rear support bar |
| 2 each | 81-312-02 | 10 in. (250 mm) shelf |
| 2 each | 81-303-01 | armrest pad |
| Note: You must specify quantity. | | |

# Faraday Cages



## Type II Faraday Cage

The Type II Faraday Cage offers improved access and simplified assembly. The "window-shade" type retracting front panel is easier to operate than hinged doors and causes less disturbance when adjusted. This front panel may be positioned anywhere between fully opened and closed and stays in position without a fastener. The front door is shipped assembled and the entire unit may be assembled in a few minutes with a screwdriver (provided).

This cage incorporates the same stainless steel frame and bronze-mesh material as previous versions. It mounts to (and requires) TMC's full-perimeter enclosures and mounts to our 63-500 Series tables.

Our 40 in. tall Type II Faraday Cages now include a convenient 2 in. diameter hole in the base of the side and rear panels. This feature eases cable interface to the interior of the cage. The hole is sleeved with a rounded rubber liner to shield sharp edges and assure long life. In addition, we now offer a new version of our armrest pads that is compatible with our cages. These armrest pads are virtually identical to our non-Faraday Cage pads but adhere with Velcro straps rather than clips or magnets.

## BenchTop Faraday Cage

We offer the same line of 40 in. tall cages with a baseplate which allows the cage to be used on a bench-top without a corresponding TMC table. The base of the cage is a reinforced stainless steel plate which can support a compact vibration isolation system, microscope, or other instrument.

Note: The TMC Type II Faraday Cage is designed for shielding in electrophysiology type applications (around 60 Hz and harmonics). It is not effective for television, radio, or other electronic type frequencies.

### Type II Faraday Cage Ordering Chart

*(requires table and perimeter enclosure, specified separately)*

| Type II Faraday Cage | Description | D | | L | |
|---|---|---|---|---|---|
| | | in. | mm | in. | mm |
| 81-333-03 | Type II Faraday Cage, 40 in. | 30 | 750 | 36 | 900 |
| 81-333-04 | Type II Faraday Cage, 40 in. | 30 | 750 | 48 | 1,200 |
| 81-333-06 | Type II Faraday Cage, 40 in. | 36 | 900 | 48 | 1,200 |

### BenchTop Faraday Cage Ordering Chart

| BenchTop Faraday Cage | Description | D | | L | |
|---|---|---|---|---|---|
| | | in. | mm | in. | mm |
| 81-334-03 | BenchTop Faraday Cage | 30 | 750 | 36 | 900 |
| 81-334-04 | BenchTop Faraday Cage | 30 | 750 | 48 | 1,200 |
| 81-334-06 | BenchTop Faraday Cage | 36 | 900 | 48 | 1,200 |

### Accessory Ordering Chart

| Description | 30 in. x 36 in. 750 x 900 mm | 30 in. x 48 in. 750 x 1200 mm | 36 in. x 48 in. 900 x 1200 mm |
|---|---|---|---|
| Armrest pads (F.Cage) | 81-303-02 (order 2) | | |
| Full perimeter enclosure, 2 in. (50 mm) tops | 81-321-03 | 81-321-04 | 81-321-06 |
| Full perimeter enclosure, 4 in. (100 mm) tops | 81-322-03 | 81-322-04 | 81-322-06 |
| Hanging shelf, "U"-shaped | 81-335-03 | 81-335-04 | 81-335-04 |
| Sliding side shelf, 8 in. wide | 81-332-04 | 81-332-04 | 81-332-06 |

Micro-g®

# SpaceSaver™

## Overhead Rack System for Ergonomic Mounting of Shelving Accessories




SpaceSaver™ offers a range of accessories for our 63-500 Series Micro-g® Vibration Isolation Tables. It is a convenient way to mount computer monitors, keyboards, power strips, and miscellaneous items to an air-isolated table system.

The Basic System includes:

4 uprights
4 tiebars (front to rear)
2 tiebars (side to side)
1 frame mounting bracket kit
1 top shelf
1 hardware kit

SpaceSaver may be retrofit to most existing TMC tables. The modular design incorporates a "building-block" approach so components may be added at a later date. SpaceSaver is ideal for electrophysiology rigs, optical microscope-based measurement setups, and any other application for a vibration isolation table requiring interface with computers, power supplies, and other large devices.

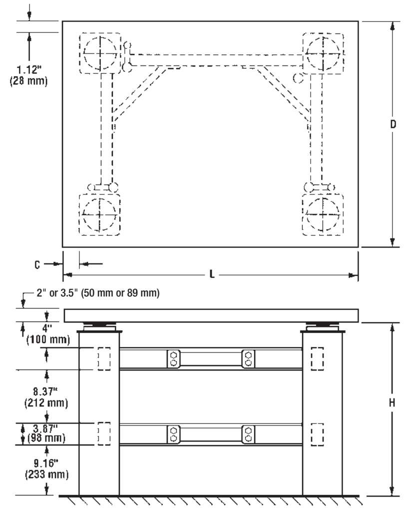
### SpaceSaver Ordering Chart

| Description | 30 in. x 36 in. | 30 in. x 48 in. | 36 in. x 48 in. |
|---|---|---|---|
| Basic System | 81-340-03 | 81-340-04 | 81-340-06 |
| Extra Top Shelf Kit** | 81-341-03 | 81-341-04 | 81-341-06 |
| Monitor Support Kit | 81-342-02 | 81-342-02 | 81-342-02 |
| Keyboard Tray Kit* | 81-343-01 | 81-343-01 | 81-343-01 |
| Power Strip Kit | 81-344-01 | 81-344-01 | 81-344-01 |
| Kit to mount perimeter enclosure option | 81-345-01 | 81-345-02 | 81-345-02 |
| Kit to mount front or rear support bar option | 81-346-01 | 81-346-01 | 81-346-01 |
| Front Support Bar | 81-301-01 | 81-301-02 | 81-301-02 |
| Padded Armrest for Front Support Bar | 81-303-01 | 81-303-01 | 81-303-01 |
| Rear Support Bar | 81-302-01 | 81-302-02 | 81-302-02 |
| Casters (set of 4) | 83-014-01 | 83-014-01 | 83-014-01 |

* Requires front support bar
** Precludes use of monitor support kit

## 68-500 Series

# High-Capacity Lab Table


For table applications that require isolating over 350 lbs (160 kg) of net load, we recommend our 68-500 Series tables. They are similar in design to our 63-500 Series tables, with higher capacity isolators and a more massive stainless steel top plate.

In addition to high load applications, 68-500 Series tables are also recommended for payloads with unusually high centers of gravity and equipment with moving stages. These applications should benefit from the increased stability of the 68-500 design.

With a stiffer, more massive top plate, a lower natural frequency isolator, and stiffer, heavier leg frames, 68-500 Series tables provide performance that is markedly superior to any other passive table in the industry.

## How to Order

See table ordering chart.

## Optional Accessories

**High-capacity casters** that retract inside the leg frames are a convenient option with this table.

It is advisable to make this choice with the original order because retrofitting requires dismantling of the table.

**A rigid front support bar,** not in contact with the isolated surface, is useful as an armrest and can be easily retrofitted. This support bar is compatible with the armrest pads and articulated armrest described on page 56.

**A rear support bar** is required to allow mounting of sliding shelves when combined with front support bars. For sliding shelf ordering information, see page 56.

**An equipment subshelf,** mounted to the tiebars beneath the isolated surface, is made of wood covered with black plastic laminate and is easy to retrofit, see page 57.

## General Specifications

**Isolator natural frequency:**
**High Input**
Vertical = 1.0 Hz
Horizontal = 0.8 Hz
**Low Input**
Vertical = 1.2 - 1.7 Hz
Horizontal = 1.0 - 1.5 Hz

**Isolation efficiency @ 5 Hz:**
Vertical = 80 - 90%
Horizontal = 80 - 90%

**Isolation efficiency @ 10 Hz:**
Vertical = 90 - 99%
Horizontal = 90 - 99%

**Recommended load capacity:**
1,200 lb (545 kg)

**Finish:** Medium texture black powder coat frame, stainless steel top

**Facilities required:**
80 psi nitrogen or air

**Shipping weight:**
Approximately 1000 lb (454 kg)

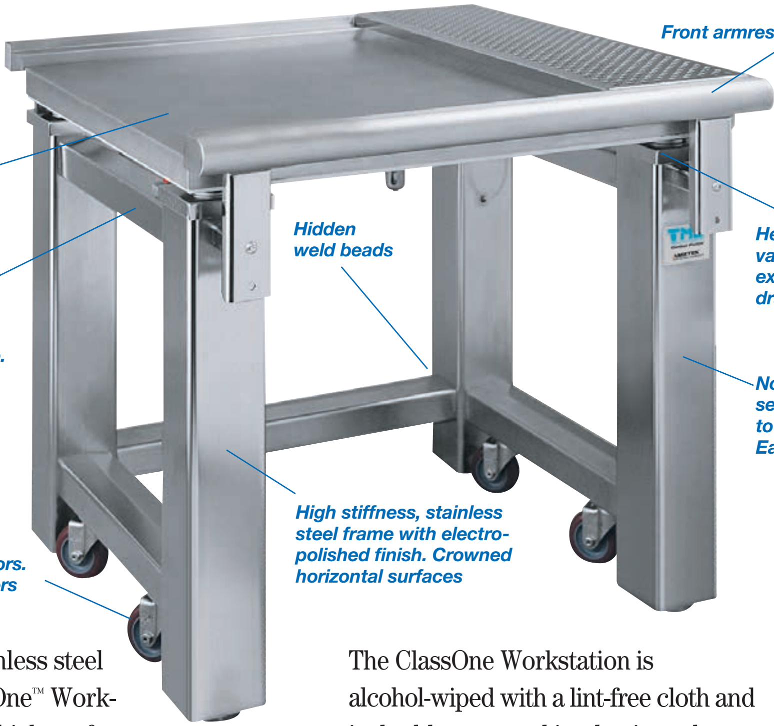
### Table Ordering Chart

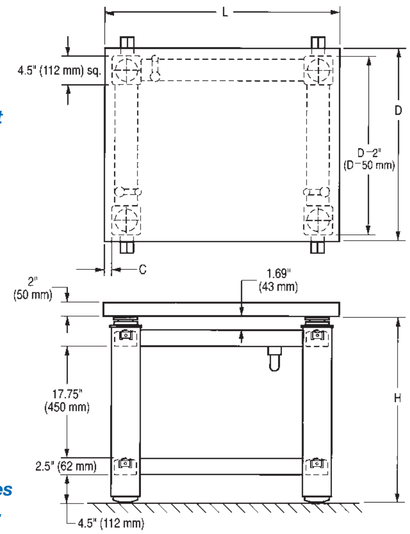
| Table Model | Description | L | D | H | C |
|---|---|---|---|---|---|
| 68-561 | Complete Table, 3 ft. x 4 ft., no holes | 47 in. (1,194 mm) | 35.75 in. (908 mm) | 30 in. (762 mm) | 2.2 in. (56 mm) |
| 68-563 | Complete Table, 3 ft. x 4 ft., CleanTop 1/4-20 holes on 1 in. centers | 47 in. (1,194 mm) | 35.75 in. (908 mm) | 31.5 in. (800 mm) | 2.2 in. (56 mm) |
| 68-564 | Complete Table, 3 ft. x 4 ft., CleanTop M6 holes on 25mm centers | 47 in. (1,194 mm) | 35.75 in. (908 mm) | 31.5 in. (800 mm) | 2.2 in. (56 mm) |
| 68-571 | Complete Table, 3 ft. x 5 ft., no holes | 60 in. (1,524 mm) | 35.75 in. (908 mm) | 30 in. (762 mm) | 9 in. (229 mm) |
| 68-573 | Complete Table, 3 ft. x 5 ft., CleanTopl 1/4-20 holes on 1 in.centers | 60 in. (1,524 mm) | 35.75 in. (908 mm) | 31.5 in. (800 mm) | 9 in. (229 mm) |
| 68-574 | Complete Table, 3 ft. x 5 ft., CleanTop M6 holes on 25mm centers | 60 in. (1,524 mm) | 35.75 in. (908 mm) | 31.5 in. (800 mm) | 9 in. (229 mm) |

| Accessory Model | Description | L |
|---|---|---|
| 81-401-012 | Front support bar kit for 68-561 | 48 in. (1,220 mm) |
| 81-401-014 | Front support bar kit for 68-563, 68-564 | 48 in. (1,220 mm) |
| 81-401-022 | Front support bar kit for 68-571 | 60 in. (1,524 mm) |
| 81-401-024 | Front support bar kit for 68-573, 68-574 | 60 in. (1,524 mm) |
| 81-402-012 | Rear support bar kit for 68-561 | 48 in. (1,220 mm) |
| 81-402-014 | Rear support bar kit for 68-563, 68-564 | 48 in. (1,220 mm) |
| 81-402-022 | Rear support bar kit for 68-571 | 60 in. (1,524 mm) |
| 81-402-024 | Rear support bar kit for 68-573, 68-574 | 60 in. (1,524 mm) |
| 81-303-01 | Armrest pads (requires Front support bar) order 2 | 60 in. (1,524 mm) |
| 81-421-01 | Subshelf | |
| 83-013-01 | Set of 4 retractable casters | |

## 63-600 Series

# ClassOne™ Workstation




The all-stainless steel TMC ClassOne™ Workstation is a high-performance, pneumatic vibration isolation table designed from the floor up for maximum cleanroom compatibility. Isolation is provided by the same Gimbal Piston™ element that provides unsurpassed performance in isolating optical tables, electron microscopes, precision balances, and scanning tunneling microscopes.

The ClassOne Workstation is alcohol-wiped with a lint-free cloth and is double-wrapped in plastic at the factory prior to shipping.

## How to Order

The basic table includes a front support bar. Options include shelves, rear support bar (required to mount shelves), and casters. The shelves include a pattern of 0.4 in. (10 mm) holes on 1 in. centers. The accessories available for the 63-600 Series ClassOne Workstation are specified separately.

## General Specifications

**Isolator natural frequency:**
**High Input**
Vertical = 1.2 Hz
Horizontal = 1.0 Hz
**Low Input**
Vertical = 1.5-2.0 Hz
Horizontal = 1.2-1.7 Hz

**Isolation efficiency @ 5 Hz:**
Vertical = 70 - 85%
Horizontal = 75 - 90%

**Isolation efficiency @ 10 Hz:**
Vertical = 90 - 97%
Horizontal = 90 - 97%

**Recommended load capacity:**
350 lb (160 kg)

**Finish:** Electopolished stainless steel frame, passivated or electropolished stainless steel top

**Facilities required:**
80 psi nitrogen or air

**Shipping weight:**
Approximately 600 lb (272 kg)

### Table Ordering Chart

| Table Model | | L | D | H | C |
|---|---|---|---|---|---|
| Complete Table and Armrest with Passivated Stainless Steel Top | Complete Table and Armrest with Electropolished Stainless Steel Top | | | | |
| 63-631 | 63-635 | 35 in. (875 mm) | 30 in. (750 mm) | 30 in. (750 mm) | 1/2 in. (13 mm) |
| 63-641 | 63-645 | 47 in. (1,175 mm) | 30 in. (750 mm) | 30 in. (750 mm) | 6 1/2 in. (163 mm) |
| 63-661 | 63-665 | 47 in. (1,175 mm) | 36 in. (900 mm) | 30 in. (750 mm) | 2 in. (50 mm) |
| 63-671 | 63-675 | 60 in. (1,500 mm) | 36 in. (900 mm) | 30 in. (750 mm) | 8 1/2 in. (213 mm) |
| Accessory Model | Description | | | | |
| 81-302-05 | Rear support bar & mounting clamps | 35 in. (875 mm) | | | |
| 81-302-06 | Rear support bar & mounting clamps | 47 in. (1,175 mm) | | | |
| 81-302-07 | Rear support bar & mounting clamps | 60 in. (1,500 mm) | | | |
| 81-312-06 | 10 in. (25 mm) wide sliding shelf | | 30 in. (750 mm) | | |
| 81-312-07 | 10 in. (25 mm) wide sliding shelf | | 36 in. (900 mm) | | |
| 83-015-01 | Casters, set of 4 | | | | |

## 20 Series

# Active Vibration Isolation Lab Table


*The affordable Active Vibration Isolation Table is available in a desk style configuration in the sizes shown in the ordering chart at right, although custom configurations are welcomed.*

TMC's Active Vibration Isolation Lab Table features state-of-the-art vibration isolation performance. By integrating our new CSP® (Compact Sub-Hertz Pendulum Isolation System) for horizontal vibration reduction with our PEPS-VX® Inertial Damper for vertical vibration cancellation, we have produced a superior, ultra-quiet table in six degrees-of-freedom.

This advanced isolation technology may be combined with TMC optical tables and other TMC products, as well as designed into equipment for OEM applications.

Featuring 10 dB of isolation vertically and 20 dB of isolation horizontally at 2 Hz (a frequency at which other tables amplify vibration), the Active Vibration Isolation Lab Table is ideal for the most demanding applications in unusually severe vibration environments.

Such applications include:

- Atomic force microscopes
- Scanning probe microscopes
- Commercial interferometers
- Electro-physiology recording
- Semiconductor inspection equipment

## General Specifications

**Isolator natural frequency (low input):**
Vertical = 0.5 Hz (actively suppressed)
Horizontal = 0.5 Hz

**Isolation efficiency @ 2 Hz:**
Vertical = 10 dB
Horizontal = 20 dB

**Recommended load capacity:**
1,200 lb (545 kg)

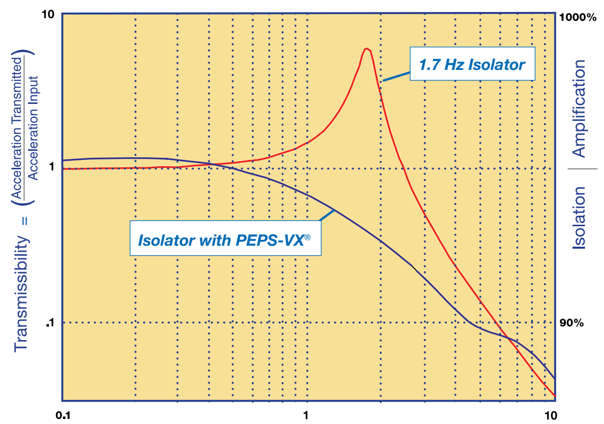
**Finish:** Medium texture black powder frame, stainless steel top

**Facilities required:**
3 CFM @ 80 psi air filtered to 20 microns or less
120 VAC or ∓ 15 VDC, 7 w nom. 12 w max

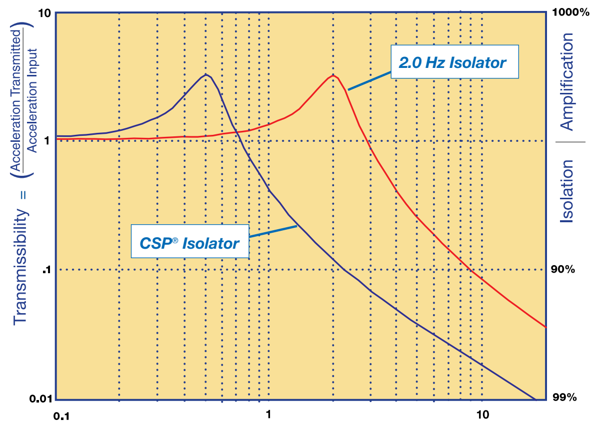
**Shipping weight:**
Approximately 1200 lb (544 kg)

## Features

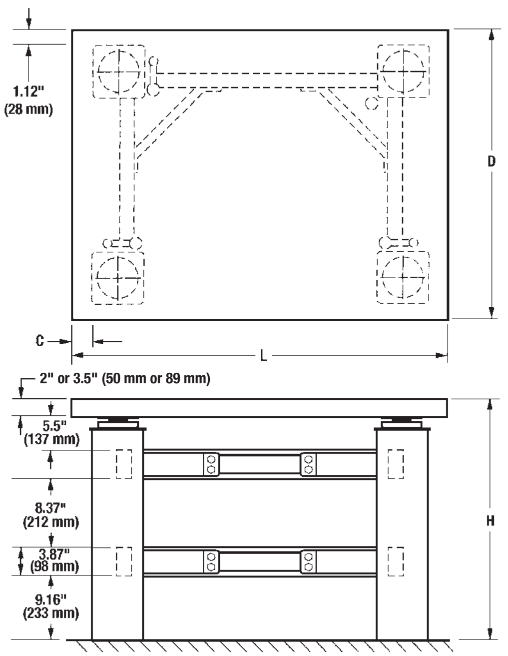
- CSP® Compact Sub-Hertz Pendulum air vibration isolation system for 0.5 Hz horizontal resonant frequency
- PEPS® II Precision Electronic Positioning System for non-contacting height control of isolated surface to one micron
- PEPS-VX® Vibration Cancellation add-on to PEPS for low frequency vibration cancellation in the three vertical degrees-of-freedom
- Rigid steel frame construction in a desk-style configuration
- Highly damped, high-stiffness 2 in. thick, stainless steel laminate top
- Optional grid of tapped holes on table top

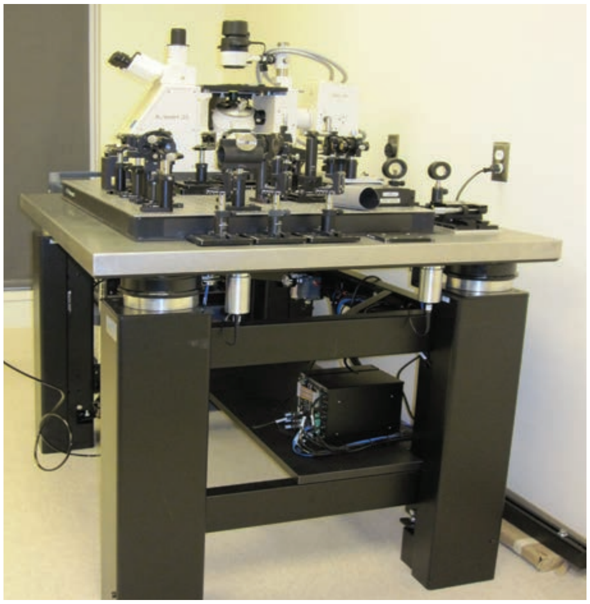



Frequency, Hz
Vibration Transfer Function: Vertical




Frequency, Hz
Vibration Transfer Function: Horizontal



*Model 20-561 – Active Table isolates Optical Microscope at Rice University Bioscience Research Collaborative.*

4

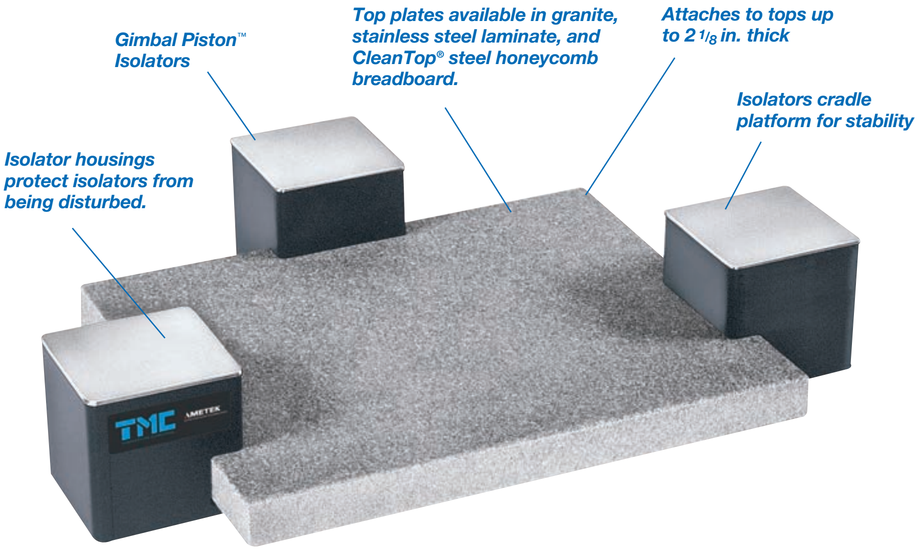
## Ordering Chart

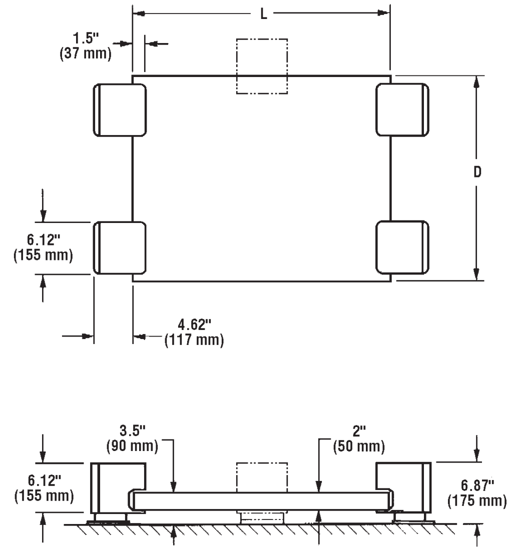
| Table Model | Description | L | D | H | C |
|---|---|---|---|---|---|
| 20-561 | Active table, 3 ft. x 4 ft.<br>no holes | 47 in. (1,194 mm) | 35.75 in. (908 mm) | 31 in. (787 mm) | 2.2 in. (56 mm) |
| 20-563 | Active table, 3 ft. x 4 ft.<br>CleanTop 1/4-20 holes on 1 in. centers | 47 in. (1,194 mm) | 35.75 in. (908 mm) | 32.5 in. (825 mm) | 2.2 in. (56 mm) |
| 20-564 | Active table, 3 ft. x 4 ft.<br>CleanTop M6 holes on 25 mm centers | 47 in. (1,194 mm) | 35.75 in. (908 mm) | 32.5 in. (825 mm) | 2.2 in. (56 mm) |
| 20-571 | Active table, 3 ft. x 5 ft.<br>no holes | 60 in. (1,524 mm) | 35.75 in. (908 mm) | 31 in. (787 mm) | 9 in. (229 mm) |
| 20-573 | Active table, 3 ft. x 5 ft.<br>CleanTop 1/4-20 holes on 1 in. centers | 60 in. (1,524 mm) | 35.75 in. (908 mm) | 32.5 in. (825 mm) | 9 in. (229 mm) |
| 20-574 | Active table, 3 ft. x 5 ft.<br>CleanTop M6 holes on 25 mm centers | 60 in. (1,524 mm) | 35.75 in. (908 mm) | 32.5 in. (825 mm) | 9 in. (229 mm) |

| Accessory Model | Description | L |
|---|---|---|
| 81-401-014 | Front support bar kit for 20-561 | 48 in. (1,220 mm) |
| 81-401-013 | Front support bar kit for 20-563, 20-564 | 48 in. (1,220 mm) |
| 81-401-024 | Front support bar kit for 20-571 | 60 in. (1,524 mm) |
| 81-401-023 | Front support bar kit for 20-573, 20-574 | 60 in. (1,524 mm) |
| 81-402-014 | Rear support bar kit for 20-561 | 48 in. (1,220 mm) |
| 81-402-013 | Rear support bar kit for 20-563, 20-564 | 48 in. (1,220 mm) |
| 81-402-024 | Rear support bar kit for 20-571 | 60 in. (1,524 mm) |
| 81-402-023 | Rear support bar kit for 20-573, 20-574 | 60 in. (1,524 mm) |
| 81-303-01 | Armrest pads (requires Front support bar) order 2 | |
| 81-421-01 | Subshelf | |
| 83-013-01 | Set of 4 retractable casters | |

## 64 Series

# TableTop™ Platform




## Effectively isolates floor vibrations while allowing for multiple choices of working surface size and type

## Benefits

- Modular design accommodates a wide range of applications.
- Lightweight for small instruments under 250 lb (115 kg)
- Choice of three or four isolators depending on desired configuration and load.

## General Specifications

**Isolator natural frequency:**

**High Input**
Vertical = 2.0 Hz
Horizontal = 1.7 Hz

**Low Input**
Vertical = 2.0-2.9 Hz
Horizontal = 2.2-3.5 Hz

**Isolation efficiency @ 5 Hz:**
Vertical = 25-50%
Horizontal = 40-60%

**Isolation efficiency @ 10 Hz:**
Vertical = 60-90%
Horizontal = 70-90%

**Recommended load capacity:**
3 isolators = 250 lb (110 kg)
4 isolators = 350 lb (160 kg)

**Finish:** Medium texture powder coat frame, stainless steel or granite top

**Facilities required:**
80 psi nitrogen or air

### TableTop™ Platform Ordering Chart

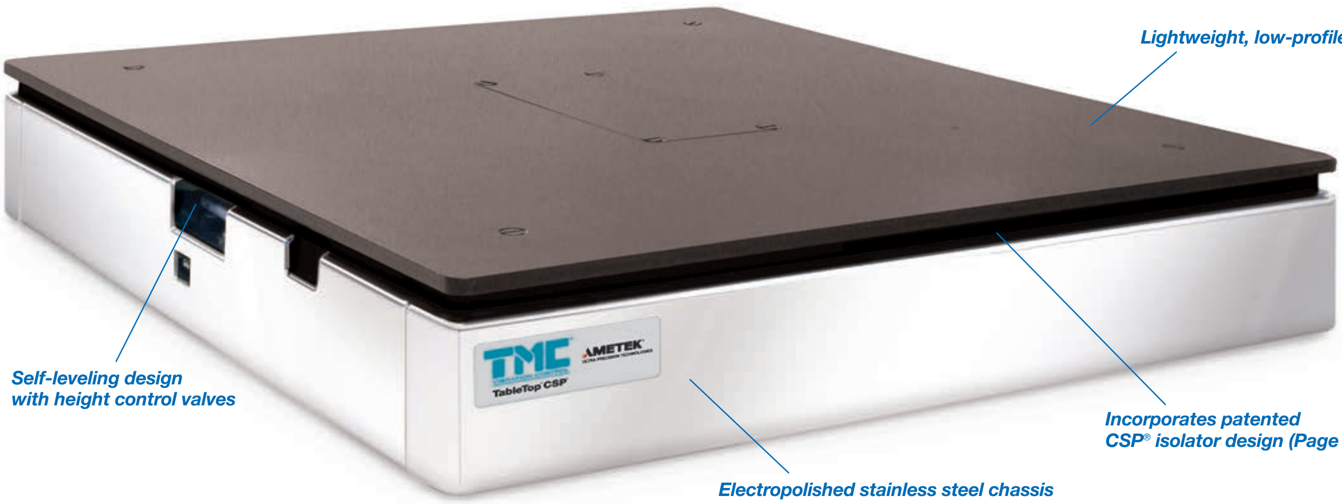
| TableTop Platform Model | Description | L | | D | | TableTop Weight | |
|---|---|---|---|---|---|---|---|
| | | in. | mm | in. | mm | lb | kg |
| 64-301 | 3 isolators and housings (no top) | | | | | | |
| 64-314 | Granite top with 3 isolators | 24 | 600 | 24 | 600 | 105 | 48 |
| 64-315 | Granite top with 3 isolators | 30 | 750 | 24 | 600 | 135 | 60 |
| 64-401 | 4 isolators and housings (no top) | | | | | | |
| 64-414 | Granite top with 4 isolators | 24 | 600 | 24 | 600 | 105 | 48 |
| 64-415 | Granite top with 4 isolators | 30 | 750 | 24 | 600 | 135 | 60 |
| 64-426 | Stainless steel top with 4 isolators | 35 | 890 | 25 | 635 | 270 | 120 |
| 64-427 | Stainless steel top with 4 isolators | 30 | 750 | 30 | 750 | 270 | 120 |
| 64-428 | Stainless steel top with 4 isolators | 35 | 890 | 30 | 750 | 270 | 120 |
| 64-446 | Imperial CleanTop® with 4 isolators | 36 | | 24 | | 115 | 52 |
| 64-447 | Imperial CleanTop with 4 isolators | 30 | | 30 | | 120 | 54 |
| 64-448 | Imperial CleanTop with 4 isolators | 36 | | 30 | | 145 | 66 |
| 64-449 | Imperial CleanTop with 4 isolators | 48 | | 24 | | 155 | 70 |
| 64-456 | Metric CleanTop with 4 isolators | | 900 | | 600 | 115 | 52 |
| 64-457 | Metric CleanTop with 4 isolators | | 750 | | 750 | 120 | 54 |
| 64-458 | Metric CleanTop with 4 isolators | | 900 | | 750 | 145 | 66 |
| 64-459 | Metric CleanTop with 4 isolators | | 1200 | | 600 | 155 | 70 |


www.techmfg.com • 978-532-6330 • 800-542-9725 (Toll Free) • Fax: 978-531-8682 • sales@techmfg.com

## 66 Series

# TableTop™ CSP®

### High-Performance Vibration Isolation System with Compact Sub-Hertz Pendulum Technology






## Low cost, lightweight system, ideal for microscopes

*Nikon TE-2000 on TableTop™ CSP®. Photo courtesy of Micro Video Instruments*

## Benefits

- Exceptional passive vibration isolation, comparable to our full-size industry standard 63-500 Series tables
- Lightweight, compact design (less than 50 lb) is easily portable.

## General Specifications

**Recommended load capacity:**
150 lb (67 kg)

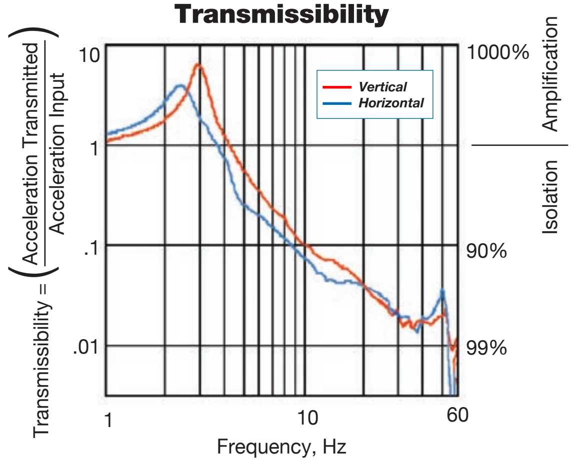
**Facilities required:**
80 psi air or nitrogen

**Finish:**
Electropolished stainless steel sides and base. Textured powder coat carbon steel top plate

**Dimensions:**
18 (w) x 20 (d) x 3 in. (h)
458 (w) x 508 (d) x 76 mm (h)

**Weight:**
50 lb (22 kg)

### Transmissibility




### TableTop™ CSP® Ordering Chart

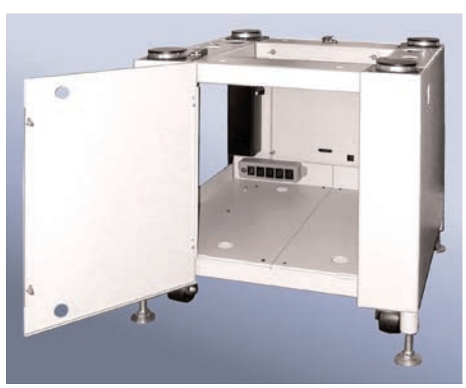
| Model | Description |
|---|---|
| 66-501 | TableTop™ CSP® Isolation System |
| 81-334-03 | BenchTop Faraday Cage, 30 x 36 in. (750 x 900 mm) *See page 58* |
| 86-16888-00 | Pressure Regulator with wall mounting bracket |


*3i's (Intelligent Imaging Innovations) VIVO 2-Photon platform is a fixed stage upright instrument designed for high-speed multiphoton imaging of live animals and tissue. The system incorporates a tunable infrared ultrashort pulsed laser to provide multiphoton excitation and imaging of cellular activity deeper into tissue than more traditional microscopy techniques. Shown above is the TMC Micro-g® Lab Table 63-573.*

# Pneumatic Vibration Isolators for OEM Applications




*Ametek Precitech Drum Roll Lathe DRL 1400 incorporates eight patented TMC MaxDamp® Isolators with a capacity of approximately 50,000 pounds. The stability of the system allows it to produce nanometer microstructures on a 5,000 pound roll for precision display master molds.*

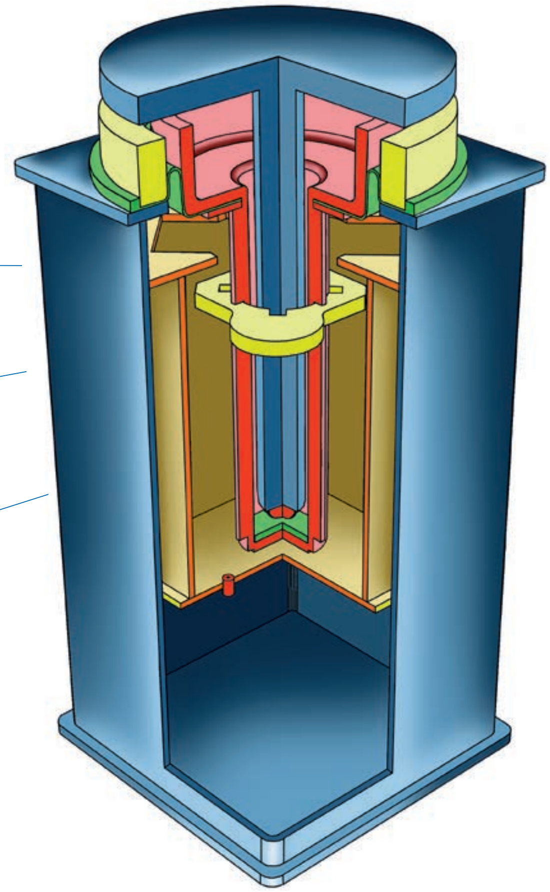


*For the vast majority of applications the Gimbal Piston™ Isolator provides outstanding horizontal and vertical vibration isolation as well as excellent damping. However, an increasing number of applications incorporate motorized stages or high aspect ratio payloads. These benefit from specialized pneumatic isolators, such as CSP® and MaxDamp® , which incorporate ultra-low horizontal resonant frequency and very aggressive damping.*

# Gimbal Piston™

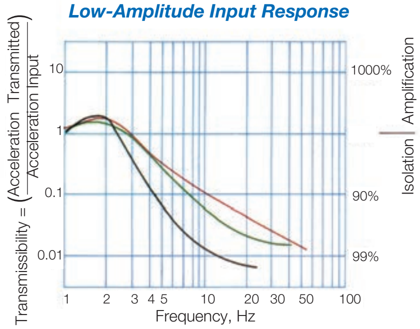
The Gimbal Piston™ Air Isolator provides outstanding isolation in all directions for even the lowest input levels. It is lightly damped and highly responsive to typical, low-amplitude ambient floor vibrations, yet achieves very high damping for gross transient disturbances, such as sudden load changes or bumping the top plate. The result is that Gimbal Piston Isolators provide superior isolation yet will virtually eliminate any gross disturbance within a few seconds. It can also stabilize isolated systems with relatively high centers of gravity without compromising isolation.

***For a detailed explanation of the Gimbal Piston, see page 50.***




***Model CPX cryogenic micro-manipulated probe station photo provided courtesy of Lake Shore Cryotronics, Inc.***

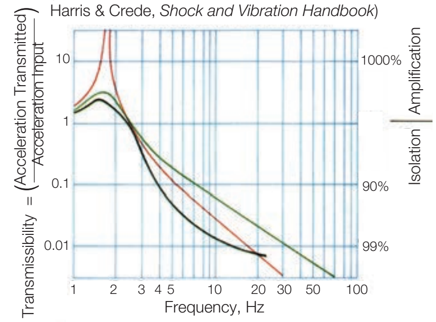
***Low-Amplitude Input Response***




■ Measured 63-500 Series Table with 40-microinch floor inputs (vertical)
■ Measured 63-500 Series Table with 4-microinch floor inputs (vertical)
■ Measured 63-500 Series Table with 0.1-microinch floor inputs (vertical)

***Vibration Isolation vs. Pneumatic Damping***

(source for theoretical curves: Harris & Crede, *Shock and Vibration Handbook*)

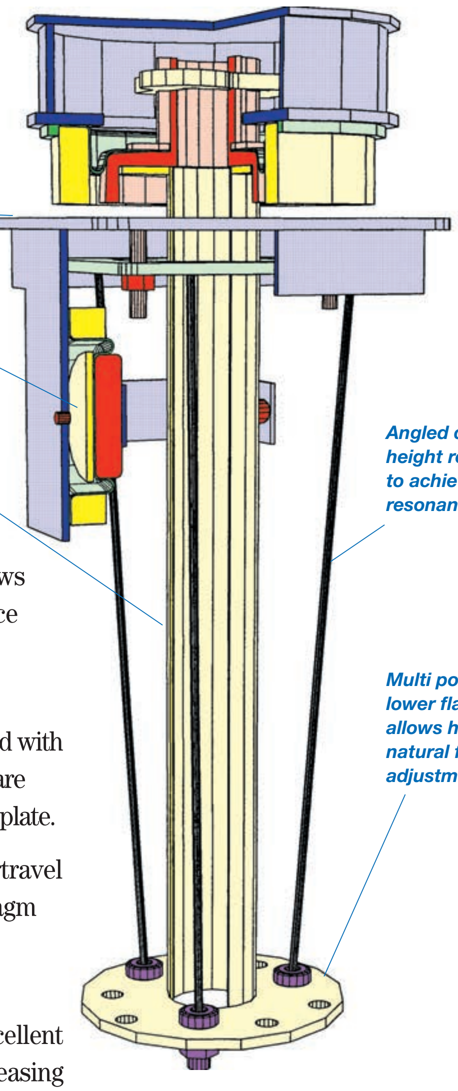



■ Theoretical 1.5 Hz isolator with no damping
■ Theoretical 1.5 Hz isolator with 0.2 damping coefficient
■ Measured 63-500 Series Table with 40-microinch floor inputs (vertical)

# CSP®

## Compact Sub-Hertz Pendulum Vibration Isolation System

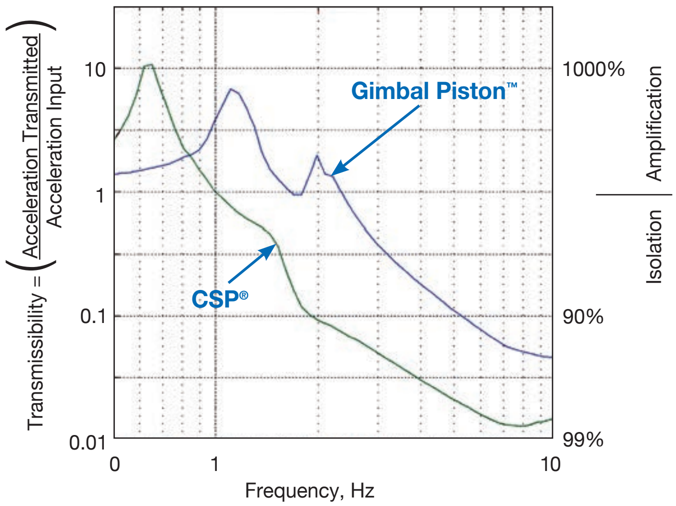
The Compact Sub-Hertz Pendulum Vibration Isolation System (CSP®) is a very low frequency horizontal vibration isolation system. Its uses include reducing the settling time of platforms subjected to horizontal (payload generated) impulses common to semiconductor manufacturing equipment.




## Features

- An adjustable and stable horizontal resonant frequency which is both load-independent and insensitive to environmental changes. The frequency range can be adjusted from 1 Hz down to 0.5 Hz or below.
- Overall height under 17 in., less than half the length of a pendulum of the same frequency.
- A lightweight pendulum design dramatically reduces the "intermediate mass" resonance common to prior pendulum system designs; the total floating mass is only a few pounds and its associated resonance is above 20 Hz in most applications.
- Fully modular design fits TMC Micro-g® leg shells and allows for easy removal and maintenance of the diaphragm assembly.
- Simple two-screw adjustment allows isolator's level to be adjusted with the payload floating. Adjustments are readily accessible on isolator's top plate.
- TMC's standard mechanical overtravel limit prevents dangerous diaphragm ruptures if the system is inflated unloaded.
- A horizontal damper provides excellent horizontal damping without increasing the system's resonant frequency.
- Reduced tilt-to-horizontal coupling makes the system ideal for use with TMC's line of active products – including the PEPS® II (Precision Electronic Positioning System) and our PEPS-VX® 3 degrees-of-freedom active cancellation system.
- An improved vertical damping characteristic due to the increased ratio of the surge tank (not shown) to top chamber volumes
- Available in a range of load capabilities from 250 lb to 2,500 lb per isolator

**Horizontal Transmissibility for CSP® vs Gimbal Piston™**



# MaxDamp®

## Vibration Isolation System

MaxDamp® is a highly damped version of our Gimbal Piston™ Air Isolator. MaxDamp is ideal for OEM equipment with motorized X-Y stages or robots which require high performance vibration isolation and aggressive settling time for stage-induced motion of the isolated payload in a low cost, passive system.

*MaxDamp® is available in a wide range of lift capacities. MaxDamp® System may be configured for payloads ranging from a few pounds to one hundred tons.*

*10,000 lb and 20,000 lb Capacity*

*5,700 lb Capacity*

*2,500 lb Capacity*

*1,000 lb Capacity*

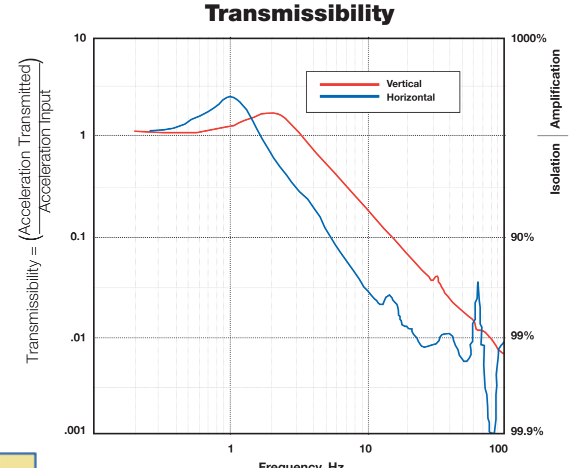
*350 lb Capacity*

*Relative size of isolators not to scale*

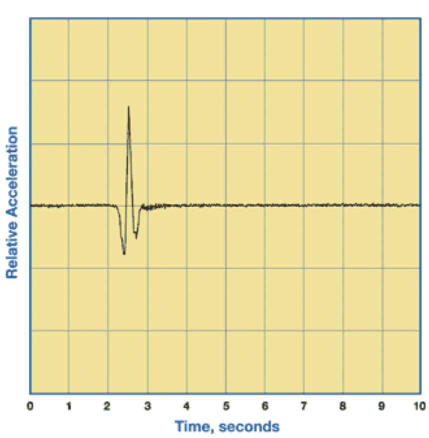
## Benefits

- Faster payload settling times
- Faster throughput and higher yields for LCD and semiconductor manufacturing/inspection tools
- "Stiffer" feel to isolated surface while maintaining high vibration isolation performance
- Less vibration induced by air currents and acoustic noise as well as "on-board" generated forces

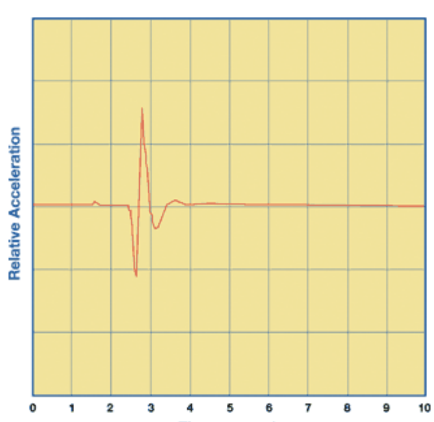
*Vibration isolation transfer function (vertical and horizontal) of MaxDamp®*




*Vertical Payload Acceleration vs. Time*




*Horizontal Payload Acceleration vs. Time*



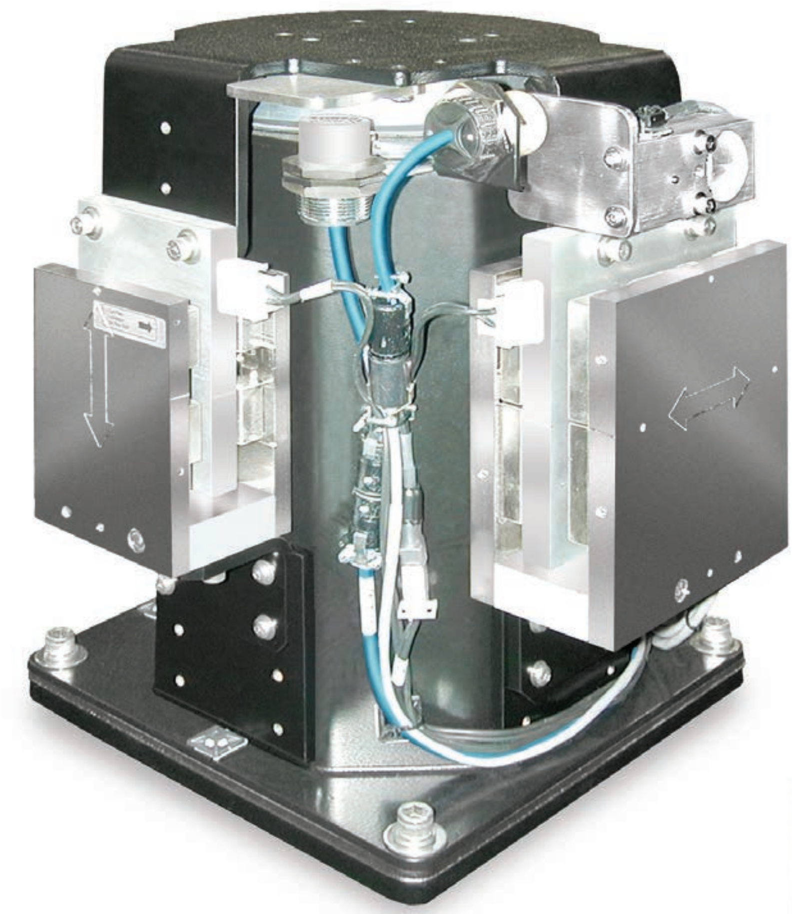

| Mount vs. Attenuation | 0.1 | 0.01 | 0.001 |
|---|---|---|---|
| Standard mount (twist) | 1.8 | 3.7 | 5.5 |
| Standard mount (X, Y, Z) | 1.1 | 2.2 | 3.3 |
| TMC MaxDamp® mounts (X, Y, Z, twist) | 0.4 | 0.7 | 1.1 |

*Comparison of settling times in seconds (isolator/DOF vs. attenuation from initial acceleration)*

# Electro-Damp®

## Active Vibration Isolation Systems





*Electro-Damp® II can be configured as individual modules, designed into a TMC-manufactured frame, or as part of a complex sub-system.*

*Electropolished Stainless Steel Acoustic Enclosure*

*PEPS® II is a digital non-contacting, height control system for TMC pneumatic vibration isolation systems*

# Electro-Damp® II

## Active Pneumatic Vibration Damping System


## Benefits

- Reduced payload motion and settling time for stage-induced motion
- Higher throughput, resolution, and yield
- Modular design allows user to specify a complete unit or components for ease of OEM integration
- Automatic tuning of feedforward parameters for reduced setup

Electro-Damp® is the first commercial, active, vibration isolation system designed specifically to increase throughput, resolution, and yield in semiconductor manufacturing applications. The Electro-Damp® II is a complete redesign of the original system, adding modularity, digital control, feedforward, high-force/high-clearance actuators, and multiple digital user interfaces specifically designed for use in OEM applications such as microlithography, inspection, and metrology tools.

Semiconductor manufacturing tools place conflicting demands on their vibration isolation system. In response to floor noise, the system must be soft to effectively filter floor vibration from reaching the isolated surface. Simultaneously, the system must be stiff in response to stage forces such that stage motion induces minimal displacement of the isolated surface and settles rapidly.

In addition to employing inertial, active feedback damping, Electro-Damp II uses information feedforward to further improve system response. Feedforward works by taking information from a stage controller about the stage's position and acceleration, then processes that data to provide force actuation to the payload, greatly reducing stage-induced payload motion. The system can read the feedforward information digitally, as bipolar analog signals, or by reading the output of quadrature encoders. The DC-2000 Digital

Controller can also automatically adjust the parameters required by feedforward using a stage test pattern. This makes setup on initial installations, or after changes to the payload, quick and easy.

Electro-Damp® II's modularity allows the system to be used with electronic servo valves alone (for heavy, low-acceleration applications like CMMs), with electromagnetic actuation only (for lighter stages which use high rates of acceleration), or a combination of both for the most demanding applications.


***The Ultratech Saturn Spectrum 300e² (above) combines TMC's Electro-Damp® II Active Pneumatic Vibration Damping System with TMC's ability to design and manufacture complex steel frames (left). Photo courtesy of Ultratech***

## GENERAL SPECIFICATIONS (may vary depending on configuration)

| | | |
|---|---|---|
| **Settling time** | | |
| | Settling time (10:1 reduction ) | 0.2 sec* |
| | Active degrees-of-freedom | 6 |
| | Height control accuracy | <10 microns at sensors |
| **DC-2000 digital controller** | | |
| | Analog inputs/outputs | 16 channels (16/14 bit) |
| | Digital inputs/outputs | 16 each |
| | Sampling rate | 6.5 KHz nominal |
| | Front panel | Two-line LCD with soft menu keys |
| | | BNC input and output for signal monitoring |
| | | Two RS-232 communication ports (second port on rear)<br>Tri-color system status lamp |
| | Physical | Single RETMA rack unit height x 15 in. deep |
| | Power | 90-240 VAC, 50-60 Hz, 100 W max. |
| | Other | Power connector for support of external devices |
| **Linear actuators (horizontal and vertical)** | | |
| | DC resistance | 5.0 Ohms |
| | Force constant | 7.5 lb/Amp |
| | Max. continuous force | 20 lb |
| | Peak force (@10A) | 75 lb |
| | Electrical time const. | 2.5 msec |
| | Stoke | 0.25 in. |
| | Transverse clearance | 0.110 in. |
| | Stray field | <1Gauss @ 2 in. |
| | Dimensions | 6.5 in.(h) x 2.3 in.(w) x 7.0 in.(d) |

| | | |
|---|---|---|
| **Power amplifier** | | |
| | Channels | 8, 10A max peak current/channel |
| | Type | PWM with RF output filtering |
| | Power | 700 W (total, all channels) |
| | Cooling | Forced air |
| | Protection | Manual circuit breaker |
| | Operation | Remote or manual enable |
| | Dimensions | 3 RETMA rack unit height x 15 in. deep |
| **Valving (active only)** | | |
| | Valve type | Proportional E/P servo valve |
| | Max flow rate | 12 scfm |
| | Air consumption | <20 scfh (no stage motion) |
| | -3 dB response | 3 Hz |
| **Height control sensors** | | |
| | Type | Non-contacting inductive (eddy current) |
| | Electronic configuration | two-wire NAMUR, 30 mm diameter |
| | Range | 15 mm nominal |
| | Resolution | <1 micron |
| **Passive pneumatic mount** | | |
| | Max. capacity | 1,000 lb (@ 80 psi) |
| | Damping (10:1) | MaxDamp® design, <3 sec |
| | Other capacities available | |

* This settling time reduction is based on a 10x reduction in the disturbance amplitude from the feedforward control and MaxDamp isolators. The actual "ring-down" is not affected by the feedforward technique.

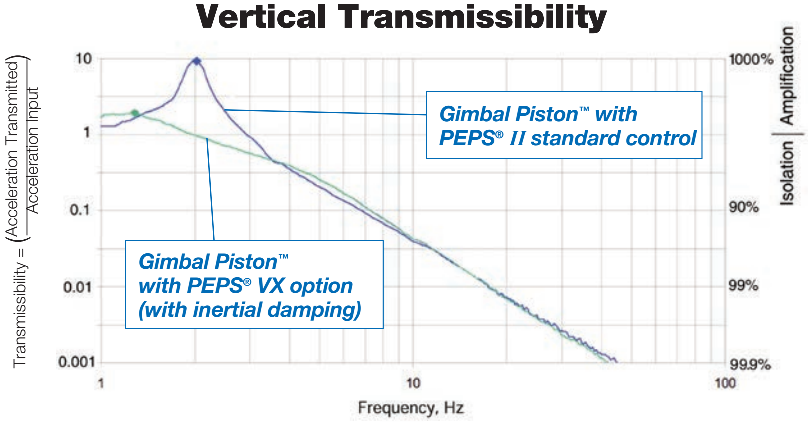
6

# PEPS® II

## Digital Precision Electronic Positioning System


PEPS® II improves and builds upon TMC's patented PEPS® (Precision Electronic Positioning System). With the addition of a new digital controller, PEPS® II is easier to use, offers more features, and has an improved user interface. PEPS® II is a digital non-contacting, height control system for TMC pneumatic vibration isolation systems. Such systems normally incorporate mechanical height valves and a mechanical height sensing linkage. Its applications range from semi-conductor manufacturing equipment to improve settling time and increase yields, to precision laboratory environments which demand the optimum noise performance and platform stability.

### Vertical Transmissibility




## How to order:

- Contact a TMC Applications Engineer for part numbers and pricing.

## Features & Benefits

- Digital control, user-friendly LCD interface
- Non-contacting electro-pneumatic height control for Gimbal Piston™, CSP®, and MaxDamp® vibration isolation systems
- Z-axis position repeatability: 10 microns
- Improved vibration isolation due to the elimination of the lever contact of conventional mechanical height control systems
- Pneumatic feedforward function minimizes Z-axis reaction to X-Y stage motion
- May be tuned to rapidly settle motion induced by X-Y stages
- Optional "VX" feature incorporates inertial sensors for active damping of vertical isolator resonance
- "Soft-dock" compatible. Allows for wafer loading/unloading without kinematic mounting
- Proportional electronic valves. No pulse noise introduced by "on-off" or conventional electronic valves
- Plumbed exhaust line for clean disposal of waste air
- Logic dock control and status


*PEPS® II – Rear View*


*Adaptor brackets can be provided to mount the PEPS® II controller in a RETMA rack.*

## General Specifications

| | |
|---|---|
| Physical Dimensions | PEPS® II Controller<br>1.72 in. (43.7mm) H x 8.0 in. (203mm) W x 9.4 in. (240 mm) D |
| Weights | PEPS® II Controller: approximately 3.0 lb (1.2 kg) |
| Environmental<br>(refer to EN 61010-1: 1993, EN 61010-1/A2: 1995) | For indoor use only, up to an elevation of 2,000 m (6560 ft.)<br>Maximum allowable temperature range: 5° C to 35° C<br>Maximum allowable humidity: 80% up to 31° C, decreasing linearly to 50% relative humidity at 40° C<br>Tolerance in main supply voltage: 85 VAC - 240 VAC<br>Over voltage category: 2<br>Pollution degree (IEC 664): 2<br>Ventilation requirements: 25 mm clearance on sides, 0 mm top and bottom |
| Power Requirements | Power input voltage range: 90-230 VAC<br>Input frequency range: 50-60 Hz |
| PEPS® II User Interface<br>(Front Panel) | Power switch<br>4 menu buttons<br>LCD display 20x2 characters<br>2 diagnostic sockets (BNC-type)<br>Three-color status LED<br>USB port |
| PEPS® II Interface<br>(Rear Panel) | AC power entry with EMI filter<br>1 air INPUT snap-in port for 1/4 in. OD tubing<br>1 air OUTPUT (Exhaust) snap-in port for 1/4 in. OD tubing<br>4 air snap-in ports for 1/4 in. OD tubing (one per isolator)<br>DB-25 male inputs-outputs and feedforward socket<br>1 Phoenix 0.2 in. pitch 6 pins GREEN header (vertical proximity sensors)<br>1 Phoenix 3.5 mm pitch 6 pins BLACK header (horizontal proximity sensors)<br>Grounding threaded stud (#10-32 thread)<br>DB-25 F socket: 1x digital Input, 3x geophone sensors interface ("-VX" option)<br>DB-25 F socket: 1x digital input, 3x current output proximity sensors (optional) |

| | |
|---|---|
| PEPS® II Performance Specifications | Analog inputs (unipolar): 8x12 bit (16 bit using over sampling), 0…3.0 V full scale<br>Analog inputs (feedforward, diag.I): 5x12 bit (16 bit using over sampling), $\mp$9 V full scale<br>Analog inputs (unipolar) protection: +5 Volts, -0.5 V clipping<br>Analog input (feedforward, diag.I) protection: $\mp$15 Volts clipping<br>Analog outputs: 4x12 bit (16 bit with over sampling), 0…3.0 V full scale<br>Analog outputs (OPTIONAL): 8x16 bit, 0…3.0 V full scale<br>Analog output protection: indefinite short circuit protection, +5 Volts clipping<br>Digital input voltage rating: 0…+3.3 V, +5 V tolerant (+5 Volts clipping)<br>Digital output rating: 0…+3.3 V, 20 m A max.<br>Digital I/O protection: +5 Volts, -0.5 Volts clipping<br>External available power: +5 VDC, 2.0 A max; +15 VDC, 1.0 A max. (20 Watt max)<br>Communication port: USB, appears as RS-232 on PC<br>Processor: ARM7TDMI / 41.78 MHz<br>Control loop rate: 100 Hz - 2.0 KHz<br>Proximity sensors: 3x vertical, (3x horizontal optional) Eddy current NAMUR 0-20 mA output<br>Velocity sensors - geophones ("-VX" option): 3x vertical, current output |
| Pneumatic Specifications | Long-term height stability: $\mp$50 microns<br>Long-term tilt stability: $\mp$50 micro radians<br>Servo valves: 4 x 2-way variable-orifice proportional servo valves<br>Valving technique: pure class-A<br>Maximum input pressure: 120 PSI or 8.3 Bar or 830 KPa<br>Nominal air consumption: 60 slpm (2 scfm)<br>Air requirements: clean, dry air, filtered to 20 microns or better<br>Fail safe: isolators deflate on power failure or power off<br>Pneumatic fittings: 'one-touch' quick fittings for 1/4 in. O.D. hose |

# Docking Capabilities

*Increasingly, tool builders incorporate the "soft docking" capability of Electro-Damp®.*
*That is, Electro-Damp maintains the payload in a very narrow window during wafer exchange.*
*However, some applications benefit from a conventional kinematic "hard dock."*

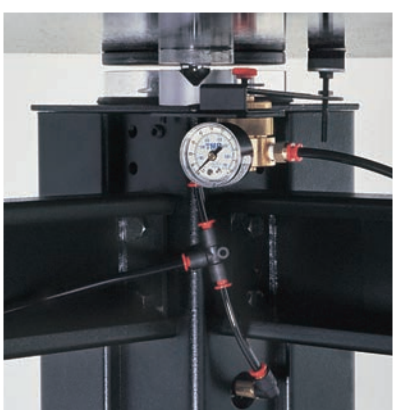
## AccuDock™

### Precision Kinematic Docking System

TMC's AccuDock™ Precision Docking System allows extremely accurate docking of air-isolated payloads for the loading/off-loading of wafers in inspection/fabrication equipment. The isolated portion of the payload remains floating and isolated until a TTL signal instructs the payload to "dock." An adjustable volume of air is then vented from the isolators, gently lowering the payload onto a set of kinematic mounts. Off-payload wafer handlers are then positioned to within ∓ 0.001 in. in all degree-of-freedom relative to the docked payload. After wafers are exchanged, the TTL signal can be switched and the existing valving system is re-enabled. The payload is refloated (isolated) and the process can resume.

*Crossed roller-bearing kinematic mounts*


*AccuDock™ controller*



*AccuDock™ shown attached to a TMC Gimbal Piston™ Isolator with mechanical self-leveling*

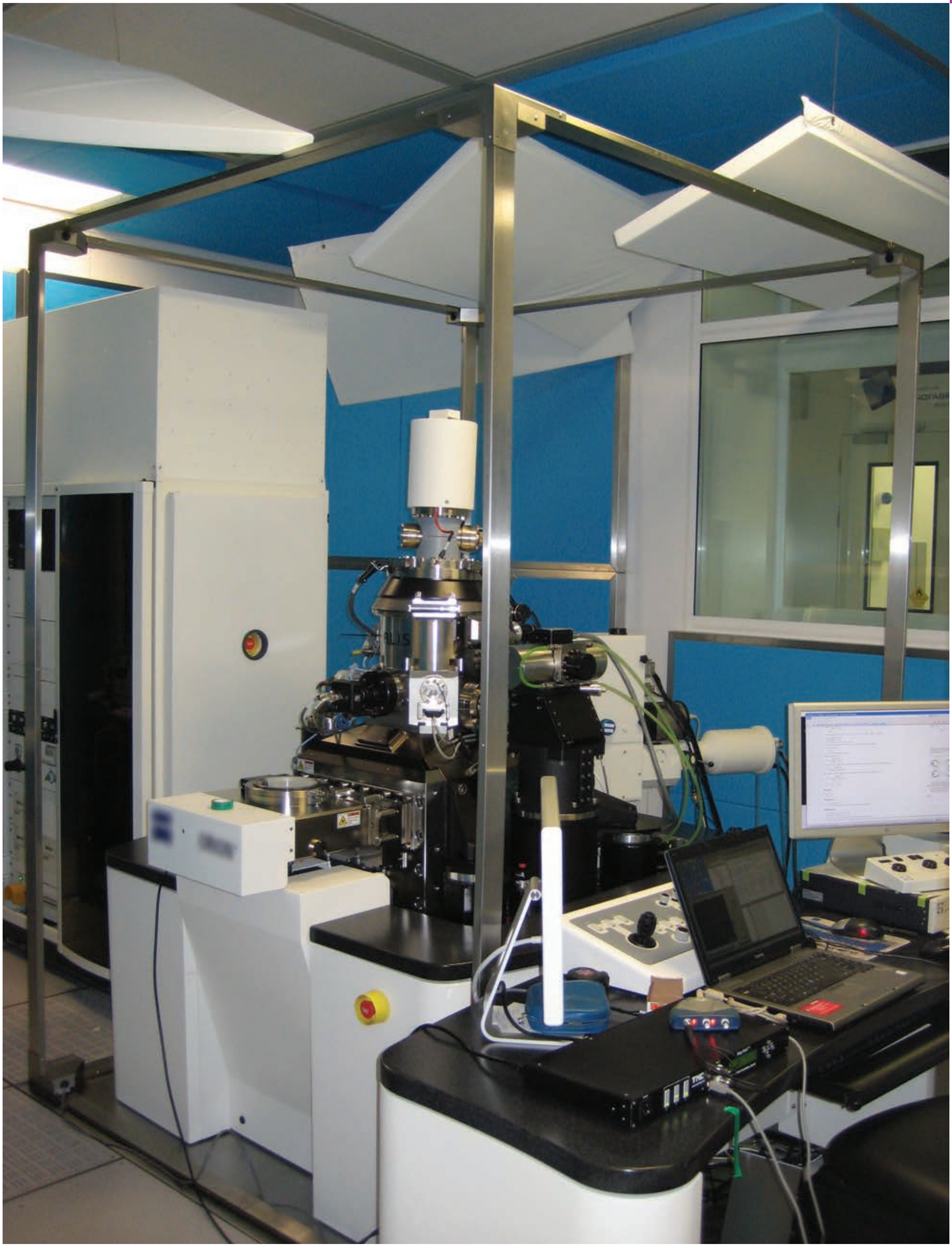
## Features

- Payload docking time is typically one second (adjustable) with a comparable refloat time.
- Precision roller bearings form a true kinematic six-point-contact mount and allow highly reproducible docking of the payload (typical repeatability is ∓ 0.001 in.).
- Docking is initiated with a TTL signal (logic 1 for dock, 0 for float). The input impedance is 1 kΩ.
- Docking force is adjusted by increasing or decreasing the system's vent time. A harder dock allows for some stage motion after docking (shift in the payload's mass distribution) but requires a longer vent time and refloat times. Lighter docking minimizes the system's cycle time.
- A fully plumbed air exhaust line allows for clean disposal of waste air.
- The system requires only a 12 - 20 VDC power supply, and a single logic input (3 wires total). The electronic interface is through a four-pin Jones connector. The maximum power consumption is 3W (intermittent: only during "docked" mode).
- System air consumption depends upon the vent time selected for the application. The controller itself requires only 70-120 psi for operating internal pilot valves.
- The system is compatible with all of TMC's mechanical valving systems.
- The system is retrofitable to all of TMC's standard vibration isolation systems and can be customized for most other air isolation systems.
- The system is modular, allowing simple replacement of the valving unit for service. All pneumatic and electronic inputs and outputs to the box are quick-connect types. All interfaces to the box are from one side, allowing easy installation in OEM applications.


www.techmfg.com • 978-532-6330 • 800-542-9725 (Toll Free) • Fax: 978-531-8682 • sales@techmfg.com

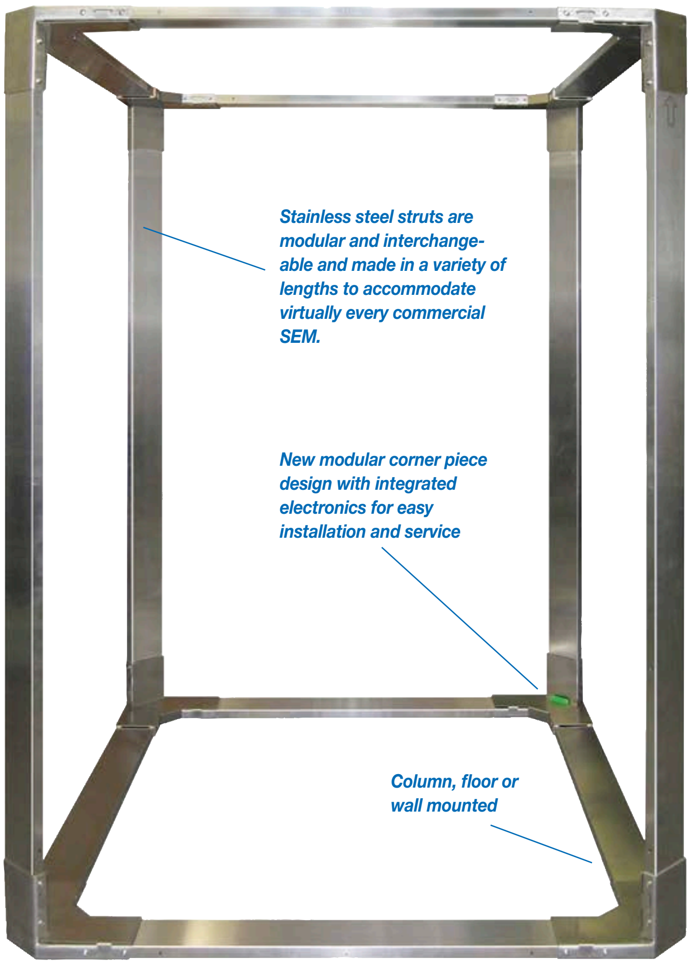
# Mag-NetX™
## Magnetic Field Cancellation





# Mag-NetX™

## Magnetic Field Cancellation System





Building upon our advanced control systems engineering and technology to actively sense and cancel building floor vibrations, we now offer Mag-NetX™, an innovative system providing active compensation of magnetic field fluctuations.

Designed both for point-of-use and OEM applications, Mag-NetX is ideal for scanning and transmission electron microscopes, electron beam lithography systems, ion beam instruments, and any tools that incorporate a charged beam. Combining Mag-NetX with TMC's advanced vibration isolation systems, we can provide the ultimate control of vibration and magnetic fields.

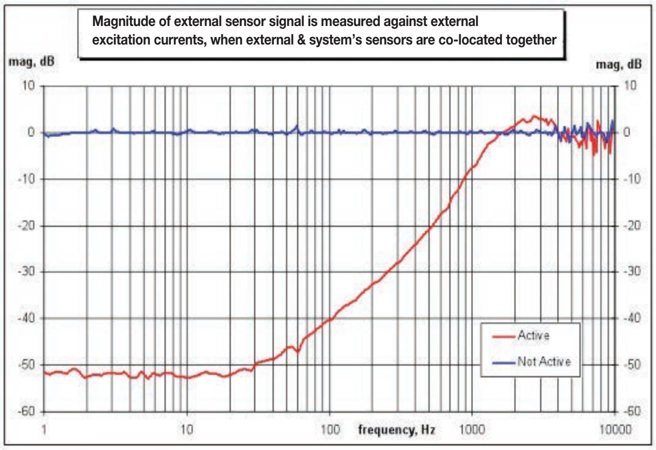
## Features & Benefits

- Helmholtz coil pairs for maximum symmetry and uniformity
- Continuous field cancellation
- Continuous field monitoring
- Set and forget operation
- Several AC and DC cancellation modes available
- 100x field improvement (typical)
- Dynamic, 100 µs response
- Accurate field measurement
- Graphical User Interface with continuous system monitoring and analysis
- Optional feedforward compensation of line frequency and harmonics
- Optional feedforward capability for other inputs
- Optional custom field creation while suppressing disturbance
- Easy to assemble stainless steel cage, in-room wall-mount systems also available

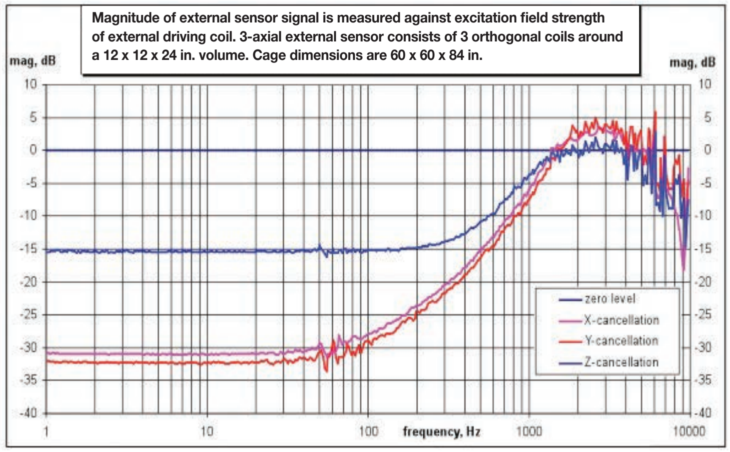
*Mag-NetX™ System with Helmholtz coils mounted on a Hitachi S-4700 scanning electron microscope column.*

## How to order:

▶ Contact TMC. An Applications Engineer will configure a system for your unique requirements and provide a quotation.




*Plot 1.* ***• Magnitude of external sensor signal is measured against disturbance field strength of external excitation driving coil.***
***• Helmholtz Cage size 36 x 36 x 52 in. (91 x 91 x 132 cm)***
***• The best performance is at the system sensor location.***




*Plot 2.* ***• Magnitude of external sensor signal is measured against disturbance field strength of external excitation driving coil.***
***• Helmholtz Cage size 60 x 60 x 84 in. (152 x 152 x 213 cm).***
***• 3-axial external sensor consists of 3 orthogonal coils around a 12 x 12 x 24 in. volume.***
***• Excitation coil positioned outside Helmholtz cage, external sensor coils positioned around system sensors.***
***• Due to cage dimensions, Z suppression is lower because Z-compensation field has lower uniformity than X and Y, but longer protected dimension (24 in. vs. 12 in. for X and Y).***

## GENERAL SPECIFICATIONS (may vary depending on configuration)

| | |
|---|---|
| **1. System Components:** | Up to 3-axes orthogonal magnetic sensor, Mag-NetX controller, Up to 3 orthogonal pairs of coils |
| **2. Performance:** | |
| Active Magnetic Field Cancellation Axes | X, Y, Z |
| Sensor type, sensor noise | Fluxgate type, noise <10 pT/√Hz at 1 Hz |
| Max ambient DC field (sensor dependent) | Choice of 3 standard sensors: ∓ 70 μT, ∓ 100 μT, ∓ 250 μT |
| Bandwidth | DC - 1 KHz typical, up to 2 KHz (depends on cage and sensor) |
| Dynamic range – ability to cancel field (depends on cage and frequency) | ∓ 10.0 μT typical, up to ∓ 100.0 μT 40 dB typ (55 dB max) |
| Controlling volume vs. magnetic field flux density | 50 $m^3$ at 10 μT RMS (depending on cage parameters)<br>1 $m^3$ at 50 μT RMS (standard controller is able to cancel Earth magnetic field with special cage construction)<br>10 $m^3$ at 50 μT (with external amplifier and special cage) |
| Field reduction ratio at sensor location (using typical console-mounting cage of X∗Y∗Z = 36 x 36 x 52 in. [91 x 91 x 132 cm]) | 40-50 dB [100x - 300x] (typical) in DC – 100 Hz<br>26 dB [20x] (typical) in 100 – 500 Hz (See Plot 1) |
| Field reduction ratio in a typical volume of electron microscope column: X∗Y∗Z = 12 x 12 x 24 in. [30 x 30 x 60 cm], using typical floor-standing cage of 60 x 60 x 84 in. (152 x 152 x 213 cm) | X, Y: 30 dB [32 x] (typical) in DC – 100 Hz<br>X, Y: 20 dB [10 x] (typical) in 100 – 500 Hz<br>Z: 15 dB [5.2 x] (typical) in DC – 100 Hz<br>Z: 10 dB [3 x] (typical) in 100 – 500 Hz<br>0 dB at 1000 Hz (See Plot 2) |

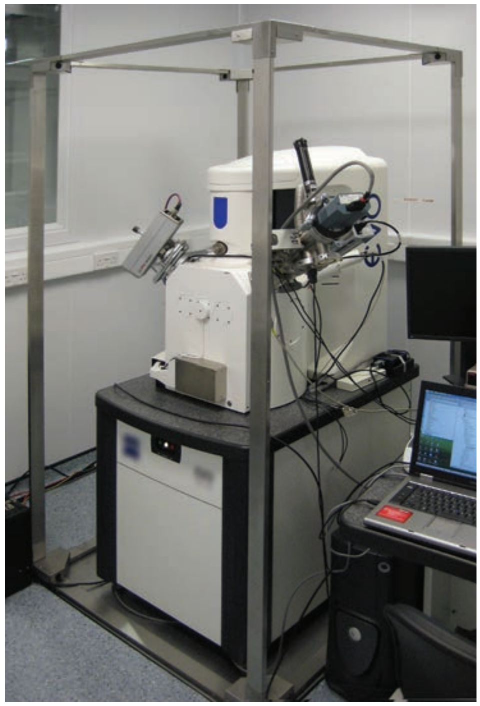
| | |
|---|---|
| **3. Mag-NetX Controller:** | 3 channels for X, Y, Z cancellation, 1U standard case |
| Dimensions of controller: | 17 x 9 x 1.75 in. (43 x 23 x 4.5 cm) |
| Operational modes: | After power-on:<br>Automatic self test/calibration and switch to controlled mode in 1 minute, no user involvement required.<br>Manual test / debug mode.<br>True DC mode (compensating Earth magnetic field)<br>Offset-DC mode (Earth magnetic field ignored)<br>Track DC-shift due to microscope moving parts<br>Quasi-DC mode (ignoring slow, >100 sec, fluctuations)<br>Cancel-and-Create (simultaneously cancelling disturbance and creating custom field) |
| Types of control loops: | Analog feedback with digitally controlled gain, DC - 2 KHz<br>Digital feedback<br>Digital feedforward (cancels AC-line power frequency and harmonics without gain-stability limits of feedback) |
| **Front panel controls:** | |
| "OK" LED indicator | Green – OK, Yellow – Warning/Error |
| LCD 2 x 20 symbols indicator | Show menu and status |
| Bar-LED indicators | Show X, Y, Z real time strength of compensation field |
| 4 push buttons | For LCD menu access |
| 2 BNC sockets | For calibration testing/debugging |
| **Interfaces:** | |
| USB socket (appears as COM port on PC) | Graphical user interface for advanced tuning/testing, accepts ASCII commands and shows menu |
| Auxiliary analog Inputs (rear DB-37) | Can be used as feedforward or to create custom field |
| GO - NO GO signal (relay) | Binary, for usage as input for protected system |
| Supply voltage, power consumption | 90 - 240 VAC 50/60 Hz, 500 VA max |

7

## Column-Mounted Helmholtz Coils

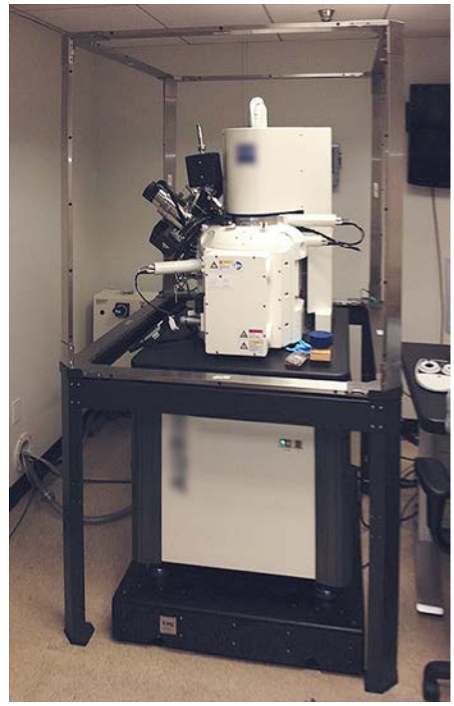
*Column-mounted Helmholtz coils are readily adapted to SEM columns but impractical for TEMs.*

## Floor-Mounted Helmholtz Coils



*Floor-mounted Helmholtz coils may be used for both SEMs and TEMs.*

## Helmholtz Coils on Leg Frame



*Helmholtz coils may be mounted on a TMC leg frame.*

## Wall-Mounted Helmholtz Coils



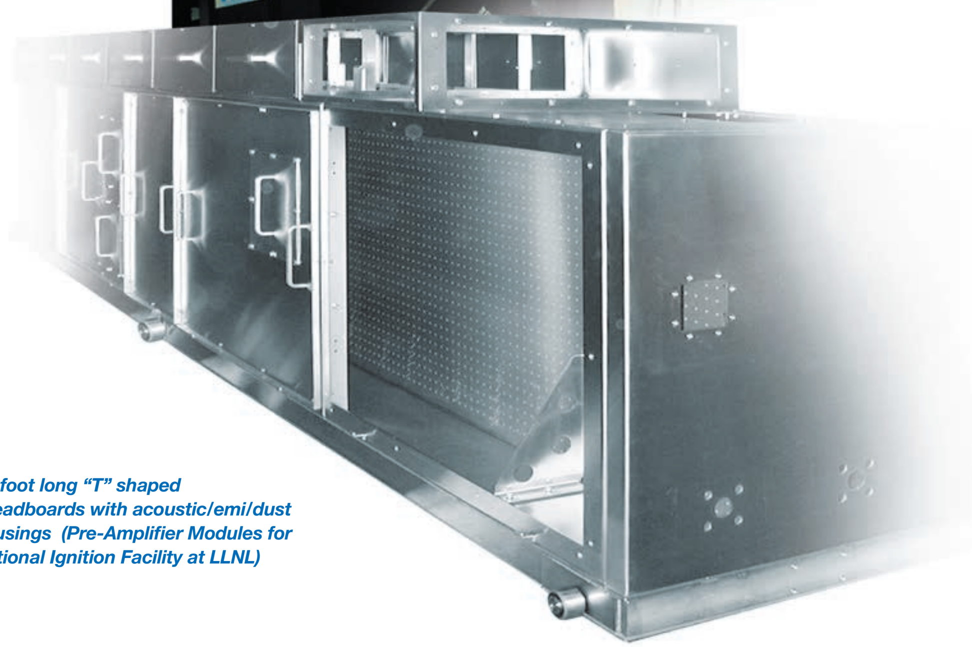
*Wall-mounted coils are a practical alternative to column and floor-mounted coils for TEMs and SEMs installed near the center of a room.*

# Acoustic Enclosures & Precision Structures



*TMC Acoustic Enclosures and Precision Structures are specifically designed to isolate acoustic noise down to low frequencies ideal for SPMs, interferometers, and other metrology instruments.*

***Integrated vibration isolation table/acoustic enclosure for Digital Instrument Atomic Force Microscope. Photo courtesy of Disc Manufacturing***

***15-foot long "T" shaped Breadboards with acoustic/emi/dust housings (Pre-Amplifier Modules for National Ignition Facility at LLNL)***

NEW From TMC!

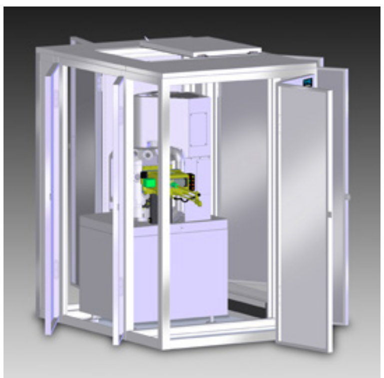
# SEM-Closure™

## Acoustic Enclosure for SEMs

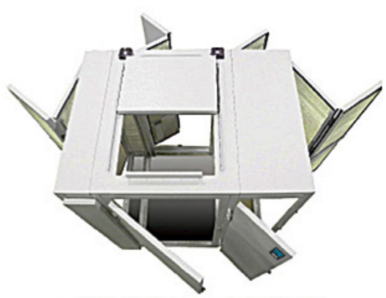
SEM-Closure™ is an acoustic enclosure designed specifically for scanning electron microscopes (SEMs). Together with TMC's SEM-Base™ floor platform and Mag-NetX™ magnetic field cancellation, SEM-Closure™ provides a total environmental solution to protect sensitive SEMs from all outside interference.

SEM-Closure is designed to accommodate SEM-Base, an active piezoelectric vibration cancellation floor platform, and Mag-NetX in a sealed and temperature-controlled acoustical chamber – protecting the SEM from vibration, magnetic field disturbances, and acoustic noise.

Integration of the three systems ensures proper fit and compatibility. The vibration isolation system can be inside the enclosure itself. Also, the SEM-Closure frame is designed to accommodate Mag-NetX Helmholtz coils as well as the acoustic panels, eliminating the need for a second frame to house the coils. SEM-Closure provides multiple access points, a heat dissipation system, and provisions for tool plumbing and cabling within the system.

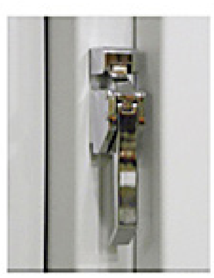


Main door is 36" wide allowing full access to front of SEM. 24" side module also includes a door on front side.



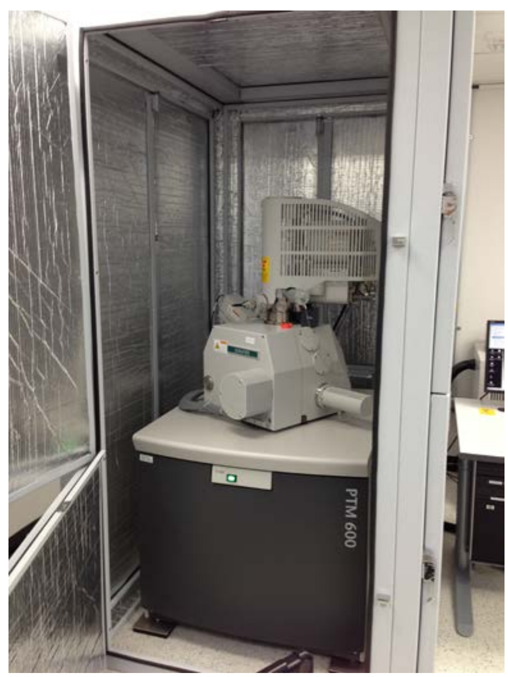
Several hinged doors allow easy access to any side of the SEM for sample preparation, adjustment of accessories and maintenance. Bi-fold doors on sides and rear help minimize clearance requirements. Optional quarter-panel door for quick and easy access. Model shown is number 30-202-12-24.

Top panel includes easy-open, space-saving hatch door for access to top of SEM. Cam-Lock ensures tight seal.



All doors include easy-to-open latch, and tight seal when closed. All panels constructed of TMC proprietary acoustic layering with powder coat steel exterior.

*SEM-Closure® provides multiple access points, a heat dissipation system, and provisions for tool plumbing and cabling within the system. Together with our SEM-Base™ active vibration cancellation platform and Mag-NetX™ active magnetic field cancellation system, TMC now provides, with SEM-Closure, the ultimate, fully integrated, total environmental solution to protect sensitive scanning electron microscopes from all outside interference.*



# 83-500 Series

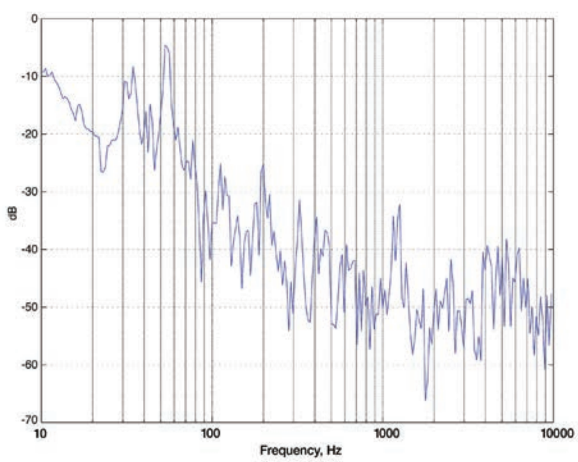
## Multi-Purpose Acoustic Enclosure

*For Microscopes, AFMs and Other Small Precision Instruments*

TMC has offered custom acoustic enclosures for our equipment maker customers for many years. These enclosures are highly engineered and uniquely suited to the specific tool being isolated.

End-users, however, were placed in a position of having to design their own acoustic enclosures for their unique applications. Given the level of design involved, this was impractical. Demand arose for a standard, "off-the-shelf" TMC enclosure incorporating many of the features of our custom enclosures with the practicality of a single, multi-purpose design. The 83-500 Series Acoustic Enclosure was designed as this multi-purpose acoustic enclosure.

### Acoustic Transmissibility



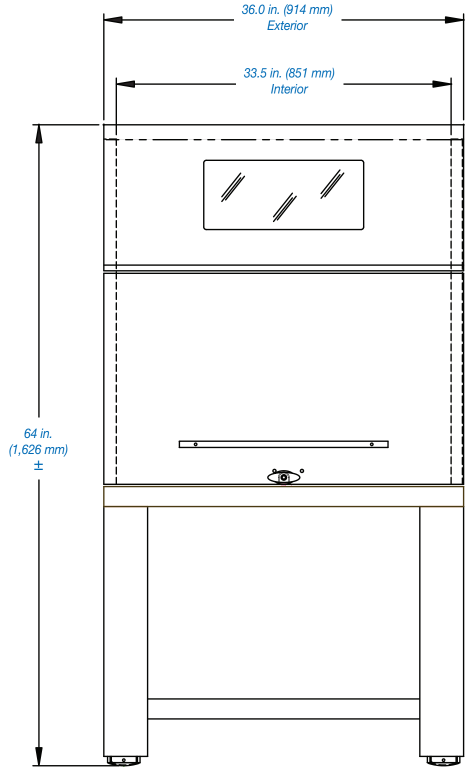

## Features & Benefits

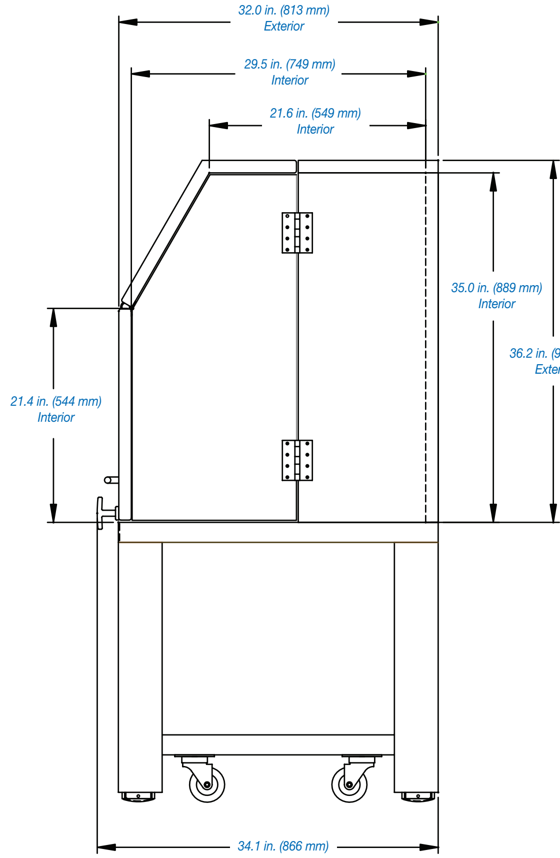
- Steel exterior with powder coat finish
- Acoustic attenuation, up to 40 dB
- Enclosure compatible with TMC line of active and passive table top vibration isolation systems
- Hinged side panels, glass window, and casters
- Self-opening front panel retracts away from operator
- Robust handle and latch ensure comfort and ease of use

*83-500 Series Multi-Purpose Acoustic Enclosure shown housing TableTop™ CSP®*

### Acoustic Enclosure Ordering Chart

| Catalog No. | Description | Width | Depth | Height | Pricing |
|---|---|---|---|---|---|
| 83-501 | Multi-Purpose Acoustic Enclosure | 36 in. | 32 in. | 64 in. | Contact TMC |




*For some applications, a custom acoustic enclosure may be necessary. This may demand a significant level of design and engineering. TMC can work with you to configure such a system tailored to your unique requirements.*

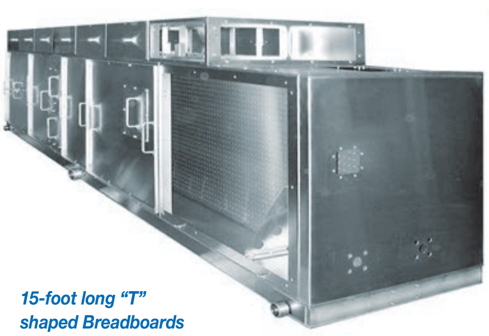
## OEM and Custom Configurations

Integrated steel and stainless steel assemblies incorporating TMC's proprietary vibration and acoustic control techniques

*Full-size "Walk-in" Acoustic Enclosure*

*Acoustic Enclosure and Vibration Isolation System*

*Electropolished Stainless Steel Acoustic Enclosure with integrated TMC Electro-Damp® PLS Vibration Isolation System for Veeco Process Metrology AFM*



*15-foot long "T" shaped Breadboards with acoustic/emi/dust housings (Pre-Amplifier Modules for National Ignition Facility at LLNL).*

8

# Room Environmental Surveys

Many of the most advanced, ultra-precision instrument manufacturers include environmental pass/fail criteria among their installation requirements for their tools. Final installation sites typically must meet stringent requirements for acoustic noise, floor vibration, and/or magnetic fields for such instruments to perform to their specifications. Such is the case for electron microscopes, semiconductor metrology tools, and NMR spectrometers, to name just a few.

The sources of such "noise" vary and may include road and rail traffic, elevators, construction, nearby human activity, and inadequate building design for a particular tool's requirements. This environmental noise must be measured, analyzed, and compared to the manufacturer's specifications to determine whether the proposed installation site is suitable. If the room is not suitable "as is," then it must be determined whether a vibration, acoustic, or magnetic field cancellation system will mitigate the disturbances back within the manufacturer's specifications.

TMC has over 30 years of experience measuring, analyzing, and reporting room environmental data. We are expert in the unique requirements of specific tools and maintain our expertise by keeping close contact with the relevant instrument manufacturers. We are familiar with not only the specific tool criteria but often the specific physical size, shape, and mass of the tool. This enables us to design and manufacture an appropriate solution.

## Among the services we offer are:

- On-site floor vibration surveys
- On-site acoustic noise surveys
- On-site magnetic field surveys
- Surveys conducted by a certified TMC Applications Engineer
- Interpretation of the measured data including FFT analysis and comparison to specific tool criteria to determine "go/no go" suitability of the proposed installation site
- A detailed written report with background, instrumentation, methodology, data analysis, conclusions, and measured data
- Recommendations for site-specific solutions as appropriate
- Measurements reported in the same units specified by the equipment manufacturer
- Post-installation site surveys as part of our certification procedure for new TMC product installations (floor vibration cancellation platforms, acoustic enclosures, and magnetic field cancellation systems)

***For more information about field surveys, contact a TMC Applications Engineer***


www.techmfg.com • 978-532-6330 • 800-542-9725 (Toll Free) • Fax: 978-531-8682 • sales@techmfg.com

# Manufacturing Capabilities



*With approximately 20 engineers and scientists few, if any, organizations can claim to have an understanding of floor vibration comparable to ours. Furthermore, few companies our size can claim to match TMC's in-depth knowledge of metal fabrication techniques and state-of-the-art manufacturing processes. Yet, it is the combination of these two assets that sets TMC head and shoulders above any other company in our field.*

*Many who tour the TMC facility are surprised to see how far we have vertically integrated our factory. For the vast majority of our products, we literally start with 16-ft long sheet steel. In this era of specialization, core capabilities, and sub-contracting, we have maintained our mission as the leading experts in the design and manufacture of precision vibration control systems.*


*Our programmable combination 4000-watt laser punch-press work centers allow TMC to provide rounded corners and special cutouts for our CleanTop® tops and prepare the top skins for subsequent automated drilling and tapping. Apart from CleanTop tops, many of our other standard and custom parts are processed through these centers.*

*Imprecise tube steel*

Our Micro-g® 63-500 Series posts demonstrate TMC's innovative design philosophy. When a tubular steel shaped post is required to house an air isolator, most competitive designs start with cut-to-length steel square tube. TMC starts with a flat steel sheet or plate then lasers, punches, bends, and welds to form the part.

*TMC precision-formed steel post*

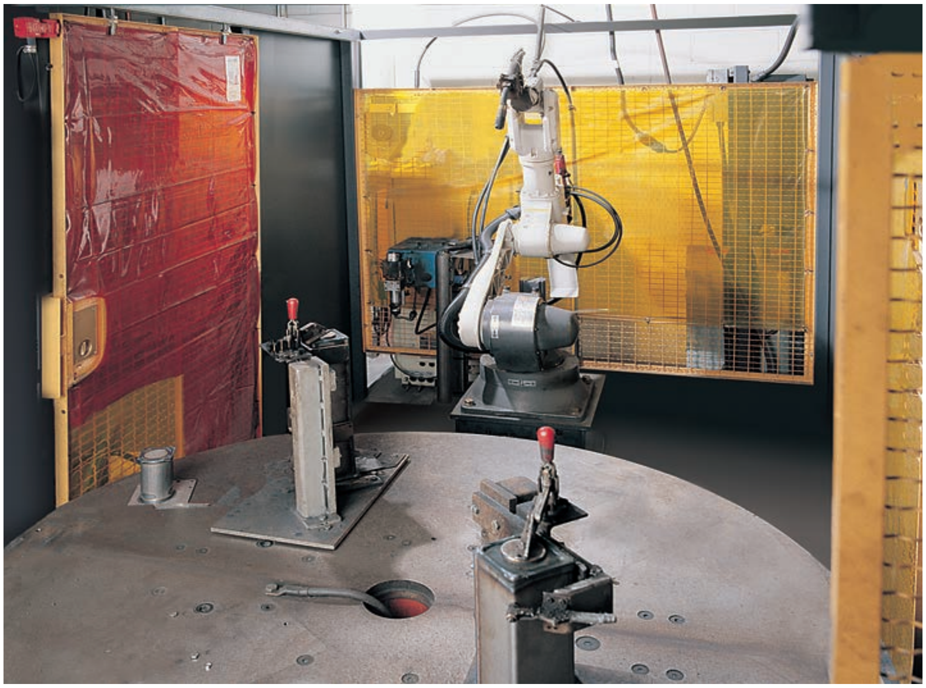
This approach has four major advantages:

1. Flat steel is much less expensive than tube steel.
2. Flat steel can be laser-cut or sheared to length. Tube steel must be saw-cut, which is expensive and imprecise.
3. Tube steel has very poor dimensional tolerance and is only nominally square. Formed parts are precise.
4. Any required holes can be punched or laser-cut in the flat prior to bending. This is much less expensive than drilling tube.

Heavier sections can be cut from stock using a 60,000 psi water jet cutter.  Accurately cutting a variety of material up to several inches thick.

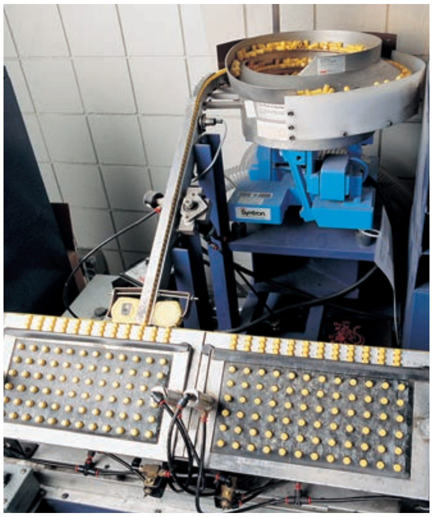


The profession of the sheet-metal mechanic has nearly become a lost art. Not at TMC. Our highly experienced mechanics operate state-of-the-art CNC press-brakes, laser punch-press machines, folding machines, and other dedicated machinery. Their expertise allows us to provide fully integrated vibration isolation solutions, not simply modules and catalog items.



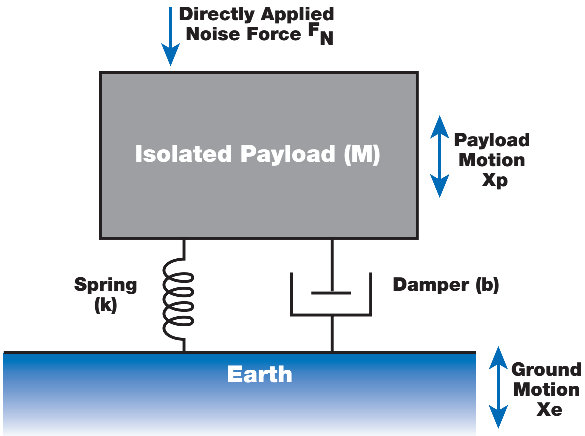
Our welding capacity consists of a team of professional, highly experienced welders. In addition, we now have an Automated Robotic Welding Facility to improve speed, cost, quality, and repeatability of regularly manufactured items.

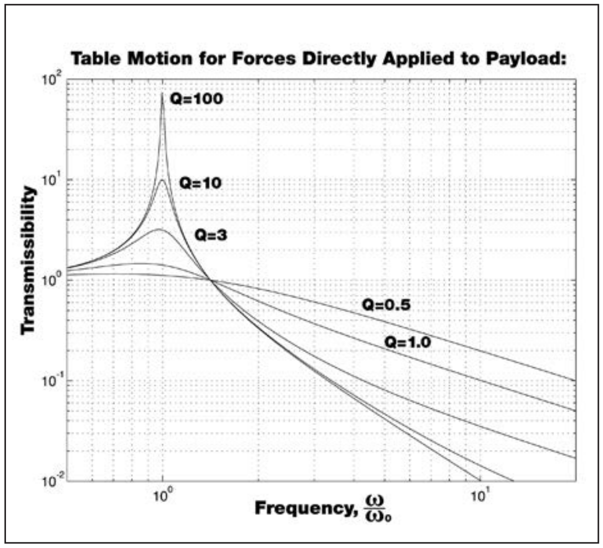
One of the many steps in the CleanTop® manufacturing process, this machine deburrs the sheet and produces a non-reflective "orbital" finish. The sheet is subsequently cleaned in our TMC-designed industrial washing center. The finished sheet is completely free of cutting oil and debris, even in the threaded holes.



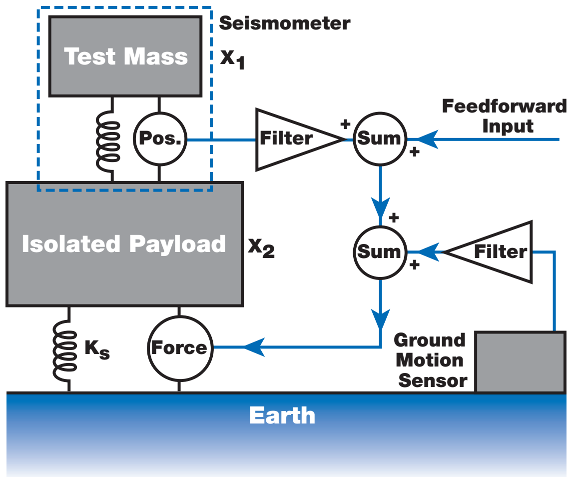
This machine is among the many unique and novel tools at TMC. Designed and manufactured internally, this device facilitates the rapid placement of the patented CleanTop cups in a precise, repeatable pattern. The device feeds and indexes cups from a syntron-feeder to either a metric or imperial pattern matrix. The grid of 72 cups is then lifted and placed using a special template.

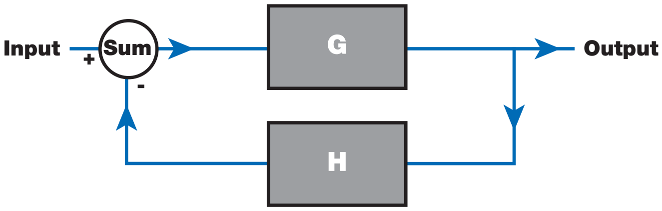

*A unique, high performance, 12,000 lb advanced metrology system on custom high-capacity Gimbal Piston Isolators.* *Photo courtesy of Zygo Corporation*

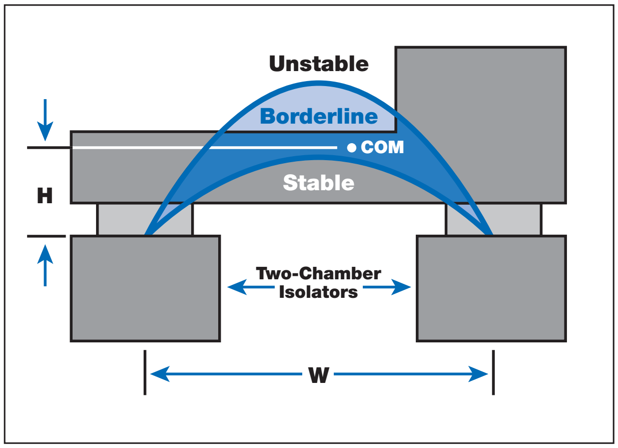



$$T \equiv \frac{X_p}{X_e} = \sqrt{\frac{1 + \left(\frac{\omega}{Q\omega_0}\right)^2}{\left(1 - \frac{\omega^2}{\omega_0^2}\right)^2 + \left(\frac{\omega}{Q\omega_0}\right)^2}}$$



# 1.0 General Introduction

TMC specializes in providing precision working surfaces and vibration isolation systems for precision measurement laboratories and industry. To provide optimal performance, both precision "tops" and their supporting isolators must be designed to address the central issue: control of environmental noise.

## 1.1 Sources of Vibration (Noise)

There are three primary sources of vibration (noise) which can disturb a payload: ground vibration, acoustic noise, and "direct force" disturbances. Ground or seismic vibration exists in all environments throughout the world. This noise has various sources, from waves crashing on coastal shorelines, the constant grind of tectonic plates, wind blowing trees and buildings, to manmade sources like machinery, HVAC systems, street traffic, and even people walking. TMC vibration isolation systems are designed to minimize the influence of these vibration sources.

Acoustic noise comes from many of the same sources but is transmitted to the payload through air pressure waves. These generate forces directly on the payload. Even subsonic acoustic waves can disturb a payload by acting as a differential pressure on the diaphragms of pneumatic isolators. Air currents generated by nearby HVAC vents can also be a source of "acoustic" noise. TMC manufactures acoustic enclosures for OEM applications which protect payloads from this type of disturbance by providing a nearly airtight, heavy, energy-absorbing enclosure over the entire payload.

Acoustic noise can be measured, but its influence on a payload depends on many factors which are difficult to estimate (such as a payload's acoustic *cross-section*). The analysis of this type of noise source goes beyond the scope of this discussion.* In general, acoustic noise is the dominant noise source of vibration above 50 Hz.

The third source of vibration is forces applied directly to the payload. These can be in the form of a direct mechanical coupling, such as vibration being transmitted to the payload through a hose, or a laser water cooling line. They can also come from the payload itself. This is the case in semiconductor inspection equipment, where moving stages are used to position silicon wafers. The force used to accelerate the stage is also applied to the "static" portion of the payload in the form of a reaction force. Moving stages also shift the payload's overall center-of-mass (COM). Reducing these sources of vibration can be done passively, with TMC's MaxDamp® line of isolators or *actively* using feedback or feedforward techniques (active systems are discussed beginning on page 106). Payload-generated noise sources are usually of a well-known nature and do not require any measurements to characterize.

The influence of vibration transmitted to the payload can be minimized through good payload design. TMC offers a wide range of honeycomb optical tables, breadboards, and platform laminations. These are available in standard and custom shapes and sizes. All reduce the influence of environmental noise by having high resonant frequencies and exceptional damping characteristics (see Section 3).

## 1.2 Measuring Noise

Seismic (floor) noise is not usually known in advance and must be measured. There are two types of seismic noise sources: periodic or coherent noise and random or incoherent noise. The first requires the use of an *amplitude spectrum* while the second is analyzed using an *amplitude spectral density*. To determine the expected levels of vibration on a payload, these must be combined with the *vibration transfer function* for the isolation system supporting it.

### 1.2.1 Periodic Noise

Periodic noise usually comes from rotating machinery. By far the most common example is the large fans used in HVAC systems. These fans spin at a constant rate and can generate a continuous, single-frequency vibration (and sometimes several harmonic frequencies as well). Another common source is air compressors. Unlike building fans, these cycle on and off according to demand. Compressors should be considered periodic, coherent noise sources, though they are *nonstationary*, meaning a measurement will change depending on whether the source is active or not. All periodic noise sources should be measured using an amplitude spectrum measurement, whether they are stationary or not.

An *amplitude spectrum* measurement is produced by taking the *Fourier transform* of data collected from a sensor measuring the noise. The most common sensor is an accel-er-ometer, which will produce a spectrum with units of *acceleration* as a function of frequency. Accelerometers are popular because they have a "flat" frequency response, and random ground noise is usually fairly "flat" in acceleration (see section 1.2.2 below). Amplitude spectrums can also be expressed as velocity or position amplitudes as a function of frequency. Most spectrum analyzers use the Fast Fourier Transform, or FFT. An FFT analyzer finds the amplitude of each frequency in the input data and plots it. This includes the amplitudes and frequencies of any periodic noise sources. The amplitudes of periodic noise sources measured using an amplitude spectrum are independent of the length of the data record.

*See Cyril M. Harris, Ed., *Shock and Vibration Handbook*, Third Ed. (The McGraw-Hill Companies, 1987)

### 1.2.2 Random Noise

Random, or incoherent noise, is measured using an *amplitude spectral density*. The difference is that the amplitude spectrum (above) is multiplied by the square root of the data record's length before being displayed by the analyzer. The result is a curve which measures the random noise with units of [units] / $\sqrt{Hz}$, where [units] may be acceleration, velocity, or position. This *normalization* for the *measurement bandwidth* ensures that the measured noise level is independent of the length of the data record. Without making this correction, for example, the level of random noise would appear to decrease by a factor of ten if the length of the data record were increased by a factor of 100. Note that periodic noise sources will appear to grow in amplitude as the data record gets longer when using the spectral density. Random ground noise levels vary greatly, but an "average" site may have 0.5 $\mu g / \sqrt{Hz}$ of noise between 1 and several hundred Hz. Random noise can also be nonstationary. For example, stormy weather can significantly increase levels of random seismic noise. Figure 1 on Page 94 illustrates common noise levels in buildings.

### 1.2.3 Measuring RMS Values

Since most locations have a combination of both random and periodic noise sources, it is often desirable to come up with a single number which characterizes noise levels. This is usually done by quoting an RMS (Root-Mean-Squared) noise level within a specified range of frequencies.

Fortunately, this is easily done by integrating the power spectral density or PSD over the frequency range of interest. The PSD is the square of the amplitude spectral density. This gives the following expression for the RMS motion between the frequencies $f_1$ and $f_2$:

$$RMS\ motion = \sqrt{\int_{f_1}^{f_2} \left[\frac{Amp(f)}{\sqrt{Hz}}\right]^2 df} \qquad [1]$$

This formula correctly calculates the RMS value of the measurement taking into account both periodic and random noise sources. Most spectrum analyzers are capable of performing this integration as a built-in function. The contribution to this RMS value from any single periodic source can be measured using the amplitude spectrum (*not* the amplitude *density*) and dividing the peak value by $\sqrt{2}$. The contribution from several peaks can be combined by adding them in quadrature. RMS values are also sometimes expressed in "1/3 octave plots" in which a histogram of the RMS values calculated in 1/3 octave frequency bins is displayed as a function of frequency. An octave is a factor of two in frequency.

### 1.2.4 Characterizing Isolators

The noise level on a payload can be predicted by measuring the ground noise as described above, then multiplying those spectra by the *transfer function* for the isolation system. The transfer function is a dimensionless multiplier specified as a function of frequency and is often referred to as the isolator's *transmissibility*. It is typically plotted as the ratio of table motion to ground motion as a function of frequency. It is common to express transmissibility in terms of decibels, or dB:

$$T_{dB} = 20 \times \log_{10}\left(\frac{Payload\ Motion}{Floor\ Motion}\right) \qquad [2]$$

In practice, measuring the transfer function for an isolation system can be corrupted by other noise sources acting on the payload (such as acoustic noise). This is the primary reason why many measured transfer functions are noisy. To improve the quality of a transmissibility measurement, a "shake table" can be used. This is dangerous, however, as it can misrepresent the system's performance at low levels of vibration. The transfer function for pneumatic isolators is discussed below.

## 2.0 An Idealized Isolator

Figure 2 shows an idealized, one degree-of-freedom isolator based on a simple harmonic oscillator. It consists of three components: The isolated mass ($M$) represents the payload being isolated and is shown here as a single block mass with no internal resonances.

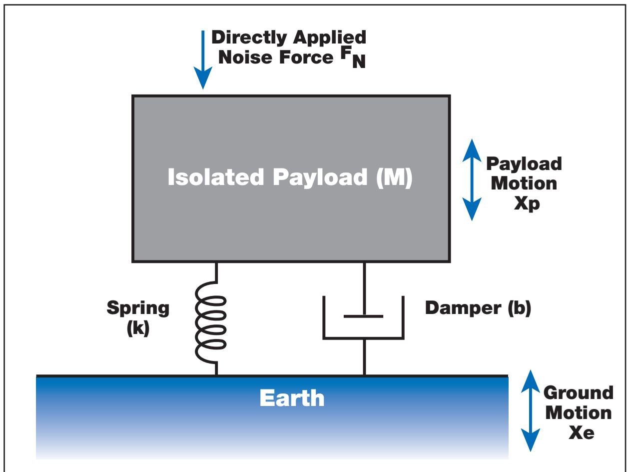
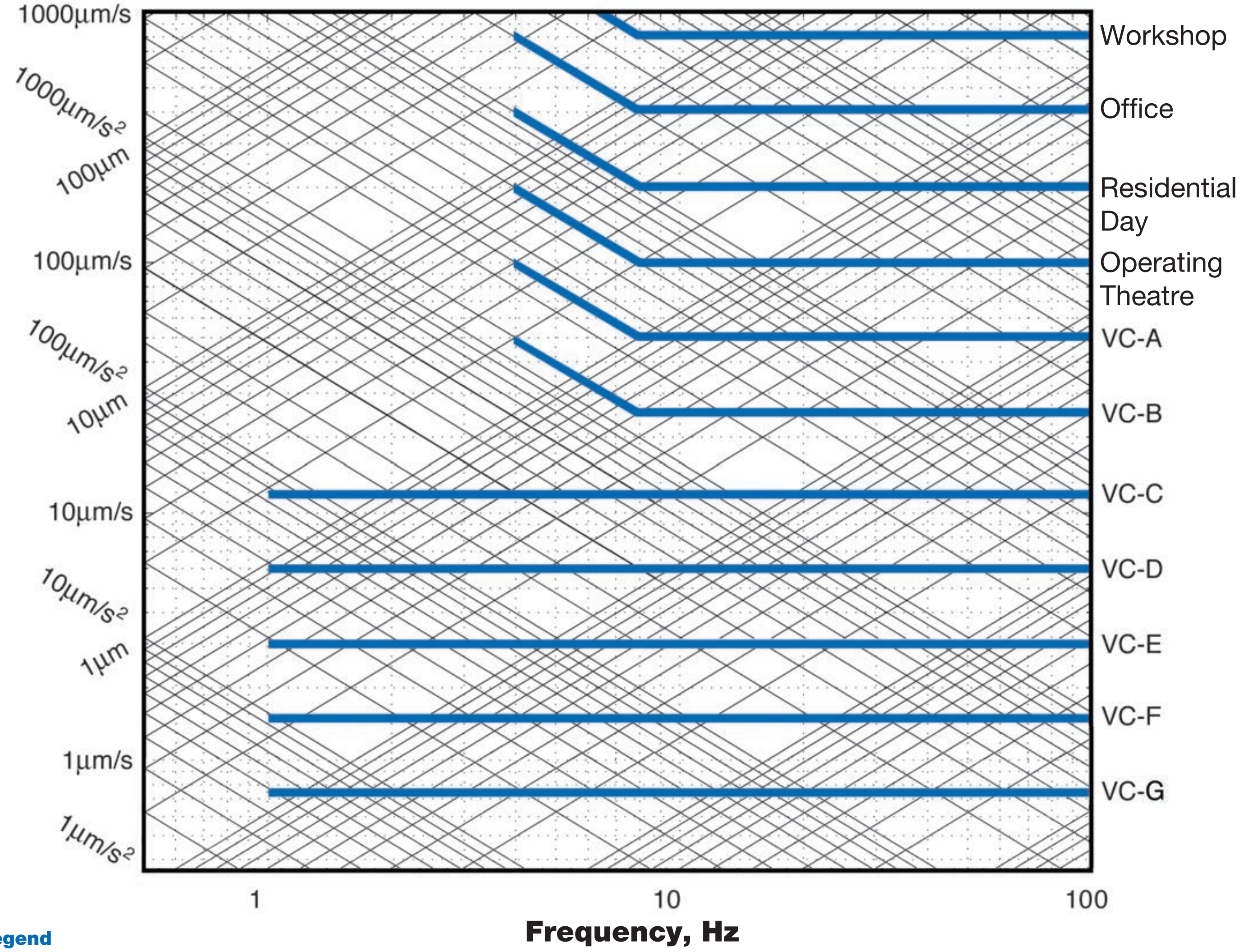


Figure 2

**Figure 1**

## Velocity, Position, and Acceleration for Different Environments:




**Legend**

| Criterion Curve | Amplitude[1] µm/s (µin/s) | Detail Size[2] µm | Description of use |
|---|---|---|---|
| Workshop (ISO) | 800 (32,000) | N/A | Distinctly perceptible vibration. Appropriate to workshops and nonsensitive areas. |
| Office (ISO) | 400 (16,000) | N/A | Perceptible vibration. Appropriate to offices and nonsensitive areas. |
| Residential day (ISO) | 200 (8,000) | 75 | Barely perceptible vibration. Appropriate to sleep areas in most instances. Usually adequate for computer equipment, hospital recovery rooms, semiconductor probe test equipment, and microscopes less than 40X. |
| Operating theatre (ISO) | 100 (4,000) | 25 | Vibration not perceptible. Suitable in most instances for surgical suites, microscopes to 100X and for other equipment of low sensitivity. |
| VC-A | 50 (2,000) | 8 | Adequate in most instances for optical microscopes to 400X, microbalances, optical balances, proximity and projection aligners, etc. |
| VC-B | 25 (1,000) | 3 | Appropriate for inspection and lithography equipment (including steppers) to 3µm line widths. |
| VC-C | 12.5 (500) | 1 - 3 | Appropriate standard for optical microscopes to 1000X, lithography and inspection equipment (including moderately sensitive electron microscopes) to 1µm detail size, TFT-LCD stepper/scanner processes. |
| VC-D | 6.25 (250) | 0.1 - 0.3 | Suitable in most instances for demanding equipment, including many electron microscopes (SEMs and TEMs) and E-Beam systems. |
| VC-E | 3.12 (125) | < 0.1 | A challenging criterion to achieve. Assumed to be adequate for the most demanding of sensitive systems including long path, laser-based, small target systems, E-Beam lithography systems working at nanometer scales, and other systems requiring extraordinary dynamic stability. |
| VC-F | 1.56 (62.5) | N/A | Appropriate for extremely quiet research spaces; generally difficult to achieve in most instances, especially cleanrooms. Not recommended for use as a design criterion, only for evaluation. |
| VC-G | 0.78 (31.3) | N/A | Appropriate for extremely quiet research spaces; generally difficult to achieve in most instances, especially cleanrooms. Not recommended for use as a design criterion, only for evaluation. |

[1] As measured in one-third octave bands of frequency over the frequency range 8 to 80 Hz (VC-A and VC-B) or 1 to 80 Hz (VC-C through VC-G)

[2] The detail size refers to line width in the case of microelectronics fabrication, the particle (cell) size in the case of medical and pharmaceutical research, etc. It is not relevant to imaging associated with probe technologies, AFMs, and nanotechnology.

*The information given in this table is for guidance only. In most instances, it is recommended that the advice of someone knowledgeable about applications and vibration requirements of the equipment and processes be sought.*

Reprinted with permission from Colin Gordon Associates. VCA–VCG refer to accepted standards for vibration sensitive tools and instruments. The levels displayed are RMS values measured in 1/3 octave band center frequencies. 1/3 octave plots are discussed in section 1.2.3.

A spring ($k$) supports the payload and produces a force on the payload given by:

$$Force = k \times (X_e - X_p) \qquad [3]$$

where $X_e$ and $X_p$ represent the (dynamic) position of the earth and payload, respectively. The third component is the damper ($b$), which is represented schematically as a dashpot. It absorbs any kinetic energy the payload ($M$) may have by turning it into heat, eventually bringing the system to rest. It does this by producing a force on the payload proportional and opposite to its velocity relative to the earth:

$$Force = b \times \left(\frac{dX_e}{dt} - \frac{dX_p}{dt}\right) \qquad [4]$$

The presence of $X_e$ in both of these equations shows that vibration of the earth is transmitted as a force to the payload by both the spring ($k$) and the damper ($b$). Rather than use the parameters ($M$), ($k$), and ($b$) to describe a system, it is common to define a new set of parameters which relate more easily to the observables of the mass-spring system. The first is the *natural resonant frequency* $\omega_0$:

$$\omega_0 = \sqrt{\frac{k}{M}} \qquad [5]$$

It describes the frequency of free oscillation for the system in the absence of any damping ($b = 0$) in *radians/second.* The frequency in cycles per second, or Hertz (Hz), is this angular frequency divided by $2\pi$. One of two common parameters are used to describe the damping in a system: The *Quality factor* $Q$ or the *damping ratio* $\zeta$:

$$Q = \frac{\omega_0 M}{b} \qquad \zeta = \frac{b}{2M\omega_0} \qquad [6]$$

It can be shown that the transmissibility for this idealized system is:

$$T \equiv \frac{X_p}{X_e} = \sqrt{\frac{1 + \left(\frac{\omega}{Q\omega_0}\right)^2}{\left(1 - \frac{\omega^2}{\omega_0^2}\right)^2 + \left(\frac{\omega}{Q\omega_0}\right)^2}} \qquad [7]$$

Figure 3 plots the transmissibility of the system versus the frequency ratio $\omega/\omega_0$ for several values of the quality factor $Q$. The values of $Q$ plotted range from 0.5 to 100. $Q = 0.5$ is a special case called *critical damping* and is the level of damping at which the system will not overshoot the equilibrium position when displaced and released. The damping ratio $\zeta$ is just the fraction of the system's damping to critical damping. We use $Q$ rather than $\zeta$ because $T \simeq Q$ at $\omega = \omega_0$, for $Q$s above about 2. There are several features which characterize the transmissibility shown in Figure 3:

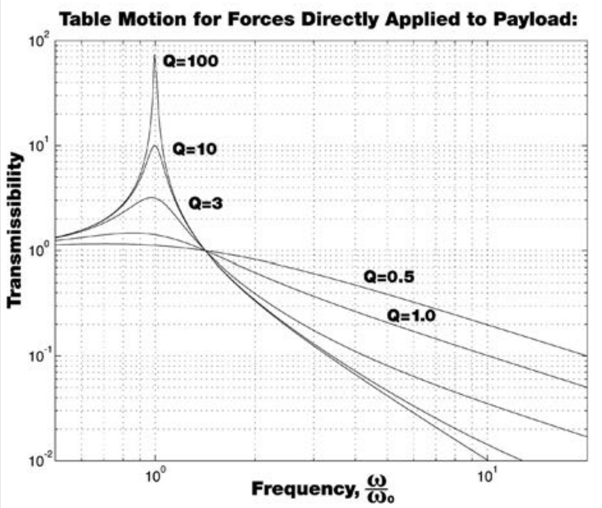



**Figure 3**

- In the region $\omega \ll \omega_0$, the transmissibility for the system is $\simeq 1$. This simply means that the payload tracks the motion of the earth and no isolation is provided.
- In the region where $\omega \simeq \omega_0$, the transmissibility is greater than one, and the spring/damper isolator amplify the ground motion by a factor roughly equal to $Q$.
- As $\omega$ becomes greater than $\omega_0$, the transmissibility becomes proportional to $(\omega_0/\omega)^2$. This is the region where the isolator is providing a benefit.
- In the region $\omega \gg \omega_0$, the best isolation is provided by the system with the smallest level of damping. Conversely, the level of isolation is compromised as the damping increases. Thus, there is always a tradeoff between providing isolation in the region $\omega \gg \omega_0$ versus $\omega \simeq \omega_0$.

The amplitude of motion transmitted to the payload by forces directly applied to it has a slightly different form than that expressed in Equation 7. This transfer function has units of displacement per unit force, so it should not be confused with a transmissibility:

$$\frac{X_p}{F_p} = \frac{Q}{M\left[Q^2(\omega_0^2 - \omega^2)^2 + (\omega\omega_0)^2\right]^{1/2}} \qquad [8]$$

Figure 4a plots this function versus frequency. Unlike Figure 3, decreasing the $Q$ reduces the response of the payload at all frequencies, including the region $\omega \gg \omega_0$.

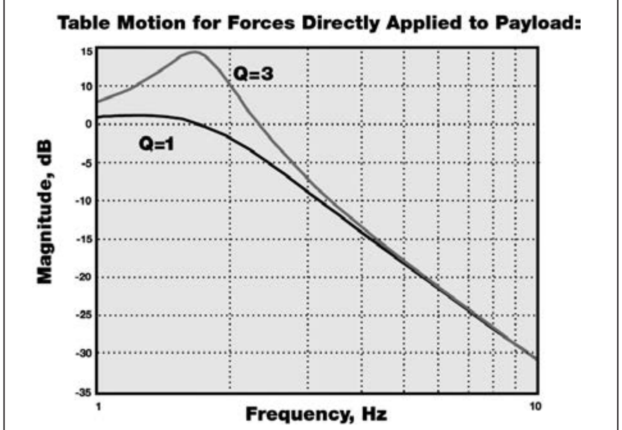



Figure 4a

TMC's MaxDamp® isolators take advantage of this for applications where the main disturbances are generated on the isolated payload. Figure 4b shows the time-domain response of the payload corresponding to the curves shown in Figure 4a. This figure also illustrates the decay of the system once it is disturbed. The envelope for the decay is exp $(-\omega_0 t / 2Q)$.

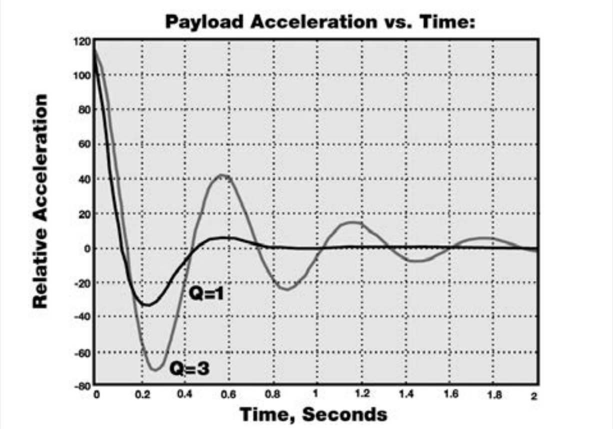



Figure 4b

There are some significant differences between real systems and the simple model shown in Figure 2, the most significant being that real systems have six degrees-of-freedom (DOF) of motion. These DOF are not independent but strongly couple in most systems. For example, "horizontal transfer functions" usually show two resonant peaks because horizontal motions of a payload drive tilt motions and vice versa. A detailed description of this type of coupling is beyond the scope of this catalog.

## 2.1 Pneumatic Isolators

Figure 5 shows a simplified pneumatic isolator. The isolator works by the pressure in the volume ($V$) acting on the area of a piston ($A$) to support the load against the

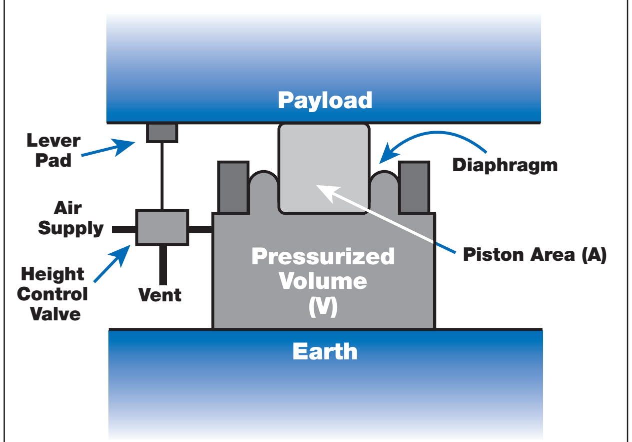



Figure 5

force of gravity. A reinforced rolling rubber diaphragm forms a seal between the air tank and the piston. The pressure in the isolator is controlled by a height control valve which senses the height of the payload and inflates the isolator until the payload is "floating." There are many advantages to pneumatic isolators. It can be shown that the resonant frequency of the payload on such a mount is approximately:

$$\omega_0 \approx \sqrt{\frac{nAg}{V}} \qquad [9]$$

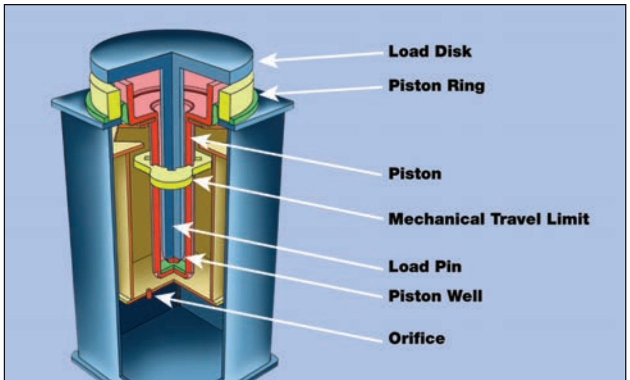
where $g$ is acceleration of gravity (386 $in/s^2$ or 9.8 $m/s^2$) and $n$ is the gas constant for air and equal to 1.4. Unlike steel coil springs, this resonant frequency is nearly independent of the mass of the payload, and the height control valve always brings the payload back to the same operating height.* Gas springs are also extremely lightweight, eliminating any internal spring resonances which can degrade the isolator's performance.

The load capacity of an isolator is set by the area of the piston and the maximum pressure the diaphragm can tolerate and is simply the product of these two numbers. It is common to rate the capacity at 80 psi of pressure. This allows a 4 in. piston to support a 1,000-lb load (for example). Though the simple isolator in Figure 5 will work, it has very little horizontal isolation and has very little damping.

*Equation 9 assumes the isolator's pressure is high compared with atmospheric pressure. Lightly loaded isolators will exhibit a slightly higher resonant frequency.

# 3.0 Practical Pneumatic Isolators

Figure 6 shows a cutaway view of TMC's Gimbal Piston™ isolator. It uses two air chambers instead of one. These are connected by a small orifice. As the piston moves up and down, air is forced to move through this orifice, producing a damping force on the payload. This type of damping is very strong for large displacements of the piston and less for small displacements. This allows for fast settling of the payload, without compromising small amplitude vibration isolation performance. Damping of this type usually produces a $Q \approx 3$ for displacements on the order of a few millimeters.




Gimbal Piston Cut-away

Figure 6

The damping provided by an orifice is limited by several factors. TMC's MaxDamp® isolators use a different method: Multi-axis viscous fluid damping (Patent No. 5,918,862). These isolators can extend the damping to near critical levels for those applications which require it. For example, semiconductor inspection equipment often uses very fast moving stages to transport wafers. MaxDamp isolators allow the payload to settle very quickly after a stage motion, while still providing significant levels of vibration isolation. The isolator uses a very low outgassing, high-viscosity synthetic oil which is hermetically sealed within the isolator's single air chamber. A special geometry ensures that the isolator damps both vertical and horizontal motions (in both X and Y directions) with equal efficiency.

Both the Gimbal Piston and MaxDamp isolators incorporate a simple and robust pendulum isolator to provide horizontal isolation. Like air springs, pendulums also produce an $\omega_0$, which is payload-independent, and equal to $\sqrt{g/l}$ where $l$ is the length of the pendulum. In the Gimbal Piston, the pendulum is actually the piston itself: The payload is supported by a *load disk*, which transfers its burden to the bottom of the *piston well* through the *load pin*. The load pin contacts the bottom of the well with a pivoting thrust bearing. As the payload moves sideways, the piston well pivots like a gimbal in the plane of the diaphragm. Thus a pendulum is formed, whose length is equal to the vertical distance from the roll in the diaphragm to the bottom of the load pin.

TMC's CSP® (Compact Sub-Hertz Pendulum System) (Patent No. 5,779,010) uses a different type of pendulum concept to extend horizontal resonant frequencies as low as 0.3 Hz. This isolator uses a geometrical lever effect to "fold" a 0.3 Hz pendulum into a package less than 16 in. (400 mm) high. An equivalent simple pendulum would have to be 110 in. (almost 3 m) tall. The CSP is discussed further in Section 5, Page 69, of this catalog.

Horizontal damping in most isolators comes from horizontal-to-tilt coupling: As a payload moves sideways, it also exercises the isolators in the vertical direction (through tilt), thereby providing damping. Some systems, like TMC's MaxDamp isolators, damp horizontal motions directly with fluidic damping.

At small amplitudes, small amounts of friction in the rolling diaphragm and the small resistance to flow presented by the damping orifice have an impact on the isolator's performance. For this reason it is important to use as small an excitation level as possible when measuring their transmissibility.

## 3.1 Limitations of other types of isolators

**Thick-Wall Rubber Diaphragms.** Most commercial isolators employ an inexpensive, thick-walled rubber diaphragm in the piston to achieve vertical isolation. Because of the relative inflexibility of these elements, low amplitude vibration isolation performance is compromised. Though such a system feels "soft" to gross hand pressure, typical low-level floor vibration causes the rubber to act more like a rigid coupling than a flexible isolator.

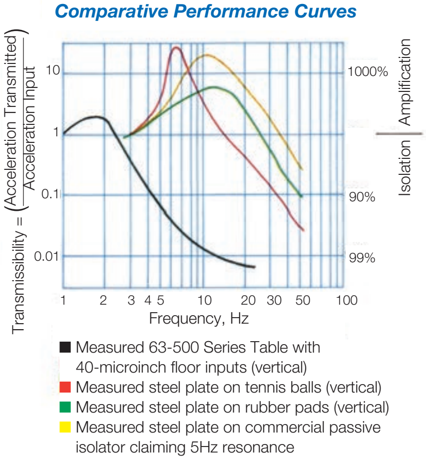
**Sealed Pneumatic Isolators (Passive).** Sealed air isolators do not automatically adjust to load changes. The primary limitation of such systems is that they must be made too stiff to be effective isolators. For example, a passive isolator with a true 1.5 Hz resonant frequency would drift several inches vertically in response to small changes in load, temperature, or pressure and require constant manual adjustment. Thus, no practical sealed isolators are designed with such low resonant frequencies.

**Bearing Slip Plates.** In theory, bearing slip plates should allow horizontal isolation by their decoupling effect. In practice, for such a design to work at low amplitudes, it would require precision ground, hardened bearings with impossibly small tolerances. The commercially available versions cannot overcome the static frictional forces at low amplitudes to get the bearings rolling at all. In addition, all such systems are difficult to align initially and easily drift out of calibration.

**Homemade Assemblies.** Homemade isolation systems – often a steel or granite slab placed on rubber pads, tennis balls, or air bladders - will work only if the disturbing vibrations are high frequency and minimal isolation is required. While all isolators use the principle of placing a mass on a damped spring, their performance is differentiated primarily by spring stiffness: the stiffer the spring, the higher the resonant frequency. Thus, homemade solutions are limited by their high resonant frequency.

A Gimbal Piston™ Isolator with a 1.5 Hz vertical resonant frequency begins to isolate at 2 Hz and can reduce vibration by over 95% at 10 Hz. A tennis ball under a steel plate with a 7 Hz resonant frequency begins to isolate above 10 Hz and reduces vibrations by 90% at 30 Hz. But most building floors exhibit their highest vibrational displacements between 5 and 30 Hz, so that a tennis ball or rubber pad actually makes the problem worse by amplifying ambient frequencies between 5 and 10 Hz.

*Comparative Performance Curves*




## 3.2 Number and Placement of Isolators

Three or more isolators are required to support a payload, the most common number being four. Since there can only be three valves in a system (see Section 3.4), two legs in a 4-post system must be connected as a master/slave combination. Although a master/slave combination forms an effective support point, the damping it produces is much different than a single (larger) isolator would provide at that point. TMC always recommends using at least four isolators (except for "round" payloads like NMR spectrometers).

Placement of these isolators under a payload has a dramatic effect on the performance of systems.

For small rigid payloads, like the granite structures in semiconductor manufacturing equipment, it is best to place the isolators as close to the corners of the payload as possible. This dramatically improves the tilt stability of the system, reduces the motions of the payload caused by onboard disturbances, and improves both the *leveling* and *settling times* for the system. *Leveling time* is the time for the valving system to bring the payload to the correct height and tilt. *Settling time* is the time for a payload to come to rest after an impulse disturbance.

For extended surfaces, such as large optical tables, the isolators should be placed under the surface's nodal lines. This minimizes the influence of forces transmitted to the table through the isolators. This is discussed in Section 4.3. For either type of payload, it is always better to position the payload's center-of-mass in the same plane as the isolator's effective support points. This improves the stability of the system (see Section 3.5) and decouples the horizontal and tilt motions of the payload.

Uneven floors can be accommodated in several ways. Most TMC isolators have a $\mp 0.5$ inch travel range, and this provides enough flexibility for almost all applications. Some systems also provide leveling feet. If a floor is extremely uneven, piers for the isolators may be required. Some free-standing isolators or other types of supports (like rigid tripods) must be grouted to the floor if the floor's surface has a poor surface quality. Quick-setting "ready-mix" concretes or epoxies are well suited for this purpose.

## 3.3 Safety Features

The ease with which pneumatic isolators can lift payloads weighing several thousand pounds belies the severity of their burden. By tying isolators together with "tiebars," the risk of toppling such massive loads through accident or events like earthquakes is dramatically reduced. TMC's tiebars are heavy-gauge, formed channels which use constrained-layer damping to prevent them from resonating. Such damping is hardly required, however, since the isolation efficiency of the isolators at those frequencies is extremely high. Systems can also be provided with earthquake restraint brackets which prevent the payload from shaking off the isolators in an extreme event.

Of great importance to safety are the travel limits built into all TMC's isolators. Figure 6 shows an internal "key" (yellow) which prevents the system from overextending even when pressurized to 120 psi (830 k*Pa* ) under "no load" conditions. Since there can be several thousand pounds of force behind the isolator's piston, an isolator without such a travel limit can quickly become a cannon if suddenly unloaded. Protection, such as chain-linked pressure reliefs, does not provide the intrinsically high level of safety a mechanical travel limit does.

## 3.4 Leveling Valves

All rigid payloads, even those with ten isolators, use only three height control valves. Because three points define a plane, using a greater number of valves would *mechanically overconstrain* the system and result in poor position stability (like a four-legged restaurant table) and a continuous consumption of air. Proper placement and plumbing of these three valves is crucial to optimizing the performance of a system.

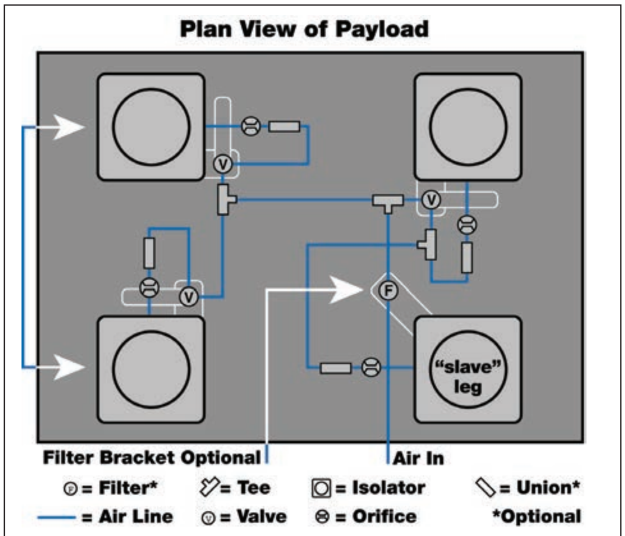



**Figure 7a**

Figure 7a and Figure 7b show the typical plumbing for a 4-post and 6-post system. A system contains three valves, a pressure regulator/filter (optional), some quick-connect tees and an orifice "pigtail" on each isolator. The pigtail is a short section of tubing with an orifice inserted inside. This section is marked with a red ring, and has a union on one end to connect to the height control valves' air lines. A mechanical valving system is a type of servo, and these orifices limit the "gain" of the servo to prevent oscillation. Some very high center-of-gravity systems may require smaller orifices to prevent instabilities. TMC uses fixed orifices rather than adjustable needle valves because of their long-term stability and ease of use.

In a system with four or more isolators, two or more of those isolators need to be tied together. Usually the valve is mounted near an isolator (for convenience) and that isolator is called the "master." The remote isolators (S) using that valve are called "slaves." Choosing which legs

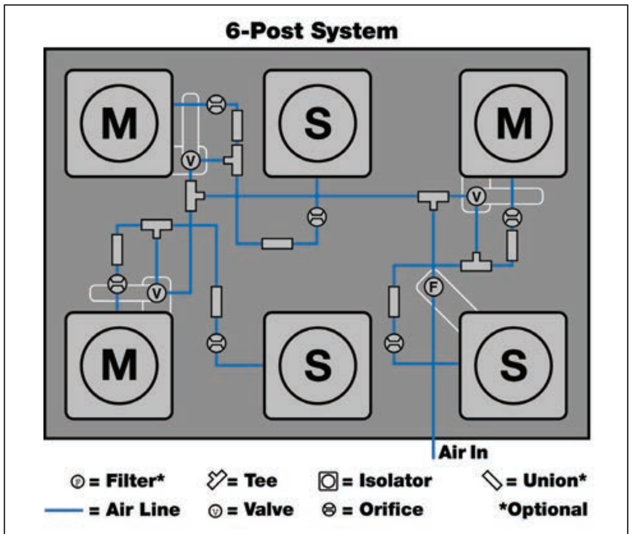



**Figure 7b**

are "master" and "slave" affects the stability of the system (see Section 3.5) and has a large impact on a system's dynamic behavior. Dynamic performance is particularly important in semiconductor inspection machines which have fast moving stages. There are several "rules of thumb" which can be applied to make the correct choice. These can conflict with each other on some systems. Some experimentation may be required to determine the optimal choice.

These rules, in approximate order of importance, are:

1. The *effective support* point for a master and its slaves is at their geometric center. For a master with a single slave, this point is midway between the mounts. There are always only three "effective" support points for any system. Connecting these points forms a "load triangle." The closer the payload's center-of-mass (COM) is to the center of this triangle, the more stable the system will be. For example, on a 4-post system, the master/slave combination should support the lighter end of the payload.

2. A corollary to rule #1 is that the system should be plumbed so that the pressure difference between all isolators is minimized.

3. The *gravitational tilt stability* of a system is proportional to the square of the distance between the isolators. Therefore, for greatest stability, the master/slave combinations should be on the long side of a payload.

4. The tilt axis with the highest stiffness, damping and stability is the one parallel to the line between the master and slave legs (in a 4-post system). For moving stage applications, the main stage motion should be perpendicular to the line between the master and slave leg.

5. A moving stage can cause a cross-axis tilt because the valve for the master/slave legs is not co-located with the effective support point. For this reason, many systems should have the valve moved from the master leg to the effective support point.

6. A *control triangle* is formed by the three points where the valves contact the payload. Like the load triangle, the system will have the greatest stability and best positioning accuracy if the COM is inside this triangle. The valves should be mounted and their "arms" rotated such that this triangle has the largest possible area.

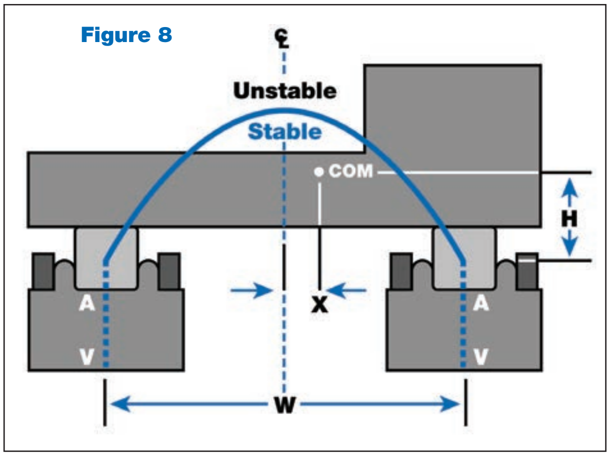
7. Sometimes following the above rules results in a system with poor height and tilt positioning accuracy. In this case, an alternate choice for the master/slave combination(s) might be required.

In addition to valve location, there are several different types of valves which are available. TMC offers *standard* and *precision* mechanical valves. The standard valve is less expensive and has a positioning accuracy (dead band) of around 0.1 in. (2.5 mm). The valve is tightly sealed for motions smaller than this. This makes it ideal for systems which must use pressurized gas bottles for an air supply. Precision valves offer a 0.01 in. (0.3 mm) or better positioning accuracy but leak a very small amount of air (they use all-metal valve seats internally). This makes them less suitable for gas bottle operation. Finally, TMC offers electronic valving systems such as the PEPS® II (Precision Electronic Positioning System, U.S. Patent No. 5,832,806), which has a ≃ 0.0001 in. (≃ 2 μm) position stability. Refer to the discussion of PEPS in Section 6, page 74, of this catalog.

For cleanroom applications, TMC offers versions of the mechanical valves made from stainless steel and/or supplied with a vented exhaust line.

## 3.5 Gravitational Instability

Like a pen balanced on its tip, payloads supported below their center of mass are inherently unstable: As the payload tilts, its center-of-mass moves horizontally in a way that




wants to further increase the tilt. Fighting this is the stiffness of the pneumatic isolators which try to restore the payload to level. The balance of these two forces determines whether the system is *gravitationally stable* or not. Figure 8 shows a payload supported by two *idealized* pneumatic isolators. The width between the isolators' centers is *W*, the height of the payload's COM is H above the effective support point for the isolators, and the horizontal position of the COM from the centerline between the isolators is X. It can be shown that there is

a region of stability given by the condition:

$$H < \frac{An}{V}\left(\frac{W}{2} - X\right)\left(\frac{W}{2} + X\right) \qquad [10]$$

or, for $X = 0$,

$$H < \frac{AnW^2}{4V} \qquad [11]$$

where $n$ is the gas constant and is equal to 1.4.

This relationship is shown in Figure 8 as an inverted parabola which defines the stable and unstable regions for the COM location. The second equation clearly shows that the stability improves with the *square* of the isolator separation. This is important as it demonstrates that it is *not* the aspect ratio *H/W* that determines the stability of a system (as some references claim) and that the stable region is not a "triangle" or "pyramid." Unfortunately, real systems are not as simple as the one in Figure 8.

The ratio $A/V$ in Equations 10 and 11 represents the stiffness of the isolators (see Equation 9 on page 96). In a two-chamber isolator, however, what is the proper $V$? Unlike the isolators in Figure 8, which have a fixed spring constant, real isolators *have a spring constant which is frequency dependent*. At high frequencies, the orifice between the two chambers effectively blocks air flow, and $V$ may be considered the top air volume alone. At the system's resonance, the "effective" air volume is somewhere between the top and total (top plus bottom) volumes. At low frequencies, the action of the height control valves gives the isolators an extremely high stiffness (corresponding to a very small $V$). Moreover, the action of the height control valves also tries to force the payload back towards level. These are only a few reasons why Equation 10 can't be applied to two-chamber isolators. Instead, we assign three regions: stable, unstable, and borderline, the first two being based on the "total" and "top only" air volumes, respectively. The stability region is also different for the axes parallel and perpendicular to the master/slave isolator axis.

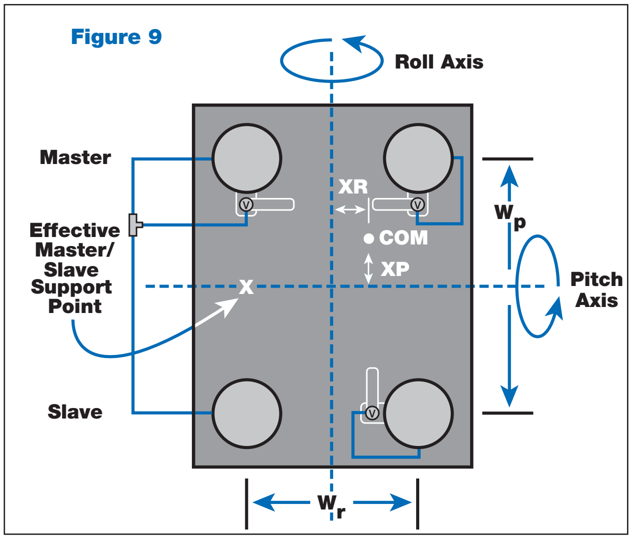



Figure 9 defines the two different axes for a four-leg system. The pitch axis is less stable because the master/slave legs on the left of the figure offer no resistance to pitch at low frequencies (though they do resist pitch at frequencies above ≅1 Hz). To compensate for this, the master/slave combination is chosen such that $W_p$ is greater than $W_r$ (rule 3 from page 99). The region of stability is the volume defined by the inverted parabolas along the two axes.

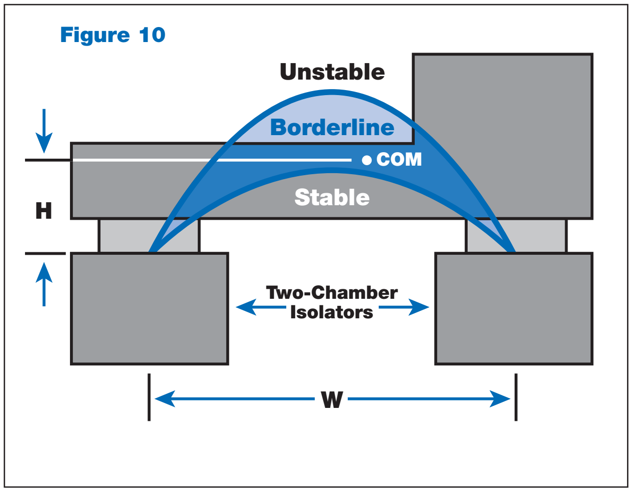
The condition for *absolute stability* is:

$$H < \left(\frac{An}{2V}\right)_{Tot.}\left(\frac{W_p}{2} - X_p\right)\left(\frac{W_p}{2} + X_p\right) \quad \text{and} \quad H < \left(\frac{An}{V}\right)_{Tot.}\left(\frac{W_r}{2} - X_r\right)\left(\frac{W_r}{2} + X_r\right) \qquad [12]$$

And the formula for *absolute instability* is:

$$H > \left(\frac{An}{2V}\right)_{Top}\left(\frac{W_p}{2} - X_p\right)\left(\frac{W_p}{2} + X_p\right) \quad \text{and} \quad H > \left(\frac{An}{V}\right)_{Top}\left(\frac{W_r}{2} - X_r\right)\left(\frac{W_r}{2} + X_r\right) \qquad [13]$$

with the volume between being "possibly" or "marginally" stable. The ratios $A/V$ are not universal and should be confirmed for different capacities and models of isolators but are approximately 0.1 $in^{-1}$ for $(A/V)_{Top}$ and 0.05 $in.^{-1}$ for $(A/V)_{Tot}$. Figure 10 illustrates what the marginally stable region looks like for two chamber isolators. Unfortunately, the COM of many systems ends up in this indeterminate region. These rules do not account for the actions of the height control valves, which will always improve a system's stability. If the payload has a mass which can shift (a liquid bath or a pendulum) these rules can also change.



Equations 14 and 15 give "rules of thumb" for calculating the stability of a system. As with all such rules, it is only an approximation based on an "average" isolation system. It is always best to use as low a COM as possible.

$$\frac{W^2}{\mathrm{H}} > 60\ in.\quad or\quad \frac{W^2}{\mathrm{H}} > 1.5\ m \qquad [14]$$

Because MaxDamp® isolators use a single air chamber, they are more stable, and the rule becomes:

$$\frac{W^2}{\mathrm{H}} > 25\ in.\quad or\quad \frac{W^2}{\mathrm{H}} > 0.64\ m \qquad [15]$$

Note that the effective support point for TMC's Gimbal Piston™ isolators is approximately 7 in. below the top of the isolator. For lightly loaded isolators, these rules underestimate system stability. If your system violates these equations, or is borderline, the stability can be improved using counterweights, special volume isolators, different isolator valving, etc. Contact a TMC sales engineer for advice on the best approach.

## 4.0 High-Performance Table Tops

Table tops are the platform for conducting many types of measurements and processes. They can serve as a mechanical reference between different components (such as lasers, lenses, film plates, etc.) as well as simply providing a quiet work surface. Tops typically use one of three constructions: a composite laminate, a solid material (granite) or a lightweight honeycomb. The choice of construction depends on the type and size of the application.

Figure 11 shows a typical laminated construction. These are usually 2 to 4 in. thick and consist of layers of steel and/or composite materials epoxy-bonded

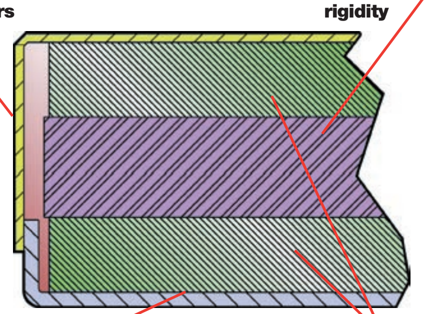


Figure 11

together into a seamless stainless steel pan with rounded edges and corners. A visco-elastic adhesive can be used between the plates to enhance the damping provided by the composite layers. All bonding materials are chosen to prevent delamination of the assembly due to heat, humidity, or aging. The ferromagnetic stainless steel pan provides a corrosion-resistant, durable surface which works well with magnetic fixtures. "Standard" sizes for these tops range from 24 in. square to 6 x 12 ft, and can weigh anywhere from 100 - 5,000 lbs. This type of construction is not well suited to applications which require large numbers of mounting holes (tapped or otherwise). The ratio of steel to lightweight damping composite in the core depends primarily on the desired mass for the top. There are many applications in which a heavy top is of benefit. It can lower the center-of-gravity for systems in which gravitational stability is an issue. If the payload is dynamically "active" (like a microscope with a moving stage), then the increased mass will reduce the reaction motions of the top. Lastly, steel is very strong, and very high-mass payloads may require this strength.

Granite and solid-composite tops offer a relatively high mass and stiffness, provide moderate levels of damping, and are cost effective in smaller sizes. Their non-magnetic properties are desirable in many applications, and they can be lapped to a precise surface. Mounting to granite surfaces is difficult, however, and granite is more expensive and less well damped than laminate tops in larger sizes. The highest performing work surfaces are honeycomb core tables.

### 4.1 Honeycomb Optical Tables

Honeycomb core table tops are very lightweight for their rigidity and are preferred for applications requiring bolt-down mounting or larger working surfaces. They can be made in any size from 1 ft on a side and a few in. thick, to 5 x 16 ft and over 2 ft thick. Larger tops can also be "joined" to make a surface which is almost unlimited in size or shape. The smaller surfaces are often called "breadboards," and the larger sizes "optical tops" or "optical tables."

Honeycomb core tables were originally developed for high-precision optical experiments like holography. They evolved due to the limitations of granite surfaces, which were extremely heavy and expensive in larger sizes and were difficult to securely mount objects to. The goal was to develop a work surface with the stability of granite without these drawbacks.

Honeycomb core tables are rigid for the same reasons as a structural “I-beam.” An I-beam has a vertical “web” which supports a top and bottom flange. As weight is applied to the beam, the top flange is put in compression and the bottom in tension, because the web holds their separation constant. The primary stiffness of the beam comes from this compression and extension of the flanges. The web also contributes to the stiffness by resisting shear in its plane.

The same thing happens in an optical table (see Figure 12). The skins of the table have a very high resistance to being stretched or compressed (like the flanges of the I-beam). The honeycomb core is extremely resistant to compression along its cells (serving the same role as the I-beam’s web). As the core *density* increases (cell size decreases), the compressional stiffness of the core and its shear modulus increase, and the mechanical coupling to the skins improves – improving the performance of the table.

Optical tables are also much better than granite surfaces in terms of their thermal properties. Because of their metal construction and very low heat capacity (due to their relatively light mass), honeycomb core tables come to thermal equilibrium with their environment much faster than their granite counterparts. The result is a reduction in thermally induced distortions of the working surface.

**TMC CleanTop® Optical Top**

**Figure 12**

## 4.2 Optical Table Construction

There are many other benefits to using a honeycomb core. The open centers of the cells allow an array of mounting holes to be placed on the table’s surface. These holes may be capped to prevent liquid contaminants from entering the core and “registered” with the core’s cells. During the construction of TMC optical tops, the top skin is placed face down against a reference surface (a lapped granite block), and the epoxy, core, sidewalls, bottom skin, and damping system built up on top of it. The whole assembly is clamped together using up to 30 tons of force. This forces the top skin to take the same shape (flatness) of the precision granite block. Once the epoxy is cured, the table’s top skin keeps this precise flatness (typically $\mp$0.005 in.) over its entire surface.

TMC’s patented CleanTop® design allows the core to be directly bonded to the top and bottom skins of the table. This improves the compressional stiffness of the core and reduces the thermal relaxation time for the table. The epoxy used in bonding the table is extremely rigid without being brittle yet allows for thermal expansion and contraction of the table without compromising the bond between the core and the skins.

Honeycomb core tables can also be made out of a variety of materials, including non-magnetic stainless steel, aluminum for magnetically sensitive applications, and Super Invar for applications demanding the highest grade of thermal stability. Lastly, the individual cups sealing the holes in the top skin (unique to TMC’s patented CleanTop design) are made of stainless steel or nylon to resist a wide range of corrosive solvents.

The sidewalls of the optical table can be made out of many materials as well. Some of TMC’s competitors’ tops use a common “chipboard” sidewall which, though well damped, is not very strong and can be easily damaged in handling or by moisture. TMC tables use an all-steel sidewall construction with constrained-layer damping to provide equally high levels of damping with much greater mechanical strength.

## 4.3 Honeycomb Optical Table Performance

The performance of an optical table is characterized by its static and dynamic rigidity. Both describe how the table flexes when subjected to an applied force. The first is its response to a static load, while the second describes the “free oscillations” of the table.

Figure 13 shows how the static rigidity of a table is measured. The table is placed on a set of line contact supports. A force is applied to the center of the table, and the table's deflection (δ) measured. This gives the static rigidity in terms of *μin/lbf* (or *μm/N*). This rigidity is a function of the table's dimensions and the physical properties of the top and bottom skins, sidewalls, core, and how they are assembled.

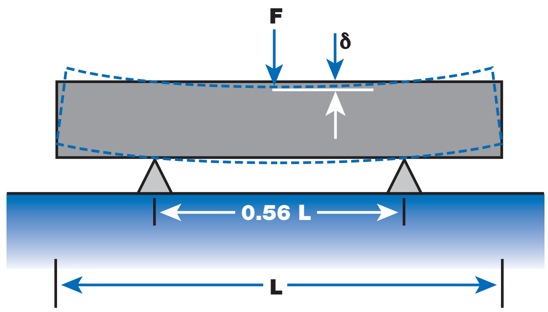



Figure 13

## 4.3.1 The Corner Compliance Curve

Dynamic rigidity is a measure of the peak-to-peak-motion of a table's oscillations when it is excited by an applied impulse force. When hit with a hammer, several *normal modes* of oscillation of the table are excited, and each "rings" with its own frequency. Figure 14 shows the four lowest frequency modes of a table. Dynamic compliance is measured by striking the corner of a table with an impact testing hammer (which measures the level of the impact's force near the corner of the table). The table's response is measured with an accelerometer fastened to the top as close to the location of the impact

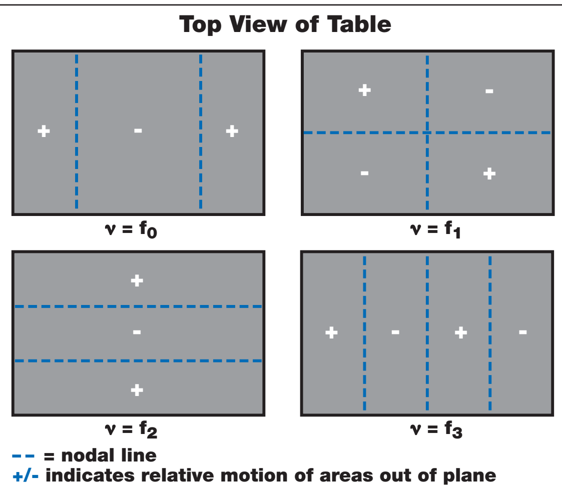



Figure 14

as possible. The signals are fed to a spectrum analyzer which produces a *corner compliance curve*. This measures the deflection of the table in *μin/lbf* (or mm/N) for frequencies between 10 and 1,000 Hz.

Each normal mode resonance of the top appears as a peak in this curve at its resonant frequency. The standard way to quote the dynamic compliance of a top is to state the peak amplitude and frequency of the lowest frequency peak (which normally dominates the response). Figure 15 shows the compliance curve for a table with low levels of damping (to emphasize the resonant peaks). The peaks correspond to the modes shown in Figure 14. The curve with a slope of $1/f^2$ is sometimes referred to (erroneously) as the "mass line," and it represents the rigid-body motion of the table. "Mass line" is misleading because the rigid-body response of the top involves rotational as well as translational degrees of freedom, and, therefore, also involves the two moments of inertia of the table in addition to its mass. For this reason, this line may be 10 times or more above the line one would calculate using the table's mass alone.

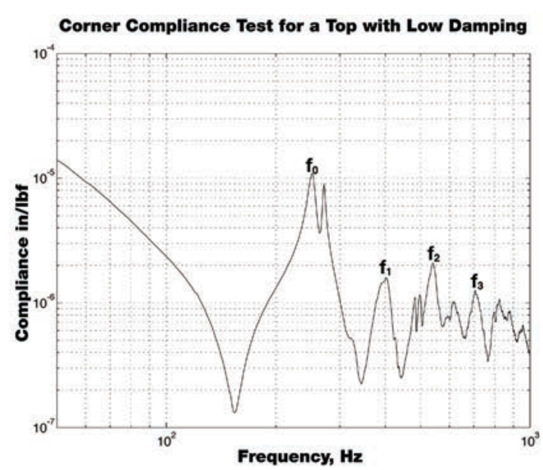



Figure 15

*Figure 15: $f_0$-$f_3$ show the four lowest resonances of the table.*

The compliance curve is primarily used to show how well a table is damped. The higher the level of damping, the lower the peak in the compliance test, and the quicker the table will ring down after an impact disturbance. There are two ways to damp the modes of a table: *Narrow-band* and *broadband* damping. The first uses tuned mechanical oscillators matched to the frequencies of the normal mode oscillations to be damped. Each matched oscillator can remove energy at a single frequency. TMC uses *broadband damping*, where the mode is damped by coupling the table to a second mass by a lossy compound. This damps all modes and all frequencies.

Tuned damping has several problems. If the frequency of the table changes (from placing some mass on it), then the damper can lose some of its effectiveness. Also, several dampers must be used, one for each mode (frequency) of concern. This compounds the matching problem. Each of these dampers are mounted in different corners of the table. This results in *different compliance measurements for each corner of a table*. Consequently, the quoted compliance curve may only apply for one of the four corners of a top. In addition, tuned dampers are strongly limited in how far they can reduce the Q. It is difficult, for example, to get within a factor of 10 of critical damping using reasonably sized dampers.

In broadband damping, the secondary masses are distributed uniformly through the table, producing a compliance curve which is corner-independent. It is also insensitive to changes in table resonant frequencies and will damp *all* modes – not just those which have matched dampers. In fact, TMC's highest grade tables can have near *critical damping* of the lowest modes (depending on aspect ratios, thicknesses, etc.).

## 4.3.2 Compliance Curves as a Standard

Although used as a standard for measuring table performance, the corner compliance curve is far from a uniform and unambiguous figure of merit. The problem is not only with tables using tuned damping. All measurements are extremely sensitive to the exact location of the test impact and the monitoring sensor. TMC measures compliance curves by placing the sensor in a corner 6 in. from the sides of the table and impacting the table on the inboard side of the sensor. Since the core of the table is recessed from the edge of the table by 1-2 in., impacting the table closer to the corner produces "edge effects." The result is a test which is inconsistent from corner to corner or even impact to impact. On the other hand, measuring further from the corner can bring the sensor and the impact point dangerously close to a nodal line for the first few modes of the table (Figure 14). This is so sensitive that a few *inches* can have a dramatic effect on the measured compliance for a top.

It is also important to properly support the table being tested. TMC supports tables at four points, along the two nodal lines 22% from the ends of the table. Either pneumatic isolators or more rigid rubber mounts can be used for this test (though rubber mounts may change the damping of higher-order modes). Though this is fairly standard with manufacturers, the customer must be aware that the compliance test will only represent their setup if they support their top in this way.

Nodal shapes present a major problem in the uniformity of the corner compliance curve as a standard figure of merit, since there is no industry or government standard for testing (like TMC's 6 in. standard for sensor locations). Part of the problem is the measurement point – near nodal line(s) for the modes – is a position where the resonance amplitude varies the most: From *zero* at the node to a maximum at the table's edge. The ideal place to make a compliance measurement would be where the mode shape is "flat." For example, this would be the center of the table for the first mode in Figure 14. Here, the measurement is almost independent of the sensor or impact locations *for the first mode only*. For many higher modes, however, this is dead center on nodal line(s), producing essentially meaningless results. Rather than bombard customers with a separate test for each mode shape, for better or worse, the corner compliance test has become the standard.

In recent years, some attempts have been made to produce other figures of merit. TMC does not use these because they compound the uncertainty of the compliance test with several other assumptions. So-called "Dynamic Deflection Coefficients" and "Maximum Relative Motion"[†] take information from the compliance curve and combine it with an assumed input force spectrum. Unfortunately, the "real" relative motion you observe will also depend on the way your table is supported. If, for example, your top is properly supported by the isolators at the nodal lines of the lowest mode (0.53 $L$ apart), then there is *no* excitation of the lowest mode from the isolators (on which these figures of merit are based). Likewise, if you support a top improperly, the mode can be driven to large amplitudes. Moreover, the "assumed" input depends on two very poorly defined factors: Floor noise and isolator efficiency. Even if these are well defined, it is much more likely that acoustic sources of noise will dominate at these frequencies (typically 100-1,000 Hz). For all these reasons, we consider these alternate figures of merit essentially meaningless and do not use them.

10

[†] These particular figures of merit were developed by Newport Corporation of Irvine, CA.

# 5.0 Active Vibration Isolation Systems

This section will assist engineers and scientists in gaining a general understanding of active vibration isolation systems, how they work, when they should be applied, and what limitations they have. Particular attention has been given to the semiconductor manufacturing industry, since many applications have arisen in this field.

## 5.1 History

Most active vibration isolation systems are relatively complex, costly, and often provide only marginal improvements in performance compared with conventional passive vibration isolation techniques. They are also more difficult to set up, and their support electronics often require adjustment. Nonetheless, active systems can provide function which is simply not possible with purely passive systems.

Two things have lead to the renewed interest in active vibration control systems in recent years. The first is the rapid growth of the semiconductor industry, and, second, the desire to produce more semiconductors, faster, and at a lower cost. Lithography and inspection processes usually involve positioning the silicon wafer relative to critical optical (or other) components by placing the wafer on a heavy and/or fast moving stage. As these stages scan from site to site on the wafer, they cause the whole instrument to "bounce" on the vibration isolation system. Even though the motion of the instrument may be small after such a move (a few mm), the resolution of the instrument is approaching, and in some cases going below, 1 nm. Instruments with this type of resolution are inevitably sensitive to even the smallest vibration levels. Active systems help in these cases by reducing the residual motions of an isolated payload after such stage motions occur.

The second change which has made active systems more popular has been the advancement in digital signal processing techniques. In general, an active system based on analog electronics will outperform a digitally based system. This is due to the inherent low noise and wide bandwidths available with high-performance analog electronics. (A relatively inexpensive operational amplifier can have a 30 bit equivalent resolution and a "sampling rate" of many MHz.) Analog electronics are also inexpensive. The problem with analog-based systems is that they must be manually adjusted and cannot (easily) deal with non-linear feedback or feedforward applications (see Section 5.4.3). Digital controllers have the potential to automatically adjust themselves and to deal with non-linear feedback and feedforward algorithms. This allows active systems to be more readily used in OEM applications (such as the semiconductor industry). They can also be programmed to perform a variety of tasks, automatically switch between tasks on command, and can have software upgrades which "rewire" the feedback system without lifting a soldering iron. To further the reader's understanding of the costs and benefits of these systems, we have provided a brief introduction to the terminology and techniques of servo control systems.

## 5.2 Servos & Terminology

Although the terminology for active systems is fairly universal, there are some variations. The following discussion introduces the terminology used by TMC and should help you with the concepts involved in active systems. The basis for all active control systems is illustrated in Figure 16.

It contains three basic elements:

- The block labeled "G" is called the *plant*, and it represents the behavior of your mechanical (or electronic, hydraulic, thermal, etc.) system *before any feedback is applied*. It represents a *transfer function*, which is the ratio of the block's output to its input, expressed as a function of frequency. This ratio has both a magnitude and a phase and may or may not be unitless. For example, it may represent a *vibration transfer function* where the input (line on the left) represents ground motion and the output (line to the right) represents the motion of a table top.


www.techmfg.com • 978-532-6330 • 800-542-9725 (Toll Free) • Fax: 978-531-8682 • sales@techmfg.com

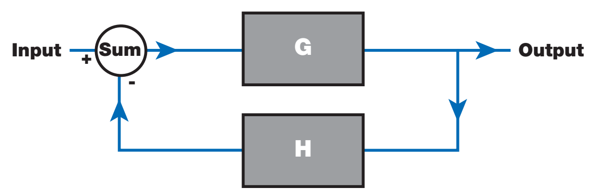



**Figure 16**

***Figure 16: A basic feedback loop consists of three elements: The plant, compensation, and summing junction.***

In this case, the ratio is unitless. If the input is a force and the output a position, then the transfer function has units of (m/N). The transfer function of G has a special name: The *plant transfer function*. All transfer functions (G, H, the product GH, etc.) are represented by complex numbers (numbers with both real and imaginary components). At any given frequency, a complex number represents a vector in the complex plane. The length and angle of that vector represents the magnitude and phase of the transfer function.

- The block labeled "H" is called the *compensation* and generally represents your servo. For a vibration isolation system, it may represent the total transfer function for a sensor which monitors the plant's output (an accelerometer), some electronic filters, amplifiers, and, lastly, an actuator which produces a force acting on the payload. In this example, the response has a magnitude, phase, and units of (N/m). Note that the *loop transfer function* for the system, which is the product (GH), must be unitless. The loop transfer function is the most important quantity in the performance and stability analysis of a control system and will be discussed later.
- The circle is a *summing junction*. It can have many inputs which are all summed to form one output. All inputs and the output have the same units (such as force). A plus or minus sign is printed next to each input to indicate whether it is added or subtracted. Note that the output of H is always subtracted at this junction, representing the concept of negative feedback. The output of the summing junction is sometimes referred to as the *error signal* or *error point* in the circuit.

It can be shown that the *closed-loop transfer function* for the system is given by Equation 16. This is perhaps the single most important relationship in control theory. The denominator 1+GH is called the *characteristic equation*, since the location of its roots in the complex plane determine a system's stability. There are several other properties which are immediately obvious from the form of this equation.

$$\frac{Output}{Input} = \frac{G}{1+GH} \qquad [16]$$

First, when the *loop gain* (the magnitude $|GH|$) is much less than one, the closed-loop transfer function is just the numerator (G). For large loop gains ( $|GH| \gg 1$), the transfer function is reduced or suppressed by the loop gain. Thus the servo has its greatest impact on the system when the loop gain is above *unity gain*. The frequency span between the *unity gain frequencies or unity gain points* is the *active bandwidth* for the servo. In practice, you are not allowed to make the loop gain arbitrarily high between unity gain points and still have a stable servo. In fact, there is a limit to how fast the gain can be increased near unity gain frequencies. Because of this, the loop gain for a system is usually limited by the available bandwidth.

Another obvious result from Equation 16 is that the only frequencies where the closed-loop transfer function can become large is where the magnitude of $|GH| \approx 1$, and its *phase* becomes close to 180°. As the quantity GH nears this point, its value approaches (-1), the denominator of Equation 16 becomes small, and the closed-loop response becomes large. The difference between the phase of GH and 180° at a unity gain frequency for GH is called the *phase margin*. The larger the phase margin, the lower the amplification at the unity gain points. It turns out, however, that larger phase margins also decrease the gain of the servo within its active bandwidth. Thus, picking the phase margin is a compromise between gain and stability at the unity gain points. Amplification at unity gain will always happen for phase margins less than 60°. Most servos are designed to have a phase margin between 20° and 40°. Amplification at a servo's unity gain frequencies appear like new resonances in the system.

## 5.3 Active Vibration Cancellation

The previous section provided a qualitative picture of how servos function and introduced the broad concepts and terminology. In reality, most active vibration cancellation systems are much more complex than the simple figure shown in Figure 16. There are typically 3 to 6 degrees-of-freedom (DOF) controlled: Three translational (X, Y, and Z motions), and three rotational (roll, pitch, and yaw). In addition, there may be many types of sensors in a system, such as height sensors for leveling the system and accelerometers for sensing the payload's motions. These are combined in a system using *parallel* or *nested* servo loops. While these can be represented by block diagrams like that in Figure 16 and are analyzed using the same techniques, the details can become quite involved. There are, however, some general rules which apply to active vibration cancellation servos in particular.

**Multiple Sensors.** Although you can have both an accelerometer measuring a payload's inertial motion, *and* a position sensor measuring its position relative to earth, *you can't use both of them at any given frequency*. In other words, the active bandwidth for a position servo cannot overlap with the active bandwidth for an accelerometer servo. Intuitively, this is just saying that you cannot force the payload to track two independent sensors at the same time. This has some serious consequences.

Locking a payload to an inertial sensor (an accelerometer) makes the payload quieter; however, the accelerometer's output contains no information about the Earth's location. Likewise, locking a payload to a position sensor will force a payload to track Earth more closely – including Earth's vibrations. You cannot have a payload both track Earth closely and have good vibration isolation performance! For example, if you need more vibration isolation at 1 Hz, you must increase the gain of the accelerometer portion of the servo. This means that the servo which positions the payload with respect to Earth must have its gain lowered. The result is a quieter platform, but one that takes longer to move back to its nominal position when disturbed. This is discussed further in Section 5.6.

**Gain Limits on Position Servos.** As mentioned above, position sensors also couple ground vibration to a payload. This sets a practical limit on the unity gain frequency for a height control servo (like TMC's PEPS® Precision Electronic Positioning System). To keep from degrading the vibration isolation performance of a system, the unity gain frequency for PEPS is limited to less than 3 Hz. This in turn limits its low-frequency gain (which determines how fast the system re-levels after a disturbance). Its main advantages are more accurate positioning (up to 100 times more accurate than a mechanical valve), better damping, better high-frequency vibration isolation, and the ability to electronically "steer" the payload using feedforward inputs (discussed later). It will not improve how fast a payload will re-level.[1] PEPS can also be combined with TMC's PEPS-VX® System, which uses inertial payload sensors to improve vibration levels on the payload.

**Structural Resonances.** Another important concern in active vibration isolation systems is the presence of structural resonances in the payload. These resonances form the practical bandwidth limit for *any vibration isolation servo which uses inertial sensors directly mounted to the payload*. Even a fairly rigid payload will have its first resonances in the 100-500 Hz frequency range. This would be acceptable if these were well damped. In most structures, however, they are not. This limits the bandwidth of such servos to around 10-40 Hz. Though a custom-engineered servo can do better, a generic off-the-shelf active vibration cancellation system rarely does.

## 5.4 Types of Active Systems

Although we have alluded to "position" and "acceleration" servos, in reality these systems can take many different forms. In addition, the basic performance of the servo in Figure 16 can be augmented using *feedforward*. The following sections introduce the most common configurations and briefly discuss their relative merits.

[1] This is an approximate statement, since PEPS is a linear system, and mechanical valves are very non-linear. PEPS generally levels faster for small displacements and slower for large ones.

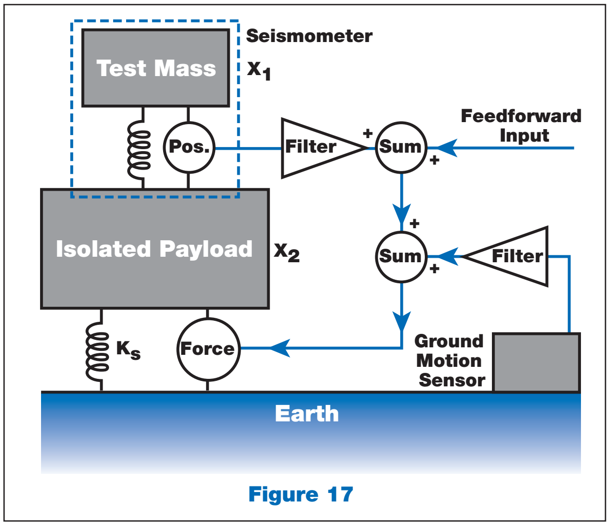



*Figure 17: The basic inertial feedback loop uses a payload sensor and a force actuator, such as a loudspeaker "voice coil," to affect the feedback. Feedforward can be added to the loop at several points.*

## 5.4.1 Inertial Feedback

By far the most popular type of active cancellation system has been the inertial feedback system, illustrated in Figure 17. Note that the pneumatic isolators have been modeled here as a simple spring. Neglecting the *feedforward* input and the *ground motion sensor* (discussed in Section 5.4.3), the feedback path consists of a seismometer, filter, and force actuator (such as a loudspeaker "voice coil"). The seismometer measures the displacement between its *test mass* and the *isolated payload*, filters that signal, then applies a force to the payload such that this displacement ($X_1 - X_2$) is constant – thereby nulling the output of the seismometer. Since the only force acting on the test mass comes from the compression of its spring, and that compression is servoed to be constant ($X_1 - X_2 \approx 0$), it follows that the test mass is actively isolated. Likewise, since the isolated payload is being forced to track the test mass, it must also be isolated from vibration. The details of this type of servo can be found in many references.[2]

The performance of this type of system is always limited by the bandwidth of the servo. As mentioned previously, structural resonances in the isolated payload limit the bandwidth in practical systems to 10-40 Hz (normally towards the low end of this range). This type of system is also "AC coupled" since the seismometer has no "DC" response. As a result, these servos have *two unity gain frequencies* – typically at 0.1 and 20 Hz. This is illustrated in greater detail in Section 5.6. As a result, the servo reaches a maximum gain of around 20-40 dB at ~2 Hz – the natural frequency of the passive spring mount for the system. The closed-loop response of the system has two new resonances at the ~0.1 and ~20 Hz unity gain frequencies. Due to the small bandwidth of these systems (only around two decades in frequency), the gain is not very high except at the natural (open-loop) resonant frequency of the payload. The high gain there completely suppresses that resonance. For this reason, it is helpful to think of these systems as *inertial damping systems*, which have the property of damping the system's main resonance without degrading the vibration isolation performance. (Passive damping can also damp this resonance but significantly increases vibration feedthrough from the ground.)

## 5.4.2 More Bandwidth Limitations

These servos are also limited in how low their lower unity gain frequency can be pushed by noise in the inertial sensor. This is described in detail in the reference of Footnote 2. Virtually all commercial active vibration cancellation systems use *geophones* for their inertial sensors. These are simple, compact, and inexpensive seismometers used in geophysical exploration. They greatly outperform even high-quality piezoelectric accelerometers at frequencies of 10 Hz and below. Their noise performance, however, is not adequate to push an inertial feedback system's bandwidth to below ~0.1 Hz. To break this barrier, one would need to use much more expensive sensors, and the total cost for a system would no longer be commercially feasible.

Another low-frequency "wall" which limits a system's bandwidth arises when the inertial feedback technique is applied in the horizontal direction. (Note that a six degree-of-freedom [DOF] system has three "vertical" and three "horizontal" servos. Horizontal DOFs are those controlled using horizontally driving actuators – X, Y, and twist [yaw]). This is the problem of *tilt to horizontal coupling*. If you push a payload sideways with horizontal actuators and it tilts, the inertial sensors read the tilt as an *acceleration* and try to correct for it by accelerating the payload – which, of course, is the wrong thing to do. This effect is a fundamental limitation which has its roots in Einstein's

[2] See for example, P.G. Nelson, *Rev. Sci. Instrum.*, 62, p.2069 (1991)

*Principle of Equivalence*, which states that it is impossible to distinguish between an acceleration and a uniform gravitational field (which a tilt introduces). The only solution to this problem is to not tilt a payload when you push it. This is *very* difficult to do, especially in geometries (like semiconductor manufacturing equipment) which are not designed to meet this requirement. Ultimately, one is forced to use a combination of horizontal *and vertical* actuators to affect a "pure" horizontal actuation. This becomes a "fine tuning" problem, which even at best yields marginal results. TMC prefers another solution.

**Passive Horizontal Systems.** Rather than use an active system to obtain an "effective" low resonant frequency, we have developed a *passive* isolation system capable of being tuned to as low as 0.3 Hz in the horizontal DOFs. Our CSP® (Compact Sub-Hertz Pendulum System) is not only a more reliable and cost-effective way to eliminate the isolator's 1-2 Hz resonance, but it also provides better horizontal vibration isolation up to 100 Hz or more – far beyond what is practical for an active system. Unfortunately, such passive techniques are very difficult to implement for the vertical direction. TMC recommends the use of systems like our PEPS-VX® Active Cancellation System to damp the three "vertical" DOFs. PZT-based active systems, such as TMC's STACIS®, use another approach which allows for active control of horizontal DOFs (see Section 5.4.4).

### 5.4.3 Feedforward

The performance of the inertial feedback system in Figure 17 can be improved with the addition of *feedforward*. In general, feedforward is much more difficult than feedback, but it does offer a way to improve the performance of a system when the feedback servo is limited in its bandwidth. There are two types of "feedforward" systems which are quite different, though they share the same name.

**Vibrational Feedforward.** This scheme involves the use of a ground motion sensor and is illustrated in Figure 17. Conceptually, it is fairly simple: If the Earth moves up by an amount $\Delta z$, the payload feels a force through the compression of the spring equal to $K_S \Delta z$. The ground motion sensor detects this motion, however, and applies an equal and opposite force to the payload. The forces acting on the payload "cancel," and the payload remains unaffected. "Cancel" is in quotes because it is a greatly abused term. It implies *perfect cancellation* – which never happens. In real systems, you must consider *how well* these two forces cancel. For a variety of reasons, it is difficult to have these forces match any better than around 10%, which would result in a factor of 10 improvement in the system's response. Matching these forces to the 1% level is practically impossible. The reasons are numerous: The sensor is usually a geophone, which does not have a "flat" frequency response. Its response must be "flattened" by a carefully matched conjugate filter. The *gain* of this

*CleanTop® Optical Table supporting a Zygo Interferometer used for testing flatness of large optics. Photo courtesy of Quality Laser Optics* signal must be carefully matched so the force produced by the actuator is exactly equal in magnitude to the forces caused by ground motion. These gains, and the properties of the "conjugate filter," must remain constant to within a percent with time and temperature. Gain matching is also extremely difficult if the system's mass distribution changes, which is common in a semiconductor equipment application. Lastly, the cancellation level is limited by the sensor's inherent noise (noise floor).

Another limiting factor to vibrational feedforward is that it becomes a *feedback* system if the floor is not infinitely rigid (which it is not). This is because the actuator, in pushing on the payload, also pushes against the floor. The floor will deflect with that force, and that deflection will be detected by the sensor. If the level of the signal produced by that deflection is large enough, then an unstable feedback loop is formed.

Because of the numerous problems associated with vibrational feedforward, TMC has not pursued it. Indeed, though available from other vendors, we know of no successful commercial application of the technique. It is possible, however, with ever more sophisticated DSP controllers and algorithms, that it will be more appealing in the future. The technique which is successfully used is *command feedforward*.

**Command Feedforward.** Also shown in Figure 17, command feedforward is *only useful in applications where there is a known force being applied to the payload, and a signal proportional to that force is available.* Fortunately, this is the case in semiconductor manufacturing equipment where the main disturbance to the payload is a moving stage handling a wafer.

The concept here is very simple. A force is applied to the payload of a known magnitude (usually from a stage acceleration). An electronic signal proportional to that force is applied to an actuator which produces an equal and opposite force. As mentioned earlier, there is a tendency in the literature to overstate the effectiveness of this technique. Ridiculous statements claiming "total elimination" of residual payload motions are common. As in vibrational feedforward, there is a gain adjustment problem, but *all* issues concerning sensor noise or possible feedback paths are eliminated. This is true so long as the signal is a true *command* signal from (for example) the stage's motion controller. If the signal is produced from an encoder reading the stage position, then it is possible to form an unstable feedback loop. These systems can perform very well, suppressing stage-induced payload motions by an order of magnitude or more and will be further discussed in Section 5.7.

### 5.4.4 PZT-Based Systems

Figure 18 shows the concept of a "quiet pier" isolator such as TMC's STACIS® line of active isolators (Patent Nos. 5,660,255 and 5,823,307). It consists of an *intermediate mass* which is hard mounted to the floor through a piezoelectric transducer (PZT). A geophone is mounted to it, and its signal fed back to the PZT in a wide-bandwidth servo loop. This makes a "quiet pier" for supporting the payload to be isolated. Isolation at frequencies above the servo's active bandwidth is provided by a ≃20Hz elastomer mount. This elastomer also prevents piers from "talking" to each other through the payload (a payload must rest on several independent quiet piers). This system has a unique set of advantages and limitations.

The vibration isolation performance of the STACIS system is among the best in the 0.6-20 Hz frequency range, subject to some limitations (discussed below). It also requires much less tuning than inertial feedback systems, and the elastomer mount makes the system all but completely immune to structural resonances in the payload. Alignment of the payload with external equipment (docking) is not an issue because the system is essentially "hard mounted" to the floor through the 20 Hz elastomers. The settling time is very good because the response of the system to an external force (a moving stage) is that of the 20 Hz elastomer mount. This is comparable to the best inertial feedback systems. The stiffness of the elastomer mount also makes STACIS almost completely immune to room air currents or other forces applied directly to the payload and makes it capable of supporting very high center-of-gravity payloads.

STACIS can support, and is always compatible with, tools incorporating any type of built-in passive or active pneumatic vibration isolation system.

Unfortunately, the PZT has a range of motion which is limited (around 20-25 μm). Thus the servo saturates and "unlocks" if the floor motion exceeds this peak-to-peak amplitude. Fortunately, in most environments, the floor motion never exceeds this amplitude. To obtain a good vibration isolation characteristic, the active bandwidth for the PZT servo is from ~0.6 to ~200 Hz. This high bandwidth is only possible if the isolator is supported by a very rigid floor. The isolator needs this because it depends on the intermediate mass moving an amount proportional to the PZT voltage *up to a few hundred Hz*. If the floor has a resonance within the active bandwidth, this may not be true. Most floors have resonances well below 200 Hz, but this is acceptable as long as the floor is *massive* enough for its resonance not to be significantly driven by the servo. The proper form of the floor specification becomes *floor compliance*, in µin/lbf (or µm/N). In general, STACIS® must be mounted directly on a concrete floor. It will work on raised floors or in welded steel frames only if the support frame is carefully designed to be very rigid. Another problem is "building sway," the motion at the top of a building caused by wind. This is often more than 25 µm on upper floors, so the system can saturate if used in upper stories (depending on the building's aspect ratio and construction).

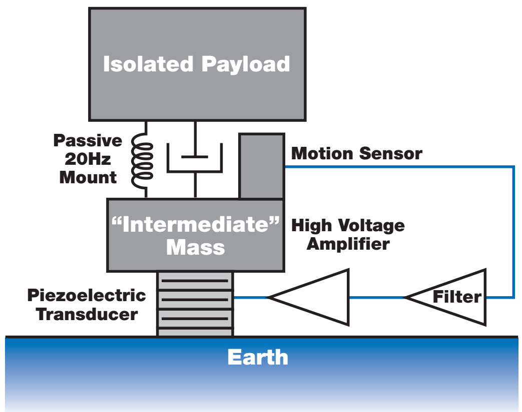



Figure 18

*Figure 18: This method involves quieting a small "intermediate mass" with a high-bandwidth servo, then mounting the main payload on that "quiet pier" with a passive 20 Hz rubber mount.*

In multi-DOF systems, each pier controls three translational degrees of freedom. With several isolators in a system, tilt and twist are also controlled. Each isolator requires five PZTs and three high-voltage amplifiers.

## 5.4.5 Exotics

There are many other types of active vibration isolation systems.

The first broad class of "alternate" active systems are the hybrids. One of these is a hybrid between a quiet pier and a simple pendulum isolator. Here, a 3-post system contains only three PZTs which control the vertical motion at each post actively (thus height, pitch, and roll motions of the payload are actively controlled). The "horizontal" DOFs are isolated using simple pendulums hanging from each 1-DOF quiet pier. This system has only about one-fifth the cost of a full-DOF quiet pier system because of the many fewer PZTs. On the other hand, the pendulum response of these systems in the horizontal direction is sometimes less than desirable.

There are also hybrids of the STACIS/quiet pier type of system with inertial feedback systems to improve the dynamic performance of the elastomer mount. These systems have additional cost and must be tuned for each application (see STACIS, page 2).

## 5.5 Types of Applications

Broadly, there two different types of applications: Vibration critical or settling time critical. These are *not* the same and each has different solutions. Some applications may be both, but since their solutions are not mutually exclusive, it is fair to think of both types independently. It is important to note, however, that since the solutions are independent, *so are their costs*. Therefore you should avoid buying an active system to reduce vibration if all you need is faster settling times, and vice versa.

## 5.5.1 Vibration Critical Applications

Vibration critical applications are actually in the minority. This means the number of applications which need better vibration isolation than a *passive* system can provide is quite small. Passive vibration isolation systems by TMC are *extremely* effective at suppressing ground noise at frequencies above a few Hz. There are only two types of applications where the vibration isolation performance of a passive isolator is a problem.

First, it is possible that the level of ground noise is so high that an instrument which is functional in most environments becomes ground noise sensitive. This usually only happens in buildings with very weak floors or in tall buildings where building sway becomes an issue. This is an unusual situation, since most equipment (such as semiconductor inspection machines) usually come with a "floor spec" which vendors are very hesitant to overlook.

The second type of applications are those with the very highest degree of intrinsic sensitivity. Prime examples are atomic force and scanning tunneling microscopes (AFMs and STMs). These have atomic scale resolutions and are sensitive to the *smallest* payload vibrations.

In both these situations the isolation performance of passive mounts is usually adequate, except for the frequency range from about 0.7 Hz to 3 Hz where a passive mount *amplifies* ground motion. This is a convenient coincidence, since active systems (such as the inertial feedback scheme) are good at eliminating this resonant amplification. Again, it is important to avoid an active vibration cancellation system *unless you have an application which you are sure has a vibration isolation problem that cannot be solved with passive isolators*. Most semiconductor equipment today has a different issue: Settling time.

## 5.5.2 Settling Time Critical Applications

Settling time critical applications are those where the vibration isolation performance of a passive pneumatic isolator is completely adequate, but the *settling time* of the isolator is insufficient. It is easy to determine if yours is such a system. If it works fine after you let the payload settle from a disturbance (stage motion), then you only have a settling time issue. (See Section 5.8). Before continuing, however, it is important to understand what is meant by "settling time."

**Settling Time.** The term *settling time* is one of the most abused terms in the industry, primarily because it lacks a widely accepted definition. A physicist might define the settling time as the time for the energy in the system to drop by $1/e$ . This is a nice, model-independent definition. Unfortunately, it is not what *anybody* means when they use the term. The most common definition is the "time for the system to stop moving." This is the worst of all definitions since it is non-physical, model and payload dependent, subjective, and otherwise completely inadequate. Nonetheless, it can be used with some qualifications.

In theory, a disturbed harmonic oscillator's motion decays exponentially, which is infinitely long lived. When in the context of a vibration isolator, one could think of the time when a system "stops moving" as the time required for the RMS motion of the system to reach a constant value, where the system's motion is dominated by the feedthrough of ground vibration. This is neither what people mean by settling time, nor is it model independent, since the "time to stop moving" depends on the magnitude of the initial disturbance and the level of ground noise. In fact, *there is no definition of "settling time" as a single specification which can be used to define system performance in this context – passive or otherwise.*

This is the definition used by TMC: *Settling time is the time required for a payload subjected to a known input to decay below a critical acceleration level.* This is an exact definition that requires *three* numbers: The *known input* is the initial acceleration of the payload immediately after the disturbance (stage motion) stops. The *critical acceleration level* is the maximum acceleration level the payload can tolerate and still successfully perform its function. The *settling time* is the time required after the disturbance for the payload's motion to decay below the critical acceleration level. Notice that we use a critical *acceleration level* and not a maximum displacement. It is not displacement of a payload which corrupts a process, but acceleration, since acceleration is what introduces the internal stresses in a payload which distort the structure, stage positioning, optics, etc. Of the three numbers, this is the most critical to understand, since it fundamentally characterizes the rigidity of your instrument.

For the product specifications in this catalog, the critical acceleration and input levels are unknowns. For this reason, we quote our settling time specifications as the time required for a 90% reduction in the initial oscillation amplitude.

## 5.6 The Problems with Inertial Feedback

Though inertial feedback systems can be used to reduce the settling time and improve vibration isolation performance, they have several significant drawbacks. As already mentioned, implementing a horizontal inertial feedback system is strongly limited by the tilt to horizontal coupling problem (Section 5.4.2). Another problem is that these systems (with the exception of PZT-based systems) have relatively poor *position* settling times.

Figure 19 shows the response of a payload to an external disturbance. It is based on a model of an idealized 1-DOF system and is only meant to qualitatively demonstrate the performance of a multi-DOF system. Both curves represent the same active system, except the first plots the ratio of displacement to applied force, and the second plots the ratio of acceleration to applied force, both as a function of frequency. The only difference is that the first graph has been multiplied by two powers of frequency to produce the second. The curves show, respectively, what a position sensor and an accelerometer would measure as this system was disturbed. Please note that the magnitude scales on these graphs have an arbitrary origin and are only meant for reference.

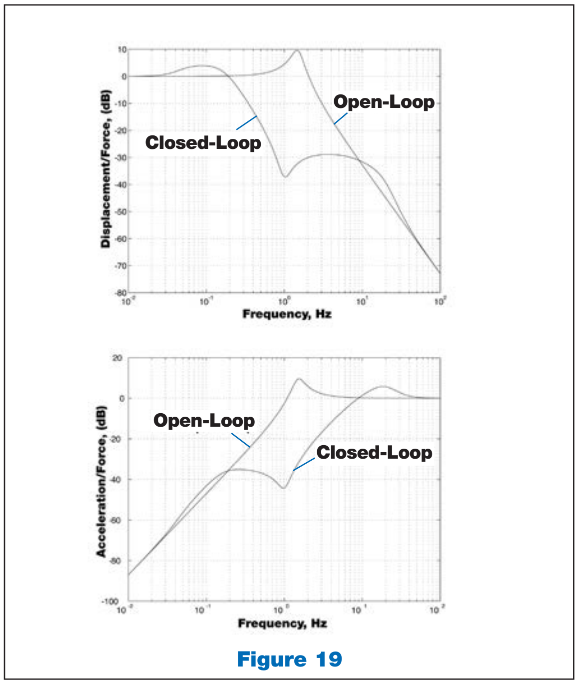



*Figure 19: The curves show that the position response is dominated by a low-frequency resonance, while the acceleration response is dominated by a high-frequency peak. Note that the peak in the open-loop response is the same.*

The curves show that the position response is dominated by a low-frequency resonance, while the acceleration response is dominated by a high-frequency peak. This is a counter-intuitive result, since the peak in the open-loop (purely passive) response is at the same frequency in both cases.

The good news is twofold. As promised, this system does a good job of suppressing the open-loop resonance in the system. In fact, it is even providing a substantial amount of additional isolation in the 0.5-5 Hz frequency range. The second piece of good news is that the acceleration curve is dominated by a well-damped resonance at around 20 Hz. If we assume the amplitude of the acceleration decays as:

$$Amplitude = A_0 \times e^{-t/\tau} \quad [17]$$

where $A_0$ is the initial amplitude and $\tau = Q / (\pi v)$. If the quality factor $Q$ is approximately 2, then $\tau \approx 32$ ms. Quite good. For any payload which is sensitive to acceleration (which most are), the settling time for this system will be improved by an order of magnitude by this servo.

The problem with this system is illustrated in the first set of curves. They show the position response is dominated by a peak at ~0.1 Hz. Assuming the same $Q$ as above, this means the decay constant $\tau$ is approximately 6.5 seconds! Even though the servo has been designed with a large phase margin to get the $Q$ down to 2, the low frequency of the peak means it takes a long time to settle in position. Although payloads are most sensitive to accelerations, there are two notable cases where a long position settling time is a problem.

First, a long position settling time in the roll or pitch DOF of a payload can *look* like a horizontal acceleration. This is due to Einstein's Principle of Equivalence: As a payload tips, then the direction that gravity acts on the payload changes from purely vertical to some small angle off vertical. By principle this is identical to having a level payload which is being *accelerated* by an amount equal to the tip angle (in radians) x g. In other words, each *mrad* of tilt turns into a *mg* of horizontal acceleration. Many instruments, such as electron microscopes, are sensitive to this.

Another significant problem is *docking* the payload. This is a common process where the payload must be periodically positioned relative to an off-board object with extreme accuracy – typically 20 to 200 µm. It can take an inertial feedback system a very long time to position to this level. There are two possible solutions to this. The first is to run the servo at a lower gain setting, sacrificing some isolation performance (which may not be needed) for a better position settling time. The second approach is to turn off the servo for docking. Servos, unfortunately, *do not like* to be turned on and off rapidly – especially when their nominal gain is as high as the one illustrated here.

## 5.7 The Feedforward Option

For settling time sensitive applications, there is another option which is less expensive and avoids the problems associated with the inertial feedback method. As discussed in Section 5.4.3, *command feedforward* can be used to reduce the response of a payload to an external disturbance. You can use this technique with or *without* using the inertial feedback scheme in Figure 17. This section deals with the latter option.

### 5.7.1 Feedforward Pros

There are many advantages to using a feedforward *only* system. Some of these are:

- You do not spend extra money on improved vibration isolation performance which you do not need. The system is less expensive because you avoid the cost of six inertial sensors and a feedback controller.

- The position stability of the payload is improved because it is now represented by the *open-loop* curves of Figure 19. There are also no issues about docking, since "turn-on transients" of the inertial feedback system are avoided. The feedforward system can remain on and the payload docked (using products like TMC's AccuDock™) with no problems.
- Since feedforward does not use any feedback, it is completely immune to resonances on the isolated payload.
- Using adaptive controllers, the amount of feedforward can be tuned to ensure at least a factor of 10 reduction in the response of the payload to a disturbance (stage motion). This is comparable to what a well-tuned inertial feedback system can do.

## 5.7.2 Feedforward Cons

Despite being more robust, less expensive, and easier to setup, there are still some disadvantages to the feedforward only option. Some of these are:

- As mentioned in Section 5.4.3, you are required to match the force capability of your disturbance (moving stage). Electromagnetic drivers which can do this can be expensive, difficult to align, have a high power consumption, and have some stray magnetic fields which can cause problems in some applications.
- For moving $X - Y$ stages, the feedforward problem is *non-linear* due to twist couplings. For example, a payload will twist clockwise if there is an $X$-acceleration when the stage is in the full $-Y$ position but counterclockwise when the stage is in the full $+Y$ position. Therefore, there are feedforward terms proportional to $X\ddot{Y}$ and $Y\ddot{X}$. This requires the use of a DSP-based controller.
- To keep the system running well, there should be a self-adaptive algorithm which keeps the gains properly adjusted. This is done by monitoring the motion of the payload and correlating it with the feedforward command inputs. This type of algorithm is *non-linear* and can be *unstable* under certain circumstances. In particular, with pure sinusoidal stage motion, stage accelerations become indistinguishable from payload tilting due to the shifting weight burden caused by the stage (the Principle of Equivalence again).
- This method requires some work on the customer's or stage manufacturer's part to provide an appropriate set of command feedforward signals. These can be either analog or digital in form, but they must come from the stage motion controller.
- The isolation from floor vibration is no better than it is for a passive system (though, as mentioned, you may not need any improvement).

## 5.8 When Will You Need an Active System?

Determining your need for an active isolation system varies depending on whether you have a vibration or settling time critical application. Both can be difficult, and in either case, you need to know something about your system's susceptibility to vibrational noise.

In vibration critical applications, it is insufficient to simply ask "does my system work?" If your system does not work with passive systems, or if the performance is inadequate, then you need to identify the source of the problem. For AFM/STM type applications, it may be obvious. The raw output of the stylus is dominated by a 1.5 Hz noise and that is correlated with the payload motion, and you *know* your isolators have their resonance at that frequency. Other times it may be much less clear. For example, you may see a 20 Hz peak in your instrument, and that correlates with noise on the payload – but is it coming from the ground? Many HVAC systems in buildings use large fans which operate in this frequency range. If they do, they produce both acoustic noise and ground noise which are correlated with noise on the payload. So what is the source of the problem? Ground noise or acoustics? It can be impossible to tell. Keep in mind, however, that if your problem is at 20 Hz, inertial feedback active systems will not help you, since they do not have any loop gain at that frequency. PZT-based isolators like STACIS® may be the only solution in this frequency range.

Settling time critical applications are more straightforward. To determine if you need an active system (which we assume to be feedforward only), there are three steps:

- **Step one**: Determine the *critical acceleration level* for your process (as discussed earlier in Section 5.5.2). A simple way to do this might be to move your stage and wait different amounts of time before making a measurement. If you know how long you need to wait and know the acceleration level of the payload after the stage stops, then you can derive this number. For a new instrument, the critical acceleration level can be very difficult to determine, and you might have to rely on calculations, modeling, and estimates.
- **Step two**: Estimate the initial acceleration level of the payload by multiplying your stage acceleration by the

ratio of your stage mass to total isolated payload mass.

- **Step three**: Compare the numbers from steps one and two. If the critical acceleration level is above the initial payload reaction, then any TMC passive system should work for you. If it is below, then you need to compare the ratio of the initial to critical acceleration levels, and use Equation 17 to determine if the system can settle fast enough.
- If your allowed settling time is insufficient to get the attenuation you need, then you might want to try a system with higher passive damping. TMC's MaxDamp® isolators have a decay rate up to five times faster than conventional pneumatic isolators (a Q-factor five times lower). This does sacrifice some vibration isolation but is often a good tradeoff.
- If MaxDamp isolators will not work, then you will need an active system (passive isolation systems have run out of free parameters to solve the problem).

There are certain extreme examples which can determine your need very quickly. For example, if your critical level is below the initial payload acceleration and you want "zero" settling time, then you need an active system. However, if the ratio of the initial to critical level is more than 10 (with "zero" time), then you will either be forced to re-design your instrument or allow for a non-zero settling time. Active systems are *not* panaceas – they can not solve all problems.

## 5.9 General Considerations

If you are designing a new system, there are several general considerations which will make your system function optimally, whether it is active or not.

You should always use four isolators to support a system (rather than three), and they should be as widely separated as possible. This dramatically improves both the tilt stability and tilt damping in a system with only a marginal cost increase. It simplifies the design of the frame connecting the isolators, reduces the frame fabrication costs, gives better access to the components under the payload, and improves the overall stiffness of the system (assuming that your instrument has a square footprint).

You should use a center-of-mass aligned system whenever possible. This means putting the plane of the payload's center of gravity (CG) in the same plane as the moving stage's CG, and both of these should be aligned with the effective support point for the pneumatic isolators. This greatly reduces the pitch and roll of the payload with stage motions and can reduce the cost of an active system by making it possible to use lower force capacity drivers in the vertical direction. Note that the "effective support point" for most isolators is slightly below the top of the isolator. Consult a TMC sales engineer for the exact location of this point for different isolation systems. A system's performance will also be improved by designing the payload such that the isolators support roughly equal loads.

The cost of the isolation system can be reduced by several means. The moving mass should be reduced as much as possible – this reduces the forces required to decelerate it and thus reduces the cost of the magnetic actuators in the active system. You should also make the payload as rigid as possible to reduce the system's overall susceptibility to payload accelerations. Lastly, you can increase the static mass of the system, which will improve the ratio of static to active mass and thus reduce the payload's reactions to stage motions.

It is quite possible that all of these steps, taken together, will allow you to avoid the use of an active system entirely.

## 5.10 Conclusions

The challenges created by Moore's Law* will require improved collaboration between systems engineers, integrators, stage manufacturers, and semiconductor tool manufacturers. There also needs to be a significant improvement in the awareness of the problem. This is simply a legacy of the by-gone days where "blind integration" of systems was sufficient. System engineers need to significantly shift their design goals for systems, since the conflict with high system throughputs and vibration isolation systems are fundamental, and active systems only improve the performance of systems by a certain factor. If the methods of design are not changed, then there may be a day in the not too distant future when even active systems will not work. Then you are really out of luck, since there *is no* next generation technology to turn to. Indeed, TMC already sees specifications which cannot be met even with the most optimistic assumptions about active system performance.

Active systems are relatively expensive. The costs are driven by components like the magnetic or PZT actuators. Their prices are high because of the cost of their materials (rare earth NdFeB magnets or piezoelectric ceramics). The cost of power amplifiers can be high. When considering costs, it is important to realize that there is no such thing as an incremental active solution. The active system, if you need one, must match the forces generated by your stage motions. A system capable of less simply will not work.

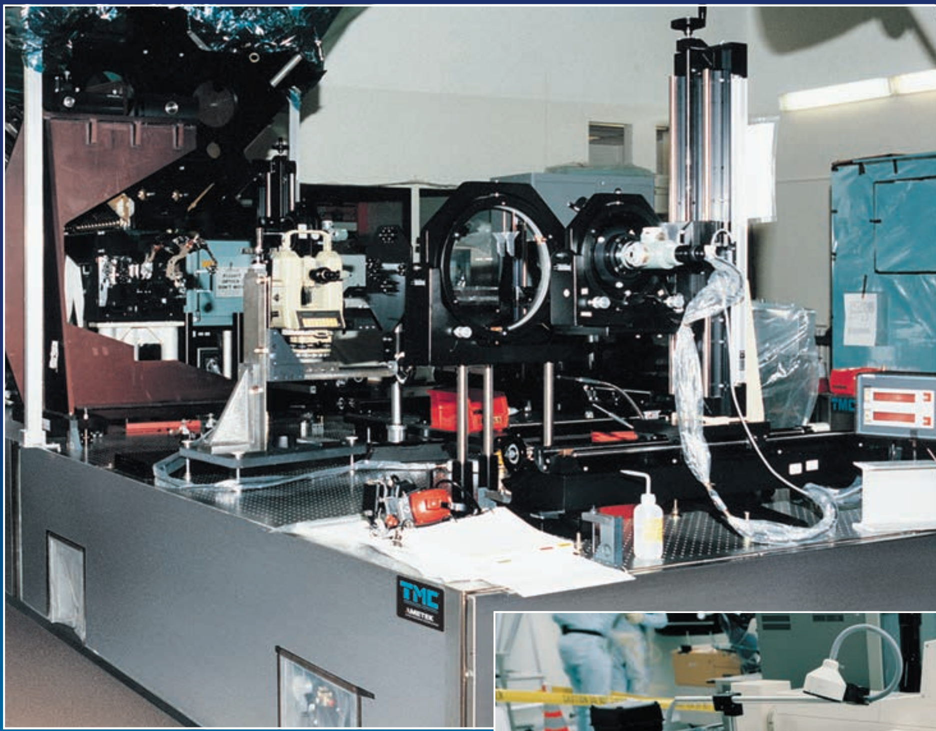
TMC is striving to improve active isolation systems. Our goal is to make them more reliable, easier to install, maintain, and configure, and to make them self-configuring whenever possible. This will reduce system costs, engineering times, and speed the production of your systems.

TMC has a staff of sales engineers who can help you with any questions raised in this presentation or assist you in the design of an isolation system.


*TMC isolators may be designed into a tool or applied as a point-of-use isolator.*

* Gordon Moore, co-founder of Intel Corp., has pointed out that the density of semiconductors (in terms of transistors/area) has roughly doubled every 18 months, on average, since the very earliest days of commercial semiconductor manufacturing (even 1960 or earlier!).

## Blending Precision Floor Vibration Control with a Commitment to Manufacturing



*COSTAR Module, now installed in the Hubble Space Telescope, was aligned and tested on TMC CleanTop® Optical Tables at Ball Aerospace. Photo courtesy of Ball Aerospace.*

*Custom electropolished stainless steel vibration isolation table installed at Motorola MOS-12. Photo courtesy of Motorola.*

ISO 9001:2008 CERTIFIED

ULTRA PRECISION TECHNOLOGIES

www.gmp.ch

| | | | | | |
|---|---|---|---|---|---|
| GMP SA | Siège principale: Avenue des Baumettes 17 | CH-1020 Renens | +41 21 633 21 21 | Fax. +41 21 633 21 29 | info@gmp.ch |
| GMP SA | Büro Zürich: Dübendorfstrasse 11a | CH-8117 Fällanden | +41 44 825 34 00 | Fax. +41 44 825 34 01 | so@gmp.ch |