



## ***Compensator***

*RCC - Remote Center Compliance Device*

## Product Description

The Compensator is a Remote Center of Compliance (RCC) device designed to correct alignment errors with peg-in-hole automated assembly applications. The Compensator is engineered to project a compliance-center (also known as center-of-compliance) forward by using three or more elastomer shear pads. These shear pads are stiff axially and compliant laterally. When the contact point is near the center-of-compliance, the part will automatically correct lateral and rotational misalignment reducing the contact force and preventing galling and jamming. Because the Compensator is a mechanical device, the insertion correction occurs rapidly allowing for high-speed automated machines to use this RCC device.

## Benefits

- Reduce scrap, downtime, machine damage.
- Eliminates jamming, wedging, galling.
- Increases automatic assembly productivity (faster throughput).
- Lowers machine and part cost due to relaxed tolerances.
- Replaces centering sleeves, springs, two-stage RCCs.
- Makes impossible assemblies possible.

## Features

- Low lateral stiffness reduces insertion force.
- Three overload pins made of hardened steel to protect Compensator from crashes..
- Variety of oil- and coolant-resistant high quality elastomer shear pads (neoprene and nitrile).
- Single-stage design lowers cost.
- Optional pneumatic Lock-up allows you to remove the compliance when not needed thereby decreasing your cycle time and increasing shear pad life.

## Typical Applications

- Locating parts in machines
- Gears onto splined shafts
- Positioning on an assembly line
- Mold alignment
- Bearings into drive assemblies
- Washers onto shafts
- Fans onto motor shafts
- Speedometer staking operation



## Customers

Hundreds of users benefiting from the Compensator include:

**Automotive:** GM, Ford, Toyota, Honda, Delco Delphi

**Electronics:** IBM , Apple, Digital Equipment Corp.

**Appliance:** Whirlpool, State Industries, General Electric

**Integrators:** Weldun Int., Bodine, Cimflex Technologies

**Others:** TRW, Schlage Lock, Dow Corning, GTE

### Note:

While the Compensator uses compliance for peg-in-hole insertion, the Compensator should not be used as a general compliance device due to possible fatigue to the shear pads.

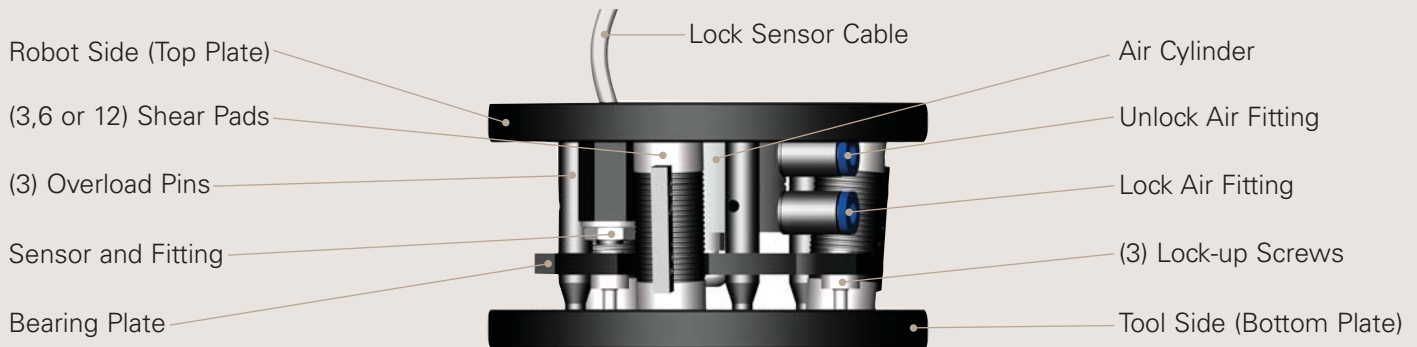
## Standard Compensator

The Compensator consists of a single device with all components contained within the unit's outside diameter and includes two high-strength anodized aluminum top and bottom plates, hardened alloy steel overload pins and elastomer bonded shear pads. The 000 and 100 size Compensators use 3 shear pads. The 200 size uses either 3 or 6 shear pads. The 400 size uses 6 or 12 shear pads. Adding extra shear pads when possible will increase strength and stiffness.

### Other options:

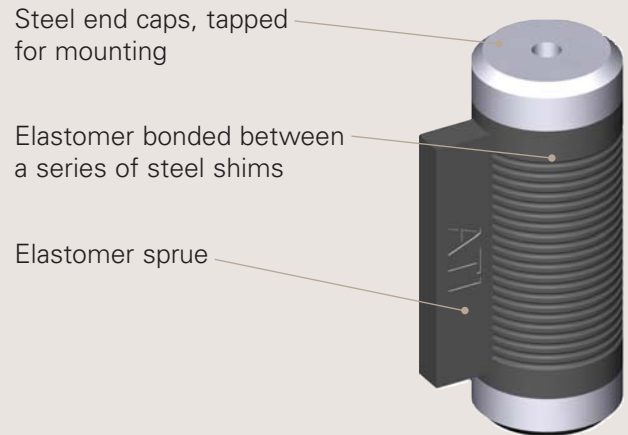
**Lock-up** for reducing vibration due to inertia, protecting the shear pads and decreasing cycle time. Units with Lock-up include air cylinders, bearing plate, lock-up screws and lock-up screw bushings.

**Lock sensing** for monitoring Lock condition. Units with Lock sensing also require a sensor fitting and a cabled proximity sensor. Lock sensing is available only on 100, 200 & 400 size Compensators.



## Shear Pad

The shear pad's lateral compliance (softness) is the key to reducing contact forces. The shear pads are made with a proprietary process that bonds high quality elastomer with metal shims, giving them high stiffness in compression and long fatigue life.



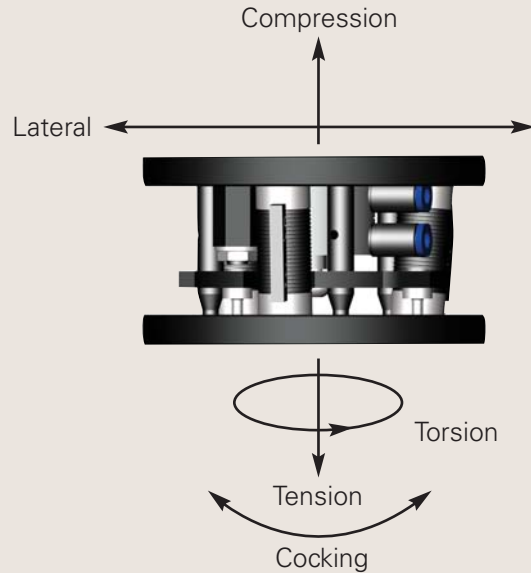
### Shear Pad Specifications

Properties	HCL-01A2	HCL-02A	HCL-11A	HCL-12A	HCL-13A
Compatible Compensator Size	000	000	100, 200	100, 200	100, 200, 400
Elastomer	Neoprene	Nitrile	Neoprene	Neoprene	Nitrile
Operating Temperature, degrees Celsius	-29 to 82	-29 to 82	-29 to 82	-29 to 82	-29 to 82
Oil Resistance	Good	Excellent	Good	Good	Excellent
Ozone Resistance	Good	Good	Good	Good	Good
Lateral Stiffness (lbs/in)	6 (Very Low)	28 (High)	20 (Low)	14 (Very Low)	34 (High)
Axial Stiffness (lbs/in)	2329	10498	24889	6075	8300

## How it Works

The Compensator fits between an assembly machine (e.g. pick and place machine) or robot and a tool (e.g. gripper), providing compliance in the lateral, cocking and torsional directions; yet it is stiff in compression, allowing the force from the assembly machine or robot to transfer to the part for assembly.

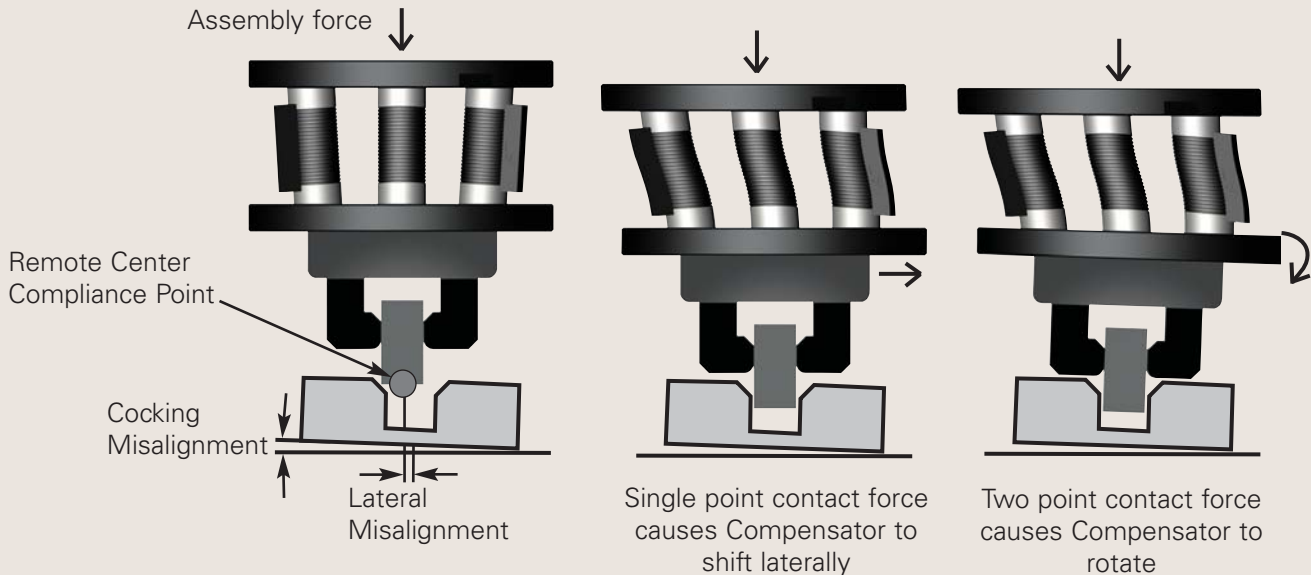
Compensators have two options for interfacing to an assembly machine or robot. Units can be mounted by using the tapped holes on the robot side (top plate) or by bolting through the robot side (top plate) to the robot or assembly machine. The tool side (bottom plate) uses the same two methods for mounting tooling to the unit as the robot side (top) plate. All units have (2) dowel pins for location on the robot side (top plate) and (2) dowel pins for location on the tool side (bottom plate).



## Center-of-Compliance

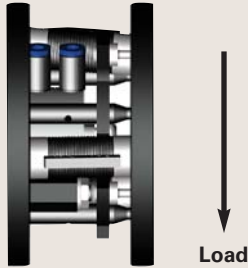
A key feature to the Compensator is the projected Remote Compliance Center. The center-of-compliance (C-of-C) is the point in space at which a contact force will cause a translation with no rotation and a torque will cause a rotation with no translation.

When the center of compliance is near the contact point, the insertion part (e.g. peg) axis will align with the location (e.g. hole) axis during assembly.



## Intended Use

The Compensator is intended to be used in "peg-in-hole" type operations in the vertical orientation. The peg-in-hole example is an application involving the insertion of one part into another. There are a variety of peg-in-hole type applications that include: dowel pin insertion, mold alignment, washer insertion, bearings into housings, and shafts into bearings.



Horizontal Lock Position / Severe

If the Compensator is used in the horizontal orientation, over time the shear pads will develop sag. Rubber and most rubber-like materials have memorization characteristics. Over time the rubber material memorizes the repeated position and will return to this position. When this occurs, the shear pads have developed sag. Use of the Lock-up option is recommended to prevent shear pad sag.



Vertical Lock Position / Normal

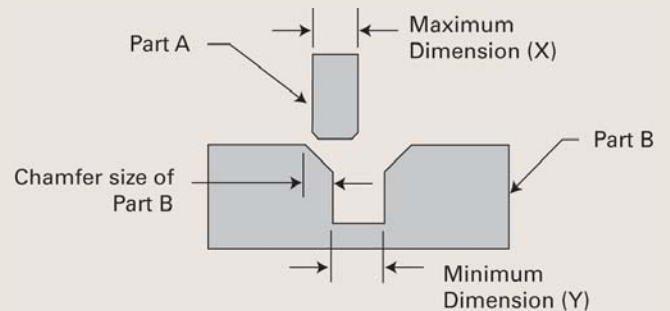
## Compensator Selection

### 1) Compare possible assembly misalignment with Compensator allowable misalignment:

Follow the two steps below (see diagram on the right):  
Step 1: Perform a tolerance study of your worst-case assembly misalignment.

- Tolerance to which your assembly machine can position part A.
- Tolerance to which your feeder can position part B.
- Repeatability of tooling handling part A.
- Locational tolerance of part B's feature (e.g.;hole).
- Repeatability of Compensator is  $\pm 0.002$ " in the vertical position.

Assembly misalignment (worst case) = a) + b) + c) + d) + e)



Step 2: Find your total clearance.

- Chamfer size on part A (a lead in is required on at least one part).
  - Chamfer size on part B.
  - Worst case part clearance, Y subtract X.
- Total clearance = a) + b) + c)

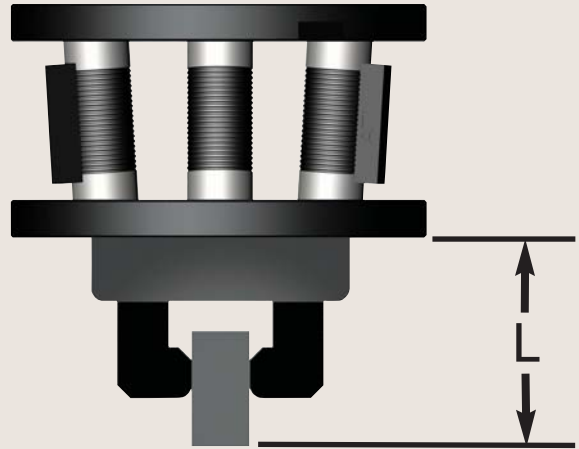
- The Compensator is needed when your assembly misalignment is greater than your part clearance.
- Your total clearance must be greater than your assembly misalignment or the two parallel surfaces will make contact. If your total clearance is less than your assembly misalignment, then increase the chamfer size on part A and/or part B.
- Select a Compensator with allowable misalignment greater than your assembly misalignment (see the table on page 8).

When the insertion axis is not vertical, the initial offset of the Compensator due to the weight of tooling and part must be taken into consideration as there is some lateral and cocking deflection of the flexing shear pads. This reduces the allowable misalignment in the downward direction, while increasing it in the upward direction.

## Compensator Selection (continued)

### 2) Calculate the optimum Center-of-Compliance (C-of-C):

Calculate the total distance, (L), from the tool side (bottom) plate of the Compensator to the initial contact point of the part being inserted (see diagram on the right). Take into account any interface plates. Select the model with a C-of-C within 30% of the distance L. It is better to have a C-of-C below the insertion point than above. If the fit between the peg and hole is loose, a model with a C-of-C within 60% of distance L is allowable.



### 3) Determine the required load capacity:

Observe the following guidelines:

- The tension load capacity for a vertical application is the weight of the tool and part.
- Use the HCL-13A shear pad for high impact loads (available only for 100, 200 & 400 size compensators).
- Use the Lock-up device to reduce high inertia loads due to acceleration (see page 7).
- A high compression load capacity will be needed for tight tolerance applications (i.e.; press fit).
- When needed, use six (6) shear pads on the 200 size and twelve (12) on the 400 size to double the load capacity.

### 4) Minimize insertion force:

Calculate your maximum insertion force by multiplying your assembly misalignment by the lateral stiffness (see the table on page 8).

Observe the following guidelines:

- Make sure your assembly device can overcome the insertion force.
- Minimize Compensator stiffness when handling lightweight or delicate parts.
- Longer, heavier parts can usually tolerate a greater insertion force.

The 100 and 200 size Compensators use three types of shear pads. The HCL-12A is the softest shear pad, while the HCL-11A is nearly as soft, but with a longer C-of-C. The HCL-13A is the stiffest shear pad with a C-of-C similar to the HCL-12A.

The 000 uses two types of shear pads, HCL-01A2 and HCL-02A. The HCL-01A2 is the softest shear pad. The HCL-02A is stiffer axially and laterally.

The 400 uses one type of shear pad, HCL-13A.

Find the lowest stiffness model that is within the applications load capacity and near the optimum C-of-C.

### 5) Environment:

The shear pads performance can be affected by the environment, such as temperature and oil. Examine the shear pads specifications in the table on page 3.

## LOCK-UP AND LOCK SENSING OPTIONS

### Description

The Lock-up option is a pneumatically-driven device that “pulls” the bottom plate toward the top plate while centering the bottom plate to a repeatable location. Varying the air pressure varies the “pull.” When activated, the Lock-up option locks the Compensator rigid, reducing vibration due to inertia. When the Lock-up is deactivated the Compensator is fully compliant. Units equipped with lock-up are recommended to use a supply of clean, dry and non-lubricated air from 60 to 120 psi (4.1 to 8.3 bar). In severe locking conditions, the air supply can be adjusted to a maximum of 120 psi (8.3 bar). Lock-up is operated by applying air to the desired fitting (lock or unlock). The opposite fitting must be exhausted for the cylinder to operate correctly. The unit is recommended to be locked in the vertical position. This creates a normal locking condition. A severe locking condition occurs when the unit is locked in the horizontal position under a load.

In such a condition, the load is being lifted by the lock-up mechanism. Using a flow control valve to reduce the acceleration of the lock-up screw into the tool-side (bottom) plate will help to reduce wear on the lock-up screw bushing. Air supply is connected to the Compensator by 5/32” or 4 mm O.D. flexible, pneumatic tubing.

Lock sensing is achieved by monitoring the position of the lock-up screw on the 100 and 200 sizes. The bearing plate position is monitored on the 400 size to achieve lock sensing. When air pressure is applied to the air cylinder to lock the unit, the lock-up screw is pulled into the tool side (bottom) plate. The lock-up screw or bearing plate enters the sensing range of the proximity sensor sending a lock signal. Units equipped with lock sensing use a M5 x 0.5 x 25 mm long threaded-barrel proximity sensor. Units that are ordered as sensor-ready should use the same type proximity sensor.

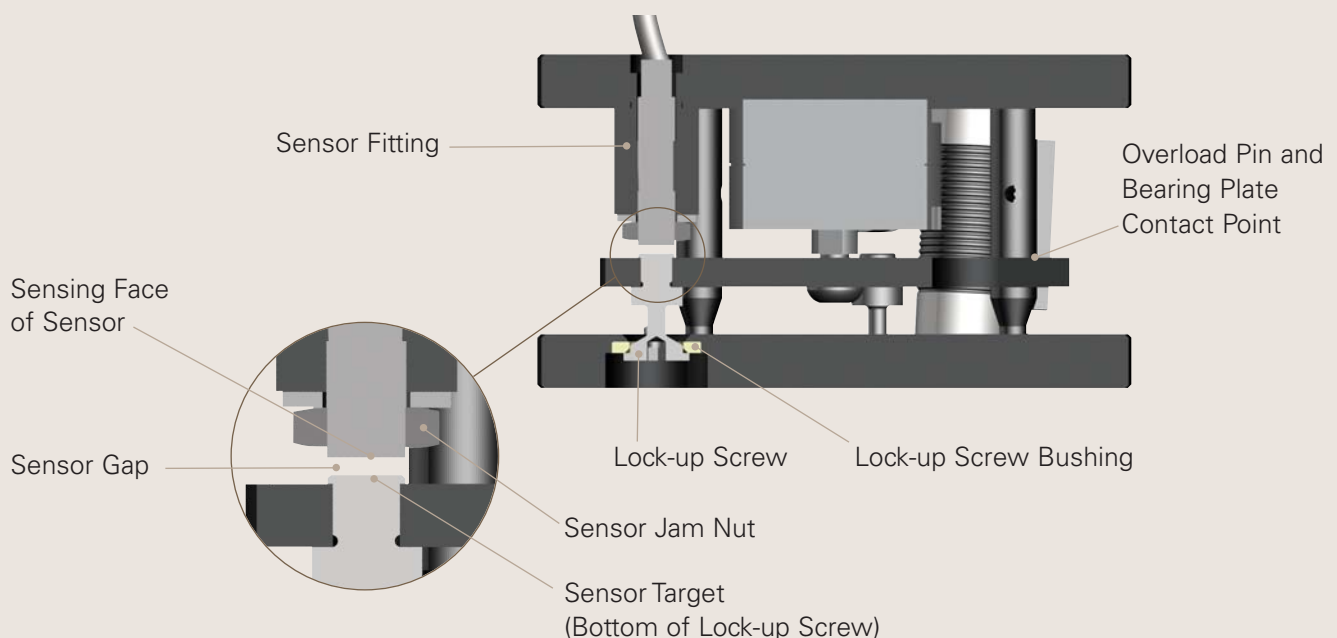
### Benefits

**Decreased Cycle Time:** The Lock-up option reduces vibration due to acceleration and deceleration during transport thereby reducing settling time.

**Increased Shear Pad Life:** Vibration due to high-inertia moves causes unnecessary wear on the shear pads.

### Centers Compensator for Repeatable Locating:

When the Lock-up option is activated, the bottom plate is centered with the top plate. The bottom plate is located to a repeatable position providing accurate tool positioning.



# SPECIFICATIONS

## Metric Units

Size	Overall Size (mm)		Weight w/(3) Shear Pads (N)		Allowable Misalignment (Standard)		
	D	H	Standard	w/Lock-up & Sensor	Lateral (mm)	Cocking (rad)	Torsion (rad)
000	56.9	41.4	1.3	1.8	1.7	0.017	0.079
100	80.0	45	2.2	3.1	2.2	0.019	0.087
200	99.1	45	3.6	4.9	2.2	0.019	0.070
400*	160.0	50.8	12.3	16.1	2.2	0.006	0.044

## Standard Units

Size	Overall Size (in)		Weight w/(3) Shear Pads (lbs)		Allowable Misalignment (Standard)		
	D	H	Standard	w/Lock-up & Sensor	Lateral (in)	Cocking (degree)	Torsion (degree)
000	2.24	1.63	0.3	0.4	0.0065	1.0	4.5
100	3.15	1.77	0.5	0.7	0.085	1.1	5.0
200	3.90	1.77	0.8	1.1	0.085	1.1	4.0
400*	6.3	2	2.76	3.62	0.085	0.3	2.5

\*Note: Weight shown is with (12) shear pads.

## Metric Units

Model Number	C of C (mm)	Maximum Load Capacities				Stiffness	
		Vertical (N)*	Horizontal (N)*	Compression (N)	Cocking (N-m)	Lateral (N/mm)	Cocking (N-m/rad)
9116-001-A	23	22.2	6.7	355.9	3.4	5.8	180.8
9116-111-B	122	44.5	8.9	1290.0	5.1	11.4	372.8
9116-112-B	69	44.5	8.9	533.8	5.1	7.2	180.8
9116-113-B	61	80.1	26.7	1290.0	7.9	26.3	632.7
9116-211-A	140	53.4	8.9	1334.5	6.8	11.4	474.5
9116-211-B	155	53.4	8.9	1378.9	7.3	11.4	553.6
9116-211-C	148	106.9	17.8	2713.4	14.1	22.8	1028.1
9116-212-A	82	62.3	8.9	622.8	6.8	7.2	226.0
9116-212-B	92	62.3	8.9	711.7	7.3	7.2	271.2
9116-212-C	87	124.6	17.8	1334.5	14.1	14.4	497.1
9116-213-A	74	97.9	26.7	1334.5	8.5	26.3	790.9
9116-213-B	82	97.9	26.7	1378.9	9.0	26.3	949.0
9116-213-C	79	195.7	53.4	2713.4	17.5	52.5	1739.9
9116-413-C	229	195.7	26.7	2713.4	39.5	70.0	9038.3
9116-413-D	229	391.4	53.4	5426.8	79.1	140.1	18076.7

## Standard Units

Model Number	C of C (in)	Maximum Load Capacities				Stiffness	
		Vertical (lbs)*	Horizontal (lbs)*	Compression (lbs)	Cocking (in-lbs)	Lateral (lbs/in)	Cocking (in-lbs/rad)
9116-001-A	0.9	5	1.5	80	30	33	1600
9116-111-B	4.8	10	2	290	45	65	3300
9116-112-B	2.7	10	2	120	45	41	1600
9116-113-B	2.4	18	6	290	70	150	5600
9116-211-A	5.5	12	2	300	60	65	4200
9116-211-B	6.1	12	2	310	65	65	4900
9116-211-C	5.8	24	4	610	125	130	9100
9116-212-A	3.2	14	2	140	60	41	2000
9116-212-B	3.6	14	2	160	65	41	2400
9116-212-C	3.4	28	4	300	125	82	4400
9116-213-A	2.9	22	6	300	75	150	7000
9116-213-B	3.2	22	6	310	80	150	8400
9116-213-C	3.1	44	12	610	155	300	15400
9116-413-C	9	44	6	610	350	400	80000
9116-413-D	9	88	12	1220	700	800	160000

\*When used in the vertical position, use the Vertical maximum load capacities, when used in the horizontal position, use the Horizontal maximum load capacities. See page 5 for intended use and recommended orientation.

-A and -B models use (3) shear pads, -C uses (6), -D uses (12).

9116 Series 100 and 200 size compensators use three types of shear pads: HCL-11A, -12A and -13A.

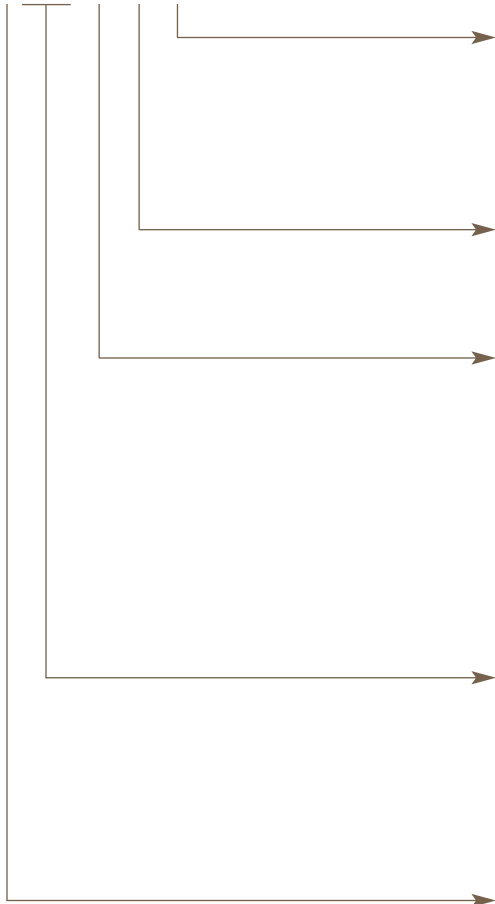
9116 Series 000 size compensator uses two types of shear pads: HCL-01A2 and -02A.

9116 Series 400 size compensator uses one type of shear pad: HCL-13A.



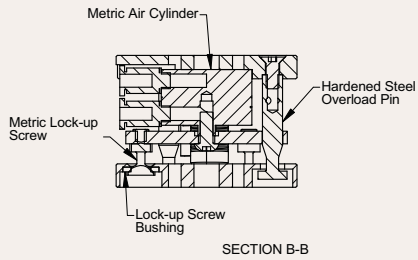
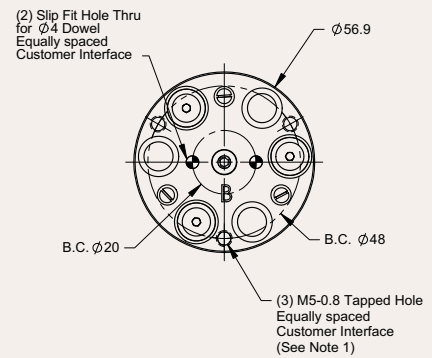
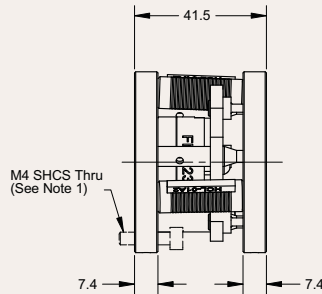
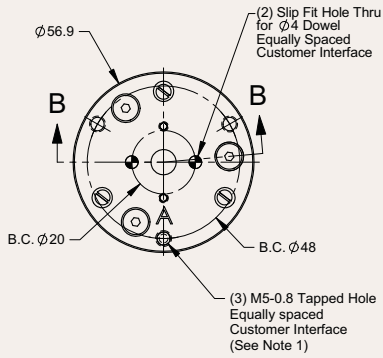
## HOW TO ORDER

9116-□□□-□-□-□



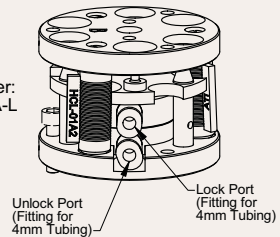
9116 COMPENSATOR	
	<p><b>Lock Sensing (100, 200 &amp; 400 sizes only)</b>  <b>P:</b> PNP Proximity switch  <b>N:</b> NPN Proximity switch  <b>S:</b> Sensor ready (customer supplied sensor)            Blank: No Lock sensing</p>
	<p><b>Lock-up</b>  <b>L:</b> Lock-up            Blank: No Lock-up</p>
	<p><b>Shear Pad Location</b>  <b>A:</b> (3) shear pads on inner bolt circle (000 and 200 sizes only)  <b>B:</b> (3) shear pads on outer bolt circle (100 and 200 sizes only)  <b>C:</b> (6) shear pads, (3) on inner and (3) on outer bolt circle (200 size, 400 size - equally spaced on bolt circle)  <b>D:</b> (12) shear pads equally spaced on bolt circle (400 size only)</p>
	<p><b>Shear Pad</b> (Refer to the tables on page 3 for more information)  <b>01:</b> HCL-01A2 (available only for 000 size)  <b>02:</b> HCL-02A (available only for 000 size)  <b>11:</b> HCL-11A (available only for 100 &amp; 200 sizes)  <b>12:</b> HCL-12A (available only for 100 &amp; 200 sizes)  <b>13:</b> HCL-13A (available only for 100, 200 &amp; 400 sizes)</p>
	<p><b>Model Designation</b>  <b>0:</b> 000 size  <b>1:</b> 100 size  <b>2:</b> 200 size  <b>4:</b> 400 size</p>

9116 & 9115 SHEAR PAD ONLY	
	<p><b>Shear Pad</b> (Refer to the tables on page 3 for more information)  <b>9116-HCL-01A2</b> (available only for 000 size)  <b>9116-HCL-02A</b> (available only for 000 size)  <b>9115-HCL-11A-C</b> (available only for 100 &amp; 200 sizes)  <b>9115-HCL-12A-C</b> (available only for 100 &amp; 200 sizes)  <b>9115-HCL-13A-C</b> (available only for 100, 200 &amp; 400 sizes)</p>

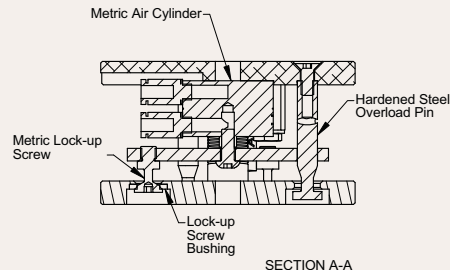
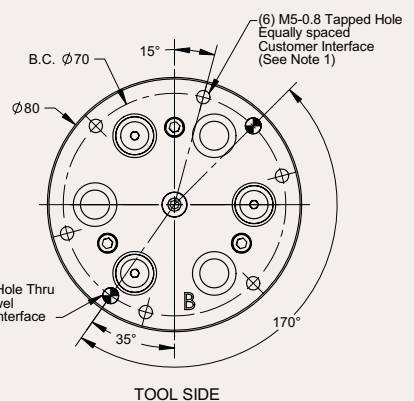
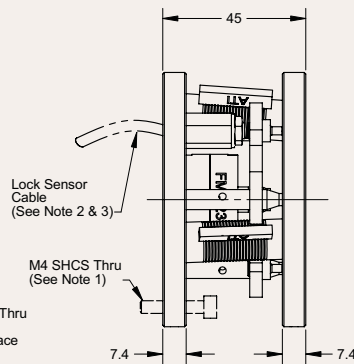
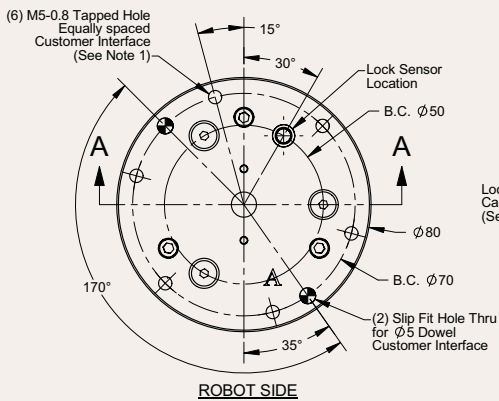


- Notes:
1. Also option of using M4 SHCS thru the M5 tapped hole for mounting. Mounting hardware not provided.
  2. Unit shown with optional lock-up.

Part Number:  
9116-001-A-L

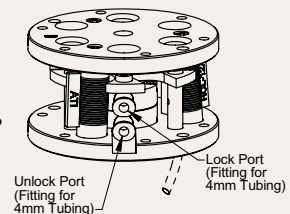


Drawing # 9230-15-1028-01



- Notes:
1. Also option of using M4 SHCS thru the M5 tapped hole for mounting. Mounting hardware not provided.
  2. Robot side interface plate must accommodate sensor cable. Recommended sensor cable exit slot dimensions, 6mm wide by 9mm deep.
  3. Unit shown with optional lock-up and lock sensing.

Part Number:  
9116-112-B-L-P



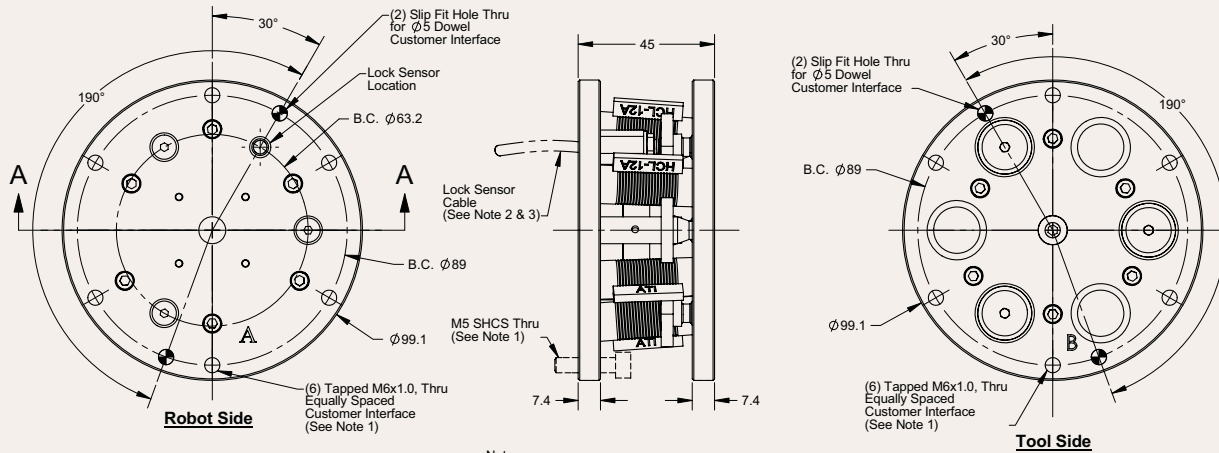
Drawing # 9230-15-1029-02

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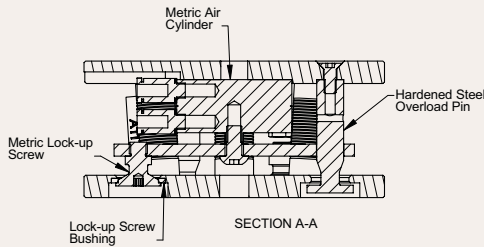
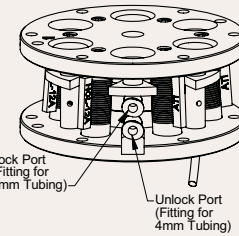
COMPENSATOR 200

9116-212-C-L-P



- Notes:
1. Also option of passing M5 SHCS thru M6 tapped hole for mounting. Mounting hardware not provided.
  2. Robot side interface must accommodate sensor cable. Recommended sensor cable exit slot dimensions, 6mm wide by 3mm deep.
  3. Unit shown with optional lock-up and lock Sensing.

Part Number:  
9116-212-C-L-P



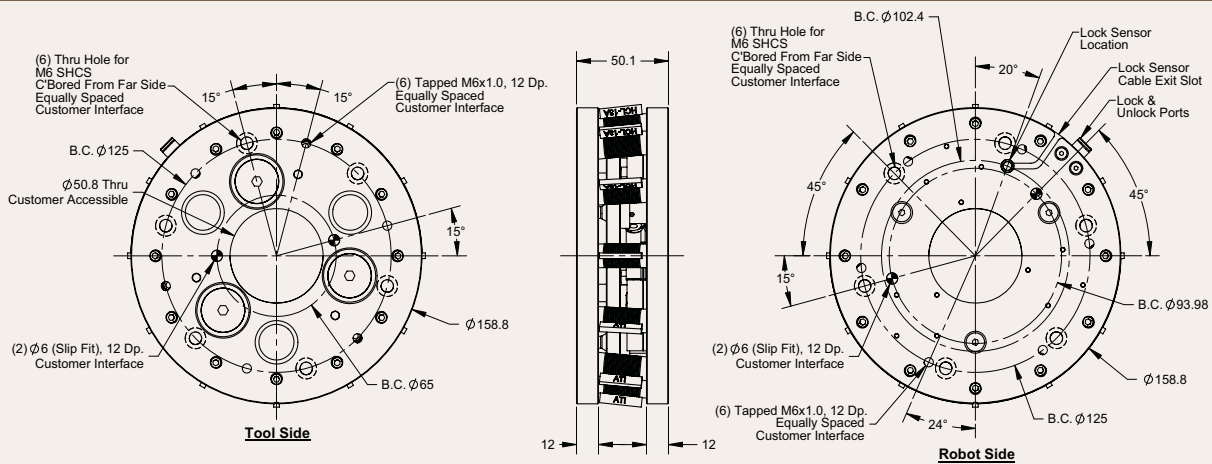
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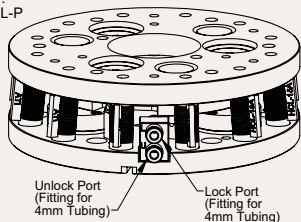
COMPENSATOR 400

9116-413-D-L-P



- Notes:
1. Unit shown with optional lock-up and lock sensing.

Part Number:  
9116-413-D-L-P



Drawing # 9230-15-1034-01

## Other ATI Products

### Robotic/Automatic Tool Changer

A high-precision rugged device that automatically changes tooling. Patented fail-safe locking mechanism uses No-Touch Locking™ technology, allowing plate separation when locking.

### Robotic/Automatic Tool Changers for Heavy Automation

This series of modular tool changers are designed specifically for high-payload and high-moment applications. **Utility Modules** to pass air, fluid, and electrical signals are also available for use in non-tool changer applications. Useful for processes requiring repeated connection/disconnection of utilities.

### Multi-Axis Force/Torque Sensor

Measures the full six components of force and torque. High overload protection and high signal-to-noise ratio. Used in robotic and research applications.

### Manual Tool Changers

Cost-effective solution for quickly changing tools by hand. Compact design combines high strength and excellent repeatability while preventing loosening.

### Utility Couplers

Quickly connects utilities such as air and electrical signals in docking and fixturing applications. Can feature a unique compliance mechanism that compensates for severe tooling misalignments. The modular body design is capable of mounting any of ATI's standard add-on **Utility Modules**.

### Robotic Collision Sensor

Designed to prevent damage to robotic end-effectors resulting from robot crashes. Features include: Automatic reset, high-repeatability, and large moment rotation.

### Robotic & CNC Deburring Tools

These air-driven robotic tools cover a wide variety of automated deburring applications with fast cycle times and clean, accurate cuts. The Radially-Compliant Deburring Tool is designed for removal of parting lines and flash. The Axially-Compliant Deburring Tool is specially designed for edge deburring and chamfering. The Axially-Compliant Finishing Tool is designed for material finishing operations on aluminum, plastic, steel and more.

## Company Profile

ATI Industrial Automation is a world-leading developer of Automatic Tool Changers, Multi-Axis Force/Torque Sensing Systems, Utility Couplers, Manual Tool Changers, Robotic Collision Sensors, Robotic Deburring Tools, and Compliance Devices. Our products are found in thousands of successful applications around the world.

For over 20 years, our engineers have been developing cost-effective, state-of-the-art products and solutions to improve manufacturing productivity.

Our Mission is to provide customers around the world with high-quality robotic peripheral devices, tooling and sensors that enhance customer profitability by increasing the effectiveness, flexibility, safety and productivity of their automation applications. We accomplish this through continuous improvement of existing products, product customization and new product innovation.

Our engineering-centric staff focuses on providing customer solutions to robotic, automation and sensing applications.

## Our Quality Policy

ATI Industrial Automation strives to provide customer satisfaction through continual improvement of on-time delivery, quality and reliability, and a constant focus on innovation and profitability.



*Engineered Products for Robotic Productivity*

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