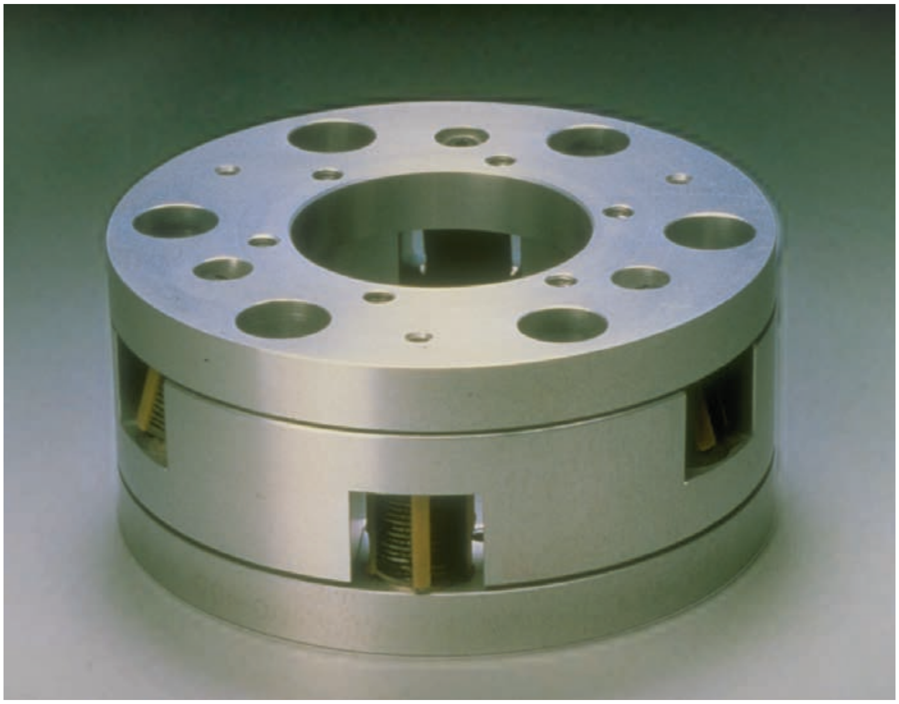
REMOTE CENTER COMPLIANCE APPLICATION MANUAL



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INTRODUCTION

Today's robots are faster and much more accurate than manual labor. What they don't offer is the flexibility to compensate for real world inaccuracies such as feeding misalignment, part tolerances and robot specifications. The inevitable variations in component dimensioning or performance can create difficult assembly problems. As a result many attempts to implement robot systems have been unsuccessful or have become very costly as significant time and money is sent over designing an assembly system with expensive fixturing.

The PFA Accommodator Remote Center Compliance Device is a unique product which passively compensates for misalignment between parts during automated assembly operations. The Remote Center Compliance (RCC) compensates for lateral, out of square, and torsional misalignment while simultaneously minimizing assembly forces to prevent jamming. This reduces damage to materials during the assembly process .

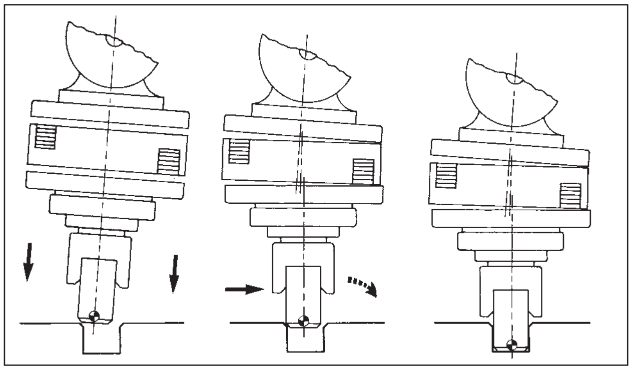


Figure 1
Represents the lateral and rotational motion required of the RCC to accomplish the insertion.

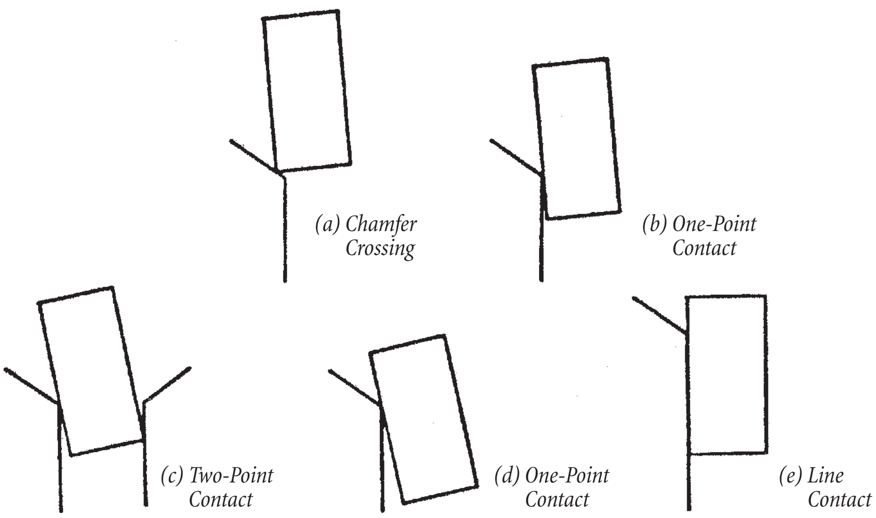
THE CHAMFER INSERTION PROCESS

The traditional peg in hole insertion operation, found in many assembly processes is inherently difficult with a rigid robot system. The generic peg in hole assembly task can be expanded to incorporate such real world applications as gear assembly, placing threaded or unthreaded plugs onto a housing, single or multiple pin insertion, force fits, fastener installation, grinding applications or drilling operations.

The basic peg in hole assembly is graphically shown below, (Figure 2). The performance of the RCC depends upon the existence of a chamfer on either or both of the mating surfaces to initially locate the two parts respective to each other.

The first phase of the assembly process involves initial point contact between the peg and the chamfer on the hole. At this point the RCC allows a slight rotation or tilting of the peg around the center of compliance point . A second plane of rotation allows the RCC and/or peg to translate laterally. This sliding motion allows the chamfer to locate the pegs respective to the hole. A force applied at the end of the peg by the robot or assembly machine then creates a lateral motion without rotation. This allows the peg to be inserted into the hole .

Figure 2
Assembly Phases

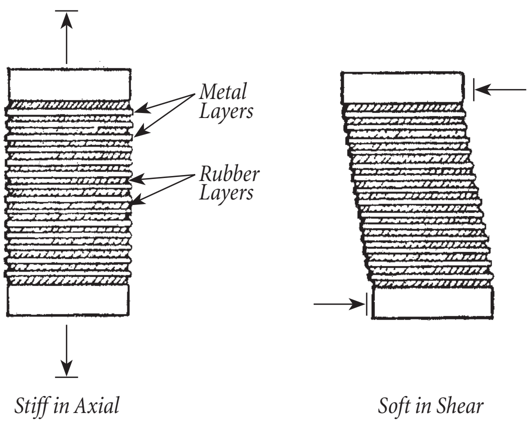


DEFINITIONS

CENTER OF COMPLIANCE - A defined point in space at the assembly interface. About this point, contact forces and torques generated by mating parts produce rotational and translational movements to accomplish the assembly operation.

ELASTOMERIC ELEMENTS, (SHEAR PADS) - A spring like component comprised of alternating layers of metal and rubber provide a structure relatively stiff in the vertical axis yet soft in shear (see Figure 3).

Figure 3
Shear Pads Consist of Alternating Layers of Metal and Rubber



HOW THE RCC WORKS

The PFA Accommodator RCC is mounted between the robot or automatic assembly machine and the gripper, (see Figure 4).

The PFA RCC uses 6 elastomeric shear pads. The positioning of the shear pads project a predetermined center of compliance remote from the tooling plate of the RCC. (see Figure 5)

Rotational and translational motion occurs around the center of compliance point. This allows the part being inserted to translate laterally. As the part translates laterally, the assembly forces on the mating parts are reduced allowing the insertion to be accomplished without jamming (see Figure 6). The compliance reduces the load required to complete the insertion. As load requirements are reduced wear on the assembly equipment is reduced, minimizing downtime, reducing scrap and eliminating the need for expensive fixturing.

Stop Pins are used as mechanical stops which protect the RCC against overload conditions in all directions, (see Figure 7).

In applications such as drilling or nutrunning, an anti-rotation option is also available which uses torque legs to transmit torque to the RCC without allowing the shear pads to absorb the torque.

Figure 4

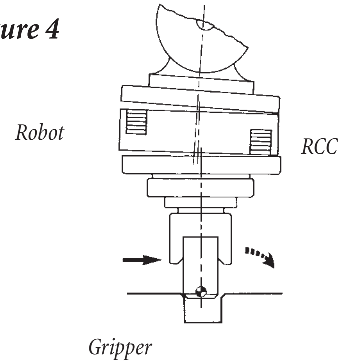
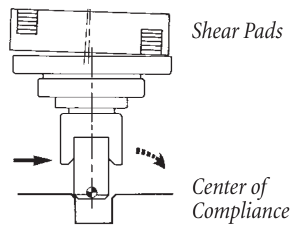


Figure 5



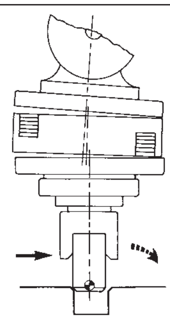
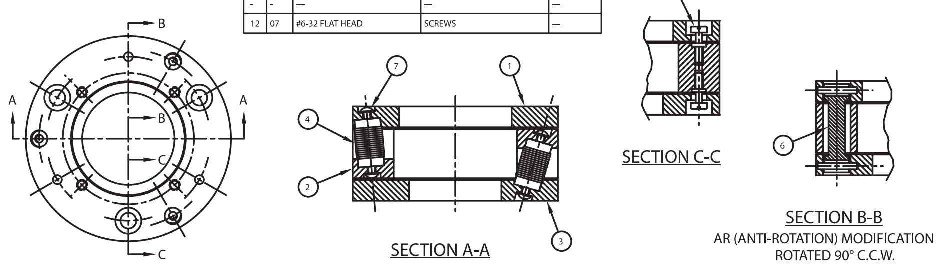


Figure 6
How it Works
Forces generated by mating parts cause elastomeric pads to deflect in shear. This allows parts to translate and/or rotate, removing misalignment. Rotation is about a point remote from the unit, called the center-of-compliance.

ASP-85-75

-56	ITEM	PART NO.	DESCRIPTION	REF. NO.
1	01	---	TOP PLATE	JP00120A
1	02	---	MIDDLE PLATE	JP00110A
1	03	---	BOTTOM PLATE	JP00100A
6	04	M030, CR35, CR45, CR55	SHEAR PAD	---
6	05	---	STOP PIN	RS00700A
-	-	---	---	---
12	07	#6-32 FLAT HEAD	SCREWS	---



WHEN TO SPECIFY AN RCC

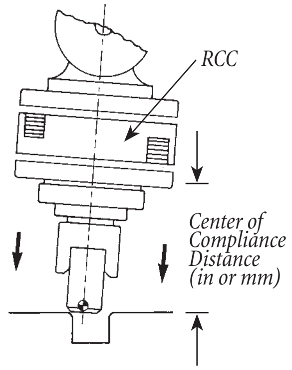
The following guidelines will determine whether an RCC is appropriate for an application.

1. Chamfer Size (unit=inches): The size of the chamfer on either or both of the mating surfaces is used to determine the maximum allowable offset for the assembly operation. Chamfer contact is required to begin part mating. The chamfer size must be larger than the expected lateral offset so that part mating may begin.

2. Clearance/Fit Tolerance (unit=inches): The clearance between the mating parts is an important parameter in determining assembly forces and the maximum allowable 4 offset. If the fit between parts is extremely tight, (0.0005" or less), a softer pad such as the CR35 will minimize assembly forces. Other considerations such as the strength of the insertion part's material, and whether the parts will distort or the surface finish will be marred due to contact forces, will have an impact upon shear pad choice. Particularly soft parts such as bronze or aluminum may require a softer shear pad while stronger insertion parts such as steel should be compatible with the stiffness of the more rigid CR55 pads.

3. Center of Compliance (unit=inches): The center of compliance is measured as the distance from the leading edge of the RCC to the leading edge of the part being inserted/assembled. This distance includes the required gripper and part dimensions, (see Figure 9). It should be placed at the leading edge of the part being assembled, at that point where contact first occurs, so as to minimize any moments generated by contact forces.

Figure 9



4. Payload (unit=pounds): Payload is the combined weight suspended on the RCC including the gripper/tool and part. RCC devices can be used in a vertical or horizontal orientation under specific loading conditions. Payload is used as a factor to determine the shear pad type required. Vertically, a standard RCC with CR35 shear pads is capable of carrying a maximum payload of approximately 25 lbs. Using the stiffer CR55 elastomer pad the maximum payload is 60 lbs. Actual payload capacity depends upon the center of gravity of the payload and accelerations. Horizontally, the maximum payloads for CR35 and CR55 shear pads are 3 lbs. and 8 lbs. respectively. There are three standard elastomer types available in four different stiffnesses. The stiffness data is discussed in more detail in the· section on shear pad specification.

5. Environment: The RCC incorporates a rugged design suitable for most manufacturing environments. No lubrication is required and operating cycles from 3-6 million can be expected. Three standard elastomer materials are available and their properties are listed below in Figure10. Neoprene is the most commonly used pad material. Standard pads are sufficient for most applications. The use of severe cutting fluids may in some cases, degrade the elastomer elements. Special coatings can be applied to protect the elastomer, eliminating the need for sleeves or boots.

Figure 10
ELASTOMER SELECTION

Properties	*CR Neoprene*	*NR Natural Rubber*	*MO Silicone*
Operating Temperature (Min.)	*-29°C (-20°F)*	*-40°C (-40°F)*	*-54°C (-65°F)*
Operating Temperature (Max.)	*+82°C (+180°F)*	*+ 82°C (+180°F)*	*+177°C (+350°F)*
Mechanical Properties	*Good*	*Excellent*	*Good*
Oil Resistance	*Good*	*Poor*	*Fair*
Ozone Resistance	*Good*	*Poor*	*Excellent*
Resistance to Heat Aging	*Good*	*Fair*	*Excellent*
Compound Color	*Black*	*Black*	*Red*
Durometer Shore A ±5	*35-Red Stripe 45-Green Stripe 55-Blue stripe*	*30*	*30*

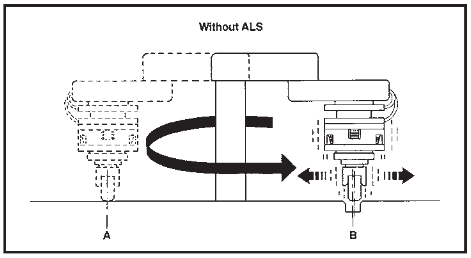
6. Speed & Acceleration: The inertial effects caused by the combination of payload and robot or machine acceleration may result in shock loading and/or vibration. This may be transmitted to the RCC. Due to the compliant nature of an RCC, any load placed on it will cause a deflection to occur. If the amount of deflection is too great, problems such vibration may require an increase in cycle time to allow the RCC to settle. In addition shear pad damage could result. In some cases this can be minimized by selecting a more rigid elastomer pad.

The maximum "dynamic" deflection which can typically be allowed for is 0.050" (1.3mm) laterally. (Note that full lateral travel for all standard PFA RCC's is 0.100" (2.5mm). For further information see the section on "Determining the appropriate elastomeric shear pad"

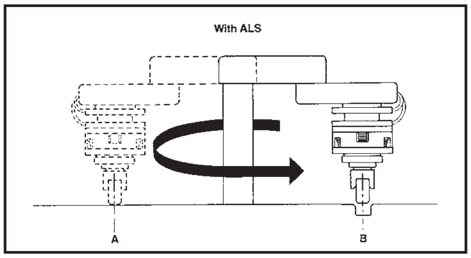
For cases of severe vibration or acceleration, an optional PFA Lock out system, (ALS), is available, (illustrated in Figure11 & #12). The pneumatically activated device, mounted directly to the RCC, locks and unlocks the RCC into a rigid or compliant mode on command.

Upon air actuation the Lock Out device neutralizes the RCC permitting rapid acceleration/deceleration and the handling of particularly heavy payloads while eliminating the effects of inertia. Just prior to the critical assembly process the Lock out device can be programed to unlock the RCC to allow for additional compliance during the insertion operation.

Figure 11



Without Lock Out System
Effects of inertia cause residual oscillation.
The net result is a slower cycle time.



With the Lock Out System
ALS System rigidly locks the RCC and tooling in place during acceleration, transport and deceleration. The net result is a faster cycle time.

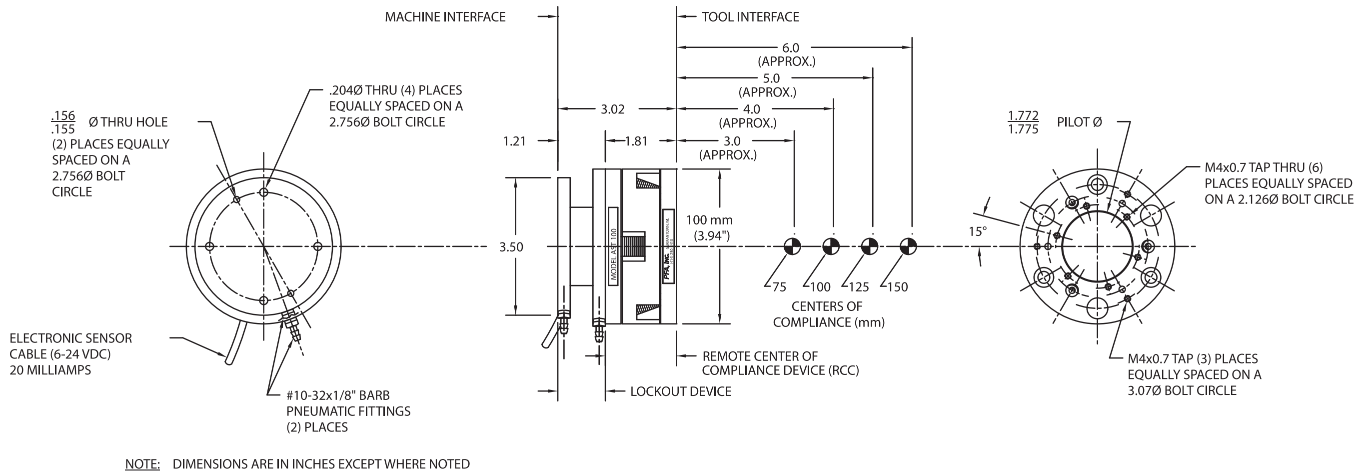


Figure 12

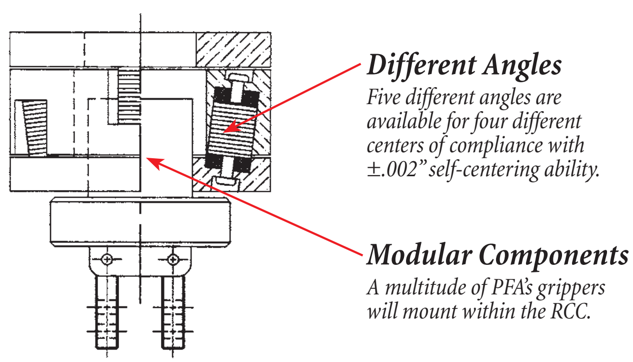
A mechanical outline of the ALS Lock Out System.

Insertion direction: In a typical insertion operation, the axial centerline of the part being inserted must be oriented in the same direction as the centerline of the RCC. If the insertion direction is perpendicular to the floor then it is an ideal application for the RCC. If the insertion direction is horizontal and the centerline is parallel to the floor, the accuracy of the RCC may be effected as the payload causes the compliant RCC to droop or sag. In these applications a stiffer pad such as the CR55 is recommended.

PFA manufacturers a line of parallel and angular jaw grippers designed to mount internal to the RCC body. This design (see example pictured below) yields an extremely compact overall design. More information is available by contacting PFA.

Figure 13

Unique design allows for mounting of PFA Grippers within the Accommodator.



HOW TO SELECT THE APPROPRIATE MODEL RCC

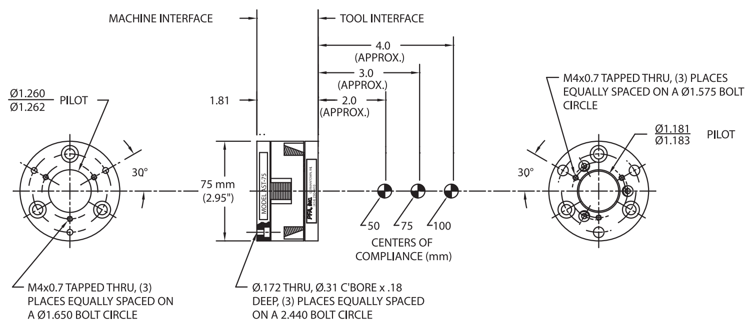
Three standard RCC models are available. The model numbers, which designate the diameter of the unit, are the AST-75, ASP-85, and the AST-100. The AST-75, for example, has a diameter of 75mm.

The center of compliance as defined on page 3 is the point about which contact forces and torques generated by mating parts produce translational and rotational movements to accomplish the assembly operation. It is measured from the tooling side of the RCC to the leading edge of the mating part. The angle at which the shear pads are mounted in the RCC and the diameter of the RCC determine the centers of compliance offered by the RCC. The required center of compliance for an application is needed to determine which RCC model is appropriate.

The AST-75 offers a center of compliance 50mm, 75mm, and l00mm from the RCC tooling plate. The ASP-85 offers a center of compliance 75mm, l00mm, and 125mm from the RCC tooling plate. The AST-100 offers a center of compliance 75mm, l00mm, 125mm, and 150mm from the RCC tooling plate. (See pages 10-11)

Upon determining the center of compliance for a particular application, choose an RCC model which will accommodate that center of compliance. For example, if the distance from the RCC tooling plate to the mating end of the part is less than or equal to 50mm, the AST-75 is the only model small enough to offer such a small center of compliance. If the application requires a l00mm center of compliance, all the standard models can accommodate this. Work envelope limitations then become the determining factor. For example, if the work envelope is crowded, the smaller diameter AST-75, with a l00mm center of compliance may be easier to design into the system than the AST-100.

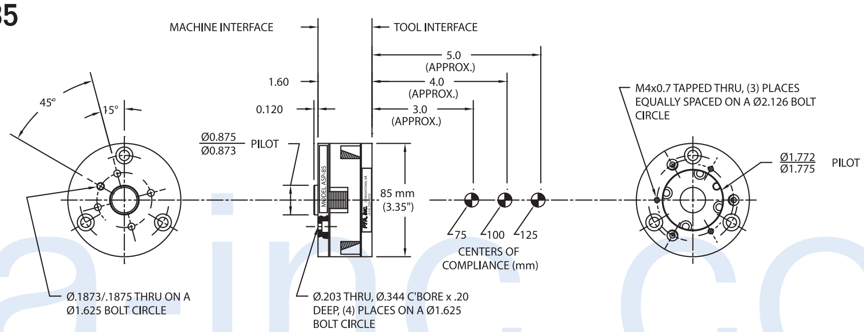
MODEL AST-75



NOTE: DIMENSIONS ARE IN INCHES EXCEPT WHERE NOTED

Model		Center-of-Compliance Projection mm (in)	SHEAR PAD TYPE MO-30	CR-35	CR-45	CR-55
MODEL AST-75	Lateral stiffness N/mm (lb/in)	50 (2.0) 75 (3.0) 100 (3.9)	12.3 (70) 12.3 (70) 10.5 (60)	21.1 (120) 21.1 (120) 18.0 (103)	34.7 (197) 34.7 (197) 29.6 (169)	49.2 (280) 49.2 (280) 42.0 (240)
	Rotational stiffness N-mm/mrad	50 (2.0) 75 (3.0) 100 (3.9)	49 (436) 90 (797) 169 (1500)	84 (749) 155 (1370) 290 (2580)	139 (1230) 254 (2250) 477 (4230)	197 (1740) 360 (3190) 676 (6000)
	Axial stiffness N/mm (lb/in)		705 (4020)	1210 (6910)	1990 (11340)	2820 (16080)
	Torsional stiffness N-mm/mrac in-lb/rad)		4.5 (40)	7.7 (68)	12.7 (112)	18.0 (159)
	Axial load (max usable) N (lb)		1200 (275)	2000 (450)	3400 (775)	4900 (1100)
		Weight 0.40 kg (0.87 lb) Lateral travel ±2.5 mm (0.100 in) Rotational travel ±17 mrad (1.0 deg) Self-centering repeatability ±0.05 (0.002) Structure material is anodized aluminum				
MODEL ASP-85	Lateral stiffness N/mm (lb/in)	75 (3.0) 100 (3.9) 125 (4.9)	12.2 (70) 13.6 (78) 10.5 (60)	21.1 (120) 23.4 (134) 18.0 (103)	34.4 (197) 38.4 (220) 29.6 (169)	48.8 (280) 54.4 (312) 42.0 (240)
	Rotational stiffness N-mm/mrad	75 (3.0) 100 (3.9) 125 (4.9)	86 (766) 130 (1140) 233 (2060)	148 (1320) 223 (1960) 400 (3540)	243 (2160) 367 (3220) 657 (5810)	344 (3060) 520 (4560) 932 (8240)
	Axial stiffness N/mm (lb/in)		720 (4080)	1240 (7020)	2030 (11500)	2880 (16300)
	Torsional stiffness N-mm/mrac in-lb/rad)		5.8 (55)	9.9 (94)	16.3 (154)	23.1 (218)
	Axial load (max usable) N (lb)		1600 (350)	2700 (600)	4400 (1000)	6400 (1400)
		Weight 0.40 kg (0.81 lb) Lateral travel ±2.5 mm (0.100 in) Rotational travel ±17 mrad (1.0 deg) Self-centering repeatability ±0.05 (0.002) Structure material is anodized aluminum				

MODEL ASP-85



NOTE: DIMENSIONS ARE IN INCHES EXCEPT WHERE NOTED

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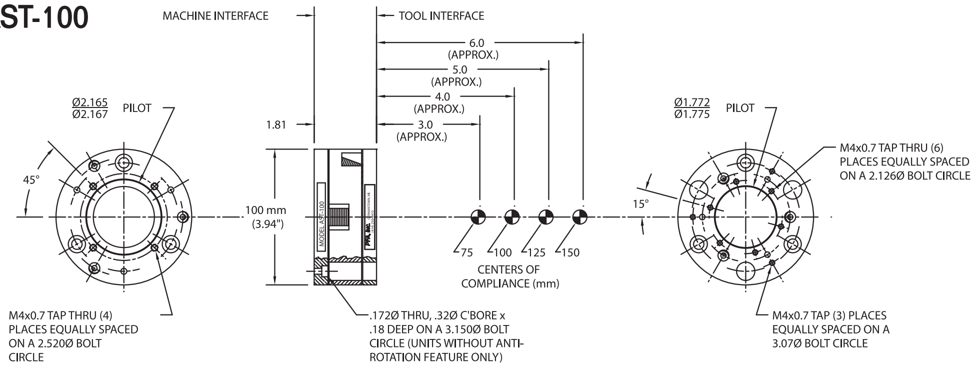
MODEL AST-100



NOTE: DIMENSIONS ARE IN INCHES EXCEPT WHERE NOTED

MODEL AST-100		Center-of-Compliance Projection mm (in)	SHEAR PAD TYPE MO-30	CR-35	CR-45	CR-55
	Lateral stiffness N/mm (lb/in)	75 (3.0) 100 (3.9) 125 (4.9) 150 (5.9)	14.9 (85) 14.9 (85) 16.9 (97) 10.5 (60)	25.6 (147) 25.6 (147) 29.0 (166) 18.0 (103)	42.0 (241) 42.0 (241) 47.7 (272) 29.6 (169)	59.6 (341) 59.6 (341) 67.6 (386) 42.0 (240)
	Rotational stiffness N-mm/mrad	75 (3.0) 100 (3.9) 125 (4.9) 150 (5.9)	81 (720) 128 (1130) 175 (1550) 338 (2990)	140 (1240) 220 (1940) 301 (2660) 581 (5140)	230 (2030) 361 (3190) 494 (4370) 953 (8430)	326 (2880) 512 (4220) 700 (6200) 1350 (11960)
	Axial stiffness N/mm (lb/in)		670 (3800)	1140 (6530)	1800 (10720)	2660 (15200)
	Torsional stiffness N-mm/mrac in-lb/rad)		8.8 (78)	15.2 (135)	25.0 (221)	35.4 (313)
	Axial load (max usable) N (lb)		2200 (500)	3700 (850)	6200 (1400)	8800 (2000)
		Weight 0.60 kg (1.30 lb) Lateral travel ±2.5 mm (0.100 in) Rotational travel ±17 mrad (1.0 deg) Self-centering repeatability ±0.05 (0.002) Structure material is anodized aluminum				

NOTE: DIMENSIONS ARE IN INCHES EXCEPT WHERE NOTED.

IDENTIFY YOUR PART NUMBER

Model Identification	Unit Diameter (mm)	Center-of-Compliance Projection (mm)	Shear Pad Selection	Anti-Rotation Feature (optional)
		50, 75, 100, 125, 150	*MO30, CR35, CR45, CR55*	*Model AST-100 & ASP-85 Only*
AST -	100 -	75 -	CR35 -	AR

Example Part No: **AST-75-75-CR35**

Model Identification (optional)	Unit Diameter (mm)	
		MB = Machine Blank *TB = Tooling Blank*
AST -	100 -	MB

Example Part No: **AST-100-MB**

DETERMINING THE APPROPRIATE ELASTOMERIC SHEAR PAD

When attempting to determine the appropriate shear pad to us for a specific application the lateral, rotational, axial and torsional stiffness; and the axial load and the center of compliance need to be taken into consideration. Figure 15, on page 16 lists the properties of the available shear pads .

How to use the chart: First identify the model of the RCC to be used, AST-75, ASP-85 or AST-100. The page is divided into three sections, one for each model of the RCC product line. The RCC model numbers are based on the diameter of the particular RCC. For example the AST-75 has a diameter of 75mm. Once you have located the correct chart, note that each elastomer pad is listed across the to row of the chart . The first column lists the various specifications which determine the appropriate shear pad for a particular application, such as the lateral, rotational, and axial stiffness.

Example: Pad MO30 on the AST-75 model RCC has a axial stiffness of:

705 N/MM (4020 lb./in.)

Note that for lateral and rotational stiffness a center of compliance projection must be identified.

Determining the ideal stiffness value for a specific application: The lateral and axial stiffness values for a particular application in conjunction with the predetermined center of compliance distance will determine the appropriate shear pad for the application. The optimum stiffness values for an RCC application can be determined by identifying the expected deflection of a given load and the force exerted on the RCC.

The following variables must be known to determine the amount of force exerted on the RCC in any single direction

m= Mass (payload) in kg(lbs/32)
a= Acceleration of the robot or machine in m/sec2, (ft/sec2)

These variables can be used in the following formula to determine the force exerted on the RCC.

F= ma

Once the force is determined it can be used with the predetermined amount of deflection to determine the amount of stiffness required of the shear pad. To estimate the amount of deflection the following should be considered.

Figure 16

Maximum Amount of Deflection or Travel for all Standard RCC's

Direction of Motion	Total Travel
±X, ±Y (Lateral)	±2.54 mm (0.100")
-Z (Axial)	±1.78 mm (0.070")
+Z (Tension)	+1.52 mm (0.060")
±T (Torsional)	±3 Degrees

To maximize cycle life, the amount of travel which occurs during robot transport motion, (acceleration/deceleration), should not exceed one half of the total available travel of the unit . To estimate the amount of deflection (D) of a given load use the following formula:

$$D = \frac{\text{Total travel or deflection in a single axis}}{2}$$

Note: During the actual assembly operation full travel can be used.

Upon determining the force exerted upon the RCC and estimating the amount of deflection of a given load, the following equation will determine the application's required stiffness of the shear pads in a given axis.

D= Estimated Deflection in mm (in)
F= Force exerted on RCC N (lb)
K= Required stiffness of shear pads
K= F/D

Upon identifying the amount of stiffness required of the shear pad in the application, simply reference the chart (pages 10-11), to determine the appropriate shear pad for your application.

Note:
- Lateral stiffness is measured at the center of compliance.
- Rotational stiffness is cocking about the center of compliance.
- Axial stiffness is measured in compression and is the maximum compressive force.
- Torsional stiffness is about the centerline of the RCC.

The ASP-85 offers a more flexibility in the lateral direction than the AST-100. The shear pads in the ASP-85 are mounted more closely together than the AST-100 pads and therefore do not have to be angled as much to achieve the same center of compliance. The pads are stiffer laterally as the angle is increased. Therefore, the ASP, with the pads mounted in a more vertical orientation, offers more lateral flexibility than the AST-100 at the same center of compliance.

To determine whether the RCC is appropriate for a given application or accurately select the appropriate RCC for a particular application, the following information is required:

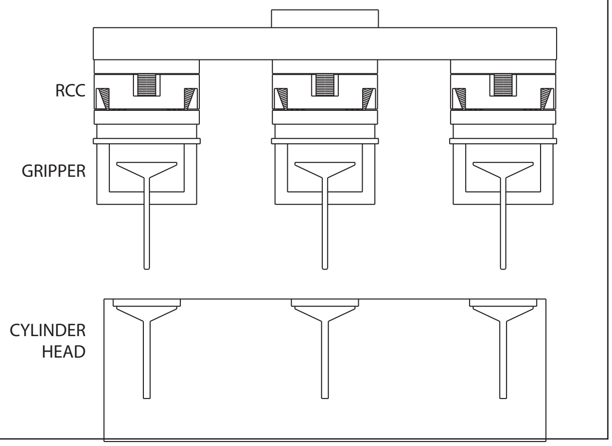
Relating to robot assembly equipment:	Repeatability Acceleration Tooling Mounting Pattern
Relating to the parts to be assembled:	Weight and location of the center of gravity Overall chamfer & tolerance dimensions Clearance between the mating parts
Environment:	Temperature Oil or Other Contaminants Clean Room Atmosphere

APPLICATION EXAMPLES

APPLICATION 1: ASSEMBLY OPERATION

A major automotive manufacturer requires the assembly of three valves simultaneously, (three exhaust and three intake), into an aluminum engine head for a V-6 engine assembly line. This application is impossible without some sort of compliance device because the maximum inaccuracy possible exceeds the total valve clearance available. The RCC enables the operation to take advantage of a chamfer of ±0.025". In order to determine whether the chamfer size is sufficient for the RCC to accomplish the insertion a tolerance study is required.

Figure 17



Tolerance Study:

1. Shot pins position the engine head to within ±0.002"	±0.002"
2. The robot which retrieves the valves from a nest and inserts them into the engine head has a repeatability of…	±0.008"
3. The tooling integrated has a repeatability of ±0.002".	±0.002"
4. The location of the valve holes are within ±0.005".	±0.005"
Total Possible Inaccuracy	**±0.017"**

1. The valve has a chamfer of ±0.025" and a chamfer is not present on the valve guides within the engine head.	±0.025"
2. Total clearance between the valve and the valve guide is ±0.0015".	±0.015"
Total Available Clearance or Allowable Mismatch is	**±0.265"**

If the Maximum possible inaccuracy exceeds the total allowable mismatch then the RCC will not complete the insertion, since two flat surfaces will contact.

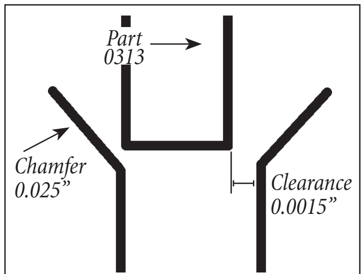


Figure 18

If the following equation true the RCC will be able to complete the insertion:

$$\text{Total Allowable Mismatch} \geq \text{Maximum Possible Inaccuracy}$$
$$\pm 0.0265 \geq \pm 0.017"$$

Because the total allowable mismatch is greater than the maximum possible inaccuracy, the RCC will be able to complete the insertion.

According to the specification charts, to accommodate a center of compliance of over 4" a 100mm Diameter RCC should be used.

To determine the appropriate shear pad for the application the equations in section on determining shear pads should be applied as follows:

Given:	Payload:	1 lb.
	Acceleration:	3 ft/sec2
	Center of Compliance:	125mm (4.9")

Force = 1 lb. / 32 x 3 ft/sec2 = .00916
Deflection = .050" (From Figure 15)

Optimum Stiffness in the lateral direction (K) is:
K = F/D .009/.050" = 1.88 lbs/in

A lateral stiffness requirement of only 1.88 lb/in does not require a particularly stiff shear pad, and because the payload is held vertical to the RCC minimizing the amount of force on the shear pad, any of the softer shear pads will work with the application.

This particular application has a very light payload and slow operating speed. As a result it does not require a stiff shear pad to maintain the payload or absorb inertia. The presence of oil in the environment indicates the use of an oil resistant neoprene pad such as the CR35. The model number indicates the durometer reading on the shore A scale. Neoprene is an all purpose polymer with a low compression set and high resilience. It is generally not affected by moderate chemicals and oils or solvents.

APPLICATION 2: NUTRUNNER APPLICATION

A manufacturer of automotive components is automating a molding process . A system is required to automatically tighten and loosen a series of 3/4" nuts on a .production mold using an air powered nutrunner.

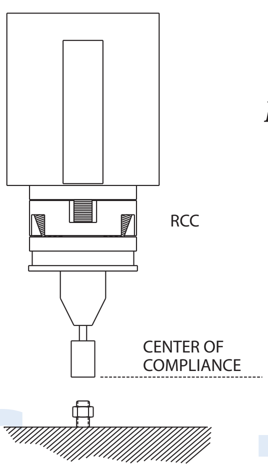


Figure 19

A Tolerance Study, (reference Application #1), indicates that the application, with a clearance of only 0.015", cannot be consistently completed without compliance. Because the RCC can take advantage of the 0.125" chamfer, the application can be successfully completed with the implementation of an RCC.

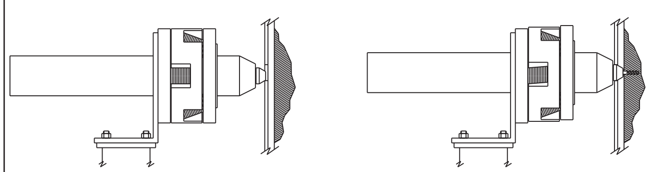
A stiffness analysis determined that even a softer shear· pad would provide the necessary lateral stiffness However, because of abrupt stops by the tooling during operation, and the very high center of gravity of the tooling, stiffer CR55 pads would be more effective.

A stiffness analysis on the torsional axis determined that a very large torsional stiffness factor is required in this application.

APPLICATION 3: DRILLING OPERATION

A manufacturer of metal computer cabinets automates a drilling operation. Holes of various sizes are drilled into the workpiece by use of a template. The RCC assists insertion of the self feed drill into the template holes.

Figure 20



A tolerance study, (reference application # 1) indicates that with a clearance of only 0.002" the operation cannot be successfully automated without some sort of compliance device or very expensive fixturing. Implementation of the RCC allows the application to take advantage of a chamfer of 0.09011 to allow the application to be completed successfully.

The drill is mounted through the center of the RCC . A center of compliance at the tip of the drill nosepiece is approximately 125mm, (4.9") from the RCC therefore an AST-100 RCC with a diameter of l00mm is required.

Although the operation is not transporting the tooling from one point to another at a high rate of speed, a particularly heavy payload of 10 lbs places significant stress on the shear pads. In addition, because the tooling is held horizontal to the RCC, additional forces are placed upon the pads increasing the need for a stiff shear pad. As a result the CR55 shear pads are designated.

Given:	Torque:	230 in-lbs
	Max Travel:	3 degrees (ref Figure 15)
	57.3 Radians:	1 degree

Use the following equation to determine the K or stiffness required to accommodate the torque:

$$\frac{\text{Torque}}{(\text{Max Travel}/2)\ /\ 57.3\ \text{Rads}} \quad \frac{230\ \text{in-lbs}\ /\ (3/2)}{57.3\ \text{Rad}} = 8779.63$$

8779.63 in-lbs/rad

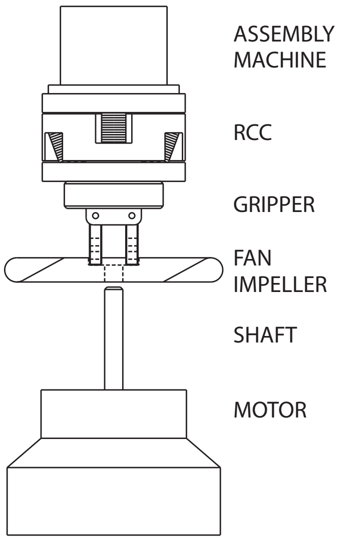
Note: Travel should only be 1/2 of the available travel in any single axis .

The maximum amount of stiffness offered by any of the shear pads is 113 in-lbs/rad. Therefore, none of the shear pads available can withstand the torque transmitted from the nutrunner. In order to eliminate the torque on the shear pads an optional antirotation device is available. Three anti-rotation pins or torque legs, mounted in the RCC virtually eliminate torsional force before damage to the pads occur. The pins are mounted in a slot so that lateral motion is still possible. The maximum recommended torque to be transmitted using torque legs is 300 in-lbs

The center of compliance is determined to be 125mm(4.9") thus an AST-100 or ASP-85 Model is appropriate. The nutrunner, with a diameter of 50mm is to mounted through the center of the RCC, (reference Figure19), therefore· for proper clearance, the AST-100 is chosen.

APPLICATION 4: FAN ASSEMBLY OPERATION

Figure 21



In this application a fan impeller is mounted onto a motor shaft. As the fan material is very light weight stamped out sheet aluminum, very little force could be used during the insertion process.

Tolerance studies indicated that with a clearance of only 0.001", the operation ·could not be completed without compliance or some very expensive fixturing. A threaded chamfer of only .05"- 0.030" could be used with an RCC to successfully insert the impeller onto the shaft.

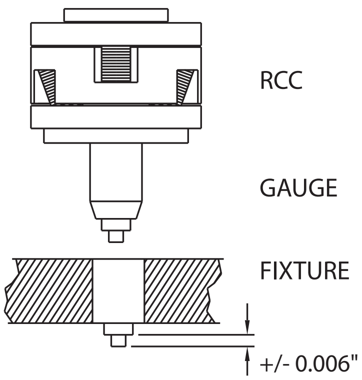
Fabricated of 0.02011 aluminum sheet stock the thin metal impeller could not withstand significant forces against the material during the insertion. Product specifications prohibit any increase in the diameter of the hole during the assembly process. As a result very soft, flexible NR30 shear pads are required to provide enough compliance to complete the insertion without producing excessive forces on the impeller surface. The RCC with NR30 pads allow £or the mounting of the impeller onto the shaft with a mismatch of up to ±0.025", without any unacceptable degradation of the inner diameter of the impeller hole.

The tooling configuration dictated a center of compliance of 75mm, (3.0"), therefore even the smallest model RCC would be adequate. The AST-75-75-NRJ O was chosen because the DAG-30 double acting gripper used in the operation could mount easilf inside the RCC minimizing space requirements within the work envelope.

APPLICATION 5: TESTING & GUAGING

In this application the RCC is successfully integrated into a high tolerance guaging operation. The operation is testing a solenoid component for error. The RCC was configured to insert the component into the testing device, (See Figure22). Testing procedure required that the guaging tool be located on the bottom of the bore of the solenoid to accomplish guaging, to within =/-0.0006".

Figure 22



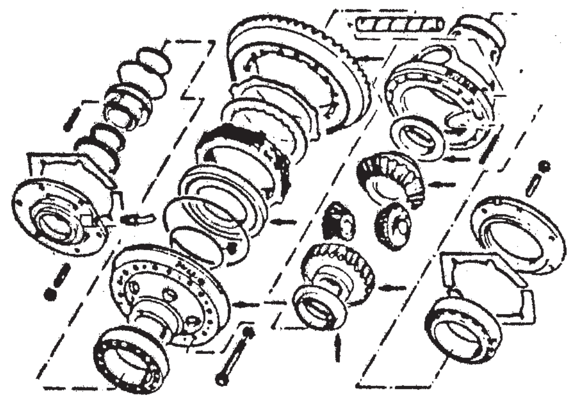
In this application the total available clearance was 0.001". This, along with the need to measure a part to within +/- 0.0006" made it impossible to automate without very expensive fixturing or some sort of compliance . The RCC is able to take advantage of a chamfer on the solenoid of 0.005", and the chamfer on the guaging tool of 0.125". The compliant nature of the RCC and the use of very soft, NR30 shear pads allows the part to be inserted without exerting significant forces on the part. This eliminates the possibility of damage to the part.

A Center of Compliance of 75mm (3.0") allows for the use of any of the RCC models. The AST-100 was chosen because the testing probe could be easily mounted inside the RCC, minimizing space requirements of the end of arm tooling.

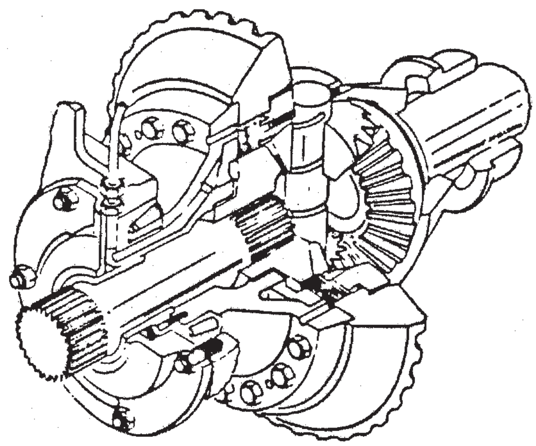
APPLICATION 6: ROBOTIC ASSEMBLY OPERATION

In this robotic assembly application several components, in a variety of sizes were assembled by a single robot work cell. The parts, to assemble a tractor differential, included half shaft gears, thrust beatings, crownears, a clutch retainer and a carrier. The parts range in size from approximately 4 to 12 inches in diameter and weigh from 3 to 25 lbs.

Figure 23



Exploded view indicating parts for which accommodator is used



Cutaway of assembled differential

The size of the parts and tooling require a 12 inch center of compliance. As the maximum center of compliance distance available in the standard RCC is 6 inches, a special unit was designed which offered a 12 inch center of compliance. Because the parts varied in size a special three fingered flexible gripper was designed. The finger placement was programmable to allow the robot to pick up components of different sizes, yet maintain the same center of compliance or distance from the RCC to the mating surface during the assembly process.

Clearance for the various assembly parts range from 0.0002" to 0.001". A tolerance study indicated that the RCC, with the medium stiff CR45 pad could easily accomplish each of the seven assembly operations .

RCC SPECIFICATION WORKSHEET

For additional assistance on choosing the appropriate RCC for your application complete the following questionnaire

1. Size of the chamfers ______________________ in/mm (circle one)
   ______________________ in/mm

2. Maximum misalignment
   Lateral ______________ in/mm
   Rotational ______________ in/mm
   Torsional ______________ in/mm

3. Center of compliance ______________________ in/mm
   (distance from RCC to point of insertion)

4. Environmental considerations (check where applicable)
   - [ ] Cutting fluids
   - [ ] High Temperatures
   - [ ] Lubricants
   - [ ] Other, (Please list) ______________________

5. Payload ______________________ lbs/kg

6. Insertion direction
   - [ ] Vertical
   - [ ] Horizontal

7. Speed/Acceleration ______________ ft/sec2 or m/sec2

8. Material of mating parts ______________________

9. Clearance between mating parts ______________ in/mm

10. Part diameter ______________________ in/mm

Please include diagrams or prints of the parts, tooling and overall process where possible .

CONTACT NAME: ______________________ TITLE: ______________________

COMPANY NAME: ______________________ DIV: ______________________

ADDRESS: ______________________

CITY: ______________________ STATE: ______________ ZIP: ______________

PHONE: ______________________

If you have any questions or need technical assistance, please call our support staff at (262) 250-4410.
Our normal office hours are from 8am to 4:30pm CST Monday – Friday.