H. Application Notes

This appendix contains the application notes relevant to operating the TDR instrument and the TR3190.

They include:

AN2: TR3190 Digital, Linear/Rotary Motion Transducer

The TR3190 transducer is used to measure the position and velocity of the operating mechanism of a circuit breaker.

This transducer consists of a reference disk of known diameter, which is directly coupled to an optical shaft encoder. When the breaker operates, it displaces a rod, and the motion of this rod is transmitted through a high pressure friction drive to the circumference of the reference disk. The angular displacement of the disk is proportional to the linear travel of the rod and is encoded by the optical shaft encoder.

With the addition of the rotary adapter, the rotary motion of a shaft in a circuit breaker can be coupled to the transducer and a measurement of angular displacement and angular velocity is obtainable.

The optical encoder translates the rotation of a shaft into interruptions of a light beam. The light source, a light emitting diode, is collimated by a molded lens into a parallel beam of light. The light beam is interrupted by a code wheel comprised of a metal disk with equally positioned apertures around its periphery.

A matching set of apertures is located in a fixed plate. The light beam is transmitted only when the apertures are aligned, which produces a light pulse for each aperture. A molded lens beneath the base plate collects the modulated light and directs it to a detector.

There are two identical channels. Each channel consists of two photodiodes, an amplifier, a comparator, and output buffers. The apertures for the two photodiodes are positioned so that a light period on one detector corresponds to a dark period on the other. The photodiode signals are amplified and fed to the comparator whose output changes state when the difference of the two currents changes sign. The second channel has a similar configuration, but the location of its aperture pair provides an output that is in quadrature to the first channel (phase difference of 90 °). The direction of rotation is determined by observing which of the two channels is the leading wave form. The number of pulses encodes the angular displacement of the disk. This pulse train is converted to a number that is stored in memory at a regular interval. This interval produces a time reference that is used to plot displacement per unit time or instantaneous velocity. The motion plot is produced by plotting the sum of the displacement data vs. time. The delta displacement for each sample interval represents the total displacement that has occurred during the sample interval. Therefore, this data can be translated directly into velocity, which is then plotted for each time interval.

There are a number of different ways the TR3190 Motion Transducer can be interfaced with a breaker. For applications in which part of the accessible breaker mechanism exhibits linear motion, the following method may be employed:

> The transducer is designed to couple to a 1/4" Mild Steel connecting rod, which must be 0.250" ± 0.010" and free from nicks or burrs. Select a point on the breaker mechanism, as close to the contacts as possible, that exhibits linear motion in one plane. The top of the lift rod on most dead tank oil breakers is provided with a #10 x 24 threaded hole for this application. This threaded hole is typically accessible through a small hole located under the cap for the stop adjustment on the center tank. If this attachment point is not provided, it is still possible to attach a rod to other

points on the breaker. For instance, it is often possible to access the lift rod in the cabinet of the breaker. A collar could be fabricated that attaches around the lift rod and provides a place to attach the 1/4" connecting rod. The transducer connecting rod will accommodate 15° of angular displacement. This displacement must be in a plane parallel with the front surface of the transducer. The degree of freedom can be ascertained by placing the rod in the transducer, closing the latch, and then moving the rod back and forth. Observe the motion of the pressure rollers. By using this feature, it is possible to attach the transducer to a point that moves in more than one plane as the breaker operates. In many breaker mechanisms, there are bell cranks that transmit the motion of the prime mover to the contacts. Using a suitable flexible coupling for attaching the connecting rod to a bell crank provides a good representation of contact motion.

Once the attachment point for the connecting rod has been determined, the next step is to provide a suitable mount for the transducer. This mount should be rigid and hold the transducer perpendicular to the line of motion of the connecting rod. In many oil breakers, the cap that covers the access hole is a pipe cap approximately 2" in diameter. Determine the pipe size of the cap. Obtain a pipe coupling, short pipe nipple, and a floor flange to assemble a simple but reliable and rugged circuit breaker mounting adapter. The pipe-coupling, short-nipple, floor-flange assembly is screwed on in place of the cap. After this adapter is screwed on to the breaker, the connecting rod is then installed and the transducer is clamped to the floor flange with *C*-clamps. If this approach is not possible, other fasteners on the breaker can be used, or suitable fixtures can be fabricated that clamp to the structure of the breaker. Remember that the data generated by the transducer is distorted by any motion of the mounting setup during circuit breaker operation.

There are several features of the transducer that are used to alleviate difficult mounting problems. The base plate of the transducer is detached by removing the four flat-head screws visible on the bottom of the device. Other mounting plates can be fabricated to meet special needs, or the transducer can be used without the mounting plate. There are threaded holes on the bottom and front surface of the transducer that are used to secure the transducer to special mounting fixtures. When using this method, take care to ensure the screws that are used are of correct length; screws that are longer than necessary may damage the internal mechanism of the transducer. The transducer can be mounted with either its top or bottom facing the breaker. Avoid applying clamping forces to the housing of the transducer, as it is possible to distort the housing and cause loss of accuracy.

The rotary motion adapter is used to interface to circuit breakers in which the mechanism moves in a rotary manner, or to couple to a part of a breaker mechanism that moves in an arc. If a breaker exhibits rotary motion, observe the mechanism and identify the shaft to be monitored. The rotary motion adapter of the transducer must be attached to the end of this shaft. The adapter is provided with a drill chuck which accommodates up to a 3/8" diameter shaft. The shaft in the breaker can be provided with a threaded hole for a suitable adapter. If this is not the case, an adapter with a 3/8" extension for the chuck collar can be fabricated. This collar slips over the end of the shaft and is retained by a set screw. If this is not possible, the chuck is removed from the rotary motion adapter and other fixtures are installed in its place.

The transducer supports itself on the end of the rotary motion shaft; however, a means of preventing rotation of the transducer during circuit breaker operation must be provided. To do this, a length of 2" x 2" angle is clamped to the transducer and to a suitable part of the circuit breaker structure. Care should be used to minimize the free motion in this setup, as it causes errors in the recorded data. The base plate of the transducer is removed to provide more clearance. When this is done, the angle stock is screwed to the transducer using the base plate mounting holes.

A sensing switch on the transducer determines whether a rotary adapter is in use before the test begins. The software then checks to ensure that the test plan motion channels are properly configured. The actual units in use for the test results are dictated by the entries into the test plan.

If a breaker has no location where there is a rotating shaft, or no point where a linear motion can be monitored, there could be a location where there is a component that moves through an arc. In this case, a small rod (approximately 1/4") is attached to the breaker mechanism with a swivel joint and to a similar length crank arm mounted in the chuck of the Rotary adapter. In this way, the rotation of this shaft is translated and measured.

Some points to consider when designing mounting fixtures for the transducer:

- The fixture should be as rigid as possible, as any motion between the fixture and the breaker appears as an error in the results. This is particularly noticeable if the fixture shakes when the breaker strikes the stop at the end of its travel. This creates the appearance of faulty damping when none exists.
- Be careful in the design of fixtures and devices applied to the moving parts of the breaker mechanism to ensure no interference occurs when the breaker operates.
- Large forces are generated when a breaker is operated; do not stand in line with the motion of the connecting rod or allow loose parts near the transducer.

Specifications

The TR3190 Motion Transducer is designed for interfacing to circuit breakers measuring the motion and velocity of the operating mechanism and particularly the movement of the contacts. Table H.1 lists its specifications. In this table, “g” refers to gravities.

Table H.1 TR3190 Specifications

Specification		Values
Range of measurement	Linear motion	0.0" - 40.0"
	Rotary motion	0.00° - 2880°
Velocity	Linear motion	50.0 ft/s (maximum)
	Rotary motion	120 rev/s (maximum) 43200°/s (maximum)
Acceleration	Linear	100 g 400 g for 50 µs
	Rotary	125,000 rad./s^2 7.162 x 106 °/s^2
Displacement	Accuracy	± 0.1% of measured value or ± 0.1" (whichever is smaller) ± 0.1% of measured value or ± 0.1° (whichever is smaller)
	Resolution/Linear	0.002"
	Resolution/Angular	0.1°

Table H.1 TR3190 Specifications (Continued)

Specification		Values
Environmental	Temperature/Storage	– 55 °C to 70 °C
	Temperature/Operating	– 40 °C to 50 °C
	Acceleration and Vibration/Transporting	ASTM D 999-75 (repetitive shock test)
	Acceleration and Vibration/Operating	Vibration 20 m/s^2, sinusoidal; 5 to 500 Hz Shock 200 m/s^2
	Humidity	95% noncondensing atmosphere
	Contaminates/Transformer Oil	Accuracy is unaffected by oil adhering to the connecting rod
	Contaminates/Soil	Accuracy is unaffected by dirt adhering to the connecting rod
Mechanical	Dimensions	Transducer App. 4.0" x 6.0" x 4.0" See Doble drawing # 76D-0195
	Mounting	Clamping plate 6.0" x 10.0" See Doble drawing # 2FC-1905
	Breaker Interface/Linear	Standard Doble 1/4" Connecting rod: maximum stroke length: 40"
	Breaker Interface/Rotary Adapter	Equipped with 3/8" x 18" threaded shaft, with Jacobs Chuck; other shaft adapters may be fabricated for mounting to the threaded shaft, as required
	Interface to TR3100	Doble P/N 181-0107 (50 ft/15.2 m cable)

Figure H.1 on page H-7 shows the assembly drawing for the TR3190.

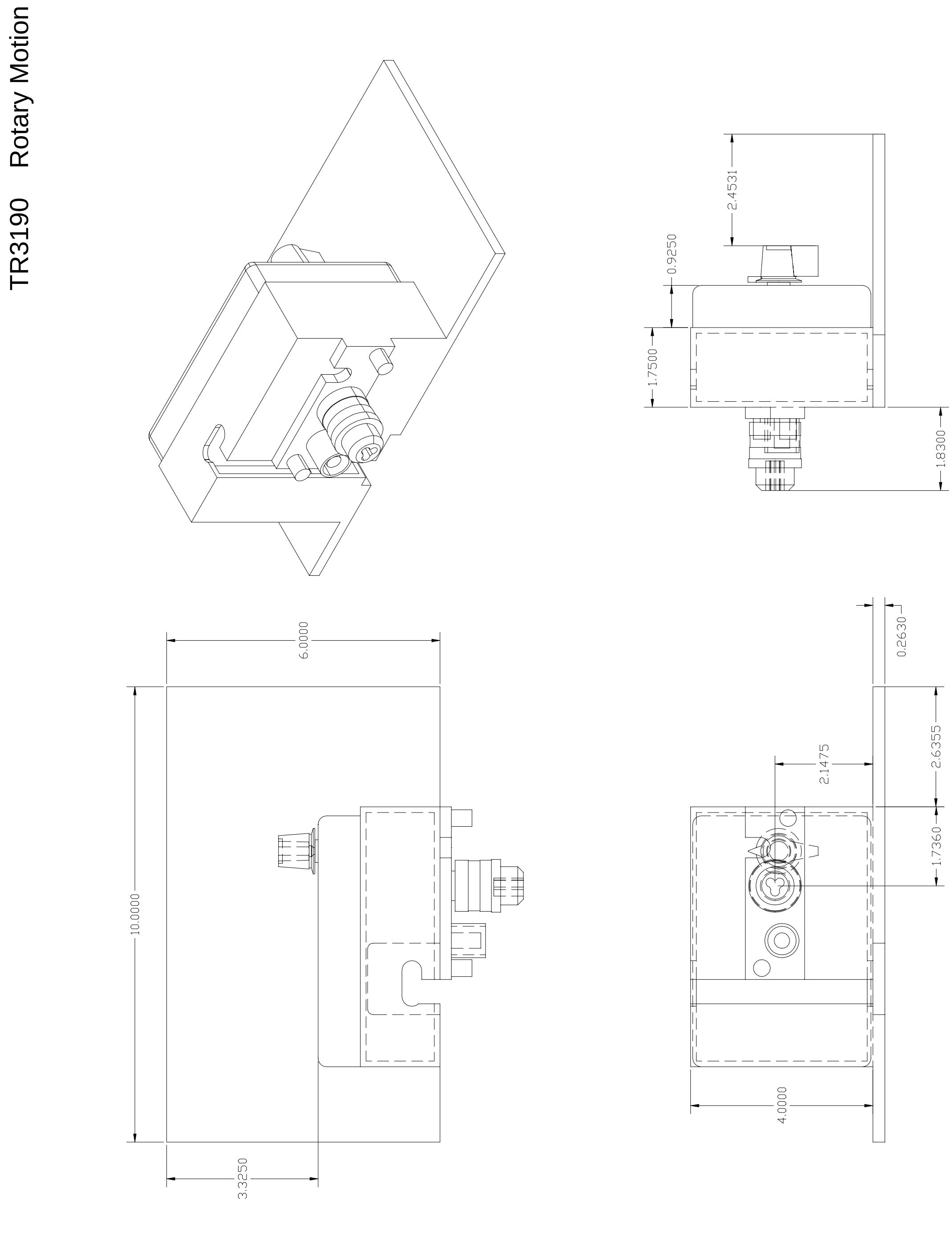

Figure H.1 TR3190 Linear Motion with Rotary Chuck Attached

Also available is the TR3170 Transducer (Figure H.2), a scaled-down version of the TR3190 Transducer, which is designed for linear use only.

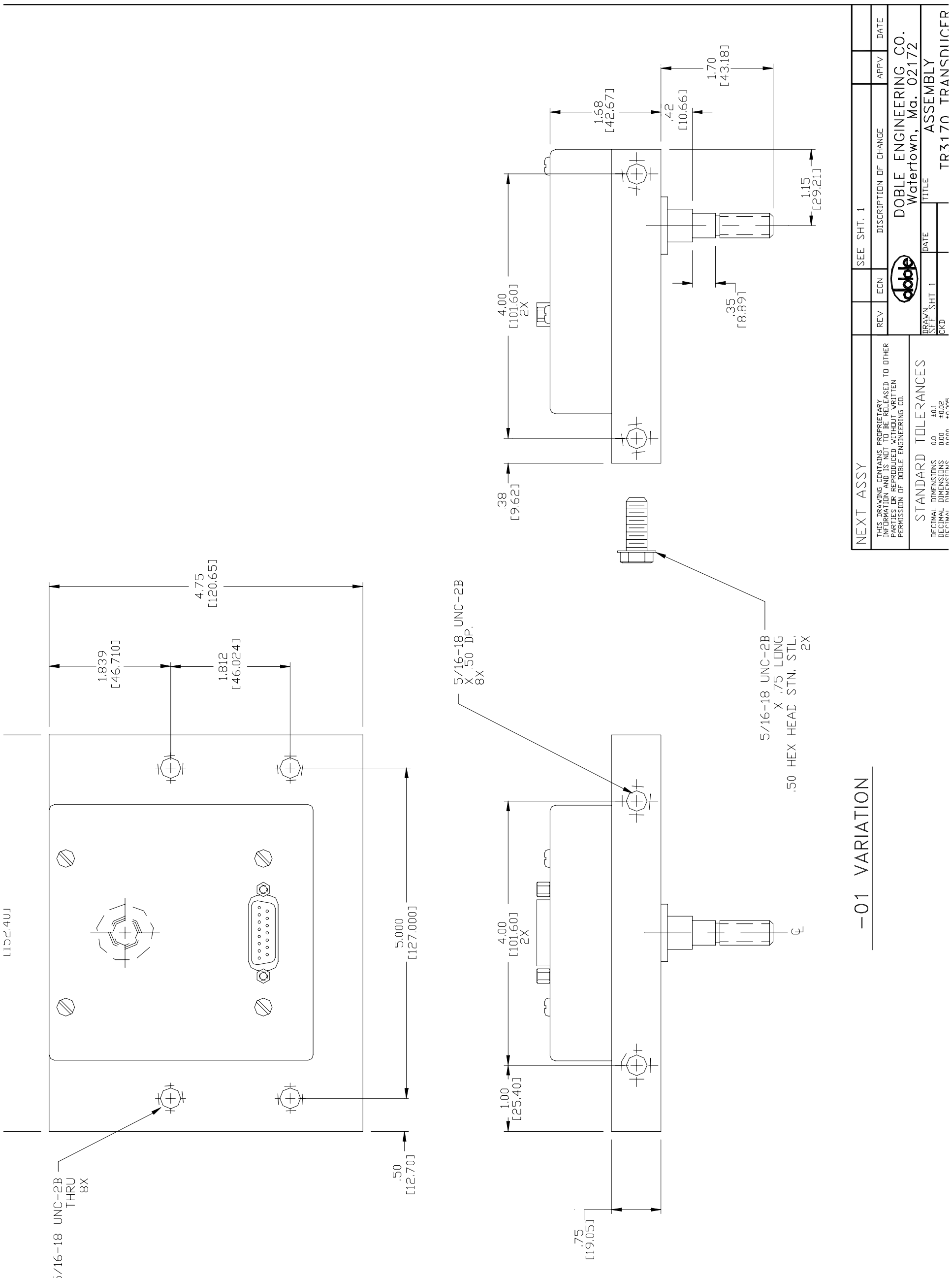

Figure H.2 TR3170 Linear Transducer

AN3: TR3190 Mechanical Interfaces and Other Transducers

Measuring the mechanical displacement and velocity of circuit breaker mechanisms vs. time and contact operation is an important analytical method.

Many utilities use simple, mechanical *Tom Edison Toys* that only measure mechanical displacement vs. time as their primary breaker timing tool. Many years of TR1 and TR2 experience have taught us much about mechanical measurements using the MY transducer, including how to successfully interface the transducer to breaker mechanisms. Although it is straightforward, it is not quite so simple as it appears. High acceleration requires interfaces and transducers with low mass, so as not to affect the measurements. High shock loads at the limits of travel require rugged interfaces so they don't fall apart or impart false movement due to their mechanical instability. High resolution and accuracy are required; none of these characteristics is commercially available, so the TR3190 was born.

"AN2: TR3190 Digital, Linear/Rotary Motion Transducer" on page H-1 describes the design of the TR3190 Digital, Rotary/Linear Transducer in detail and provides insight into the design of adapters and interfaces. It is Doble's policy to develop both rotary and linear motion mechanical interfaces for the TR3190.

Over the years the client users of TR1/TR2 have also developed interfaces and documented many of them. The SFA interface has been developed because the OEM slide wire adapters supplied by Westinghouse to provide electrical measurements of motion are no longer available.

NOTE

The T3 Input Expander was an auxiliary instrument designed to interface between Westinghouse SFA slide wires and TR2/PR2, and to interface to additional MV Transducers for measuring a total of three mechanisms simultaneously.

Photographs of the interface connected to an SFA breaker module, a sketch of the interface form part of this design, will be provided on request.

Other additions include the TR3170 Rotary Transducer and the TR3171 AHMA-4/8 Transducer. The TR3171 Transducer is used on any circuit breaker that uses the AB AHMA-4/8 operator. This includes ABB Type PA circuit breakers, certain ELF circuit breakers, and PM circuit breakers where the voltage class is 345 kV and above.

Adapters and Transducers

Figure H.3 shows the SFA Adapter with the motion lever arms mounted on the TR3170 Transducer, and the hardware supplied with the SFA Adapter.

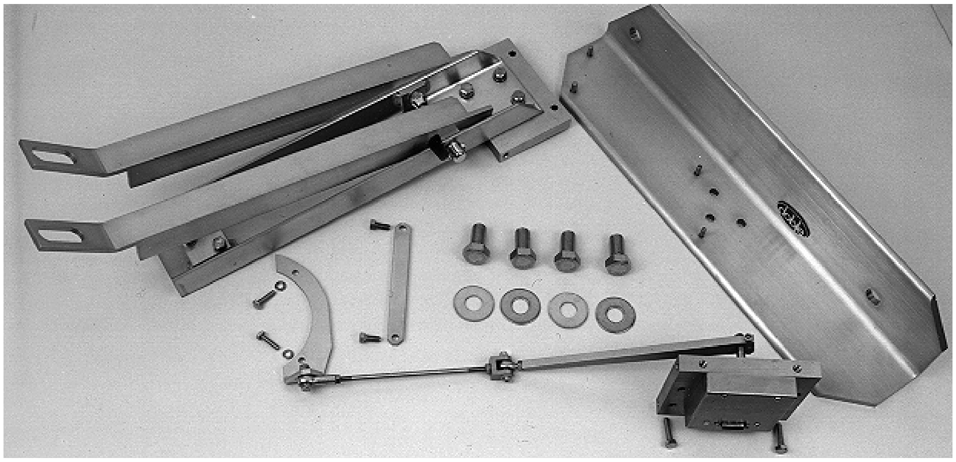

Figure H.3 Westinghouse SFA SF6 Gas Circuit Breaker

Figure H.4 shows the Doble ABB AHMA 4/8 Transducer for use with the ABB SF6 Gas circuit breakers using the AHMA 4 or AHMA 8 operating mechanism. It shown with the drive fork and the gauge block stored on the transducer using the same bolts used during testing.

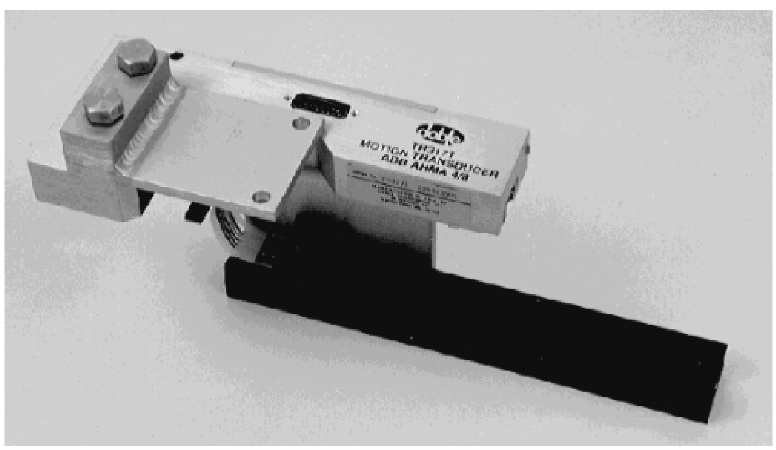

Figure H.4 ABB PA, ELF, and PM (345 kV and above) SF6 Gas Circuit Breakers

Figure H.5 shows the Doble ABB AHMA 4/8 Transducer for use with ABB SF6 Gas circuit breakers using the AHMA 4 or AHMA 8 operating mechanism. It is shown with the drive fork engaging the optical encoder assembly and the gauge block in front of the transducer. The gauge block is used to insure the coupler block is in the same plane as the surface to which the transducer is attached.

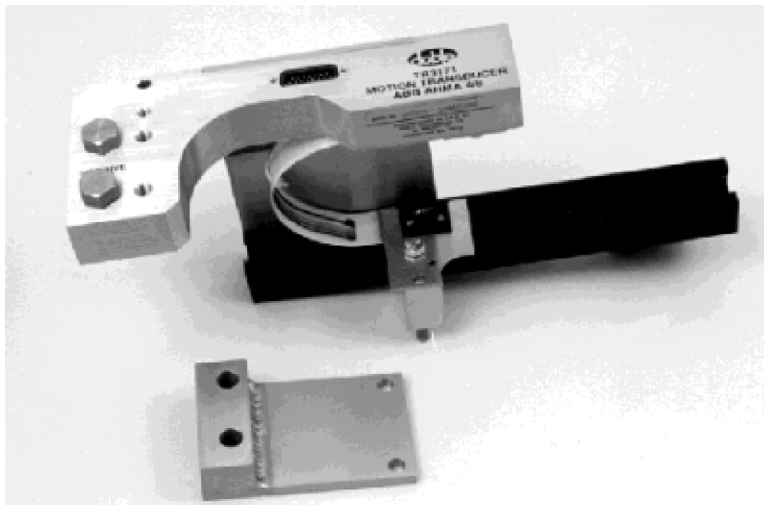

Figure H.5 ABB PA, ELF, and PM (345 kV and above) SF6 Gas Circuit Breakers

Figure H.6 shows an adapter/transducer combination that measures travel at the base of the insulator column. A hex adapter (3/8" - 24 to 12 mm) is mounted on the TR3170 rotary transducer and is attached to the rotating element of the phase.The disc that drives the semaphore remains with the rotary element. The transducer support plate is then attached to the transducer using 5/16" bolts. The transducer or transducer support plate assembly is then bolted to the aluminum casing at the base of the insulator using 8 mm x 25 mm bolts in the tapped holes used for screwing the cover on.

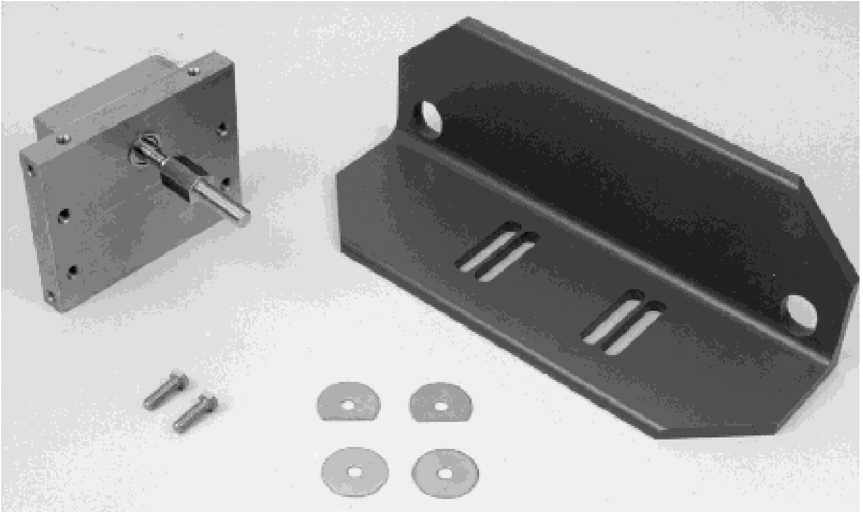

Figure H.6 ABB HPL SF6 Gas Circuit Breaker – Insulator Column

Figure H.7 shows a adapter/transducer combination that measures travel at the chain sprocket in the mechanism cabinet. A hex adapter (3/8" - 24 to 8 mm) is mounted on the TR3170 rotary transducer and is attached to the rotating element in the cabinet. The transducer hex adapter is attached to the rotating mechanism and then to the support plate. The support plate is the clamped to the structural plate in the cabinet using *C*-clamps.

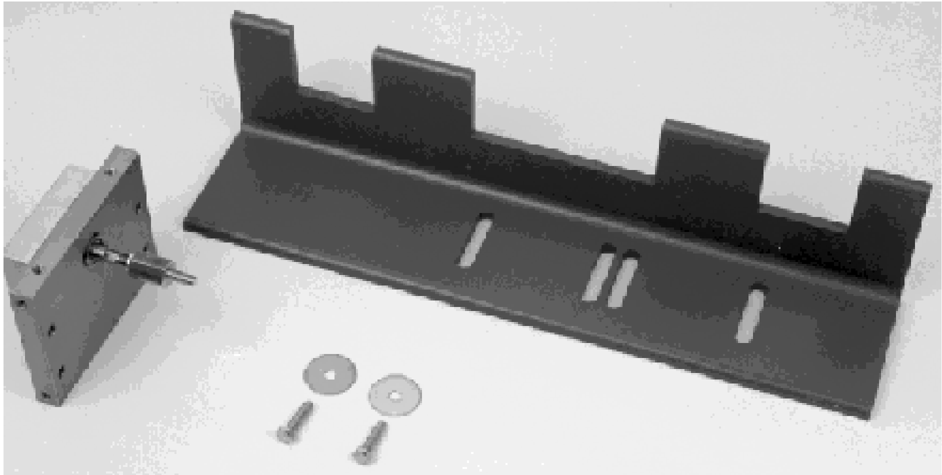

Figure H.7 ABB HPL SF6 Gas Circuit Breaker – Chain Sprocket

Figure H.8 shows an adapter for use with the HVB SF6 Gas circuit breakers that uses a ganged operating mechanism. The adapter has a metric 16 mm thread that treads into a tapped hole on the horizontal operator adjacent to pole 1 and the mechanism cabinet. This is shown with a 24" travel rod.

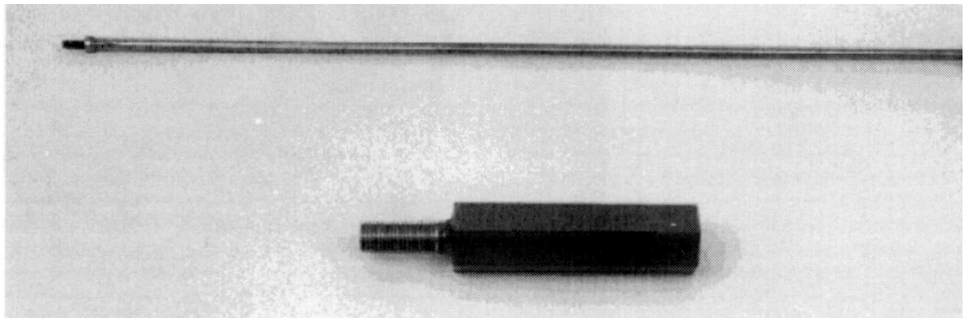

Figure H.8 HVB SF6 Gas Circuit Breakers with Ganged Operating Mechanisms

Figure H.9 shows an adapter for use with HVB SF6 Gas circuit breakers that uses an individual mechanism for each pole. A plate is removed from each pole, the large metric bolt is threaded into the moving element, and the spacer is attached to the point from which the plate was removed using existing hardware. The travel rod is inserted through the large holes in the spacer and is threaded into a tapped hole in the top of the large metric bolt. The transducer is then centered on the travel rod and clamped to the spacer.

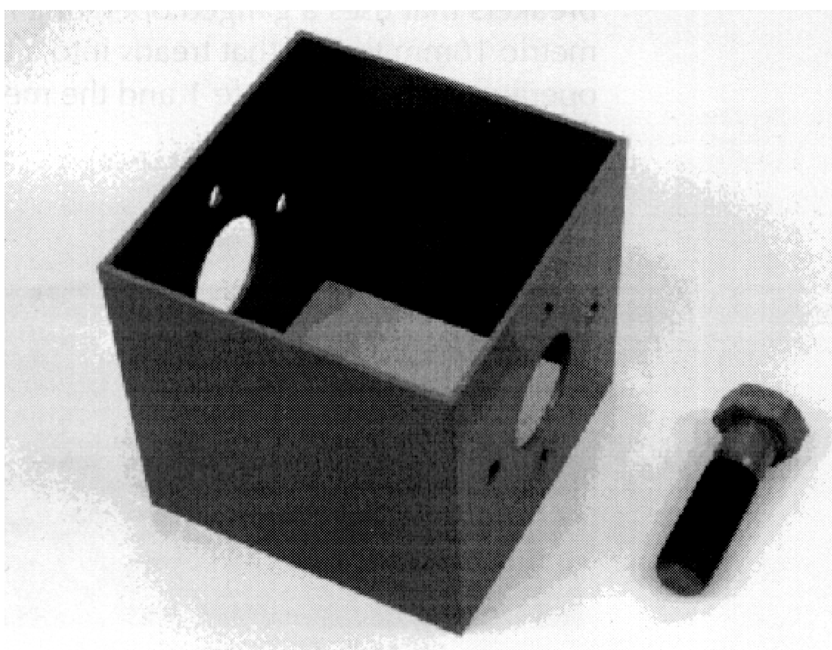

Figure H.9 HVB SF6 ® Circuit Breakers with Independent Pole Operating Mechanisms (IPO)

Figure H.10 on page H-14 shows an adapter that mounts on the moving contact assembly using existing hardware. The plate is clamped to the top of the circuit breaker with the forked arms extending beyond the bushing. The transducer is clamped to the support plate. The plate is bent at the proper angle to ensure the travel rod does not touch the transducer case during circuit breaker operation.

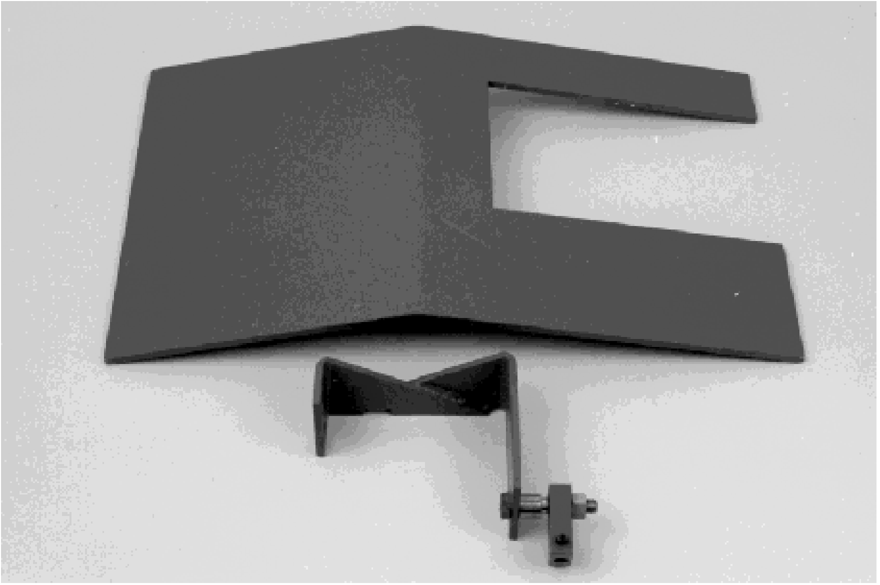

Figure H.10 General Electric Metalclad Air Magnetic Circuit Breakers (600 and 1200)

Figure H.11 on page H-15 shows this adapter for the 2000 A and above range.

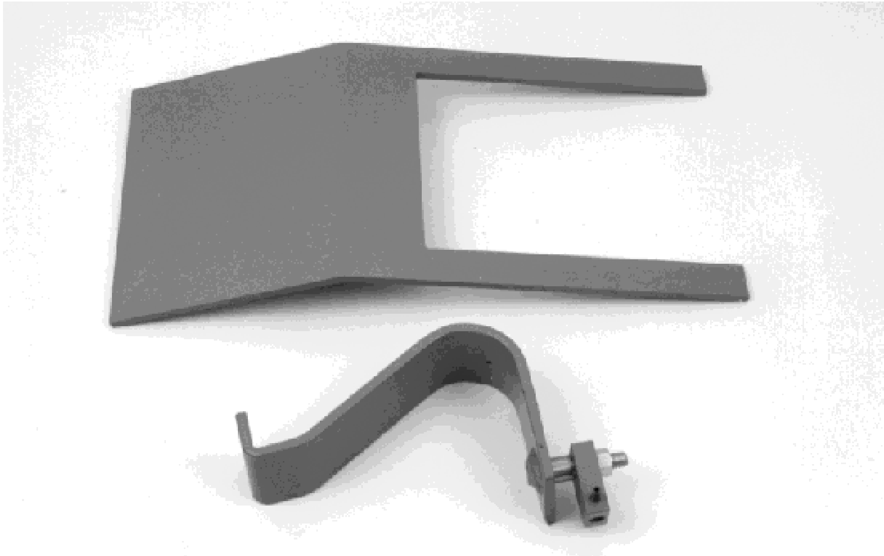

Figure H.11 General Electric Metalclad Air Magnetic Circuit Breakers (2000 A and above)

Figure H.12 shows the adapter for the VBI with the ML-18 operator (left) and the VBl with the ML-17 operator (right). These adapters mount on the vacuum bottle erosion ring and allow travel measurements to be made on the circuit breaker contacts.

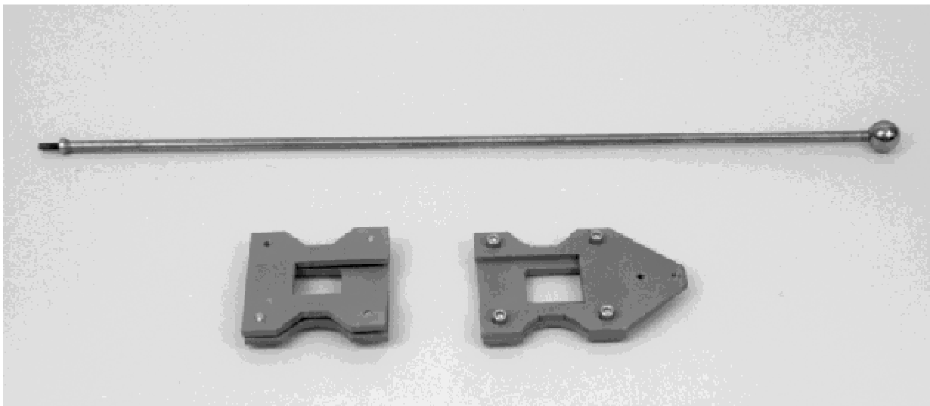

Figure H.12 General Electric Metalclad VBI Vacuum Circuit Breaker

Figure H.13 shows an adapter/transducer combination that measures travel at the bellcrank assembly where operating rod travel perpendicular to contact travel is changed to travel parallel to interrupter travel. A hex adapter (3/8" - 24 to 10 mm) is mounted on the TR3170 rotary transducer and is attached to the rotating element of the phase. The transducer is then secured to the cast aluminum casing that surrounds the moving elements with 5/16" bolts and several 5/16" fender washers.

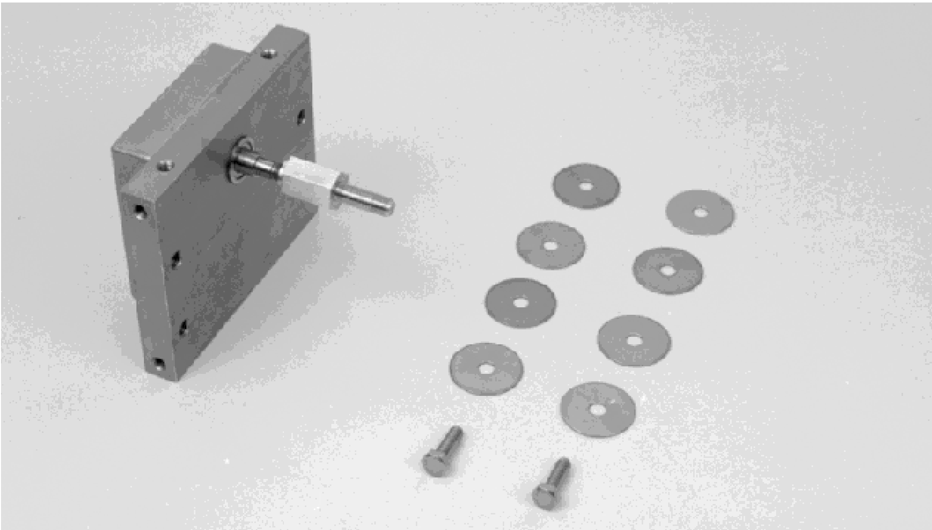

Figure H.13 GEC Alsthom HGF Series SF6 Gas Circuit Breakers

Figure H.14 shows the extended pin that replaces the normal drive pin. A tab slips over the pin extension and the transducer rod is threaded into a tapped hole in the tab. The transducer is clamped to the mechanism cabinet.

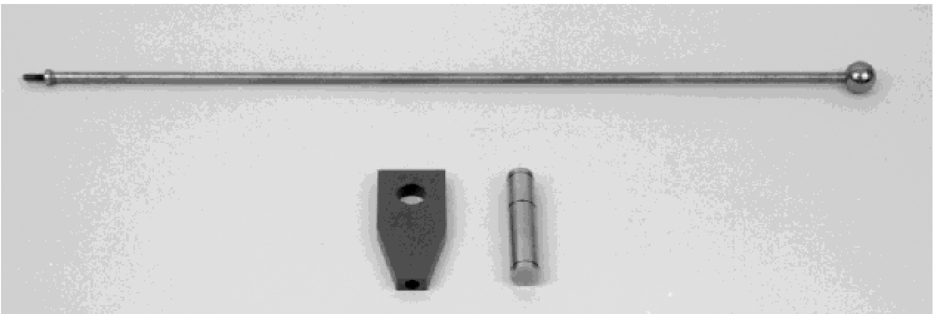

Figure H.14 Mitsubishi Electric Power Products 100 SFMT SF6 Gas Circuit Breakers

Figure H.15 shows the large *L* shaped plate that replaces the standard bottom plate on the TR3160 Transducer using the hardware that secures the standard base plate to the transducer body. The small *L* shaped bracket is attached to the moving element of the circuit breaker mechanism using metric cap screws. A shortened transducer rod completes the installation.

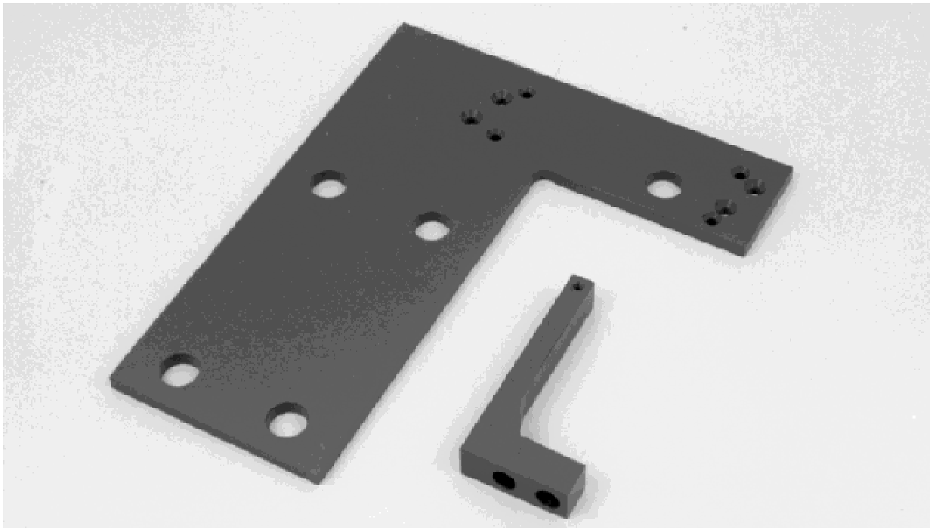

Figure H.15 Mitsubishi Electric Power Products SFMT SF6 Gas Circuit Breakers

Figure H.16 shows a general-purpose adapter, with reducers and spacers, to allow mounting of various size circuit breaker fittings. The reducers and spacers consist of a close nipple, a coupler, and a reducer.

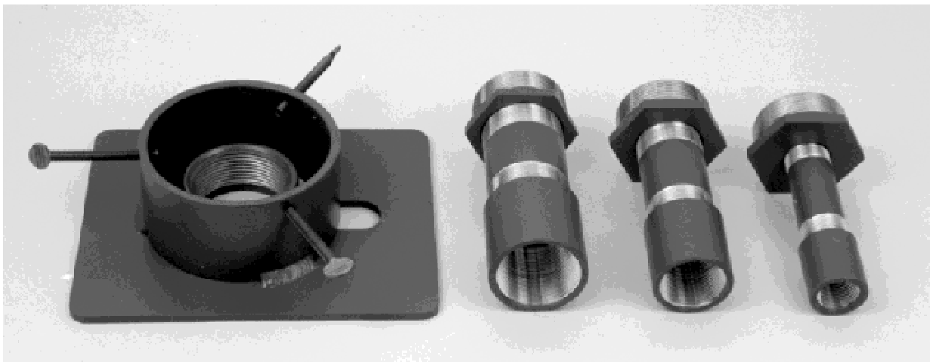

Figure H.16 General Purpose Adapter

Figure H.17 shows a general purpose spacer that is used where it is difficult or impossible to mount the transducer directly to the circuit breaker. The spacer is bolted to the circuit breaker using existing bolt holes and the TR3160 Transducer is clamped to the other end of the spacer using *C*-clamps. A hole through two ends of the space is provided for the transducer rod.

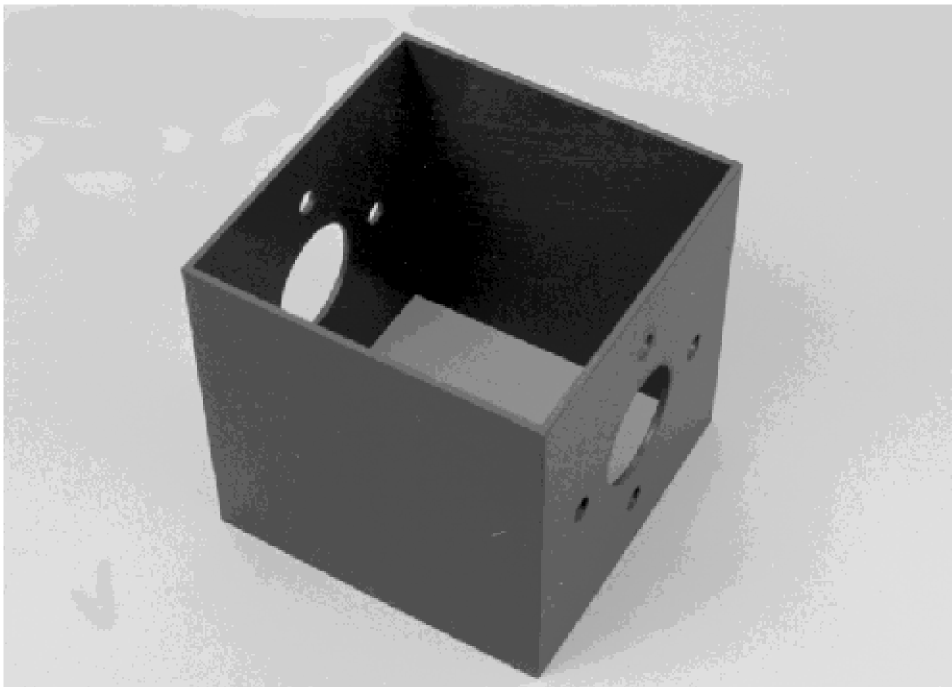

Figure H.17 General Purpose Spacer

Figure H.18 shows various clamps used to temporarily secure the transducer to a fixture.

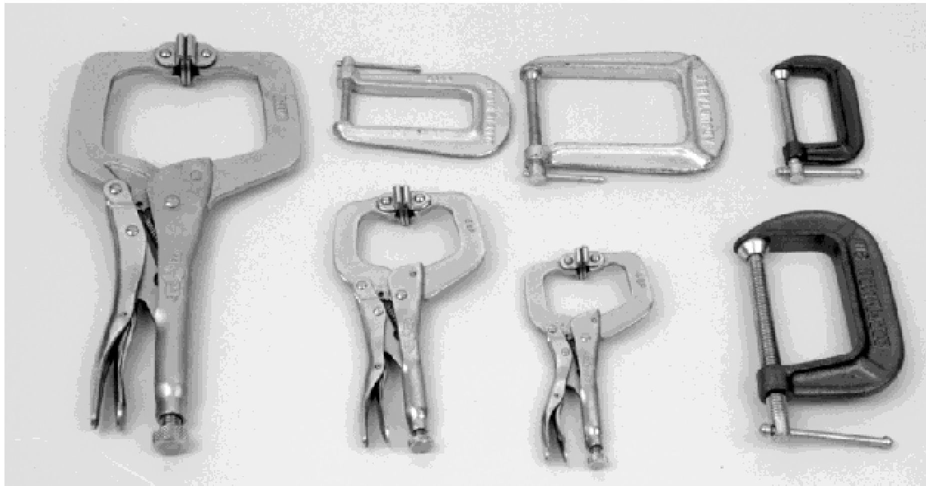

Figure H.18 Various Transducer Clamps