



Model 117B67

Conformal ballistics pressure sensor

Installation and Operating Manual

**For assistance with the operation of this product,
contact PCB Piezotronics, Inc.**

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The information contained in this document supersedes all similar information that may be found elsewhere in this manual.

Total Customer Satisfaction – PCB Piezotronics guarantees Total Customer Satisfaction. If, at any time, for any reason, you are not completely satisfied with any PCB product, PCB will repair, replace, or exchange it at no charge. You may also choose to have your purchase price refunded in lieu of the repair, replacement, or exchange of the product.

Service – Due to the sophisticated nature of the sensors and associated instrumentation provided by PCB Piezotronics, user servicing or repair is not recommended and, if attempted, may void the factory warranty. Routine maintenance, such as the cleaning of electrical connectors, housings, and mounting surfaces with solutions and techniques that will not harm the physical material of construction, is acceptable. Caution should be observed to insure that liquids are not permitted to migrate into devices that are not hermetically sealed. Such devices should only be wiped with a dampened cloth and never submerged or have liquids poured upon them.

Repair – In the event that equipment becomes damaged or ceases to operate, arrangements should be made to return the equipment to PCB Piezotronics for repair. User servicing or repair is not recommended and, if attempted, may void the factory warranty.

Calibration – Routine calibration of sensors and associated instrumentation is

recommended as this helps build confidence in measurement accuracy and acquired data. Equipment calibration cycles are typically established by the users own quality regimen. When in doubt about a calibration cycle, a good “rule of thumb” is to recalibrate on an annual basis. It is also good practice to recalibrate after exposure to any severe temperature extreme, shock, load, or other environmental influence, or prior to any critical test.

PCB Piezotronics maintains an ISO-9001 certified metrology laboratory and offers calibration services, which are accredited by A2LA to ISO/IEC 17025, with full traceability to N.I.S.T. In addition to the normally supplied calibration, special testing is also available, such as: sensitivity at elevated or cryogenic temperatures, phase response, extended high or low frequency response, extended range, leak testing, hydrostatic pressure testing, and others. For information on standard recalibration services or special testing, contact your local PCB Piezotronics distributor, sales representative, or factory customer service representative.

Returning Equipment – *Following these procedures will insure that your returned materials are handled in the most expedient manner.* Before returning any equipment to PCB Piezotronics, contact your local distributor, sales representative, or factory customer service representative to obtain a Return

Materials Authorization (RMA) Number. This RMA number should be clearly marked on the outside of all package(s) and on the packing list(s) accompanying the shipment. A detailed account of the nature of the problem(s) being experienced with the equipment should also be included inside the package(s) containing any returned materials.

A Purchase Order, included with the returned materials, will expedite the turn-around of serviced equipment. It is recommended to include authorization on the Purchase Order for PCB to proceed with any repairs, as long as they do not exceed 50% of the replacement cost of the returned item(s). PCB will provide a price quotation or replacement recommendation for any item whose repair costs would exceed 50% of replacement cost, or any item that is not economically feasible to repair. For routine calibration services, the Purchase Order should include authorization to proceed and return at current pricing, which can be obtained from a factory customer service representative.

Warranty – All equipment and repair services provided by PCB Piezotronics, Inc. are covered by a limited warranty against defective material and workmanship for a period of one year from date of original purchase. Contact

PCB for a complete statement of our warranty. Expendable items, such as batteries and mounting hardware, are not covered by warranty. Mechanical damage to equipment due to improper use is not covered by warranty. Electronic circuitry failure caused by the introduction of unregulated or improper excitation power or electrostatic discharge is not covered by warranty.

Contact Information – International customers should direct all inquiries to their local distributor or sales office. A complete list of distributors and offices can be found at www.pcb.com. Customers within the United States may contact their local sales representative or a factory customer service representative. A complete list of sales representatives can be found at www.pcb.com. Toll-free telephone numbers for a factory customer service representative, in the division responsible for this product, can be found on the title page at the front of this manual. Our ship to address and general contact numbers are:

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OPERATION MANUAL FOR CONFORMAL BALLISTICS PRESSURE SENSOR Series 117B

1.0 INTRODUCTION

The Model 117B Conformal Sensor measures pressure inside metallic cartridges and paper or plastic shotshell, during firing of the round, without drilled holes in the round.

The sensor is mounted flush with the chamber walls, matching the curvature exactly. The expanded cartridge or shotshell transmits forces through the thin wall to the sensor.

The Model 117B is a conventional charge output type sensor using synthetic quartz as the piezoelectric sensing material.

An alignment guide now standard on all 117B Models, simplifies installation by automatically controlling rotational alignment of the sensor, leaving only the depth adjustment consideration.

2.0 DESCRIPTION

Refer to enclosed installation drawing for outline dimensions and physical description.

The basic sensor is a probe design with captivated hollow clamp nut. The clamp nut rotates independently of the probe body and serves to lift the sensor out of the mounting port as it is unscrewed.

The alignment device consists of a pin and slotted clamp assembly which fits tightly over the collar of the sensor.

The hardened steel pin is accurately aligned with the axis of the diaphragm curvature and when assembled into a precisely drilled mating hole in the barrel or calibration chamber, achieves near perfect rotational alignment of sensor diaphragm.

The slotted clamp arrangement allows for tolerance in the location of the guide pin hole in an axial direction on the test barrel or calibration adaptor.

The precise depth adjustment is obtained by the use of the correct thickness spacer selected from a set of 9 spacers of various thicknesses supplied with each sensor.

Once the proper thickness spacer is found, removal and re-installation now becomes a routine matter.

3.0 INSTALLATION

3.1 PORT PREPARATION

Prepare mounting port in accordance with installation drawing 117-20 (XX)-90 supplied as part of this manual.

NOTE: The installation port for the 117B is identical to that for the 117A.

Drill guide pin hole as shown in installation drawing, paying particular attention to locating C/L of hole exactly on C/L of barrel.

Do not use a drill that is worn, as this may cause the hole to be slightly undersized and the guide pin may bind as it is drawn into the hole.

It is extremely important that the guide pin hole be drilled parallel to the sensor mounting port to permit the guide pin to move freely into the hole.

NOTE: Each model variation of the 117B is designed to fit in a specific location (measured from the bolt face) on a specific ammunition caliber. Changing location and/or caliber will cause a mismatch of diaphragm curvature with cartridge case diameter since most cartridge cases are tapered.

3.2 INSTALLING THE SENSOR

After mounting holes have been prepared, proceed with installation as follows:

1. On most models of 117B, it is not important which side of the sensor is mounted toward the muzzle.

However, on certain types of ammunition (such as 20 mm cannon) which have a severe taper, the diaphragm has a matching taper in

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the curvature. In these latter cases, the sensor forward side is identified with the legend "FWD" etched on the guide collar to which the slotted clamp is attached. The clamp must be removed to find this legend. If it does not appear, the sensor may be mounted with either side toward the muzzle.

2. Loosen slotted clamp, but do not remove clamp.
3. Select the middle thickness (.014) spacer from the set of nine (065A19) supplied and place it around sensor barrel.
4. Begin threading the sensor clamp nut into the threaded mounting port, sliding slotted clamp fore and aft as needed to allow guide pin to fully enter hole.

Continue to turn clamp nut into hole by hand or using 5/16 open end wrench.

Do not tighten when sensor bottoms.

5. Now tighten the screw closing slotted clamp.
6. Using open end wrench, tighten sensor clamp nut.

NOTE: It is not necessary to put large amounts of torque on this nut since a pressure seal is not necessary. Approximately 5 to 10 ft. lbs. is sufficient.

7. Now inspect flushness of diaphragm with inside surface of chamber. This can be accomplished visually in most cases.

If the diaphragm extends too deeply into the chamber, select a thicker spacer and repeat mounting procedure.

If the diaphragm is too deeply recessed, select a thinner spacer and remount.

Once the proper thickness is found for perfect flushness, the sensor may be removed and reinstalled using this same spacer and the proper depth will be achieved each time.

NOTE: For best accuracy of results, use same charge amplifier for calibration and for actual operation. Use long TC for calibration, medium or short TC for best drift free operation.

4.0 POLARITY

Polarity of the Model 117B is negative i.e., the charge output is negative for increasing pressure input, making it compatible with inverting type charge amplifiers.

5.0 CALIBRATION

Calibration of the Models 117B is facilitated by a calibration adaptor which exactly matches the chamber dimensions of the cartridge under test. An actual cartridge case is hydraulically pressurized with reference pressure to obtain a point-by-point sensor calibration.

These calibration adaptors can be fabricated by the user or can be purchased from PCB as our Model 090B calibration adaptor. Simply specify caliber and longitudinal location of sensor.

For most rimfire applications, the sensor is located .25 inches forward of the boltface.

For center fire cartridges a location .175 inches back from the cartridge shoulder is preferred. Consult PCB for recommendations on sensor locations if questions arise.

Since most cartridge cases are tapered and diameter is dependent upon longitudinal location, this location may not be changed after the sensor is fabricated since it is essential for proper operation that the sensor curvature exactly match chamber curvature.

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5.1 LOW-END NONLINEARITY

It will be noticed during calibration, especially with metallic cartridges, that a certain amount of pressure is necessary before linear output is attained from the conformal sensor.

This is due to the fact that since the cartridge cases are made nominally smaller in diameter than the chamber to allow easy insertion and extraction, the case must be expanded slightly by the internal pressure before force can be transmitted to the sensor.

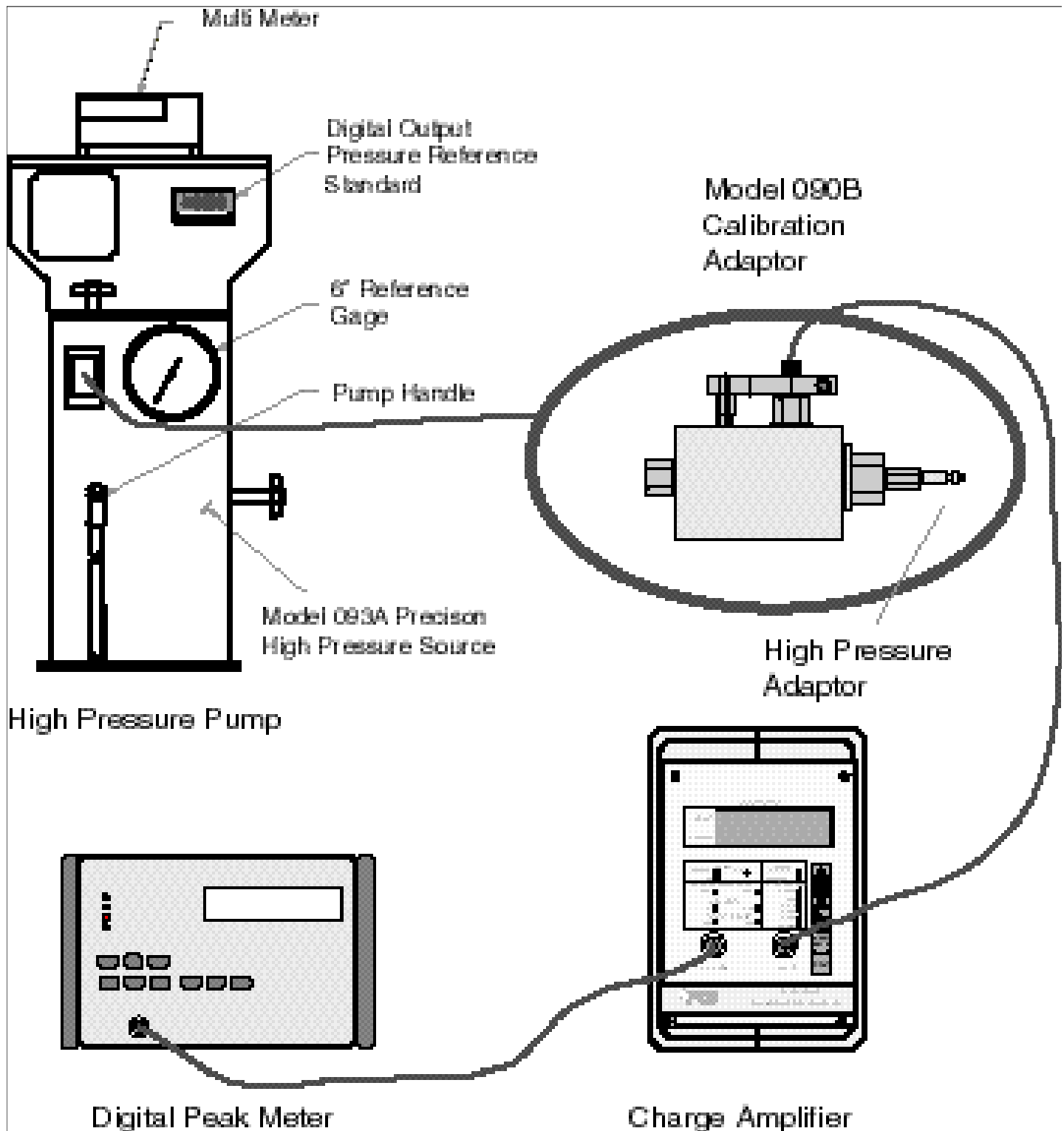
See the enclosed guide "An Improved Technique for Utilization of Conformal Ballistics Sensor Calibration Data" for methods of dealing with this topic.

6.0 MAINTENANCE

It is essential for normal operation of the Model 117B that the insulation resistance be maintained above 10^{12} ohms. If insulation resistance should deteriorate, wipe connector with clean cloth or paper wipe dipped in a solvent compatible with Teflon[®] such as isopropyl alcohol, then bake in oven at 250°F for ½ hour.

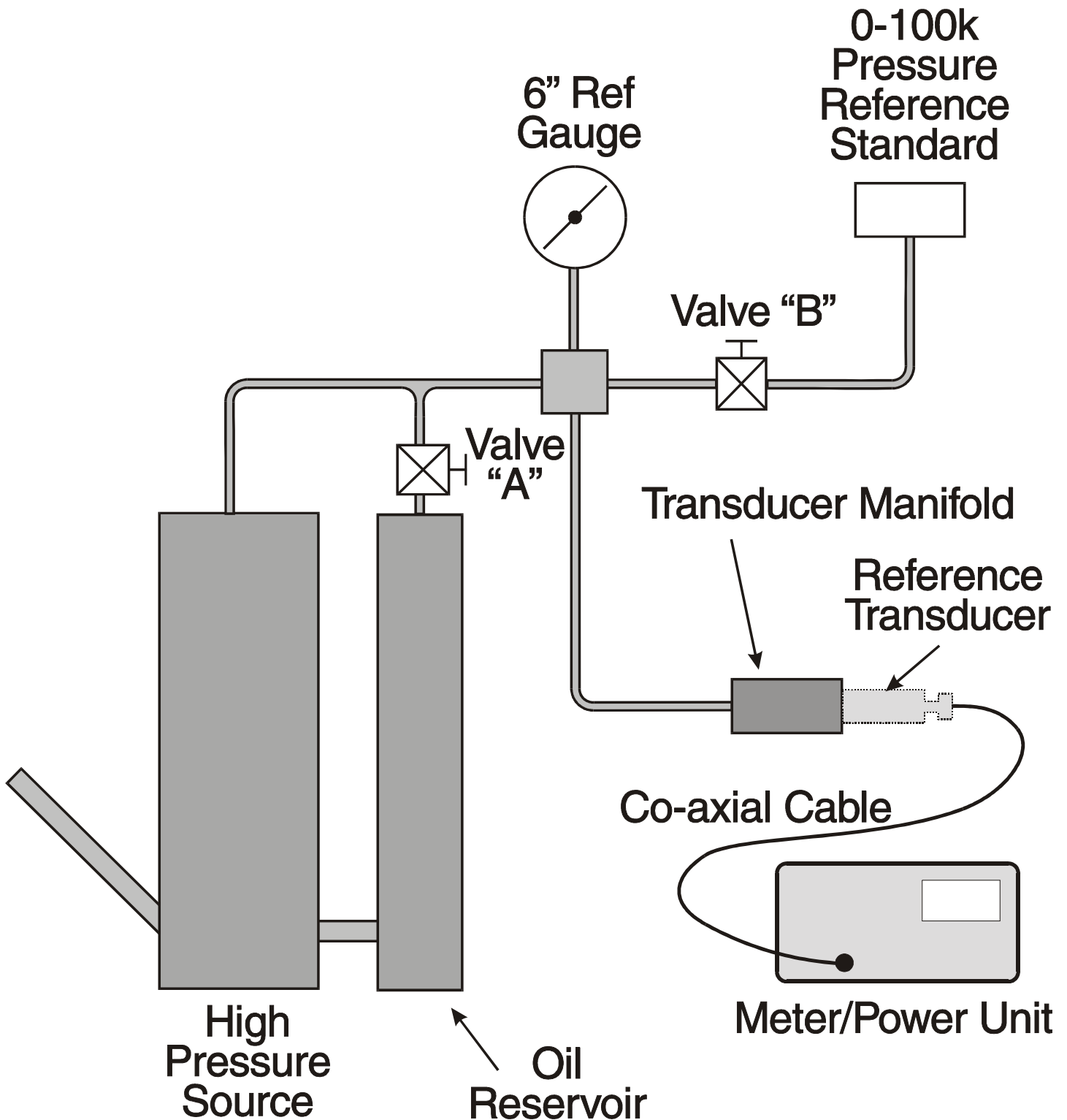
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Series 117B

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AN IMPROVED TECHNIQUE FOR UTILIZATION OF CONFORMAL BALLISTICS SENSOR CALIBRATION DATA

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The PCB Series 117B Conformal Ballistics Sensor (patented) measures chamber pressure in a novel manner.

The sensitive surface of the sensor, when properly installed in the gun chamber, conforms or blends in precisely with the inside surface of the chamber actually forming a portion of the wall adjacent to the cartridge case.

When the round is fired, the pressure builds up rapidly inside the case, obturating the case outward against the chamber. The force, transmitted through the thin cartridge case wall stresses the sensor crystals producing an output charge analogous to chamber pressure.

An exclusive calibration technique has been developed in conjunction with the conformal sensor, consisting of a simulated gun chamber which positions the sensor at the same location as in the test barrel and provides for hydraulic pressurizations of an actual cartridge case.

Using this system and a reference standard pressure source, a point by point calibration is performed on samples of the actual lot of ammunition under test to take into account transmissibility characteristics of the cartridge case for each lot of ammunition.

Because a certain amount of pressure is required to fully obturate the cartridge case in the test chamber, a rather severe non-linearity is exhibited over the first several thousand psi of input pressure, i.e. until the cartridge case is pressed firmly against the inside chamber walls.

Figure 1 illustrates a typical calibration result with .22 caliber rimfire ammunition.

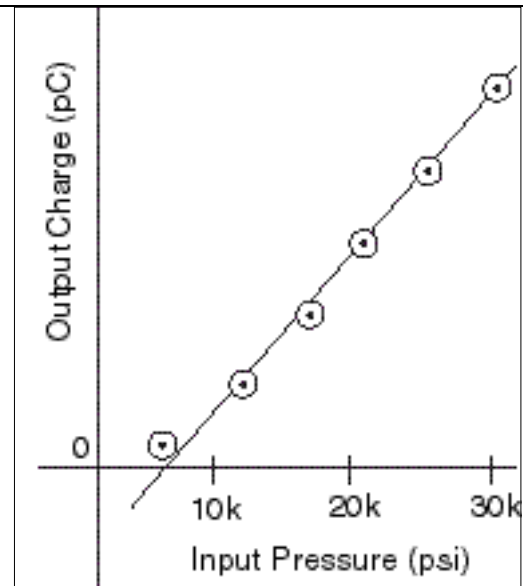


Figure 1: Typical calibration graph
Conformal sensor with .22 caliber rimfire.

As shown in figure 1, the best straight line that can be drawn through the majority of the data points in the linear portion of the curve, does not pass through the origin.

Because of this, the widely accepted zero based best straight line method of linearity determination cannot be applied to the conformal sensor. Also, the actual sensitivity of this sensor may only be specified at one input pressure level since the sensitivity is not a constant, but varies with input pressure level.

This paper outlines a simple alternative approach to utilization of conformal sensor data.

The most universally accepted method of defining conventional sensor nonlinearity is the full scale error band method used in conjunction with the zero based best straight line.

AN IMPROVED TECHNIQUE FOR UTILIZATION OF CONFORMAL BALLISTICS SENSOR CALIBRATION DATA

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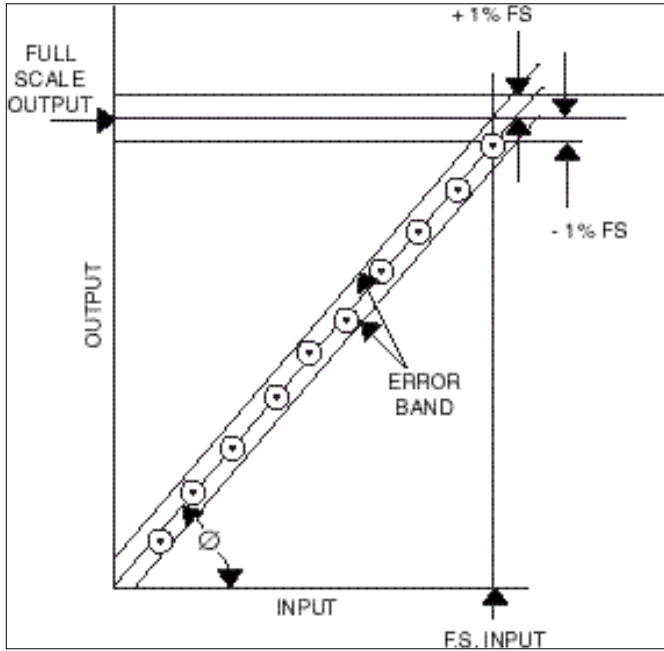


Figure 2: Zero based best straight line method of linearity determination.

To utilize the zero based best straight line method, the corresponding value of the sensor output is plotted for each value of input measurand up to full scale as shown in Figure 2.

A straight line, intercepting the origin as shown, is fitted to the data points by equalizing the error between the points below the line and the points above the line.

Error bands, as delineated by the instrument specification are constructed as shown in figure 2. Typically, plus and minus one or two percent of full scale is specified for quartz sensors.

An acceptable instrument is then defined as one whose data points all fall within this error band.

The "sensitivity" of an instrument so calibrated is simply the full scale output (charge or voltage) divided by full scale input pressure, where F.S. output is determined by the straight line as defined above.

$$\text{Sensitivity} = \frac{\text{F.S. output}}{\text{F.S. input}} \quad (\text{Eq. 1})$$

The units for sensitivity are commonly pC/psi or mV/psi.

Note that in this case, the sensitivity is identical to the slope of the line, since the line does intersect the origin by previous definition.

The general equation for a straight line in terms of the dependent variable is:

$$y = mx + b \quad (\text{Eq. 2})$$

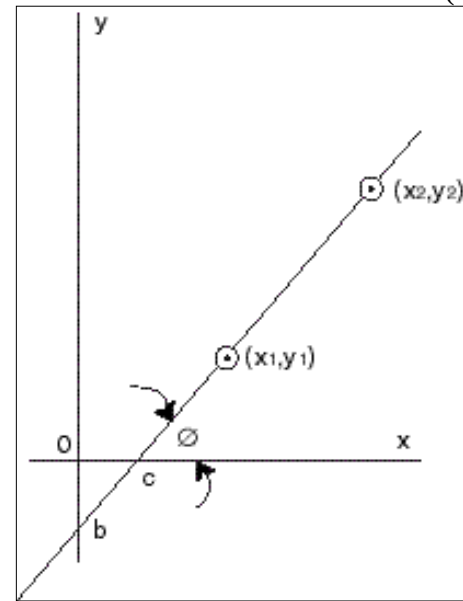


Figure 3

b in equation 2 is the y axis intercept.
m is the slope of the line defined as:

$$m = \tan\theta = \frac{y_2 - y_1}{x_2 - x_1} \quad (\text{Eq. 3})$$

Equation 2, expressed in terms of the independent variable x is:

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$$x = \frac{y}{m} + C \quad (\text{Eq. 4})$$

Where C is the X-axis intercept.

Equation 4 is directly applicable to the conformal sensor even through the X variable (psi) becomes the dependent variable when using the sensor output to determine pressure.

Consider again the calibration graph of a typical conformal sensor, shown in figure 4.

To calibrate a conformal sensor, the input pressure is increased in discrete steps from 0 psi to full scale with the corresponding output recorded at each step. The information must be taken only once and only with increasing pressure. A repeat run on the same cartridge case will not yield the same values as the initial run due to work hardening of the cartridge case metal.

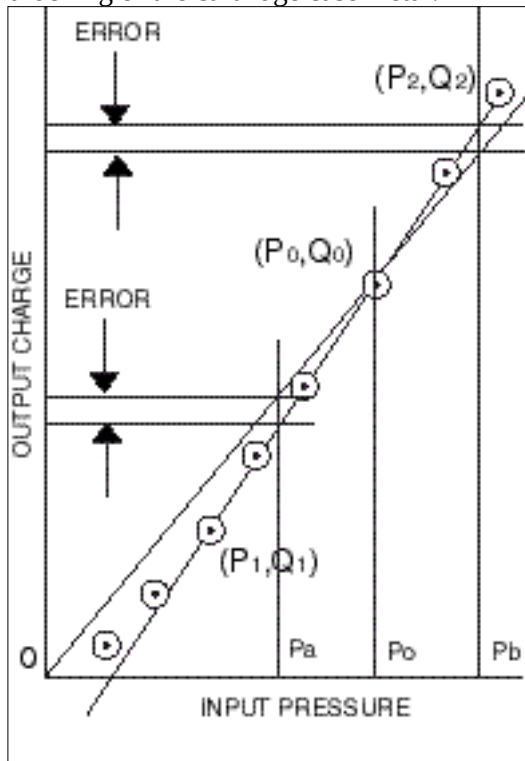


Figure 4

At the lower pressures, the sensor has very little output because there is a certain amount of clearance between the cartridge case and the chamber wall. Obturation of the cartridge occurs in this region.

However, when obturation is complete, the sensor output is then linear with pressure from this point up to maximum rated pressure.

In the past, a common procedure has been to calibrate the conformal at the expected nominal pressure, deriving a sensitivity at this point, e.g. point Po, Qo in figure 4.

The sensitivity determined by dividing output Qo by corresponding pressure input Po, would then yield the exact result if the input pressure was always exactly Po.

However, should the input pressure change to Pa, it is clear that the reading would be in error, as shown in Fig. 4, since the actual sensitivity of the instrument is not the same at Po, as it is at Pa.

A solution to this problem lies in utilization of equation 4.

$$x = \frac{y}{m} + C \quad (\text{Eq. 4})$$

Expressed in terms of sensor transfer parameters, input pressure and output charge

$$\text{Indicated pressure (psi)} = \frac{\text{indicated charge (pC)}}{\text{slope (pC/psi)}} + \text{intercept} \quad (\text{Eq. 5})$$

Where the slope of the line is defined as:

$$\text{Slope} = \frac{Q_2 - Q_1}{P_2 - P_1} \frac{\text{pC}}{\text{psi}} \quad (\text{Eq. 6})$$

and the intercept is the pressure axis intercept.

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The straight line is the best line that can be constructed through the linear portion of the curve as shown in Figure 4 and the pressure intercept (or offset) is the point at which this line crosses the pressure axis, in psi.

Instead of establishing the sensitivity parameter (which has been shown to have little meaning for this sensor) the user now determines the slope as defined in Eq. 6

and the accompanying pressure offset by constructing the best straight line as described previously.

Pressures P1 and P2 are arbitrarily established at some point well above and well below the expected nominal pressure of the test.

The corresponding outputs at these pressures should be an average of at least 20 cartridges taken from the same lot of ammunition as is under test.

The main difference between utilization of the data with this method is that now a constant (pressure offset) must be added to each reading. However, this can be easily handled by most data reduction methods in use today.

Example:

In actual practice, this is how a conformal sensor/charge amplifier system could be utilized:

Assume that averaging the data from 20 consecutive calibration runs performed on a conformal sensor yielded a slope of .04 pC/psi and an intercept of 7,500 psi, determined by constructing the best fitting straight line as described previously.

Assume also that average expected peak pressure is 25,000 psi.

Approximate full scale charge output is:

$$25,000 \text{ psi} \times .04 \text{ pC/psi} = 1000 \text{ pC}$$

Set range of charge amplifier output to 1000 pC/volt (or other desired range).

Read peak output voltage of .800 volts during test.

Peak indicated charge is then:

$$1000 \text{ pC/volt} \times .80 \text{ volts} = 800 \text{ pC}$$

Indicated peak pressure is:

$$\text{Pressure (pk)} = \frac{\text{peak charge}}{\text{slope}} + \text{offset}$$

$$P = \frac{800 \text{ pC}}{.04 \text{ pC/psi}} + 7,500 \text{ psi}$$

$$P = 20,000 \text{ psi} + 7500 = 27,500 \text{ Psi}$$

As previously stated, this method will yield accurate results anywhere within the linear portion of the sensor calibration curve without inherent errors due to variability of sensitivity with pressure level.

Accuracy should be close to that expected for standard piezoelectric sensors within the limitation of transmissibility variations in the cartridge cases.

Simplified standardization techniques for Conformal Sensor

The technique described by the previous example outlines one basic method of output signal utilization. This method in actual practice may be cumbersome for repeated testing because of the conversions that must be made from measured charge output to indicated peak pressure.

Other system scaling methods exist which further simplify signal utilization.

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Dial Gain Standardization

Many charge amplifiers feature a calibrated gain pot for dialing in sensor sensitivity for the purpose of setting system sensitivity to standardized unit of output voltage (PCB Model 462A).

To utilize such amplifiers, dial in the actual value of slope as determined by the calibration graph for the particular ammunition lot.

Using the slope value effectively displaces the calibration curve to pass through the origin (0) of the calibration graph.

See Figure 5.

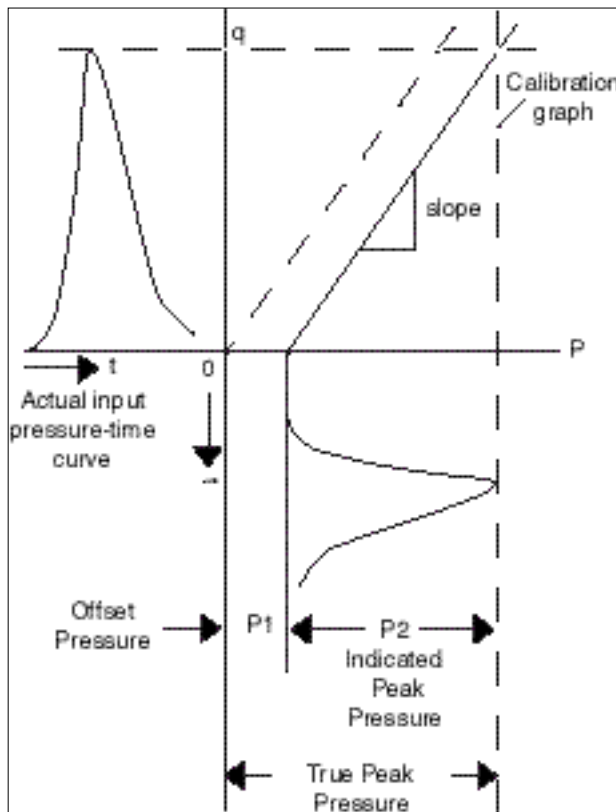


Figure 5

The indicated peak pressure $P2$ from the conformal, which through scale factoring can be read to read directly in psi (on a digital peak meter for example) is simply added to the offset pressure to arrive at true peak pressure, $P1 + P2$

This process can be further refined to, include a variable voltage source as a bias in series with the output of the charge amplifier. This voltage bias can be set to simulate the offset pressure, and then the true peak pressure can be read directly. (See figure 6 on the next page)

Example:

Assume a 20 round calibration lot and attendant graph yield a slope of .250 pC/psi and an offset of 5,000 psi.

Proceed as follows:

Dial the slope (.250) into the dial gain pot and select a convenient full scale range over which to operate.

For example, for an expected full scale range of 40,000 psi, select 10,000 units/volt.

Now the indicated peak pressure can be read directly from a digital peak holding meter such as the PCB Model 451B.

If the offset supply is not used, simply add the offset pressure (5,000 psi) to the indicated pressure to arrive at true peak pressure.

If an offset supply is used as in figure 6 simply dial in the offset voltage equivalent to offset pressure. Now the offset will be automatically added and the true peak pressure can be read directly from the peak meter.

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Calibrate Signal Insertion

Another method that is useful especially when utilizing a storage oscilloscope readout is to use a charge calibrator to inject a full scale charge signal into the charge amplifier. Multiply the sensor slope value by full scale pressure to find full scale picocoulombs.

$$40,000 \text{ psi} \times .250 \text{ pC/psi} = 10,000 \text{ pC}$$

Set the charge calibrator for 10,000 pC and apply this signal to the input of the amplifier. Now adjust the gain of the oscilloscope (or charge amplifier if gain adjust is available) to make full scale equal to a selected number of oscilloscope divisions.

For example: 6 Div = 40,000 psi

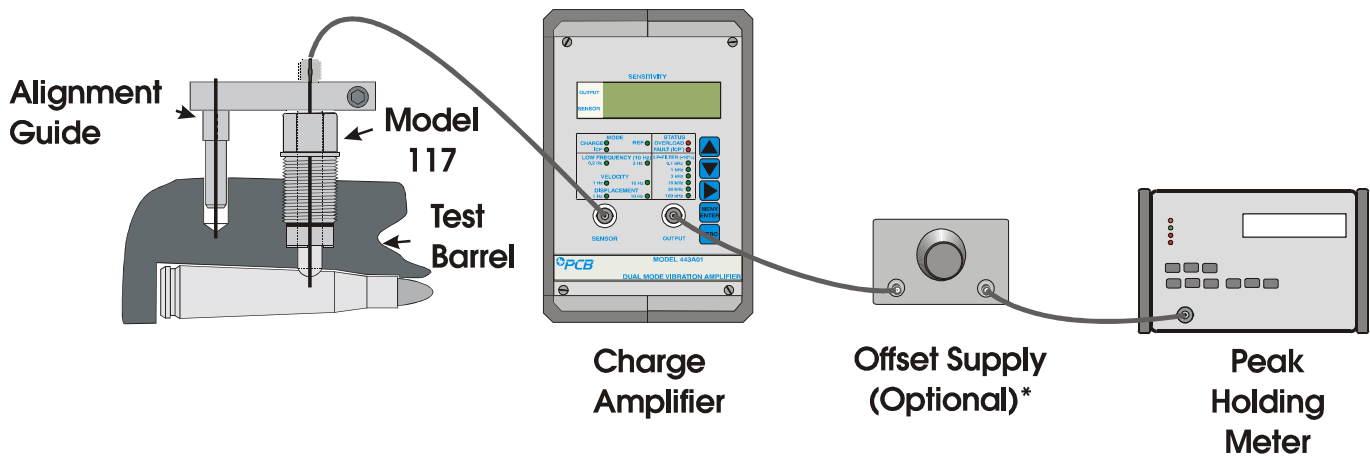
Now the peak value can be determined from the oscilloscope face or scope photo using a variable scale or other interpolative methods.

Then, add the offset pressure to this value to determine true peak pressure.

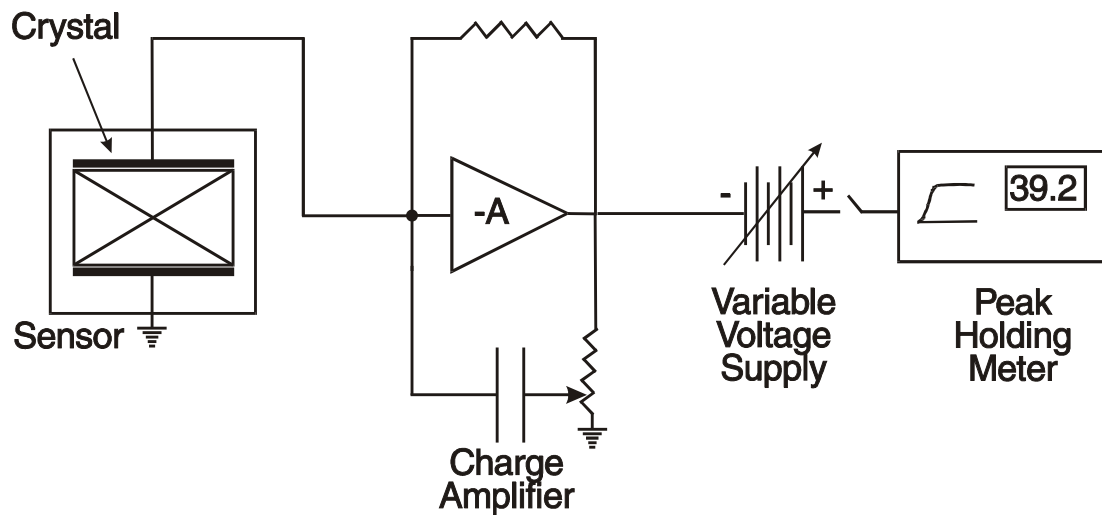
AN IMPROVED TECHNIQUE FOR UTILIZATION OF CONFORMAL BALLISTICS SENSOR CALIBRATION DATA

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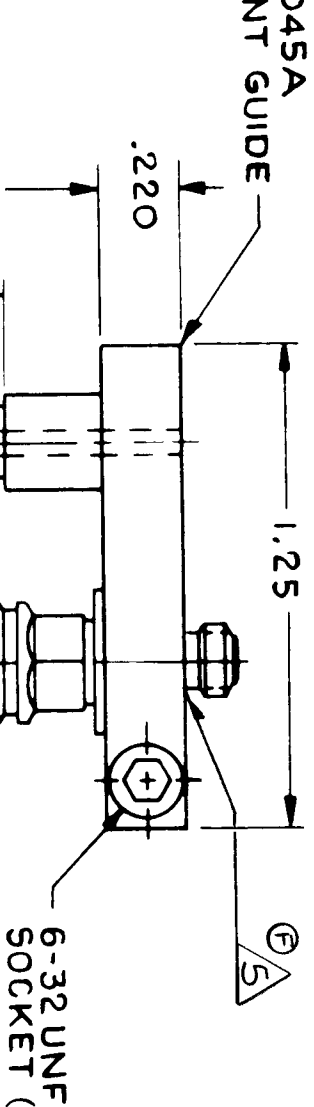
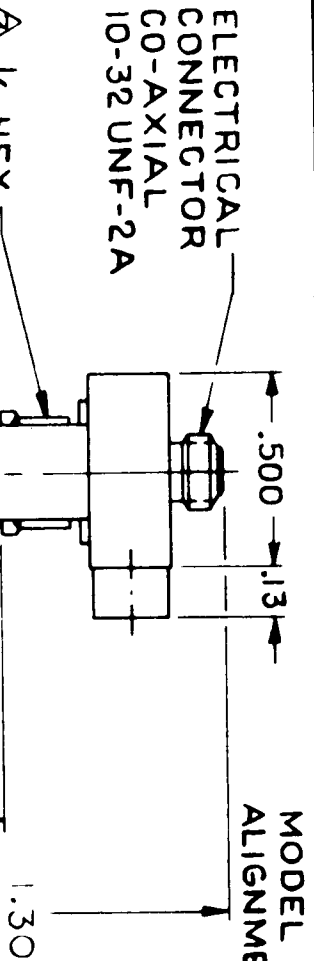
* Adds offset pressure (not available from PCB).



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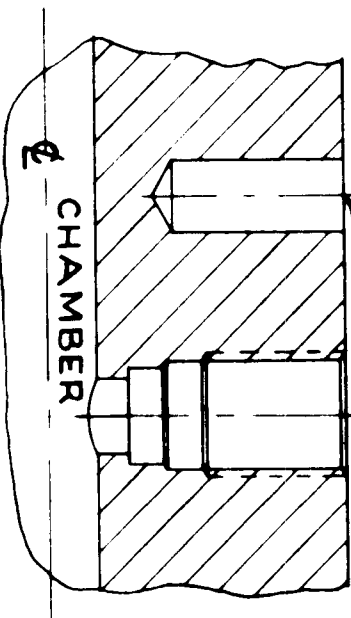
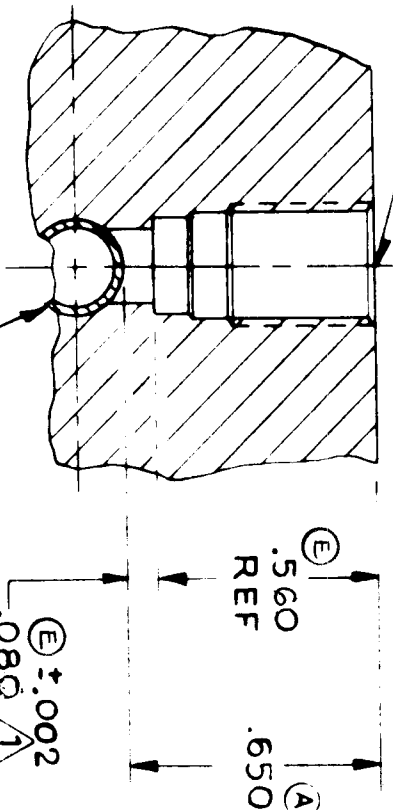
APPLICATION			
QTY.	NEXT ASSY.	USED ON	/A/R



REVOLUTIONS		
REV	DESCRIPTION	APP'D
A	.710 WAS .765, .650 WAS .700 ECR #99	206 4-26-77
B	.750 WAS .250 ECR #334	206 10-26-78
C	REV PER ECR #578	206 6-11-80
D	065A27 WAS A21 ECR #1056	206 11-24-82
E	REUSED PER ECR #1439 E4	206 4/12/84
F	APPROVED ECR #2087 E4	206 7/2/97

MODEL 065A27 SPACER SET
 CONSISTS OF 9 SPACERS
 .248 O.D. X .010 THRU .018 THK

DRILL #9 (.1960 DIA) THRU 1 WALL
 BORE 1/4 (.250 DIA) X .565 DEEP
 CD RILL "I" (.272 DIA) X .450 DEEP
 TAP 5/16-24 UNF-28 X .350 DEEP



OF XDCR HOLE TO BE
 PARALLEL WITH
 ALIGNMENT HOLE
 TO WITHIN ±15 MIN
 PILOT DRILL #16 (.177 DIA)
 X .500 DEEP MIN.
 REAM 3/16 (.1875 DIA)
 X .500 DEEP

LOCATE YELLOW DOT TOWARD CASE MOUTH.

ALIGNMENT HOLE MAY BE LOCATED EITHER
 FOR OR AFT OF XDCR MOUNTING HOLE.

MOUNTING TORQUE ON 1/4 HEX, 2-5 FT. LBS.

OF (.1960 DIA) HOLE MUST INTERSECT OF CHAMBER BORE WITHIN .001

HOLD THIS DIMENSION TO OBTAIN FLUSH MOUNT.

UNLESS OTHERWISE SPECIFIED:		MATERIAL	
DIMENSIONS ARE IN INCHES.		FINISH	
TOLERANCES		TITLE	
FRACTIONS : 1/64		INSTALLATION DRAWING	
DECIMALS : .005		MODEL 117B67 CONFORMAL	
ANGLES : 1/2 DEG		BALLISTICS TRANSDUCER	
BREAK SHARP EDGES		SCALE	
.003 - .005		2 X	

.750	22 WMRF
.250	22 WRF
"X"	CALIBER

pcb piezotronics, inc.
 BUFFALO, NEW YORK 14225

CODE	DWG. NO.
IDENT NO.	117-2670-90
SHEET	1 OF 1