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PRESSURE-PULSE GENERATOR FOR THE CALIBRATION OF PRESSURE GAGES

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UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND

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PRESSURE-PULSE GENERATOR FOR THE CALIBRATION OF PRESSURE GAGES

Prepared by:
P. M. Aronson and R. H. Waser

ABSTRACT: This report describes a pressure gage calibration device which is especially useful for piezoelectric-type gages having short RC decay times. The device produces a positive - going, isothermal pressure pulse which is in the form of a step pulse with a rise time of less than 100 microseconds. Calibration pressures from 0.1 psi to 1,000 psi are obtainable using any gas as a working medium. Provision is made for simulating ambient pressures from high vacuum to several hundred psi during calibration.

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U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

PRESSURE-PULSE GENERATOR FOR THE CALIBRATION OF PRESSURE GAGES

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The authors wish to acknowledge the work done by Mr. C. Holthaus in running tests with this calibration device as well as for helpful suggestions concerning design modifications.

R. E. ODENING
Captain, USN
Commander

a. e. Seigel
A. E. SEIGEL
By direction

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INTRODUCTION

Piezoelectric pressure gages are generally used in the NOL shock tunnels for measuring test section pressures. Most commonly, barium titanate and lead zirconate crystals are used as the sensing elements in these gages. Because these crystals have the inherent characteristic of charge leakage (RC decay), these gages cannot be calibrated statically. Accordingly, a pressure-gage calibrator, described herein, has been designed and built to calibrate these gages. This calibrator uses any gas as a working medium, applying a pressure pulse to the gage to be calibrated by the operation of a fast opening poppet valve. The pressure pulse seen by the gage to be calibrated is of the form of a positive going step pulse with a rise time which can be made less than 100 microseconds. The pressure range of the calibrator is 0.1 psi to 1,000 psi. Provision is made for pressurizing the gage to any initial ambient pressure from a vacuum to several hundred psi before the calibration pulse is applied. The pressure pulse is isothermal, so that the effect of temperature on the gage to be calibrated does not have to be taken into account.

DESCRIPTION OF CALIBRATOR

Figure 1 is a drawing of the pressure-pulse generator. The pressure gage to be calibrated is inserted in the top of the device. The gage shown in figure 1 is in the form of a long rod with the sensing area being only the lower plane end. There is a very small cavity left between the end of the gage and the poppet valve. With the poppet valve closed, the entire area around the gage is sealed so that it may be evacuated or pressurized through port "C" to any desired ambient pressure.

To produce a calibration pressure pulse, the main pressure reservoir is first pressurized to the desired value of $P_{reservoir}$ through port "A," and the impact weight is raised. Next, the ambient pressure, $P_{ambient}$, is established through port "C." $P_{calibration}$ equals $P_{reservoir}$ minus $P_{ambient}$. The push-pull valve is open while the ambient pressure is being established, so that the sensing element as well as the back end of the gage sees this pressure. Before the calibration pressure pulse is applied, this valve is closed so that the back end of the gage remains at the ambient pressure. (It is important that the main reservoir be pressurized and the impact weight raised before the ambient pressure is established if an ambient pressure other than high vacuum is used; otherwise, the poppet valve o-ring will be compressed during the main reservoir loading and lifting of the weight, resulting in a change of the volume of the cavity between the poppet valve and gage, and a corresponding change in ambient pressure.) The poppet valve is opened by dropping the impact weight onto the impact plate assembly. This action opens the poppet valve rapidly and maintains it in the open position for the duration of the calibration pulse. A piezoelectric crystal is mounted in the impact plate assembly to trigger the sweep of an oscilloscope just prior to the opening of the poppet valve. This oscilloscope, equipped with a camera, is used to record the voltage output of the pressure gage being calibrated. Figure 2 is a photograph of the pressure-pulse generator. The complete calibration set-up including the pressure-pulse generator, the pressure gages used as standards, and vacuum pumps used to produce low ambient pressures are shown in figure 3. The recording oscilloscope is not shown.

The pressure pulse applied by the generator to the gage being calibrated is a step pulse (see fig. 4). The rise time of this pulse is most dependent on the sound speed of the working gas used in the calibrator - the higher the sound speed, the shorter the rise time. Air produces a rise time of approximately 120 microseconds; helium produces a rise time of approximately 80 microseconds; hydrogen, which has not been used by the authors, should produce the minimum rise time obtainable. The duration of the calibration pressure pulse is approximately 30 milliseconds, which is sufficiently long for obtaining a gage calibration. If desired, a pressure pulse of infinite duration may be obtained by removing the poppet valve closing spring.

CONSTRUCTION DETAILS

Particular consideration had to be given to the design of several of the pressure-pulse generator components (see fig. 1) to insure proper operation. One of these components is the push-pull valve used in setting the ambient pressure. Because of the extremely small volume which this valve shuts off between the poppet valve and gage, this valve must not change the volume as it is closed, or the ambient pressure will be changed to some unknown value. For this reason, a sliding valve with neoprene o-ring seals was designed which does not change the volume significantly when it is operated.

Another component requiring careful design is the poppet valve. A neoprene o-ring is used again for this seal. The o-ring groove narrows in width at the poppet valve face so the o-ring cannot come out. A minimal amount of o-ring squeeze is used so that there is little volume change during the poppet valve opening before the o-ring breaks its seal. The fact that some volume increase does occur results in an initial negative pressure pulse prior to the positive calibration pulse whenever an ambient pressure other than vacuum is used.

The impacting assembly (under the system support stand), which opens the poppet valve, merits some discussion. A cylinder with slots in the sides acts as a guide for the impact weight to insure that there is no bending of the valve stem which would result in improper sealing of the poppet valve. The impact plate assembly consists of three elements. On top is a plate which is impacted by the weight. This plate contains a piezoelectric crystal whose voltage output is used to trigger the sweep of the recording oscilloscope. Next is a neoprene cushion which damps the vibrations set up in the valve stem by the impact of the weight. On the bottom is a steel plate, screwed on to the valve stem, which transmits the impact to the valve stem.

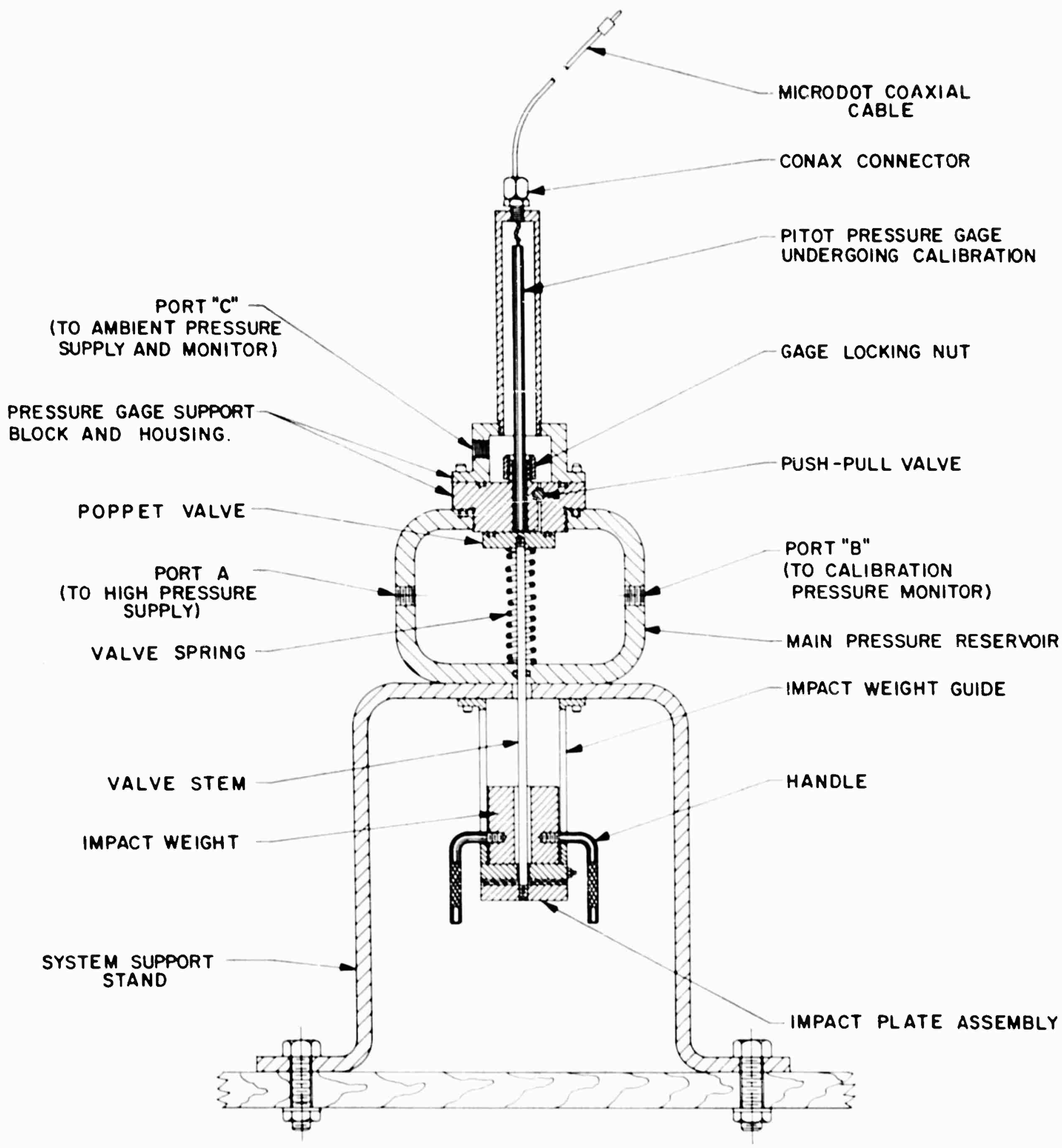
CALIBRATION ACCURACY

The accuracy of a pressure-gage calibration obtained with this device is governed by a number of factors, the most significant being the pressure gages used to set the pulse generator pressures and the overall accuracy of the readout system connected with the pressure gage being calibrated. One further factor which must be checked for cause of inaccuracy is the relationship between the pressure pulse rise time and the RC decay time of the gage being calibrated. If the pressure pulse rise time is long compared with the RC decay time of the gage undergoing calibration, there will be a significant electrical charge leakage before the pressure pulse reaches its maximum, with a corresponding calibration inaccuracy. To keep this calibration error below one percent, the pressure rise time must be less than one percent of the RC decay time of the gage and associated electronics; with a rise time of 200 microseconds, easily obtainable with this pulse generator, a RC decay time as short as 0.02 second can be tolerated with less than one percent calibration error.

DISCUSSION

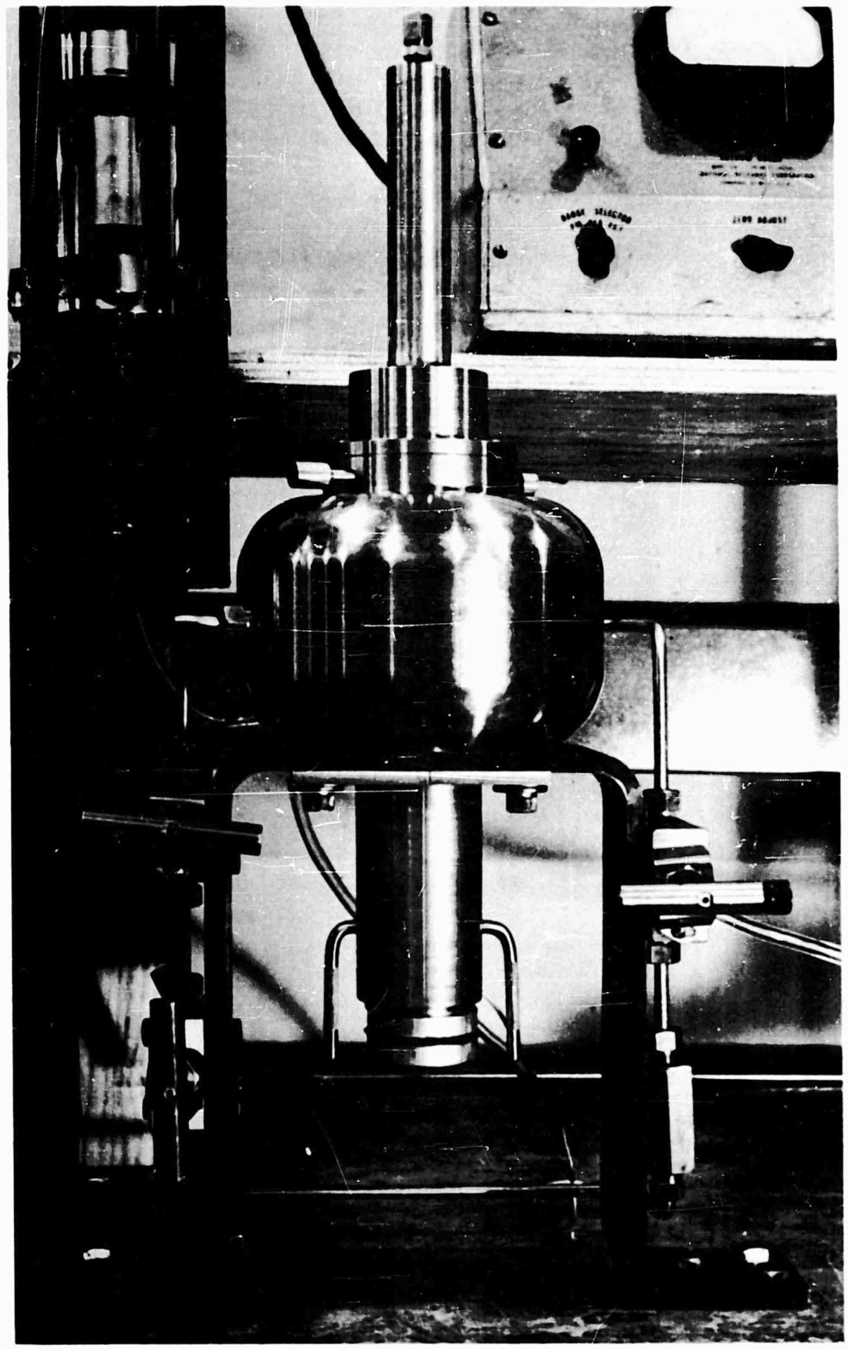
The pressure pulse generated by this calibrator is a positive-going pulse with sustained amplitude following the short rise time (see fig. 4). At the very beginning of the initial rise, there is a short negative pressure pulse whenever an ambient pressure other than zero pressure is used (see fig. 4b). This pulse results from the cavity volume between the gage and poppet valve increasing as the poppet valve o-ring expands before it breaks its seal as the valve is opened. Some low level, high frequency, pressure oscillations occur in the calibrator for a short time after the initial pressure pulse rise. These oscillations are caused by stress waves in the poppet valve stem (generated by the impact opening the valve) driving the poppet valve.

The pressure-gage calibrator described here has significant advantages over other types of calibration devices. It has first, the unusual capability of providing any desired initial ambient pressure prior to the application of the calibration pressure pulse. Over other calibrators utilizing a mechanical valve, this calibrator has the advantage of a shorter pressure pulse rise-time because of the design of the poppet valve and the impact opening method. Over shocktubes and other devices utilizing diaphragms, it has the advantage of rapid operation since disassembly to replace diaphragms is not necessary; operation is particularly fast if several calibrations are desired at the same pressure, as the main reservoir maintains its pressure because of the large volume ratio between it and the cavity between the poppet valve and gage being calibrated. This calibrator also has the advantage over shocktubes of being an isothermal device, so that any temperature sensitivity of the gage to be calibrated does not affect the calibration. Although the foregoing discussion has described this calibrator as being designed specifically for the calibration of piezoelectric type pressure gages, it should be pointed out that any type pressure transducer can be calibrated with this device.



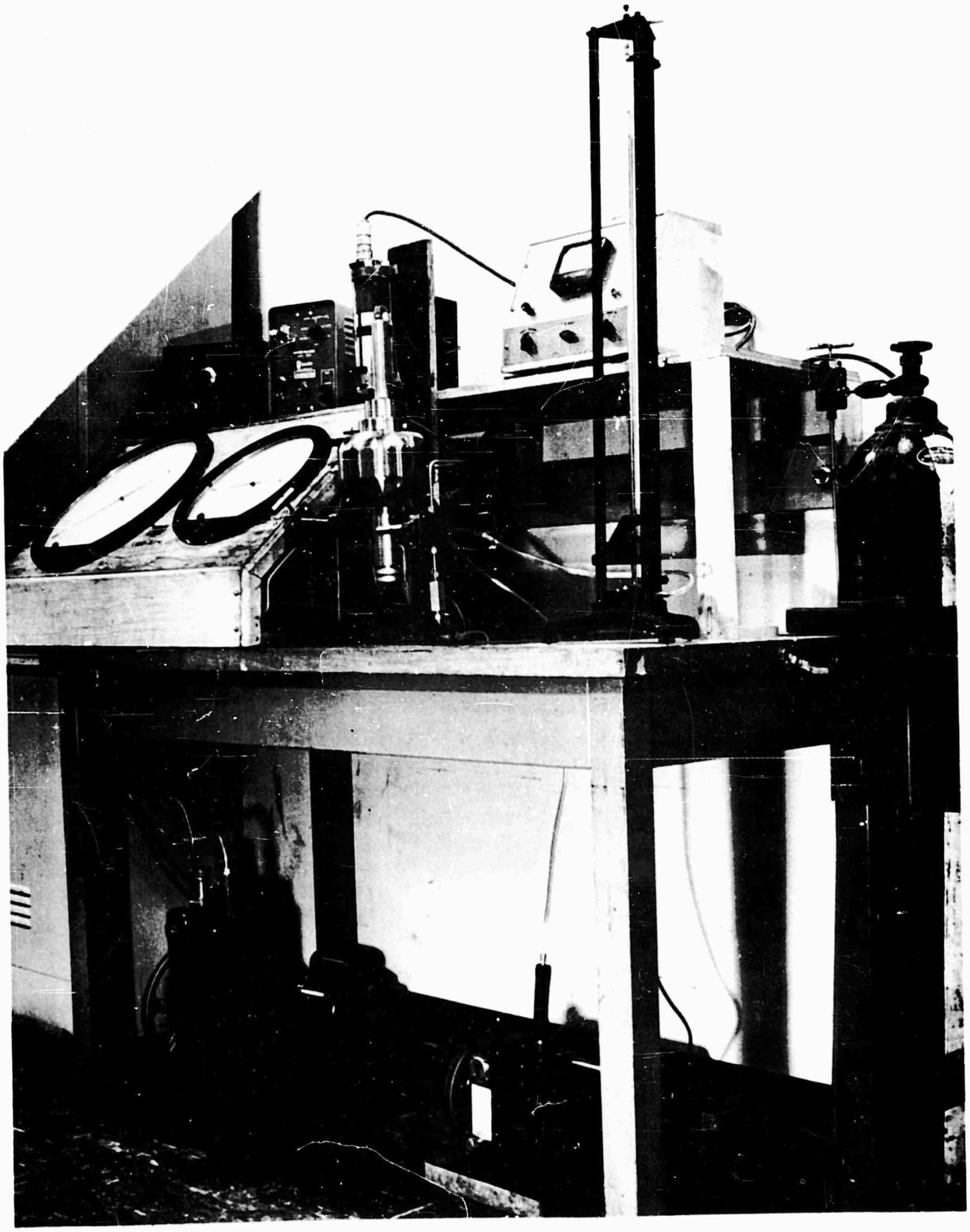
PRESSURE PULSE GENERATOR
(SECTIONED VIEW)

FIG. 1

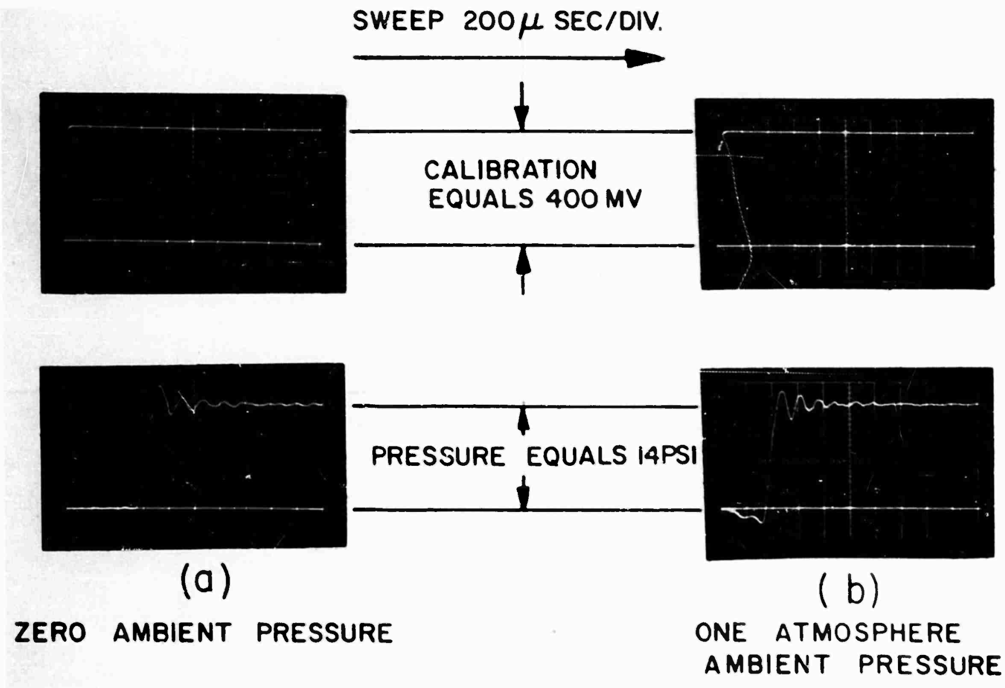


PRESSURE PULSE GENERATOR ASSEMBLY

FIG. 2



PRESSURE GAGE CALIBRATION SYSTEM
FIG. 3



CALIBRATION TRACES FROM A PIEZOELECTRIC GAGE.

FIG. 4

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SUBJECT ANALYSIS OF REPORT

DESCRIPTORS	CODES	DESCRIPTORS	CODES	DESCRIPTORS	CODES
Pulse	PULS	Simulation	SIMU		
Generator	GENR	Calibrator (Design)	CALBD		
Calibration	CALB	Calibrator (Fabrication)	CALBF		
Gages	GAGE	Accuracy	ACUR		
Pressure	PRES				
Device	DEVI				
Piezoelectric	PIEZ				
Positive	POSV				
Isothermal	ISOH				
Step	STEP				
Gas	GASE				
Medium	MEDU				

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3. Gages, Pressure - Calibration
4. Gages, Piezoelectric

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