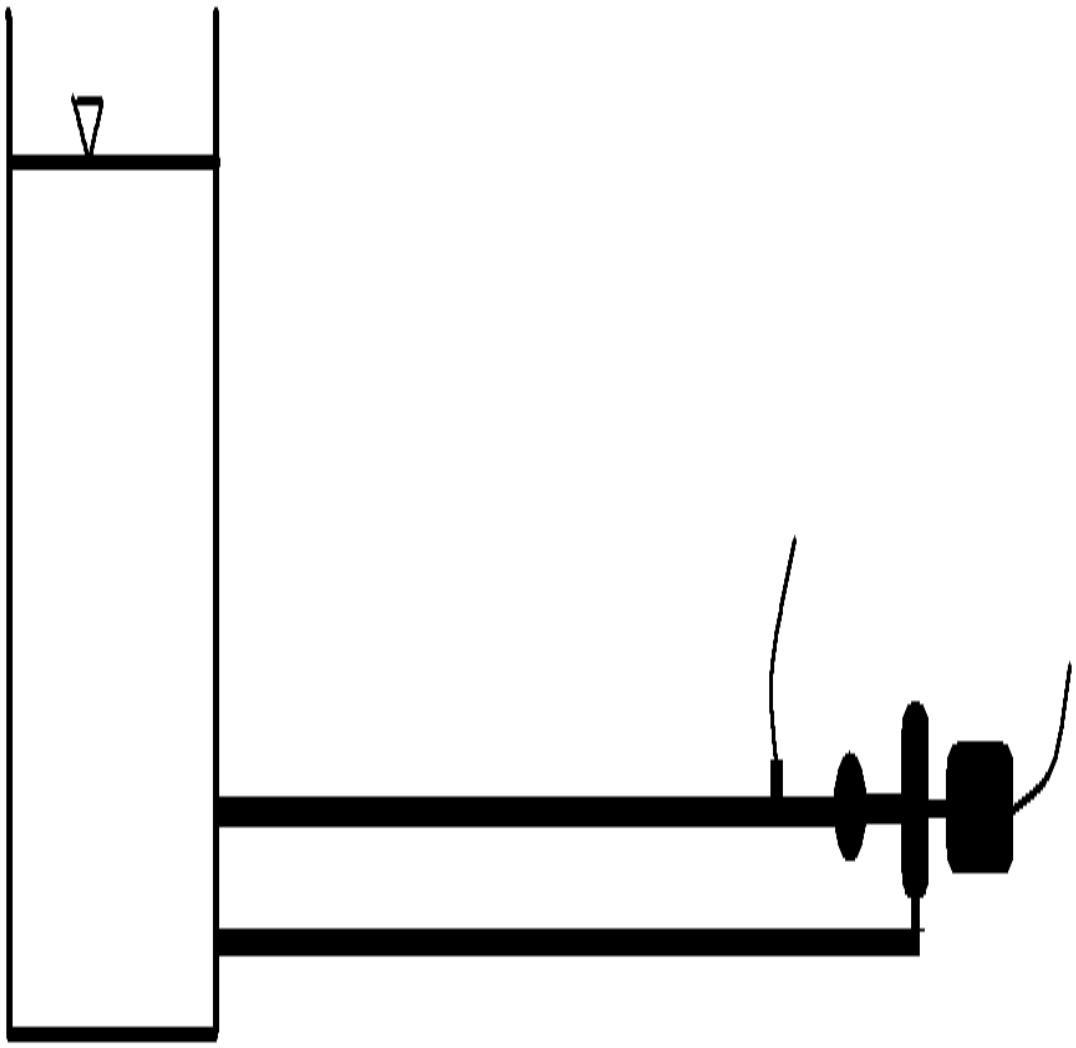
WATERHAMMER LAB

PURPOSE: The main purpose is to measure the wave speed for a water pipe and to compare the measured speed with theoretical speeds. Another purpose is to measure the pressure rise generated by a sudden valve closure and to compare this rise with a theoretical pressure rise.

SETUP: The setup consists of a pump which draws water through one long pipe from a tank and sends it back to the same tank through another long pipe. A high speed manual valve is installed just upstream of the pump inlet. A high speed pressure sensor is installed just upstream of the valve. It is used to measure the pressure transients that are generated by a sudden valve closure. The sensor is connected to an oscilloscope.

PROCEDURE: Use a sudden valve closure to determine the pipe period. Use the period to calculate the wave speed of the pipe. Compare the measured wave speed with the speed for a rigid pipe and the speed for a flexible pipe. Calculate the pressure rise for a number of flow rates and in each case compare with the theoretical pressure rise.



WAVE PROPAGATION IN PIPES

The pressure change caused by a flow speed change is

$$\Delta P = - \rho a \Delta S$$

For a wave travelling up a rigid pipe wave speed is

$$a = \sqrt{[K/\rho]}$$

where K is the bulk modulus of the fluid and ρ is its density. For a flexible pipe wave speed is

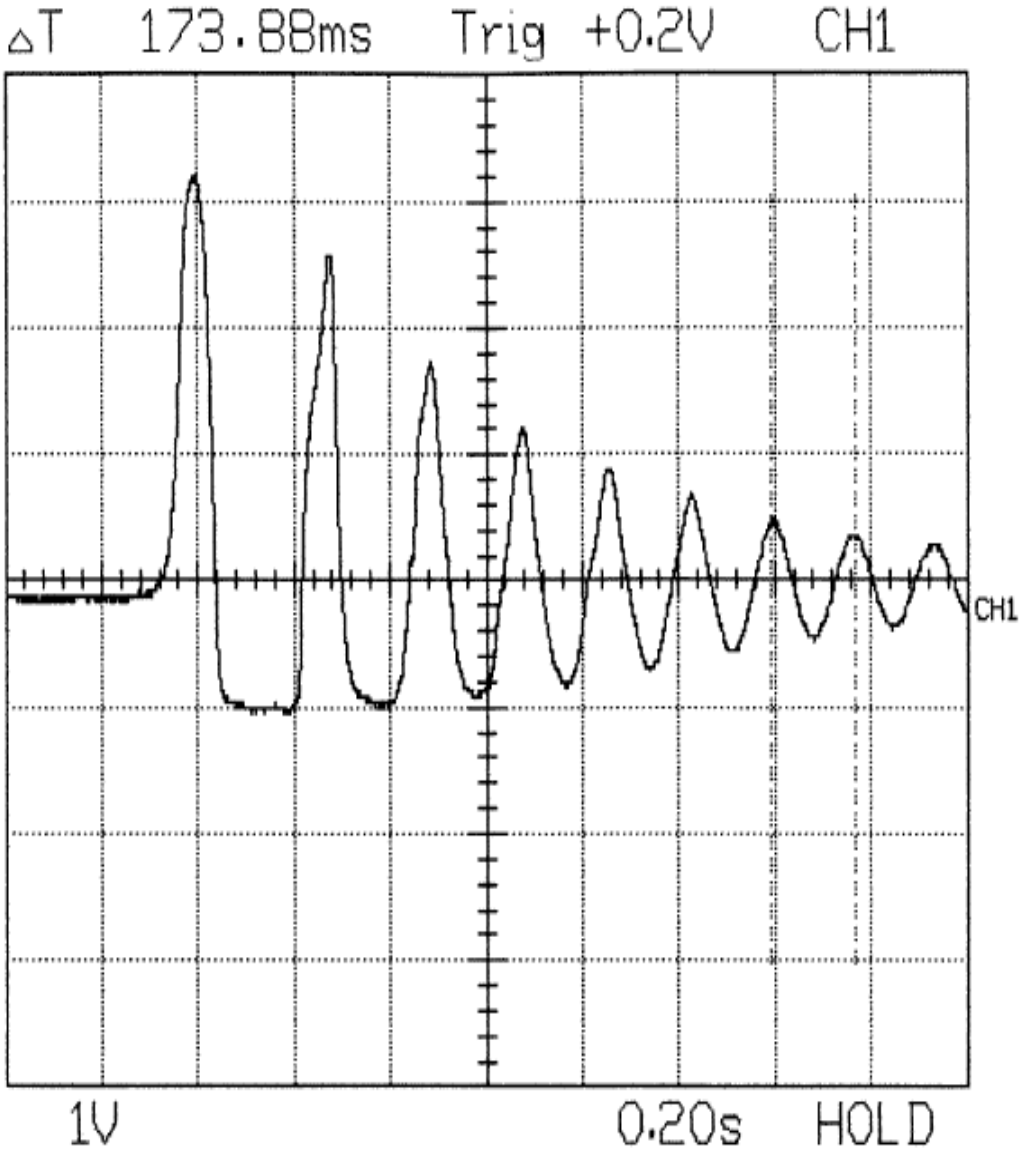
$$a = \sqrt{[\mathbf{K}/\rho]}$$

where **K** is the effective bulk modulus of the pipe

$$\mathbf{K} = K / [1 + DK/Ee]$$

where D is its diameter, e is its wall thickness and E is the Elastic Modulus of the pipe wall material. It takes 4 wave transits of a pipe to complete a cycle. This implies

$$T = 4 L / a \qquad a = 4 L / T$$


ΔT 173.88ms Trig +0.2V CH1
CH1
1V
0.20s HOLD

WATERHAMMER DATA SHEET

PIPE PERIOD

RUN	Q LPM	U M/S	ΔP VOLTS	ΔP_T BAR	ΔP_E BAR

SAMPLE CALCULATIONS

EXPERIMENTAL WAVE SPEED

$a_E = 4L/T$

THEORETICAL WAVE SPEEDS

$a_R = \sqrt{K/\rho}$

$\mathbf{K} = K / [1 + DK/Ee]$

$a_F = \sqrt{\mathbf{K}/\rho}$

PRESSURE RISE

$S = M\ Q$

$\Delta P_T = \rho\ a_E\ S$

$\Delta P_E = N\ \Delta P$

ABS PIPE DATA

$L = 13.41$ m

$D = 40$ mm

$e = 4$ mm

$E = 2.2$ GPa

WATER DATA

$K = 2.2$ GPa

$\rho = 1000$ kg/m^3

CALIBRATION FACTORS

$M = 0.013$ [m/s] / [lpm]

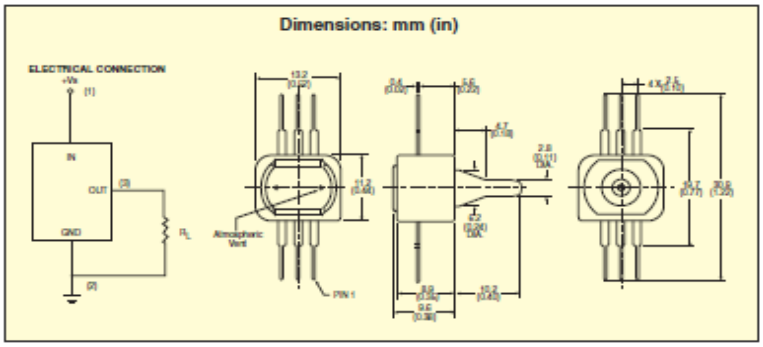
$N = 1.7$ [bar] / [volt]

MINIATURE VOLTAGE OUTPUT PRESSURE SENSORS
FULLY TEMPERATURE COMPENSATED

PX40 Series
0.5 to 4 Vdc Output

PX40-15G5V, $65, shown much larger than actual size.

All Ranges
$65



- Smallest Amplified Package
- Small Lightweight Package
- Fully Signal Conditioned
- Temperature Compensated
- Port Designed for O-Ring Interface
- Excellent Media Compatibility
- Wet or Dry Industrial Applications

Typical Applications

- Laboratory Equipment
- Electronic Brake Systems
- Engine Oil Level
- Transmission Fluid Level
- Air Conditioning Systems
- Industrial Fluid Level

SPECIFICATIONS

Excitation: 5 Vdc @10 mA
Output Source Current: 0.5 mA max
Output Sink Current: 1.0 mA max
Hysteresis and Repeatability: 0.15% FS

Span:	Output:	Linearity:
±50 mmHg	4.00 Vdc typical	0.80%
0 to 15 psi	4.00 ±0.11 Vdc	0.20%
0 to 30 psi	4.00 ±0.08 Vdc	0.30%
0 to 100 psi	4.00 ±0.09 Vdc	0.10%
0 to 150 psi	4.00 ±0.07 Vdc	0.10%

Null:

±50 mmHg	2.50 ±0.05 Vdc
0 to 15 psi	0.50 ±0.11 Vdc
0 to 30 psi	0.50 ±0.04 Vdc
0 to 100 psi	0.50 ±0.04 Vdc
0 to 150 psi	0.50 ±0.04 Vdc

Operating Temp:
-45 to 125°C (-49 to 257°F)
Compensated Temp:
-45 to 125°C (-49 to 257°F)
Overpressure:

±50 mmHg	±170 mmHg
0 to 15 psi	45 psi
0 to 30 psi	60 psi
0 to 100 psi	200 psi
0 to 150 psi	300 psi

Response Time: 1 ms
Gage Type: Silicon
Media Compatibility: Limited to media that will not attack invar, copper, silicon, stainless steel, glass and solder (i.e., air, water, refrigerants, engine fuel)
Vent: Dry gases only
Weight: 5 g (0.18 oz)

Recommended Reference Book:
What Every Engineer Should Know About Project Management,
GE-0511, $70
See Section Y
For Additional Books

☐ ***MOST POPULAR MODELS HIGHLIGHTED!***

To Order *(Specify Model Number)*

GAGE MODELS (One Port)

RANGE		MODEL NO.	PRICE	COMPATIBLE METERS*
±50 mmHg	6.7 kPa	**PX40-50BHG5V**	**$65**	DP24-E, DP25B-E, DP41-E
0 to 15 psi	0 to 1 bar	**PX40-15G5V**	**65**	DP24-E, DP25B-E, DP41-E
0 to 30 psi	0 to 2.1 bar	**PX40-030G5V**	**65**	DP24-E, DP25B-E, DP41-E
0 to 100 psi	0 to 6.9 bar	**PX40-100G5V**	**65**	DP24-E, DP25B-E, DP41-E
0 to 150 psi	0 to 10.3 bar	**PX40-150G5V**	**65**	DP24-E, DP25B-E, DP41-E

** See section D for compatible meters.*

Ordering Example: PX40-15G5V,** 0 to 15 psi transducer with 0.5 to 4.5 Vdc output, **$65.