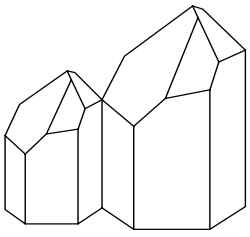
Application Note
Doc. G8108-001 Rev. A - 19-Sep-00

ACCURACY, PERFORMANCE, AND HANDLING OF OIL-FILLED DIGIQUARTZ® PRESSURE INSTRUMENTATION

For more information regarding Digiquartz® products contact:



Paroscientific, Inc.
4500 148th Ave N.E.
Redmond, WA 98052
Tel: (425) 883-8700
Fax: (425) 867-5407
Internet: http:\\www.paroscientific.com

Summary

Paroscientific pressure instrumentation may be used to measure pressure of gas or liquid media. Liquid media applications require that the transducer and buffer tube be filled with oil. The oil prevents the measurement media and contaminants from entering the transducer where they may cause damage. This technical note discusses issues relating to the accuracy and performance of oil-filled pressure instruments, an explanation of the oil-filling procedure, and handling of Digiquartz® pressure transducers. Oil-filled instruments are capable of accuracy comparable to their dry counterparts. In order to achieve high accuracy, it is necessary to carefully review this note and follow installation recommendations.

Instrument Configuration

When ordering a new instrument it is important to specify if the instrument is to be oil-filled.

- Instruments to be used with a non-condensing gas media should **not** be oil-filled.
- Instruments used to measure a liquid media should be oil-filled.
- If a condensing media is to be used with the instrument, you should contact Paroscientific to determine the proper configuration specification.

Note: Absolute pressure ranges of 15, 23, and 30 psia and all Paroscientific differential pressure ranges are not normally oil-filled due to the performance issues discussed below. Consult Paroscientific if your application requires a low-pressure, oil-filled instrument.

Also note that gauge pressure transducers can be configured to have the positive pressure port oil-filled. The reference, or atmospheric, pressure port remains dry.

It is important to note that a dry instrument may be oil-filled at a later date. Removing oil from an instrument is a difficult process. Success can not be guaranteed and instrument performance may be compromised. Proper specification at time of order is critical.

Use of Oil-Filled Instruments with Gas Media

It is not recommended that an oil-filled transducer be used with a gas media. The gas media can dissolve into the oil upon pressurization. When the system is depressurized, the gas will come out of solution, forming bubbles in the pressure port. This may push some of the oil out of the pressure port and lead to erroneous pressure measurements.

Measurement Errors Associated with Oil-Filled Instruments

There are a number of issues specific to oil-filled transducers that will affect the overall accuracy of your pressure measurement. Listed below are common problems areas...

- Air bubbles in a liquid line.
- Surface tension of the oil interface in the tubing system.
- Temperature induced measurement errors
- System tubing size and tension effects

These effects can exceed the 0.01% accuracy of Paroscientific transducers. In many cases, the combination of these errors can be as great as 0.03 psi.

Air Bubbles in a Hydraulic System

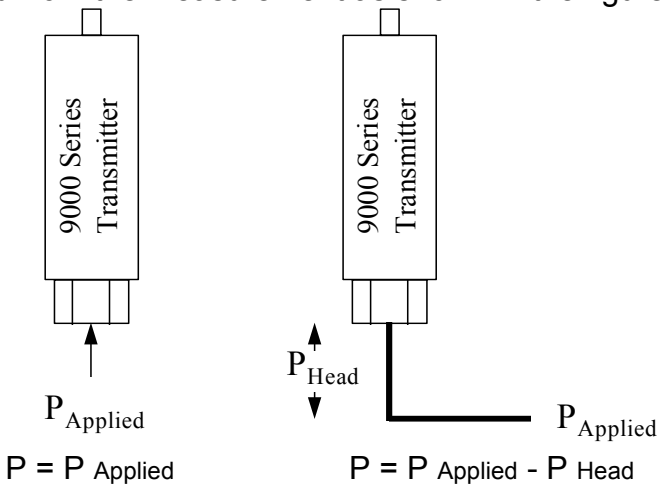
Air bubbles in a liquid measurement line will result in measurement response delays and can cause erroneous measurements. The contraction of gas bubbles under pressure can cause fluid motion and changes in head pressure. Changes in temperature can cause movement of bubbles with associated changes in meniscus tension and head pressure.

When installing the transducer, it is important to remove any residual gas in the measurement lines. Careful attention to installation and the use of purge valves will result in an air-free transducer interface.

Pressure Head Effects

A pressure head effect is defined as the measurement deviation caused by the oil interface and liquid media acting on the transducer's sensing mechanism. All Paroscientific transducers are balanced axially to reduce the effect of gravity on the sensing mechanisms. The additional weight of the oil amplifies these effects. This effect is best illustrated by rotating an oil-filled transducer off axis and monitoring the pressure reading. As the transducer is rotated a pressure offset will occur. Depending on the orientation of the instrument and any additional tubing, the head effects may be either positive or negative. It is necessary to compensate for this offset to achieve best accuracy.

Each transducer is subject to factory calibration adjustment after the oil-filling process is complete. This procedure requires that the transducer be placed in a known, consistent orientation. Unless noted otherwise, oil-filled depth sensors are placed with the port down as this is the most common orientation for depth measurements (oil-filled sensors for other applications are calibrated in the vertical position with the port up). If the transducer is to be used in an orientation other than that used during the re-zero process, a small offset equal to the head of the oil will be induced on the measurement. The addition of oil-filled lines to the transducer will also produce a head pressure that should be accounted for in the measurement. Head effects can be measured or calculated and should be appropriately tared from the measurement as shown in the figure below.



Calibrated any typical installation

Oil is retained within the transducer by surface tension. A vacuum condition will result in loss of oil and a change in the head effect. Never draw vacuum on an oil-filled sensor unless you are attempting to refill the sensor.

Careful consideration of oil-related pressure offsets will result in best transducer performance.

Temperature Related Effects

Variations in transducer operating temperature can cause the properties of the pressure media to change. These effects are typically very small. The effect will be amplified if there is air in the measurement system. Expansion and contraction of the air due to temperature changes will result in poor measurement stability.

Buffer Tubes and Surface Tension Effects

Buffer tubes are coiled pieces of tubing that are attached to the transducer pressure port. The buffer tube serves as a mechanical isolator to prevent shock or vibration from being transmitted directly to the transducer. The buffer tube also provides a means to connect the transducer to the measurement system. The buffer tube may be internal to the instrument package or externally attached to the sensor. Mechanical shock can result in a non-repairable failure of the sensor. It is recommended that the buffer tube not be removed. The oil-filling procedure is normally performed with the buffer tube attached to the transducer. Generally the tube is small in diameter and made from 1/16” stainless steel or 1/8” Nylon tubing.

The diameter and material type of buffer tube are determined by the transducers' full scale pressure range. Smaller tubing requires more pressure to reduce the surface tension effects of the oil. This effect can be as large as 0.01 psi, which is 0.01% of full scale for a 100-psia transducer. The pressure required to overcome the surface tension is inversely proportional to the internal radius. A larger diameter buffer tube must be used for transducers with a range of less than 100 psia in order to maintain the accuracy of the pressure sensor. Larger diameter stainless steel tubing will meet the surface tension requirement but is more rigid and will not meet the shock isolation requirement. The 1/8” Nylon tubing is used for oil-filled transducers with a full scale of less than 100 psia, in order to maintain acceptable shock isolation with a larger diameter tube.

Surface tension effects can result in relatively large pressure errors when using transducers with a full scale of less than 30 psi. We do not recommend oil-filling pressure ports on devices with a full scale of less than 30 psi, except after special order review.

Installation of Oil-Filled Instruments

It is important to remove any air bubbles in the system tubing before the oil-filled pressure transducer is connected. This can be done by filling the lines prior to connecting the transducer, or through the use of a properly positioned bleed valve. A slow acting bleed valve is recommended to prevent over-pressuring the pressure transducer. Fast moving fluids can generate a "water-hammer" effect, causing a pressure spike and possible transducer breakage. Always bleed lines with caution.

If a shutoff valve is used to isolate the pressure transducer from the system, it is important to be sure that the operation of the valve does not exert pressure on the transducer. Over-pressure can result if the volume of the system is reduced when the valve is closed. The incompressibility of the liquid-filled lines generates a pressure resulting in transducer damage.

Proper deployment of depth sensors is important, especially with shallow measurements. Be sure that there are no air bubbles at the pressure port. It may be helpful to remove and reattach the anti-fouling port after the sensor has been submerged. Water in the pressure port will force air from the anti-fouling port.

Summary of Errors

The combination of the deviations described above can result in errors as large as 0.03 psi (0.03% of 100 psi full scale). Careful installation of the instrument will result in best possible performance. Remember to...

- Purge all gas from a hydraulic system to eliminate bubbles.
- Calculate and compensate for head effects when changing sensor orientation.
- Be sure to calculate head effects when adding or removing additional oil-filled tubing.
- Be sure the sensor is mounted in a stable orientation.
- Minimize temperature changes.
- Do not expose the sensor to a vacuum condition.
- Purge line slowly when using valves and avoid closed systems with incompressible fluids.
- Calibrate and compensate for head effect using the same orientation of the sensor as used at the factory for initial calibration. For most oil-filled depth sensors, this is with the pressure port at the bottom.
- Use horizontal pressure lines in the calibration lab to avoid head effects.

Oil-Filling Described

Unless specified differently, Digiquartz® pressure transducers are oil-filled with Dow Corning FS-1265, 300-centistoke, silicone oil. This oil may be interfaced with most liquids. It is soluble in Freon and some hydrocarbon derivatives. It is possible to fill the sensors with other types of oils depending on application specific needs. Contact Paroscientific if your media is in question.

The oil-filling procedure occurs during final instrument assembly. In order to ensure that the sensor's complete internal volume is filled a vacuum filling technique is used. The pressure transducer is first evacuated to remove air from the pressure port. The oil is then introduced to the sensor as shown in Figure 2.

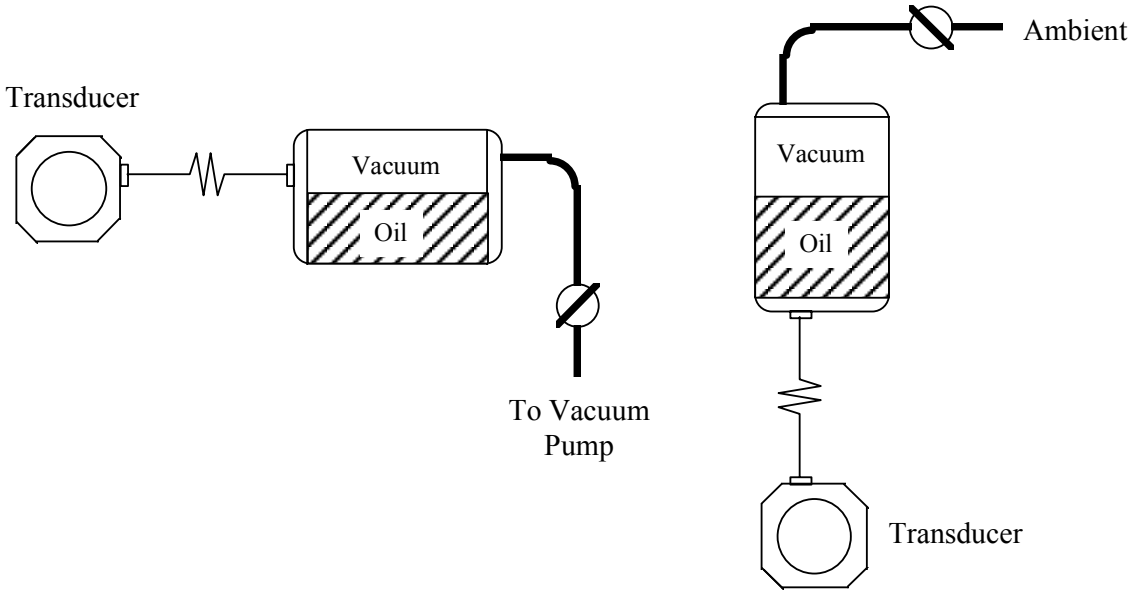


Figure 2

For optimum results, the oil should be degassed for one hour.
Open the valve to draw vacuum on the sensor.
Once vacuum is achieved, introduce the oil into the transducer pressure port.
Slight heating of the oil and stirring it with a magnetic stirrer speeds up the process.

For more information on oil-filling transducers contact Paroscientific.