

## Section 8 – Calibration

Complete calibration requires more than just determining the sensitivity at one or more values of input pressure. Kulite tests 100% of production, and supplies calibration data on the most important static input, electrical, and thermal characteristics. Dynamic characteristics are established from periodic sampling tests. All specifications and calibrations are in accordance with applicable ANSI and ISA standards.

### 8.1. Temperature Calibrations

Although Kulite's passive compensation technique reduces thermal zero shift and thermal sensitivity shift to very low values, there is some change of performance over temperature. If these inaccuracies are quantified, data can be corrected for improved accuracy. Kulite provides a test report giving measured data for each transducer. Not only is the maximum value tabulated, but curves plotting several temperature points can be provided to allow the user to correct zero and sensitivity data at any temperature in the operating range.

### 8.2. Electrical Calibrations

Bridge resistances and isolation resistance are very convenient quick checks and provide excellent indicators of the health of a transducer. The input and output resistance and isolation resistance are measured on each unit and are included on the test report. A multimeter/ ohmmeter can be used to measure the input and output resistances, ensuring that the voltage used is no greater than 10 volts dc to avoid damaging the transducer. As the resistances measured at the factory are made at room temperature, the values of input and output resistance may shift significantly with temperature variations. Therefore, variations in resistances of as much as 25% from the room temperature values on the test report should be considered acceptable. Insulation resistance measurements using a voltage of 50 volts dc maximum between a) all leads connected together and case, b) all leads connected together and cable shield and c) cable shield and transducer case should all be greater than 100 megohms. In certain configurations, the cable shield may be connected to the transducer case, in which case the measurement c) will be zero.

### 8.3. Static Calibrations

Ranges up to 1000 psi are calibrated on computer-controlled automatic test facilities, using gas as the pressure medium. Ranges above 1000 psi range are calibrated manually using oil or alcohol media. The calibration standards all have accuracies better than  $\pm 0.01\%$ .

Computer-controlled calibrations are performed at zero and 20% increments of full scale to 100%. Manual calibrations are performed at zero and 25% increments of full scale. For all transducers the test data is fed into a computer which calculates the test parameters, plots nonlinearity, thermal zero shift and thermal sensitivity shift, and prints out the test report. The computer then compares the test data with stored specification limits and accepts or rejects each transducer.

Measurements are first made at zero pressure, then 2 times full scale, then zero, to establish zero shift after 2 x FSO. Then two complete cycles from zero to full scale and return are performed, measuring output at 20% (or 25%) increments. These data points are used for calculation of nonlinearity, hysteresis, and non-repeatability.

All output measurements are made typically with 10.0 Vdc excitation applied. For aircraft pressure transducers there will be an agreed Acceptance Test Procedure (ATP) which is carried out on each transducer.

### **8.3.1. Dead Weight Testers**

Dead weight testers are primary standards that are used to generate precise pressures for calibrating pressure measuring instruments. They are primary standards because the factors influencing the accuracy of the generated pressure are traceable to standards of mass, length, and time.

The accuracy of the pressure generated by a dead weight tester is dependent only on the accuracies of the weight and area measurements at operating conditions.

Corrections are often applied for 1) local acceleration of gravity, 2) air buoyancy, 3) change of piston area caused by temperature, 4) change in effective area due to pressure, and 5) difference in height of test instrument. Consideration of the magnitude of these corrections under actual operating conditions may indicate that some, or all, can be ignored.

## **8.4. Dynamic Calibrations**

Most pressure measuring instruments are calibrated statically in order to achieve the greatest possible accuracy. However, the accuracy available in dynamic measurements cannot be extrapolated from only static calibrations.

The prime reasons for conducting dynamic pressure calibrations are to evaluate the frequency response of a measurement system used in a dynamic application. To complete this calibration, either a continuous wave (periodic) input or transient input (step, pulse, etc.) can be used. Calibration uncertainties for both of these approaches are much larger than for the static calibration approaches, so they are not generally used for acceptance testing of static responding transducers.

Several of the more commonly used methods of dynamic calibration are described below:

### **8.4.1. Oscillating Pressure Calibrations**

Comparison pressure calibrations can be performed dynamically with a range of sinusoidal pressure generators, four of which are described briefly here:

#### **8.4.1.1 Hydraulic Pressure Generator**

This device incorporates a compression spring, piston and seismic mass assembly, hydraulic oil-filled chamber, and mounting cavities for the reference standard and test transducers. Sinusoidal vibratory motion applied to the generator housing imparts sinusoidal pressure to oil which is exposed simultaneously to the sensing surfaces of both transducers providing a direct comparison calibration capability..

#### **8.4.1.2. Vibrating Liquid Column**

Sinusoidal vibration of a vertically-mounted liquid column provides a dynamic pressure which is applied to a test transducer mounted at the bottom of the tube. By attachment to an electrodynamic vibrator, short liquid columns can be used to provide about  $\pm 5$  psi from about 50 Hz to 2000 Hz. Amplitude is limited since the approach is only linear over  $\pm 1\%$ . Low frequency is generally limited by the vibrator and the high frequency is limited by the resonance frequency and damping of the liquid column. Calibration errors are better than  $\pm 4\%$ . One advantage of this technique is that it is a primary calibration (since it is not simply a comparison to another transducer). Because of its limited amplitude and frequency range, the vibrating liquid column is seldom used.

#### **8.4.1.3 Inlet Modulated Pressure Generator**

The Inlet Modulated Pressure Generator (IMPG) consists of a wheel with holes drilled through

its periphery which is rotated at high speed. Air is blown through the holes from one side of the wheel and there is a cavity on the opposite side of the wheel in which are located the transducer under test and a reference transducer. The frequency of the signal generated is directly proportional to the speed of rotation. Frequencies of up to 12 kHz can be generated with pressure amplitudes of 1 Bar at 1 kHz falling to 0.1 Bar at 12 kHz. Static mean pressures can be generated of up to 7 Bar.

#### **8.4.1.4 Gulton Whistle**

The Gulton whistle consists of a tube which is sharp edged at one end and is closed with a moveable piston at the other. Air which is blown over the edge of the tube excites the first organ pipe resonance. The resonant frequency is adjusted by the position of the piston within the tube. Mounted in the piston are the reference pressure transducer and the transducer under test. Figure 8-5. Frequencies of up to 4.5kHz can be generated with pressure amplitudes of up to 0.1 Bar. Static mean pressures can be generated of up to 20 Bar.

#### **8.4.1.5 Gas Pistonphone**

Periodic pressure oscillations are generated by a piston moving in and out of a small gas cavity. Using a motor to drive a piston, pressures of 124 dB SPL are obtained at 250 Hz. Accuracy is  $\pm 2.5\%$  when calibrated optically to determine piston displacement. The dynamic pressure is a function of the relative volume change.

### **8.4.2. Step Pressure Generators**

#### **8.4.2.1. Fast Acting Valves**

Liquid: To provide a dynamic calibration at high pressures a convenient and safe method is to quickly release the pressure in a closed liquid system. Figure 8.9 shows such a method using an oil dead weight system and a fast acting ball valve. Pressure can be ramped from one value to another within about 1 ms using this method. For this approach to be accurate the measurement system must have flat frequency response for the frequency content of the pulse. The starting and ending static pressures are accurately known.

Care must be taken to protect the dead weight tester. Also, note that the pressure change is negative-going, which is not representative of many usage applications. Valve action may not be highly repeatable. However, this method provides a good comparison or evaluation test.

Gas: Step pressures in gas can also be achieved by opening fast-acting valves between gas pressure vessels. This method may be preferable for transducers which are incompatible with liquid media. However, greater care must be taken in designing and operating a high pressure gas system because of the greater danger of explosion.

#### **8.4.2.2. Gas Shock Tubes**

Small shock tubes are often used to provide rise time and frequency response characteristics for transducers. Because of difficulties in determining the pressure level in the step, shock tubes are not usually used for pressure sensitivity calibration. Pressure rise times of about 1 microsecond are practical, which permits transducer characterisation to frequencies beyond 100,000 Hz. Kulite uses shock tubes to determine the frequency response of all diaphragm designs.

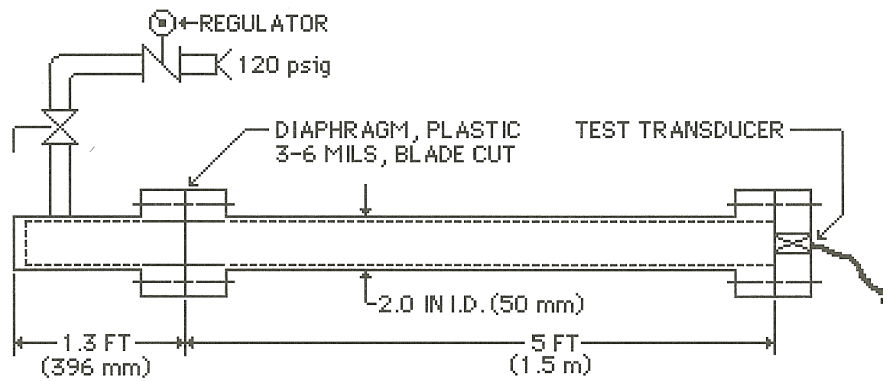


Figure 8-10: Pressure Shock Tube

The excitation source is a shock tube which has a 2.5-inch diameter cylindrical cross section with a 15-inch driver end and 60-inch driven end. The tube sections are mechanically coupled by a bolted flange which can be disengaged to enable insertion of a diaphragm material as a separator. The driver section is pressurised with a gaseous medium until the test pressure is reached. The membrane is then punctured by a pneumatically actuated needle from outside the shock tube. This results in the sudden release of the pressurised air into the lower pressure driven compartment and produces a hypersonic shock wave front which impinges the end plate in which the pressure transducer is flush-mounted. The transducer diaphragm is thus exposed to a very fast rise time pressure step which has significant high frequency content, such that extended frequency response information is available.