



# FLOW ANGLE PROBE MINIATURE PRESSURE TRANSDUCER

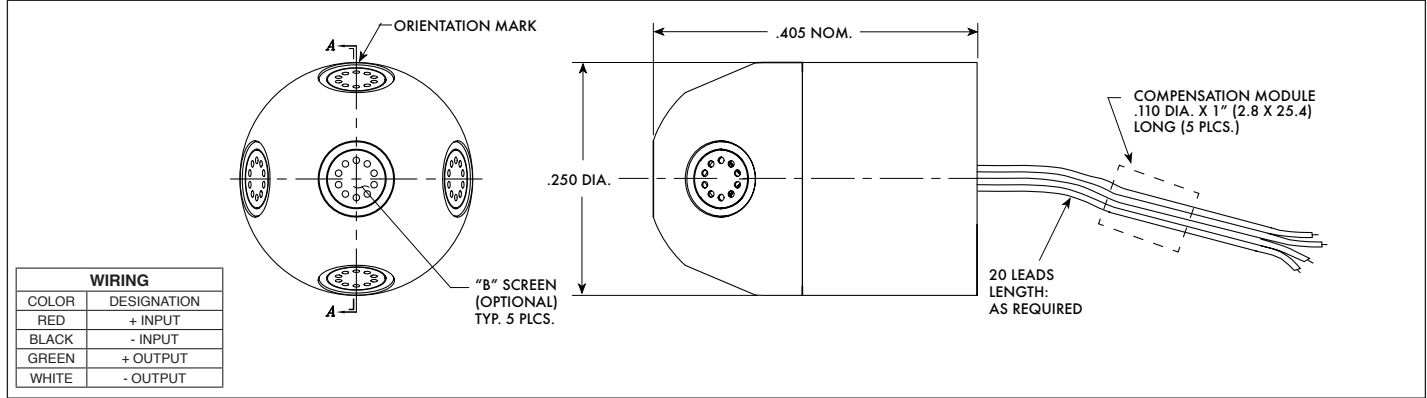
## FAP-250 SERIES

- High Frequency, High Accuracy Performance
- Patented Ultra Miniature Rugged Design
- Ideal For Aero Propulsion Measurements and Complex Flow Structures
- Patented Leadless Technology VIS®

The FAP-250 design features Kulite's patented SOI leadless technology with sensors positioned at the tip of the probe head. These fast response probes are ideal for aerodynamic measurements with complex flow structures, including turbomachinery flow distortions diffusers/mixers. The 5 position sensor construction allows concurrent measurements of 2 flow angles, total and static pressure, Mach number and flow speed.



Kulite recommends the [KSC Series](#) of signal conditioners to maximize the measurement capability of the FAP-250 transducer.



INPUT	Pressure Range	3.5 50	7 BAR 100 PSI
	Operational Mode	Absolute	
	Over Pressure	2 Times Rated Pressure With No Change in Calibration	
	Burst Pressure	3 Times Rated Pressure	
	Pressure Media	Most Conductive Liquids and Gases - Please Consult Factory	
	Rated Electrical Excitation	10 VDC	
	Maximum Electrical Excitation	12 VDC	
	Input Impedance	1000 Ohms (Min.)	
OUTPUT	Output Impedance	1000 Ohms (Nom.)	
	Full Scale Output (FSO)	100 mV (Nom.)	
	Residual Unbalance	± 5 mV (Typ.)	
	Combined Non-Linearity, Hysteresis and Repeatability	± 0.1% FSO BFSL (Typ.), ± 0.5% FSO (Max.)	
	Resolution	Infinitesimal	
	Natural Frequency of Sensor Without Screen (KHz) (Typ.)	300	380
	Acceleration Sensitivity % FS/g Perpendicular	3.0x10 <sup>-4</sup>	1.5x10 <sup>-4</sup>
Insulation Resistance	100 Megohm Min. @ 50 VDC		
ENVIRONMENTAL	Operating Temperature Range	-65°F to +250°F (-55°C to +120°C)	
	Compensated Temperature Range	+80°F to +180°F (+25°C to +80°C) Any 100°F Range Within The Operating Range on Request	
	Thermal Zero Shift	± 1% FS/100°F (Typ.)	
	Thermal Sensitivity Shift	± 1% /100°F (Typ.)	
	Steady Acceleration	10,000 g. (Max.)	
Linear Vibration	10-2,000 Hz Sine, 100g. (Max.)		
PHYSICAL	Electrical Connection	4 Leads 36 AWG (Length as Required)	
	Pressure Sensing Principle	Fully Active Four Arm Wheatstone Bridge Dielectrically Isolated Silicon on Silicon Patented Leadless Technology	

Note: Custom pressure ranges, accuracies and mechanical configurations available. Dimensions are in inches. Dimensions in parenthesis are in millimeters. All dimensions nominal. (l) Continuous development and refinement of our products may result in specification changes without notice. Copyright © 2014 Kulite Semiconductor Products, Inc. All Rights Reserved. Kulite miniature pressure transducers are intended for use in test and research and development programs and are not necessarily designed to be used in production applications. For products designed to be used in production programs, please consult the factory.

# FULLY INTEGRATED MINIATURE, HIGH FREQUENCY FLOW PROBE UTILIZING LEADLESS, SOI TECHNOLOGY SUITABLE FOR GAS TURBINES

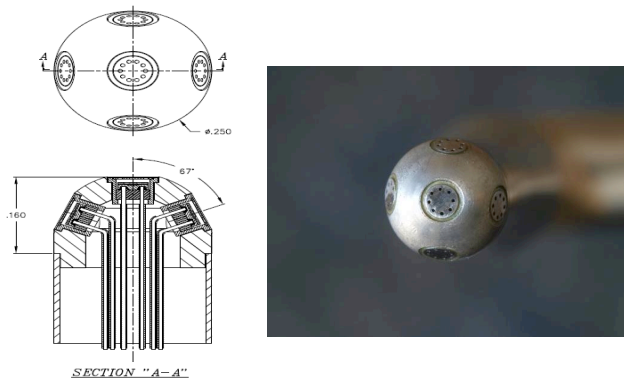
Alexander A. Ned, Dr. Tonghuo Shang, Scott Goodman, Adam Hurst, Dr. John Chivers  
Kulite Semiconductor Products, Inc.

Dr. Gerald R. Guenette  
Massachusetts Institute of Technology

Raymond S. Castner  
NASA Glenn Research Center

The measurement of pressure and flow direction have been essential measurements in the development of turbomachines since the very early days of the gas turbine. More recently, these measurements have been used in flow field diagnosis to verify the correct operation of a turbomachine. Over the last three decades there has been a requirement to measure time-varying pressures in turbomachinery applications which have necessitated measurement bandwidths in the order of 100 kHz and the silicon piezoresistive pressure sensor has been the device which has most frequently been used for many of these measurements.

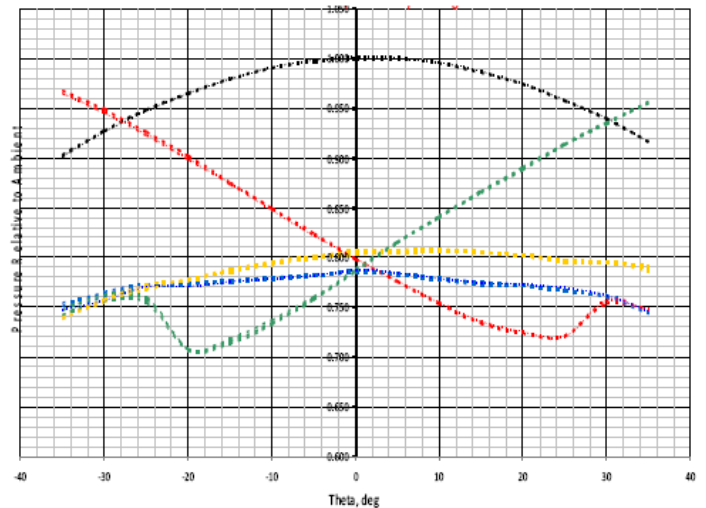
This paper concentrates on the design and application of a 5-hole pressure probe designed for the accurate measurement of unsteady total pressure and flow angle for turbo-machinery applications. Fast response pressure probes have the advantage of offering a high analogue bandwidth, a high signal-to-noise ratio, and a good reliability and robustness as compared to hot-wire techniques for instance. In addition to the magnitude and direction of the flow velocity vector, aerodynamic probes also indicate the total and static pressure as time-resolved quantities. Appropriate data processing then derives not only the steady, but also the periodic and random components of the measured variables.



**Figure 1: High Temperature 5-Hole Probe**

The first generation of the smallest, high frequency 5-hole flow probe was developed and optimized. As part of this development effort, specifically designed, ultra miniature, leadless piezoresistive sensors were fabricated and optimized. The probe hardware and all associated assembly and interconnecting processes were established and optimized. Both static and dynamic testing of the sensors demonstrated excellent

performance characteristics with sensors having a natural frequency above 530 kHz with flat response to 100 kHz.



**Figure 2: Pressure Reading as Function of Yaw Angle with Elevation Angle of 0 Degrees. Five runs show excellent overlap**

Aerodynamic testing performed at MIT provided excellent validation of the five position flow angle probe design. The goal of pressure sensor positioning was to measure pressure variations as a function of flow angle; thus in reverse pressure measurements can be used to deduce flow angle data. Test data obtained at MIT/GTL provided the expected sensor response to flow angle. For instance, the nose sensor's pressure reading drops as it moves away from the incoming flow, whereas the left (or right) sensor's pressure increases as it moves toward the incoming flow.

At early stages of this development effort there were some concerns if small surface discontinuities on the probe's spherical shape can lead to uncertainties to probe performance. Test data shows these concerns are insignificant, because repeated probe performance calibrations demonstrated excellent repeatability and stability in probe performance. The tests also showed excellent flow angle range; probe performance was shown to be stable to a flow angle range of at least +/- 35 degrees, which is the measurement range achievable at test.