# *Test & Data Analysis Draft Plan – Evaluation of a Total Pressure Transducer with Digital Compensation for Engine/Inlet Compatibility Testing*

U.S. AIR FORCE

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kulite®


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**412TW-PA No.:**

# Background/Purpose

- For the last 30 years the aircraft engine inlet test community have used a combination of electronic and pneumatic transducers and associated analysis techniques to capture airflow pressure characteristics at the engine face.

- This dual approach was necessary for the high accuracy needed to measure both steady state (DC content) total pressure as well as high response (AC content) dynamic pressure fluctuations over a wide variety of inlet operating conditions. Historically, piezoresistive high response transducers were susceptible to thermal drift making their DC signal accuracy unacceptable.

- Kulite®, using a SBIR effort, has developed and validated a miniature absolute piezoresistive pressure sensor in conjunction with high-resolution digital electronics for sensor output amplification and correction that have shown transducer accuracy similar to steady state accuracy transducers (0.1% error based on full-scale over a wide temperature range (50°F - 250°F)).

**The purpose of this test would be to demonstrate to the propulsion T&E community that a single piezoresistive pressure transducer can provide both accurate steady state (DC content) and dynamic measurement (AC content) across a range of operationally representative flight conditions**

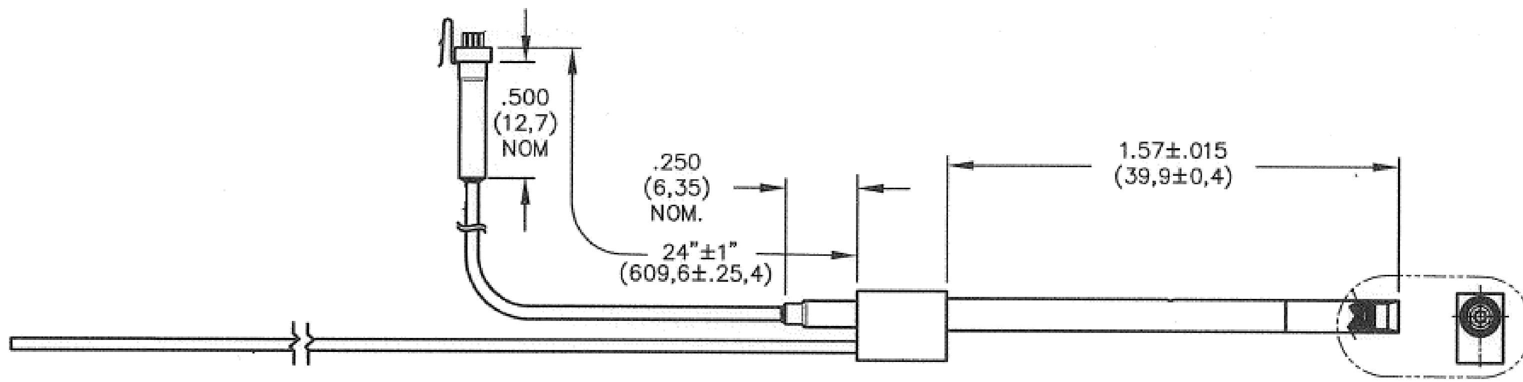
# Benefits of a Single Transducer

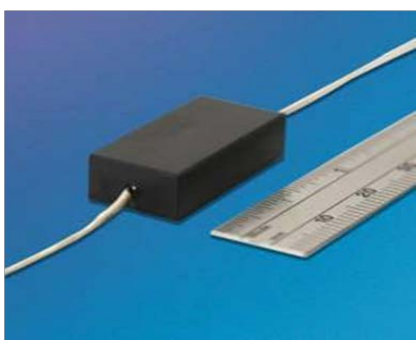
1. Cost reduction from removal of the steady state pressure scanner and reference transducer
2. Reduction in installation and sustainment costs
3. Improved accuracy  from eliminating steady state pressure pneumatic lag and time sync concerns from two unique data sources
4. Reduced costs from signal conditioning on data acquisition system and post-test
5. Reduced airflow blockage at the aerodynamic interface plane

# Test Item Configuration

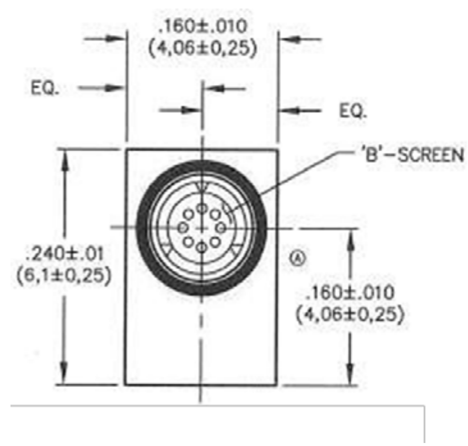
Two primary test configurations:

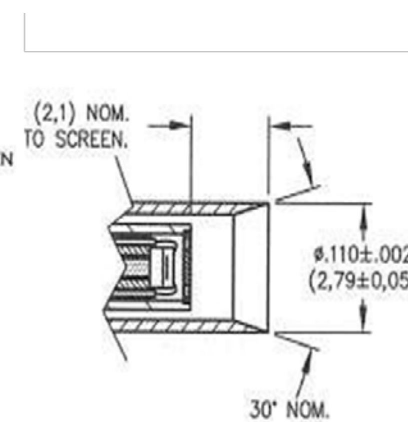
1. Concentric total pressure probe baseline
2. Concentric total pressure probe with latest high-accuracy electronic digital compensation



High-Resolution Digital Compensation
(calibrated from -40 to 250 deg F)

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# Transducer Specifics

| | Manufacturer | Model Number | AC/DC Coupled | Pressure Range (psia) | Sample Rate (Sps) | Compensated Temp Range (deg F) |
|---|---|---|---|---|---|---|
| **Configuration #1** | | | | | | |
| High Response Transducer | Kulite | XCP-110-25A | DC | 0 - 25 | 18K | +75 to +150 |
| Steady State Transducer | Mensor | - - - | DC | - - - | - - - | - - - |
| **Configuration #2** | | | | | | |
| High Response Transducer w/digital compensation | Kulite | XCP-110-DCA-25A | DC | 0 - 25 | 18K | -40 to +250 |
| Steady State Transducer | Mensor | - - - | DC | - - - | - - - | - - - |
| **Facility Stilling Chamber Pressure** | | | | | | |
| Steady State Transducer | Mensor | - - - | DC | - - - | - - - | - - - |
| **7-Hole Probe or Reference Probe** | | | | | | |

# Test Objectives

**Overall Test Objective**:

Evaluate the total pressure measurement performance of a digitally compensated transducer within a concentric probe design

**Specific Test Objective**:

1) **Evaluate the high response transducer's DC content thermal drift with and without the digital temperature compensation package**
2) Evaluate probe steady state and high response flow angularity sensitivity
3) Evaluate the dynamic response from impulse shock tube (Complete; Performed by the manufacturer)
4) Evaluate dynamic bandwidth using a rotating apparatus (Complete; Performed by the manufacturer)

# Objectives 1 & 2
# Test Matrix

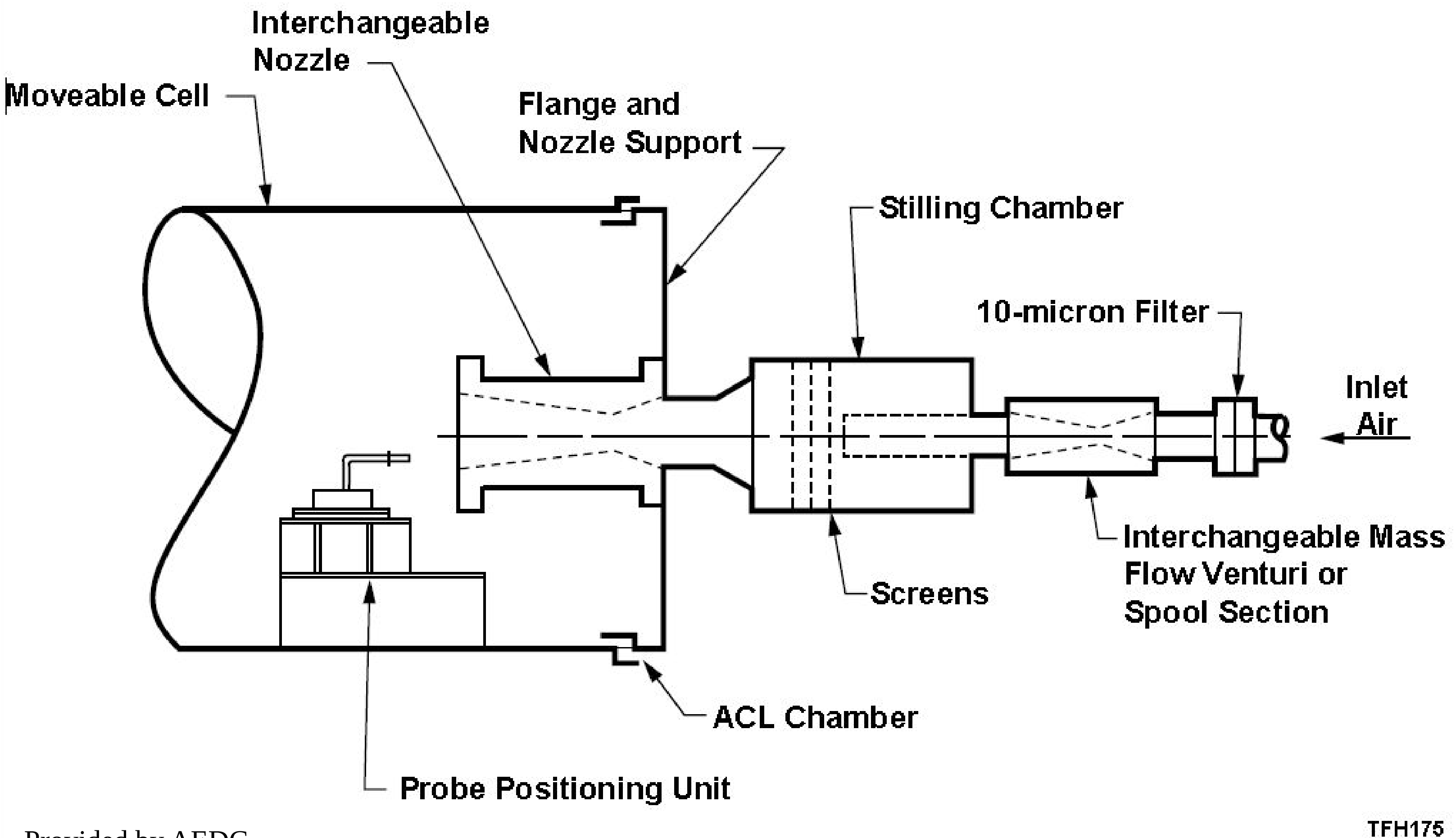
| Mach Number | Total Temperature (def F) | Flow Angles |
|---|---|---|
| 0.3 | 80 | -10 |
| 0.3 | 80 | 0 |
| 0.3 | 80 | 10 |
| 0.3 | 80 | 20 |
| 0.3 | 80 | 30 |
| 0.3 | 80 | 40 |
| 0.3 | 175 | -10 |
| 0.3 | 175 | 0 |
| 0.3 | 175 | 10 |
| 0.3 | 175 | 20 |
| 0.3 | 175 | 30 |
| 0.3 | 175 | 40 |
| 0.3 | 250 | -10 |
| 0.3 | 250 | 0 |
| 0.3 | 250 | 10 |
| 0.3 | 250 | 20 |
| 0.3 | 250 | 30 |
| 0.3 | 250 | 40 |

| Mach Number | Total Temperature (deg F) | Flow Angles |
|---|---|---|
| 0.5 | 80 | -10 |
| 0.5 | 80 | 0 |
| 0.5 | 80 | 10 |
| 0.5 | 80 | 20 |
| 0.5 | 80 | 30 |
| 0.5 | 80 | 40 |
| 0.5 | 175 | -10 |
| 0.5 | 175 | 0 |
| 0.5 | 175 | 10 |
| 0.5 | 175 | 20 |
| 0.5 | 175 | 30 |
| 0.5 | 175 | 40 |
| 0.5 | 250 | -10 |
| 0.5 | 250 | 0 |
| 0.5 | 250 | 10 |
| 0.5 | 250 | 20 |
| 0.5 | 250 | 30 |
| 0.5 | 250 | 40 |

| Mach Number | Total Temperature (deg F) | Flow Angles |
|---|---|---|
| 0.7 | 80 | -10 |
| 0.7 | 80 | 0 |
| 0.7 | 80 | 10 |
| 0.7 | 80 | 20 |
| 0.7 | 80 | 30 |
| 0.7 | 80 | 40 |
| 0.7 | 175 | -10 |
| 0.7 | 175 | 0 |
| 0.7 | 175 | 10 |
| 0.7 | 175 | 20 |
| 0.7 | 175 | 30 |
| 0.7 | 175 | 40 |
| 0.7 | 250 | -10 |
| 0.7 | 250 | 0 |
| 0.7 | 250 | 10 |
| 0.7 | 250 | 20 |
| 0.7 | 250 | 30 |
| 0.7 | 250 | 40 |

Notes:
1) Test will be repeated for both configurations

# AEDC ACL Set Up

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# Objectives 1 & 2
# Post Processing/Analysis

1. Digitally low pass high response transducer data with consistent filter type and cutoff frequency
2. Time average high response transducer's DC content
3. Compare the DC content of each transducer to truth source
4. Calculate error based transducer to truth source pressure ratio

# Test Concerns & Open Questions Remaining

- Manpower for Execution and Facility Availability
- Flow Quality Consistency between Configurations (Angle)
- Truth Pt Data Source
- AC Content Resolution Degradation?
- Need for Hysteresis, Repeatability, or Variability Testing?
- Follow on test of an aspirated probe?

# Inputs or Questions?

# REPORT DOCUMENTATION PAGE

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**14. ABSTRACT**
This presentation details the test and data analysis draft plan of an upcoming probe calibration task to assess the total pressure measurement performance of a digitally compensated piezoresistive high response transducer within a concentric probe design.

**15. SUBJECT TERMS**
Piezoresistive transducer, thermal drift, total pressure, concentric probe

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