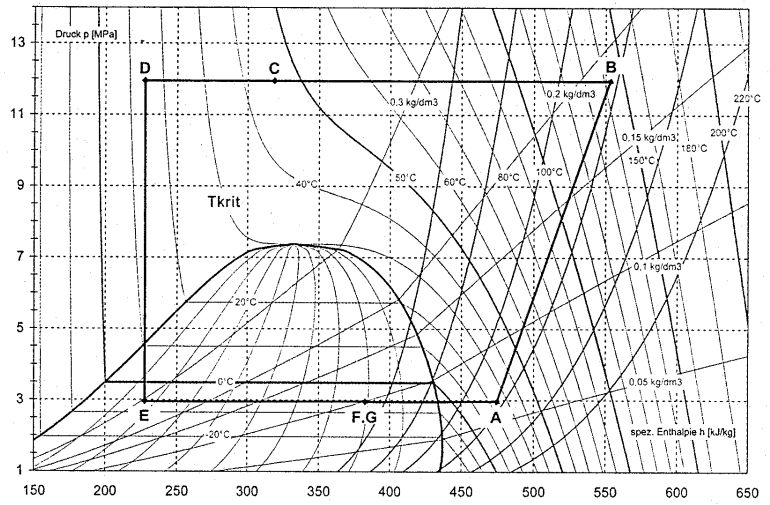
PRESSURE CONTROLS
FOR R744 CLIMATE CONTROL SYSTEMS



INTRODUCTION

Observations In Auto A/C

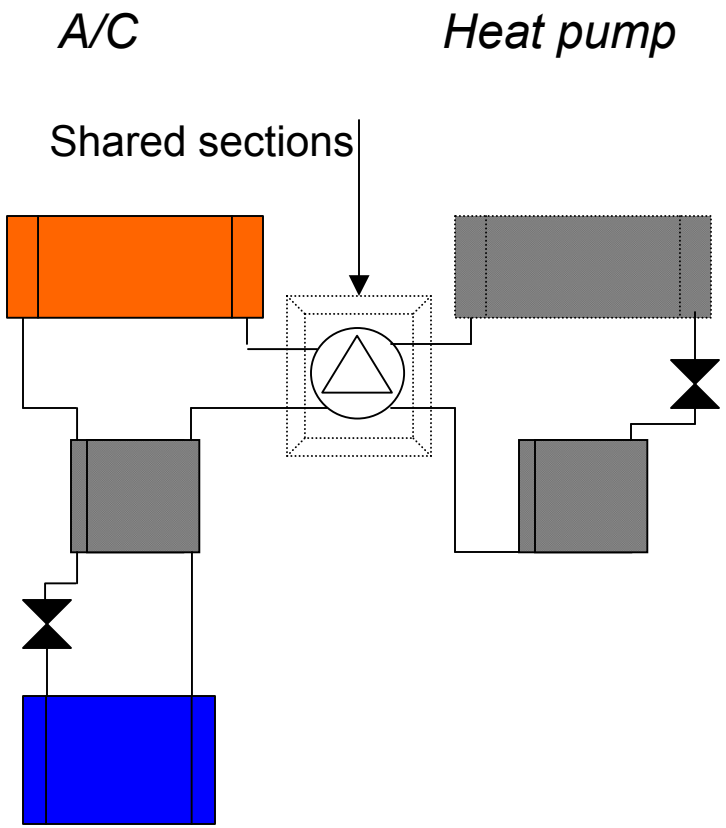
- Automotive Industry Searching For Alternative Refrigerants
- New Functionalities Are Added
- System Control More Complicated

INTRODUCTION

Consequences For Sensors

- Requirements Trend Up
  - Introduction Under Severe Cost Pressure
- Suppliers contribution to enable introduction in cost and innovation

MOUNTING POSITION CONTROLS



- Heat pump capability limits sensor mounting flexibility
- Mounting position drives specifications
- Pressure and temperature used for A/C & heat pump control

Therefore:

I. Integration Of Pressure And Temperature Sensor

II. To Maintain Flexibility, All Mounting Positions Must Be Possible

CONSEQUENSES MOUNTING POSITION R134a SYSTEM vs R744 SYSTEM

Pressure Control Requirements				
		R134a high side liquid	**R744 discharge**	
Pressure		30..35	120 .. 160	[bar]
Temperature	*Medium*	80	180	[°C]
	Ambient	125	125	[°C]
Mol Mass		102	44	[u]

ALTERNATIVE TECHNOLOGIES

- MEMS P+T
  - – Die attach / Bondwires exposed to 180°C, dynamic gas flow
  - – Trade off between reliability (out-of-stream) and signal accuracy (into stream)
- Ceramic P+T
  - – Elastomer seal
  - \+ Production Experience
- Discrete Silicon Strain Gauge
  - \+ High temperature capability
  - \+ Capability to separate SE and Conditioning Electronics
  - \+ Production Experience
  - \+ P&T Sensitivity
  - \+ Cost

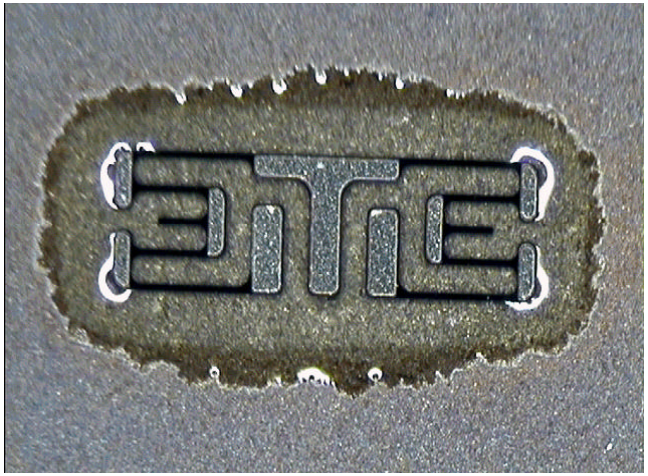
MSG PRESSURE SENSOR
Base Technology

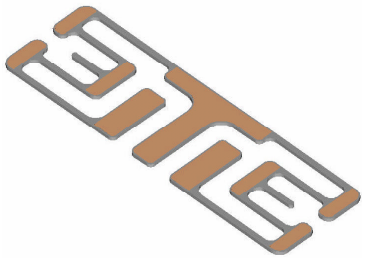
Micro Fused Strain Gage

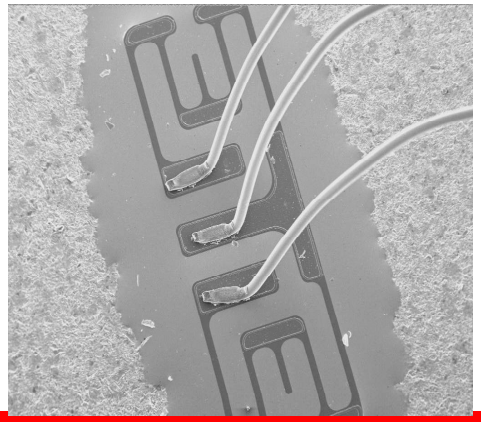
Design Assumptions:

- ✓ Hermetic Pressure Sensor (Metal 1 piece / weld)
- ✓ High Volume Manufacturability Against Minimized Cost
- ✓ Modular Build For Configuration Flexibility
- ✓ Temperature Compensated (Extreme Temperature Span)
- ✓ <2%FS Error Band (for Pressure Control)
- ✓ Diagnostics (Safety)
- ✓ High Proof/Burst Capabilities

SILICON SENSING ELEMENT

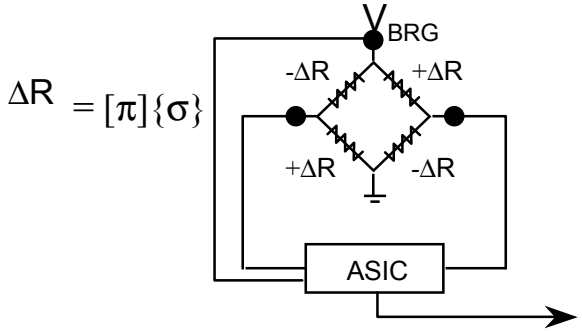


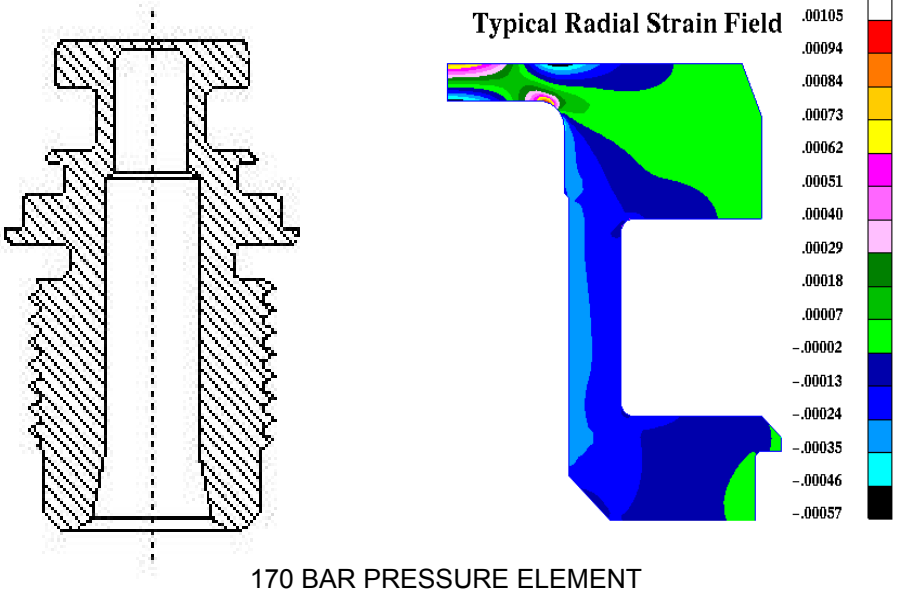




- Mono crystalline silicon gages fabricated with standard semiconductor processes
- Gage geometry defined in DRIE process. Minimizes geometry variation
- Aluminum metallization
- Standard glass bonding process attaches gages to element
- 0.5 mm x 1.5 mm x 10 µm

SENSOR DEVELOPMENT





170 BAR PRESSURE ELEMENT

- FEA guides sense element geometry
- Regions of tensile and compressive surface stress set-up full Wheatstone bridge
- Port material:17-4PH stainless steel
- Strain gages are glass bonded over appropriate local stress field
- At full scale pressure s_{max}/s_Y= 0.2.

PT SENSOR FOR R744

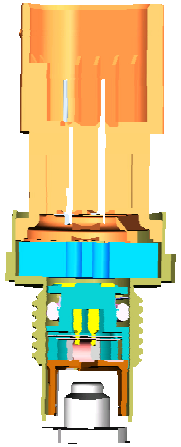
Target:

Integration of pressure sensor and intrusive temperature sensor

- Use existing sensing elements / electronics → cost target €3 D
- In-flow sensing elements
- Response time & accuracy
  - ~ second(s)
  - ±5°C, target ±3°C (…)

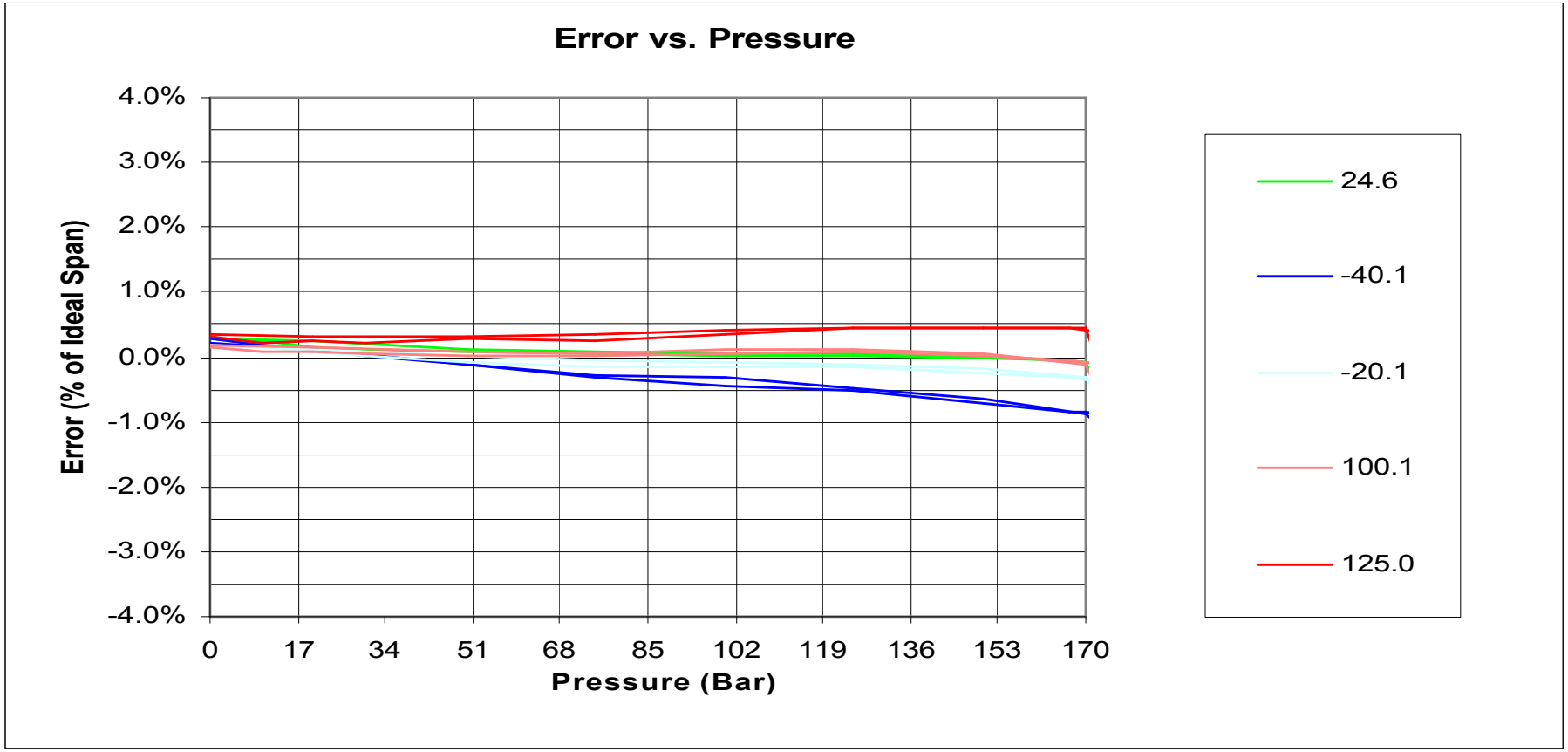
- Thermal Rules
  - Sensing Elements Exposed To Gas Temperatures
  - Conditioning Electronics Thermally Insulated

MSG – R744 A/C PT SENSORS



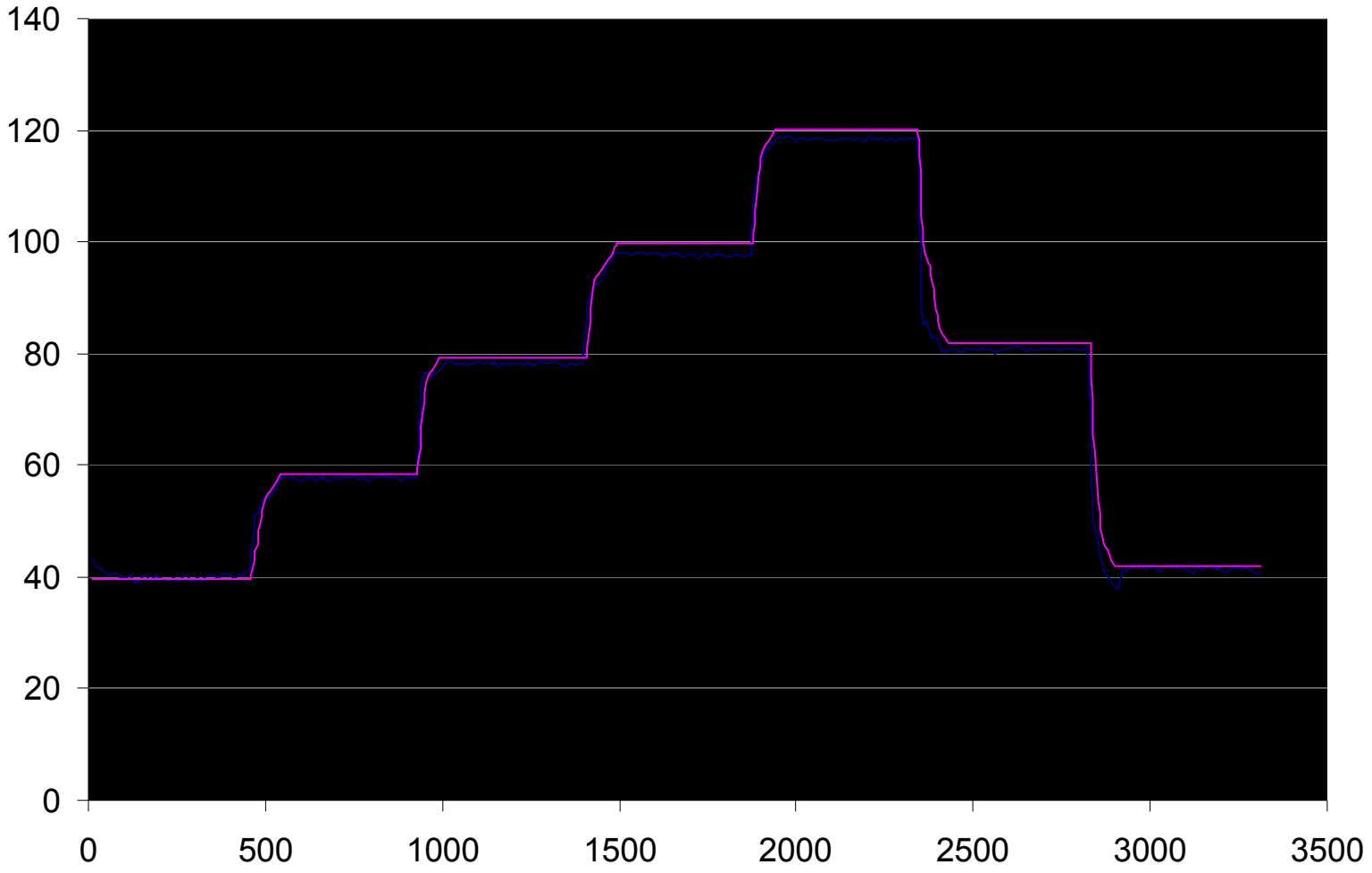
- P/T MSG
  - hermetic design
  - should enable fast T response and acceptable T- accuracy
- 3rd Generation PT Design IN PROTO STAGE
  - 1st generation = Brake Pressure 67%
  - 2nd generation = SFF 86/89%
  - 3rd generation = Proto scratch 99+%
- T-Accuracy under investigation
  - Current ‘capability’ ±10°C
  - With several calibration algorithm modifications, and a A/C algorithm optimization, an accuracy of ±3°C is feasible
- Next steps
  - Further evaluate 3rd generation
  - Improve T-calibration / Accuracy
  - Design Validation

PRESSURE OUTPUT



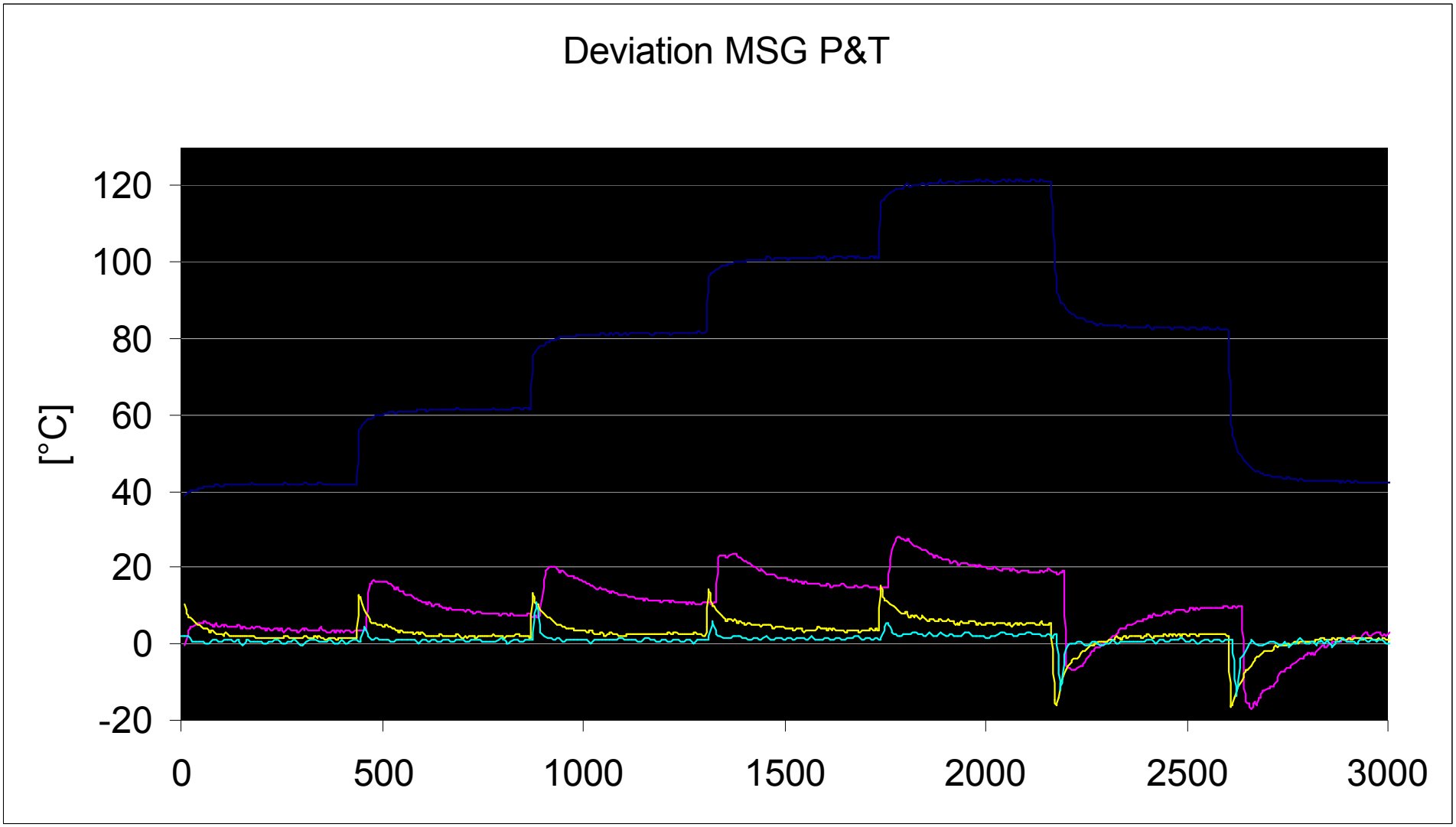
Typical Pressure Accuracy – based on average 2200 production parts

TEMPERATURE OUTPUT



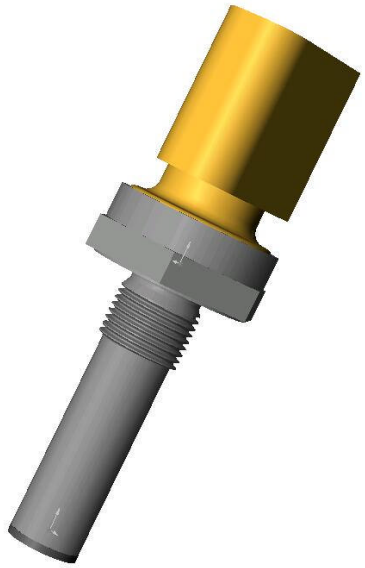
Note: T signal faster than DAQ

TEMPERATURE OUTPUT



PT PROJECT

- 3rd Gen A evaluation February 2002
- P/T: Concept freeze 1Q03
- A sample capability 2Q03



Milestones MSG P+T

Milestone	Due	Note
A-samples	Apr-03	
B sample Tooling release	Apr-03	Customer commitment
B-samples	Sep-03	Estimate, limited production tools
C-sample Tooling Release	Nov-03	
Process development	Jul-04	
C-samples	Sep-04	
PPAP	Jun-05	

ACKNOWLEDGEMENTS

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- Thank you for the attention!