# Glow Plug Integrated Piezo-Ceramic Combustion Sensor for Diesel Engines

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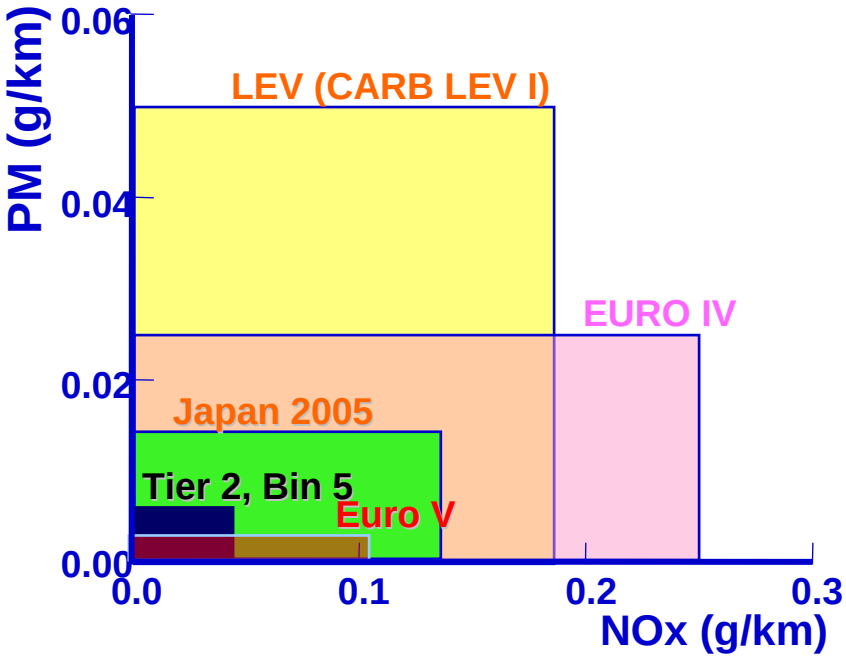
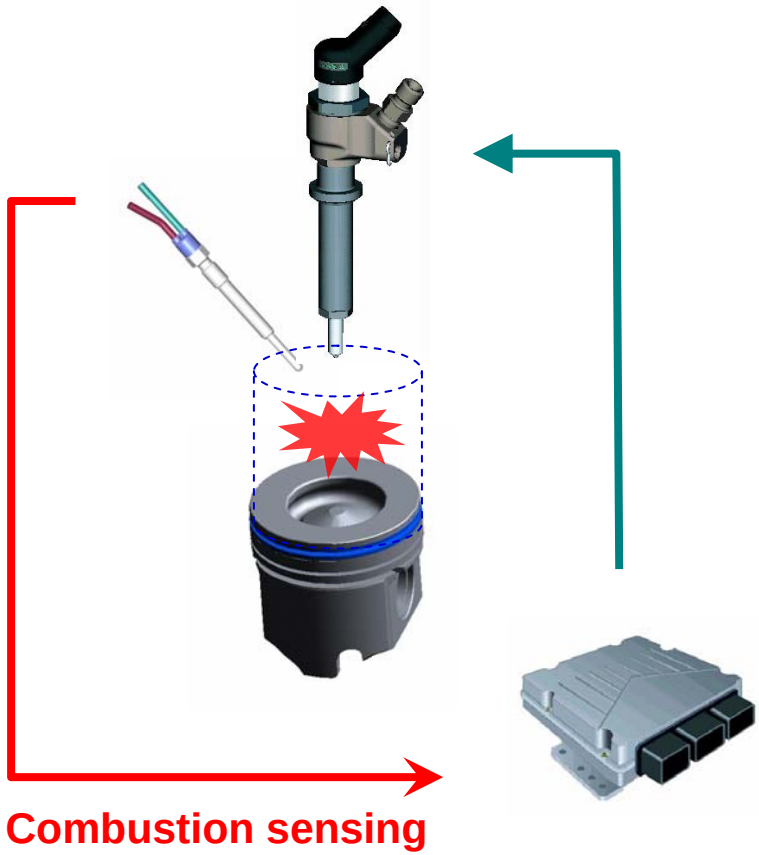
SIEMENS VDO Automotive

FEDERAL MOGUL




New emission legislations for Diesel engines

⇨

HCCI with CLCC
Need of a pressure sensor

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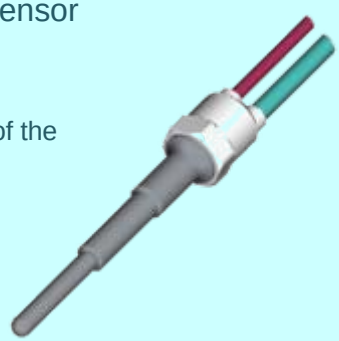
# Pressure sensor portfolio

## Combustion sensing family
### ( Cylinder head deflection measurement )

### GPCS

Glow Plug Combustion sensor



Sensing principle :

Measurement of the deformation of the cylinder head

Advantages :

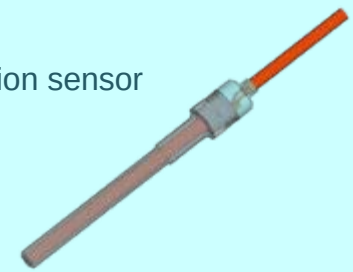
- Low cost
- Robustness

Drawbacks :

- Need a calibration on engine

### NICS

Non intrusive Combustion sensor



Sensing principle :

Same as GPCS

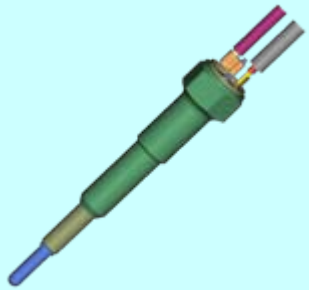
Advantages / Drawbacks:

- Do not require a hole in the cylinder

## Pressure sensing family
### ( Direct pressure measurement )

### GPPS

Glow Plug Pressure sensor



Sensing principle :

Measurement of the deformation of the probe

Advantages :

- Direct pressure sensor ( Can be calibrated )
- Robustness

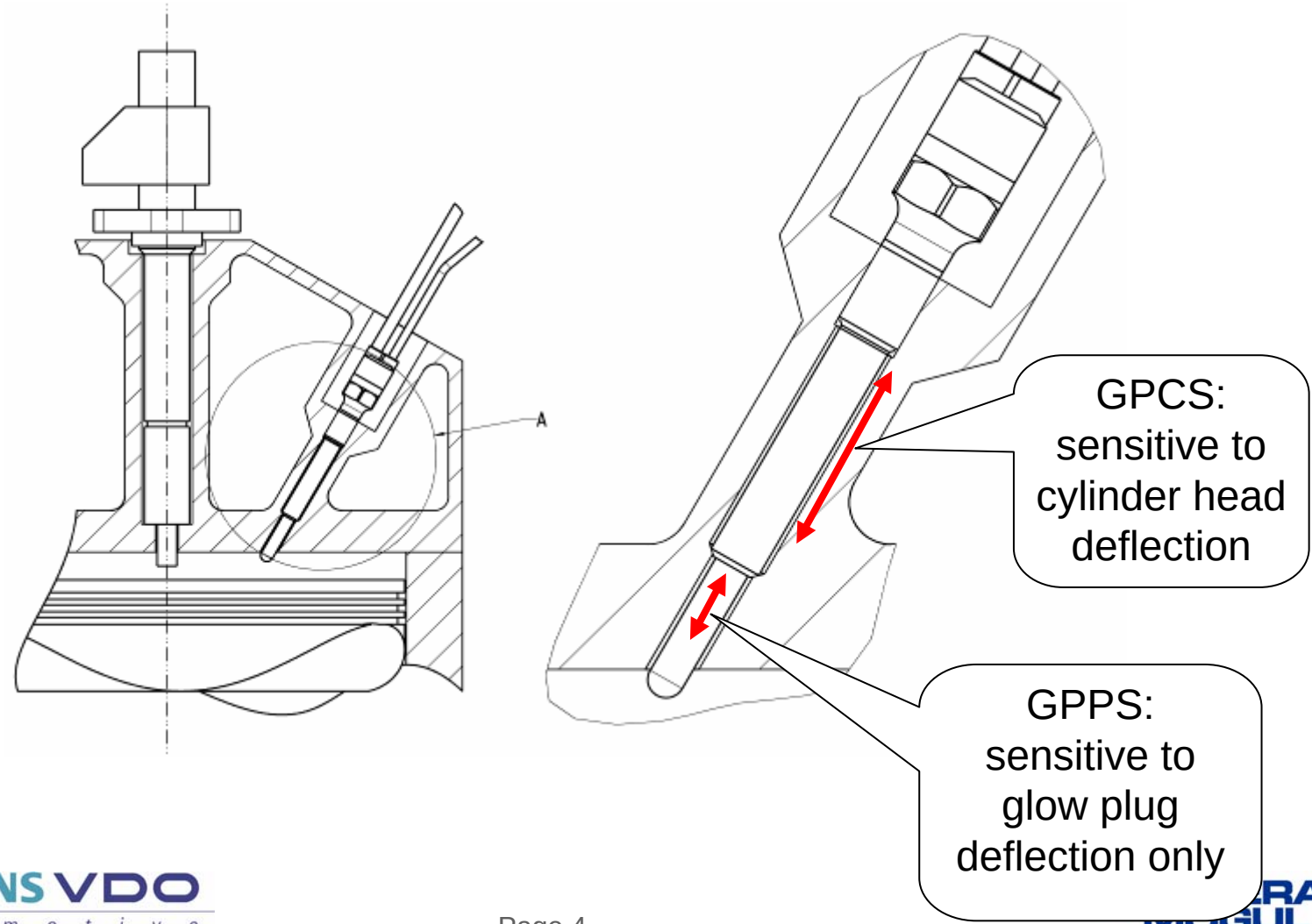
### SAPS

Stand alone Pressure sensor

Sensing principle :

Same configuration than GPPS but without the probe

# Combustion sensor : Measurement of cylinder head deflection versus direct measurement



# Pressure sensor portfolio

**GPCS**

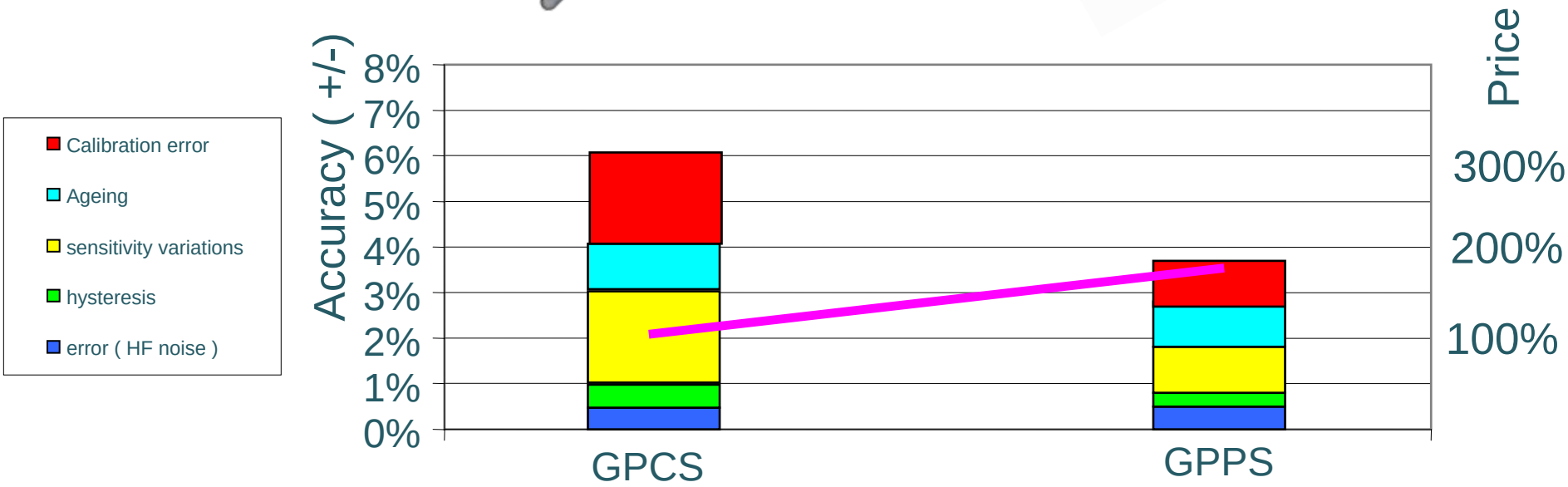
Glow Plug Combustion sensor

Passive

**GPPS**

Glow Plug Pressure sensor

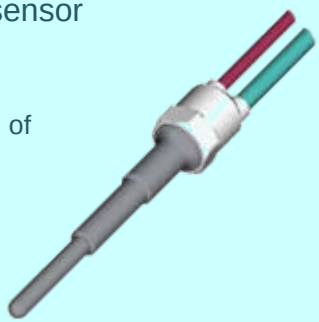
Active



# Combustion sensing family

## GPCS

Glow Plug Combustion sensor



Sensing principle :

Measurement of the deformation of the cylinder head

Advantages :

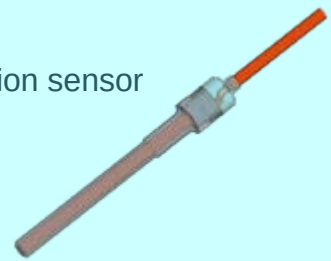
- Low cost
- Robustness

Drawbacks :

- Need a calibration on engine

## NICS

Non intrusive Combustion sensor

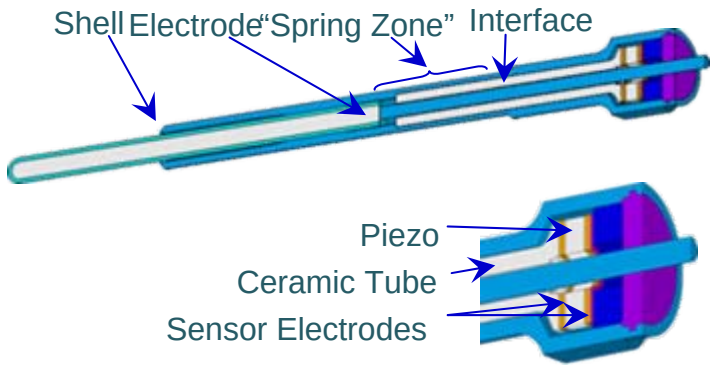


Sensing principle :

Same as GPCS

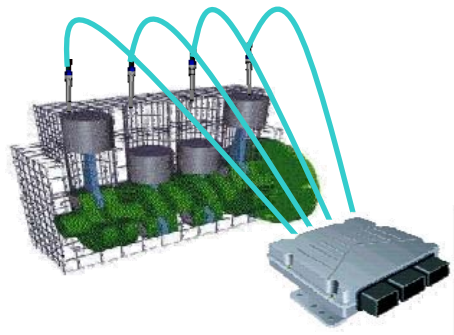
Advantages / Drawbacks:

- Do not require a hole in the cylinder




## Passive sensor:

- signal conditioning in ECU



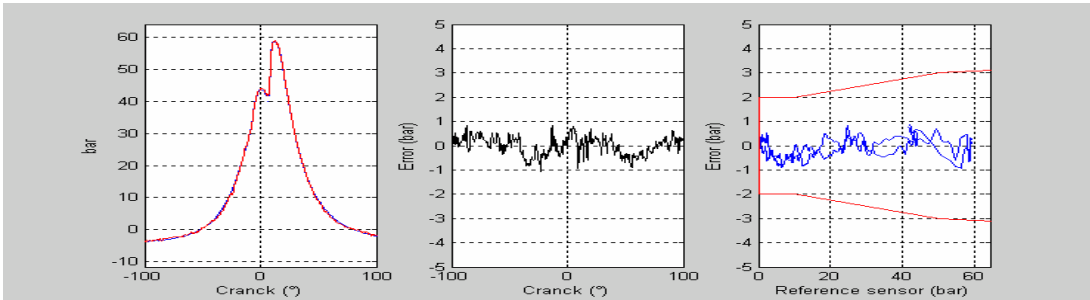
# GPCS : Sensing principle

## Piezo ceramic based product

- ✓ Manufacturing process similar to knock sensor process
- ✓ Robust and environmentally sealed
- ✓ Very long time stability, (very low ageing rate of the piezo ceramic)
- ✓ High signal to noise ratio : Low sensitivity of the sensor to engine vibrations

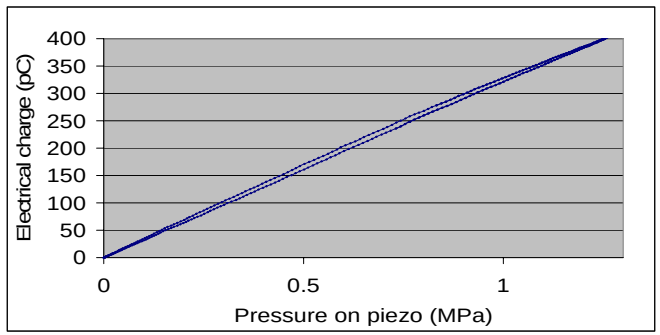
# GPCS : Accuracy

- Signal to noise ratio




➡ SNR always below +/- 1 bar

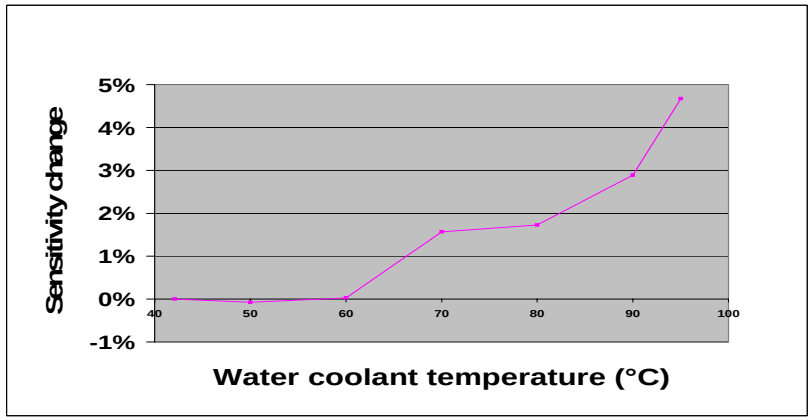
- Hysteresis




➡ 2% hysteresis, repeatable, can be compensated in ECU

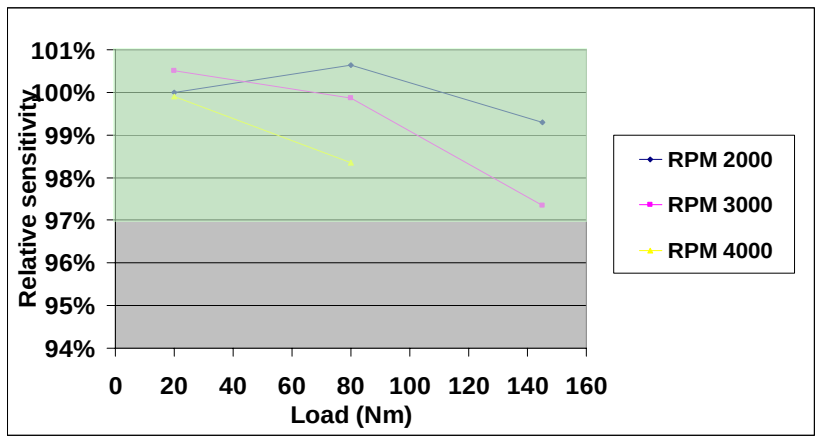
# GPCS : Sensitivity change

- Change of sensitivity over temperature: 5%
  - Very repeatable
  - Easily compensable in open loop

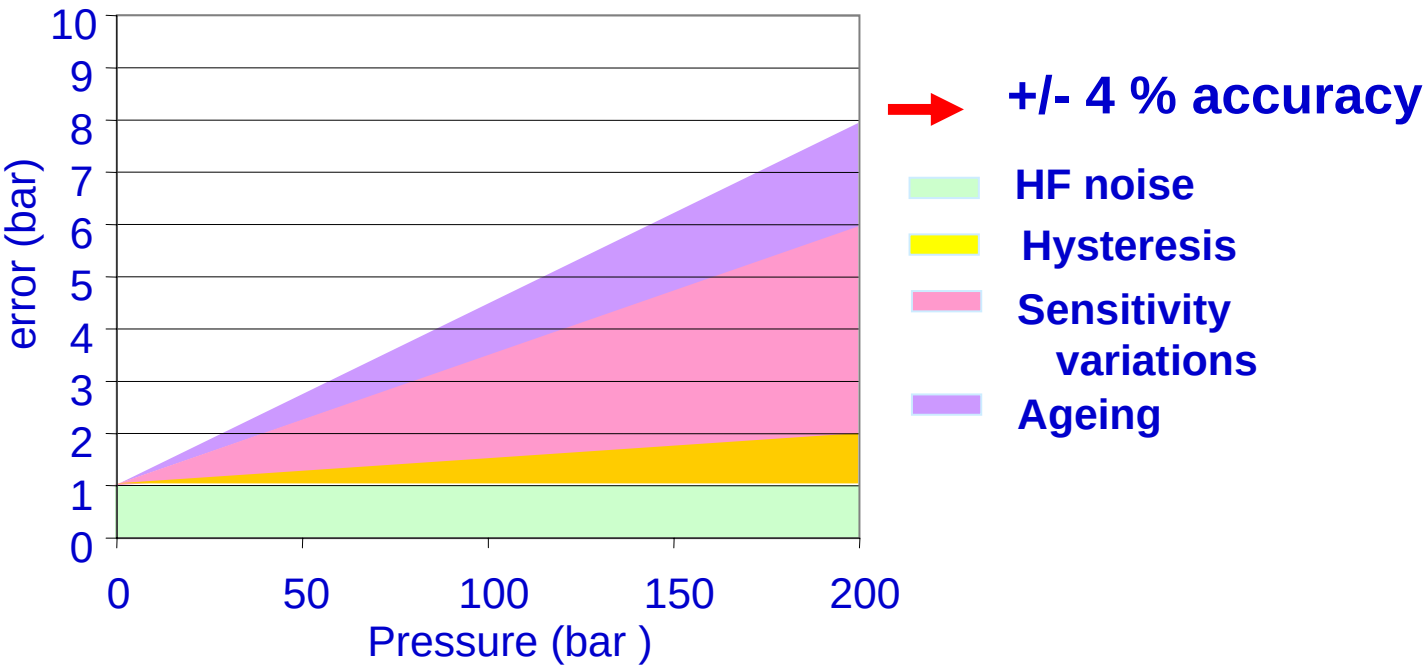



- Change of sensitivity over Engine conditions

(Load / rpm): < +/- 2%



# GPCS Sensor Error summary



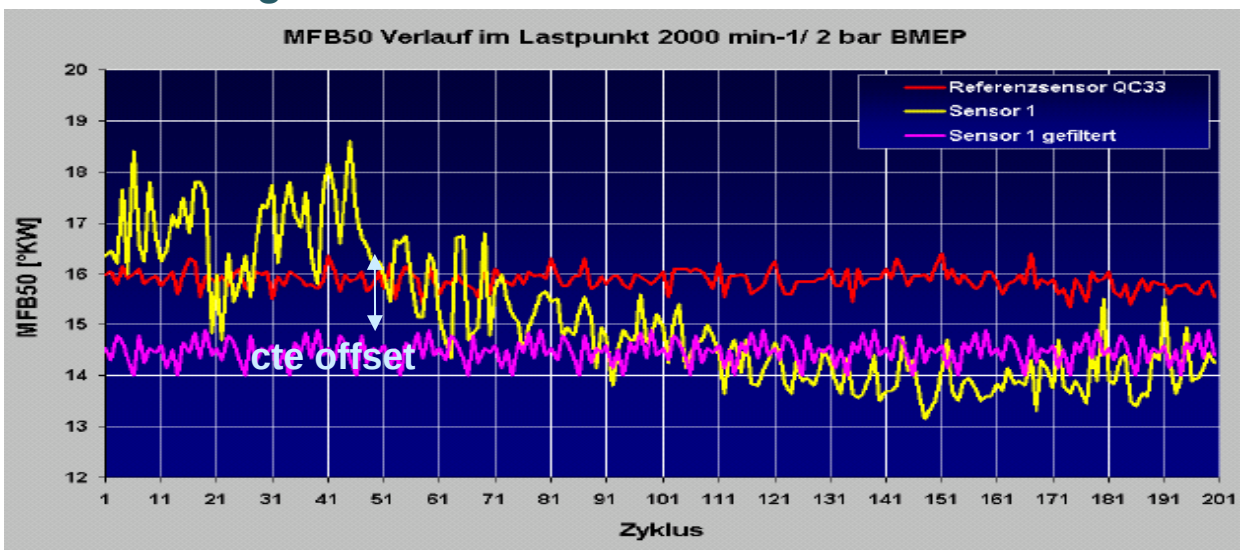

✓ GPCS accuracy is 4% without calibration
✓ GPCS robustness demonstrated on engine tests
✓ GPCS SNR evaluated successfully for accurate measurement of MFB ( location of the 50% of the heat release curve ), thus enabling HCCI control

# GPCS within engine control strategy

GPCS as used for HCCI control:

- Sensor signal is used to compute MFB_50% angle
- ECU is handling following operation:
  - charge to voltage conversion
  - **constant amplification (no open loop compensation)**
  - low pass 5Khz filtering
  - signal pegging (offset compensation) @ constant crank angle

- **2 different engines have been used for tests:**




**Ref sensor**

**Raw GPCS signal**

**Filtered GPCS signal**

**MFB_50% computation**

# Pressure sensing family

## GPPS

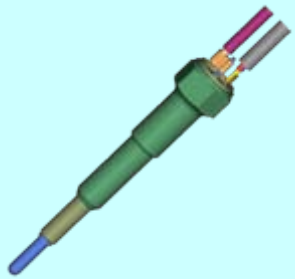
Glow Plug Pressure sensor

Sensing principle :

Measurement of the deformation of the probe

Advantages :

- Direct pressure sensor ( Can be calibrated )
- Robustness

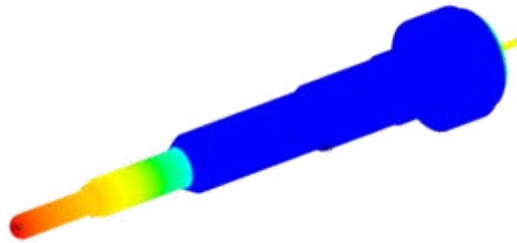


## SAPS

Stand alone Pressure sensor

Sensing principle :

Same configuration than GPPS but without the probe



**Probe stress measurement**

**Active sensor calibrated**

**Conditioning in the sensor**

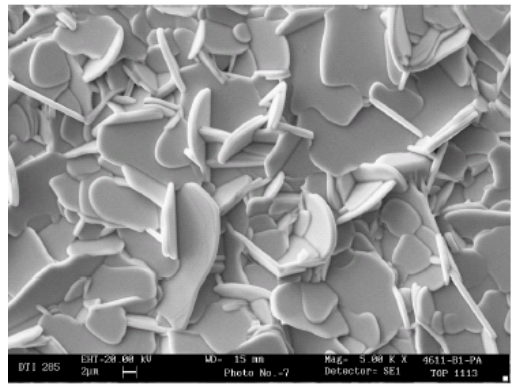
**Standard analog output**

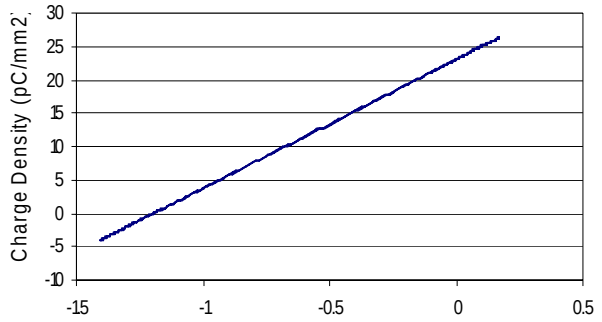
# GPPS : Sensing principle

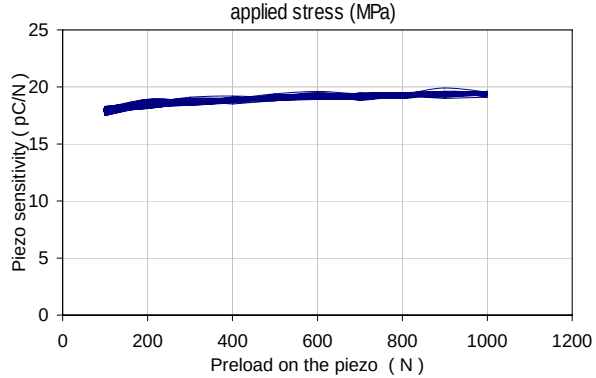
- Use of piezo-electric element
- Miniaturization of the sensor in the bottom of the Glow Plug shell ( M8 )
- Use of a ceramic heating probe
- Assembly of the ceramic probe on a "Thick membrane "
- Solution fully sealed, not sensitive to dust contamination
- Electronic integrated into the Glow Plug shell
- Compact integrated connector within automotive standards

# GPPS : The piezo electric element

- Highly stable poly crystalline piezo electric element
- Lead free composition
- High Curie temperature : 650°C
- No hysteresis ( < 0.1 % )
- Low sensitivity
- Time stability demonstrated in other product application with 500 °C operating temperature
- No change of sensitivity versus preload and temperature ( < 1% )





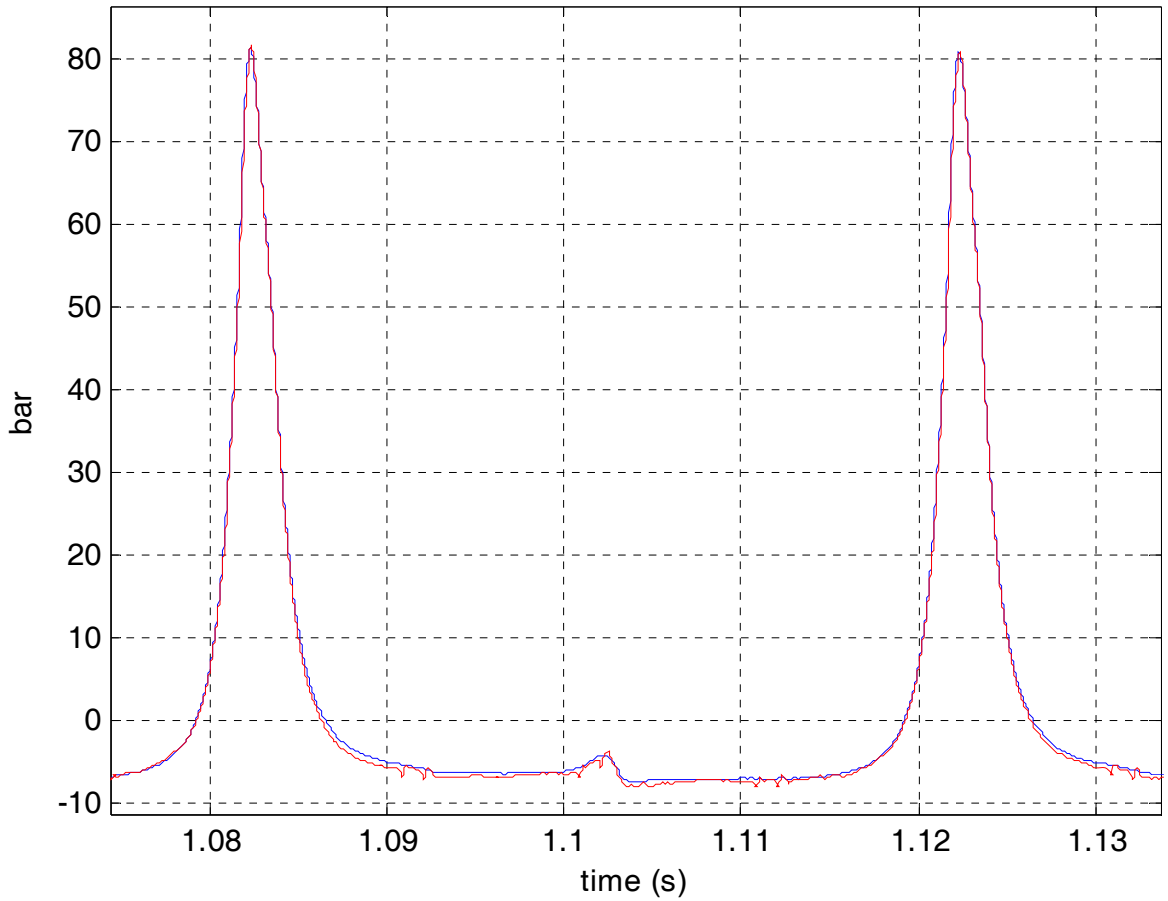
# GPPS : The ceramic probe technology

- Ceramic Technology for the "Glowing Part" has been developed by Federal Mogul in order to fulfil new Customer's requirements.
- The Federal-Mogul Ceramic Glow Plug Technology is a multi-layer structure made of a silicon nitride substrate with different percentage of Molybdenum Di-Silicide to create conductive paths
- The heating part is the tip of the ceramic probe, where the major amount of electrical resistance is concentrated
- The technology is fully protected by several worldwide patents

- **Ceramic heating element are proposed by Federal Mogul for standard plugs, and for GPCS, though GPPS will be available with Ceramic probe only**

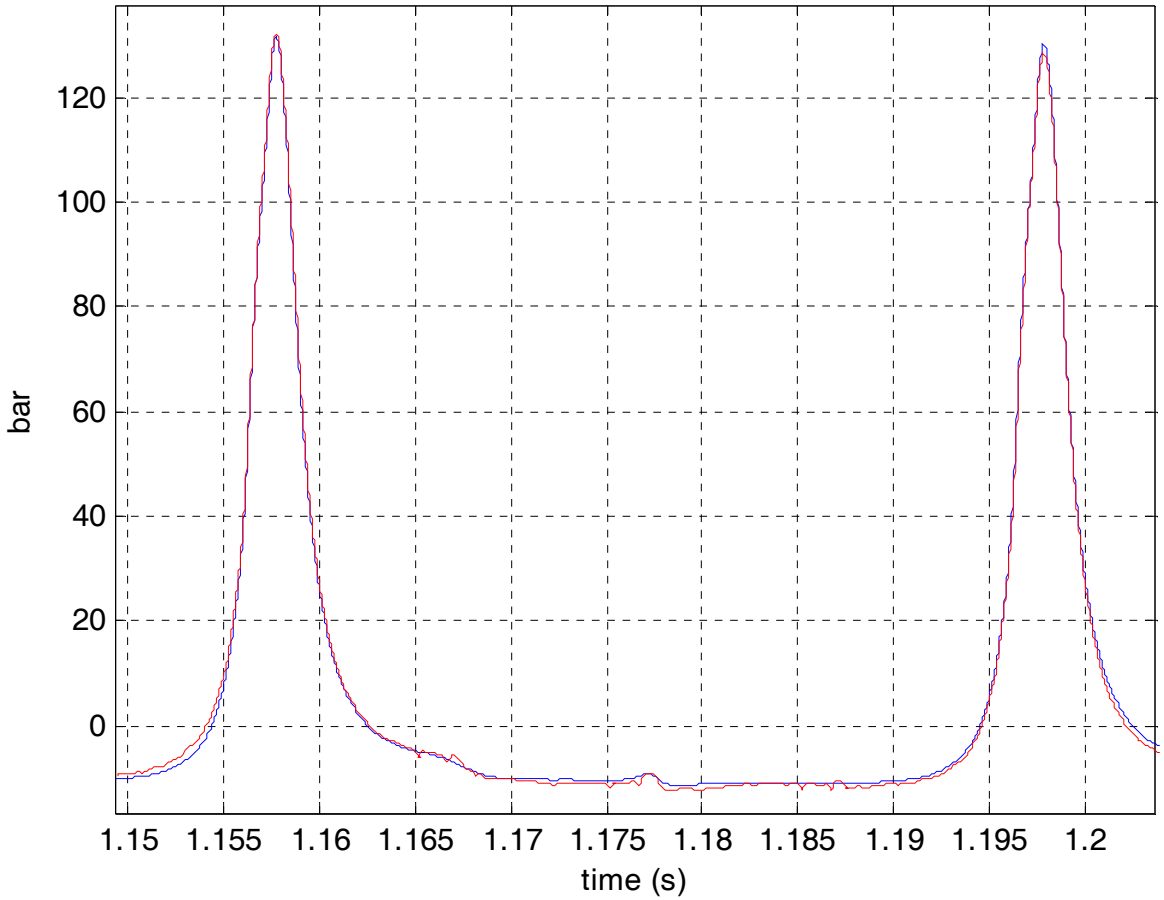
# GPPS : Example of engine test results

## 3000 RPM / 80 Nm

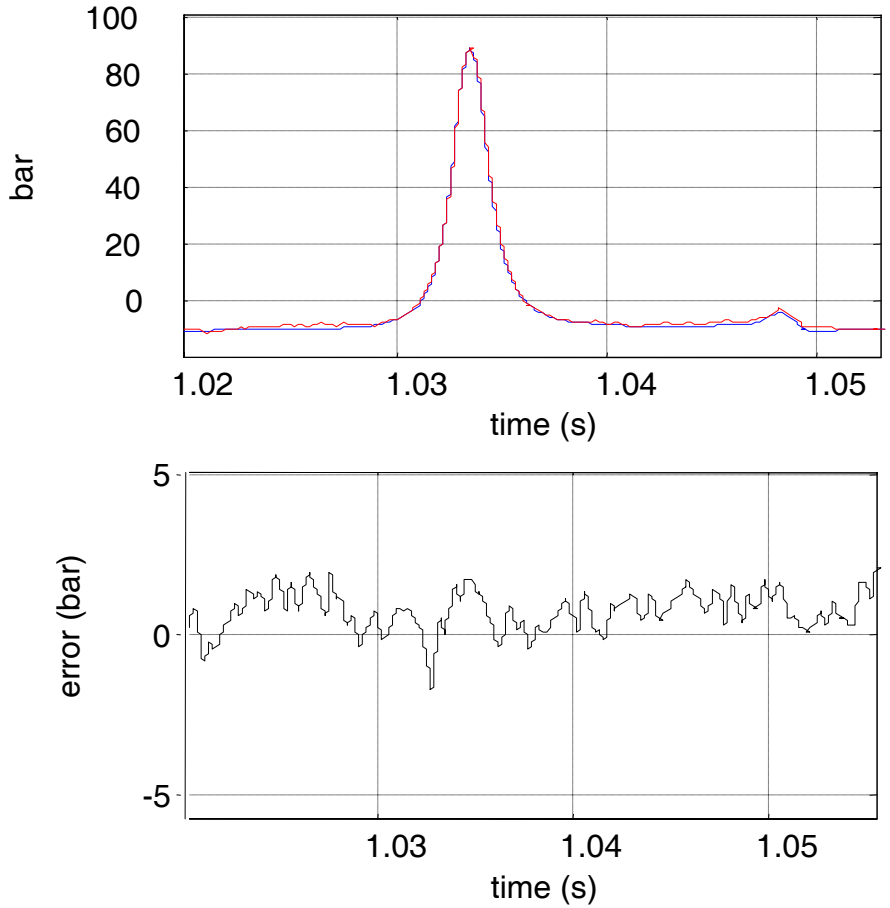


# GPPS : Example of engine test results

## 3000 RPM / 120 Nm

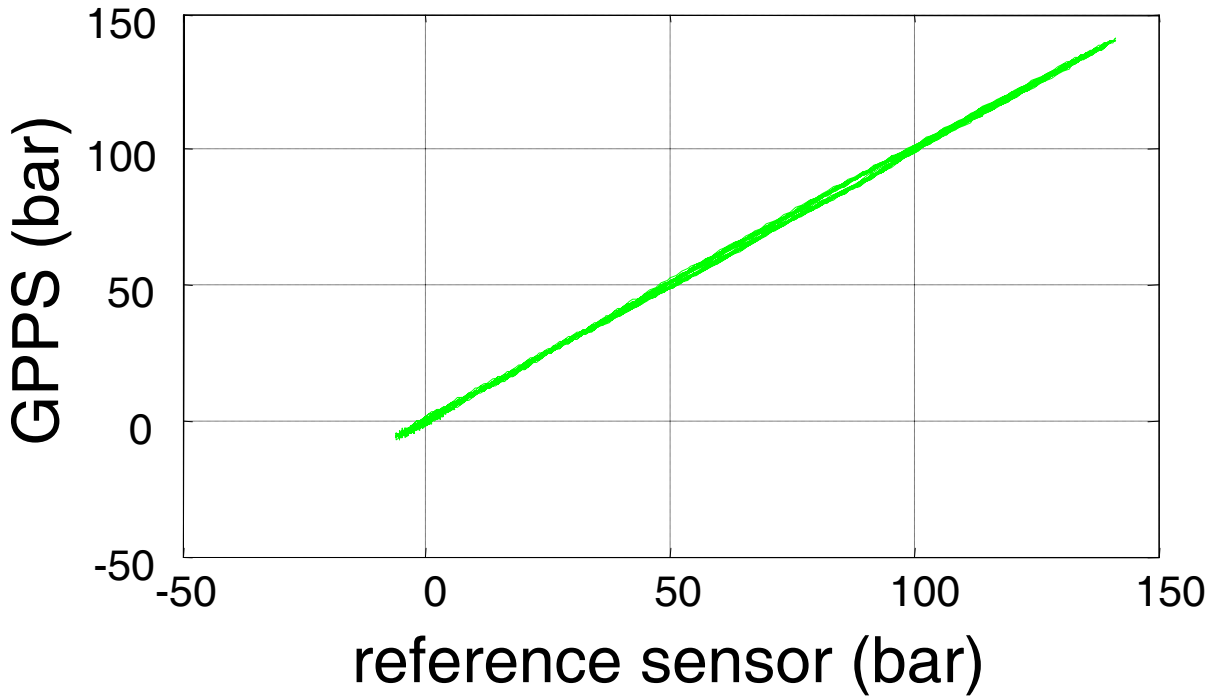


# GPPS : Example of engine test results



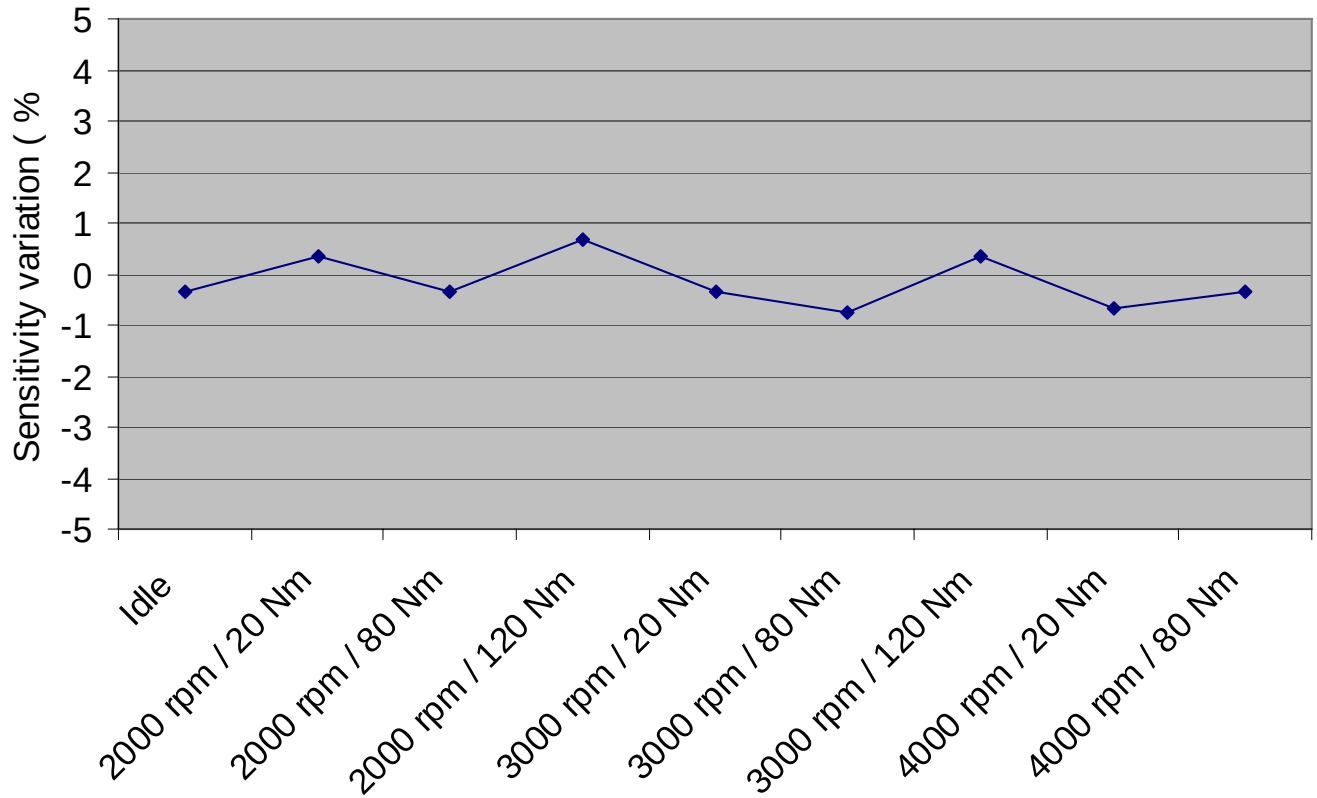

GPPS High frequency noise below +/- 0.5 % of FSO

# GPPS : Hysteresis




GPPS Hysteresis below 0.5 %

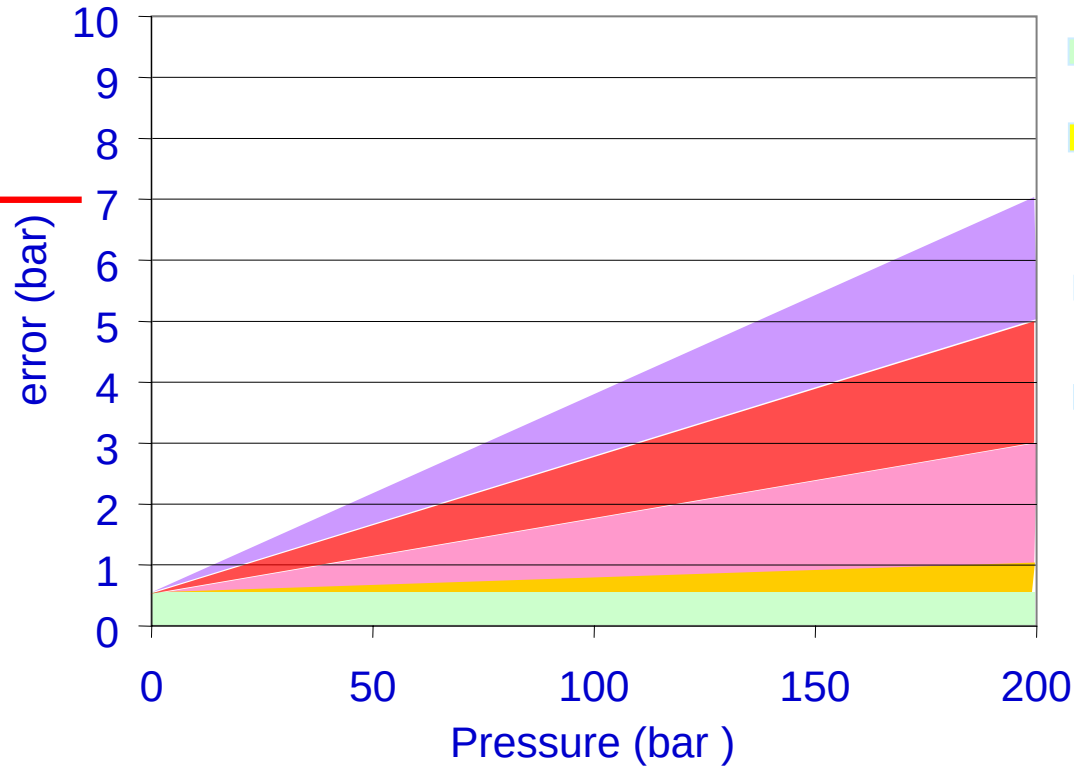
# GPPS : Sensitivity changes versus engine conditions




**Sensitivity variations always below 1%**

# GPPS : Sensor Error summary

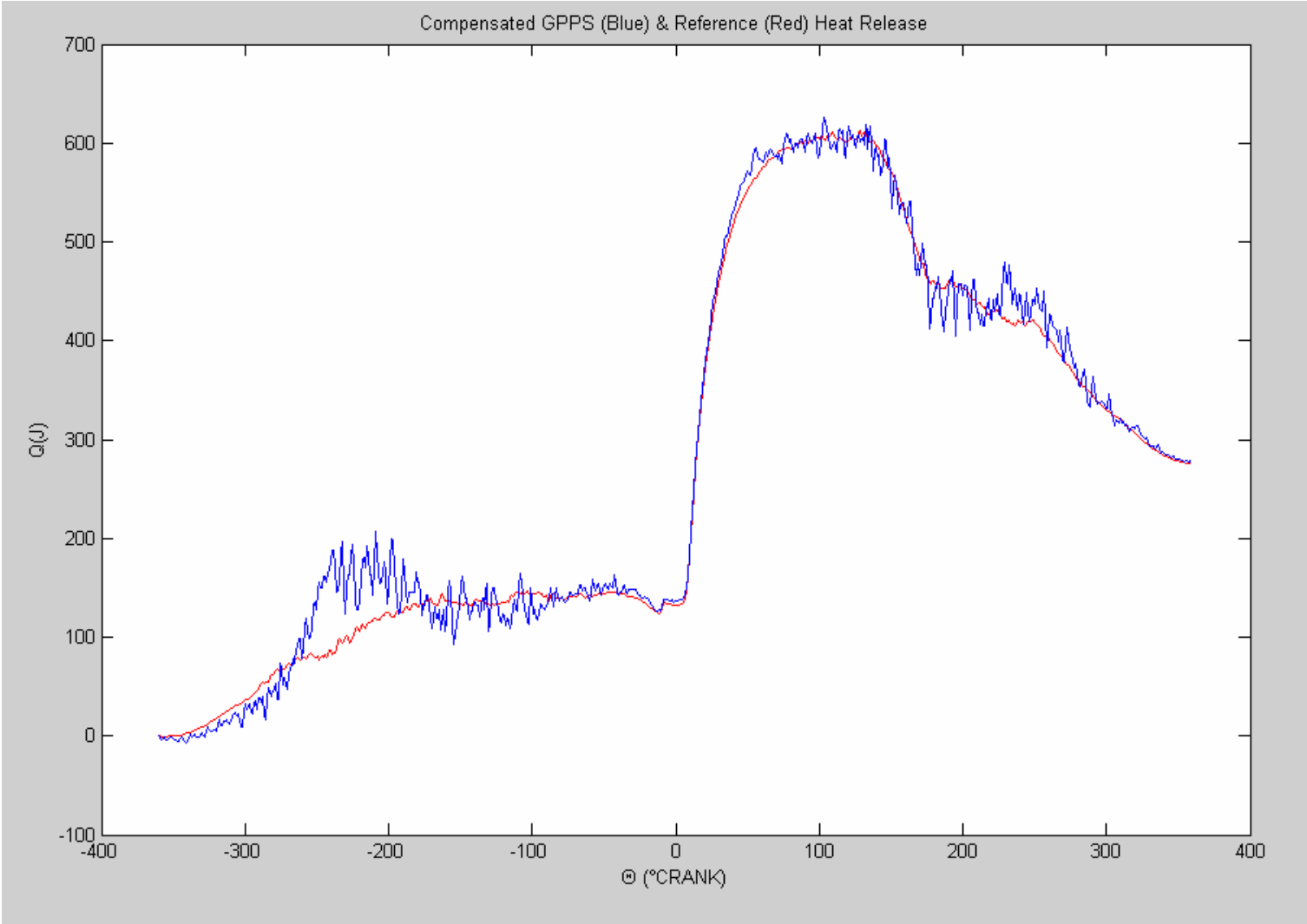
+/- 3.5 % accuracy




Target of GPPS : 3.5 % Accuracy over lifetime

- Including calibration
- Sensor time stability will be soon demonstrated by engine endurance tests

# GPPS : Heat release monitoring

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*Thank you for your attention !*