

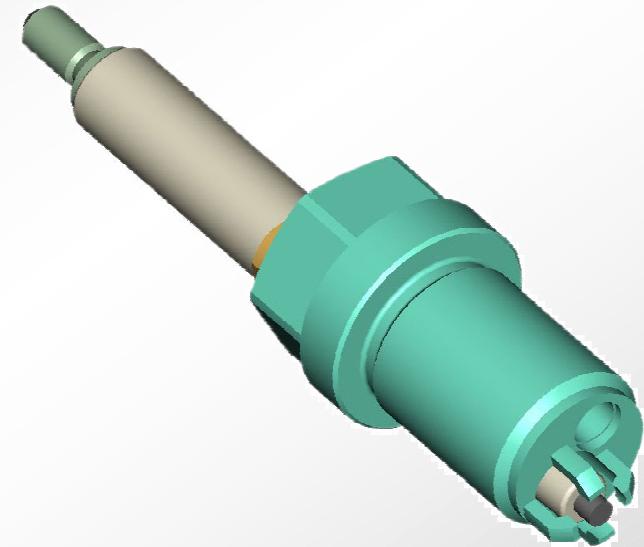
Pressure Indicating with Measuring Spark Plugs - Status of Performance

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1. Introduction

Measuring Spark Plugs for Pressure Indication

The use of Measuring Spark Plugs provide significant benefits:

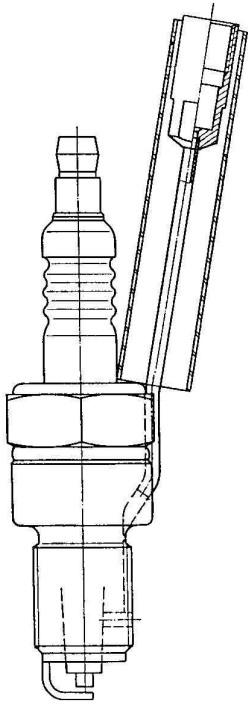
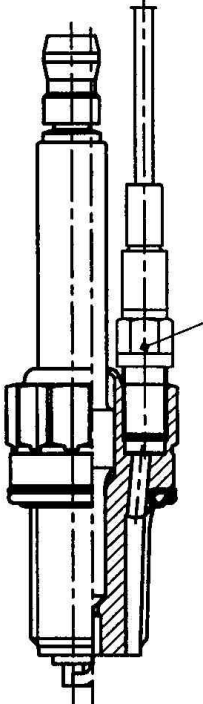
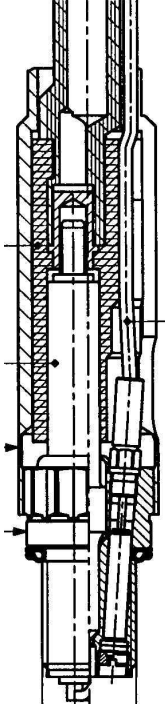
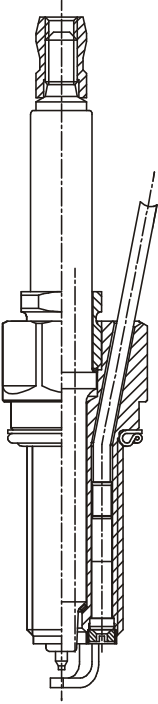
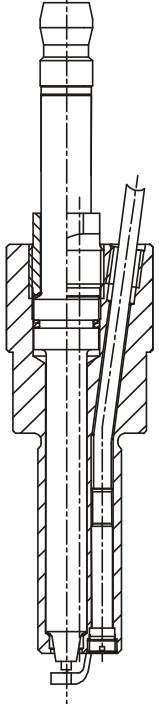
- Access to the combustion chamber without preparation of an additional bore
- No modification of chamber geometry and of thermal conditions
- Suitable for in-vehicle measurements, quick checks and monitoring
- Quick and easy exchange of sensors

... but only, if the following requirements are fulfilled:

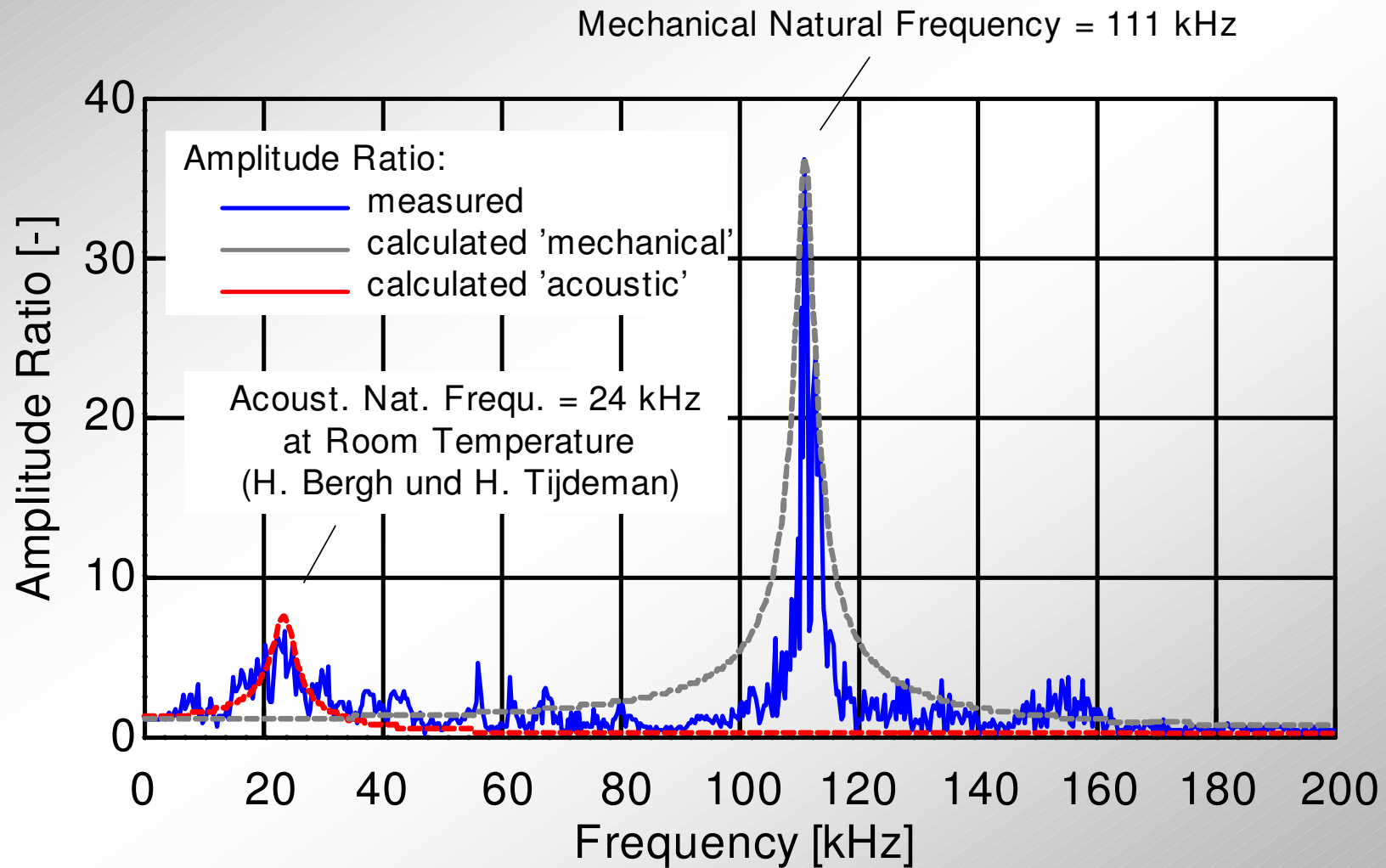
- Identical combustion conditions as with the original spark plug
- Mechanical and thermal stability, even at the highest combustion temperatures
- No fouling of electrodes and insulators within operating range of engine
- Reliable sealing of combustion chamber
- Most accurate sensing of pressure trace (amplitude, phase shift)
- No interference between measuring signals and electrical spark equipment

2. Technology of Measuring Spark Plugs

Design and Key Specifications within the last 30 Years

Year	1968	1989	1991	2001	2003
					
Type	6511	6517	6117	6115	6113
Thread	M14x1.25	M14x1.25	M14x1.25	M12x1.25	M10x1.00
Sensitivity	16 pC/bar	20 pC/bar	15 pC/bar	10 pC/bar	10 pC/bar
Acoustic Reson. Frequ.	2 kHz	7 kHz	55 kHz	60 kHz	>60 kHz

2. Technology of Measuring Spark Plugs Dynamics



2. Technology of Measuring Spark Plugs Proper Heat Range is the Challenge ...

Objective for Design of Heat Range of Measuring Spark Plug:

- as identical as possible with original spark plug
- within total operating range of engine

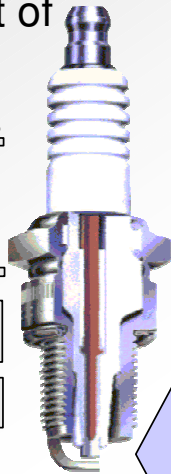
Heat Flux out of Spark Plug

Ceramic Isolator 5%

Body 5%

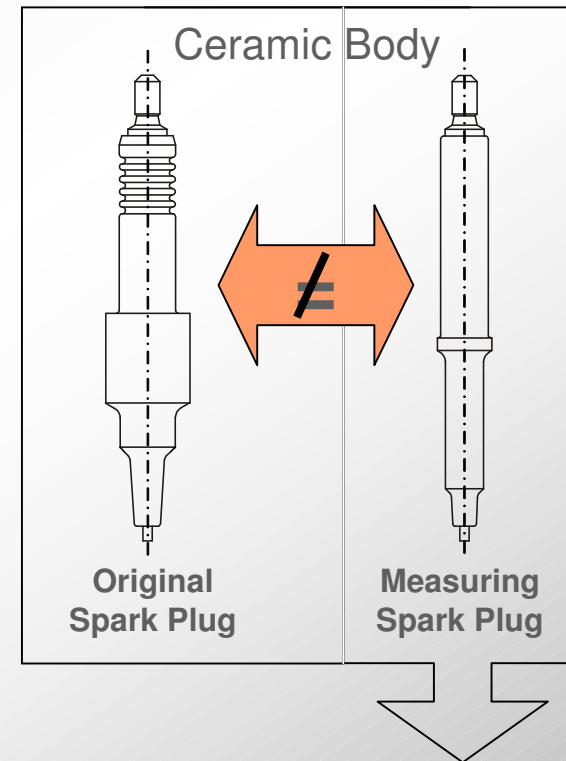
Seat 48%

Thread 42%



Heat Flux into Spark Plug

Front face of body	67%
Ceramic Isolator	21%
Center Electrode	4%
Shell Electrode	8%



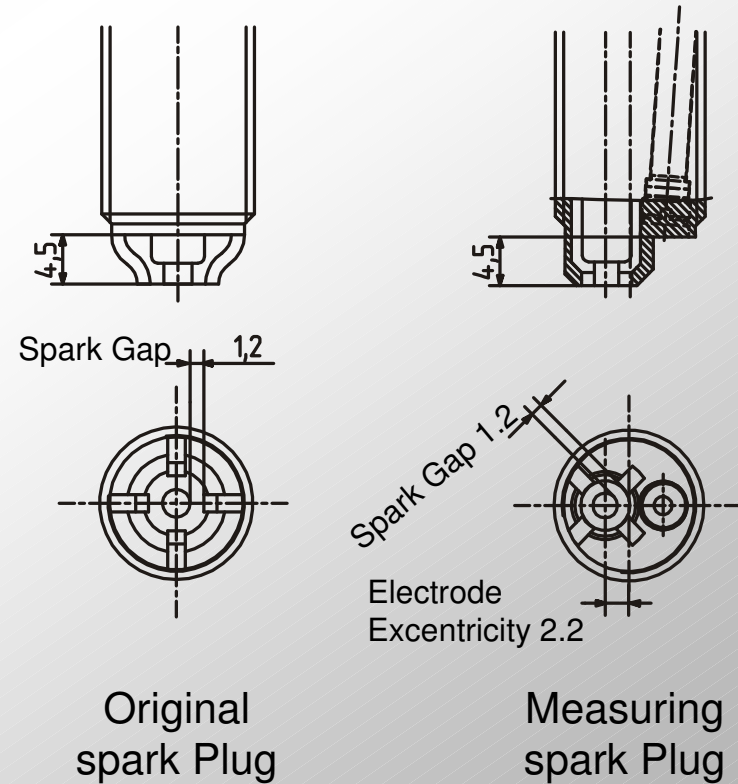
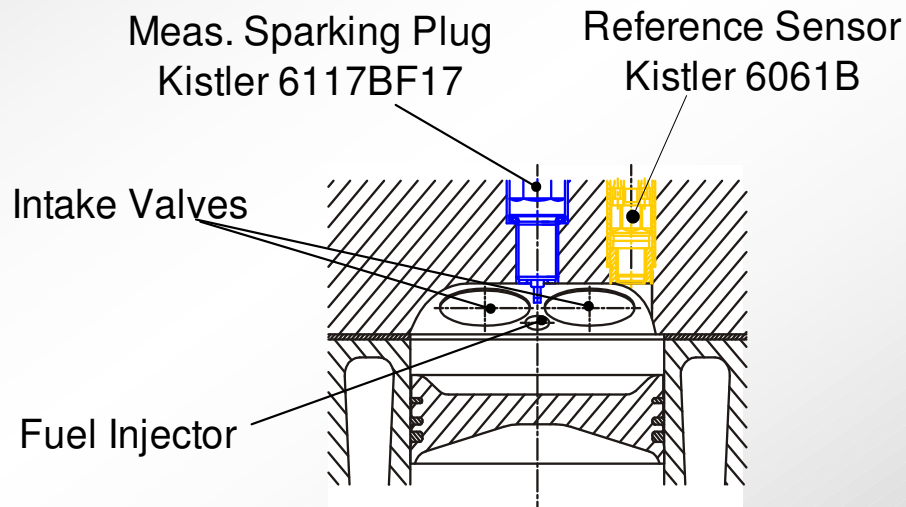
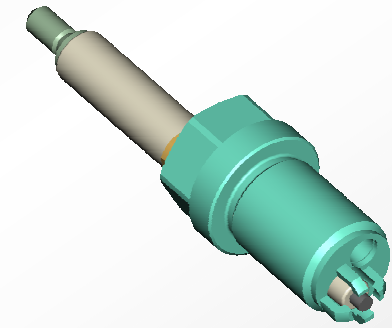
Design of Heat Range:
→ sometimes compromise necessary!

3. Application on a DI-Gasoline Engine Typical Measuring Tasks within Engine Development

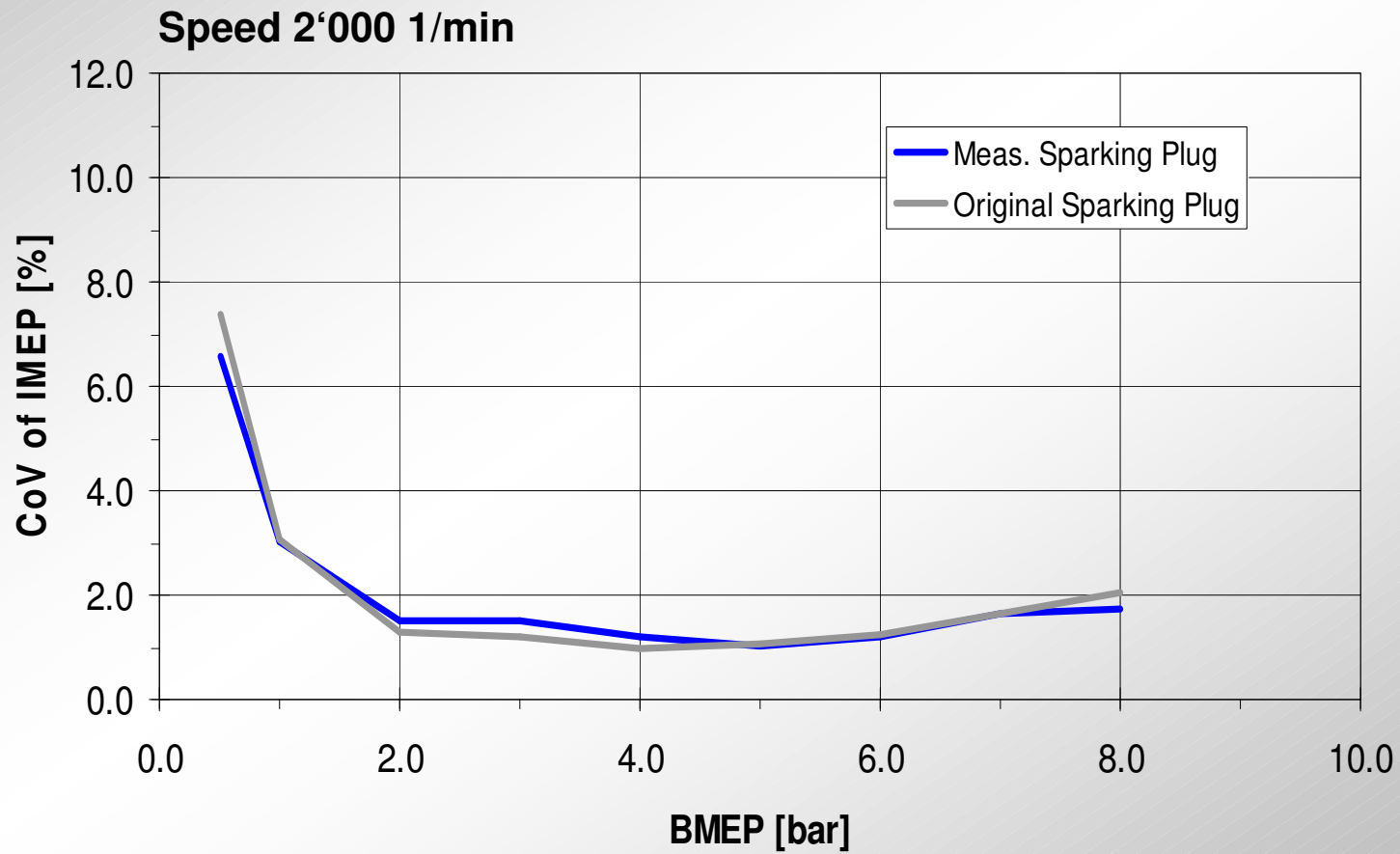
Measuring Task	good suitability	limited suitability	none suitability
Cyclic Variations			
Misfiring			
Determination of Thermodynamic Loss Angle			
Combustion / Heat Release (Start-50%-Ending)			
<i>Combustion / Energy Balance</i>			√
<i>Gas Exchange / Absolute Mass Flow</i>			√
Peak Pressure			
Detonation Detection			
<i>Cylinder Balancing (IMEP absolute Value)</i>			√
<i>Friction Losses (IMEP absolute Value)</i>			√

3. Application on Engine Instrumentation

	Meas. Spark Plug	Reference Sensor
Type	6117BF17	6061B
Type of Sensor	uncooled	cooled (50 °C)
Thread	M14x1.25	M10x1.00
Excentricity of Spark [mm]	2.2	----
Sensitivity [pC/bar]	-16.0	-26.0

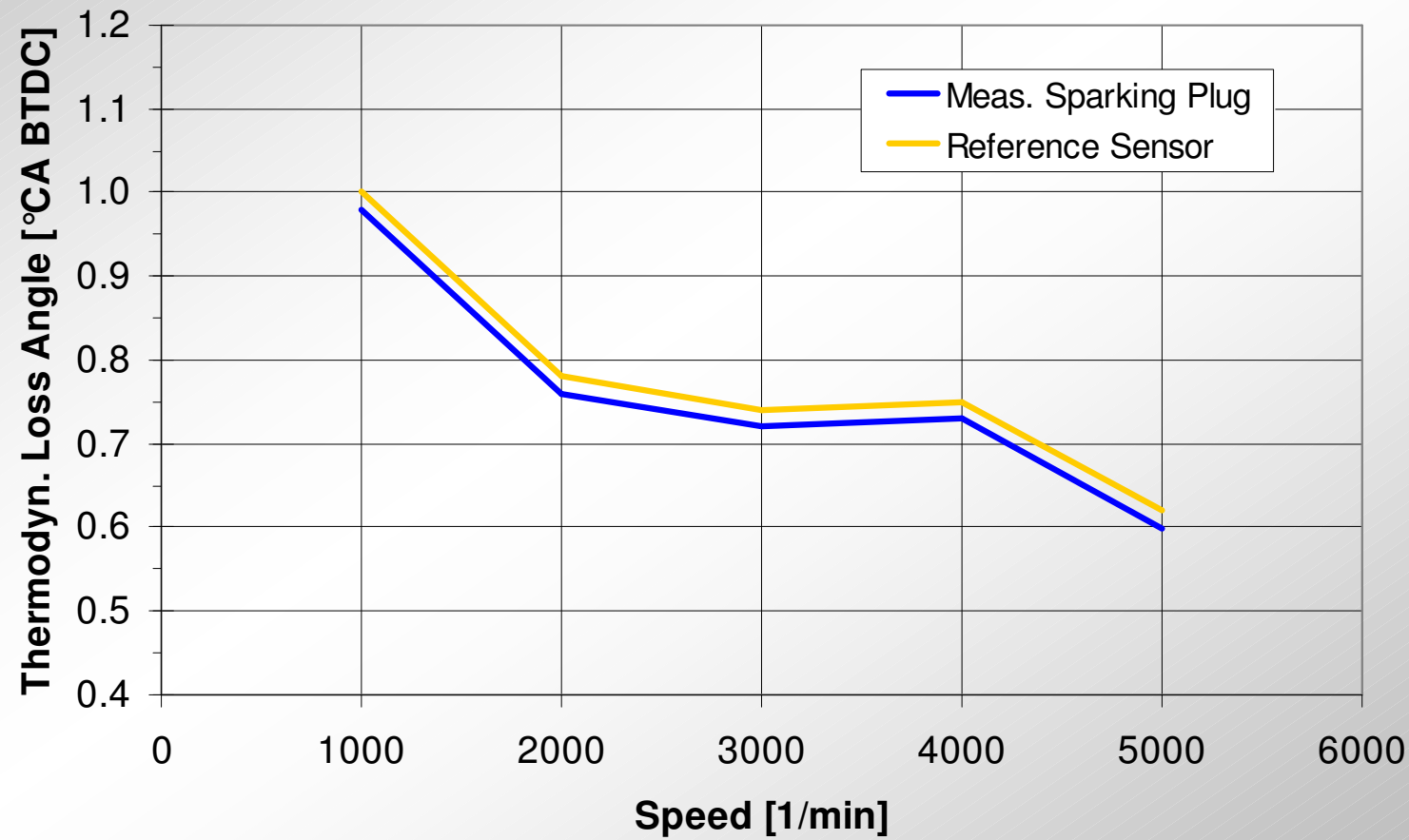


4. Results Cyclic Variations



4. Results

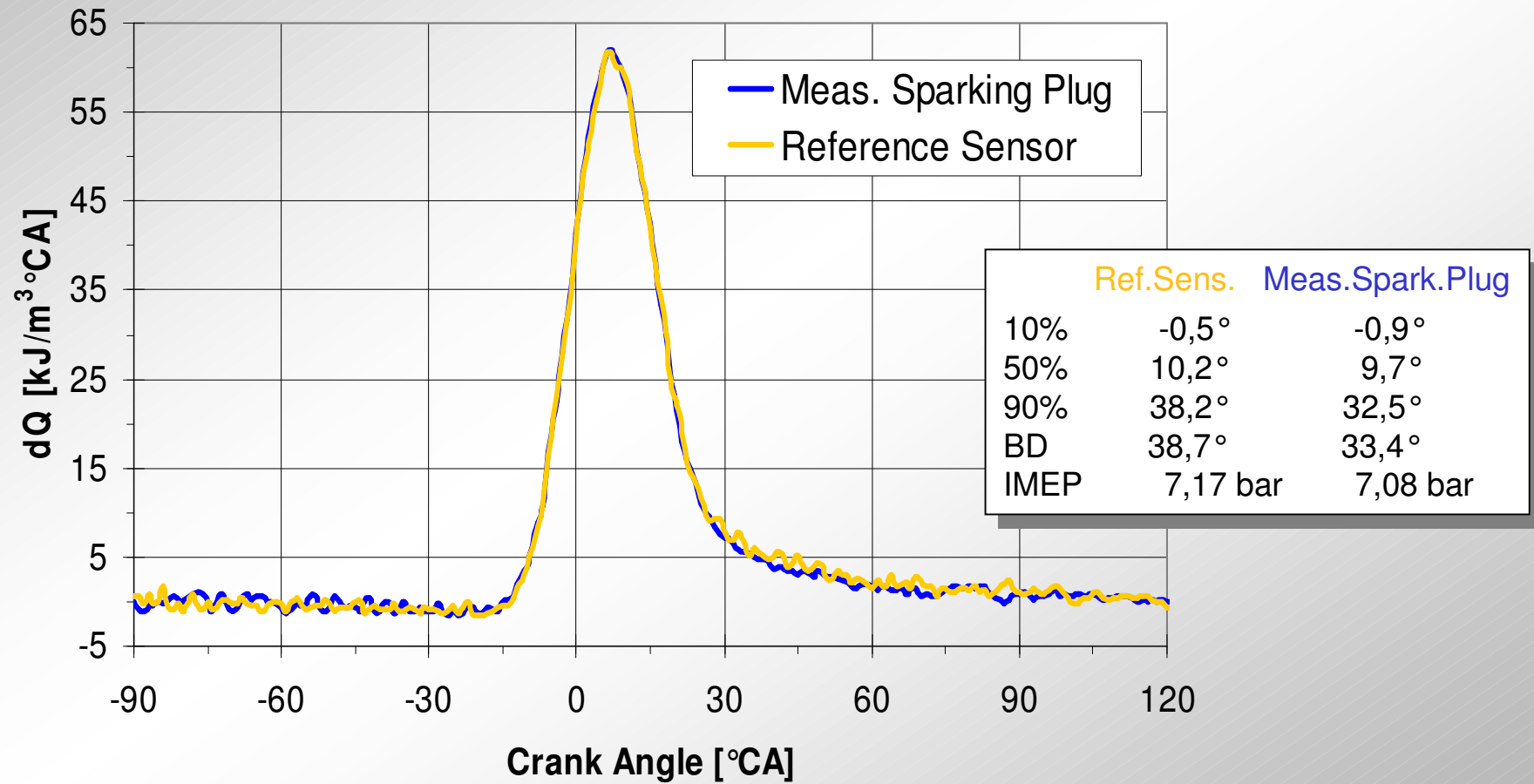
Thermodynamic Loss Angle



4. Results

Heat Release

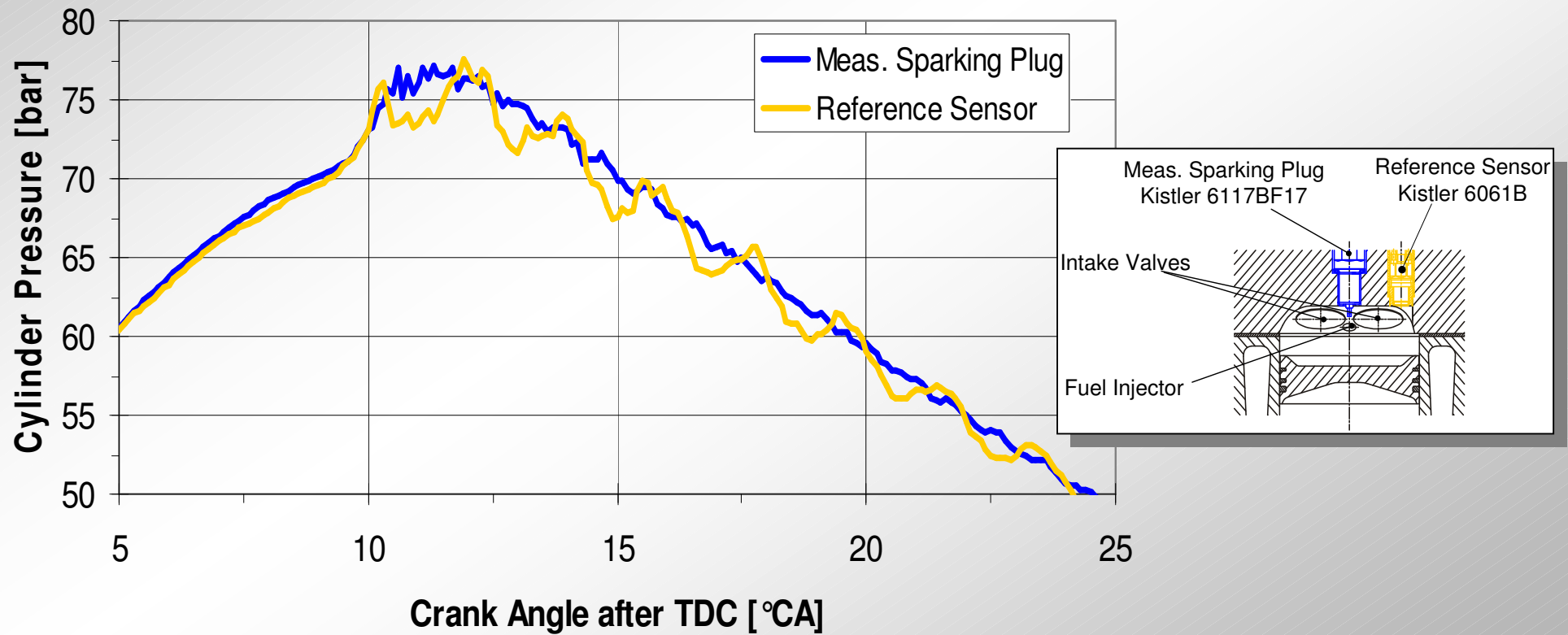
Speed 4'000 1/min, BMEP 6 bar



4. Results

Detonating Combustion

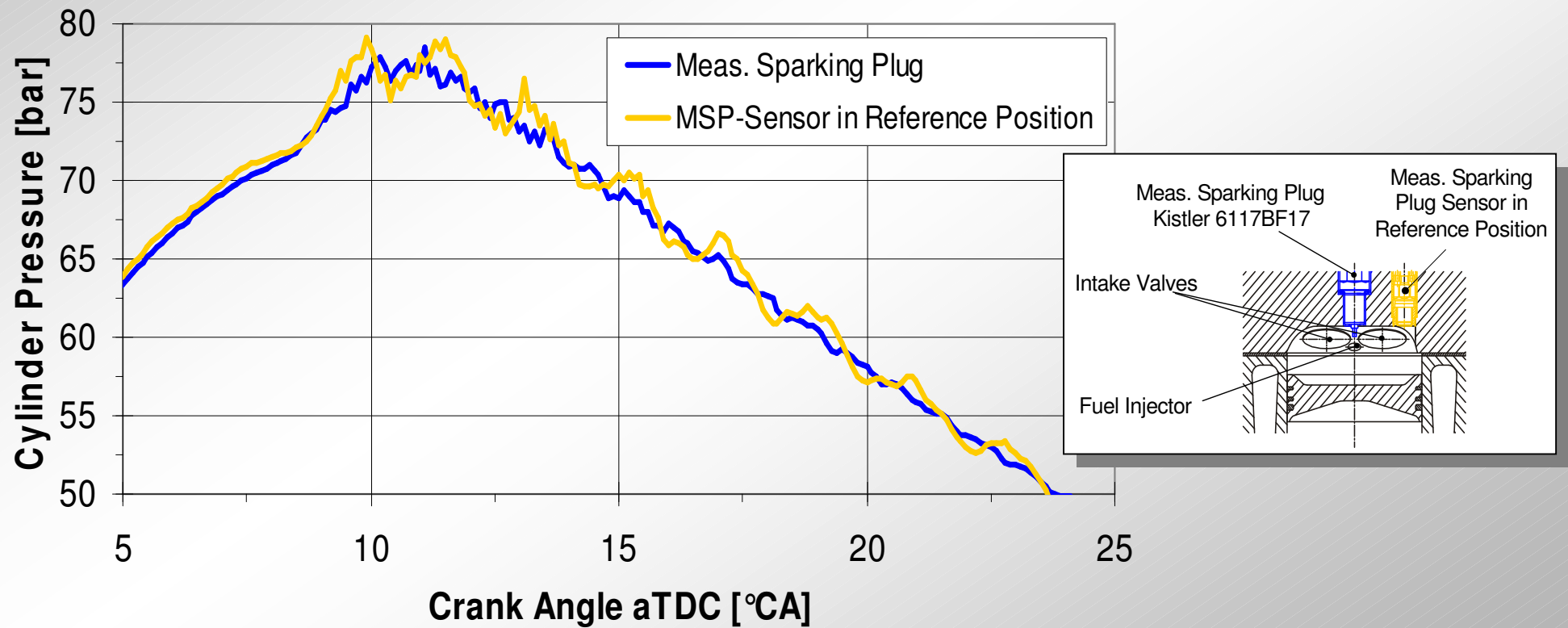
Single cycle #89, Speed 2'000 rpm, BMEP 10 bar,
Standard configuration



4. Results

Detonating Combustion

Single Cycle #62, Speed 2'000 rpm, BMEP 10 bar,
Measuring Spark Plug Sensor in Reference Position

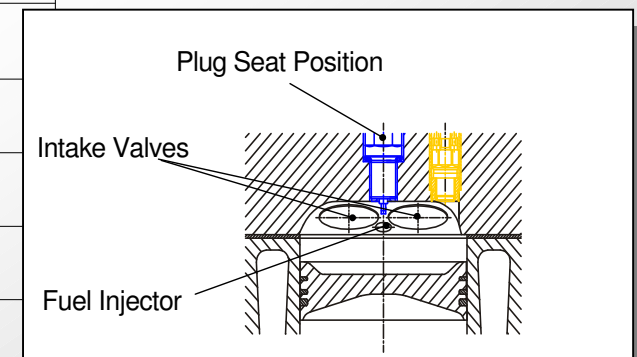
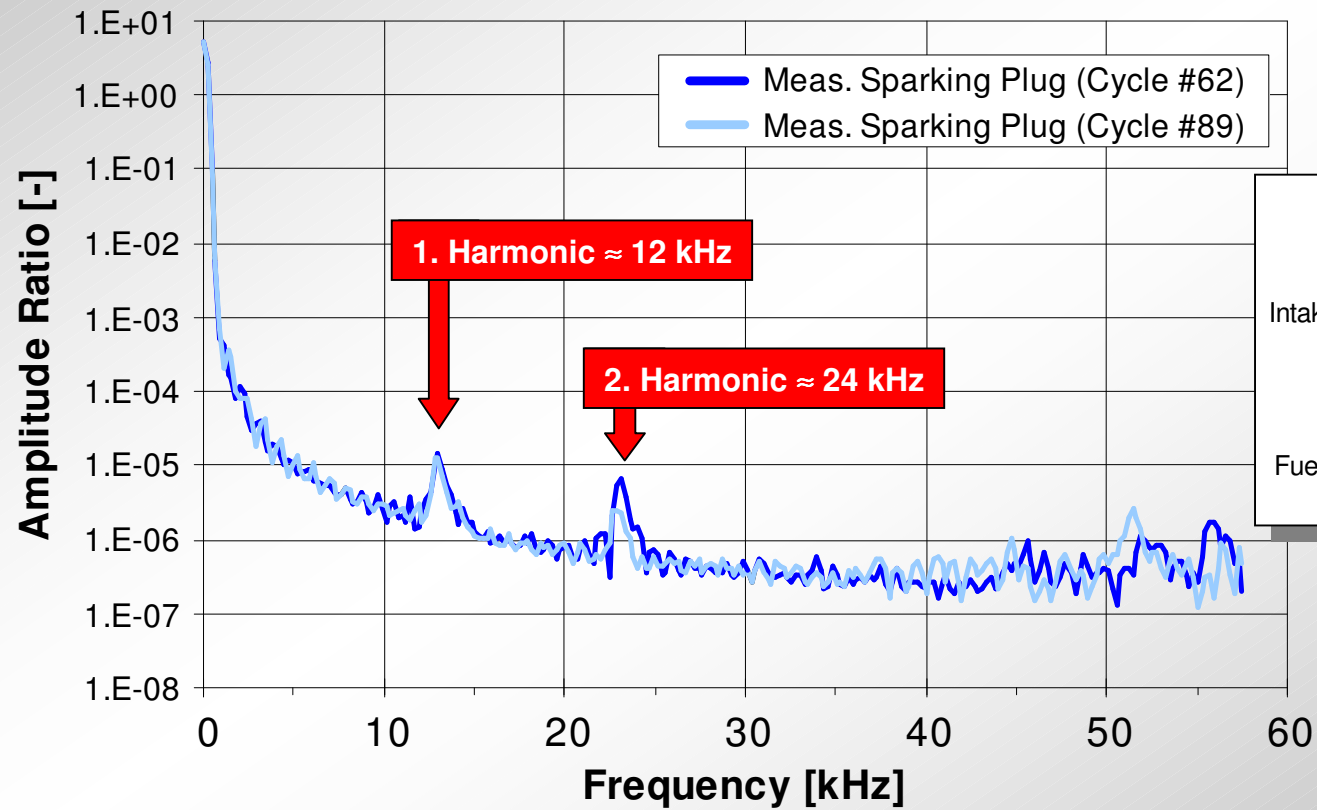


4. Results

Detonating Combustion, Amplitude Spectrum 'Plug Seat Position'

Speed 2'000 rpm, BMEP 10 bar

Meas. Spark Plug at Single Cycle #62 and #89



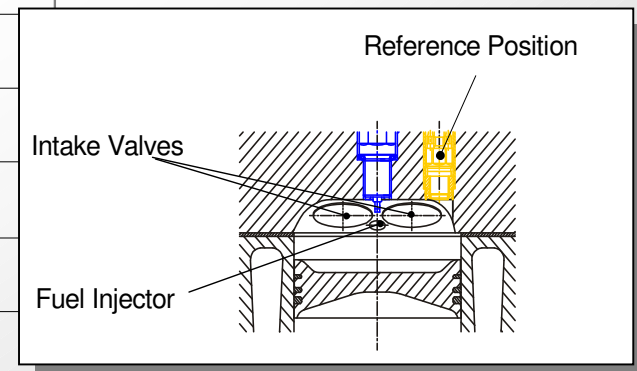
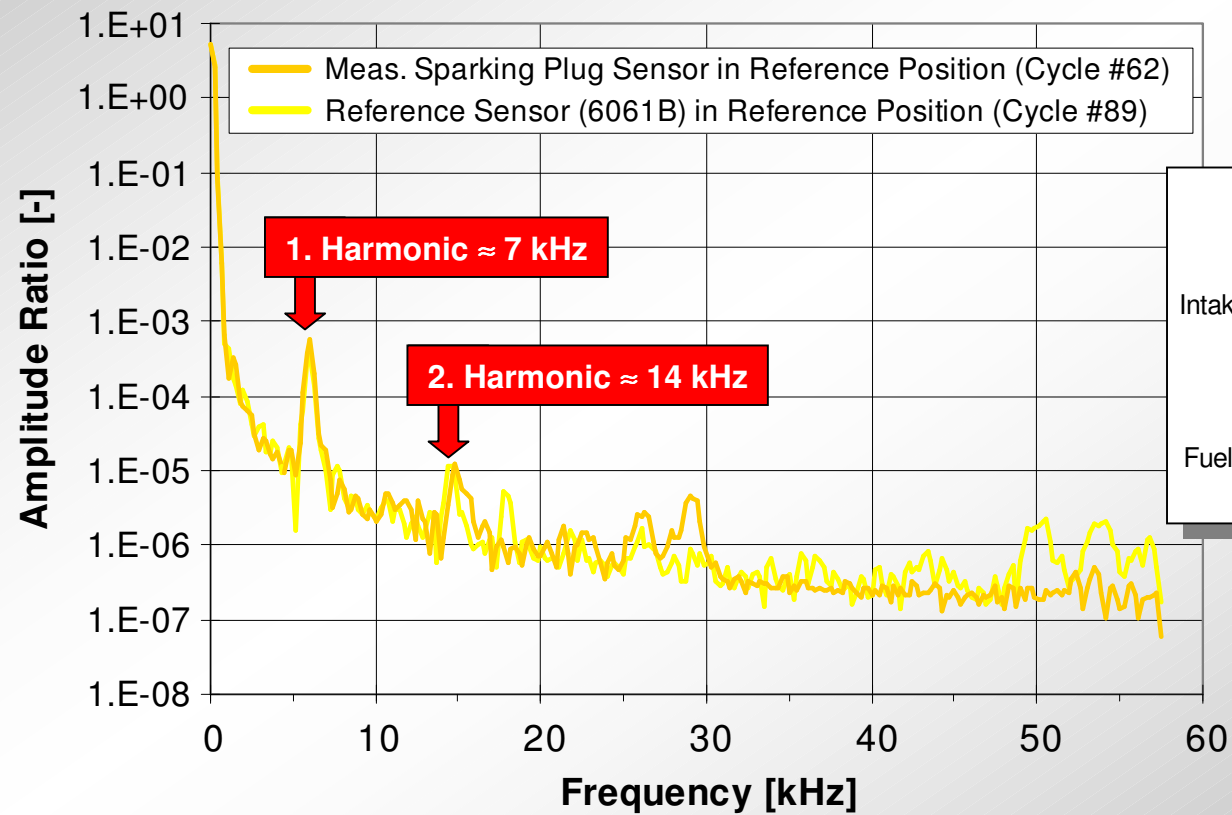
4. Results

Detonating Combustion, Frequency Spectrum 'Reference Position'

Speed 2'000 rpm, BMEP 10 bar

Single Cycle #62: Meas. Spark Plug Sensor in Reference Position

Single Cycle #89: Reference Sensor (Kistler Typ 6061B) in Reference Position



5. Conclusion

Suitability of Measuring Spark Plugs for different Measuring Tasks

Measuring Task	good suitability	limited suitability	none suitability
Cyclic Variations [when mismatching of heat range]	√	[√]	
Misfiring	√		
Determination of Thermodynamic Loss Angle	√		
Combustion / Heat Release (Start-50%-Ending)	√		
<i>Combustion / Energy Balance</i>			√
<i>Gas Exchange / Absolute Mass Flow</i>			√
Peak Pressure	√		
Detonation Detection [at Sparking Plug Position]	[√]	√	
<i>Cylinder Balancing (IMEP absolute Value)</i>			√
<i>Friction Losses (IMEP absolute Value)</i>			√