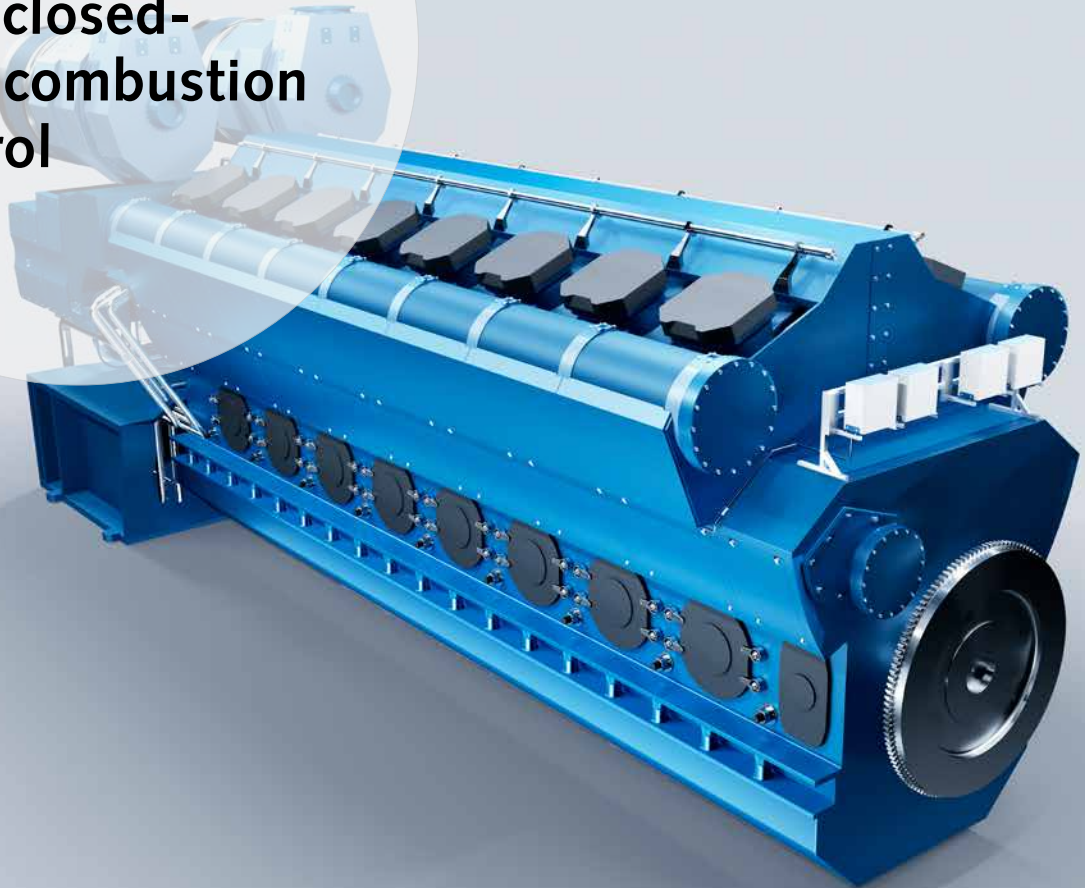


**Reduce costs  
with closed-  
loop combustion  
control**



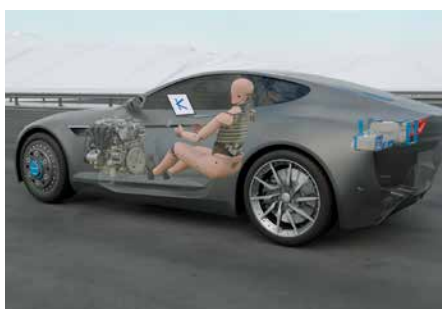
## **Monitoring and control of Marine & Stationary engines**

Reliable efficiency improvements with combustion monitoring and control in large engines with sensor technology from Kistler



## Absolute Attention for tomorrow's world

Kistler develops solutions for challenges in measurement technology with a portfolio that comprises sensors, electronics, systems and services. We push the frontiers of physics in fields such as emission reduction, quality control, mobility and vehicle safety: our products deliver top performance to meet the standards of tomorrow's world, providing the ideal basis for Industry 4.0. This is how we pave the way for innovation and growth – for our customers, and with our customers.



Kistler: the byword for advances in engine monitoring, vehicle safety and vehicle dynamics. Our products deliver data that plays a key part in developing efficient vehicles for tomorrow's world.



Measurement technology from Kistler ensures top performance in sport diagnostics, traffic data acquisition, cutting force analysis and many other applications where absolutely reliable measurements are required despite extreme conditions.



By supporting all the stages in networked, digitalized production, Kistler's systems maximize process efficiency and cost-effectiveness in the smart factories of the next generation.

# Editorial



**The world is facing an unprecedented challenge. Halting climate change requires a rapid transition to carbon-neutral energy production – and large internal combustion engines (ICEs) have a vital part to play here. Kistler is collaborating closely with leading engine OEMs to provide sensors and solutions that are helping to realize the transition.**

Peak-shaving power plants driven by dual-fuel engines have already been used for years to stabilize power grids when renewable solar and wind energy

is unable to meet demand. Going forward, these grid-stabilizing ICE power plants will become even more environment-friendly thanks to the introduction of alternative carbon-neutral fuels such as green hydrogen produced with excess renewable energy.

The International Maritime Organization's greenhouse gas (GHG) strategy calls for a reduction of at least 50 percent in total annual GHG emissions from international shipping by 2050. Some major shipping companies have set even more ambitious goals and are aiming for net zero GHG emissions by as early as 2040. If these challenging targets are to be met, the shipping sector must rapidly introduce alternative carbon-neutral fuels such as green ammonia or green methanol.

Over the past decade, Kistler has delivered thousands of cylinder pressure sensors for continuous monitoring of large power plant and ship engines powered by fuel oil and natural gas. Our OEM customers have used the reliable and accurate measurement data from these sensors as the basis for

implementing closed-loop combustion control (CLCC) in their engines. As well as helping to reduce fuel consumption by up to 2%, CLCC facilitates control of NOx emissions and enables predictive maintenance.

Cylinder pressure sensors from Kistler are not only accurate but also extremely robust and reliable. Years of field experience with state-of-the-art engines have proven that our sensors' properties remain extremely stable, with a long track record of supplying reliable measurement data at a very low total cost of ownership (TCO).

Testing and validation of sensors for the alternative fuels of the future are key elements of Kistler's ongoing close collaboration with leading engine OEMs. Hand in hand with our customers, we stand ready to face the many challenges and opportunities that decarbonization will bring.

Miika Jussila  
Head of Business Unit OEM Sensor Solutions

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Efficient operation of marine engines with Closed-Loop Combustion Control from Kistler.

## Sensor and system expertise – from one single source

**When you need to monitor and control large engines, look no further than Kistler: we offer high-quality cylinder pressure sensors backed by all the service and system expertise you require – so we can develop cost-effective solutions tailored to each customer's specifications.**

### **Trouble-free operation with lower fuel consumption**

Efficient, safe and reliable operation of large marine and stationary engines depends on one critical factor: monitoring and control of cylinder pressure. Optimal adjustment and accurate monitoring of combustion during continuous operation will deliver major benefits: you will make substantial savings on fuel consumption while reducing the risk of breakdowns and premature wear. Sensor technology from Kistler delivers reliable solutions to achieve these goals.

### **Increased efficiency means long returns**

At Kistler, we can draw on our lengthy experience of developing custom solutions for manufacturers of large engines all over the world. Our know-how is recognized by numerous shipbuilders, shipping companies and power plant operators. By drawing on our expertise in sensor technology and our all-round system know-how, we can assist with improving the efficiency of large marine and stationary engines. The basis: cooperation amongst all parties involved. The objective: to develop more cost-effective solutions.





#### **Benefits**

##### **Excellent operational reliability**

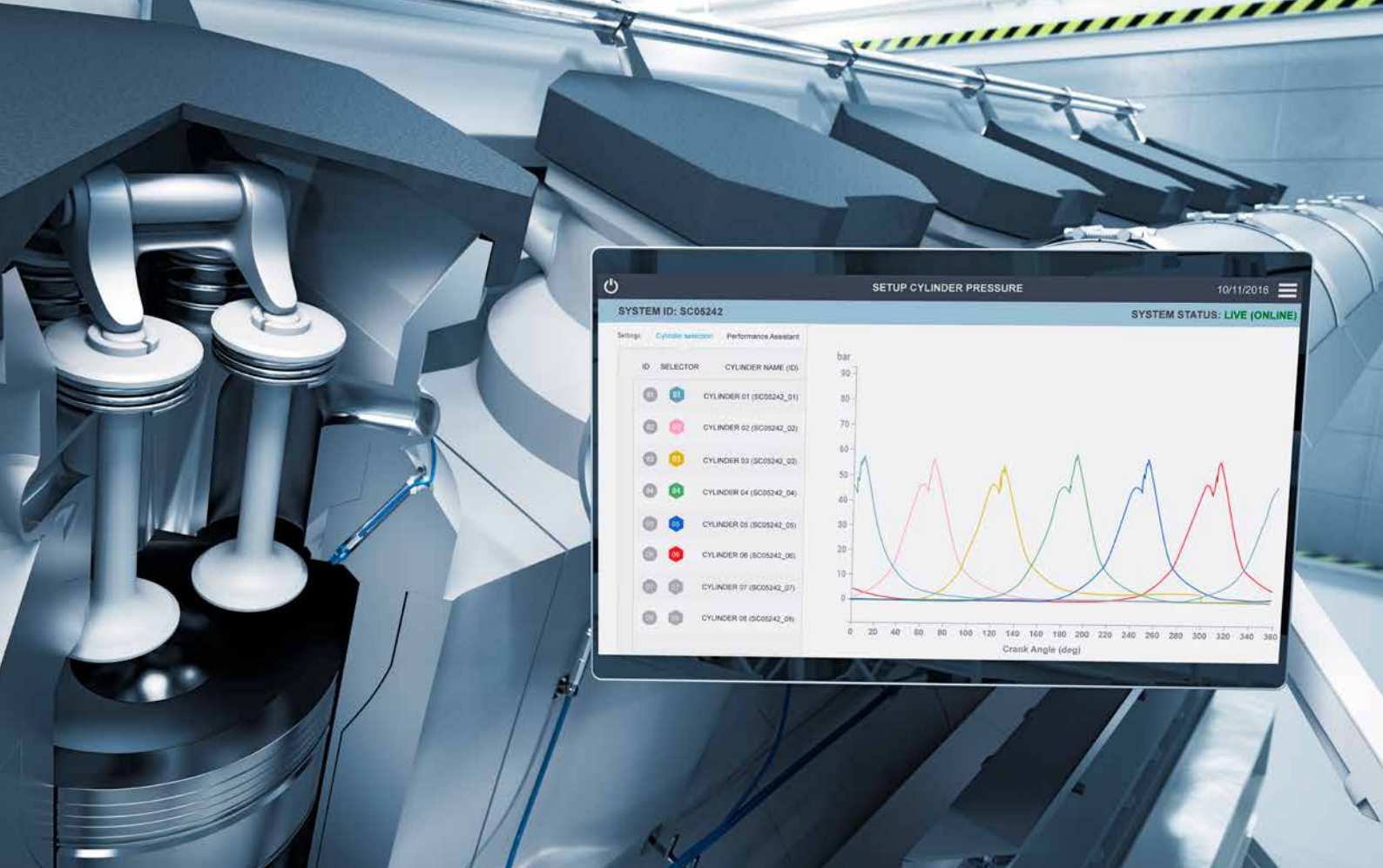
- Proven, high quality products ensure trouble-free, continuous operation

##### **Technical excellence**

- Repeatable, high resolution cylinder pressure data
- Accurate feedback for optimized combustion
- Customized sensors for any application
- Ideal for engines with multi-/flexible fuel options

##### **Optimized resources**

- Fuel consumption reduction
- Lower emissions
- Reduced service requirements
- High return on capital from long sensor life



Simple handling and first-class results: reliable online monitoring with Kistler pressure sensors.

## Continuous monitoring

**Rugged piezoelectric cylinder pressure sensors from Kistler are designed to give many years of service providing continuous monitoring of cylinder pressure in internal combustion (IC) engines.**

**Closed-Loop Combustion Control (CLCC) for increased efficiency**  
Continuous monitoring of the cylinder pressure provides the key element to optimizing combustion efficiency in any IC engine – feedback control of the actual combustion process. Enabling this, the engine operator gains not just optimized fuel consumption and emissions but also reduced engine wear and the tool to access critical data for preventative maintenance.

### Application areas

Many industries today have to meet ever greater business expectations with stricter regulatory requirements on their engines. The response: more widespread use of cutting-edge engine technology to maximize engine efficiency – with CLCC a highly regarded route to improve efficiency in all industries operating IC engines. The major exceptions to this are in engines where alternative fuels or variable fuel quality requires continuous monitoring not just to make efficiency improvements but to ensure engine health under the highly variable combustion regimes these engines can operate in. Leading engine manufacturers put their trust in the quality of Kistler's sensors to deliver the combustion data necessary – where data reliability and consistency are high on their list of priorities. Kistler sensors are installed in both two and four stroke applications, operating on diesel, gas or alternative fuels, in low and medium speed engines.

Consistency are high on their list of priorities. Kistler sensors are installed in both two and four stroke applications, operating on diesel, gas or alternative fuels, in low and medium speed engines.

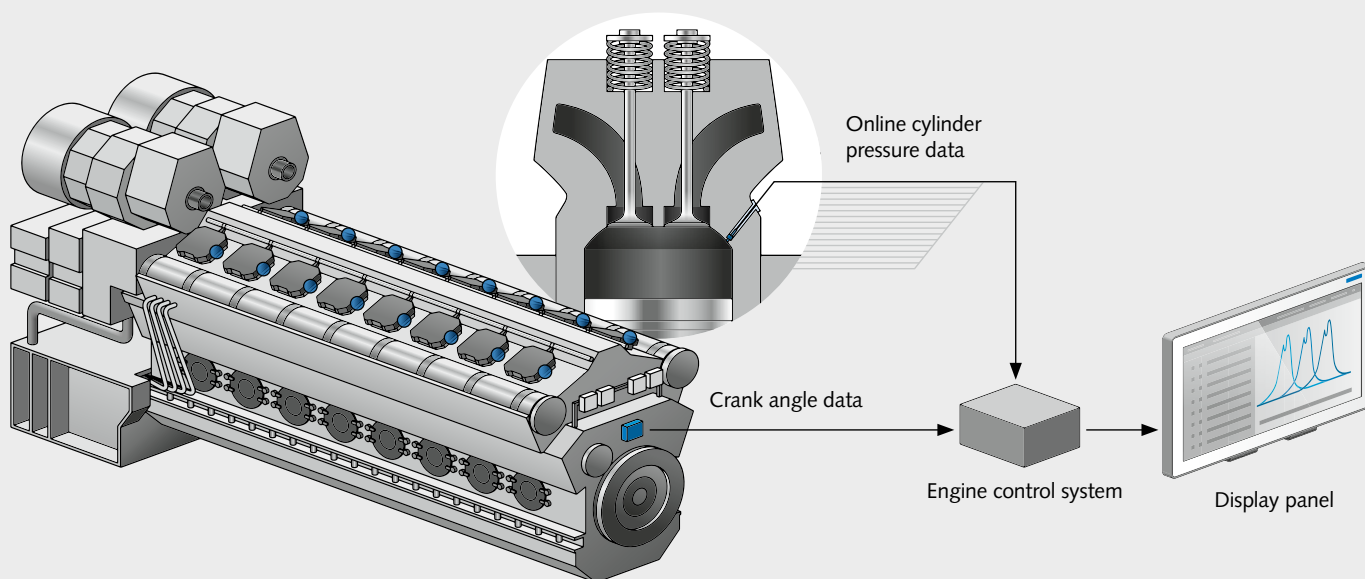
### Benefits

- Fuel is saved
- Emissions are minimized
- Wear is reduced
- Servicing intervals are optimized

### Certificates



## Closed-Loop combustion control process



### Closed-Loop combustion control process

Use our animation to experience convincing, first-class Kistler solutions – the sure way to achieve maximum engine efficiency:



[www.kistler.com/continuous-monitoring](http://www.kistler.com/continuous-monitoring)





Convenience and precision: within the shortest possible time, this Kistler diagnostic device provides the necessary data as the basis for offline monitoring.

## Offline engine diagnosis

**Cylinder pressure is a crucial factor in monitoring low and medium speed combustion engines. The parameter provides meaningful information about the engine's operation. This is why regular cylinder pressure measurement is a standard – and this data provides the essential basis for optimizing fuel consumption.**

### **Pressure sensors and diagnostic equipment from Kistler**

Kistler's diagnostic equipment is the solution of choice for regular recording and evaluation of peak pressures on large engines. Quickly and easily mounted on the indicator valve, these rugged devices deliver accurate and reliable measurement data from sensors with long-term stability. That is why measurement technology from Kistler is also the preferred choice for equipment manufacturers who produce their own diagnostic instruments.

### **Kistler's on-site service**

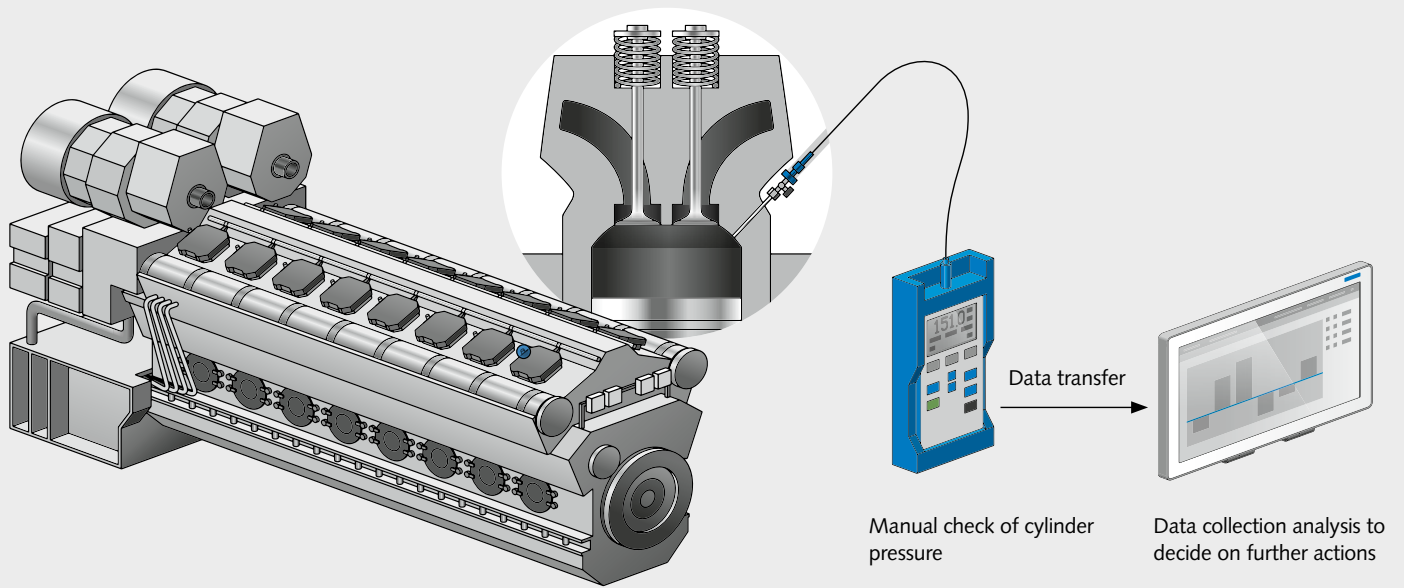
Safe and reliable operation is the overriding priority for large engines – so our specialists are always standing by to assist you with advice and practical help at any time, anywhere in the world.

### **Benefits**

- Damage is detected at an early stage
- Servicing intervals are optimized
- Emission limits are respected
- Cylinder balancing is simple
- Fuel consumption is optimized



## Process offline engine diagnosis



### Offline engine diagnosis

Use our animation to experience convincing, first-class Kistler solutions – the safe way to achieve maximum engine efficiency:



<https://www.kistler.com/INT/en/offline-engine-diagnostics/C00000046>



## The right sensor for your application

**Exact and reproducible cylinder pressure measurements can only be obtained with reliable sensors that measure precisely. Piezoelectric pressure sensors from Kistler are rugged and easy to maintain.**

### **Accurate and reliable**

The heart of a Kistler cylinder pressure sensor is a specially developed piezoelectric measuring element. This forms the basis for accurate and stable measurement results throughout the whole sensor lifetime, even in demanding environments. Kistler cylinder pressure sensors deliver high-precision measurements up to 350 bar in a temperature range of up to 350°C.

### **Fits your unique environment**

The Kistler patented “antistrain” design enables the measuring element to be insensitive to varying mounting conditions – this enhanced flexibility easily allows the integration of the sensors in individual environments.

### **The sensor's lifetime**

Flexible regarding fuels, the cylinder pressure sensors can be used in large two- and four-stroke engines, which are operated with diesel, gas or alternative fuels. The sensors are designed for a service life of thousands of operating hours; however the individual sensor's life time strongly depends on the specific application.

### **Kistler PiezoStar crystal**

- High sensitivity
- High stability over service life
- Industrial scale production
- Years of field experience

High measurement accuracy and reliability are essential for Closed-Loop Combustion Control

PiezoStar crystal technology providing long sensor service life

4-stroke and 2-stroke optimised diaphragm designs

Reliable signal transfer with welded connections

Early collaboration between the engine and sensor manufacturers is highly recommended to optimise the sensor mounting bore and sensor lifetime



Kistler sensor Type 6635A1 for Closed-Loop cylinder pressure control





The PiezoStar crystal from Kistler is up to five times more sensitive than quartz: it delivers excellent measurement stability and is virtually independent of temperature.





Welded connections enable reliable, wear-free signal transmission in harsh environments with high levels of vibration and mechanical shock

## Closed-Loop Combustion Control sensors for 4-stroke engines

Technical data		Type 6635A1	Type 6634A1
			
Pressure range	bar	0 ... 350	0 ... 250
Sensitivity	$\mu\text{A}/\text{bar}$ / $\text{mV}/\text{bar}$	50 $\mu\text{A}/\text{bar}$	10 $\text{mV}/\text{bar}$
Linearity	%FSO	$<\pm 0.5$	$\leq \pm 0.5$
Operating temperature range	$^{\circ}\text{C}$	-40 ... 350	-40 ... 350
Frequency range	Hz	0.016 ... 10 000	0.02 ... 10 000
Signal output		4 ... 20 mA/3 wires galvanic isolated	0 ... 5 V/3 wires galvanic isolated
Properties		<ul style="list-style-type: none"> <li>• Excellent lifetime</li> <li>• Suitable for knock detection</li> </ul>	<ul style="list-style-type: none"> <li>• Excellent lifetime</li> <li>• Suitable for knock detection</li> </ul>

## Closed-Loop Combustion Control sensors for 2-stroke engines

Technical data		Type 7636A2	Type 6636A2
			
Pressure range	bar	0 ... 250	0 ... 250
Sensitivity	$\mu\text{A}/\text{bar}$	50 $\mu\text{A}/\text{bar}$	50 $\mu\text{A}/\text{bar}$
Linearity	%FSO	$<\pm 0.5$	$<\pm 0.5$
Operating temperature range	$^{\circ}\text{C}$	-40 ... 350	-40 ... 350
Frequency range	Hz	0.016 ... 10 000	0.016 ... 10 000
Signal output		4 ... 20 mA/3 wires galvanic isolated	4 ... 20 mA/3 wires galvanic isolated
Properties		<ul style="list-style-type: none"> <li>• Front-end sealing or shoulder sealing</li> <li>• Excellent lifetime</li> <li>• Suitable for knock detection</li> <li>• Mounting thread M14x1.25</li> </ul>	<ul style="list-style-type: none"> <li>• Excellent lifetime</li> <li>• Suitable for knock detection</li> <li>• Build-up of combustion deposits is reduced in combination with Kistler's patented adapter 7523B...</li> <li>• Mounting thread M10x1</li> </ul>



# Instruments for machinery maintenance

Technical data	Type 2516B12
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Properties	<b>Engine peak meter Type 2516B...</b> Type 2516B... supports monitoring of engines with speeds of up to 4000 min <sup>-1</sup> . The data evaluation software included in the accessories supplied with the Peak Meter provides graphic visualization and recording of following parameters:
	<ul style="list-style-type: none"> <li>• Maximum peak pressure (pmax)</li> <li>• Minimum peak pressure (pmin)</li> <li>• Average peak pressure (pav)</li> <li>• Standard deviation of the peak pressure (Sdev)</li> <li>• Maximum gradient of the pressure curve (dp/ca)</li> <li>• Speed (r/min)</li> <li>• Current peak-pressure; measuring function unlimited in time (ppeak)</li> </ul>

Technical data	Type 6513AK
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<b>Thompson adapter</b> The Thompson adapter is a standard tool that fits almost all indicator valves on most engines. It is intended for short-term pressure measurements only. It's recommended to use the sensor with adapter Type 6513AK, which provides additional cooling to reduce the temperature of the sensor and maximize the life time.	
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Technical data	Type 6019A110	Type 6619AP25	Type 6619AP35
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Pressure range	bar	0 ... 350	0 ... 250	0 ... 350
Linearity	%FSO	<±0.3	<±0.3	<±0.3
Operating temperature range	°C	-40 ... 350 (max. 400°C for <10 min)	-40 ... 350 (max. 400°C for <10 min)	-40 ... 350 (max. 400°C for <10 min)
Sensitivity		30 pC/bar	20 mV/bar (Piezotron)	13mV/ bar (Piezotron)
Properties		<ul style="list-style-type: none"> <li>• High precision sensor with excellent thermal stability</li> <li>• Extended temperature range 400°C</li> <li>• Mc M10x1</li> <li>• Charge output</li> </ul>	<ul style="list-style-type: none"> <li>• High precision sensor with excellent thermal stability</li> <li>• Extended temperature range 400°C</li> <li>• Mounting thread M10x1</li> <li>• 6619AP25AK: sensor installed in Thompson adapter 6513AK</li> </ul>	<ul style="list-style-type: none"> <li>• High precision sensor with excellent thermal stability</li> <li>• Extended temperature range 400°C</li> <li>• Mounting thread M10x1</li> <li>• 6619AP35AK: sensor installed in Thompson adapter 6513AK</li> </ul>
Application		For general use in combination with Kistler charge amplifier	Replacement of 7613C with same measuring range, sensitivity and connector. IMPORTANT: Different mounting thread, for mounting at the indicator valve please order 6619AP25AK	State of the art for pressure measurement above 250 bar  Used for new Kistler Engine Peak Meter 2516B12



## Kistler – your partner for innovation

Kistler provides customer support with customized service options available throughout our global service network. Depending on the individual customer situation, Kistler will determine the optimum location to complete the service to best meet customer timing requirements.

### **PMI calibration-box**

The PMI auto-tuning system installed at MAN ME-engines measure the cylinder pressure with online sensors. For commissioning and regular calibration the Kistler PMI Calibration-Box (consisting of a handheld device and a highly accurate reference sensor) is used. To ensure correct functionality Kistler recommends a recalibration of the device and sensors every 5 years. Efficient engine operation is assured. The proposed time for recalibration is during overhaul.

### **Onsite measurements**

Outside of basic data retrieval, or automated calibration procedures, analyzing and interpreting the data from cylinder pressure measurements does require a certain level of expertise. Kistler supports your individual measurement questions or a more detailed technical analysis of any engine with experienced professionals and additional rental equipment, for example our portable Combustion Analysis System – the Kistler KiBox.

### **Retrofit and adaptation**

Existing large diesel/gaseous/multi fuel engines can benefit from the advantages of cylinder pressure monitoring by retrofitting with combustion control technology. Our experts are available to discuss the best technical solution for any specific engine application.

### **Consulting and engineering**

Experienced Kistler experts can offer guidance and advice at any time. This can range from a customized solution for a specific technical issue to an in-house training session on pressure measurements or combustion control. Kistler has the technical knowledge to assist our customer in finding solutions promptly.



## At our customers' service across the globe

Thanks to Kistler's global sales and service network, we are always close to our customers. Some 2,000 employees at more than 60 locations are dedicated to the development of new measurement solutions, and they offer customized on-site support for individual applications.



**KISTLER**  
measure. analyze. innovate.

Making ships and offshore structures safer and more efficient



Solutions for hydrodynamic testing

Wind and water measuring equipment for all wind and marine applications

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Measuring wave impacts under extreme conditions

How advanced pressure sensors from Kistler help structures to withstand loading

**MARIN**  
THE ATMOSPHERE

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measure. analyze. innovate.



Innovative KiBox setup for large engine development

KiBox is a rotating air measurement technology from Kistler to optimize a new marine engine

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[www.kistler.com/applications](http://www.kistler.com/applications)

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