KISTLER

measure. analyze. innovate.

Highest efficiency and stable operation by measuring combustion dynamics

Gas turbine monitoring

Measuring combustion dynamics in high-temperature environments

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

Marco Gnielka
Head of SBF Thermoacoustics

Measuring systems from Kistler allow to monitor thermoacoustic phenomena in harsh environments with extreme temperatures up to 700 °C. Applications include monitoring of gas turbines and other turbo machinery, R&D of continuous detonation engines as well as monitoring and control of pressure oscillations in pipes and acoustic thermometry. Our very robust piezoelectric sensors are based on proprietary crystal material developed for very high temperatures called PiezoStar. Thanks to the in-house growing of crystals, the availability of our piezoelectric sensor equipment is ensured at all times. Furthermore, the fully differential measuring system is insensitive to electromagnetic interferences and even allows low level sound pressure measurements. In contrast to many ceramic materials, the sensors show whether pyroelectric nor popcorn effects. Kistler's modular thermoacoustics portfolio comprises of a great variety of sensors, including Ex-versions certified in accordance with ATEX directives. As a summary, Kistler is able to deliver or develop an optimal solution for almost all thermoacoustics application scenarios.

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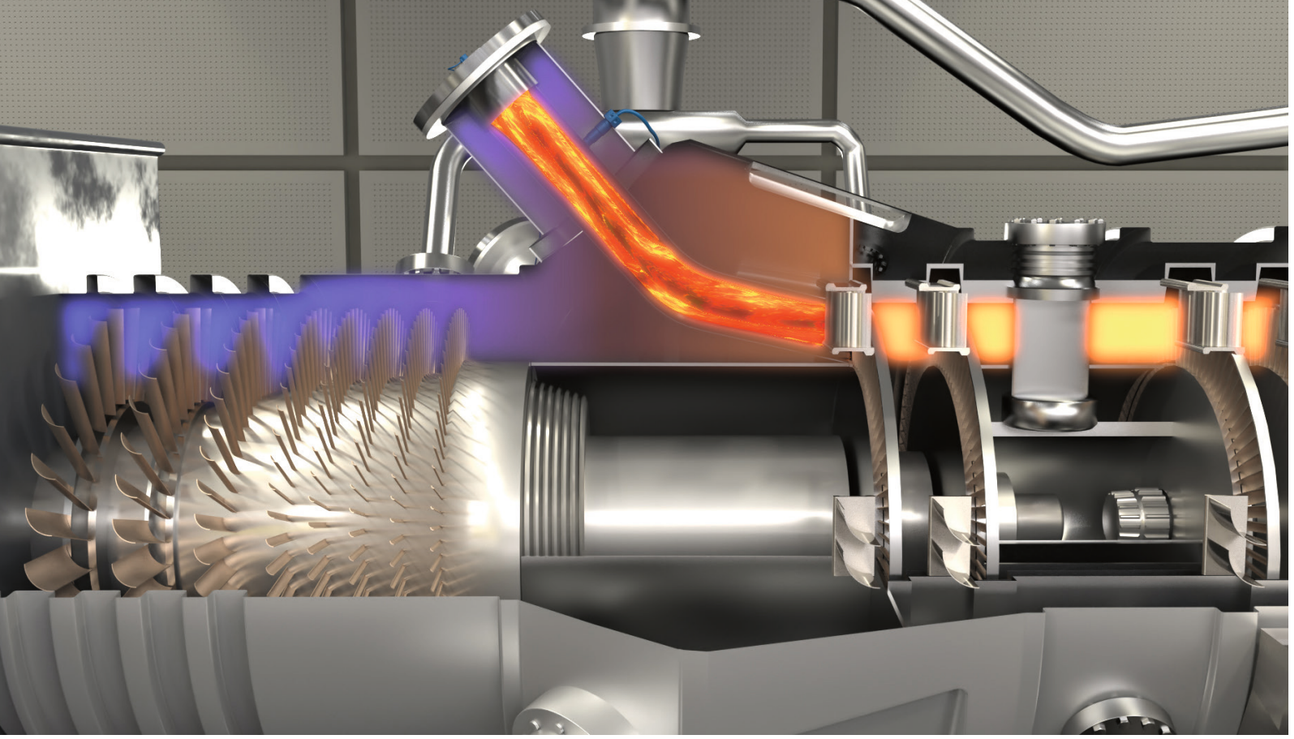


Gas turbine combustors instrumented with high-temperature pressure sensors and accelerometers from Kistler

Reliable gas turbine monitoring in environments up to 700 °C

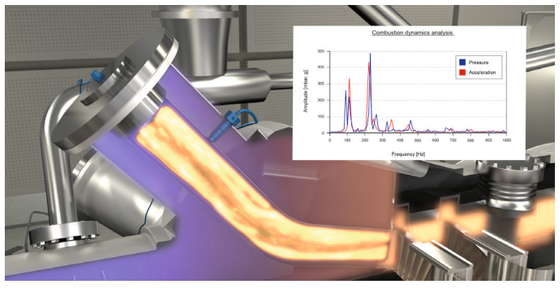
Today's gas turbines must meet ever increasing demands. Among them are high fuel efficiency, fuel flexibility and optimal partial load behavior while complying to increasingly stringent emissions standards. This leads to combustion processes that need to be monitored and controlled within small margins.

Pressure pulsations in the combustors play a prominent role. Excessive pulsations caused by instabilities could potentially damage the equipment. To avoid unstable conditions and maintain safe operation, the pulsations must be continuously monitored.

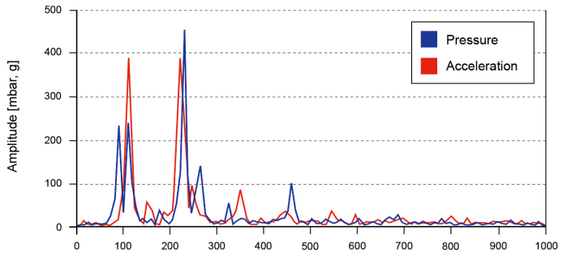
High-temperature pressure sensors and accelerometers from Kistler are designed for use in gas turbine combustors. Thanks to their outstanding high-temperature capability, they can be applied without a 'long tube' and, if desired, placed in very hot locations. This simplifies the system and delivers more accurate pressure measurements.

Benefits of Kistler combustion monitoring solution

- Complete differential, ground isolated measuring chains to detect smallest pulsations
- Resistant to high temperatures over years (700 °C / 1 300 °F)
- Interference resistant by design (EMI, RF)
- Own-grown PiezoStar sensing element guarantees permanent availability



Pressure pulsation and vibration monitoring



Analysis and monitoring of pressure pulsation and acceleration

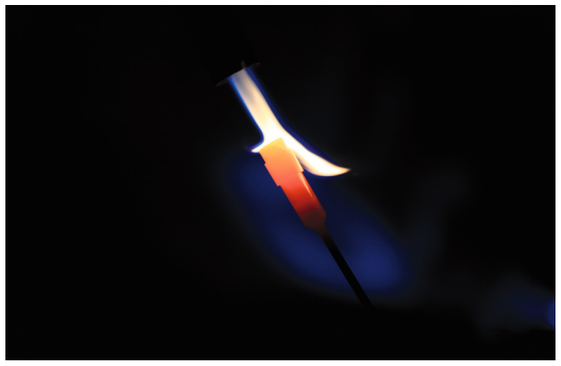
PiezoStar crystals, the heart of all Kistler high-temperature sensors

The PiezoStar advantage: superior performance meets availability control

The proprietary single crystal PiezoStar sensing elements are the foundation of our superior performance delivered by pressure and acceleration sensors for ultra-high temperatures – they have been thoroughly tested at well over 700 °C (1 300 °F). Unlike ceramic-based sensor elements, they are not pyroelectric and show no popcorn effect. And in contrast to using natural materials, Kistler controls the whole supply chain and is therefore able to ensure the availability of its products at any time.

Our crystal compounds are the result of over 10 years of co-operation and research with universities throughout the world, exhibiting unique performance to improve the data quality for physical measurements. The PiezoStar elements features utmost temperature stability which leads to a high reliability of the sensors that are built upon them. This material is the key element for our high-temperature pressure and acceleration sensors.

The unique design of the crystal shows no pyroeletric effect nor popcorn effect. This features, combined with permanent stable performance under temperature, are the foundation for reliable measurements at temperatures up to 700 °C / 1 300 °F. Even higher temperatures over a short time are possible for the PiezoStar crystal.



The PiezoStar sensing element can be placed directly in very hot areas

Independent high-quality crystal production

Today, we are able to produce the quantity needed for our sensors and solutions completely on our own. That makes us independent from suppliers, market fluctuations and especially the availability of natural materials used as sensing elements. As a self-sustaining manufacturer of piezoelectric sensors, we guarantee the availability of the PiezoStar high-performance sensing elements.

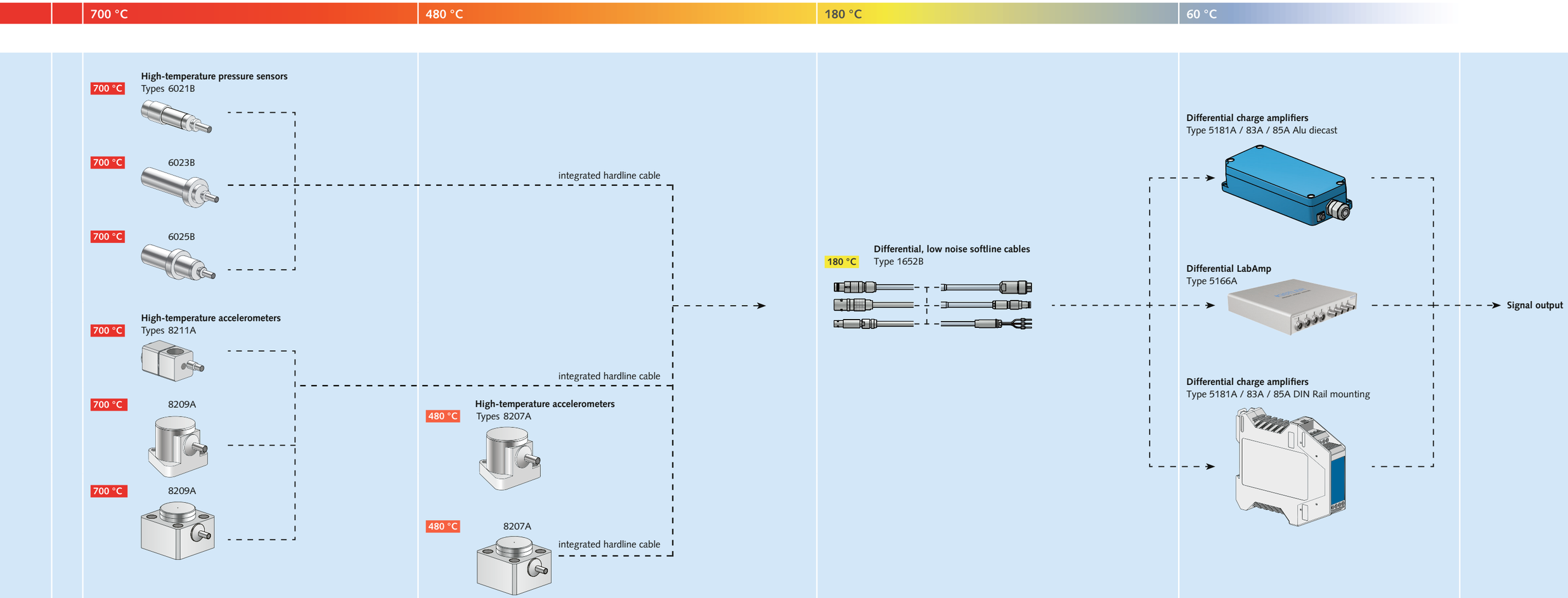
Excellence in every single part – the measuring chain adapted to your needs

Pressure sensors
Our high-temperature pressure sensors for long term monitoring applications is the core element of your pressure measuring chain. All types are based on our PiezoStar crystal technology.
The differential and ground isolated design in combination with the internal acceleration compensation allows you to measure smallest pressure fluctuations in a harsh environment. The robust integral hardline cable is also capable for temperature up to 700 °C.

Accelerometers
Kistler accelerometers are available for different temperature classes. All designs are fully differential and ground isolated.
The sensor architecture is the key reason to achieve accurate and reliable measuring results with lowest transverse sensitivity and base strain errors. All types work with our Kistler PiezoStar crystals as sensing element. The robust integral hardline cable is also capable for temperature up to 700 °C.

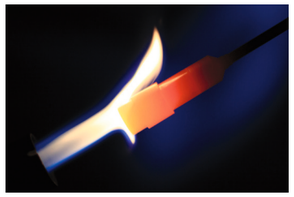
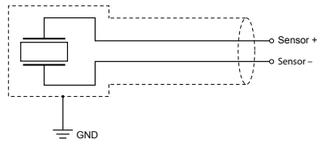
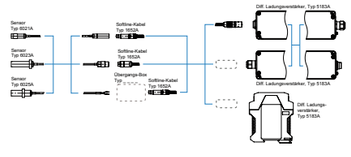
Cables
The softline cable simplify your installation and cable routing after the hot zone. With a temperature capability of up to 180 °C, a low noise design and a high flexibility, this robust cable is the ideal solution to connect the charge amplifier with the sensors. All the different available connector possibilities ensures to meet your preferred connector standards.

Charge amplifiers
Our differential charge amplifier with its high modular design converts the charge input into a voltage or current output.
The available high- and lowpass filters, in combination with the customizable sensitivity, precondition your signal according your requirements.



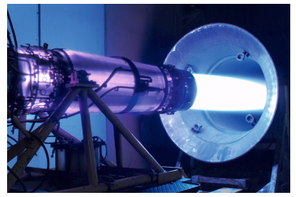
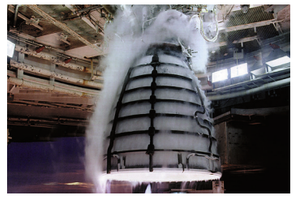
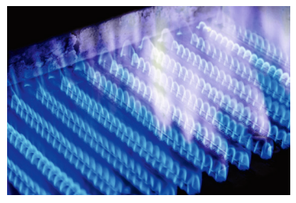
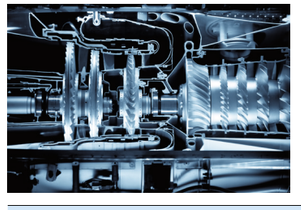
Features and benefits at a glance

As a leading provider of sensors and measuring solutions, Kistler offers its customers a lot of unique features and benefits. Of course, it all starts with the PiezoStar sensing element, but it doesn't stop there. Driven by decades of experience and deep technological know-how, we built up our portfolio to meet specific customer demands for a great variety of possible thermoacoustic applications.

	Features	Benefits
Unique crystal for ultra-high temperature environments		
	– Proprietary PiezoStar sensing element	– Operating temperature up to 700 °C for application close to the combustion – Excellent long-term stability – High sensitivity – Not pyroelectric – No popcorn effect
Highest reliability and durability		
	– **H**ighly **A**ccelerated **L**ifetime **T**esting (HALT) under defined conditions in order to determine the true operating limit. – Possibility of individual, customer-specific tests – Several years of experience with established gas turbine manufacturers	– High reliability and repeatability – Long lifetime – High flexibility whereby almost every customer need can be fulfilled – Field-proven durability and reliability in our customers' gas turbines
Immune against electromagnetic interference		
	– Internally ground isolated two-wire design	– Able to measure smallest pressure pulsations – Robust against electromagnetic interferences – Effective interruption of ground loops
Modular portfolio that meets your needs		
	– Modular portfolio design – Various cable and connector options – Broad variety of charge amplifiers and signal filters	– Tailored, customized measuring chains available – Flexible configuration of sensor and measuring chain – Small number of components
Explosion protection		
IECEx EAC Ex CE RoHS	– All components are optionally available with ATEX, IECEx, EACEx – Certified protection concepts Ex nA and Ex ia – CE and RoHS conform – Other regions on request	– Matching components available – Efficient implementation for applications in hazardous environments

Further thermoacoustic applications

Our high-temperature pressure and acceleration sensors are able to benefit many applications other than gas turbine monitoring. Wherever pressure pulsations or vibrations in extremely hot environments need to be measured, our sensors will do the job, be it for R&D projects or for monitoring applications with the sensor permanently installed to protect expensive capital equipment.

Application	Objective	Benefits
Aero engine testing		
	**Measure vibrations in hot environments during:** – Development phase – Engine tuning and qualification process – EoL test after major overhaul	– Increased power and efficiency – Improved safety and reliability – Accurate and trustworthy measuring results
Rocket engine		
	– Measuring dynamic pressures and vibrations on gas generator and combustion chamber – Suitable for R&D & monitoring applications	– Increased power and efficiency – Improved safety, performance and reliability
Acoustic thermometry		
	– Determine two-dimensional temperature profiles using acoustical methods – Measure temperature distribution in power plant boilers, blast furnaces and other large industrial furnaces	– Efficient plant operation – Meet emission regulations – High accuracy; no heat radiation error – Temperature measurements exceeding 1 000 °C
Turbo machinery		
	– Measuring in turbo machinery (compressors, propellers, steam turbines, etc.) for R&D and continuous monitoring purposes – Measurements at optimal locations	– Optimize performance – Improve efficiency – Reduce emissions – Protect equipment
Vibration in piping systems		
	– Investigation of pressure pulsations and resulting vibrations in piping systems for hot media – Identification of excitation mechanisms – R&D and continuous monitoring purposes	– No cooling adapters needed – Protect equipment – Avoid fatigue stress and improve lifetime

Applying measuring technology benefits from know-how and regular calibration

Training and calibration

In order to enable maximum performance for your equipment, Kistler offers training services dedicated to the application as well as calibration services on different levels.

While regular calibration is indispensable to maintain the desired accuracy of your measuring technology, the training of personnel gives you the opportunity to build up know-how inhouse and optimize your processes more independently.

Kistler aims to offer specific trainings and events for all of its products and their applications respectively. Seminars and training sessions typically take one to three days, providing participants with everything they need to know about a specific sensor or solution from Kistler.

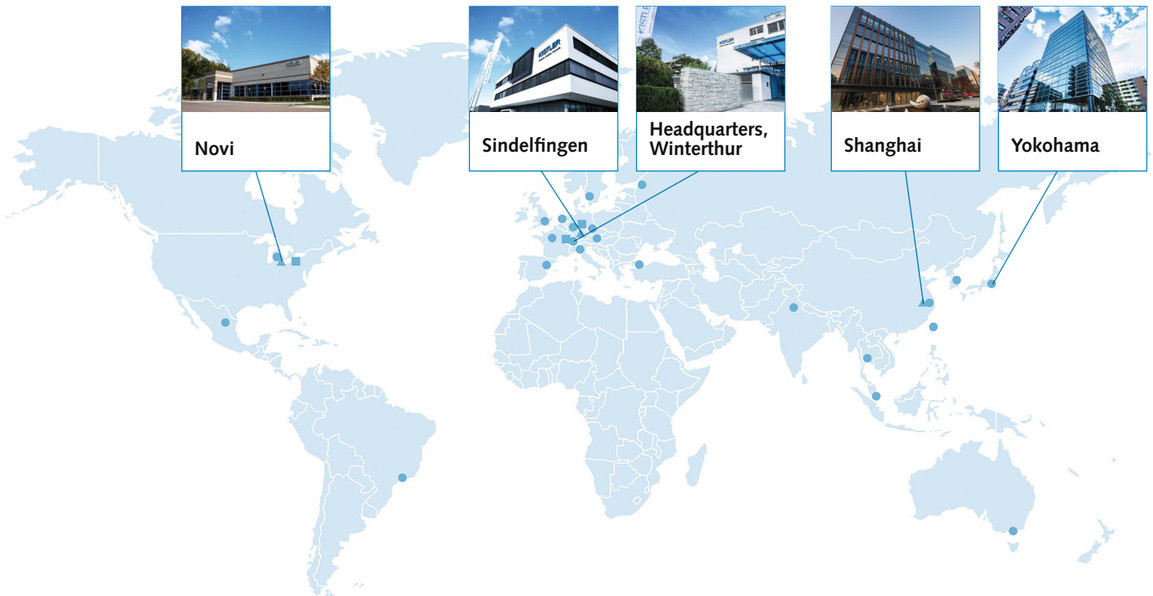
The education portfolio for thermoacoustics and gas turbine monitoring is currently in development. Please check upcoming dates and events at www.kistler.com/de/services/trainings/. If available, you can either take part in public sessions for a greater audience – or if you prefer, you may also set up a more personal training event at your company's premises.

Calibration services
Precise and reliable measurements demand regular recalibration. To support its clients best, Kistler operates a network of calibration laboratories from its premises around the world.

Why calibrate?
- Be confident in your equipment and machinery
- Keep measurements accurate and reliable over time
- Meet industry standards and customer requirements
- Further enhance quality and production standards

Your benefits
- Expertise based on decades of calibration experience
- Check-up of device included in every calibration service
- Calibration of 3rd party products also possible
- Service available for complete measuring chains (including electrical measurands)

Our experts have developed application-oriented calibration procedures especially for products and systems from Kistler. For example, measuring range, loading profiles, boundary conditions and evaluation algorithms are defined to suit the sensor and its application.



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 61 locations are dedicated to the development of new measurement solutions, and they offer customized on-site support for individual applications.

Find out more about our applications:
www.kistler.com/applications

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