KISTLER

measure. analyze. innovate.

Process monitoring and control

Transparency in networked injection molding production

About the Kistler Group

Kistler is the global leader in dynamic measurement technology for measuring pressure, force, torque and acceleration. Customers benefit from Kistler's unique sensor technology and the company's experience as a development partner, enabling them to optimize their products and processes so as to secure a sustainable competitive edge. With some 1 860 employees at 61 locations worldwide, the Kistler Group posted revenue of CHF 422 million in 2017.

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, digitized production, Kistler's systems maximize process efficiency and cost-effectiveness in the smart factories of the next generation.

Contents

Kistler systems: the ideal basis for enhanced transparency in networked injection molding production

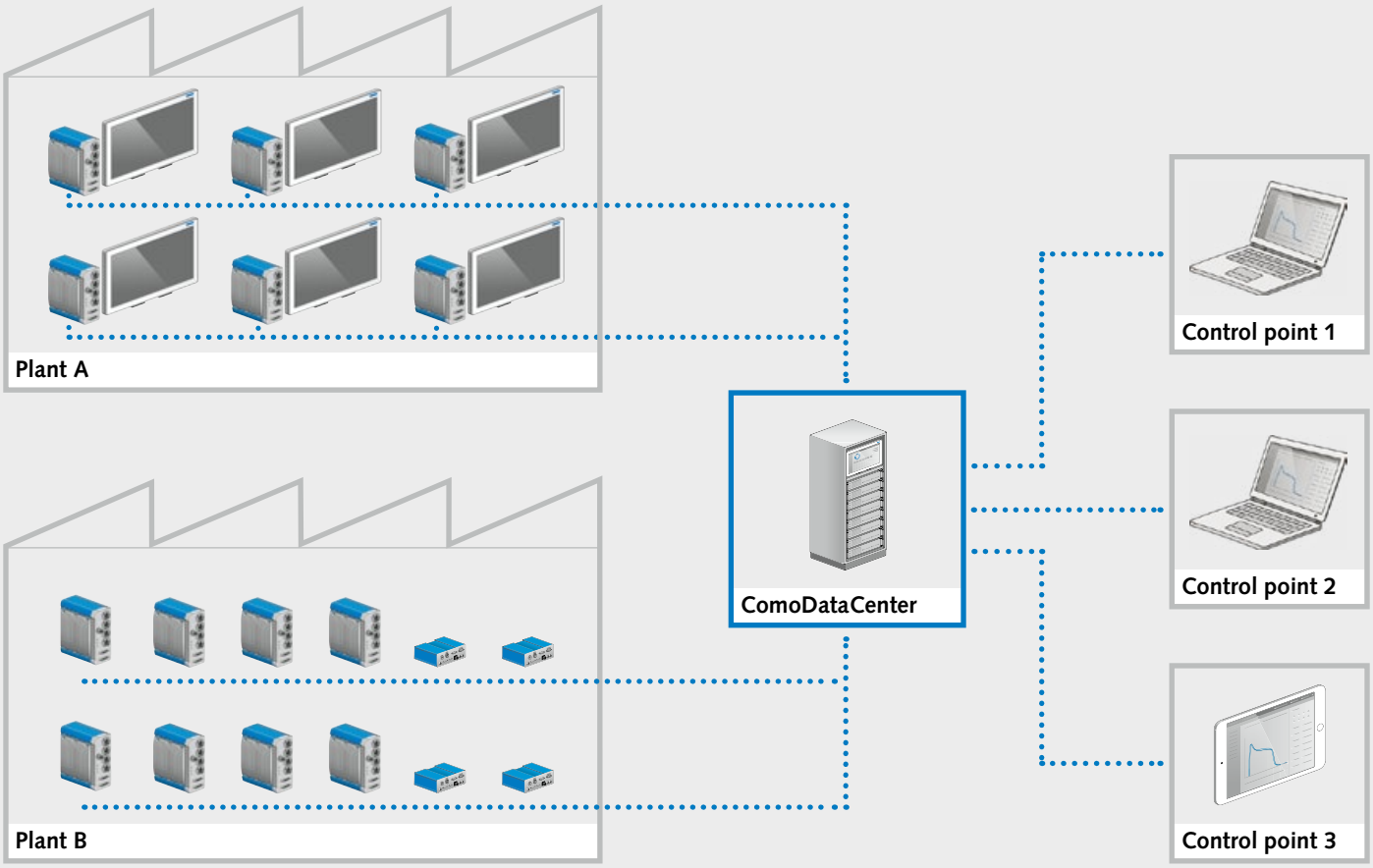
The Industry 4.0 vision has already emerged as a distinct reality in the injection molding sector. The new approach to production focuses on consistent digitization – leading to enhanced product quality and increased cost-efficiency. Injection molders equipped with Kistler systems for process monitoring and control are ideally placed to meet the requirements for digital networking. Information networking and data management are gaining importance as we advance towards Industry 4.0.

Quality requirements for injection molding are constantly increasing, so permanent control of the entire production chain is essential. Kistler presents ComoNeo and ComoDataCenter: two system components that offer the best possible basis for achieving this goal – and they are perfectly suited to novices as well as experienced users.

The new features integrated into ComoNeo have been specifically developed to meet the requirements that are arising as this happens. First and foremost among these new features is the ComoNeoRECOVER Restart Assistant now integrated into ComoNeo, which allows efficient reproduction of established processes when changing machines. But there are many other innovations as well: for example, the system now supports the

Benefits of Kistler systems:

- Zero-defect production
- Quality costs are cut
- Optimal process efficiency
- Process reliability is enhanced
- Cycle times are optimized
- Staff costs are reduced
- Plant efficiency is increased
- Rapid amortization (RoI)
- Industry 4.0
- Networking
- Data management and optimization



OPC-UA interface, which is on the way to becoming the standard for injection molding production. Integration of OPC-UA in ComoNeo also makes it possible to implement hot runner control as an entirely standalone solution, without an additional PC. The benefit: significantly less effort is required because the entire setup process is simplified.

Another new feature for ComoNeo: an integrated feature that allows reliable advance predictions about every part to be produced, so the full bandwidth of cavity pressure monitoring methods is available – from monitoring of process fluctuations and manual or automated EO monitoring (with ComoNeoGUARD) through to online quality prediction (with ComoNeoPREDICT). This is a high-end solution for direct calculation and evaluation of part characteristics.

In a nutshell: by adding these new features to ComoNeo and ComoDataCenter, Kistler is paving the way for yet more future improvements to product quality and cost-efficiency in injection molding production.

Injection molding with Kistler – now online!
View our animation to experience convincing, first-class Kistler solutions – the surest route to 100% quality in your production:
www.kistler.com/comoneo

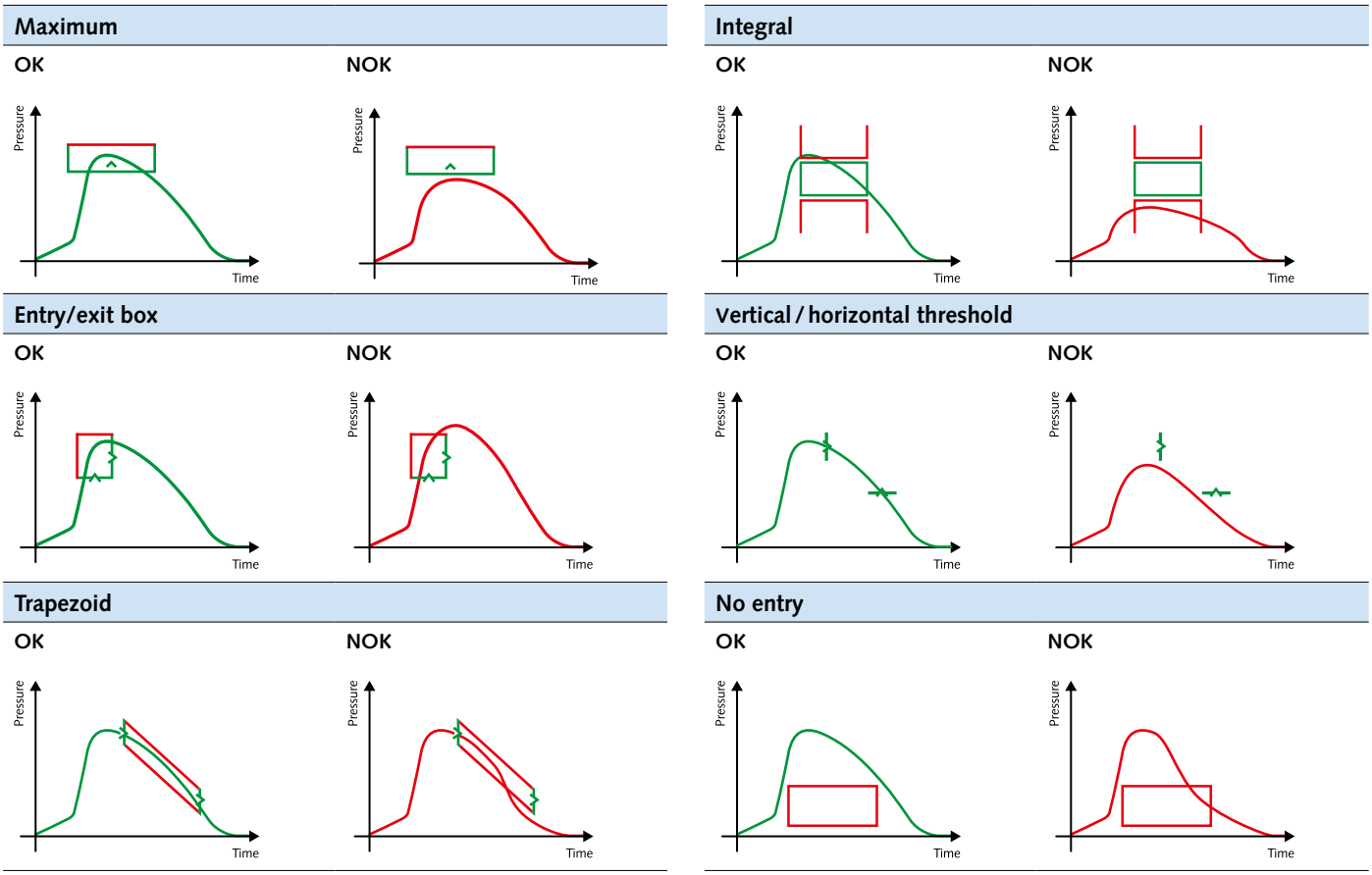
Process monitoring with ComoNeo: transparent injection molding processes guarantee quality

The ComoNeo process monitoring system uses the measurement values (such as temperature and pressure curves) from the injection molds to monitor and evaluate the quality of an injection-molded part. For this purpose, the system checks whether a specified value is reached or exceeded in the profile, with the help of defined evaluation objects (EOs) that are set either manually or automatically.

The ComoNeo monitoring system analyzes quality-relevant sections of the measurement curves captured via the measurement functions, with the help of defined Evaluation Objects – known as EOs. To do this, ComoNeo verifies whether the curves pass through the evaluation objects as predefined (illustration on page 7). If so, ComoNeo generates an "OK" result; otherwise, the result is "Not OK" (NOK). This allows sorting into good and bad parts. The EOs are set either manually or with the help of an intelligent assistance function. Additional practical tools are also at the user's disposal: online quality prediction based on statistical test planning, and the Restart Assistant.

Advantages of process monitoring with ComoNeo:

- The integrated process dashboard provides a quick overview of the status and progression of production
- Separation of good and bad parts
- Monitoring of cavity pressure by setting Evaluation Objects (EOs)
- Automatic monitoring of cavity pressure with ComoNeoGUARD
- ComoNeoPREDICT as an additional method for separating out scrap
- ComoNeoRECOVER: the simple way to transfer established processes from one machine to another



ComoNeo Evaluation Objects (EOs)

Manual monitoring of cavity pressure

Cavity pressure monitoring with manually set evaluation objects (or EOs) makes it possible to determine various quality features in the injection molding process, and they can be evaluated with reference to the specified tolerances. Six frequently used functions are presented in the following overview.

Maximum
The Maximum function checks whether the curve reaches a specified pressure value (green line) or whether it does not exceed that pressure value (red line). Typically, this box is used to determine whether the cavity was completely filled (short shot).

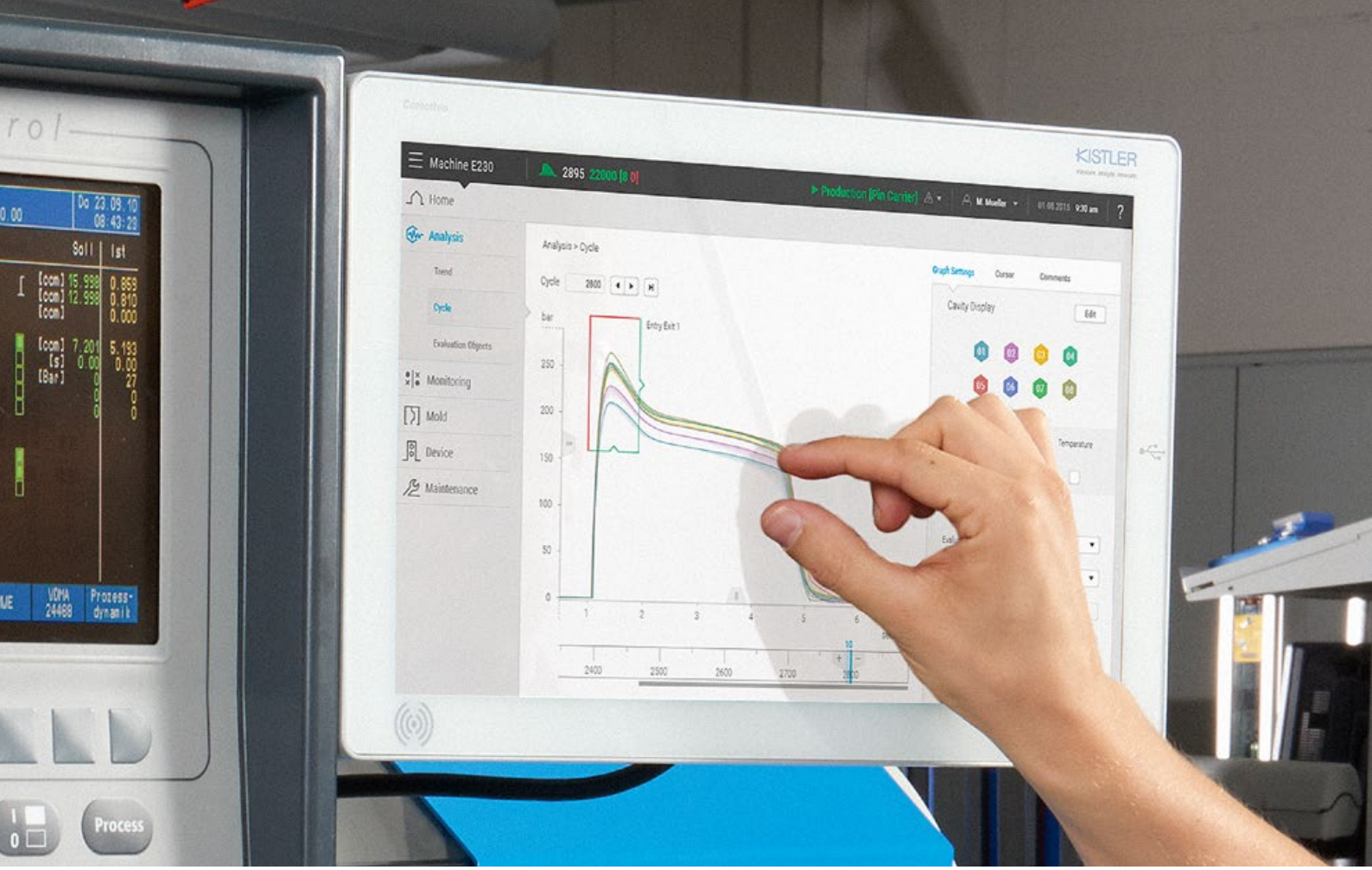
Entry/exit box
The entry/exit box ensures that values only pass through the green lines, not the red ones. These can be selected freely. The progression may be horizontal or, as in the illustrated example, via entry (below) and exit (right). This box is always rectangular. This box can be used for virtually all applications because it allows checking of the pressure level as well as the time component.

Trapezoid
The curve can only enter from the left and must exit to the right. The upper and lower limits must not be at the same level. If it is necessary to ensure conformance to a specified holding pressure profile, this box is recommended.

Integral
The area below the curve must maintain a specified value for a defined period. The Integral function is used for a variety of purposes including monitoring sink marks.

Vertical / horizontal threshold
A vertical threshold has to be crossed from left to right. For complex curves, this EO should be used in addition to other EOs. The horizontal threshold monitors crossing of the line from above or below.

No entry
No curve is allowed to touch this box. This function monitors whether pressure losses occur.

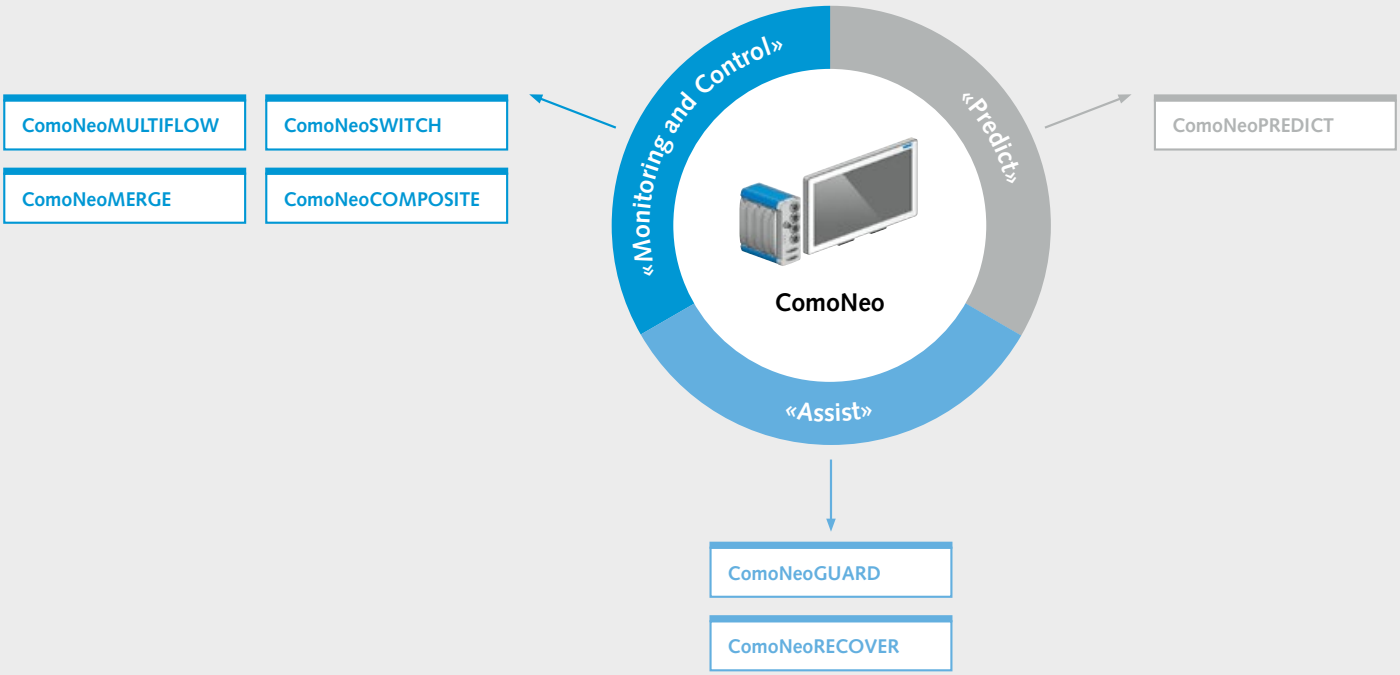


ComoNeo: with innovative features for all-round process optimization

Whether you want useful assistance with setting up the injection molding process, a system that can optimize process monitoring and control, or a quality prediction tool: the ComoNeo system is the ideal choice for these requirements and many other varied applications.

On the one hand, ComoNeoGUARD and ComoNeoRECOVER are assistance systems that provide valuable support during the setup phase. And on the other, ComoNeoMULTIFLOW, ComoNeoSWITCH, ComoNeoMERGE and ComoNeoCOMPOSITE are used as specific monitoring and control systems. Kistler also offers ComoNeoPREDICT, the online quality prediction system, so that you can benefit in advance from reliable forecasts for each part to be manufactured.

Practical tools provide optimum support
ComoNeo supports users not only during the setup phase, but also when recovering injection molding processes that have already been successfully validated. ComoNeoGUARD is the ideal assistant to give users reliable support with defining the scrap boxes (page 11). And to avoid losing time when restoring a process (after a machine changeover, for example) then ComoNeoRECOVER is the solution of choice.



The customized system for monitoring and control
ComoNeoMULTIFLOW is used to provide individual control of the nozzle temperature on the hot runner so as to achieve optimum hot runner balancing. The ComoNeoSWITCH system was specifically developed for manual or automatic adjustment of the switchover point in order to optimize fill time differences. The ComoNeoMERGE feature allows users to adapt the process sequence and its monitoring specifically for multi-component injection molding; and with ComoNeoCOMPOSITE, the monitoring strategy can be geared to the special requirements for fiber-reinforced plastic parts (RTM).

ComoNeoPREDICT – the basis for reliable quality prediction
Thanks to ComoNeoPREDICT, the online quality prediction system, machine settings can be improved to such an extent that the best possible values for quality, production time and process stability can be achieved.

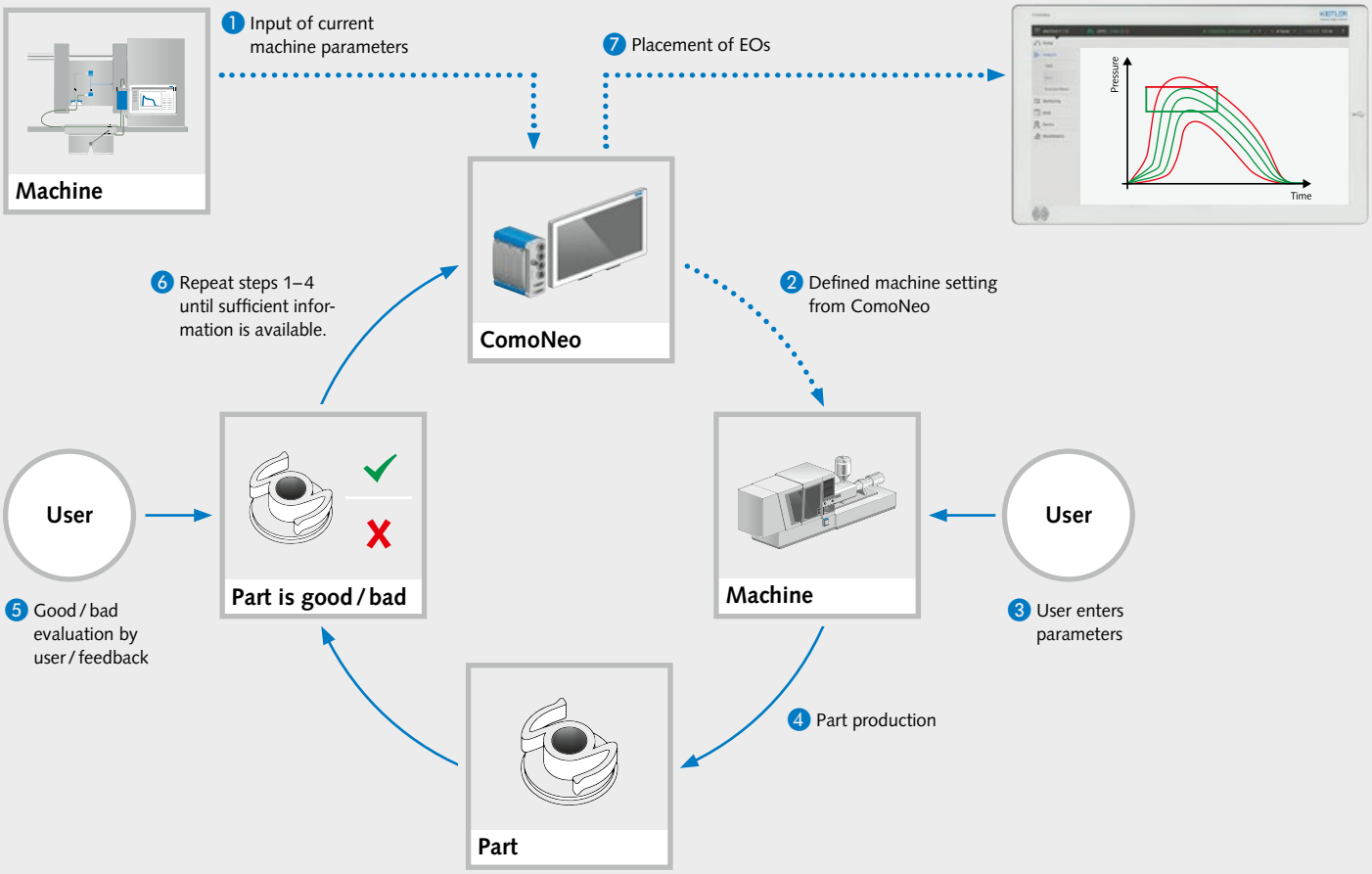
ComoNeoGUARD: the user-friendly assistant for high-precision part monitoring

ComoNeoGUARD is a tool that generates and positions the monitoring boxes for good / bad evaluation itself – guiding users quickly and seamlessly to the scrap limits. The results define the evaluation types and the relevant limits. Thanks to this approach, components can be monitored and sorted into good and bad with high precision – and pseudoscrap (i.e. "presumed" scrap) is reduced.

ComoNeoGUARD allows user-prompted generation of the EO limits: users are supported with the procedure for defining the sorting limits (illustration, page 11). This means that they have no need of specific previous knowledge when defining limits in order to set up full process monitoring.

Simple user guidance
This automated method requires an existing established process with good parts. Taking this as the basis, ComoNeoGUARD selectively changes the machine parameters to provoke a new cavity pressure profile, with the result that the part's characteristics change.

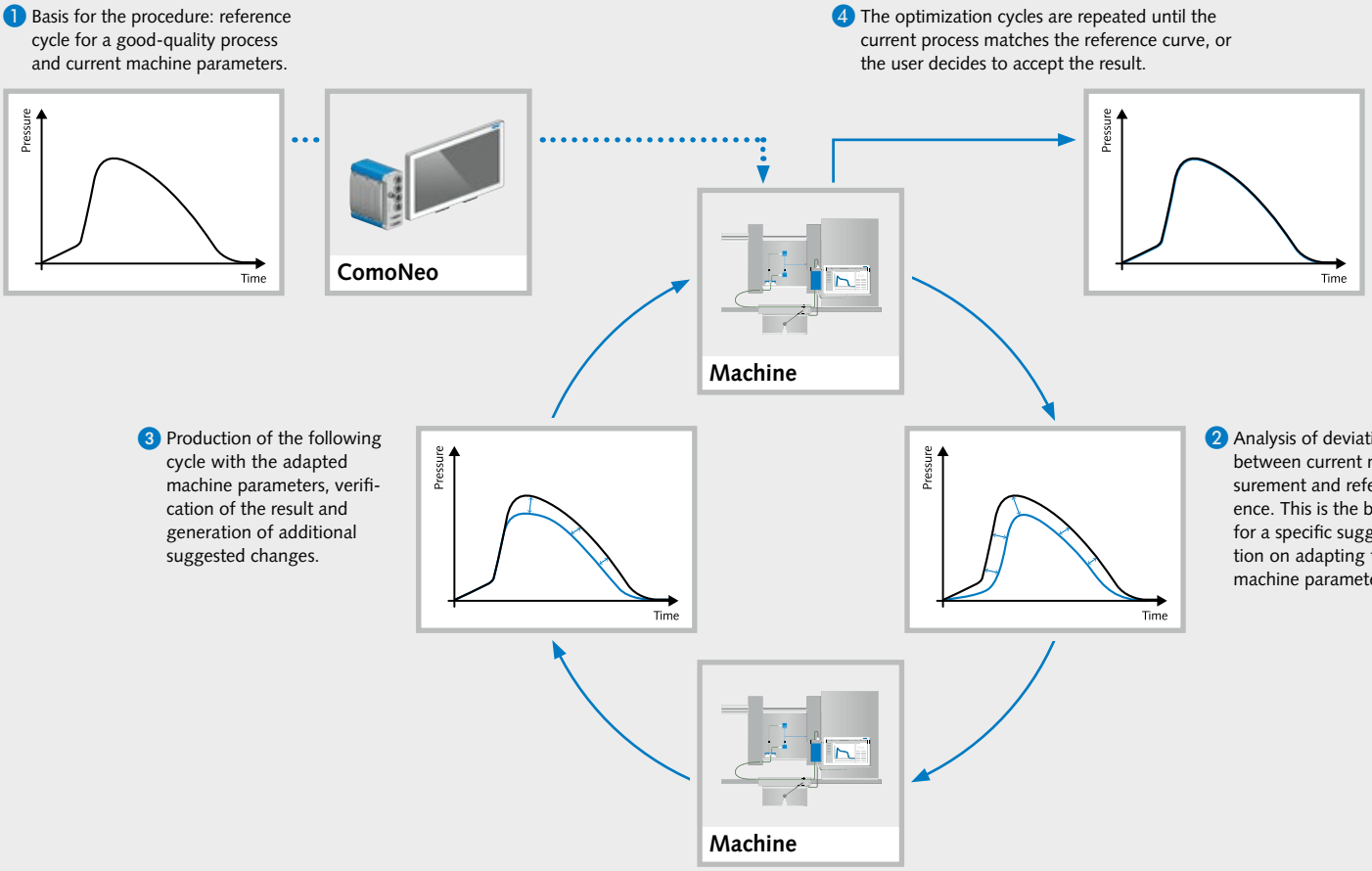
Benefits of ComoNeoGUARD:
- Users are guided through the individual steps
- Know-how is integrated within the system, so users do not need to be specialists
- More accurate evaluation limits (as wide as possible, as narrow as necessary)
- Scrap is separated out more accurately
- Pseudoscrap is reduced
- Systematic procedure, not dependent on individual staff members
- Adaptive system with learning ability, so it can increase the accuracy of the scrap limits
- Standardized, documented procedure
- Option of choosing the monitoring strategy (e.g. one EO across multiple cavities)



User-guided generation of EO limits with ComoNeoGUARD

After this, the user can take measurements or perform an optical assessment to evaluate the produced parts, and then decide whether the relevant cavity pressure profile is good or bad.

Systematic changes make it possible to work through the process window within a short time and then to repeat the steps performed until sufficient information is available for automatic placement of the EOs (Evaluation Objects) to monitor the parts. Users themselves can decide when to discontinue EO evaluation. The more test cycles are completed, the more accurately the EOs can be placed. In this case, "more accurately" means that fewer good parts are declared and segregated as scrap. Of course, all bad parts are always separated out.



Step-by-step optimization in the injection molding process with the Restart Assistant

ComoNeoRECOVER: identical reproduction of the injection molding process after changing machines

ComoNeoRECOVER makes it possible for users to transfer pre-established processes from one machine to another with no problems at all. This makes it easy for users who have no previous knowledge of cavity pressure to optimize processes and improve part quality.

The Restart module has been integrated into the system since ComoNeo Version 2.0. The purpose of this module is to reproduce the quality of an established injection molding process identically on another machine (see the illustration above). ComoNeoRECOVER is therefore used as a tool to optimize injection molding processes, rather than as a monitoring instrument.

Know-how integrated in the assistant
With this module, processes can be quickly and systematically optimized after a machine change, and the procedure is user-guided. As the basis for this procedure, the Assistant needs a reference curve representing a process of good quality.

Once the reference cycle is stored and the Assistant is started, measurement and analysis of the current process can begin. For this purpose, the current machine parameters are fed into the system as reference points. A detailed analysis then shows where there are deviations from the reference cycle. Based on the degree and position of the deviation, the Assistant automatically suggests changes to the machine parameters.

After checking the results, new changes are suggested on the basis of the deviations and the Assistant's accumulated experience of previous changes. Process optimization is completed when the cavity pressure profile deviations are reduced to a tolerable level.

Benefits of ComoNeoRECOVER:
- Users are guided through the individual steps
- Know-how is integrated within the system, so no specialists are needed
- Systematic approach
- Standardized, documented procedure
- Transparent, no dependencies on individual staff members
- Time is saved on process start-up
- Part quality differences are minimized when manufacturing on different machines
- Users' process understanding is actively developed

Monitoring and control systems: new approaches to balanced injection behavior

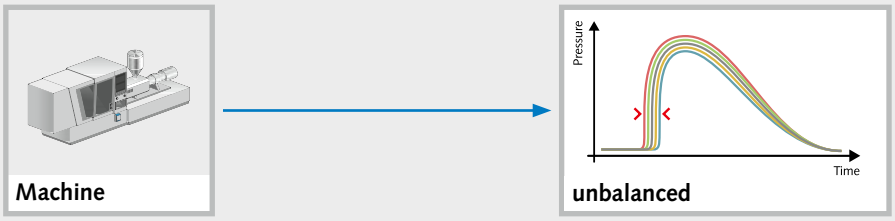
ComoNeo is not only suitable for monitoring – it is also an excellent choice for the control of injection molding processes. As a ComoNeo option, ComoNeoMULTIFLOW can balance hot runner molds by individually controlling the nozzle temperatures on the hot runner, based on cavity pressure curves. The system also includes automated switchover to ensure perfect timing when switching over in response to cavity pressure.

The purpose of hot runner control is to give the pressure curves of the individual cavities an identical filling progression so as to guarantee constant production quality. This is achieved by automated temperature control of the relevant hot runner nozzles.

With switchover-point control, the control within a cycle is either set up manually or is automated. The main advantage of manual control setup is that multiple dependencies can be set; however, the Switch Level Process (SLP) scores because calculation of the switchover point is self-optimizing.

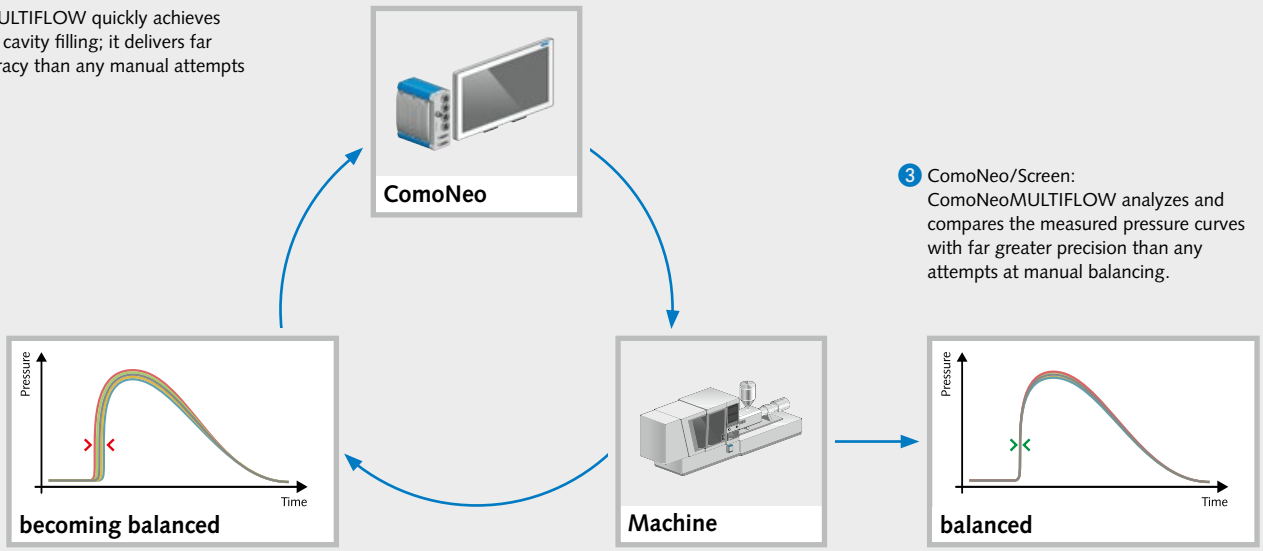
Thanks to these process control options that are newly integrated in ComoNeo, process fluctuations can now be compensated during the production phase as well. ComoNeoMULTIFLOW uses hot runner balancing to compensate for differences in filling behavior when multiple cavities are present; ComoNeoSWITCH, on the other hand, ensures optimal timing of the switchover point throughout the entire production sequence.

1 Cavity pressure curves for an unbalanced 8x mold



2 ComoNeoMULTIFLOW quickly achieves synchronous cavity filling; it delivers far greater accuracy than any manual attempts at balancing.

3 ComoNeo/Screen: ComoNeoMULTIFLOW analyzes and compares the measured pressure curves with far greater precision than any attempts at manual balancing.



ComoNeoMULTIFLOW synchronizes the pressure profiles on the hot runner

ComoNeoMULTIFLOW: temperature-controlled hot runner balancing

As an option for ComoNeo, ComoNeoMULTIFLOW synchronizes the pressure profiles by individually controlling the nozzle temperatures on the hot runner. It stabilizes the process and adjusts for batch fluctuations as well as other process disruptions.

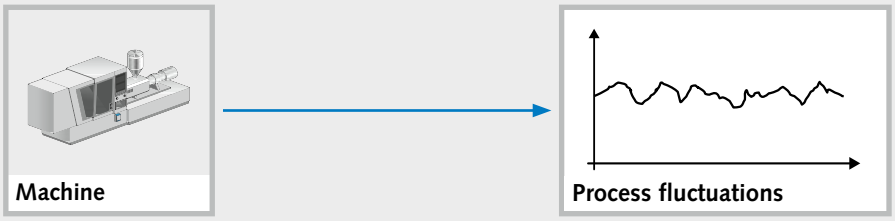
ComoNeo combines the advantages of automated hot runner balancing with 100% quality assurance based on cavity pressure (see the illustration above). The purpose of hot runner balancing is to ensure identical injection and pressure conditions in all the mold's cavities. The control variables used by ComoNeoMULTIFLOW are the cavity pressure profiles in the individual cavities. The actuating variables are the temperatures of the hot runner nozzles.

ComoNeoMULTIFLOW analyzes and compares the measured pressure curves. Nozzle temperature setpoints are calculated on this basis and transmitted to the external or machine-integrated hot runner control system via an interface such as OPC-UA.

Automated balancing in case of process fluctuations
The basis for ComoNeoMULTIFLOW is provided by reliable information about the entire mold filling process, so it enables automatic compensation for batch fluctuations and process disruptions. This is a key advantage as compared to systems based on melt front detection that control the point in time when the melt front reaches a specified position in the cavity.

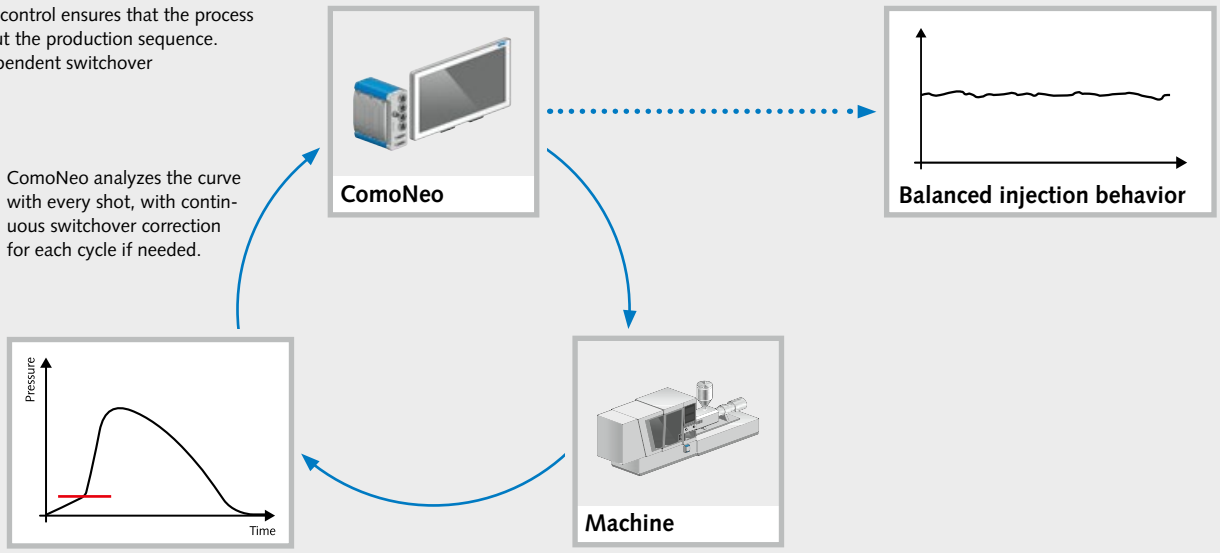
Benefits of ComoNeoMULTIFLOW:
- Identical filling conditions in all cavities
- Shorter tooling and setup times
- Fast injection molding process startup
- No manual setting or readjustment of temperatures and parameters
- Fully automated compensation of material fluctuations and process disruptions
- Integrated in ComoNeo as a standalone solution

Process fluctuations in ongoing production without real-time control.
► Screw position-dependent switchover



ComoNeo's real-time control ensures that the process is balanced throughout the production sequence.
► Cavity pressure-dependent switchover

ComoNeo analyzes the curve with every shot, with continuous switchover correction for each cycle if needed.



Compensation of process fluctuations based on cavity pressure-dependent switchover

ComoNeoSWITCH: reliable process control with switchover based on cavity pressure

ComoNeoSWITCH actively provides the machine with feedback. This allows ideal timing during the switchover from speed control to pressure control in response to cavity pressure.

The automatic switchover control can be used in two different ways. The first option involves manual setup, and control behavior only changes after the user intervenes. For example, a user can specify the defined level of cavity pressure at which the switchover should take place. The second option is called SLP (Switch Level Process): setup in this case is fully automated, and control behavior is automatically optimized from one cycle to the next (illustration above).

For molds with multiple cavities, automatic switchover behavior has been optimized for the specific purpose of compensating for different behavior patterns throughout the production sequence. When conditions are set manually, additional dependencies across multiple cavities are available as control criteria.

On the other hand, the ComoNeoSWITCH fully automated switchover feature is mainly used for molds with small numbers of cavities. The benefit here: ease of handling. All that is needed is to activate the process: everything else is controlled automatically by the internal algorithm, virtually at the touch of a button. Both switchover options actively help to prevent mold damage because safety functions respond to excessive pressure increases, so mold overfill is prevented.

Benefits of process control with ComoNeoSWITCH:
- Perfect timing of the switchover from speed-controlled to pressure-controlled injection molding
- Maximum process consistency throughout the entire production sequence
- Switchover point can be adjusted automatically or manually, according to choice
- Optimized fill time differences
- Mold-friendly process
- Reduced internal stresses in the component

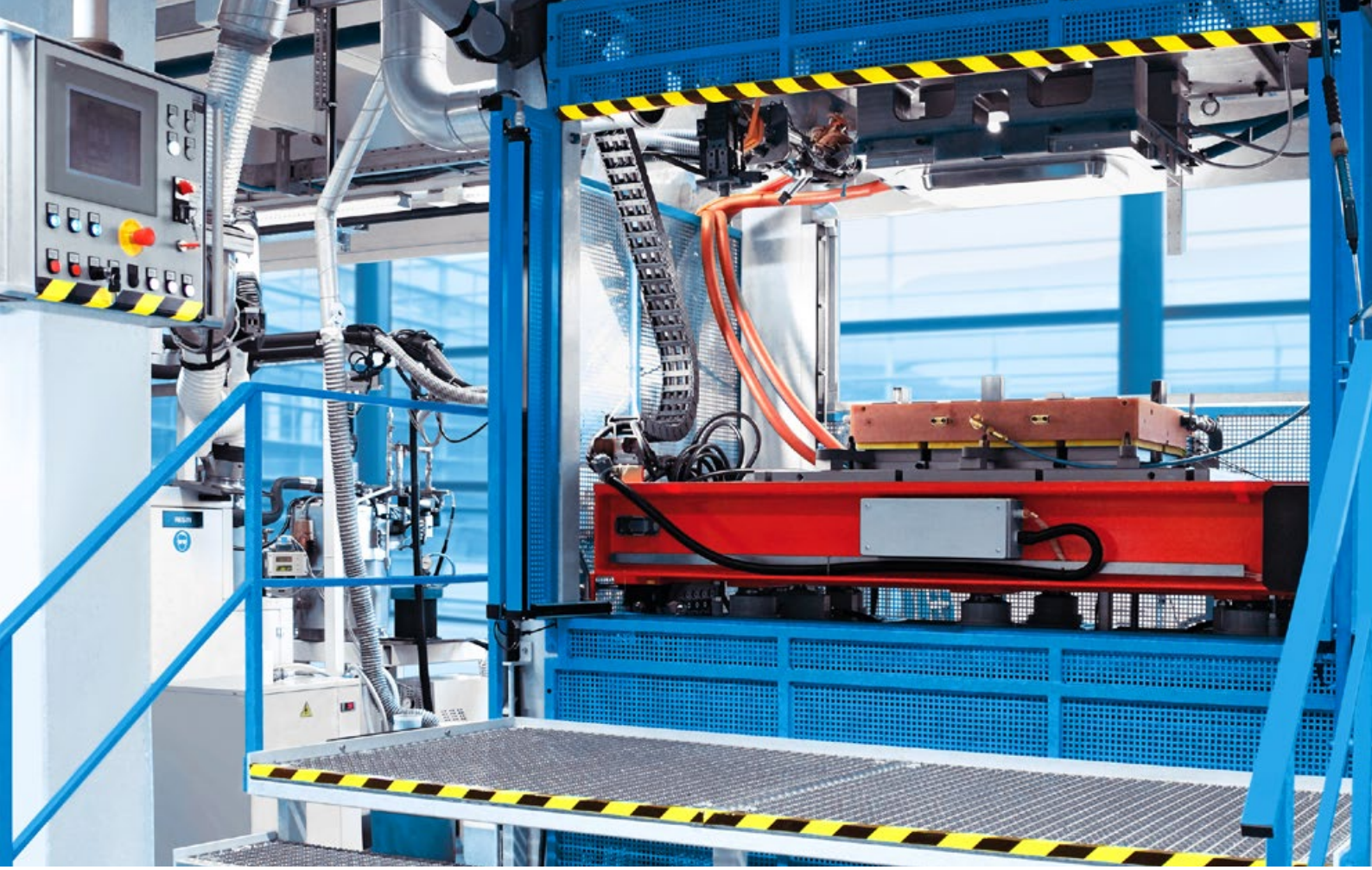
ComoNeoMERGE: transparent process monitoring for production of parts with multiple components

ComoNeoMERGE is especially helpful with the production of multi-component parts such as toothbrushes, complex housings with sealing functions, and switches. All the cavity pressure data measured in the manufacturing process is merged to provide a clear visual overview of the complex multi-component injection molding process.

In multi-component injection molding, different materials are joined successively to create a complex product. Different (and sometimes highly complex) molds are used for this purpose. ComoNeoMERGE maps all the components and the individual process steps for each cavity as a curve. The benefits: precise monitoring of the complex process sequence for multi-component injection molding, and a corresponding reduction in quality costs for the production process. This allows users to make use of ComoNeo's full functionality as a process monitoring system for multi-component injection molding, allowing an overall assessment of parts that are manufactured in stages.

Benefits of ComoNeoMERGE:

- Specially designed for multi-component parts
- Different multi-component molds are visualized (different sensor positions or slider molds)
- Individual process steps and components are visualized
- Part-based good/bad assessment, independently of the shot
- Part-based storage of process data



ComoNeoCOMPOSITE: quality assurance and process optimization through monitoring and control of the RTM process

As is the case with other filling processes (such as injection molding), the pressure curve in the mold is also a critical factor in optimization and production monitoring for the RTM process. ComoNeoCOMPOSITE ensures that users can easily recognize the characteristic phases of the process such as evacuation, filling and curing in the cavity pressure curve. This makes it possible to optimize the parameters for industrial processing of long-fiber composites, paving the way for more cost-efficient production in the lightweight construction segment.

The ComoNeoCOMPOSITE software takes account of the specific requirements for the RTM process such as long measurement times, evaluation of the evacuation phase and point recognition.

The pressure signal can also be used as a control variable for individual steps of the process – so online process control becomes possible. At the same time, anomalies in the pressure curve indicate whether faults can be expected in the finished part and, if so, which ones.

Capture and recording of the pressure signal with ComoNeo-COMPOSITE also ensures traceability of the manufactured components. All these reasons make the pressure curve indispensable as a quality assurance tool.

Using the pressure curve to identify defects:

Vacuum is too weak or intermittent

Causes:	Faulty mold sealing Vacuum pump failure
Consequence:	Air bubbles and imperfections in the part

Irregularities in the injection phase

Causes:	Dislocation of the preform Preform defect/incorrect orientation of a layer
Consequence:	Incorrect fiber content Dry spots

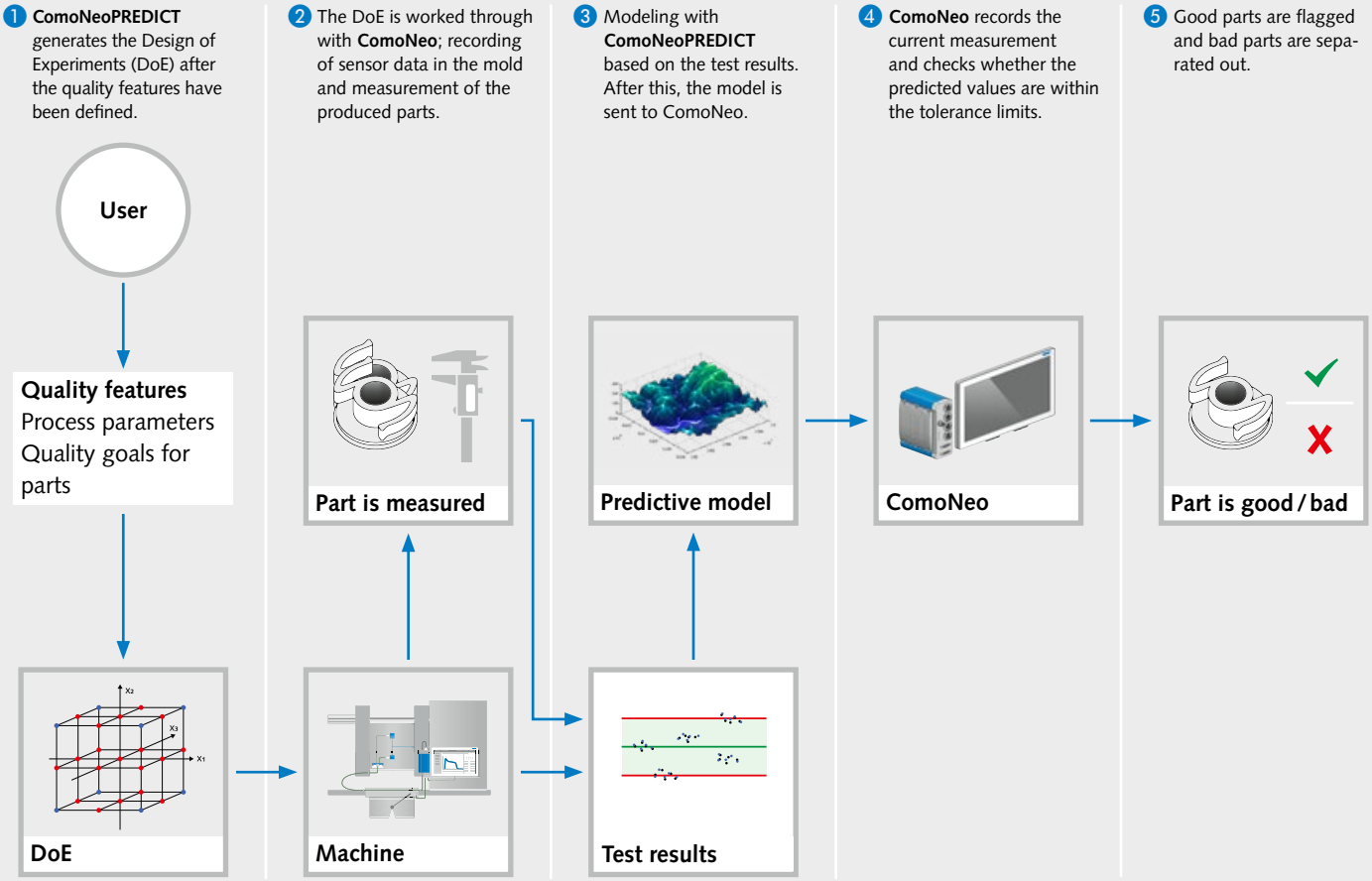
Prediction systems: ComoNeoPREDICT – the systematic method to determine part quality

Integrated online quality prediction is the basis for reliable statements about every manufactured part – ahead of time. Taking the current cavity pressure profile as the basis, ComoNeoPREDICT forecasts the part's eventual dimensions.

The ComoNeoPREDICT online quality forecasting system is based on models that make it possible to calculate the characteristics of parts (illustration on page 19). The statistical DoE (Design of Experiments) process for test planning helps to determine relationships between pressure / temperature profiles and defined quality features. To carry out online quality prediction, users need the machine and the component, plus the ComoNeoPREDICT monitoring system and the software (PC software) to generate the DoE and the prediction model.

Performed in a few easy steps
The first step is for the user to enter specified tolerance limits for the part's quality features in the ComoNeoPREDICT software. Then, the software automatically generates a Design of Experiments (DoE) which users can adapt as they wish.

Benefits of ComoNeoPREDICT:
- An exact method for separating scrap, thanks to complete quality records
- Direct monitoring of predicted quality features makes it much easier for users to understand
- Pseudoscrap is minimized
- Simple handling of tolerances as sorting criteria (transferred from the part drawing)
- Systematic determination of part quality
- Automatic selection of relevant curve points for calculation
- Can be used even without in-depth mathematical or statistical knowledge
- Models can easily be retrained to achieve further improvements



In the second step, the DoE is worked through with ComoNeo on the injection molding machine; all cavity pressure curves are recorded and the parts are removed and measured. Features such as surface quality or flash can also be evaluated. Then the results are fed into the ComoNeoPREDICT software and linked to the mold measurements (pressure, temperature). The software uses this data to produce a model so that part quality can be predicted on the basis of the mold measurements.

As the next step, the model is forwarded to ComoNeo. The output from the model on ComoNeo consists of predicted values for the defined quality features (length, width, weight, etc). At the same time, checks determine whether these predicted values are within the tolerance limits. Once all the features for a component are correct, the component is flagged as 'good'; as soon as a component is 'bad', it is separated out and flagged as such.

For manufacturers of high-grade components

This standardized and documented procedure means that tests and model calculations can be performed regardless of which individuals are available. The transparency of the method gives users a far better understanding of the process. Manufacturers of sensitive precision parts for the medical technology sector and producers of other critical high-quality components benefit from this new tool, which gives users a 100% in-process prediction of all quality features.

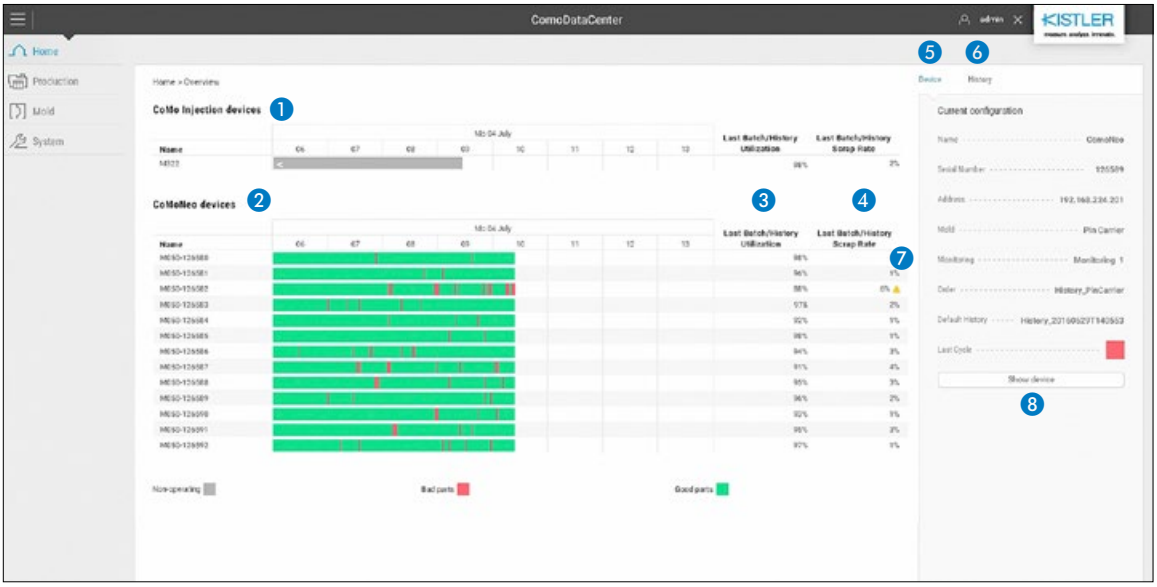
ComoDataCenter: central storage of process data and integration into higher-level systems

ComoDataCenter links all the user's ComoNeo systems, combining process- and quality-related production data for both live and completed orders in one database.

Kistler's ComoDataCenter (CDC) is also enhanced with features that make it easier to network data and improve the traceability of part quality. Furthermore, mold management is integrated into the CDC. The settings can be stored centrally, so mold settings can be transferred from ComoNeo to other plants via CDC.

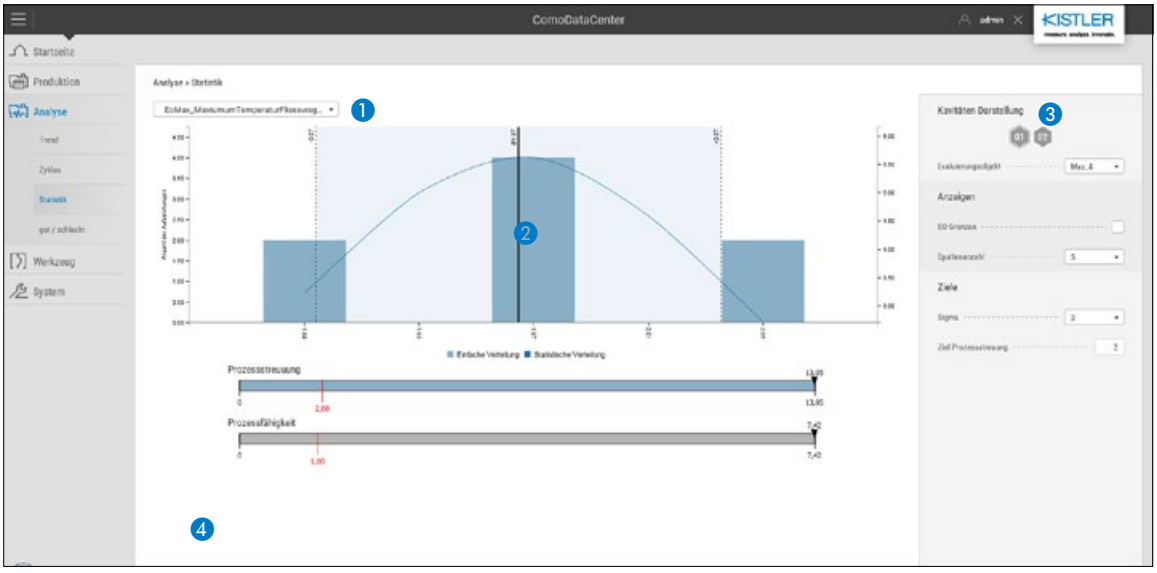
Simple data networking
In addition, there is provision for integration into higher-level systems such as SAP or other MES systems via the OPC-UA interface. The CDC acts as the link between the process and higher-level systems. The benefit: all data can easily be networked with other systems across the company. What's more, the CDC's user interface is now standardized with the tried-and-tested ComoNeo interface – entirely in keeping with the universal operating philosophy that Kistler advocates.

ComoDataCenter at a glance:
- Fast overview of the production efficiency of all connected machines with ComoNeo
- Central data storage for all recorded process data
- Fast detection of process fluctuations
- Detailed analysis options and statistical evaluations of all historic and live production runs
- Central storage and management of all mold settings
- Statistical evaluation tools (cp, cpk, ...) to assess process reliability and consistency.



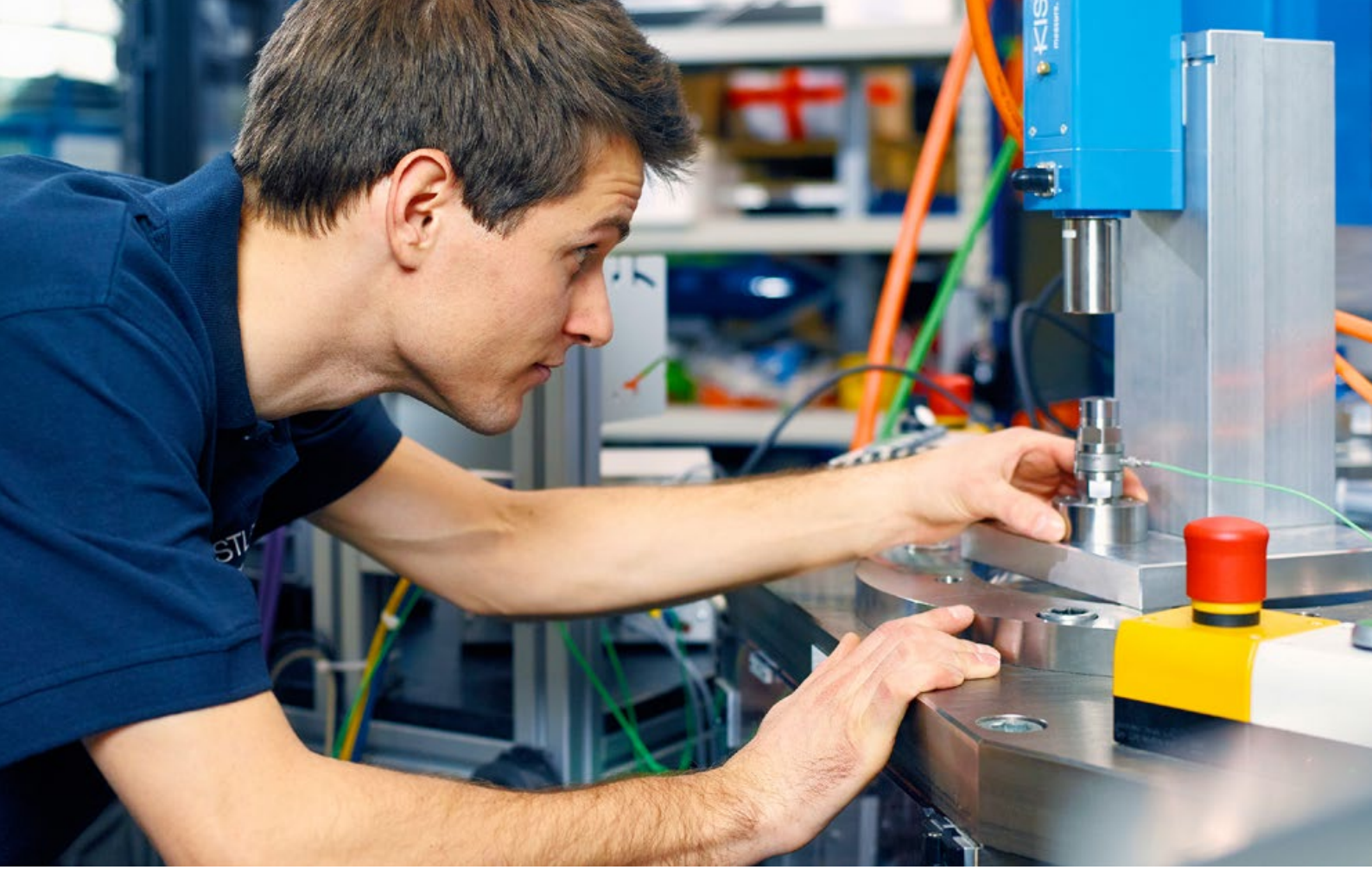
Overview of ComoNeo/CoMo Injection equipment

1. Overview of all CoMo Injection equipment.
2. Overview of all ComoNeo equipment.
3. Utilization factor display: shows the performance of good part production in relation to the defined shift period.
4. Scrap rate: shows the scrap rate for the current production run.
5. The Device tab shows key information about the selected ComoNeo. This may include the mold currently loaded and the live production order.
6. The observation period can be set on the History tab.
7. Warnings indicate when the tolerance limit has been exceeded.
8. Use the Show Device key to open the selected device directly in the browser.



Example of a statistical evaluation

1. Use the dropdown menu to select the characteristic for which you want to view statistics.
2. The main window shows the pressure distribution for the individual cycles, the average and the relevant standard deviation.
3. Visualizations can be adjusted individually. This allows you to show the EO limits and to define the sigma and cp values. You can also adjust the number of columns to be shown so that the image resolution is finer.
4. The cp and cpk values are shown in relation to the predefined limits. So at a glance, you can see how stably production is running.



From professional advice on installation to speedy deliveries of spare parts: Kistler's comprehensive range of services and training is at your disposal across the globe

Kistler service: customized solutions from A to Z

Kistler offers sales and service wherever automated manufacturing processes take place.

In addition to sensors and systems, Kistler offers a host of services – from professional advice on installation to speedy worldwide deliveries of spare parts. For an overview of the services we offer, visit **www.kistler.com**. For detailed information on our training courses, please contact our local distribution partners (see page 23).

Kistler service at a glance:

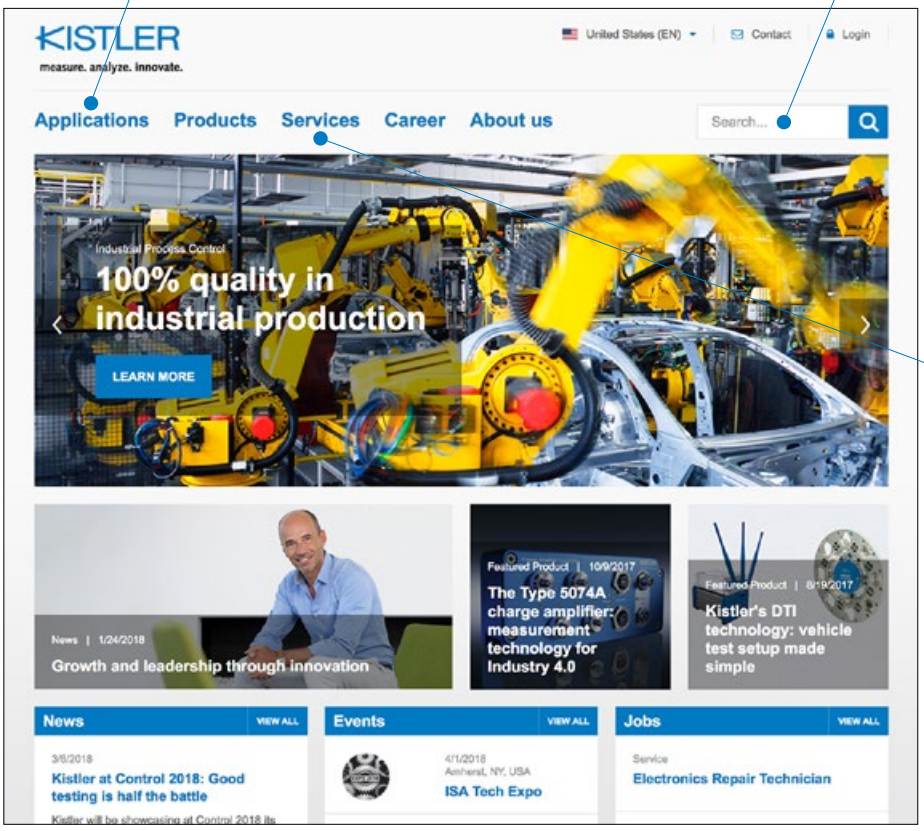
- Consulting
- Support with installing sensor technology and systems
- Our experts support you with process optimization
- Periodic on-site calibration of sensors in use at customers' premises
- Education and training events
- Development services

Kistler – at our customers' service across the globe

The Kistler Group, with 1 860 employees, is the world market leader in dynamic measuring technology. 30 Group companies in over 30 countries guarantee close contact with customers, individual application support and short delivery times.

Our representatives are here to help
Whether you would like a consultation or need support during installation – visit our website to find the contact information for your local representative, anywhere in the world.

Data sheets and documents
Use our Online Search to download data sheets, brochures or CAD data.



Education and training events
During our education and training courses, Kistler experts explain our sensors and measuring systems – the most efficient way for you to obtain the user knowledge you need.

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

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The Kistler Group includes Kistler Holding AG and
all its subsidiaries in Europe, Asia, the Americas and Australia.

Find your local contact at
www.kistler.com

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measure. analyze. innovate.