WHITEPAPER

Process systems

The optimal solution for temperature control in technical applications

Whether synthesis or analytical techniques – defined temperatures or temperature profiles are required for numerous tasks in the laboratory and industry, which are guaranteed by temperature control systems. But what is important for modern temperature control instruments? Which parameters play a key role in the selection of the temperature control system? In this article, JULABO explains the key guidelines for finding the optimal and most efficient solution for an application.

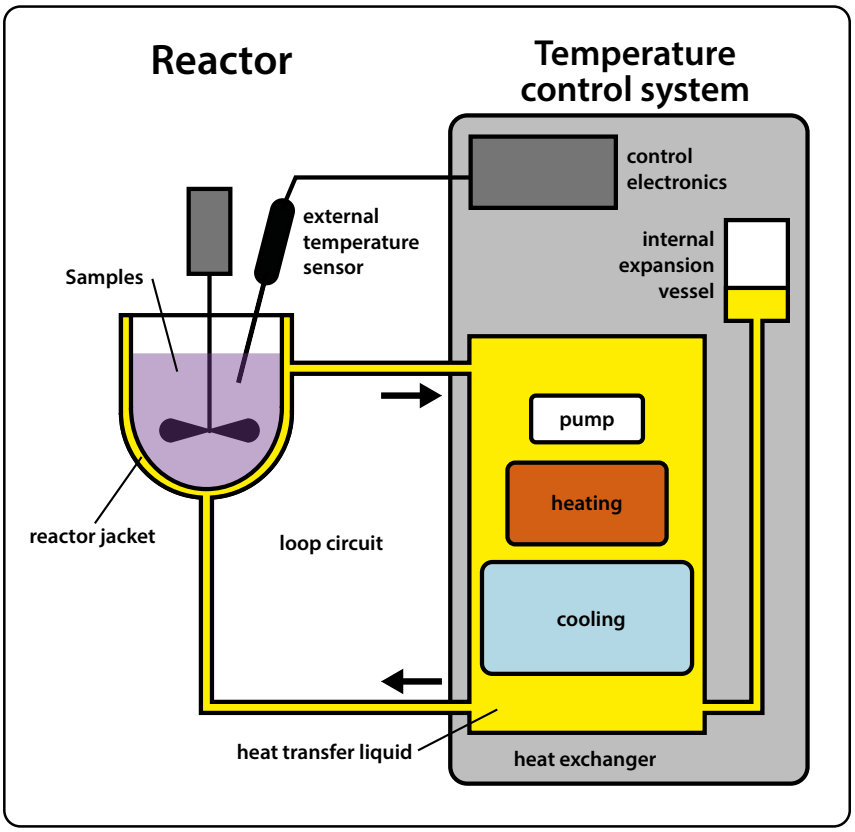
Contents:

Basic principle of temperature control applications

Reactor temperature control in pharmaceutical and chemical laboratories, as well as in industrial and experimental plants, generally requires the use of highly dynamic temperature control systems. Endo- and exothermic reactions in the applications must be compensated for quickly and reliably. Reactors, for example, are also available in a wide range of designs and operating modes that take into account the variety of chemical reactions and their complex relationships.

Example applications

- Miniplant (e.g. small batches)
- Technical center (e.g. pharmaceuticals or chemical industry)
- Component testing (e.g. automotive and aircraft construction, space research)
- Temperature simulation
- Food production (e.g. fermentation, distillation)



In the classic reactor application, the basic materials used, such as glass, steel or enamel, each have specific advantages and disadvantages for individual applications. These include, among other things, the reactivity of the boiler material with the processed products or their stability against pressure and temperature. The materials also have an impact in highly dynamic temperature control applications, such as the different heat transfer properties of the materials or different wall thicknesses.

This article focuses on the frequently used double jacketed glass and steel reactors. This reactor type consists of an inner vessel for the reaction components for which the temperature is to be controlled. This is enclosed by a jacket in which the bath medium circulates. With this type of reactor temperature control, the temperature control system pumps the bath medium permanently through the reactor jacket. It is connected to it via connections. Sudden temperature changes inside the reactor are dynamically compensated for by rapid heating or cooing of the bath fluid. This heating or cooling takes place within the temperature control system.

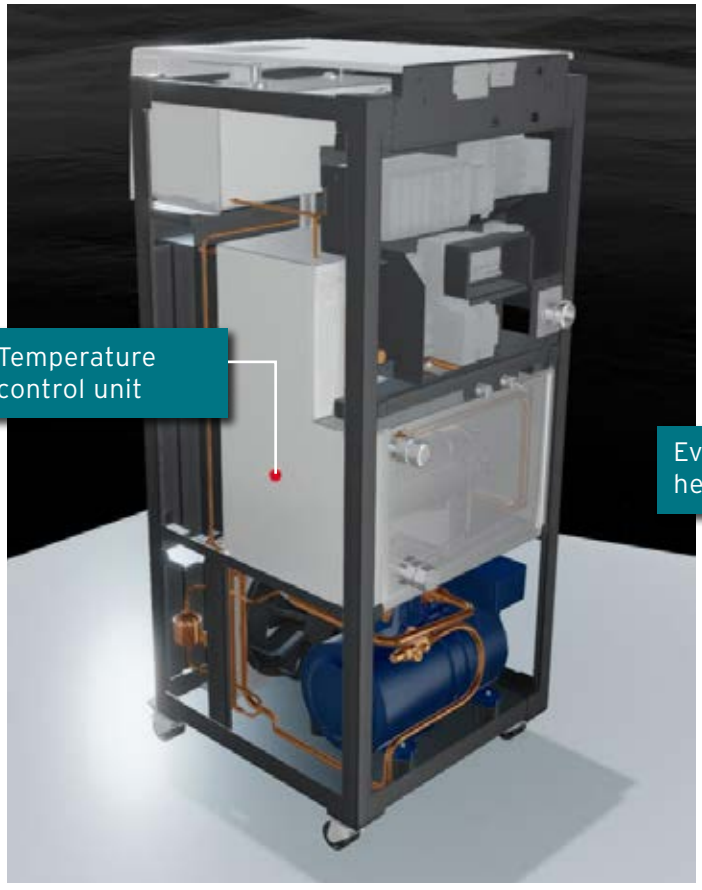
Anyone looking to optimize a chemical reaction process needs the best possible compromise to meet the high selectivity, quality, and therefore productivity required in a chemical production process. An important point here is to determine the optimal reaction temperature for the individual process steps – because the function of the temperature control system and the efficiency of the reaction control are closely related.

Three system components play a key role in achieving these objectives:

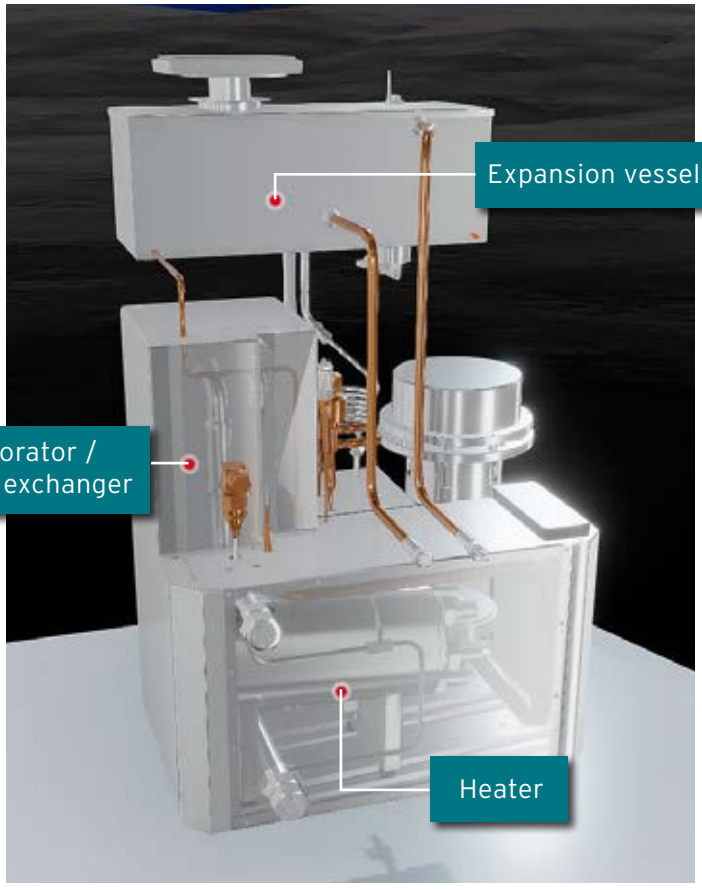
- Heat exchanger
- Pump
- Control electronics

Highly dynamic temperature control systems have been developed primarily for use in miniplant, pilot and distillation plants, chemical and bioreactors, calorimeters and autoclaves. Such devices with optimized thermodynamics are the first choice for these applications, even in difficult or highly fluctuating plant conditions.

These systems offer significant advantages in practice in terms of performance, safety, as well as process reliability, comfort and costs. The following sections evaluate the impact of the aforementioned key factors and provide important evaluation criteria for selecting the temperature control system.



Interior view PRESTO



View temperature control unit

Power output: Optimum matching of the pump used

In practice, it is not only the primary performance data of a temperature control instrument that is important. The optimized interplay of heating, cooling and pump output is also key. Cooling and heating capacity have a major impact on the speed at which certain temperature values are achieved. The following factors, among others, must be taken into account when determining the required output:

- Mass of the temperature control object
- Required temperature differences
- Desired cool-down or heat-up times
- Specific heat capacity of the bath medium

At the same time, optimal values for heating and cooling output only reach their full potential if the circulation pump also fully supports the heat transfer. Separate regulations apply to the pumps used in the temperature control system as specified by the reactor manufacturer.
There are maximum permissible pressure values for each reactor type and the selected temperature control solution must not exceed these limit values during operation. Before initial operation, the corresponding limit values must be adjusted on the temperature control instrument as one of the control variables, depending on the reactor.

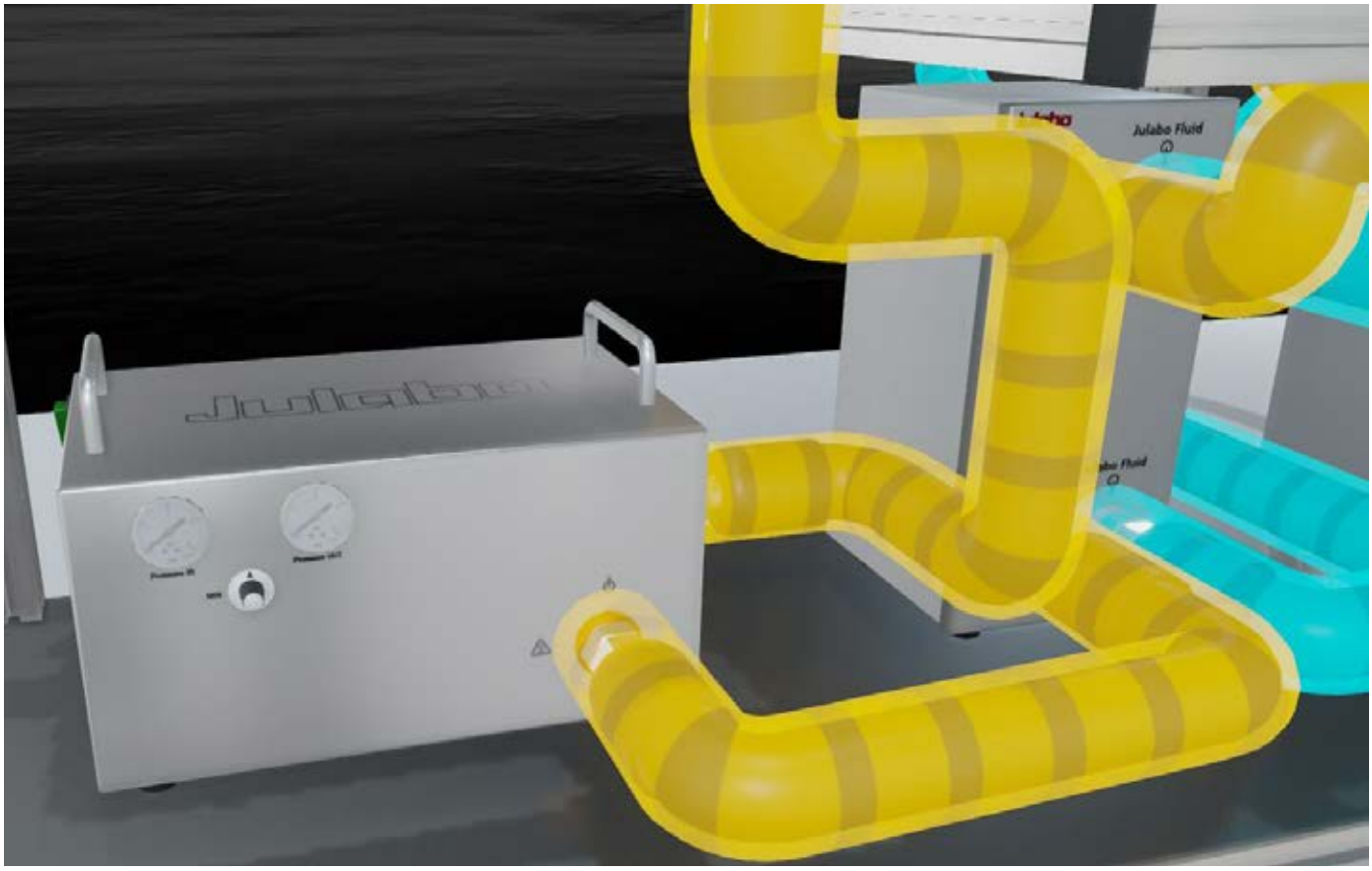
The pump must therefore be designed with sufficient power that it achieves high flow rates at constant pressure. It should build up the required pressure quickly and at the same time under constant control to ensure that the reactor pressure limits are not exceeded. For this purpose, it must be possible to set the pump output either via stages or a specified pressure value.

Special temperature control systems also have pumps that automatically compensate dynamically for changes in viscosity in the bath medium and thus maintain energy efficiency. This is because viscosity changes the flow and therefore also the energy transfer.

The overall concept of the PRESTO™ family has been adapted to this important influencing factor and ensures constant use with reproducible and precise results. These efficient solutions rely on a small active heat exchanger volume, which, in combination with the required cooling and heating capacity, ensures fast heating and cooling times. The models of the PRESTO™ series enable up to 36 kW heating capacity and 33 kW cooling capacity depending on the unit.

Temperature expansion kits are available on selected models to improve the performance of a unit. They enable a larger temperature range to be covered with just one bath medium. With the help of the additional equipment, overpressure can be applied on the loop circuit in the system. This can raise the boiling point of the bath medium and thus raise the working temperature. For the medium THERMAL HL30 (water glycol mixture), for example, this is up to + 150 °C. An integrated precision pressure regulator ensures precise regulation of the required pressure and thus enables highly accurate temperature control. Only one compressed air connection is required by the user.

The advantages of this concept are clear: If temperature control systems work with the same bath fluid over the entire working temperature range, users do not have to change the medium frequently and stockpiling is simplified. The system is also more flexible and saves time. Without breaks for draining, cleaning and refilling, for example, test series can run at short intervals at different temperatures.



The magnetically coupled booster pump can be used to raise the pressure or flow rate within an application.

Safety: Ensure plant and product safety

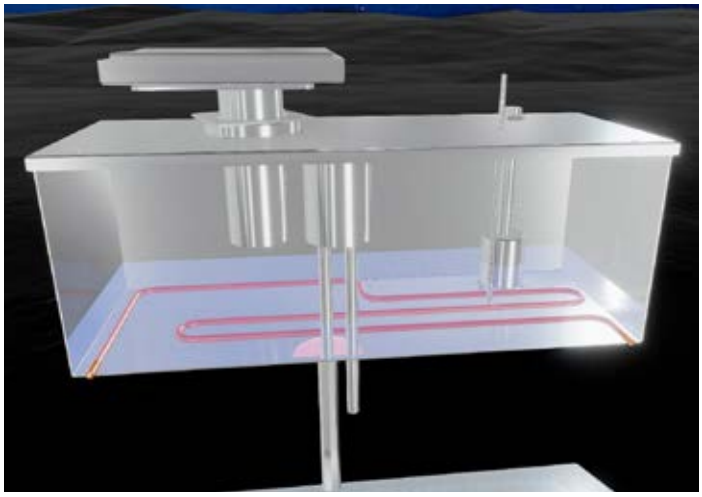
Before purchasing a temperature control system, safety-relevant aspects should be examined critically to ensure smooth operation for the users. This applies both to the safety of personnel and to the safety of the entire system and, as a result, to product quality.

Temperature-related volume changes in the heat exchanger must be permanently absorbed by an expansion vessel. Internal expansion vessels must therefore be sufficiently large. Separate cooling of the expansion vessel should also ensure that the temperature control instrument itself does not heat up excessively and that there is no risk of injury to operating personnel.

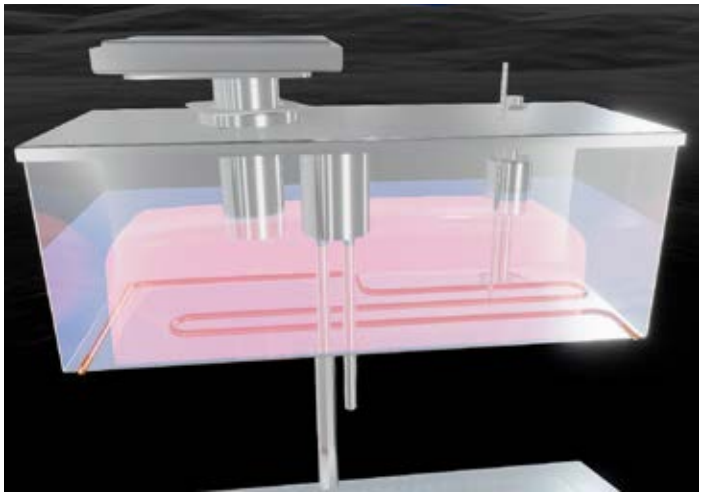
A reactor-specific criterion is the delta T limit. It describes the maximum permissible difference between the flow temperature and the temperature of the reactor contents. The delta T limit, also known as the band limit, is heavily dependent on the reactor type; glass reactors, for example, react much more sensitively than steel reactors and have common band limits between only 50 and 80 K. This value is therefore one of the internal parameters that must be continuously monitored automatically. The temperature control instrument should therefore have the option of entering reactor-dependent limit values per unit of time – the function then actively limits the temperature difference and protects the reaction mixture from thermal stress. This enables safe working with high temperature bandwidths.

The band limit is also of interest for product quality. For example, tight control prevents the wall temperature from becoming too high and substances from reacting on the wall while it is cooler inside the reactor.

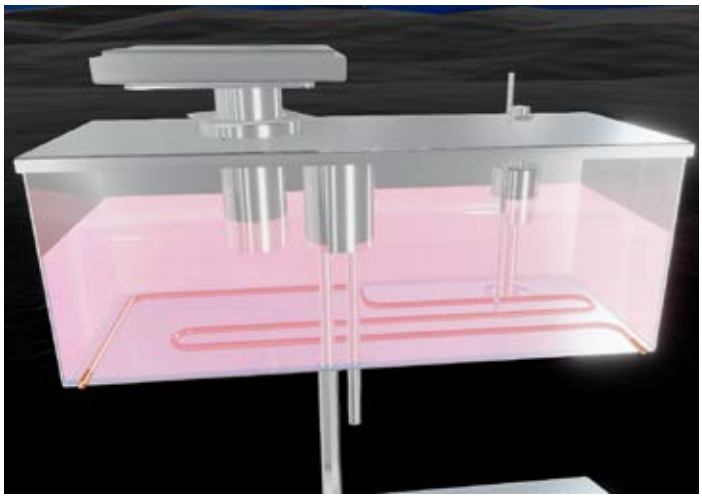
Another safety aspect is integrated warning and alarm functions, which benefit the user, the system and the product. The devices of the PRESTO™ series are also equipped with this. Warnings are automatically generated when limits are exceeded. All warnings are displayed in multiple languages, are simple and easy to understand, and provide clear instructions for quick troubleshooting. The temperature control system is designed and built as a closed circuit where the bath fluid does not come into contact with the ambient air. This enables safe working above the flash point of the bath fluid. The design also prevents moisture ingress and oxidation and prevents oil vapors from escaping into the working environment. A closed circuit significantly extends the service life of the bath medium.



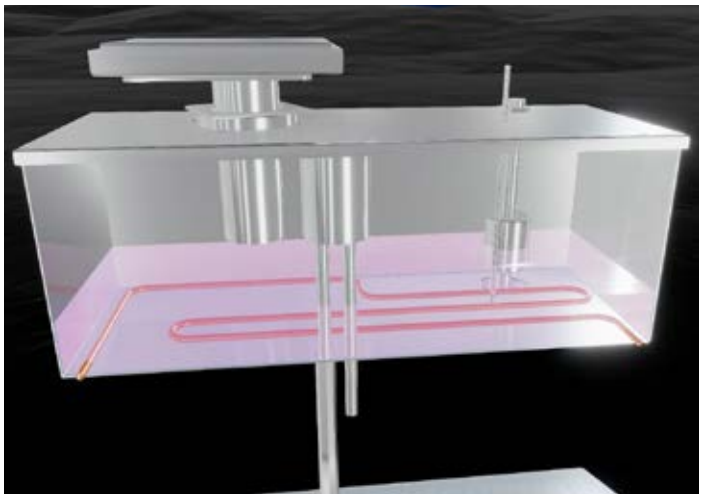
Expansion vessel for permanent compensation of temperature-related volume changes in the heat exchanger.



The expansion vessel absorbs the temperature-related volume change.



In order to absorb the entire volume change, internal expansion vessels must be sufficiently large.



Additional cooling of the expansion vessel prevents the temperature control instrument from overheating.

Process safety: Extremely precise temperature control

Continuous and high-precision temperature control is important in the temperature control process. This is ensured by sophisticated control electronics in the temperature control system, which monitor and control the process in the reactor and the internal processes in the system in order to quickly adjust a control variable to the target value in the event of changes – with as little overshoot as possible.

The control electronics are an important prerequisite for high consistency in temperature control applications. One criterion for its evaluation is the effort required for parameterization. Optimal temperature control systems merely require a target value to be entered. During the actual temperature control process, the control electronics then ensure that the PID control parameters are complied with via ICC algorithm (Intelligent Cascade Control).

The PRESTO™ units ensure exceptional accuracy and temperature stability up to ± 0.01 °C.
In everyday operation, test series under exactly the same temperature control conditions are common practice. For such series, the device control should be equipped with a corresponding memory function to enable clear reproducibility. Functions like these also help to archive the experimental documentation without gaps. PRESTO™ units, for example, are equipped for these purposes.

To protect process parameters in everyday operation, high-quality operating programs are used on several user levels with password protection.
For example, an administrator can set parameters in advance, while other user levels have restricted access rights and can only call up settings. The procedure simplifies operations and avoids unintended parameter changes and incorrect operation

The control electronics are an important prerequisite for high consistency in temperature control applications.

Robustness with regard to ambient conditions also plays an important role in process reliability. Sample calculations are often based on a room temperature of +20 °C, which rarely corresponds to reality in practice. Even when used in a mini-plant, the system is subject to higher requirements. Temperature control systems are also exposed to critical situations during the summer months. Units that can handle wider tolerance ranges are an advantage here.
PRESTO™ units can be operated up to an ambient temperature of +40 °C. Tap water for cooling can also be up to +30 °C in this model series without the units switching off automatically. If the temperature in the reservoir becomes too high, a two-stage de-gas mode takes effect automatically.

One unit-dependent aspect concerns the cooling technology of the unit itself: Highly dynamic temperature control systems are available with air or water cooling. Air-cooled units offer independent choice of location as they do not consume water. Waste heat dissipation into the room may need to be taken into account, however. This is much less important for water-cooled units. They require a connection to a cooling water line.
A sturdy and wear-free condenser should also be integrated in the unit. This ensures that contaminated cooling water does not block the heat exchanger.

The choice of location is decisive for the cooling technology used: Highly dynamic temperature control systems are available with air or water cooling.

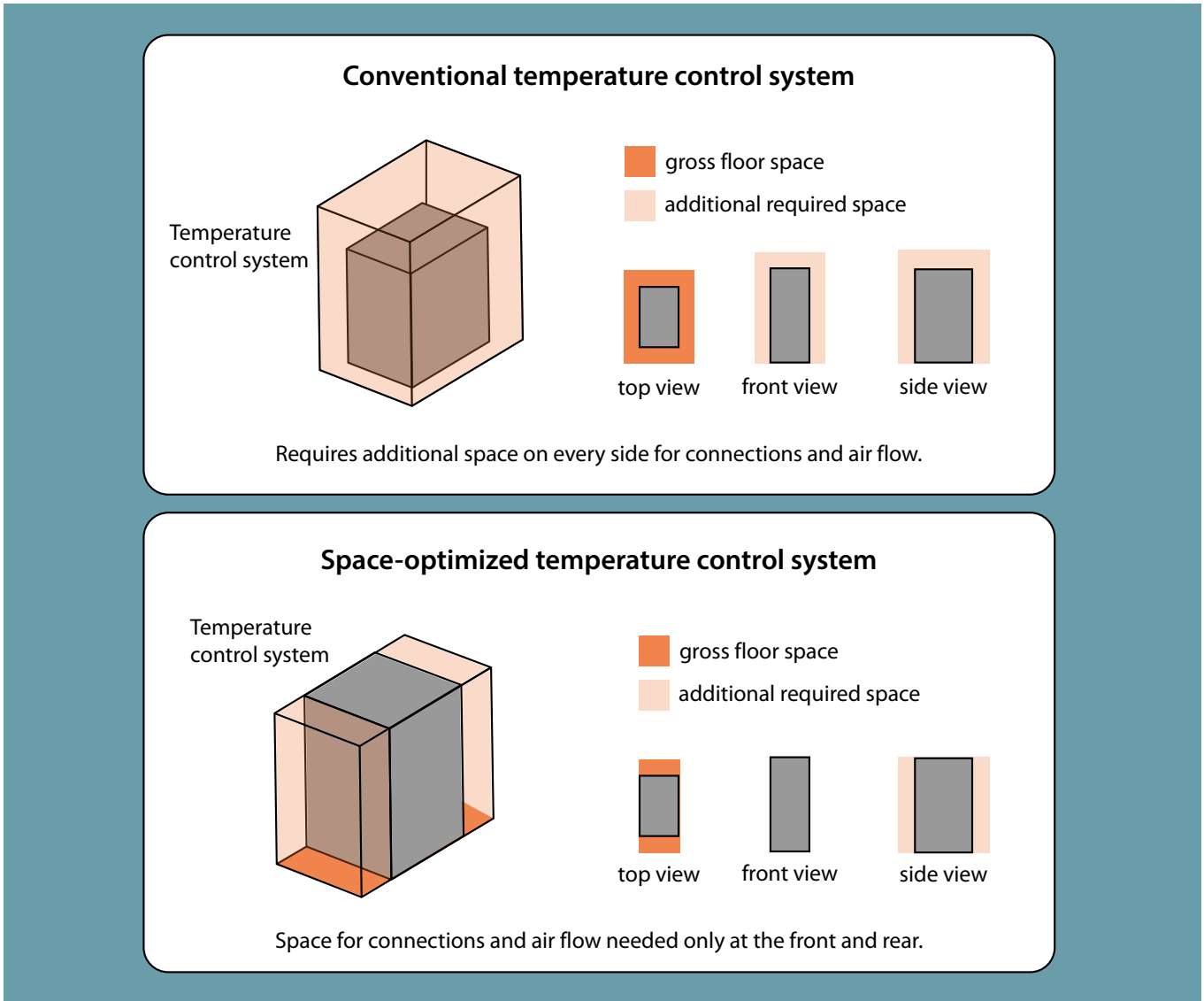
Comfort: Simple and intuitive operation

Comfort is largely reflected in two factors, the structural design and the operating safety of the unit.

A well-thought-out design makes it easier to work from several perspectives, because in laboratories, the space available usually plays a major role in the system layout. For this reason, a space-optimized design of the temperature control instruments combines all interfaces and operating elements, as well as connections and ventilation slits, on the front and back as much as possible. This reduces the space required for all connections and allows undisturbed circulation of recirculated air. This means that other system components can also be placed close at the side and means that operating personnel have unrestricted access to all functions.

The reduced cabling required for a temperature control instrument like this simplifies installation and improves the mobility of the unit. If it is mounted on castors and equipped with handles, it can be used flexibly at different locations. The repositioning can be carried out by one or more people depending on the size of the system.

If the temperature control system is located in a room where employees regularly work, the volume of the temperature control system is an important assessment criterion. So-called "quiet" temperature control systems are available for this purpose, which offer a strong ergonomic advantage.
In rooms like this, a hydraulically sealed design also offers advantages, as it prevents vapors and odors. Just as important is the accessibility of the filling



opening for safe and convenient filling. It should be positioned so that filling is as easy and clean as possible and that no fluid enters the unit in the event of spillage.

The operating elements of modern temperature control systems offer a clear and well-structured representation of all important information in the form of values, graphical representations and notes in plain text on generously sized displays. This means that relevant process information is available on the display in real time. An integrated touch function further increases user-friendliness.

A further criterion for a high level of operating safety are extensive interfaces for remote control of the temperature control system via networks or integration into control systems. Direct operation on the temperature control system is not always desired, and in some cases may even be impossible. Modern interface standards offer ideal options for remote access to all system functions. It is particularly advantageous for the user if the user interface have the same functionality via a network as for operation directly on the device. This removes the need for additional training and also prevents incorrect operation in this case.

The filling port should be located so that filling is as easy and clean as possible and no spilled fluid enters the unit.

Costs: Low-maintenance, compact and flexible

Reactor systems and temperature control objects are often investment-intensive equipment. In this sense, an optimally coordinated temperature control system not only ensures a specified process flow, but also the safety of the system and application.

The cost factor for the temperature control instrument itself can be primarily influenced by the device design. The small footprint of space-optimized units enables excellent use of space. A well-thought-out device design also reduces downtime and service costs, as all elements can be accessed quickly and individually if required. With JULABO temperature control instruments, for example, care is taken to ensure that the complete heating unit does not always have to be removed. Thanks to the magnetic coupling, changing the pump motor is quick and easy. The PRESTO™ series generally requires less bath fluid compared to heating circulators, meaning that the costs for consumables are low. Self-lubricating assemblies also ensure wear-free operation and therefore lower consequential costs and downtimes. Another criterion is the working temperature range. The larger the version selected, the more flexibly the temperature control system can be used.

On-site, the long service life is guaranteed by high-grade components; on the user side, for example, cyclical maintenance intervals make a significant contribution. The service and support offerings of the temperature control solution providers also play a role. In addition to expert advice, intensive customer service and support during installation or calibration, the provision of all documentation for equipment qualification should also be ensured. With this globally recognized certificate, suppliers certified in accordance with DIN EN ISO 9001 set a clear sign of high quality.

Conclusion

Alongside the reactor, the temperature control system is the heart of the application. The requirements vary greatly depending on the application and the company, the application goal or workflow.

In addition to traditional specifications, the units must also meet functional requirements. In daily use, particular attention is paid to the wide range of criteria for operational safety. The optimal temperature control solution enables quick installation and commissioning, operation that is quick to learn and well thought-out details that make the application more convenient, ergonomic and safe.

Although temperature control instruments are increasingly intuitive to operate, users should never forgo supplier training. Systems and plants are becoming increasingly complex, with ever increasing requirements in practice. Training during initial operation or selective further training ensures a consistently high level of safety during operation. In order to make the correct decision, it is important to understand how the equipment will impact the application. A key element in the decision-making process is therefore the advice provided by the supplier of the desired temperature control instrument.

At JULABO, the customer service representatives always work with application specialists to ensure that the unit is correctly dimensioned and improves the application. Early involvement of departments such as Service or Electronics also ensures that the scenarios for integrating a solution into the customer's system are appropriate and well thought-out.

An optimal temperature control system is therefore a long-term investment in a flexible and reliable system component, which enables users to focus on the core process.

Designing customer-specific flow measurement and control systems for maximum flexibility in temperature control is one of JULABO's strengths.

Business Unit Solutions (BUS)

Products such as PRESTO process systems are increasingly used in the process industry and automation. Particularly in areas of the process industry, users demand products or solutions that meet their specific temperature control requirements precisely. JULABO has not only listened to its customers but has also responded to these very requirements by setting up its own Business Unit Solutions.

The JULABO Business Unit Solutions (BUS), an in-house development team of engineers and designers, specializes specifically in optimizing or modifying existing equipment designs to meet individual customer requirements. Many years of experience and maximum flexibility are the perfect basis for extraordinary requirements.
This is a foundation that enables JULABO to constantly break new ground with its customers. This produces impressive results.

At the beginning of each development process, there is always an intensive exchange of information about the wishes and expectations of the user. Based on these findings, our temperature control specialists develop an initial concept for an optimum solution, which takes technological and economic aspects into account. The focus is on practicability and cost effectiveness as well as on quality and benefits. Throughout the entire development phase, the team of experts is in close contact with the customer. After completion of the unit and extensive functional tests under simulated conditions, as well as after preparation of the required documents (e.g. CE approval), customer release and joint initial operation take place on-site. Attractive service offers round off the portfolio.

Customers have the challenge, JULABO implements the perfect solution.

A development team optimizes and modifies existing unit models individually according to customer requirements.

Special solutions from a single source: in areas of the process industry, users demand products or solutions that are precisely tailored to their specific temperature control requirements.