65 YEARS

KAYE

SUBSIDIARY OF AMPHENOL

A STORY OF INNOVATION AND COMMITMENT TO QUALITY

Kaye's Time Warp

65 YEARS OF RELIABILITY AND QUALITY IN GXP COMPLIANT THERMAL PROCESS VALIDATION AND CONTINUES MONITORING

Innovation distinguishes between a leader and a follower.

Steve Jobs

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Foreword

As we commemorate our 65th anniversary, we reflect on the remarkable journey of Kaye, a journey defined by groundbreaking advancements, perseverance, and a steadfast commitment to quality. This milestone is not just a celebration of our past, but a testament to the innovation and dedication that continue to shape our future. To mark this occasion, we've crafted a special commemorative book that chronicles our company's history and achievements. Each chapter serves as a tribute to the key milestones that have made Kaye a leader in validation and calibration technology.

In Chapter #1, "How It All Began", we take a trip back to our origins, exploring the foundational steps and vision that brought Kaye to life. Moving forward, Chapter 2 delves into the evolution of our calibration technology, from early prototypes to the advanced and agile systems we employ today. Our commitment to precision is highlighted in Chapter #3, where we explore the development of the Traceable Temperature Standard, a cornerstone of accuracy that has become synonymous with our brand. In Chapter #4, we take a technical deep dive into Ice Point and Cold Junction Compensation, crucial elements ensuring the reliability of our devices.

The journey to meet the highest industry standards continues in Chapter #5, which covers our quest to achieve ISO Accreditation and the rigorous practices that underpin our credibility in the field. Chapter #6 details the introduction of Battery-Powered Data Loggers, emphasizing our strides in portable and convenient technology solutions. Adapting to industry regulations has always been pivotal to our growth. In Chapter #7, we explore our alignment with critical regulatory standards, including 21 CFR Part 11, underscoring our commitment

to compliance and quality. Technological evolution takes center stage in Chapter #8, where we document our transformation from chart recorders to sophisticated monitoring systems. In Chapter #9, “Think Globally – Act Locally”, we highlight the impact of our global reach combined with local engagement, illustrating how we have created a strong, connected presence worldwide. We then shift our focus to the comprehensive support we provide our clients in Chapters #10 and #11, showcasing the ancillary tools and services that enhance our core offerings—from accessories to comprehensive customer care, spanning commissioning to long-term maintenance.

Finally, we conclude this journey with insights into our leadership and workforce through sections like General Managers and Kaye Today. The book ends with a look ahead in The Future of Kaye, outlining the exciting advancements we’re poised to make in the years to come.

As you explore this book, we hope you will not only gain a deeper understanding of our past but also be inspired by the relentless pursuit of excellence that drives everything we do.

Thank you for being part of the Kaye family and for contributing to the legacy of innovation, dedication, and teamwork that we celebrate today. Here’s to many more years of success together!

Warm regards,
Mark DeNovellis
General Manager

Chapter 1: How It All Began

In this chapter, we invite you to embark on a journey through time, exploring the origins of Kaye and the company‘s pioneering steps in validating thermal processes within the pharmaceutical and biotechnological industries. Through an engaging narrative, we will uncover the significant milestones that laid the foundation for Kaye‘s enduring legacy in innovation and precision.

Before we dive in, it may be helpful to understand a little more about our company‘s founder, as his work and principles still inform Kaye’s values today. These values are innovation, utilizing available technology at its edge, finding solutions that are practical for the end user, and always being curious in trying out new technologies first.
Dr. Joseph Kaye was a Professor of Thermodynamics and Mechanical Engineering at MIT in Boston. He held several foundational patents in precise temperature measurement and had already established a good reputation in professional circles for high-precision temperature measurement as early as the 1950s.

Dr. Kaye‘s foundational research on topics such as power generation from heat, thermodynamic properties of gases, and heat transfer led to the invention of the so-called thermoelectron engine, a device that directly converts heat into electricity. His work at MIT also covered areas such as fluid dynamics, thermodynamics, heat transfer, the influence of sound on heat transfer, and the combined effects of heat transfer, mass transfer, and chemical reactions.
In collaboration with other authors, he published two significant books—“The Thermodynamic Properties of Air“ (1945) and „Gas Tables“ (1948). The latter book was widely used in the design of turbine and jet engine units. He was also a co-author of the book „Direct Conversion of Heat into Electricity,“ which was published in 1960.

And even though one might believe that this background was the focus immediately after the company’s founding, one would be mistaken. What we know is that the company was founded by MIT engineering graduates, with Dr. Joseph Kaye as the owner and president, along with colleagues and former students from MIT. As is often the case with start-up companies, each founding member held a leading position. The leading positions were Dr. George Harper (Thermal Engineering), Dr. Clarence Kemper (Thermal Engineering and published author in Thermocouple Technology), Dr. T. Vincent Corsini Jr (Tufts University, Head of Sales), Dr. Robert

Goldsmith (Engineering), Dr. Richard Eastman (Engineering), Arnold Fields (Engineering), and Paul Thomas as financial officer. It was somewhat like a company structure divided by areas of expertise. Who wonders, obviously with a heavy focus on engineering expertise in different mechanical and electronic areas.
After the sudden and unexpected death of Dr. Joseph Kaye in March 1961, Clarence Kemper became the chief CEO. Contemporary witnesses report that Mrs. Kaye still owned the company, and her son Harvey Kaye worked there during the summers while pursuing his degree at Harvard. The company primarily operated as engineering consultants, solving technical problems for large companies. For example, they improved air conditioning systems for the company Fruehauf Trucking or improved large desalination systems for entire islands. Or they acted as expert witnesses for Kaiser Aluminum in a multi-million-dollar court case accusing all other aluminum companies of stealing their patent rights. (The Kaye Institute built a large Plexiglas water tank with submerged blasting caps and set them off in the courtroom to demonstrate the fusion process. The lawsuit lasted several years, but Kaiser lost in the end.)

Kaye was also commissioned to develop a longer-flying golf ball. A large 40-foot wind tunnel was installed in the company, with a trap door at the top and cameras along its length. Identical golf balls with slightly modified outer shells were dropped into the wind tunnel until one design outperformed all others. The Titleist #1 longest-distance golf ball was born.

However, what particularly fascinated Dr. Joseph Kaye and all his founder peers were the possibilities of achieving fast and yet highly accurate temperature measurements using a variety of thermocouples combined with a measurement and data collection system. Thus, a measurement system originally designed for cold junction compensation—the so-called Kaye Ice Point Reference—evolved into the world's first commercially available multi-channel recorder using thermocouples as measuring sensors—the Kaye System 8000.

The newly created ability to perform fast, reproducible, and highly accurate temperature measurements over a very wide temperature range using the same thermocouple sensor has been implemented in nearly all industrial applications. Therefore, Kaye data loggers can be found in the aircraft industry, electrical and heat power stations, gas turbine development, in the steel industry at blast furnaces, or in nuclear power plants. Customers like NASA, Lockheed, or the Alaska Pipeline were clients, just to name a few.

In the early 1970s, the Septicemia Outbreak, caused by improper sterilization of Small and Large Volume Parenteral (SVP/LVP), prompted the pharmaceutical industry to reevaluate the existing rules for sterile manufacturing and control of sterility. Kaye was at the forefront in providing appropriate measurement and calibration systems. These enabled precise and rapid monitoring and validation of sterilization temperatures during the autoclaving of pharmaceutical products. Thus, the concept of validating a thermal process was born.

From the multi-channel recorder Kaye 8000, which can be used for general temperature measurements, a whole range of different Kaye validation systems developed over the next several generations—always in connection with the necessary peripheral systems for calibrating and adjusting thermocouples. The wired measuring systems from Kaye, based on thermocouples as measuring sensors, quickly established themselves as a worldwide recognized solution, accepted by regulatory authorities in both the pharmaceutical and biotechnological industries.

Starting in 1972, with the launch of Kaye‘s first data recorder termed Validator—Kaye Validator Digistrip I, the subsequent product generations Kaye Validator Digistrip II, III, IV, Kaye Portable Validator KL, and Kaye Validator 2000 up to the current Kaye Validator AVS—demonstrate the continuous adaptation of the foundations developed in the 1960s to the ever-increasing requirements of the industry in terms of precision, transparency of measurement data, and number of required measurement points. This applies equally to the validation of a steam autoclave, a hot air tunnel, a freeze dryer, a heating cabinet, or an incubator.

Thanks to its dynamic and market-oriented product development, Kaye has consistently set standards and had a significant influence on what we today refer to as thermal process validation. Starting with a relay-programmable multi-channel recorder, the Kaye System 8000, followed by the MS-DOS® operable product family Kaye Digistrip/Portable/KL, to Microsoft Windows® based solutions like the Kaye Validator 2000, all the way to the complex yet user-friendly product family Kaye Validator AVS. Kaye‘s validators, in combination with the automated calibration and adjustment of connected sensors using a traceable temperature standard and high-precision liquid bath or block calibrators, are considered the gold standard in thermal process validation in the pharmaceutical and biotechnology sectors.

Kaye HTR-300 Dry Well Calibrator

Chapter 2: From the Bulky Block Calibrator to the Flexible Calibration Unit

The calibration of systems and sensors currently in use, along with the complete elimination of identified deviations, constitutes a fundamental component of qualification. These tasks are essential for the subsequent validation of a critical process within a GxP context.

As we know, the steps for a standards-compliant validation of a thermal process can be broken down into four key steps:

- **Step 1:** Calibration and adjustment of the temperature sensors used.
- **Step 2:** Placement of the sensors in the unit to be validated and data acquisition.
- **Step 3:** Removal of the temperature sensors and, depending on the type of sensor, checking the calibration and adjustment through a post-calibration.
- **Step 4:** Analysis of the collected measurement data and standards-compliant preparation and documentation of all calibration and measurement protocols.

This chapter will now focus more extensively on Step 1: the calibration and adjustment of the temperature sensors used. For this, the heat source for temperature calibration is a crucial component.

Although scientific literature extensively covers the calibration of temperature sensors, specifications, permissible deviations, and possible sources of error, we want to raise awareness around some basic points. We hope this encourages a deeper understanding of one‘s own knowledge.

AVAILABLE HEAT SOURCES

Several potential heat sources (temperature calibrators) are available, and two different types have established themselves in validation practice:

- **Block calibrators (Calibration ovens)**
- **Calibration baths (Liquid calibration baths)**

Both systems are widely used. However, it is important to be aware of their respective design-related characteristics to ensure that the subsequent calibration delivers the desired results. In the course of this chapter, we will discuss some fundamental differences and potential errors to be mindful of.

THE KAYE BLOCK CALIBRATORS

Almost simultaneously with the introduction of the first Kaye Validator Digistrip I, Kaye focused not just on thermocouple-based data collection. The company also provided equipment for perfect calibration: the calibration units.

The Kaye HTR-300 was the first calibration unit specifically designed for thermocouples. Special sleeves were employed to minimize measurement errors, fitting the diameter of the thermocouples to be calibrated and reducing potential measurement errors due to the temperature transition between the sensor and the heat source. Further sources of error, especially when calibrating sensors in block calibrators, will be discussed later.

Strictly speaking, the Kaye HTR-300 was a hybrid between a calibration bath and a block calibrator. Its high-temperature stability was based on the use of calibration oil in the double wall of the calibration body. This gave it the advantage that the sensors did not come into contact with the calibration bath medium and were not wetted with silicone oil.

The relatively high weight and the slow heating and cooling rates of liquid baths were disadvantages. It required more time for calibrating several measuring points for adjustment.

True to Kaye‘s philosophy of providing better solutions, the development of block calibrators since the 1960s advanced with a focus on optimizing these devices for thermocouple calibration needs. The Kaye HTR and LTR product family has seen remarkable developments over the last 20 years. The Kaye HTR-400 and Kaye LTR-140 block calibrators were the first portable units in this series and quickly became the industry standard.

To extend the temperature range, especially for applications below -25°C, the Kaye LTR-40 and the Kaye LTR-90 expanded the product line, enabling temperatures as low as -90°C. Later, the Kaye HTR-420 extended the range up to +420°C. The Kaye LTR-150 covers a range from -30°C to +150°C and offers conversion into a liquid bath calibrator or configuration for surface temperature calibration. The product line was further extended with the Kaye LTR-200, offering an even broader temperature range.

With the extended temperature range, the focus shifted to increasing the number of sensors calibrated simultaneously. While the LTR-140 was limited to 18 sensors per run, the HTR-400 could only handle up to 24 sensors due to design limitations.

Current technology allows for the parallel calibration of 48 thermocouples with both the Kaye LTR-150 and HTR-420 block calibrators. The LTR-90 initially supported 12 sensors, which increased to 25 with special Kaye inserts. These inserts ensure optimal temperature transition between the sensor and calibrator without affecting block temperature distribution or calibration stability.
The range is supplemented by practical options such as interchangeable thermocouple inserts and a Kaye-exclusive thermocouple holder. Notably, Kaye enables the automatic calibration and adjustment of thermocouples via software modules. The Kaye IRTD-400 serves as a traceable temperature standard between the data logger or thermocouple and the calibration unit.

All block calibrators can be directly connected to the Validator AVS or ValProbe System and are backward compatible with the Kaye Validator 2000 and ValProbe data logger systems, facilitating automatic sensor calibration and adjustment.

KAYE CALIBRATION BATHS

Following its expansion with battery-operated data loggers, Kaye continued to pursue automatic sensor calibration and adjustment. This includes linking the sensors to calibration units, a traceable temperature standard, and the evaluation unit. In the early 2000s, when Kaye data loggers were introduced, the range was supplemented by appropriate calibration baths.

For flexible sensors, calibration in a block calibrator (Dry Well Oven) is possible, but a precise calibration, considering form and sensor length, is best achieved in a liquid bath. With battery-operated loggers, minimizing measurement uncertainty requires calibrating both the sensor and evaluation electronics at the same temperature.

The Kaye calibration baths, CTR-25, CTR-40, and CTR-80, cover a range from -80°C to +140°C. For calibration under liquid nitrogen conditions (-196°C), the Kaye LN2 Comparator is utilized.

TEMPERATURE COVERAGE BY KAYE DRY-BLOCK CALIBRATORS AND CALIBRATION BATHS

What are the fundamental differences between a Kaye Block Calibrator and a Kaye Liquid Calibration Bath? In addition to obvious differences, such as portability, cleaning effort, speed of temperature change, capacity, maximum number of sensors to be calibrated at the same time, and possible temperature range, the following criteria should be considered when choosing the right calibration unit:

- Axial and radial homogeneity of temperature (temperature distribution)
- Errors during loading/heat output/heat transfer
- Temperature stability
- Stabilization time
- Hysteresis
- Influence of ambient temperature
- In liquid baths, the chemical properties of the calibration medium also play a role. This includes temperature range, aging, off-gassing, and hygroscopic properties.
- Additionally, for calibration baths, consider the possible contamination and subsequent cleaning of the sensor by the bath fluid.

Of course, all of these mentioned sources of error have already been taken into account in the design and development of Kaye block calibrators and calibration

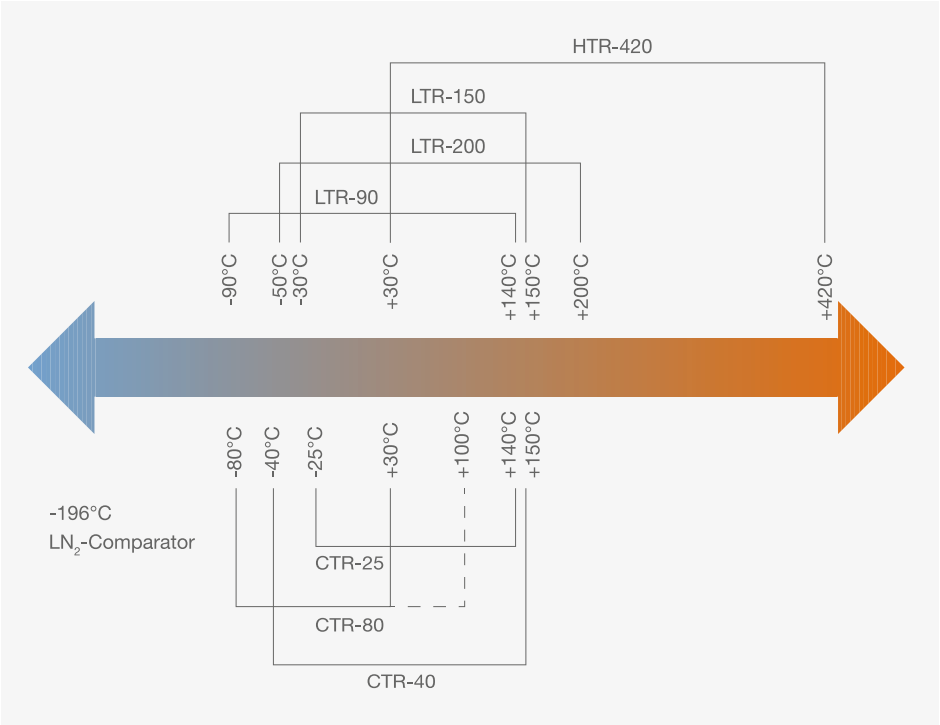
baths, according to the „Quality by Design“ principle. Often, despite the precision and accuracy of the devices, the user can be one of the greatest remaining sources of error. Yet, precisely for such cases, Kaye provides a global network of specialists. These experts can conduct practical user training sessions to ensure that the equipment is operated in the best possible manner and that potential user-related errors are avoided. This representation of the development of block calibrators and calibration baths at Kaye, in connection with technical advances, is evidence of the company‘s continuous innovation. It shows commitment to providing practical and optimal solutions in the field of thermal process validation in the GxP environment. With groundbreaking technologies and solution-based approaches, Kaye assumes a leading market position and symbolizes sustainable innovation power.

Chapter 3: The Traceable Temperature Standard

This chapter deals with another important part of the measurement philosophy that Kaye established early on as a system supplier for measurement systems for the validation of thermal processes. As early as 1972, with the introduction of the first Kaye Validator Digistrip I, it was clear that a data recorder or data logger for data acquisition and the calibration furnaces and baths described were only part of the journey toward an automated validation system.

For a sensor to be used in calibration, regardless of whether it‘s a thermocouple or a Pt-100, it is imperative that it be calibrated and adjusted before the actual data recording begins. In the 1960s and 70s, the calibration and adjustment of temperature sensors were relatively time-consuming, manual, and thus prone to errors. It became clear: A complete calibration system needs a traceable temperature standard to enable standard-compliant calibration.

In the context of reducing user-dependent errors, maximizing the degree of automation of the largely manual calibration process was aspired. Furthermore, an additional development focus of the Kaye innovation team was on a significant improvement of the temporal progression of the calibration, including several calibration and adjustment points.



Temperature coverage by Kaye Dry-Block Calibrators and Calibration Baths

Thus, the next stages of development in the evolution of Kaye‘s validation systems were established in the late 1970s:

1. **The necessity for a highly accurate, robust, and traceable temperature standard was recognized, one that could withstand the high demands of mobile applications.**
2. **There was a push to provide a largely automated and user-independent calibration process to eliminate potential user-related sources of error.**

A brief excursion into the topic of traceability may be helpful here. Even though this topic has the potential for its own chapter, we aim to briefly illuminate this term in the context of the Kaye IRTD.

SHORT EXPLANATION OF TRACEABILITY

The traceability of temperature standards is essential in metrology to ensure the accuracy of temperature measurements. Through a continuous chain of comparison, it is ensured that the measured temperature data is traceable back to an internationally recognized standard, such as the National Institute of Standards and Technology (NIST) or the Physikalisch-Technische Bundesanstalt (PTB). Therefore, temperature standards must undergo calibration processes that verify their measurement accuracy against these standards and document this in corresponding calibration certificates. This chain of traceability is described in detail in technical literature and is vital for adhering to quality standards in industry and science.

RETURNING TO OUR PRIMARY FOCUS: THE IMPLEMENTATION OF AUTOMATION IN CALIBRATION

At that point in time, the traceable temperature standards available typically provided an analog output signal of 0-10V or 4-20mA. This necessitated a separate, often expensive, electronic evaluation system. To overcome this limitation, the Kaye development team, in collaboration with external specialists, developed the Kaye IRTD 400. The result is a highly accurate, traceable temperature standard based on a resistance thermometer that directly converts the measured temperatures (or respective resistances) into a digital output signal. This innovation is already reflected in the product name, with the „I“ standing for „Intelligent“ (some might also say „Innovation“), and „RTD“ standing for „Resistance Thermometer.“

This groundbreaking development from over 40 years ago is demonstrated by the fact that since the market introduction of the Kaye IRTD 400, only minimal changes have been made to the components used and the original design. This shows that thoroughly conceived designs often only need fine adjustments to stay relevant and effective over time.

The generation of a digital output signal enabled seamless integration with both Kaye‘s data acquisition systems and data logger systems. Additionally, it was compatible with the digital output signals of Kaye‘s calibration furnaces and baths. With this development, the second challenge was successfully overcome: a fully automated calibration and adjustment process could be realized.

WHAT ARE THE FUNDAMENTAL, INNOVATIVE FEATURES OF THE KAYE IRTD 400?

The Kaye IRTD 400 is an innovative, traceable temperature standard. Its high precision and wide temperature range of -196 to 420 °C make it the ideal measuring tool for calibrating sensors in pharmaceutical and biotechnological applications. One of the groundbreaking features of the IRTD 400 is its ability to enable largely automated sensor calibration in conjunction with Kaye data loggers or data recorders and their extensive range of Kaye calibration baths and ovens. The available add-ons, the IRTD Console Software, and the external IRTD display allow for intuitive operation and efficient real-time communication with up to two IRTDs. The Kaye IRTD display, a sophisticated touchscreen device, provides a clear representation and accurate analysis of the temperature data from various IRTDs. Both units support standard connecting cables, enhancing the accuracy and efficiency of calibration in industrial and scientific contexts.

The realization of the first complete, largely automated validation system marks a significant milestone in the history of industrial measurement technology. This system, consisting of Kaye data loggers or recorders, the universal series of Kaye calibration baths and ovens, and the Kaye traceable temperature standard, represents an impressive advancement in the validation of thermal processes in line with GxP regulations. Since its market introduction, this system has received widespread recognition and has brought about a significant paradigm shift in the workflows of its users.

In addition, the global network of Kaye calibration laboratories accredited in accordance with ISO 17025 ensures the assurance of traceability to national standards without any gaps.

Chapter 4: Ice Point and Cold Junction Compensation

This chapter provides more insights into the significance of the Kaye Ice Point Reference in the context of validating thermal processes in the GxP environment. In fact, Kaye Ice Point references are more likely to be found on aluminum furnaces, in turbine test stands, or in power plant control rooms. However, the

basic knowledge that our company founder Dr. Joseph Kaye acquired in the early 1950‘s in this context is crucial for the development of high-precision validation systems based on thermocouples as temperature sensors.

Like any sensor element, thermocouples, regardless of type, exhibit inherent error sources. These must be taken into account when setting up a measurement circuit. To ensure accurate temperature measurement, complete compensation of these error sources is absolutely necessary. Particularly, the careful execution of cold junction compensation is of paramount importance in thermocouples.

Kaye Product Line of Multi-channel Ice Point References

WHAT IS COLD JUNCTION COMPENSATION?

The temperature measurement of a thermocouple is based on the so-called Seebeck effect, in which a voltage is generated when two different, electrically conductive materials are thermally connected at one point and heated differently. In short: A temperature gradient along a connection of different metals generates an electrical voltage.

The challenge now is that any connection of two different metals also acts as a thermocouple and generates a thermoelectric signal corresponding to its temperature. In practice, the signal of the thermocouple is often distorted by

the unwanted thermocouples of the measuring line terminals – this is referred to as the cold solder joint effect. Cold junction compensation is therefore a critical component in thermocouple measuring circuits. Without it, the temperature signal that is measured at the end would be a function of two temperatures – the actual desired temperature and the temperature at the cold solder joint. This compensation allows the signal of the actual measuring point to be isolated and thus provides an accurate and reliable temperature measurement.

For the purpose of addressing effective cold junction compensation in thermocouple measurement technology, three technical solutions are available:

1. **Utilization of the **Seebeck effect**:** This effect, named after the German physicist Thomas Johann Seebeck, describes the conversion of temperature differences into electrical voltage and vice versa. In a thermocouple, temperature differences at the junctions of the two different metals generate a voltage.

2. **Utilization of the **Peltier effect**:** This effect, named after the French physicist Jean Charles Athanase Peltier, describes the amount of heat that is generated or absorbed in a circuit when a current flows through two different materials.

3. **The direct measurement of the actual ambient temperature** directly at the cold solder joint.

METHOD 1: SEEBECK EFFECT

Historically, the Ice Point Reference method (Seebeck effect) was the first to be used for cold solder joint compensation. The method is relatively simple, requiring only an ice bath to maintain a constant temperature at the junction, precisely at 0°C. This method was already implemented in the early days of thermocouple measurement technology, long before measurement systems equipped with software-controlled and fast process computers were available for the efficient compensation of this measurement error.

A thoughtful combination of ice and water, packed in a robust industrial casing, equipped with rudimentary control technology and a power supply – what sounds like building instructions from the movie „Back to the Future“ is, in reality, the basis for Dr. Kaye‘s multichannel ice point references, applicable for a variety of industrial uses. Yes, you read that right! As surprising as it sounds, this innovative concept

found widespread acceptance in various industrial applications and has not lost its relevance to this day. Although this measuring principle still forms the foundation for today‘s Kaye Ice Point references, the control electronics have naturally evolved – and the remarkable thing is that the Kaye Ice Point references, despite these minimal technical changes, are still among the most accurate on the market.

METHOD 2: PELTIER EFFECT

The Peltier effect is usually not explicitly used for the compensation of cold solder joints in industrial measuring instruments. The Peltier effect is typically used in Peltier coolers/heating units to create a temperature difference and thus achieve cooling, like in the case of the Kaye Block Calibrator LTR-150.

Although it is theoretically possible to use a Peltier cooler at the cold solder joint to keep the temperature at the cold solder joint constant and thus eliminate the need for compensation, this approach would be impractical and costly in most applications and is therefore only used in very specific thermocouple measurement circuits.

METHOD 3: DIRECT MEASUREMENT OF THE ACTUAL AMBIENT TEMPERATURE DIRECTLY AT THE COLD SOLDER JOINT

The now most widespread method is the direct measurement of the temperature at the cold solder joint and the subsequent compensation using software. This became possible with the advent of microprocessor technology and software algorithms.

In this method, a separate temperature sensor, often a high-precision resistance thermometer or a thermistor, is used to measure the temperature at the cold solder joint. This information is then used to compensate the thermocouple signal. The compensation is done by converting the measured cold solder joint temperature into a corresponding thermocouple voltage using the known thermocouple voltage-temperature relationship (Seebeck curve). This „compensation voltage“ is then subtracted from the measured thermocouple signal to obtain only the signal of the „hot“ joint (the measuring point). It is important to note that the quality of the compensation strongly depends on the precision, stability, and response of the cold solder joint temperature sensor used. In addition, the cold solder joint must be well thermally insulated to minimize disturbances due to external temperature fluctuations.

This measuring principle is also used in Kaye‘s data loggers. As early as the first Kaye Digistrip product family, this method was used, and the modern Kaye AVS Validators use this compensation option directly at the connection point in the SIM (Sensor Input Module), where all thermocouples are connected.

In conclusion, it can be noted that the basic research findings of company founder Dr. Kaye have been and continue to be consistently implemented into industrial solutions by Kaye. A continuous adaptation, based on new, more precise, and faster electronic components on a microchip basis, is an integral part of the development philosophy at Kaye. Interestingly, the fundamental physical knowledge remains the same since the early days of the company‘s foundation, highlighting the timeless relevance and applicability of these scientific principles.

Chapter 5: ISO Accreditation

Having delved into the history of the various Kaye measurement systems in previous chapters, this chapter is dedicated to the essential service offerings that go hand-in-hand with Kaye‘s validation systems. In chapter 3 of this booklets, we already addressed the necessity for traceability in calibration. From the very first Kaye validation systems, this traceability was ensured by the Kaye IRTD-400 temperature standard. However, complete traceability in relation to national standards is only ensured by the necessary accreditation.


United States Department of Commerce
National Institute of Standards and Technology

NVLAP®

ilac-MRA

Certificate of Accreditation to ISO/IEC 17025:2017

NVLAP LAB CODE: 200913-0

Amphenol Advanced Sensors
St. Marys, PA

is accredited by the National Voluntary Laboratory Accreditation Program for specific services, listed on the Scope of Accreditation, for:

Calibration Laboratories

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2017. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (refer to joint ISO-ILAC-IAF Communique dated January 2009).

2023-11-30 through 2024-12-31
Effective Dates

For the National Voluntary Laboratory Accreditation Program

Accredited laboratories guarantee certified traceability to national standards

WHAT DOES TRACEABILITY TO A NATIONAL STANDARD MEAN?

Traceability to a national standard refers to a direct link between the measurements taken by a measuring instrument or a sensor and established standards. These standards are managed by national metrological institutes, such as the German Accreditation Body (DAkkS) in Germany and the National Institute of Standards and Technology (NIST) in the United States. In calibration, traceability ensures that the sensor‘s measurements accurately match the values of these renowned standards. The calibration process is standardized and documented, making each step traceable back to the national standard. Traceability is crucial for quality assurance, as it guarantees the precision and accuracy of the measurement results, which are essential for product safety and performance, and are validated by internationally recognized institutions.

HOW IS TRACEABILITY ENSURED?

In principle, traceability can be achieved either directly or indirectly:

- **Direct Traceability:** This refers to the calibration of a measurement by direct comparison with a national or international standard, which is considered the most accurate method.
- **Indirect Traceability:** This, on the other hand, uses other measurements or standards for calibration when a direct calibration is not practicable, which, however, involves more measurement uncertainties.

Both methods require proper documentation and verification by accredited bodies.

In short: Direct traceability, where the measuring system or sensor is calibrated directly with a national or international standard, often provides the highest accuracy and reliability as uncertainties associated with additional calibration steps are minimized. Even though the costs of direct traceability are often higher, it provides the greatest accuracy and is therefore preferable over indirect traceability for measurements that require high precision.

HOW IMPORTANT IS IT TO PERFORM CALIBRATION IN ACCREDITED CALIBRATION LABORATORIES?

Observing the landscape of various calibration laboratories, it is clear that there are differences in accuracy and quality. Generally, accreditation inherently entails

compliance with universally applicable norms and guidelines, and is therefore, particularly the preferred solution in the context of calibrations in the GxP environment. The use of accredited calibration laboratories guarantees compliance with rigorous quality standards according to ISO/IEC 17025. These laboratories ensure the accuracy and reliability of measurements by ensuring the traceability of the measurement results to national or international standards. This reinforces the validity and credibility of measurement results and enhances confidence in the established quality and accuracy. In addition, they meet legal or industrial requirements, and their accreditation certificates are internationally recognized, thus facilitating global business operations.

WHAT ADVANTAGES DO USERS OF KAYE VALIDATION SYSTEMS HAVE?

In line with the central philosophy of our founder, Kaye has always strived to provide comprehensive solutions for the validation of thermal processes. Over the years, Kaye has established an extensive network of company-owned calibration laboratories that adhere to ISO-certified standards. Thus, we ensure that users of our measurement systems can receive accredited calibration anywhere in the world.

The traceability of calibrations to national standards is fundamentally important to ensure the precision, accuracy, and reliability of measurement data. It is a critical aspect in ensuring high-quality measurement results and is essential for quality assurance systems. The realization of traceability can be achieved either directly or indirectly, with the direct method often providing greater accuracy but also being more cost intensive. The use of accredited calibration laboratories ensures the upkeep of stringent quality standards in accordance with ISO/IEC 17025. Furthermore, the international recognition of accreditation certificates secures both the confidence of users and the fulfilment of legal requirements. Kaye has made it its mission to meet these high standards and to provide its global customer base with access to accredited calibration of their measurement systems. This confirms Kaye‘s longstanding commitment to providing comprehensive solutions for the validation of thermal processes.

Kaye ValProbe RT Product Family

Chapter 6: Battery-Powered Data Loggers

Now we would like to focus on the addition to the Kaye product line that occurred in the early 2000s: The integration of wireless, battery-powered data loggers, an aspect that was hinted at in our whitepaper on wired vs. wireless validation systems.

Kaye‘s significant contribution to the development of what we understand today as recognized standards and guidelines in this area becomes particularly clear when looking at the ‚PDA Technical Monograph No. 1, Validation of Steam Sterilization Cycles‘. This is one of the first globally accepted sets of rules for the validation of sterilization processes. Kaye played a leading role in the development of Chapter 17 – ‚Temperature/Pressure Measurement & Calibration‘.

In the continued development towards wireless data loggers, the findings previously gained in the field of wired validation systems were consistently implemented and realized with the holistic solutions typical for Kaye.

FROM SIMPLE DATA LOGGER TO COMPLEX, RF-TECHNOLOGY-BASED REAL-TIME VALIDATION SYSTEM

Admittedly, entering the era of battery-powered data loggers in the field of thermal process validation was somewhat tricky and bumpy. Data loggers, originally designed for other industries such as food, found their way into pharmaceutical applications. However, the demands for accuracy, reliability and seamless data collection posed high challenges that quickly pushed some logger systems to their limits. Technical solutions, such as battery operation over wide temperature ranges up to 140°C, seamless and reliable data recording and storage, as well as permanent use in pressurized, hot sterilization chambers had to be adequately solved to enable use in the demanding GxP environment. Additional requirements, such as water resistance, on-site replaceable batteries, and calibration capability, or at least user verification, also had to be met. Finally, regulations for final data evaluation emerging in the 2000s, such as 21-CFR Part11 (electronic records, electronic signatures), posed another challenge that also had to be addressed with appropriate solutions.

With nearly four decades of experience in developing reliable measuring systems, the Kaye development team rose to this challenge. This eventually led to the technical realization of the first Kaye data logger, the Kaye ValProbe system.

Once again, we aimed at developing more than just a data acquisition system, but a comprehensive, user-oriented solution. It should provide a connection to a traceable temperature standard, offer options for the user to calibrate, and of course, ensure standards-compliant data acquisition and subsequent evaluation. All in keeping with the principle of thermal validation in the GxP environment established by Kaye with the first Digistrip validation systems. In the best Kaye tradition – no compromises and consistent in the implementation.

The introduction of the Kaye ValProbe data logger system marked a significant extension of the product range and now allows users to choose the optimal measuring system depending on the specific application. Both wired data acquisition systems such as the Kaye Validator AVS and the battery-operated product line of Kaye data loggers, Kaye ValProbe, are available.

Of course, the Kaye ValProbe system has continuously adapted to the increasing demands of its users and technical developments such as high-quality Li batteries, temperature-resistant electronic components, and microchips since its introduction.

The range of available temperature sensors has been continuously expanded and now includes rigid sensors of various lengths, flexible or bendable sensors, and sensors for measuring surface temperature. In addition, we have integrated additional variables such as pressure, relative humidity, and CO_2. Another innovative step within this product line is the extension of the temperature range, particularly to lower temperatures down to -80°C or the provision of data loggers with up to 5 temperature sensors.

Thanks to the reliable components for transmitters and receivers based on RF technology, available for a few years now, and their implementation in the Kaye ValProbe products, this product line has developed into a currently outstanding, fully qualified, and recognized validation system on the market. The combination of easy handling as well as seamless and reliable data transmission in real-time is a professional alternative and addition to wired recorders such as the Kaye AVS Validator and offers a perfect synergy with the entire Kaye product range.

While the original Kaye ValProbe data loggers and the current Kaye ValProbe RT system carry the same name, the technology and functionality have significantly evolved. In keeping with the long-standing Kaye tradition of combining continuous innovation with tried and trusted methods, the Kaye ValProbe RT system represents a significant advance in technology. Consistent with this tradition, we offer existing users the opportunity to easily and cost-effectively upgrade to the latest product generation, the Kaye ValProbe RT.

We look back on an evolution that began with the introduction of wireless, battery-powered data loggers and has advanced to today‘s state of technology. As an innovative pioneer in this field, we faced challenges from accuracy and reliability to compliance with regulations like 21-CFR-Part11. Our technology has continuously evolved, both in the accuracy and functionality of the data loggers as well as in the evaluation, transmission, and storage of data.

The integration of RF technology has significantly expanded the development of our product line. Our products, like the Kaye ValProbe RT System, now offer

a combination of easy handling, seamless and reliable data transmission in real-time, and are optimally adapted to the specific application. The continuous adaptation and extension of available temperature sensors and measurement variables demonstrate our ambition to provide currently outstanding and complete validation systems.

The Kaye ValProbe RT system represents a significant advance in technology, whereby the improvements address not only technical aspects but also practical ones. In the spirit of our long-standing tradition, we aim for continuous innovation, always with a focus on customer needs. With this commitment and our expertise, we look forward to continually meeting the growing demands of the industry with reliable, efficient, and state-of-the-art solutions.

Chapter 7: Kaye and 21 CFR Part 11

Looking back on the exciting technological history of the 90s, one can‘t help but feel a sense of nostalgia for achievements like 3.5“ diskettes, Excel spreadsheet calculations, or thermal paper printouts. That decade saw the pharmaceutical industry and regulatory authorities still in their infancy when it came to issues like data security, data integrity or even the ALCOA principles.

Microsoft DOS™-based measurement systems, handwritten documents or basic paper recording instruments were the standard tools of the day. In fact, manipulating measurement data (either unintentionally or intentionally) was probably easier than hitting play on a Walkman. A quiet, humorous undertone of the zeitgeist even suggested that GMP (Good Manufacturing Practice) should be interpreted as „Give Me Paper“. Plainly put, the trust in electronically generated measurement data was at a very low level.

But in the midst of this technological change, the FDA – the U.S. Food and Drug Administration – responded to the rapid digitalization and introduced the groundbreaking 21 CFR Part 11 regulation in 1997. With its implementation,

specific criteria were defined, under which electronic records and signatures would be recognized as equivalent to handwritten notes and signatures. In this chapter, we focus on the pioneering role of Kaye in implementing this revolutionary regulation for measuring systems, specifically for the validation of thermal processes. Join us as we delve into a perspective of technological history and the ongoing innovative implementation of new regulations in the Kaye product range.

WHAT DO DATA INTEGRITY, DATA SECURITY, AND ALCOA MEAN?

Data integrity, data security, and ALCOA are essential concepts in the pharmaceutical environment, especially in the field of quality assurance and regulatory compliance.

Data integrity refers to the accuracy, completeness, and consistency of data throughout its entire lifecycle. In the pharmaceutical industry, a high level of data integrity is crucial to ensure that the data generated in clinical trials, production processes, or during quality controls is reliable and correct.
Data security encompasses the protection of data from unauthorized access, manipulation, and loss. It represents a fundamental prerequisite for ensuring data integrity and safeguarding sensitive information, such as formulations or other trade secrets.

ALCOA is an acronym that stands for the core principles of data integrity:

- **Attributable:** Every action must be attributed to a specific person.
- **Legible:** The records must be permanently stored in a readable form.
- **Contemporaneous:** The data must be recorded at the time of the event.
- **Original:** The original data must be retained and accessible.
- **Accurate:** The data must be correct, and mistakes or changes must be documented.

The correct application of these principles helps to ensure data integrity in the pharmaceutical industry and to document regulatory compliance.
The introduction of 21 CFR Part 11 in August 1997 was a crucial step regarding the manipulation of raw data. Terms like audit trail, encryption of raw data, data redundancy, or access regulation were new, and both the users and suppliers of relevant measurement systems faced a challenging task that needed to be implemented technically.

HOW WAS THIS IMPLEMENTED IN THE KAYE PRODUCT LINE?

The answer is simple. Based on its already established experience as a recognized supplier of validation systems and in accordance with its company philosophy, Kaye introduced the first 21 CFR Part 11 compliant validation system, the Kaye Validator 2000, in 1999. This met the increasingly stringent requirements regarding data security and all the other requirements listed in this regulation.

The Kaye Validator 2000 was a standalone validation system that simplified the entire validation process: It reduced setup time, minimized the handling of sensors, and presented important study data in an easily customizable report format. This advanced system was specifically designed to meet the requirements of the 21 CFR Part 11. It met the international and European standards for validating applications in the pharmaceutical industry, biotechnology, and medical device manufacturing. In addition, it included an improved and expanded software for user-friendly data management and handling. In doing so, it considered the proven and accepted procedures for precise measurement of temperature and pressure that were already used in previous Kaye models, like the Digistrip Validator, the Portable Validator, and the Validator KL.

Thus, it was a consistent implementation of regulatory requirements for a recognized, user-friendly, technical solution. The Kaye Validator 2000 was the first validation system available on the market that met these requirements.

In summary, the pioneering role of Kaye in implementing technical standards and regulatory requirements in the pharmaceutical and biotechnological industry. With the introduction of the FDA‘s 21 CFR Part 11 guidelines in 1997, data security and integrity took center stage. In response to this transformation from a simple chart recorder to a complex data evaluation unit, the Kaye Validator 2000 was launched in 1999, the first validation system that met 21 CFR Part 11 requirements and simultaneously facilitated efficient validation of thermal processes. With its user-friendly data management software and precise temperature and pressure measurement functions, which were based on tried and tested procedures, the Kaye Validator 2000 represented a groundbreaking solution that has significantly shaped the transformation in the validation of thermal processes. This demonstrates that continuous innovation and consistent adaptation to regulatory changes are crucial for progress in the pharmaceutical and biotechnological industry.

The journey from a simple chart recorder to a complex measurement unit, adhering to all regulatory requirements for both hardware and software:

Kaye Digistrip Validator
Microsoft DOS-based programming and special thermal paper for documentation

Kaye Portable Validator and Validator KL
Microsoft DOS-based, later Microsoft Windows Software

Kaye Validator 2000
The first Validator system based on Microsoft Windows and 21 CFR Part 11

Kaye Validator AVS and
Kaye ValProbe RT System
Validation systems of the latest generation

Chapter 8: Simple Chart Recorder to Complex Monitoring System

It‘s clearer than ever, especially in light of the Corona pandemic, that monitoring and documenting temperature, relative humidity, and other critical parameters are crucial not only during the production of pharmaceuticals but also in their storage, transport, and all the way to the end consumer at the pharmacy. The storage and distribution of temperature-sensitive vaccines have caught the public‘s attention through radio and television stations, making the public more aware of this as a key quality criterion. The importance of maintaining the cold chain was a topic of public discussion.

We must not forget that this topic was defined many decades ago in the guidelines, specifications, and regulations of various organizations and regulatory agencies such as Good Manufacturing Practice or Good Distribution Practice. The WHO (World Health Organization), ISPE (International Society for Pharmaceutical Engineering), USP (US Pharmacopia), the FDA (US Food and Drug Administration), and European regulatory authorities have designed guidelines to ensure product quality over the entire lifecycle of a pharmaceutical product.
In this chapter, we would like to shed light on Kaye‘s role in this area of continuous monitoring.

FROM HANDWRITTEN RECORDING TO GXP-COMPLIANT MONITORING SYSTEM

The regular monitoring of temperature, relative humidity, light, CO_2, or other critical measurements, for instance in the storage of pharmaceutical finished products, shows the full range of possible implementations. The spectrum ranges from reading and manually recording installed sensors to cloud-based monitoring systems with uninterrupted data access whenever the data is needed. This reflects the technical development since the mid-1970s. Also, the initially very rudimentary recommendations from regulatory authorities have evolved into very detailed guidelines and regulations that require corresponding technical solutions for implementation by the pharmaceutical industry. Nowadays, in addition to the physical implementation of corresponding sensors, data integrity requirements (audit trail, 21 CFR Part 11), a user-friendly software interface and flexibility in terms of data access and data evaluation are important stipulations.

HOW WAS THIS IMPLEMENTED IN THE KAYE PRODUCT LINE?

The origins of using data loggers that recorded data on paper can be traced back to the 19th century. These were primarily used in meteorology and for geological measurements, while in industry, they were mainly used to continuously monitor steam engines. These recording systems were based on mechanical components such as springs and levers to quantify and graphically display movements.
With the progression of industrialization in the 20th century, these devices were widely used in many industries and sectors, especially in manufacturing and production. The introduction of electronic versions in the 1970s and 1980s led to a revolution in data collection, enabling precise digital recording of measurements and replacing the classical physical mechanical movement with an electronic measuring method. This allowed for data-based processing and output of recorded measurements.

This was also true in the pharmaceutical industry, where multichannel data loggers were used to record measurements such as temperature, relative humidity, and pressure.

The precise recording of measurements such as temperature was, as we know from the previous chapters, exactly the topic of our company‘s founder. As early as the 1970s, the Kaye System 8000 was brought to the market for the technical implementation of industrial requirements. The ability to connect a multitude of temperature sensors along with other measurements such as pressure or relative humidity to the same base unit and create paper documentation developed into an industrial standard in many applications. Thus, Kaye data loggers were found in areas such as power generation in steam power plants, basic research, gas turbines, or simply monitoring refrigerators in the pharmaceutical or food sector. With more precise requirements in the GxP area, the development of a continuous monitoring system was a logical consequence.

The groundwork regarding the technical implementation was already laid. Successor models such as those from the Kaye Digistrip family reflected the technical progress. This was evident in improved accuracy, the growing need for more measurement channels, and the necessity to process measurement signals that were based on a 0–10V/4–20mA output signal in addition to temperature. With the introduction of the Kaye NetPac product line, almost unlimited possibilities emerged regarding the number of measurement channels and recorded measured values. The next

progress towards a continuous monitoring system focused on data processing and evaluation. While a simple paper printout on thermal paper was sufficient in the early days, databases based on SCADA (Supervisory Control and Data Acquisition) were increasingly used. Future development steps shaped additional functions such as the definition of different alerting levels, the implementation of „21 CFR Part 11“, data redundancy, the integration of graphical overview plans, and a growing desire for flexibility of the software interface. In particular, the flexibility with regard to the number of measuring points and their easy placement experienced a further development surge with the introduction of wireless system loggers. With the Kaye ValProbe RF in the early 2000s and the later development into the Kaye RF II Monitoring Loggers, this development was addressed.

Therefore, in this application area, both wired and wireless measuring systems are available for selection, which can be optimally used depending on the respective application.

The last development step away from server-based SCADA systems towards a cloud-based data management system was realized in 2019 with the introduction of the first GxP-compliant monitoring system, Kaye LabWatch IoT.

Over a period of 65 years, the technology for validating thermal processes in the pharmaceutical and biotechnology industry has continuously evolved. What once began with simple handwritten recordings has been continually developed through technological progress and growing requirements. Today, we have the ability to precisely capture complex measurement data and analyze and store it in a cloud-based data management system. Products such as those in the Kaye Digistrip family have significantly contributed to this technical development, offering enhanced accuracy and the ability to process a multitude of measurement signals.

The GxP-compliant monitoring system, Kaye LabWatch IoT, introduced in 2019, represents the latest innovation. With its strong focus on technical innovation and adaptation to changing requirements, Kaye has secured a key position in continuous monitoring of critical parameters in the pharmaceutical and biotechnology industry. Moreover, through its core competency – the precise recording and processing of temperature, pressure and other measurements – Kaye has shown that continuous adaptation to technological progress is the foundation of its current success. This is true not only for the validation of a steam autoclave but also for the continuous monitoring of critical processes in the pharmaceutical and biotech industry.

Chapter 9: Think Globally – Act Locally

An interesting chapter about the impressive development of a small start-up, driven by a professor of Mechanical Engineering at MIT Boston and some of his visionary students. With an inspiring arsenal of innovative concepts for quick and precise temperature measurement and an unstoppable pioneering spirit, the company has evolved into a global leader in the field of measurement systems and complete solutions. This expertise proves indispensable for the validation of thermal processes and the continuous monitoring of critical processes in the pharmaceutical and biotechnology industries, leading to technical solutions that are essential for compliance and conformity in these industries today.

FROM LOCAL PROVIDER TO GLOBAL MARKET LEADER

We can all imagine this well because we all have similar examples at hand. Whether it‘s Carl Benz, who tinkered with the first horse-drawn carriage with an internal combustion engine in a small village in the northern Black Forest of

Germany named Pfaffenrot in his grandfather‘s smithy, or the story of Apple, founded by Steve Jobs and two fellow students in a double garage. Both have shaped the world as we know it today with their ideas. And with all due modesty and respect for these giants of industrial history, it is not our intention to put Dr. Joseph Kaye on the same podium. Yet the power of small but determined beginnings, as experienced by Dr. Kaye, can be found in the humble roots of many of today‘s market leaders.

As early as 1955, Dr. Kaye acquired a license to open a consulting firm – Joseph Kaye and Company – at the Cambridge City Hall (Boston) for $2.00. Initially run from his private home or rented rooms at MIT Boston, the move to 2 rooms, rented on the 2nd floor at 87 Washington Street in the Boston neighborhood of Brookline directly above an Italian restaurant, took place as early as 1956. The move was necessary as the number of employees, mostly final year students as part-time staff, had increased. Just 3 years later, the next move took place, this time to the Cambridge district, and finally the registration in 1959 as Kaye Instruments.

The business focus was then the Boston-Washington D.C catchment area. And like every start-up, although supported by good ideas, but with the challenge of commercial implementation, the years after the death of the company founder in 1961 were a turbulent time for the young company. Clarence A. Kemper (later also an icon in the field of thermal validation), who had been working as a student assistant for Dr. Kaye until then, took over the management of the company and led the company from a pure consulting firm to a manufacturer of corresponding measurement technology. The corporate dogma he defined was ultimately decisive for the later growth of Kaye to the point of market leadership.

- Identify a need or a problem
- Develop a (hopefully) clever plan to solve
- Patent this plan
- Looking for financial support
- Define the development strategy and technical implementation of the patented solution
- Implement a commercial plan for economic implementation

The first commercial result of this strategy was finally the Kaye System 7000, later developed into the Kaye System 8000. Due to the economic success and growth of the company resulting from it, the move to a new company in Bedford/

MA took place in 1973, along with some intermediate stations. The sales focus had long since not been limited to the US East Coast, and with the rapidly growing international linkage and implementation of recognized regulations, international sales and service channels had also emerged exclusively via partner organizations. To better support the European market, Kaye Instruments GmbH in Pforzheim/ Germany was founded in 1998. Followed by the founding of the Kaye branches in China and India in the following years, all Kaye customers worldwide now have an extensive network of direct branches and certified partner companies available to support them before and after purchase. Direct Kaye branches for AMER, EMEA, China and India are complemented by 48 certified partner companies and form the basis for direct local access on-site worldwide. According to the motto Think Global – Act Local.

The impressive journey of Kaye Instruments began in 1955 as a small consulting start-up, founded by Professor Dr. Joseph Kaye, which then transformed in 1959 with the founding of Kaye Instruments Inc into a manufacturer of high-precision measurement technology. Today, the company is a global leader in measurement systems and solutions for the pharmaceutical and biotechnology industry. The key to success was the identification of problems and the development of innovative solutions. From humble start-up to global market leader – Kaye Instruments shows that through the continuous implementation of innovative solutions and targeted action, small beginnings can develop into significant successes. With its own branches and certified partner companies worldwide, the company lives by the maxim: „Think global, act local.“

Chapter 10: Useful accessories

Kaye is more than „just“ a supplier of high-precision measuring systems. From the outset, the technical solution has always been viewed in the context of the application. Over the years, an extensive range of useful and labor-saving accessories has been developed. From a variety of different temperature sensors (thermocouples) and special pressure sensors, brackets and feedthroughs, shipping cases or necessary IQ/OQ documents, to specially coordinated calibration units, application-specific complete solutions are offered.

From sensor to IQ/OQ documentation, everything from one source!

THERMOCOUPLES

A variety of different sensor elements ensure optimal use depending on the application. Whether +400°C or liquid nitrogen – always the right sensor element. The accuracy of the overall validation system is critical for process validation. Kaye‘s ultra-premium type-T thermocouple wire and probes, made from the purest and most even copper and constantan metals, ensure unmatched accuracy and robustness in the range from -200°C to +400°C. Before the finished thermocouple is manufactured, the purity of each batch of metal is checked to meet the highest specifications. The extraordinary accuracy of ±0.25°C at 121°C, four times better than the commercial standard, minimizes the risk of calibration errors in the application.

MARKING LABELS

These labels make it easy to identify each thermocouple and enable uncomplicated documentation when qualifying a system. They are simply attached to the Teflon® thermocouple and shrunk onto the thermocouple cable with a heat gun.

PROBE TIP KIT

The lifespan of self-welded thermocouples can be extended by enclosing the tip in a sealed PTFE sleeve. The kit is available for 3- and 7-strand type-T Teflon® thermocouple wires. Each kit provides material for making 45 to 60 sensor tips.

THERMOCOUPLE FEEDTHROUGHS

The Kaye thermocouple feedthroughs offer an efficient method for validating processes in closed chambers such as steam sterilizers and freeze-drying systems. These TÜV-certified feedthroughs allow direct connection to pressure chambers and can accommodate up to 18 thermocouples. By using a Y-connector, additional feedthroughs and a pressure sensor can be added, allowing up to 36 thermocouples to be installed. With various sealing options for different temperature ranges, they ensure maximum tightness, both in pressure and in vacuum applications and at extreme temperatures.

THERMOCOUPLE BRACKET

Professional bracket for the Kaye block calibrators for safe insertion and fixing of the sensor elements to be calibrated during calibration.

PRESSURE TRANSMITTER

To meet the strict requirements of EN285, ISO-17665 or HTM2010 with regard to saturated steam conditions, pressure must also be measured in the chamber to be validated during validation. For the Kaye Validator® systems, a pressure sensor is available that is easy to connect, reliable and accurate even at high temperatures.

SHIPPING CASES

Robust transport cases provide secure protection for the measuring equipment during transport or shipping – the ideal accessory for increasing durability and usability. Especially matched transport cases for the respective measuring equipment/accessories are available for all Kaye systems. A perfect solution especially for mobile use.

IQ/OQ DOCUMENTS AND SERVICE/VALIDATION DOCUMENTS

Kaye provides system-specific IQ/OQ protocols for each validation and monitoring system to ensure proper installation and use in accordance with Kaye‘s manufacturer recommendations. These protocols can be obtained in printed form or electronically on CD and can be adapted to individual company requirements. In addition, Kaye also offers further validation documentation such as standard

SOPs and validation reference materials, which form a comprehensive, cGMP-compliant documentation package.

Optionally, Kaye also offers a full qualification service for Kaye measuring systems. Customers can choose between qualification on-site or qualification before delivery by the manufacturer. Of course, based on the IQ/OQ documentation, the qualification can also be carried out independently by the user.

Comprehensive validation documentation is available for Kaye validation systems. They provide an insight into quality policies, ISO9001 procedures and applied standards for the development, maintenance and review of hardware, software and firmware. This includes quality control documents, development procedures and quality assurance procedures. Adjustments due to changes in firmware, updates and new software versions are considered. Registered users can adapt and keep their validation protocols up to date at any time.

CALIBRATION EQUIPMENT

Kaye validation systems rely on high-precision, traceable references and use block calibrators, baths, and the IRTD temperature standard to ensure reliable measurement results across a large temperature range. The integrated software of the validation systems enables direct communication with the references and the Kaye IRTD, enables a fully automatic calibration process and minimizes calibration errors. This automation ensures high accuracy and repeatability of the calibration of the temperature sensors used. The user-friendly operating software allows the user to individually define calibration target values, stability and deviation criteria and to define them as acceptance criteria. The software provides comprehensive reporting options that ensure reliable and easy documentation of the calibration process.

Kaye offers not only high-precision measuring systems, but also comprehensive, application-specific and practical solutions for the entire process of thermal validation. In addition to a wide range of thermocouples and pressure sensors, the company offers useful accessories, transport cases, Thermocouple feedthroughs and brackets. The provision of GxP-compliant documents such as comprehensive IQ/OQ protocols, SOPs and validation documents makes implementation in the company easier. If required, Kaye technicians are also available to the user for a comprehensive qualification service – globally and wherever needed. Kaye is more than just a manufacturer of highly accurate measuring systems.

Chapter 11: All-Around Care from Commissioning to Maintenance

Everyone who has purchased a measuring system knows this. The true quality of the supplier is not only shown in printed words on a data sheet or a favorable offer. It shows itself when it comes to essential after-sales support. Be it the annual calibration, help, and support during commissioning, training for changing operating personnel, or bridging bottlenecks in your own measuring device.

PRE- AND AFTER SALES SERVICE MAKES THE DIFFERENCE

The origins of the company go back to advisory activities for the industry in the context of accurate temperature measurement. Even here, the consideration of the complete life cycle of a possible measurement solution was part of the consulting concept. Thus, not just the selection of a technical solution, but also the subsequent support, the so-called after-sales. Based on the experience gained back then, it was clear to our company founders after the transition to a system provider. The technical solution of a measurement task is only one component of the entire solution. Application-related adjustment, commissioning, user training, accredited calibration and repair, complete and detailed documentation, the provision of necessary accessories, and professional support after installation make the difference. Therefore, we would like to delve a bit deeper into the important building blocks of service and rental.

HOW IS THIS EXPERIENCE REALIZED IN OUR TIME AT KAYE?

The maintenance and calibration of validation and monitoring systems are essential for their best possible function and compliance with regulatory requirements. Through the connection with quality management systems such as NAVLP (National Institute of Standards and Technology/USA), CNAS (China National Accreditation Services), NABL (National Accreditation Board for testing and Calibration Laboratories/India), DAkkS (Deutsche Akkreditierungsstelle GmbH), and ISO17025, external monitoring and continuous adjustment of the service services are ensured. The service is rounded off by annual calibrations, repair services, and product upgrades that are carried out by trained specialist personnel and certified partner companies. With service locations worldwide, comprehensive support for all Kaye products is offered. Individual service agreements and access to all service parts required by the manufacturer guarantee high availability of the systems used and help minimize possible downtimes.

AND HOW DO WE SUPPORT USERS IN BOTTLENECKS AND VALIDATION PEAKS?

Short-term or long-term rental solutions offer a flexible and situation-adapted solution. An extensive, well-maintained rental park of all Kaye systems offers the possibility to use additional measuring systems for short-term or long-term bridging of bottlenecks in one‘s own equipment park. Renting additional measuring equipment for short-term increased validation and qualification requirements in companies minimizes potential downtimes and ensures the operational readiness of the facilities.

Kaye offers more than just high-precision measuring systems – Kaye offers a comprehensive package based on 65 years of customer experience. Thanks to worldwide accredited service locations and flexible rental solutions, Kaye acts as a reliable partner. The use of Kaye systems extends from commissioning through support to maintenance. Because as a wise head once stated: A measuring system is only as good as its service.

The Kaye Ownership History

2013 – today Part of Amphenol

2001 – 2013 Part of General Electric (GE)

1987 – 2001 Part of Bowthorpe plc. later changed into Spirent

1959 – 1986 Kaye Instruments Inc. privately owned company

The Kaye Leadership History

Note:
During General Electric's ownership, there was no dedicated General Manager (GM) or CEO. Instead, individuals were in charge on a global basis for the destiny of the Kaye product line as product managers or sales directors, and they served as the point of contact and decision-makers.

2023 – today	Mark de Novellis
2014 – 2023	Frank Kies
2009 – 2013	Frank Kies (interim during GE)
2007 – 2009	Dr. Jürgen Tietge (interim during GE)
2007	Brenda Beauchamp (interim during GE)
2002 – 2006	Karen Huffman (interim during GE)
1987 – 2002	Kenneth B. Hurley
1980 – 1986	Tom R. Liebermann
1961 – 1979	Dr. Clarence A. Kemper
1959 – 1961	Dr. Joseph Kaye

Kaye Today

Founded **1959**

part of Amphenol since **2013**

160+ global employees

6 global operations

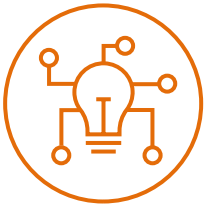
CORE VALUES

ETHICAL

SUSTAINABILITY

DIVERSE

INTEGRITY



INNOVATION

Kaye History at a Glance

65 YEARS

2024

2023

Extension of Kaye's R&D Center of Excellence including ISO 17025 Accreditation by NABL (National Accreditation Board for Testing and Calibration Laboratories)

2022

Extension of European Center of Excellence in Germany

2021

Kaye extended Calibration Laboratory in China and received ISO 17025 Accreditation

2021

Launch of LabWatch IoT, Cloud-based environmental and facility monitoring system

60 YEARS KAYE

2019

Kaye – Leader in Thermal Validation celebrating 60 Years of Innovation and Compliance

2018

Introduction of Kaye ValProbe RT Loggers with newest RF Technology collecting real-time Wireless Data in Harsh Environment

2018

Re-design of Calibration Dry Block and Bath line utilizing current technology for improved capacity, accuracy, efficiency, and user interface. Kaye LTR-150, Kaye HTR-420, Kaye CTR-25

2015

Introduction of Kaye Validator AVS; Revolutionary platform to address current and future requirements for Data Integrity and Data Management

2010

Opening of Sales and Service Centers in China and India, offering local support in growing markets. Local Calibration Labs provide in country for country services

2007

Launch of Kaye ValProbe II; Expansion of wireless Datalogger platform geared for real-time non-harsh applications

2003

Launch of Kaye ValProbe Wireless Data-Logger System extending portfolio to non-wired system for Harsh Environment

1999

Re-design of Calibration Dry Block and Bath line utilizing current technology for improved capacity, accuracy, efficiency, and user interface. Kaye LTR-150, Kaye HTR-420, Kaye CTR-25

1998

Creation of European Kaye Office; Providing local sales, calibration, and technical support for growing European Market; Couple of months later official accreditation of European Calibration Lab in Pforzheim, Germany for EN 17025

1997

Introduction of Kaye Portable Validator and Validator KL Compact; portable windows based Validation Systems designed for ease of transportation.

1991

Introduction of Kaye Labwatch System; PC based System used for Continuous Monitoring, Alarming and Reporting of Critical Processes

1983

Introduction of Kaye Digistrip IV; Kaye's 1st programmable DOS based Thermocouple Chart Recorder

1978

Launch of Kaye Digistrip I, II and III family; 1st full page formatted Thermocouple Chart Recorder with Micro-processor Technology

1974

Through addition of Temperature Standard (IRTD) & Calibration Bath, Kaye offers complete turnkey solution dedicated to Thermal Validation

1972

Launch of Kaye System 8000;1st Data Recorder widely utilitized for Thermal Validation in Pharmaceutical Industry

1963

Kaye IcePoint/UTR Reference; 1st patented industrial solution for Cold Junction Reference Compensation for high accuracy Thermocouple Measurement Systems

1959

Kaye founded by Dr. Joseph Kaye/Professor of Thermodynamics at MIT in Boston

Testimonials

TEAMS

Team China

HAPPY
65TH
ANNIVERSARY!

Team Americas

Team Germany

Team India

SUBSIDIARIES

Piher

i2s

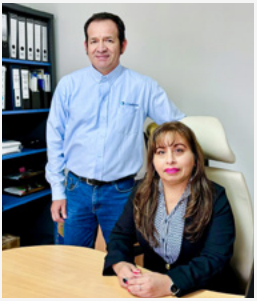
Charles Industries

Temposonics

PCB Piezotronics

PARTNERS

JS INDUSTRIAL



TESTEK Group

Validation group
LS Consult

Afterword by the Author

Although I have spent almost 30 years of my professional career with Kaye, piecing together the period before 1996 has been challenging due to the limited availability of documents and the accounts of living witnesses. Therefore, I ask the readers to forgive any occasional gaps in the timeline. The purpose of this summary is not to provide a meticulously detailed historical account but to highlight the most significant milestones in the development of the company Kaye. Special thanks go to Dennis Plante and Jack Sullivan, who assisted me with their knowledge and recollections of the time before I joined Kaye. Compiling all this information has been a kind of time travel for me, revealing some surprising insights.

I hope this summary has been enjoyable for both the current Kaye family and the users of Kaye systems. I wish the company continued success in the future. As one can see, the journey from a small startup to a global market leader has not always been straightforward and smooth. However, if we continue to embody the innovative Kaye spirit into the future, I am excited to see where the journey will take us in the coming decades.

The transformation of a hardware-focused company into a globally recognized supplier of comprehensive solutions for thermal process validation and continuous monitoring of critical measurements is ongoing. We must address new challenges, such as Pharma 4.0, paperless documentation, and seamless data management. I am confident that Kaye will master these challenges in the tried-and-true spirit of our company‘s founder.

About the Author

Frank was born and raised near Karlsruhe, Germany. After earning his Master's degree in Precision Mechanics (Mechatronics) at the Fachhochschule in Karlsruhe, he began working in a design department for special-purpose machines. He primarily focused on designing and developing machinery for the pharmaceutical and food industries. After completing a part-time distance course in Business Administration, he transitioned to Technical Sales.

Frank joined Kaye in 1996, initially as a distributor for Kaye products in Germany. In 1998, he was a founding member of the Kaye subsidiary in Germany and has since served as the Head of Sales for Kaye in Europe. Frank also took on joint representational responsibilities for Kaye Instruments. During General Electric's ownership (2001-2013), he held various leadership roles at the European and global level, including Marketing, Product Management, Application Support, and Services for the Kaye product line, specialized in the pharmaceutical and biotech industries. Since 2007, he has supported Kaye's activities in Asia, China, and India. As the Sales Leader, he conducted various training sessions related to the Thermal Validation of GMP applications like steam sterilization, freeze-drying, and dry heat tunnels. From 2013 until the end of 2023, Frank served as the General Manager for Amphenol-Kaye, managing the entire Kaye product line globally. Recently, he assumed the role of Global Strategic Marketing Director.

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