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60 years of Framatome in Karlstein:

Experience, Expertise and Innovation for the Safe and Efficient Operation of Nuclear Facilities Worldwide

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Content

Greetings from the Management

Framatome's Karlstein location – Germany's longest-existing site for nuclear development, planning, qualification, and production – is celebrating its 60th anniversary. The location's special facilities, including its globally unique testing equipment, and the know-how of its experts draw on decades of internationally recognized experience that remains in demand to this day.

Close cooperation with the community

In 1960, when AEG's nuclear energy test facility was established in Karlstein (formerly Großwelzheim) on Seligenstädter Straße, both the community and its citizens were intrigued. They were also intrigued by the construction of the Kahl experimental reactor, which took place at the same time. The high level of approval from both the community and its citizens led to the atomic symbol becoming an integral part of the Karlstein municipal coat of arms in 1965. For six decades, the community and the site have cultivated a close relationship, one characterized by mutual support.

It was also 1965 when the production of fuel assemblies for boiling water reactors was made independent and today's Karlstein Am Kieswerk plant, owned by the Framatome subsidiary Advanced Nuclear Fuels GmbH (ANF), was established for fabricating fuel assembly components. From that point on, two nuclear energy companies with their own areas of responsibility called Karlstein their home.

International Development

During the 1960s, the Karlstein site evolved from serving as an internal development and test center into a sought-after service supply facility for the German nuclear industry, which was still in the process of establishing itself in that decade. The stormy pioneering era that spanned 1960 to 1975 was followed by a long phase that saw the Karlstein site establish a solid international reputation for nuclear expertise that extended far beyond Germany's borders. →

Fig. 1
Carsten Haferkamp
Managing Director
of Framatome GmbH

Ongoing Adaption

The company has, however, never rested this success: Over the decades, the company, today Framatome GmbH, has repeatedly adapted its portfolio to meet market requirements and established new topical areas of focus. Established as a key competence in the very beginning, the qualification of components for use in nuclear plants remains a service in high demand around the world by manufacturers of all types of reactors, as well as operators and their suppliers. Today, product development and highly qualified production of a wide range of special components also play an important role. These products and services include instrumentation for neutron flux measurement, ultrasonic testing systems for special applications, and diagnostic and monitoring systems for valve actuators as well as nuclear qualified electrotechnical assemblies and systems for radioactive waste treatment. In addition, Framatome GmbH develops special solutions for nuclear power plant safety and environmental protection and operates an on-site training center.

Since the reactor accident in Fukushima, Japan, following a tsunami in March 2011, these special safety engineering competencies have seen particular high demand internationally, and development continues in this area.

This event also marked the beginning of a reorientation for the nuclear industry in Germany: The German government decided in summer 2011 that Germany would fully withdraw from nuclear energy while at the same time demand for the climate-friendly electricity produced by nuclear power plants was increasing in other parts of the world. Framatome in Karlstein has readied itself to address these changes, and, by realigning its competencies, the company has further strengthened its pioneering role as an expert for the safe operation of nuclear power plants.

A look at the future

Thanks to its special competencies and unique infrastructure, the site considers itself well equipped to meet future challenges. Recognized as an important part of Framatome worldwide and within the EDF Group, the site's many years of experience in safety technology "Made in Karlstein" will continue to send important impulses from Germany to all over the world far beyond 2022.

These six decades of success would not have been possible without the motivation, special efforts, and commitment of several generations of employees. They all deserve the highest recognition and great thanks from the entire company!

Carsten Haferkamp
Managing Director

Greetings from the Mayor

Framatome GmbH has been operating two locations in Karlstein for 60 years now: one on Seligenstädter Straße, the other Am Kieswerk. Approximately 450 employees work at both locations, making Framatome one of the largest employers in our community.

With its development of safety technology for nuclear power plants and the company's test facilities and training center, Framatome offers high-tech fuel-assembly solutions for the peaceful use of nuclear energy.

The "Made in Karlstein" systems and components developed and manufactured here in Karlstein are used worldwide to increase both the efficiency and safety of nuclear power plants.

Despite all of the critical discussions in Germany about this technology, the municipality of Karlstein is proud of its nuclear history, which is reflected in its municipal coat of arms.

Fig. 2
Peter Kreß
First Mayor of
Karlstein am Main

The experimental nuclear power plant (Versuchsatomkraftwerk [VAK]) Kahl was built at the end of the 1950s in Karlstein, or rather in the former independent community of Großwelzheim, as the first power plant of its kind. It was commissioned in 1960. With this plant in operation, more new nuclear technology companies settled in Karlstein.

The VAK was closed down in November 1985 after 25 years of operation, and a green meadow covers the site where it once stood. In the years that followed the end of operations, companies that had business activities related to the VAK also discontinued their operations.

Framatome, however, remains at its historical business premises to this day, which, as the mayor, I am very pleased about.

I join with the municipal council and administration to celebrate the sixtieth anniversary of the site and wish the two locations and their workforces all the best for the coming years as well as continued excellent development opportunities in Karlstein for the benefit of the community.

For many years now, Framatome employees have supported us with an annual Christmas donation, which we put to use to benefit our community. Our three child daycare centers were considered in the last three years, for example. For this reason, I would like to take this opportunity to personally thank Framatome employees for their support.

Best regards

Peter Kreß
First Mayor

Everything began 60 Years Ago

On January 1, 1957, AEG established the Nuclear Power Plants department. One year later, on June 13, 1958, the 16-megawatt (MW) experimental nuclear power plant Kahl (VAK) won the tender to become Germany's first nuclear power plant, beating out competition from Siemens-Schuckertwerke.

As a subcontractor of AEG, General Electric supplied not only the design of the reactor plant but also the fuel assemblies, the control rods including drives, the other reactor internal components and part of the core instrumentation.

It was clear to AEG that they could only become an equal partner of General Electric (GE) if they operated an independent development program for the boiling water reactor (BWR). However, this required AEG to have its own test facilities to experimentally validate the computational programs and test all essential BWR components.

The test facilities for this nuclear power plant development program were originally to be built at the AEG Research Institute in Frankfurt where one of the core facilities included a new Argonaut-class test reactor, referred to as the PR-10. AEG was not, however, able to obtain approval for the PR-10 at the Frankfurt site, so looked for a suitable location near the Kahl nuclear power plant, which was still under construction. They found a site close by: in Großwelzheim (now Karlstein) at Seligenstädter Straße 100.

Initial start of work at Seligenstädter Straße

Construction of the nuclear energy test facilities began in January 1960 at the new site on Seligenstädter Straße, and already by October 1 of the same year an initial group of 35 employees could start work in the pilot plant building. At the same time, construction of the PR-10 test reactor began in 1960 as well. On January 27, 1961, the PR-10 achieved criticality for the first time. →

Fig. 3
The **Kahl experimental nuclear power plant** went into operation in early 1961.

Fig. 4

Today's Framatome GmbH traces its beginnings back to 1960 when the **machine workshop JH1 and TH1** were constructed in Großwelzheim.

In addition to the VAK, development of the superheated steam reactor became a special focus of work for the site in the first half of the 1960s. As a test plant for this new concept, the Großwelzheim superheated steam reactor, with a thermal capacity of 100 MW, was built in the immediate vicinity of the VAK in 1965 and reached criticality for the first time on October 14, 1969.

Successful completion of the project meant a reorientation for the Karlstein Seligenstädter Straße site whose unique research capacities were urgently needed to further develop BWR technology: The necessary work included providing support for component development through thermal engineering tests and postirradiation investigations; component testing (control rod drives, internal circulating pumps); special problems relating to materials, circulation chemistry, and measurement technology; assembly of the control rod drives; and manufacturing fuel assembly prototypes and devices for incore instrumentation.

Manufacturing fuel assemblies

In light of the growing number of BWR nuclear power plants commissioned in Europe, AEG decided to establish industrial production of fuel assemblies in Germany in 1965. As AEG's technology partner, GE was also interested in expanding its involvement in the European market and was prepared to contribute its knowledge. This led to the two companies founding Kernreaktorteile GmbH (KRT) on May 31, 1965, which in turn set up a plant for BWR fuel assemblies as well as for control and absorber elements at the Am Kieswerk plant.

While the Seligenstädter Straße site focused on its test facilities between →

Fig. 5

The **nuclear energy test facility** in 1962: The pilot plant building is on the left, the PR-10 building on the right.

1966 and 1995, the Am Kieswerk site also manufactured fuel assemblies for nuclear reactors.

First order from Lingen

The Am Kieswerk plant started fuel assembly production in October 1966 with an annual capacity of 50 tons of uranium (in the form of U02). The first order was the initial core for the Lingen nuclear power plant, which consisted of 296 fuel assemblies.

A very special order was then processed at KRT in 1970: In a consortium with Fiat, a second core was manufactured for the nuclear-powered cargo ship Otto Hahn.

By 1995, 13,500 fuel assemblies for BWRs had been manufactured in Karlstein. They were subsequently used in every country (Germany, Finland, Japan, Mexico, Spain, Sweden, Switzerland, Taiwan, and the United States) that was operating BWR nuclear power plants. Karlstein has not been manufacturing fuel assemblies since 1995, but it does manufacture all types of mechanical fuel assembly components, in particular spacers for Framatome. This gives the site a central role to play, especially when new product lines are introduced.

Subsequent years saw both Karlstein sites experience constant growth in demand and capacity utilization. This was due to Framatome (or AREVA) having had a much broader customer base than Siemens/KWU and Karlstein serving as a center of competence within the Framatome Group in its fields of activity at both Karlstein sites. In addition, nuclear energy is important in connection with measures to reduce CO2 emissions and interest in it is on the rise internationally. As a result, the services the Karlstein sites provide are increasingly in demand. →

Fig. 6

Kernreaktorteile GmbH in Großwelzheim. Fuel assemblies for nuclear power plants worldwide have been produced here since 1966.

Nondestructive testing

In the past, a subdivision of AREVA's subsidiary intelligeNDT Systems & Services GmbH also operated in Karlstein in the area of nondestructive testing of safety-relevant components for nuclear power plants. The company found an increasing number of customers for its testing systems outside the nuclear industry. Now part of Framatome, the employees at the Karlstein site develop and manufacture equipment as well as provide onsite services for mechanized ultrasonic testing.

Since the beginning of 2001, the Seligenstädter Straße plant has been owned by Framatome NP (as part of the Framatome Group), which was founded as a joint venture between Siemens AG and Framatome SAS. In 2012, Siemens ultimately sold its shares in AREVA NP (now integrated into AREVA). Since 2016, Framatome has been owned by EDF (75.5%), MHI (19.5%), and Assystem (5%). Today, the Am Kieswerk plant belongs to Framatome's subsidiary ANF.

Fig. 7
The **hot steam reactor** in Großwelzheim.

The Karlstein Site on Seligenstädter Straße Today

The German government's 2011 decision to phase out nuclear power led to a reorientation for nuclear technology in Germany and increased the international demand for German skills and abilities, particularly with regard to safety technology. With this in mind, the company relocated many employees from Offenbach to the site in Karlstein on Seligenstädter Straße in 2015. As a result, the workforce there has almost doubled to nearly 300 employees.

The 60th anniversary of the Seligenstädter Straße site in Karlstein in 2020 means it's one of the oldest locations involving nuclear technology in Germany, alongside the country's major state-sponsored research institutions. Over the six decades, many unique competencies and facilities were developed and refined.

Safety solutions and products

From the very beginning, highly qualified engineers at the site have developed innovative new solutions and products for safety systems and components. Their expertise coupled with that of the specialists for qualification, manufacturing, testing, and services, represent a unique set of competencies in Karlstein–competencies that complement the site's high-performance infrastructure. Components and systems from Karlstein are in successful operation worldwide.

Protection systems for the retention of radioactive materials

Karlstein specializes in, for example, the development and delivery of systems and equipment for the protection of containments in the event of severe accidents. Passive autocatalytic hydrogen recombiners, systems for filtered pressure relief of the containment, monitoring systems for the release of radioactive material, and much more define the current state-of-the-art technology. →

Fig. 8
Karlstein site 2016.

Qualification of components

Tests for safety components have been carried out in Karlstein since the site was founded. By bringing together test engineers specialized in this field with the unit responsible for the qualification of safety-relevant components (e.g., pumps, valves, sensors, electrical equipment), the company has created unparalleled comprehensive on-site coverage for this range of topics.

Unique measuring systems

Another important field of activity has been incore instrumentation, which has been consolidated in Karlstein because of the site's long-standing expertise, especially in the pressurized water reactor (PWR) design known as EPR that Framatome developed. Incore instrumentation includes measurements for neutron flux, temperature, and level in the reactor core. The experts in Karlstein also support further development and optimization of core instrumentation for such future reactors as the EPR2.

Monitoring of operational safety

In addition to developing software and hardware for state-of-the-art ultrasonic testing systems used, for example, in reactor pressure vessels, the site produces unique modules for monitoring safety valves and drives for currently operating nuclear power plants and future plants of the latest generation III+. Due to the special requirements of the safety control technology for electrical components, various modules with software-free electronics have been developed in Karlstein that are used worldwide.

Fig. 9
Security and integrity are of the highly valued.

Practical training

Karlstein is also home to the German training center for both employees and customers from all over the world. All technical aspects pertaining to BWRs and PWRs as well as to the measuring and automation equipment for them are taught in the specially designed training rooms.

The unique systems, experience, and knowledge available in Karlstein, especially as they relate to all possible aspects of nuclear safety, are recognized the world over and are in constant demand.

Worldwide reputation

Many competencies developed in the past have also been adapted and further refined over the last decade in order to align them with international developments in nuclear technology. Thanks to this internationalization as well as the special mix and cross-divisional cooperation within the Framatome network, the location will be able to successfully react to new challenges faced in the future. Both Karlstein sites enjoy a good reputation and fulfill all the prerequisites to be able to contribute to the safe development of nuclear technology worldwide even after the last German nuclear power plant has been shut down.

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GAP: The Largest Valve Test Rig in the World

The quality of the components used in a nuclear power plant is crucial to both the safety of the entire plant and its reliable, efficient operation. Safety-relevant components therefore require type approval and fittings play a special role in this respect.

Fig. 10
Large valve
in test setup in GAP.

Since 1976, a valve test bench has been available in Karlstein for the experimental qualification of valves under conditions of normal operation and those involving incidents. In addition, the large valve test rig (Großarmaturenprüfstand, or GAP) was put into operation in 1981 as the world's largest valve test rig. The reason for constructing the large value test bench was a newly issued regulation by the German technical supervisory authority Technischer Überwachungsverein (TÜV): According to this regulation, the live steam safety and closure valves of pressurized water reactors had to be tested under pressure and temperature conditions that represented normal operation as well as those of incidents.

Each type of valve has been tested on the large valve test rig before being installed in a preconvoy or convoy nuclear power plant.

Worldwide interest

The large valve test rig is still used for the qualification of large valves such as live steam shutoff valves used by various manufacturers both in Germany and internationally. Such type tests are a prerequisite for the valves to be used in nuclear power plants. The technical center in Karlstein can perform such type tests in accordance with all relevant international standards.

With its storage volume of over 120 cubic meters, a pipe diameter of 700 millimeters, and steam supply from the very powerful 20-MW Benson steam generator, the large valve test rig built in 1981 is the world's largest test facility of its kind.

The test rig is now internationally established for the qualification of large valves such as live steam shutoff valves, safety valves, and control valves of various valve manufacturers and plant operators in Germany and abroad. Such tests are a prerequisite for use of these valves in nuclear power plants or for their continued operation.

INKA-Tests and Passive Safety Technology

Karlstein played a special role in the further development of the advanced BWR power plant KERENA (formerly known as BWR 1000), which has a large number of passive safety devices.

The KERENA concept was developed by Siemens in the 1990s as part of a planning contract with German operators of BWR nuclear power plants and with the participation of international partners. This generation III+ reactor is characterized by its many passively acting safety systems. Individual passive components have been tested on a small and full scale in Karlstein and in external research facilities since 1995. In 2008, Framatome (formerly AREVA) and PreussenElektra GmbH (formerly E.ON Kernkraft GmbH) agreed on the joint further development of KERENA. In the course of developing KERENA, the large valve test rig was extended to the integral test facility Karlstein (INKA), which can be used to demonstrate the overall system of controlling an accident with or without loss of coolant.

World's largest test facility

Approximately 30 meters tall, INKA simulates the conditions of KERENA on a one-to-one scale. The volumes correspond to a ratio of one to 24. Due to this scaling and in conjunction with the availability of the 20-MW Benson steam generator for simulating decay power, INKA is considered the largest integral test plant worldwide.

The experimental data obtained at INKA has both supported the development of the KERENA reactor and continues to serve international partners for the validation of thermalhydraulic calculation codes.

Left, Fig. 11
INKA test rig.

Right, Fig. 12
Successful test of KERENA's **passive safety systems** at INKA.

KATHY: Investigations into the Critical Heat Flux Density of Fuel Assemblies

Fig. 13
KATHY test rig: Can be modularly adapted for various experiments involving fuel assembly simulators.

Framatome operates the KATHY test rig at its Seligenstädter Straße site and thus supports colleagues in the business unit Fuel with the design of fuel assemblies in terms of the onset of critical departure from the surface heat flux density (known as the departure from nucleate boiling [DNB] or dryout).

The dummy fuel assemblies are simulated via electrically heated rods. These have the same geometry as the actual fuel assemblies (or a section of them) without radioactivity. Important structural components such as spacers, water channel (BWR), and guide tubes (PWR) are also installed or simulated in the fuel assembly simulator. In contrast to real fuel assemblies loaded with uranium pellets, the fuel assembly simulators used are heated exclusively with electricity. Both radial and axial power profiles are simulated. To be able to realize the energy input corresponding to the real fuel rod bundles, a separate power supply of up to 20 MW is available.

Production and operation of fuel assembly simulators for qualification

These fuel assembly simulators, which are developed and manufactured on-site, are equipped with thermocouples to detect the rapid temperature increase that occurs when critical heat flux density is reached.

KATHY is designed for 185 bar and 360 degrees Celsius, thus covering the full spectrum of possible power plant operating conditions a fuel assembly could experience. The plant's main components comprise the test vessels for PWR or BWR tests in which the fuel assembly simulators are installed, a circulation pump to provide the required mass flow, an electrically heated pressurizer that applies the system pressure, and two 10-MW heat exchangers that remove the introduced power from the circuit. Thanks to the multifunctional, modular design of the KATHY test rig, experiments can be run for all different fuel assembly types and geometries.

Continuous improvement of safety and performance

The thermodynamic conditions in the test facility are realized in accordance with the conditions in a reactor. The parameters pressure, temperature, and mass flow are set at the beginning of the experiment, with electrical power then increased until critical heat flow density has been reached. Within the scope of the respective test campaigns, various test conditions are measured that cover the reactor's operating characteristic diagram both in power operations and accident conditions. The test results are fed back into design adjustments or into the qualification of the fuel assemblies, thus making a valuable contribution to their further optimization with regard to safety and performance.

The Manufacture of Heating Conductors to Simulate the Thermodynamic Behavior of Fuel Assemblies

Before introducing a new fuel assembly design for use in a nuclear power plant, heat transfer from the fuel rod to the passing primary water must be investigated to ensure that no hot spots are formed anywhere in the cooling flow that could damage the fuel rod cladding.

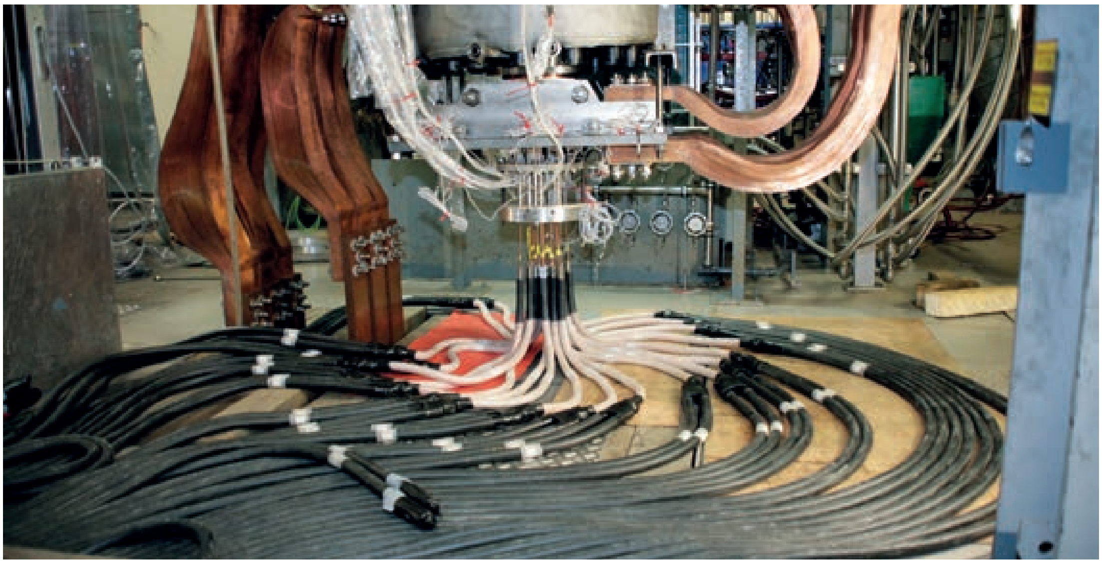


Fig. 14
Electrical connections on the KATHY test rig.

Fuel rod simulators (without uranium) are manufactured in Karlstein for this purpose. They have the same external dimensions as real fuel rods, but generate their heat electrically.

In this process, up to 1,000 amperes flow through a single electric heating rod (the equivalent of about 100 hairdryers switched on at once) at a direct voltage of about 200 volts. As each fuel rod in a fuel assembly emits a different amount of heat and the center produces the highest power, the dummy heating rods are individual one-off products made of tubes with varying wall thicknesses across a range of lengths.

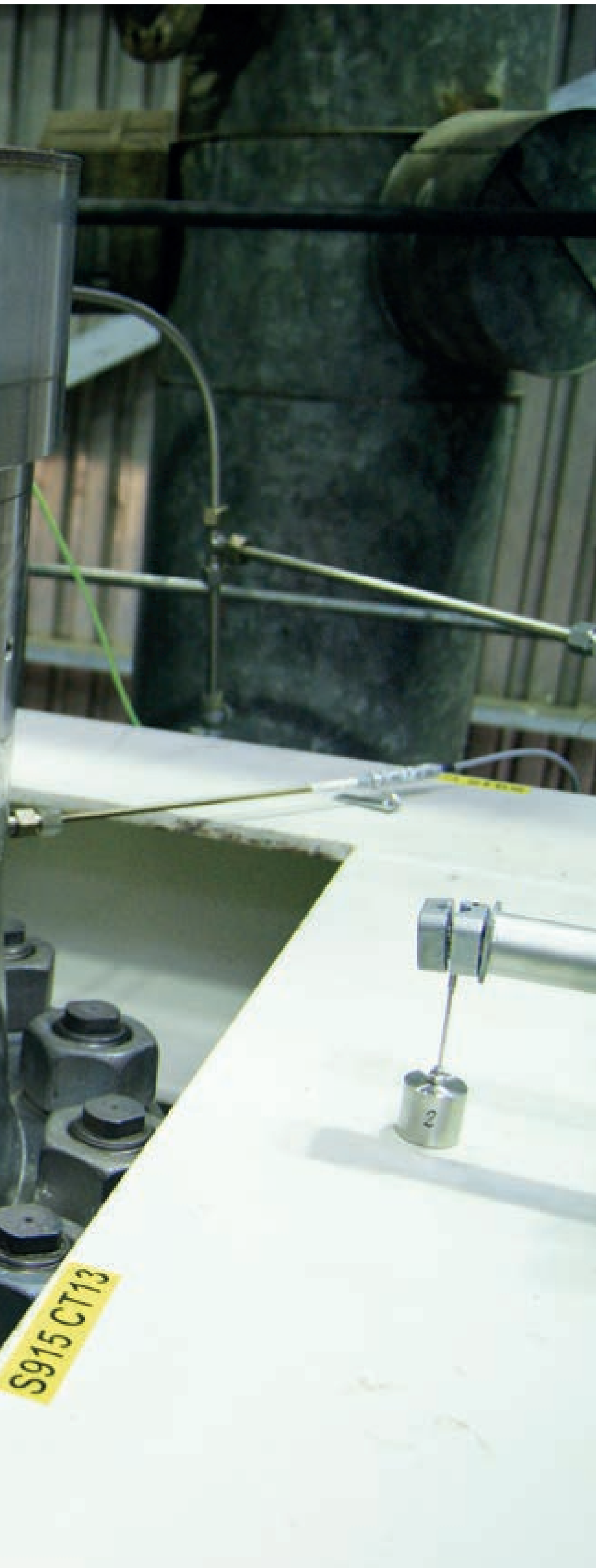
Highly specialized manufacturing expertise

Up to 12 thermocouples, soldered manually in each pipe by skilled precision mechanics so they are electrically insulated, measure the temperature in the pipe wall. To prevent them from collapsing under high pressure in the test rig, the thermocouples are filled with ceramic, which is then hardened in an oven.

The production team then puts together up to 114 fuel assembly dummy heating rods from the fuel assembly design to be tested. The fuel assembly can be completely heated with electricity. The fuel assembly is then installed in the KATHY test rig, electrically heated with up to 20 MW, and, in this way, tested for its thermohydraulic properties.

If these tests are successful, the result will form the basis for designing the next generation of EPR, PWR, or BWR fuel assemblies to be manufactured in Framatome plants.

KADYSS: Qualification of Circulating Pumps



KADYSS (KArlstein DYnamic Shaft Seal Test Facility) simulates the effect of a complete power failure, known as a station blackout (SBO), on the shaft sealing systems of the main coolant pumps or circulation pumps in nuclear power plants.

The simulation of SBO conditions in a long-term test of the shaft seal of the circulating pump requires feedwater under PWR conditions to compensate for the leakage flow of the sealing system. Imitating the thermal expansion of the shaft requires precise control of shaft displacement due to internal thermal transients.

The plant operates under full PWR conditions. The thermohydraulic conditions such as pressure and temperature are kept stable while the KADYSS compensates for the leakage current of the shaft sealing system.

The heart of KADYSS is a shaft displacement system developed to realize very precise axial movements at very low speeds. KADYSS is equipped with extensive instrumentation for pressure, temperature, and mass flow.

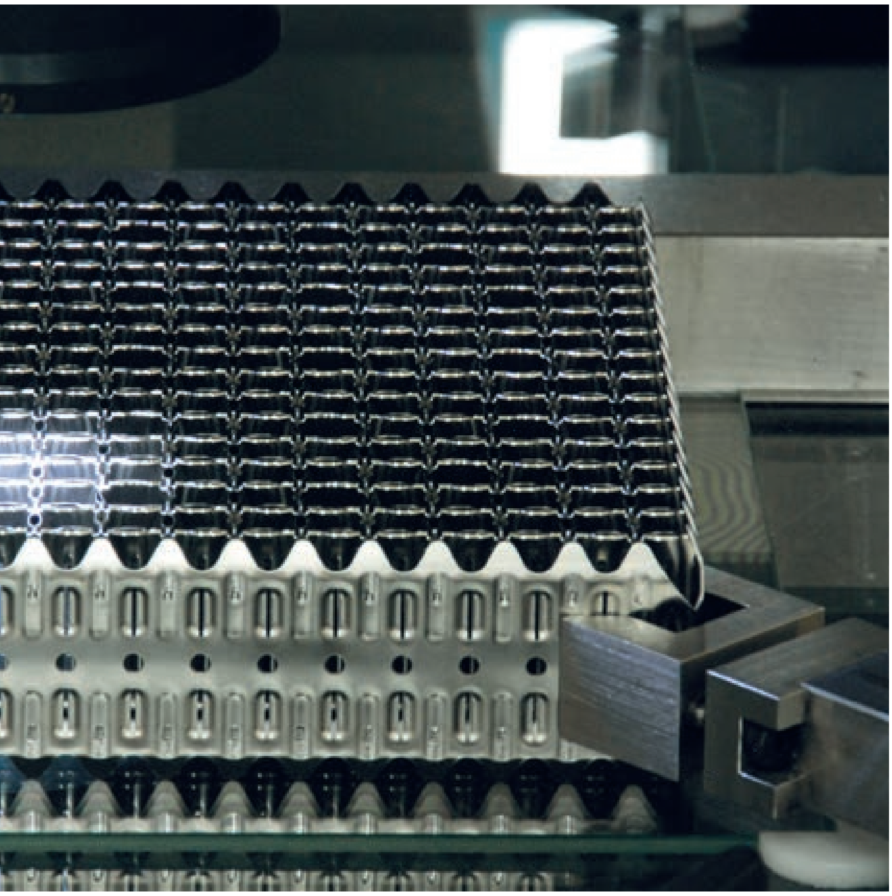
Abb. 15
KADYSS – Qualification of shaft sealing systems.

Production of Spacers for Fuel Assemblies

Karlstein has not manufactured fuel assemblies since 1995 and instead manufactures all types of fuel assembly spacers for Framatome.

The spacer is one of the components that has to meet the most stringent of requirements, therefore it must be manufactured with absolute precision.

This is due to the important task this structural part plays: The spacer must fix the fuel rods in the fuel assembly to ensure the coolant water always flows evenly around the rods. It ensures exact spacing of the fuel rods is maintained in the fuel assembly under the extreme conditions of reactor operation and throughout the entire burnup period. This is very important because fuel rods are fixed in the spacers' cells by springs and opposing nubs in such a way that, despite varying expansion due to high temperatures, they remain mobile and can adapt to the fuel assembly structure. The material used is also significant: Materials such as Inconel and zircaloy are used in the production of such individual parts of the spacer as the springs and bridges. Welding Inconel and zircaloy spacers involve tolerances in the range of one hundredth of a millimeter, placing extreme demands on the technical equipment, the welding process, the welding devices, the quality of the starting material, and, of course, the system operator. →



Powerful welding center

In 2004, the first welding center was put into operation. It had small welding chambers, fast evacuation and flooding times, integrated test systems (WeldWatcher), and an optical measuring system to automatically correct the welding position. Thanks to the two-chamber system, setup times could be carried out simultaneously during the main times. A further advantage was the ability to process different types of spacers simultaneously in the welding center. As a result, the system proved to be a great success both technically and economically: Massively reduced cycle times led to a high productivity as well as to a reduction in unit costs because capacity was increased to 60 BWR-AH and 30 PWR-AH. In 2007, the old laser welding system LSA2 was dismantled to make room for a second welding center. After a year of construction, commissioning, and qualification activities, the second welding center went into production in early 2009. The old system was dismantled shortly afterward. Today, ANF Karlstein is a leader in the production of spacers and is able to cover the needs of all types of spacers used by Framatome.

Left, Fig. 16
Automatic testing of a PWR fuel assembly spacer "Made in Karlstein".

Middle, Fig. 17
Visual inspection of the support structure of a spacer for an ATRIUM® fuel assembly designed for BWRs.

Right, Fig. 18
Spacer welding center: Meticulous work by hand is the secret to high-quality production.

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The Manufacture of Modern Neutron Flux Instrumentation for EPR Reactors Worldwide

From the beginning, measuring sensors (neutron detectors) and instrumentation for BWRs have been manufactured in precision mechanical workshops in Karlstein. Called lances because of their shape, these tubular support structures for detectors measure up to 15 meters long. In 1971, the mechanical workshops were merged into the Manufacturing department in Karlstein, which has also built instrumentation lances for PWRs since the beginning of the 1980s. In these workshops, several measuring fingers are combined with a common yoke to form the lance. This process simplifies and accelerates handling during fuel assembly replacement in the power plant.

Manufacturing in Karlstein offers the advantage that all instrumentation can be tested directly on-site in the technical center's test rigs to ensure the instrumentation functions under pressure and at temperature.

In the early days, detectors for PWR instrumentation were purchased from smaller suppliers that manually produced these detectors in individual lots with varying quality.

To become independent of detector purchases in the production of PWR instrumentation, the production staff developed a neutron detector with improved quality features. It can be semiautomatically manufactured in a small series through prefabrication based on division of labor.

Unique measurement of the neutron flux

These pencil-sized detectors, called SPND, generate a very small signal current under neutron radiation without an external power supply. This places extreme demands on the manufacturing processes and requires precision, purity in the materials used, cleanliness, quality assurance, and, above all, training and skill on the part of the precision mechanics. This applies when the individual parts have to be assembled under a microscope, welded using a laser, and inductively pressure-tight brazed under high vacuum at up to 1100 degrees Celsius so they can be safely operated in the reactor for over 10 years.

Extensive cooperation between the physicists, engineers, and technicians from the production department and the material scientists in the technical center resulted in the detector being ready for series production and tested for function and reliability in power plants over several years under the supervision of TÜV.

Due to the positive operating experience with this SPND in terms of its signal stability, the decision was made in 2010 to qualify and use this detector in the EPR instrumentation lances.

For Siemens PWRs, instrumentation with eight PWR lances is sufficient in the reactor core. The significantly larger EPR reactor core, however, calls for much more dense instrumentation, including fixed detectors in the core for power control and monitoring.

For this purpose, a new mechanical design for its instrumentation lances was chosen and the necessary manufacturing processes and their testing were implemented using 21st century methods. Nevertheless, its manufacture requires experienced, trained personnel who handle the long, fragile, and sensitive components with precision and great skill. →

Production of the instrumentation lances for the EPR

Each EPR uses 12 instrumentation lances that each measure 12.5 meters in length and weigh about 120 kilograms. In total, these lances have 40 measuring fingers for calibration and 12 neutron measuring fingers with 72 SPND and 36 thermocouples for temperature measurement. In addition, there are four level probes to indicate the level of the coolant in the event of a malfunction.

Serial production of this EPR instrumentation means a new future-oriented reactor instrumentation product was created in Karlstein and Framatome does not have to make detector purchases from external manufacturers.

Thanks to the work of many teams, the instrumentation has already proven its efficiency in the Taishan 1+2 EPR reactors and will be used in all future reactors of this type. An on-site team of developers, designers, and production and qualification personnel as well as product management has already begun work to further develop the next generation of EPR reactors, called EPR2.

Fig. 19
Quality assurance of the assembly hall in which incore instrumentation is produced.

Type and Requalification Tests of Power Plant Components

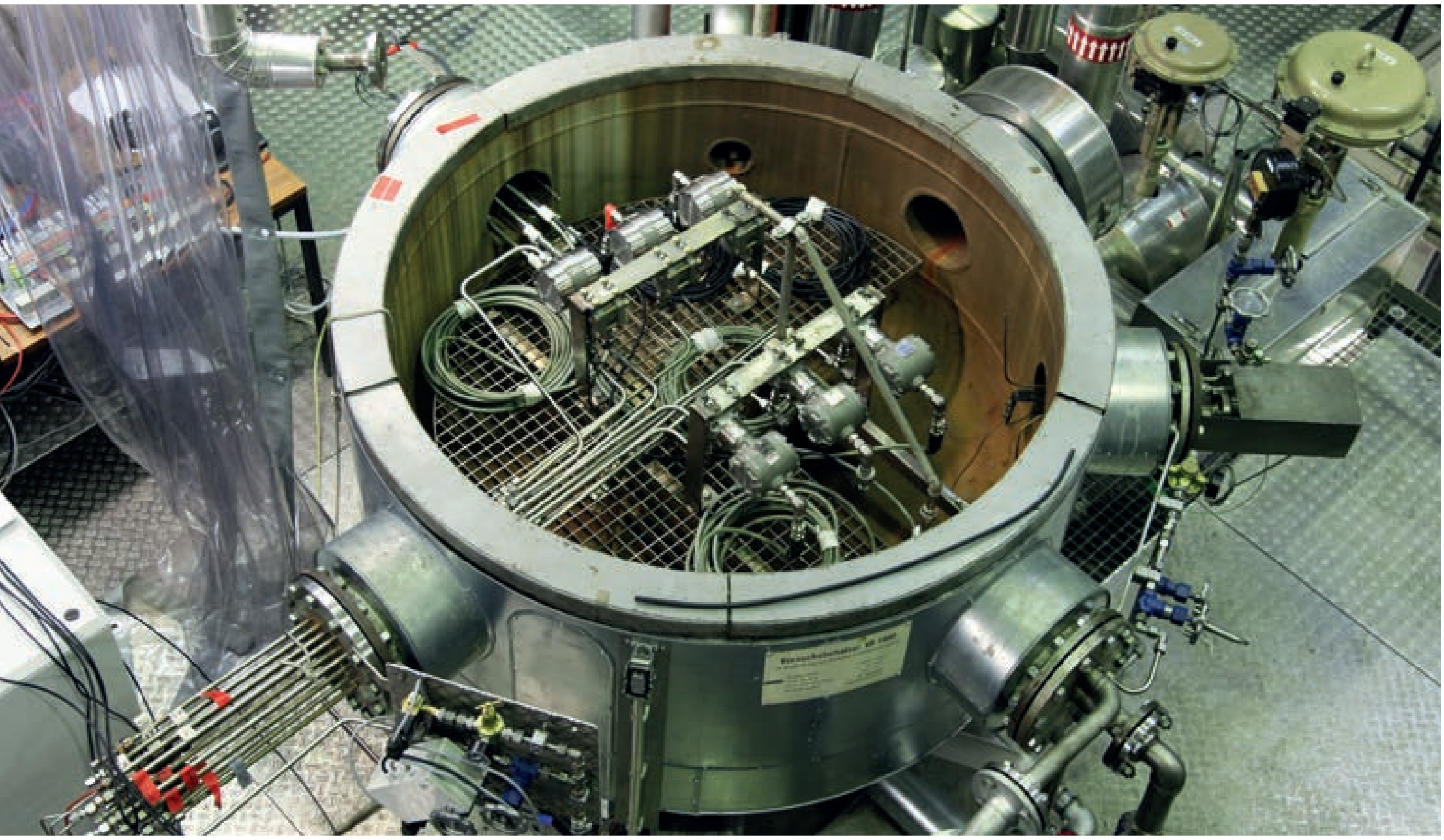

Fig. 20
Type testing of several pressure sensors.

The Karlstein site is one of the best equipped facilities for component qualification worldwide. As an accredited laboratory according to DIN EN ISO/IEC 17025 and inspection body of type C according to DIN EN ISO/IEC 17020, staff at the facility carries out the relevant safety tests and inspections of nuclear components and systems, including sensors, cables and cable bushings, actuators for valves, and plug connections.

These components have to prove they still function perfectly should they be needed under accident conditions and until the end of their respective expected life span. Time-lapse tests involve aging the components to simulate an operating life of up to 60 years.

Aging consists of a sequence of thermal, radiological, and mechanical stresses. After aging, the components must function perfectly under simulated accident conditions, including high humidity, high pressure, high temperature, and chemical stress.

Over the last 10 years, the test experts at Framatome's technical center have performed more than 50 type and requalification tests in Karlstein.

Manufacturer and Equipment Qualification at the Karlstein site

All structures, systems, and components with safety-relevant functions or properties in a nuclear power plant must demonstrate that they fulfill their safety functions under all given circumstances. This verification is performed in accordance with national and international nuclear regulations and requires approval from the responsible technical experts and authorities. Performing technical verification of the suitability of components and equipment is referred to as the process of qualification. This includes ensuring the suitability of the manufacturing process.

In Karlstein, Framatome concentrates on the implementation of qualification measures for components of the reactor protection system (electrical-engineering components, electronic modules for signal processing and their sensors, nuclear instrumentation, and field devices) as well as for other safety-relevant electromechanical systems. Synergies with neighboring departments at the site are leveraged, especially those with the test laboratories, engineering, and production facilities located there. This enables very efficient development of device-specific qualification strategies at the site.

Framatome's work groups are directly involved in either national or international supply projects and are engaged in R&D projects for new or further development of devices for specific environmental conditions. Framatome also directly offers qualification services to external component manufacturers.

Qualification for use in nuclear power plants

The field of equipment qualification covers a wide range of different fields of competence in Karlstein: from knowledge of the equipment and its production to individual methods of verification. The experts in Karlstein have specialist knowledge of the devices and expertise to evaluate the manufacturing process and execute practical tests. They are also well versed in a multiplicity of different analysis methods, including analogy comparisons, computations, view of material characteristics and their aging phenomena, and evaluation of operating experiences.

All knowledge gained and the qualification certificates issued are compiled in a central database (equipment qualification database [EQDB]). This allows future qualification statements to be issued more efficiently and existing qualifications to be used multiple times in Framatome's various projects.

Fig. 21
Accelerated aging in climate chambers: Decades-long reliability must be guaranteed for many components
(left: chamber for temperature shocks; right: chamber for long-term tests).

Full-Scale Testing of a BWR's Coolant Loop Components

The Leibstadt nuclear power plant (KKL) is a GE type BWR-6 with a capacity of 1,200 MWel. The plant was put into operation in 1984. Since the beginning of the millennium, KKL has been experiencing increasing maintenance costs for its piping system and the components of the two external reactor coolant circulation loops (YU system).

Framatome was commissioned to replace large amounts of the piping system and their components (pumps, motors, and gate valves) within the YUMOD project. The control valves, which controlled the mass flow of the reactor, were to be omitted and replaced by speed-controlled motors, supplied by frequency converters.

Simulate original operating conditions

Framatome won the contract mainly because the company could test all primary components under original operating conditions and in interaction with one another at its test site in Karlstein. This minimized the risk of downtime extensions during the rebuild. →

Fig. 22

YUMOD test rig: All components of the drive train are integrated into a closed steam-water cycle in order to simulate the conditions in the KKL one to one.

Another advantage was that the test rig was available for the acceptance tests of the pumps.

The Karlstein site has invested a lot into this project: The test rig was extensively modified and optimized for the tests. A new hall was built especially for the frequency converters, and a transformer tailored to the test operation was installed.

In 2018, the first set of drive train components (pump, motor, and frequency converter) as well as the switchgear and control cabinets were installed and tested. In 2019, the second set and a gate valve were tested. The customer was actively involved in the trial operation, which was also used to train the customer's service and operating personnel.

Fig. 23
Switchgear: frequency converters and control cabinets in the YUMOD test bay.

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Accident Control: Safety Technology from Karlstein for Nuclear Power Plants Worldwide

Karlstein has established itself internationally as a top location for systems to protect the containment of nuclear power plants. Since the 1980s, components to control accidents in nuclear power plants have been developed and tested at the Karlstein site. Originally aimed at further increasing the safety of German nuclear power plants, these products have found their way into nuclear power plants worldwide in past decades.

Combustible gas control

Passive autocatalytic hydrogen recombiners (PAR) have witnessed great export success. These devices are used for the decomposition of combustible gases, especially hydrogen and carbon monoxide, which are released during core melt accidents in the containment. The Fukushima Daiichi accident has again demonstrated the danger hydrogen poses to the containment. In the event of a severe accident, the containment is the final barrier to confine radioactivity and prevent its release into the environment. At the surface of the catalyst located in the PAR, flammable gases are converted into nonflammable water vapor or carbon dioxide without any need to supply energy– i.e., also without electricity–so the risk of explosion is eliminated and the integrity of the containment is ensured. After first equipping a Belgian nuclear power plant in 1995, Framatome has seen its PARs installed in more than 160 nuclear power plants in 22 countries to date. That means this product, which originated in Karlstein, is clearly the world market leader in this field. And Framatome PARs have also been able to demonstrate their outstanding suitability in several international test campaigns, even when compared with the products of well-known competitors.

New developments in the field of hydrogen control in recent years include the CATI passive hydrogen igniter and the new generation of hydrogen sensors called WS85 PLUS that were installed in a nuclear power plant for the first time in 2019. The measurement of the containment atmosphere's composition, in particular the hydrogen content, plays a crucial role in assessing the hazard situation of the containment over the course of an accident.

Leader in reactor containment protection against overpressurization

Another successful product developed at the former Offenbach site and tested and qualified in Karlstein is the filtered venting of the containment vessel. Karlstein's experimental and test facilities include a steam generator, a pressure reservoir, and similar equipment to support testing of components and systems for maximum reliability and safety on a large scale. Core meltdown accidents are inevitably associated with pressure buildup in the containment. This last barrier before the release of radioactive fission products into the environment must be maintained by preventing overpressure failure. To achieve this, the gas atmosphere is removed from the vessel to reduce pressure. However, radioactive substances, especially iodine and cesium, have to be safely retained to a significant degree. The filtered pressure relief from Karlstein is the first choice of power plant operators in already more than 100 reactors in 16 countries around the world. This product guarantees the safety of the environment and the population in the vicinity of the power plants, so that large-scale evacuations and many years of costly work to eliminate the consequences, as in the case of Fukushima, are unnecessary. →

Sampling systems for extreme environmental conditions

Systems for taking samples from the damaged containment in the event of a core meltdown accident were also developed for series production readiness in Karlstein. They have now become part of the EPR reactor line. The reactor accident following the tsunami in Fukushima demonstrated the importance of obtaining reliable measurement data from the containment even during a core meltdown accident. As a result, these systems are often being retrofitted in existing nuclear power plants.

In addition to the construction of prototypes for testing, components for products developed in-house are also manufactured in Karlstein today. Here, short delivery times and flexibility while maintaining high quality are required–a challenge met by the colleagues in precision parts production at Karlstein.

In this way, safety systems “Made in Karlstein” contribute to the safe operation of nuclear power plants worldwide even following Germany’s politically motivated withdrawal from nuclear energy production. This competence must be maintained.

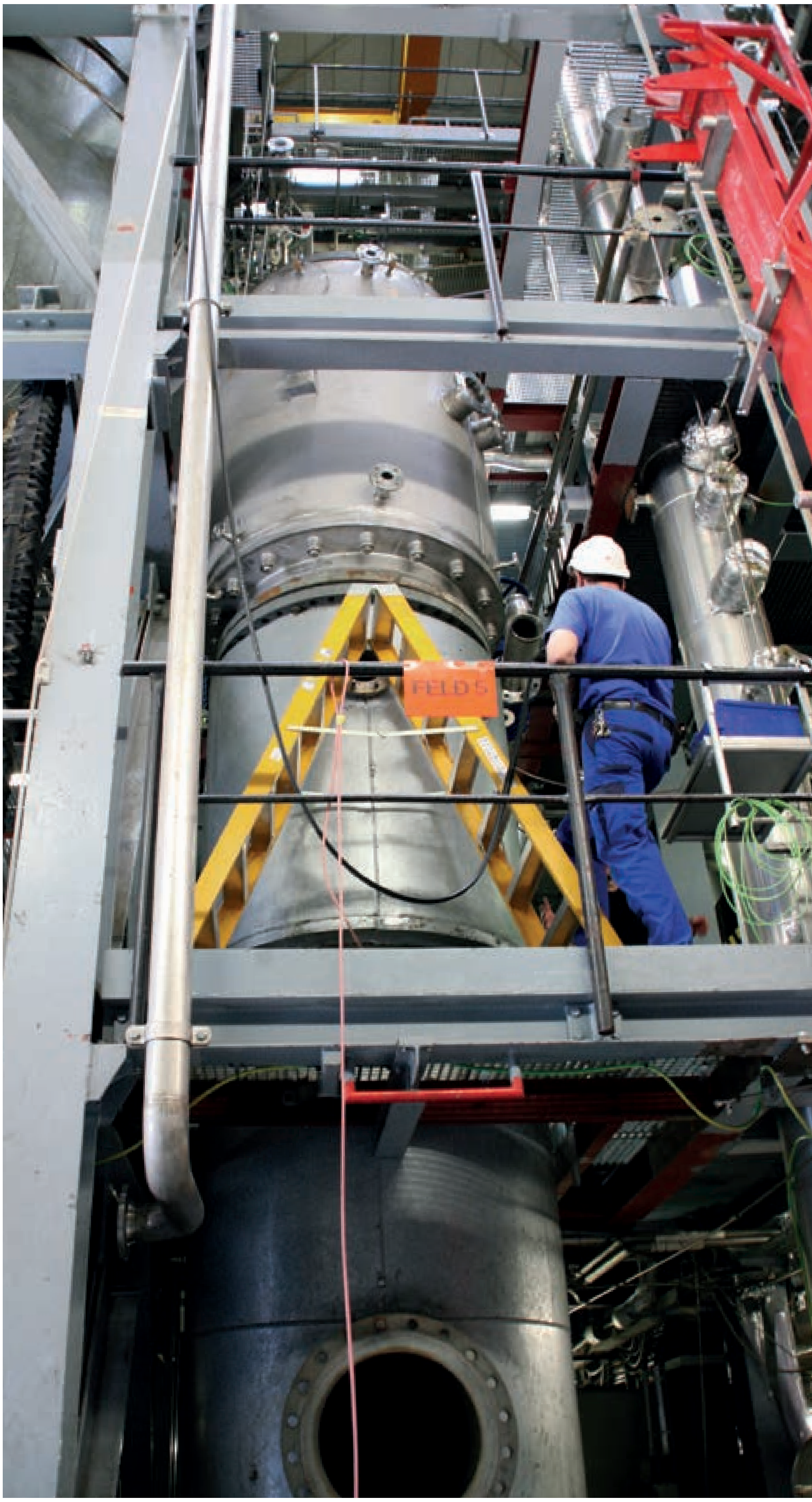

Fig. 24
Full-scale test facility
for filtered venting.

Radioactive Waste and a Commitment to the Environment

During the operation and life cycle of nuclear facilities, all types of radioactive waste are generated that must be safely treated and processed. Systems and components for waste and wastewater treatment are designed in Karlstein that aim to release as little radioactivity as possible into the environment.

Initial developments in the field of waste treatment took place in Karlstein with the operation of the company's own-waste treatment facilities in the early 1960s. As part of in-house developments to condition waste from the then newly built nuclear power plants in Germany, a cementing test rig was set up in the 1980s and later a complete mobile cementing plant. In 1999, an evaporator was assembled and tested in Karlstein for the Lingen nuclear power plant, which was still in safe enclosure at that time.

The merger of the two locations of Offenbach and Karlstein in 2016 created a unique competence center for designing, providing approval support, and processing systems and components.

Retention of radioactive materials to protect the environment

One of the main topics in the treatment of liquid and solid radioactive operational waste today is planning the waste treatment facilities for the latest generation of nuclear power plants (EPR generation III+) and completing the new construction contracts currently underway. →

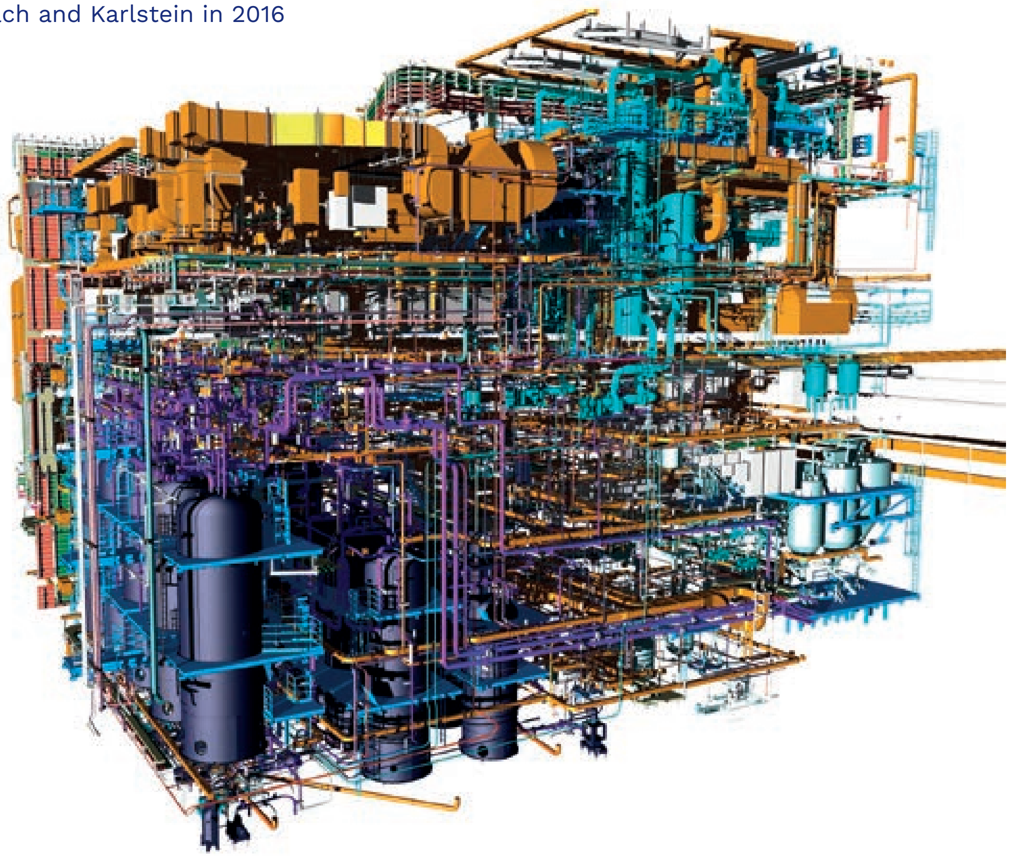

Fig. 25
3D model of a **wastewater treatment plant** in an EPR reactor.

Abb. 26
CRAFT: Patented filter system for noble gas retention.

For the nuclear power plants Olkiluoto 3 in Finland and Taishan in China, planning the waste and wastewater treatment buildings as well as designing the system and handling specific plant parts and components were carried out. Milestones included successful completion of commissioning for the wastewater treatment plant in June 2018 in Taishan and in October 2019 in Olkiluoto 3.

As early as the 1970s, KWU had carried out equally extensive research into the possibilities of retaining radioactive gases and supplied the necessary treatment facilities for the nuclear power plants under construction at the time. Today, Karlstein serves as the technical base for further developing and supporting this technology, which is used in many older nuclear power plants as well as in all EPRs worldwide.

In 2019, Framatome received an order for two new CRAFT (control room accident filtration system) modules, which are uniquely developed in Karlstein. These modules have been developed on the basis of the retention processes mentioned previously and are capable of filtering contaminated air from the environment, including noble gases that may be present should a nuclear accident occur. In this special project, up to 250 people located in a separately secured building will be supplied with purified air in an assumed accident scenario.

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Innovative Reactor Control: Our Contribution to the Energy Transformation

Wind and solar power generate highly variable levels of energy; increasingly, this type of energy is being fed into the European power grid. Since energy cannot be stored in the power grid, power consumption and power generation always has to be balanced.

With the innovative, fully automated, digital reactor control (advanced load following control, ALFC) for PWRs produced in Karlstein, it's possible to react optimally to the various network control modes completely automatically (without manual intervention).

The following network control modes are distinguished:

The primary frequency control

The primary frequency control reacts within a few seconds to fluctuations in the grid with immediate, fast, and short power changes for grid frequency support.

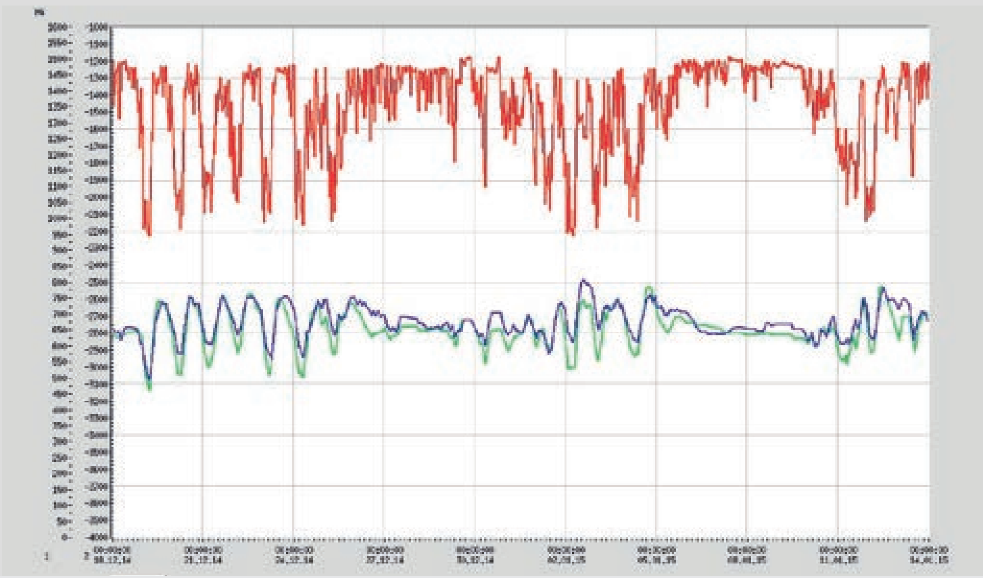


Fig. 27
Typical one-month run of the **network secondary control.**

The Grid Secondary Control

The grid secondary control reacts to unpredictable, stochastic generator output changes (sometimes several hours). It must be ensured that plant output can be increased to a selectable maximum target output at any time. With ALFC, the time-complex xenon amount in the power change is taken into account cyclically via a suitable reactivity balance.

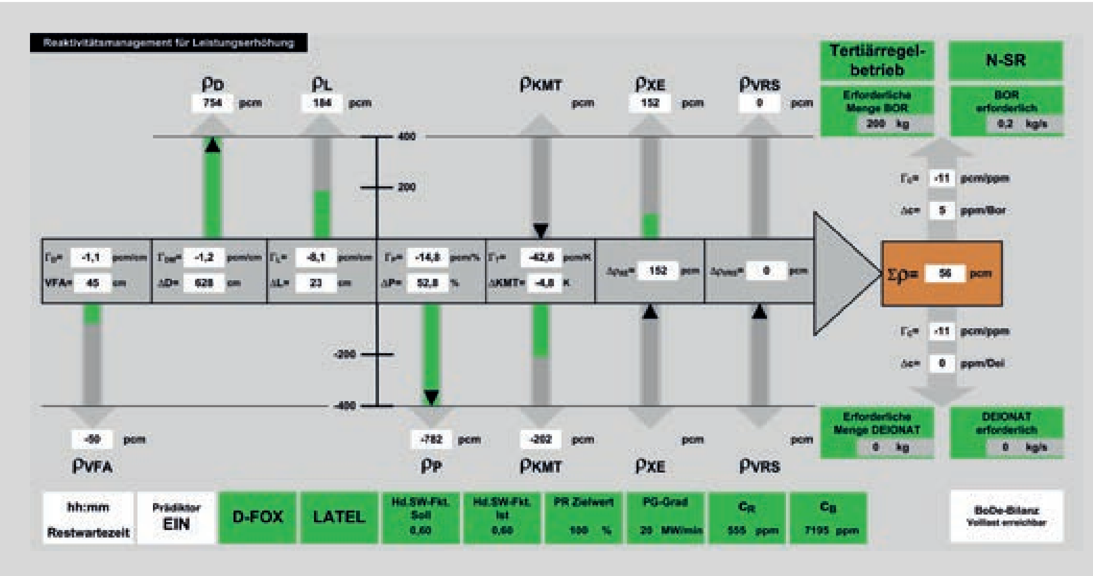


Fig. 28
To support shift personnel, the **predictive reactivity balance** is displayed in an image of the plant.

The Grid Tertiary Control

The grid-tertiary control serves mid- to long-term generator output changes. Operationally reasonable targets are automatically selected depending on the partial load's duration, which lasts several hours. The ALFC add-on module Predictor considers the partial load duration in the reactivity balance by means of a predictive xenon calculation.

A unique product, the ALFC has enabled Framatome to make a significant contribution to the energy transformation into CO2-free power generation as well as to stable grid frequency and thus a secure power supply.

Equipment for Nondestructive Testing

AEG already had a presence as a supplier of products and services to the nuclear energy industry. To ensure the safe operation of the power plants built by the company itself as well as of third-party plants, cyclical tests on safety-relevant components are carried out. During regular inspections for the replacement of fuel assemblies in nuclear reactors, the piping of the primary circuit and many other critical components are checked for integrity using nondestructive testing methods such as ultrasound, eddy current, and X-ray.

Independent tests

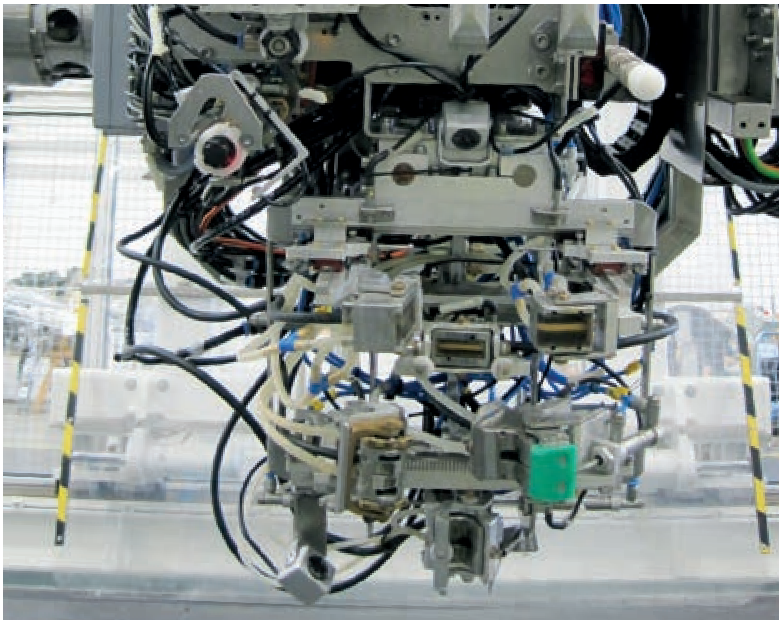
To ensure tests are carried out independently of the company constructing and operating the plant, the subsidiary Siemens NDT was founded. After merging with Framatome ANP and later operating under the name of AREVA, the company was renamed IntelligeNDT Systems & Services GmbH. Since then, the company's product portfolio has been reintegrated into Framatome GmbH.

IntelligeNDT Systems & Services offers a complete spectrum of testing services, including those using ultrasonic and eddy current sensors with cabling, customer-specific manipulators, and the company's own testing devices from the SAPHIR family as well as operating and evaluation software. The company's current ultrasonic devices, SAPHIRquantum, have been developed and manufactured in Karlstein. They are used by Framatome GmbH, the French Intercontrôle, and other international customers in nuclear services worldwide.

Developed for nuclear technology – in demand by other industries

Quality assurance systems are also in high demand in the nonnuclear industry. Wheels and axes of trains are regularly checked using Framatome equipment. Framatome test systems are also used for production control of large steel forgings and composite fiber parts of airplanes and wind power plants. Specially trained Framatome inspectors are sent from Karlstein to customers all over the world to carry out quality assurance monitoring and to support customers in complying with the extensive regulations the must comply with.

Fig. 28.
A combination of mechanical, electrical-engineering, and metrology expertise was applied to develop the **remote-controlled ultrasonic search unit.**



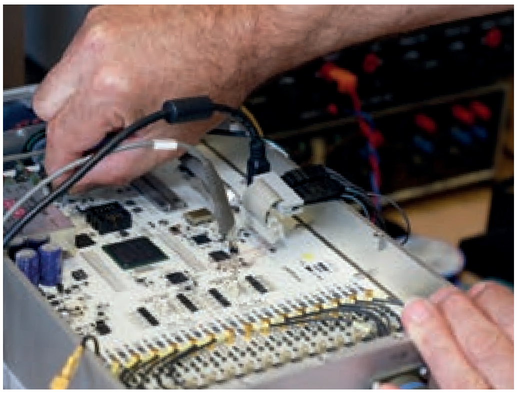


Fig. 29
Ultrasonic testing devices (here: SAPHIRquantum) are developed, manufactured, and tested in Karlstein.

Nuclear Power Plant Simulators at the Karlstein Site

The development of more modern simulators for nuclear power plants at the Karlstein site began in 1978 with training the operating crew using a PWR simulator.

New fields of activity such as verification and validation of the I&C architecture and the operating manual, training measures for Framatome development engineers, and courses in the field of general plant operation and incident management are now possible and have since become an important tool for both training and servicing new projects and plants already in operation.

The BWR close loop simulator, the EPR engineering simulator, and simulators for the fuel assembly loading machine are, for example, located in Karlstein.

All BWR competencies bundled at the Karlstein site

The BWR simulator is built as a copy of the Forsmark 3 development simulator with a visual process control system, process computer, and OM650 system. Due to the operability of the simulator through a soft panel or visual process control system, realistic tests can be carried out by Forsmark 3 reactor operators during the design phase following real operating instructions and transients or fault scenarios.

Forsmarks Kraftgrupp AB, the operator of the plant, also repeatedly emphasizes the use of the simulator in Karlstein as a key factor in early risk minimization for integrating new solutions into the plant at a later point.

All Framatome BWR technology competencies are bundled at the Karlstein site, from process and safety engineering to control technology and HFE. Training courses for customers, authorities, and Framatome employees are offered at the EPR engineering simulator in cooperation with the training center.

In addition, several simulators of the fuel loading machines at various power plants are located at the Karlstein site.

Fig. 31
User interface of the Forsmark 3-closed-loop simulator in Karlstein.

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BWR Crisis Staff and Systems Competence

The findings from the incident at the TMI 2 plant (United States) led NPP operators and Framatome to decide to set up a crisis management team to offer operators advice and support in the event of an incident.

This crisis management team has been in operation since March 1980 at the Erlangen and Karlstein (formerly Offenbach) sites. Originally set up for 14 PWR plants and six BWR plants, today the team is also used for an EPR plant.

The aim of Framatome and the operators is to quickly and effectively employ Framatome's potential expertise should an incident occur in a contractual partner's nuclear power plant. Taking into account the Fukushima event as well as the changing support requirements in nuclear power plants, the focus is on beyond-design-basis events involving severe accidents.

Crisis-management team

Framatome has a crisis management team to provide consultation and support should an incident occur in a nuclear power plant as well as in the context of emergency exercises, which primarily focuses on the following specialist areas:

- Serious incidents
- Radiology and radiation protection
- System and building technology
- Process engineering (incident management) and thermal hydraulics

The crisis management team is on call at all times. The infrastructure required to provide this support is located in specially equipped crisis team rooms in Erlangen and Karlstein.

Within the framework of crisis management, the Karlstein site has primarily had responsibility for providing expert support in the areas of boiling water technology, building analyses, and radiology.

Planned and unplanned alarm exercises ensure the crisis management operation runs smoothly. In addition, an extensive Framatome internal training program has been developed to maintain the know-how of crisis management team members and further strengthen their competencies.

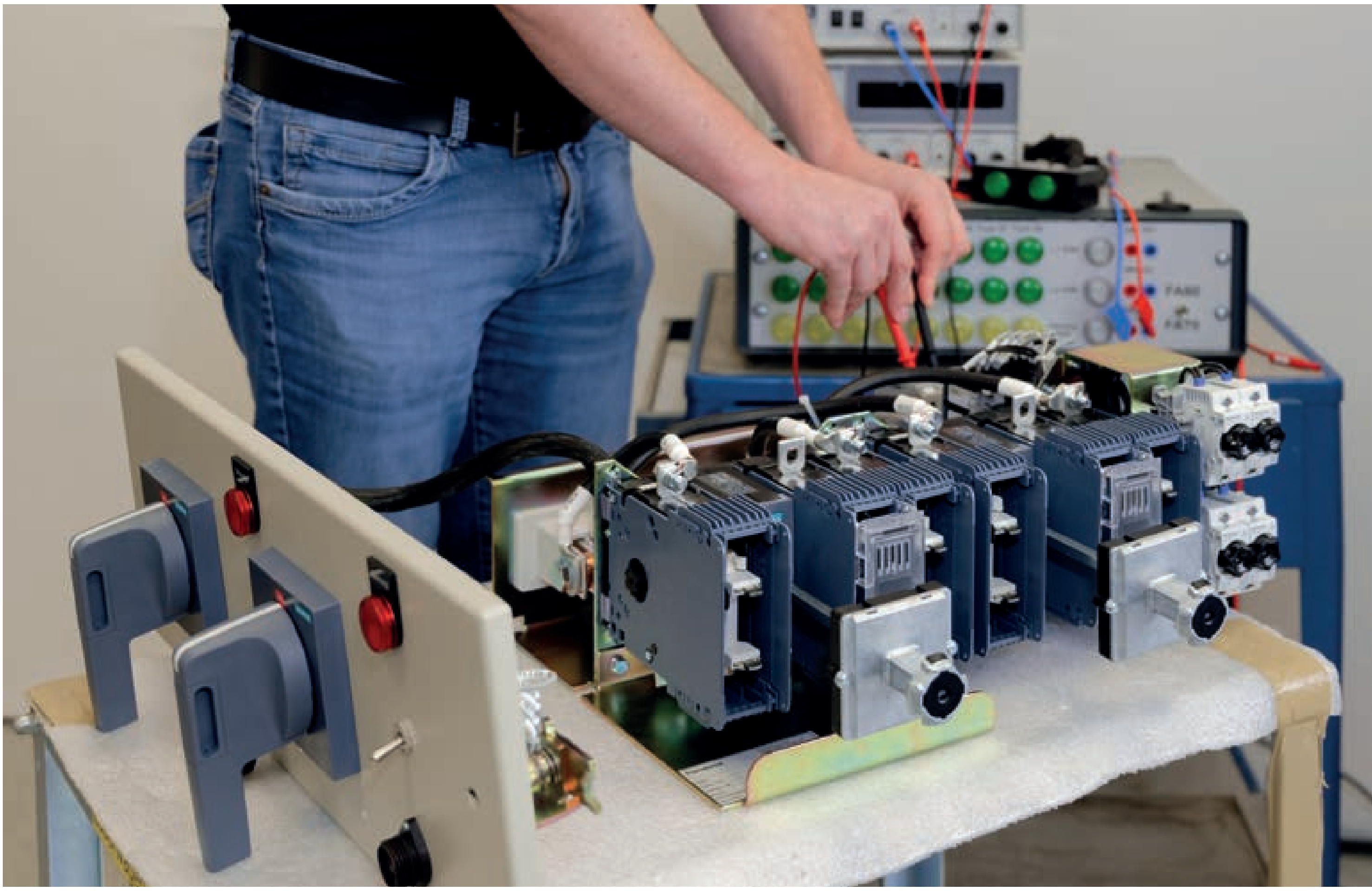
Software-Free Power Electronics for Safe Operation

Digital transformation involving the use of smart systems is occurring in almost all areas and presents nuclear power plants with great challenges when it comes to renewing their safety-relevant systems. How can their increasingly older electrotechnical systems and safety-relevant components be replaced sustainably and economically with compatible, modern, and, above all, nuclear-qualifiable technologies?

Framatome has been pursuing answers to this question at the Karlstein site since April 2016. Through the area-wide cooperation of the electrical engineering departments, Framatome is finding solutions for discontinued products and technologies that are no longer available.

In doing this, Framatome helps its customers to further meet nuclear and regulatory requirements in the design, engineering, and modernization of safety-relevant components and to counteract the industry trend toward ever shorter product life cycles. →

Fig. 32
Testing of a **modernized retrofit switchgear feeder** at the test bay.



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Innovations in electrical engineering

Framatome drives many new and innovative software-free electrical engineering products, which it develops, manufactures, and qualifies in-house at the Karlstein site. In this work, the company always focuses on:

- Security
- Quality
- Sustainability
- Availability

The company was able to further develop products in the field of power electronics, including THORC (thyristor power controller for the safe supply and control of control valves) and to serve customers worldwide.

Also in the field of uninterruptible power supply (UPS), such components have been developed as software-free battery rectifiers, AC/DC and DC/DC switching power supplies MAGIC for the safe power supply of the operational and safety control technology. Today, compatible retrofit solutions for low-voltage switchgear are also part of the established portfolio of Framatome in Karlstein.

The driving force behind the company's success is its highly motivated and qualified employees. Thanks to close, interdisciplinary cooperation, they have an ideal environment to develop and produce innovative ideas and products at this location.

Fig. 33
Testing the functions of the THORC


FLUKE
25.17
HOLD
RANGE
FB20
FB30
FB40
FB70
FC60
FC70

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Analysis, Calculation and Design of Electrotechnical Systems

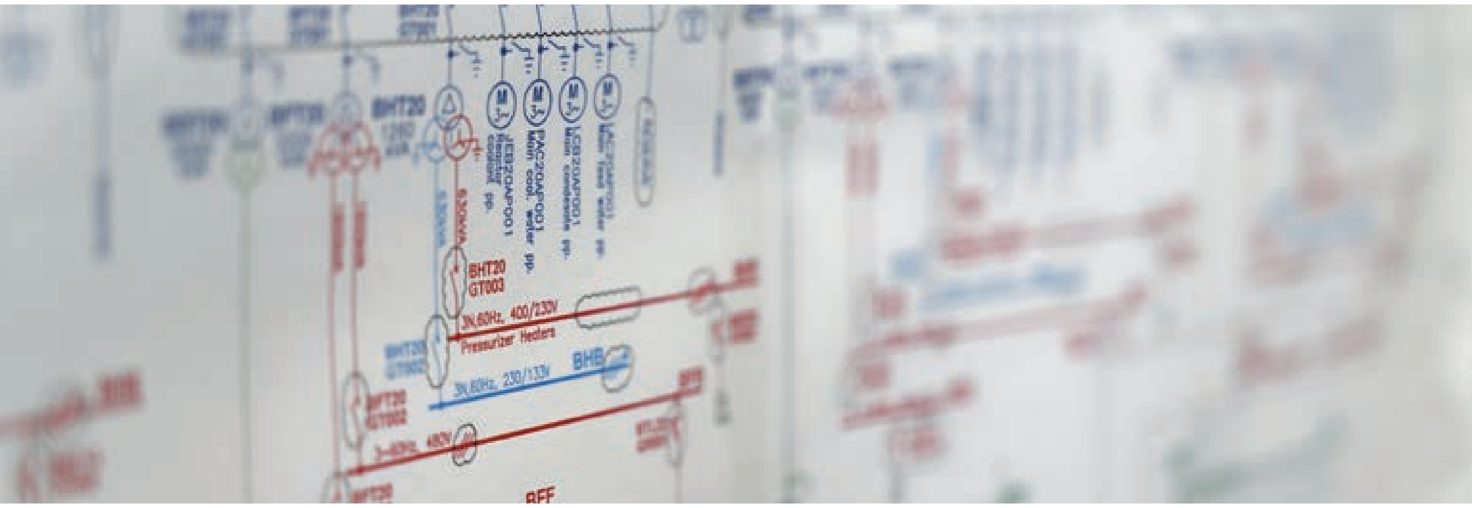

Fig. 34
Section of an **electrical circuit diagram**

> Efficient, reliable operation of power plants requires careful designing the electrotechnical systems and components. Knowledge of complex system structures and the various functional, process engineering, operational, and accident requirements must be met by the electrical systems of power plants.

Since July 2016, Framatome has been serving its customers from Karlstein with well-founded calculations for designing and protecting electrical-engineering systems and components of auxiliary systems worldwide. Investigations are carried out under all power plant operating conditions, including:

- Start-up operation
- Shutdown
- Power operation
- Accident

Special calculation programs developed

With more than 25 years of experience in power plants, the qualified employees in Karlstein form the backbone of the electrical engineering department and prepare the electrotechnical analyses and calculations for operational requirements and for issues relating to operational electrotechnical disturbances, such as investigations of short circuit and voltage conditions or selectivity analyses.

The department in Karlstein is the only Framatome department to use the calculation programs EKB and SEDI, which were developed specifically for this purpose. This allows practice-oriented documentation to be created clearly, completely and seamlessly with input data and calculation results. This enables Framatome to provide its customers and their authorities with the traceability of the calculations at any time and to ensure the approval procedures for modernizations or new construction.

Monitoring and Diagnosis of Valves and Actuators

Since the 1970s, a department at the Karlstein site has always specialized in special measurement technology for use in nuclear power plants. Fields of application have included vibration measurements on pipelines and components, recording of temperature-related linear expansions and displacements, and measurements of all kinds that relate to pressure, temperature, and electrical signals.

The special measurement technology department's technicians also oversee an accredited calibration laboratory where the measuring instruments and sensors they use are maintained and the devices' measuring accuracy is checked and documented.

Computers facilitate data collection

In the 1970s and 1980s, the signals were still being recorded in analog form and stored on magnetic tapes. As early as in the first part of the 1980s, digital data acquisition and storage also came into play for the experimental facilities at the site. At that time, this meant using a Data General mainframe computer that, although consider medium sized, still had the dimensions of several refrigerators; its computing power and storage capacity is surpassed by any of today's smartphones. Because department management had the foresight at the time to see that the future would lie in computer technology, groupwide computer-aided testing and measuring technology was created, which has formed the basis for today's technology for monitoring and diagnosing valves and actuators.

Since the 1990s, personal computers have been used for data acquisition, and during that decade the company developed its own specialized software called ADAM (Armaturen-Diagnose- und Auswertemethoden: valve diagnostics and evaluation methods). The company also developed its own data acquisition electronics called SIPLUG, which is now available in its fourth generation. In 2012, the advanced technology of the SIPLUG4 earned third place in a company-wide innovation award contest.

Advanced monitoring technology for valves and actuators

Today, 16 employees continue to develop SIPLUG measurement technology and ADAM software, which are used as state-of-the-art technology in many new plants (e.g., OL3 in Finland, Taishan in China, Angra 3 in Brazil).

By 2019 more than 7000 valves worldwide had been equipped with SIPLUG technology.

Large orders for Hinkley Point (England, two EPR plants), as well as for external plants such as Hanhikivi (Finnish-Russian-designed VVER 1200 reactor), secure the future for the coming years.

Fig. 35
SIPLUG module
in a test setup.

Structural Dynamics of Buildings: Exceptional Know-How Worldwide

The structural dynamics team at the Karlstein site is mainly responsible for designing the building structures of nuclear facilities, including investigating all possible static and dynamic loads.

This work is manifold, since the stresses involved may consist of natural phenomena (e.g., earthquakes, tornadoes), plant operation (e.g., vibrations, temperature, crack formation), and damage (e.g., a line break) or may have a terrorist background (plane crash or explosions).

At the beginning of a typical investigation, Framatome's experts generate 3D finite element models of building structures and major components as well as Fiat 500 models for tornado loads or whole passenger or military aircraft to simulate aircraft crashes. To simulate load cases, the team uses high-performance computers and employs linear as well as nonlinear methods to determine result values needed for verifying structural safety.

Consideration geological conditions

Some of these results are processed (e.g., response spectra) so they can be used by colleagues from other work groups to design different systems and components. A major part of work the structural dynamics team does concerns inclusion of soil-structure interaction. In this work, the geological conditions specific to the plant site are included in the calculation (soil properties, earthquake wave propagation) as is the interaction of special structures like pile foundations, plants, and plant components on spring-damper systems.

Since much of the input data has scattering, the team may use probabilistic methods and mathematical models to evaluate the structural safety of the plant. These results are then incorporated into fragility calculations and seismic probabilistic risk assessments (SPRAs) of the entire plant.

This team's background knowledge is unique within the company and some of its methods lead the way in the nuclear industry.

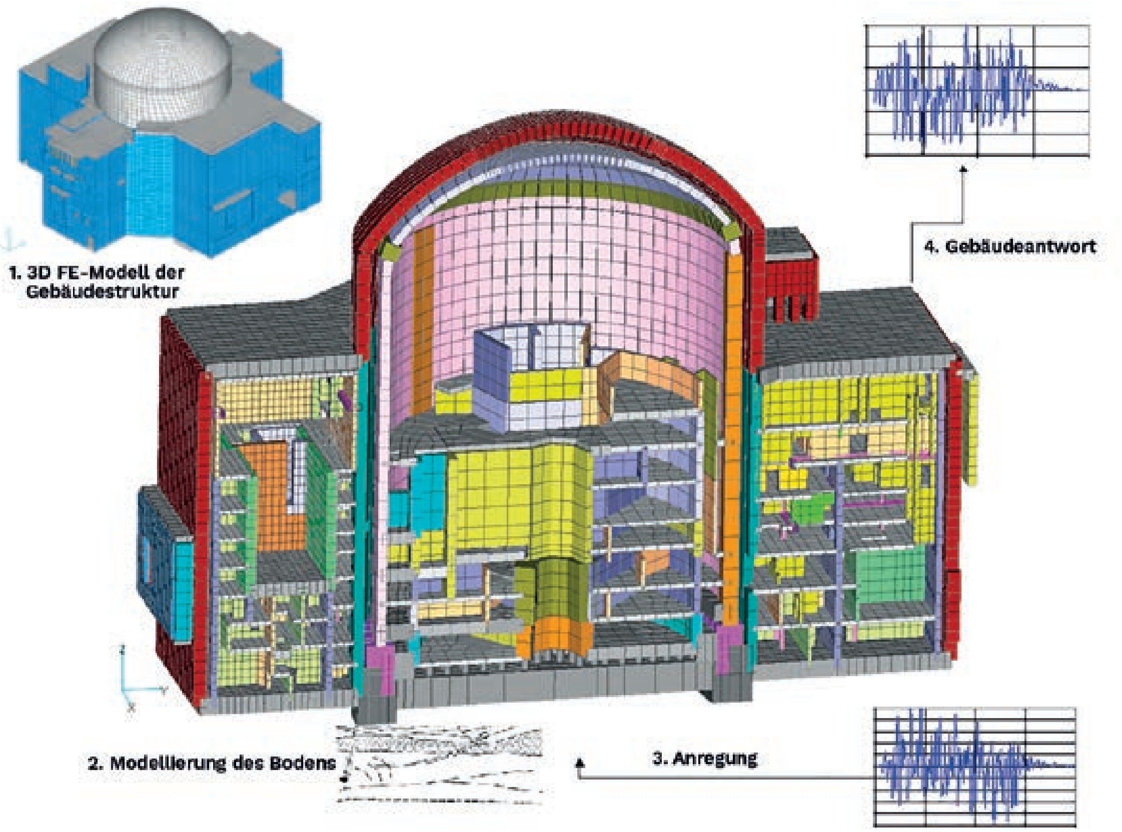

Abb. 36

Calculation of EPR building dynamics considers various natural and artificial influences on the building.

Karlstein Training Center

Company success and competitiveness depend largely on employee competence. For more than 40 years, the training center in Karlstein has been both training internal personnel and offering training to customers and their employees.

The first scheduled briefing of power plant personnel took place in 1978 with the training of the operating team for the planned Bushehr nuclear power plant in Iran. Since then, customers from all over the world have been trained in Karlstein.

NPP Biblis: a model

To support training, a PWR simulator based on a model of the Biblis nuclear power plant was set up in Karlstein. This meant that courses were not limited to theory, and instead supplemented by practical training on the simulator. The simulator was also used to train KWU commissioning personnel and foreign individuals with a specific interest, such as groups from the International Atomic Energy Agency (IAEA) and the Chinese Ministry of Energy. A modular training system was developed that made it possible to combine different course modules into individual training programs as needed.

In 1982, the simulator was replaced by a newer system that had been intended for use in the training center of the Brazilian company NUCLEBRAS. This system was able to simulate the control room of the Grafenrheinfeld nuclear power plant, the reference plant for the Angra 2 and 3 nuclear power plants in Brazil. The Brazilian instructors and the operating teams for the Grohnde (Germany), Trillo (Spain), and Brokdorf (Germany) nuclear power plants were trained at this facility. At the end of 1984, the simulator was transported to Brazil and recommissioned at the training center there.

User-specific practical training and education programs

The training center, which was redesigned in 2016, makes optimum use of the synergies available at the numerous production facilities in Karlstein. This includes conducting tours of lance and component production and the test rigs so customers experience practical demonstrations as part of their training courses.

The modern rooms in building 33 house a lot of equipment for practical training. In addition to the TXS and THORC cabinets and the various control platforms and components, the EPR training simulator for OL3 (Finland) can be used to display and practice operational scenarios under realistic conditions.

Abb. 35.

The **training center** in Karlstein is a welcoming location for customers to visit.

The modular training courses on technology, I&C, and Framatome products are designed to meet the needs of specific user groups in the nuclear power plant and its environment.

Process and system-engineering expertise for constructing and operating nuclear power plants

The portfolio includes courses on power plant engineering and encompasses the fields of process-engineering design and layout of primary and secondary systems, reactor physics and nuclear operating practices, nuclear instrumentation, operational and accident behavior, electrical engineering, and process-engineering requirements for safety I&C and I&C at the turbine set.

Operational use and functions of safety instrumentation and control technology

Extensive training in the field of safety I&C using the digital system platform TELEPERM XS is offered for various subareas: system computers and architectures, hardware, software, engineering, and maintenance. In addition, training courses for analog equipment families such as ISKAMATIC and EDM are also offered.

These courses cover the necessary basics as well as provide detail and background knowledge for the safe operation, efficient modernization, and maintenance of plants. In this way, the Framatome Training Center makes a significant contribution to maintaining competence in nuclear technology.

The training center's long-standing contact with internationally operating power plant operators, authorities, and institutions provides important impulses for addressing nuclear safety issues and solutions.

Fig. 38, above
Completing training on the **I&C training platform TXS.**

Fig 39, below
Use of digital training materials **reduces the need for paper.**

A look into the Future

Thanks to its special competencies and unique infrastructure, the Karlstein location is in a strong position to meet the challenges of the future. In its current setup, the Karlstein location is recognized as an important part of Framatome worldwide and within the EDF Group. This means the Seligstädtler Straße and Am Kieswerk sites will continue to draw on their many years' experience in safety technology "Made in Karlstein" to provide important impulses from Germany to all over the world.

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English: Framatome is an international leader in nuclear energy recognized for its innovative solutions and value added technologies for the global nuclear fleet. With worldwide expertise and a proven track record for reliability and performance, the company designs, services and installs components, fuel, and instrumentation and control systems for nuclear power plants. Its more than 14,000 employees work every day to help Framatome's customers supply ever cleaner, safer and more economical low-carbon energy.

Visit us at: www.framatome.com, and follow us on Twitter: @Framatome_ and LinkedIn: Framatome.

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