SICK AG WHITEPAPER

SENSOR SOLUTIONS FOR FUEL CELL PRODUCTION

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Sensor Intelligence.

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SUMMARY

Hydrogen and fuel cell technologies are enjoying steadily growing interest among the public, companies and politicians worldwide. Especially in light of climate change, the use of fuel cells can play a decisive role in the switch to renewable energies. A key driver is the application of fuel cells in vehicles such as buses and trucks. However, expensive hydrogen and the high production costs of fuel cell systems stand in the way of widespread implementation in this field. The competitiveness of fuel cell technologies depends heavily on the extent to which companies succeed in automating production of the cells and significantly increasing their quantities. This is the only way to significantly reduce costs.

The following whitepaper describes the current state of automated production of fuel cell systems. It is divided into the production of the cell components, the connection of the cells to form a „stack“ and the integration of the stack into the final fuel cell system.

This whitepaper also shows specific SICK sensor applications throughout the production processes. Whether in the roll-to-roll processes essential for high volumes, in the robot-guided picking of individual cells for a stack, or in the identification of components and fuel cells throughout the entire manufacturing process, sensor solutions enable the automation of fuel cell production anywhere.

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1. The fuel cell – the energy system of the future

Hydrogen is the most abundant substance in the universe and will play an important role in the future energy economy, as it can store electricity from renewable sources. Fuel cells use this stored chemical energy from hydrogen and in most cases only require additional oxygen directly from the air. Especially in light of climate change, the use of fuel cells can play a decisive role in the switch to renewable energies. It is therefore not surprising that fuel cells are attracting more and more attention as an alternative to established systems such as internal combustion engines. Fuel cell vehicles can be completely refueled in just a few minutes and achieve ranges of more than 500 kilometers without generating climate-damaging emissions. There are different types of fuel cells, which differ mainly in the substances used and their operating temperatures. While the solid oxide fuel cell (SOFC) is often used in stationary applications, it is the polymer electrolyte membrane fuel cell (PEMFC) that is currently at the forefront of fuel cell development due to its flexibility. The low operating temperature, high efficiency and simple design make this type of fuel cell ideal for vehicles and power supply systems that are to be produced in high volumes.

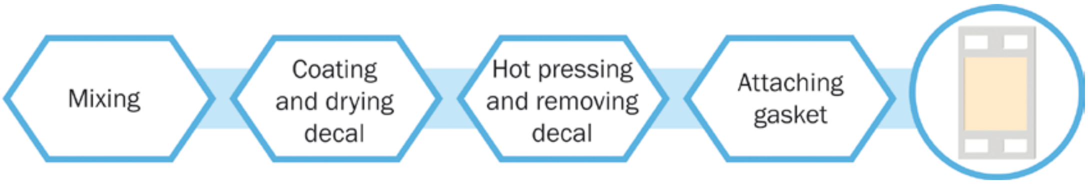
2. Production of a polymer electrolyte membrane fuel cell system

Two challenges currently stand in the way of the market success of the polymer electrolyte membrane fuel cell (PEM fuel cell): firstly, the establishment of a well-developed hydrogen infrastructure, which is fundamental for mobile applications in particular, and secondly, the general reduction in the cost of fuel cell systems. In order to make their acquisition costs more affordable, the switch from manual manufacturing of fuel cells to automated production with universally valid process chains is necessary above all else. The industrialization of manufacturing processes helps to reduce costs as well as to increase process and product quality.

Since the processes for higher manufacturing speeds are still in development and manufacturing companies are currently identifying ideal technologies, little information on concrete process specifications is coming out. Nevertheless, three overarching process steps that are necessary to manufacture fuel cell systems can be identified: cell component manufacturing, stack manufacturing, and finally system manufacturing.

The core components of a PEM fuel cell include the catalyst coated membrane (CCM) and the gas diffusion layers (GDL), which together form the membrane electrode assembly (MEA). The ion transport necessary for the use of electrical energy takes place via the MEA. The bipolar plates (BPP) feed the electrons into the consumer circuit. The reaction media of the cell flow through the flow fields of the BPP. In stack manufacturing, the cells consist of MEA and BPP to form a functional module. Additional electrical, mechanical and thermal components are combined with the fuel cell stack in system production.

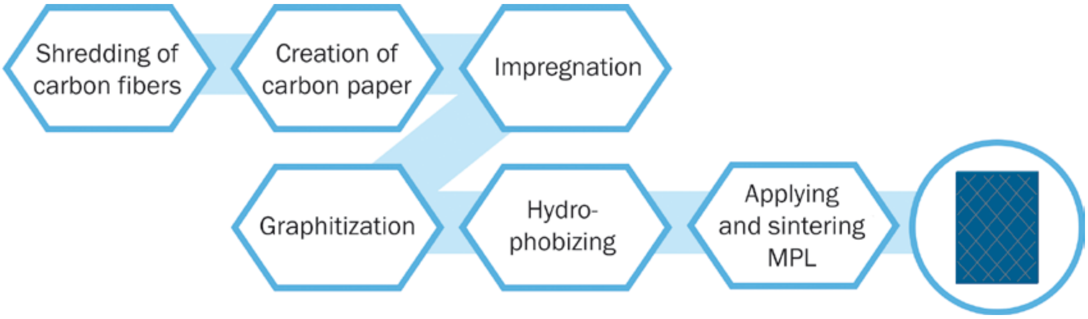
2.1. Production of catalyst-coated electrolyte membrane



According to the current state of the art, the manufacturing process of a **catalyst-coated electrolyte membrane** (CCM) consists of four steps. The catalyst material (usually platinum) is mixed with a supporting substrate of carbon, a solvent, and an ionomer (a thermoplastic resin). Due to the high sensitivity of the membrane to moisture, the catalyst ink is first printed onto a transfer film and dried. The cathode and anode layers can be produced separately and transferred from both sides of the transfer film to the membrane in a hot pressing process. In a later process step, the coated membranes are separated from the film strip and pressed with a carrier material that also acts as a gasket. This so-called “subgasket” is fed to the membrane from both sides and perforated in such a way that it precisely encloses and connects the separated CCMs. To achieve the targeted production speeds, roll-to-roll processes are unavoidable.

Alternatively, for smaller quantities, the catalyst ink is applied by spray coating, tape casting, screen printing, or slot die coating. In addition to indirect coating via carrier film, the polymer electrolyte membrane can also be coated directly on both sides. However, the film must be kept continuously tensed and dried at a high temperature to prevent swelling of the moisture-sensitive membrane.

2.2. Production of gas diffusion layers

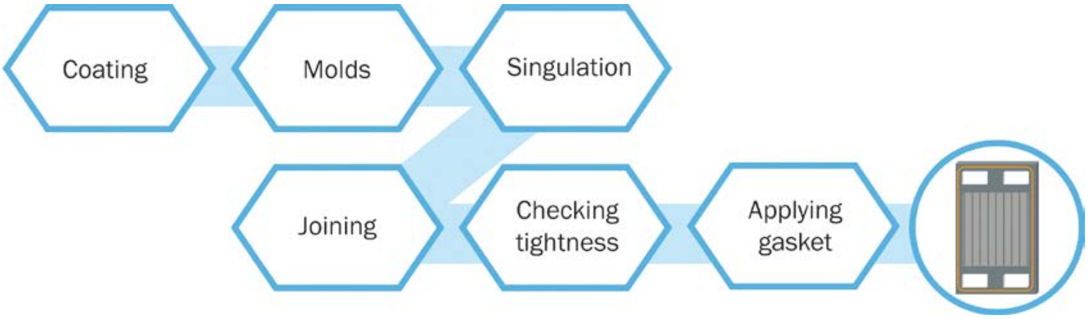


Gas diffusion layers (GDL) are applied to both sides of the CCM. The layers have a high influence on the efficiency of the fuel cell, as they distribute the reactants evenly on the anode and cathode side and regulate the water balance at the electrolyte membrane. Shredded carbon fibers and a binder polymer form the basis of GDL, the carbon paper. Impregnation and graphitization of the layers provide the desired properties in terms of porosity, material strength and electrical and thermal conductivity. After hydrophobizing the GDL, it is coated with a porous layer of carbon and graphite particles and sintered. Alternatively, this layer can also be applied to the GDL by slot die, screen printing or screen application.

Hot presses apply the finished GDL to both sides of the CCM. For this purpose, the GDL is coated with adhesive, perforated and stapled to the CCM film with the help of rollers. The connected components are then separated.

At low volumes, components is still joining discontinuously, since roll-to-roll processes are still rarely used in GDL and CCM production. In this case, CCM and GDL are already separated before unification.

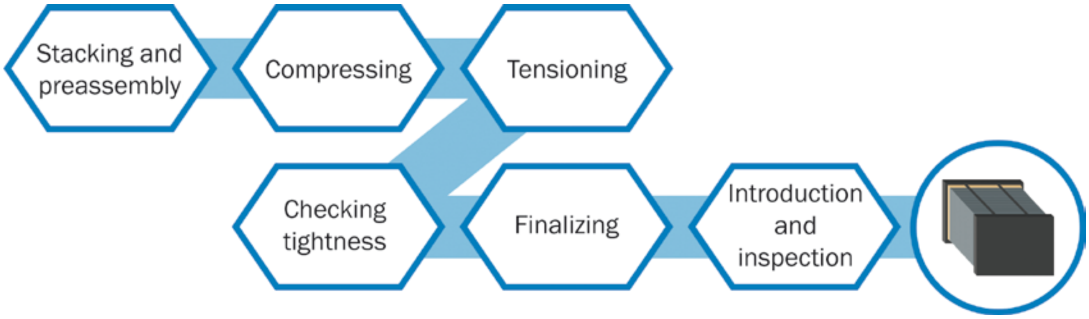
2.3. Production of bipolar plates



Gas flow, current collection and thermal management of the cell take place in the bipolar plates (BPP). In applications where weight, volume and cost play a major role – as is the case in the automotive industry – BPPs are made of metallic materials. Otherwise, graphite can be used. The manufacturing process is subject to tight tolerances. Due to the several hundred cells that are installed within a stack, even small errors in the flatness and parallelism of the boards lead to large deviations.

The BPP manufacturing process begins with the coating of the raw material. For better conductivity and corrosion resistance, this is done in a vacuum. This is followed by the decisive shaping of the distribution panels, either by injection molding, deep drawing or stamping the metal sheets. Alternatively, the hydroforming process allows the bipolar plate halves to be formed directly from a roll of material. That is why it is preferred for mass production of plates. After the gas channels are shaped, the plate halves are separated and joined together in a welding process so that a finished BPP has one anode and one cathode side. Then the BPP is checked for leaks. A gasket for the subsequent cell is applied to its outer surface by screen printing or, alternatively, dispensed.

2.4. Mounting of fuel cell stack



To achieve the desired performance of a fuel cell system, the individual cells are electrically connected in series. Fuel, reaction air and coolant are supplied in parallel to ensure the same electrical current flow in each individual cell. The required voltages and currents define the number of cells and the size of their reaction areas. In addition to the several hundred individual cells, the stack consists of two end plates, the distribution plate, two current collectors and a monitoring unit. Up to now, small quantities have been manufactured manually. However, the high number of repetitions of the same processes during stacking offers great potential for automation by robots.

The base of the stack is an end plate on which a current collector is mounted. The cells follow, consisting of a BPP, a gasket, an MEA, another gasket and another BPP. After the desired number of cells is reached, a current collector and the second end plate are added again. The subsequent pressing seals the stack and lowers the contact resistance of the components. Tension bands or tension rods then hold the compressed stack together permanently. At this point, the cell is checked for leaks. Stack finishing includes the attachment of the monitoring unit and the busbars, as well as joining of the housing and the distribution plate. Now the fuel cell stack can be “retracted”. In this process, the operating media are supplied to the stack and an electrical load is applied. During testing, the fuel cell stack goes through various parameter combinations until the optimal performance of the stack is achieved.

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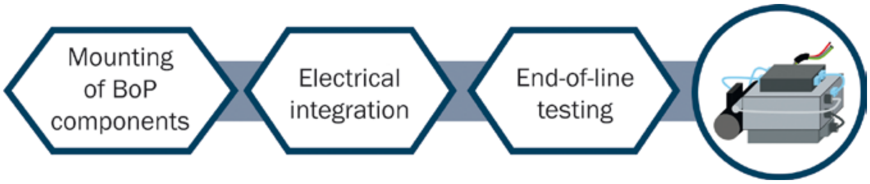
2.5. Mounting of fuel cell system



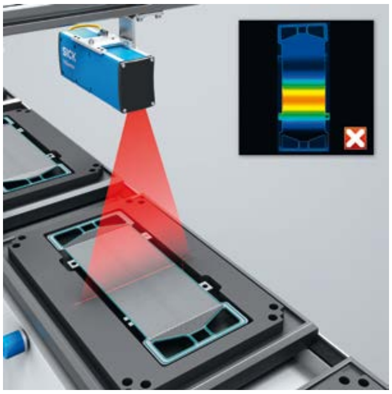
The stack is the heart of a fuel cell system. However, in addition to the stack, other components are necessary for the system to work. These include the cooling, air and hydrogen circuits, as well as the control device and power conductors. While the cooling circuit ensures the dissipation of the reaction heat, the air circuit compresses and humidifies the ambient air and feeds it to the cathode side of the PEM fuel cell. The hydrogen circuit brings the hydrogen to the anode side of the cell, regulating the power of the system.

Completion of the fuel cell system begins with mounting of the balance-of-plant (BoP) components. These include: the cooling system, which consists of a filter, cooling water pump and pressure regulator; the anode module, which is composed of a hydrogen pump and pressure regulator; and the cathode module, a combination of compressor, air filter and pressure regulator. A control device for regulating the system is also included. Many of the BoP components of a fuel cell system are the same as those from internal combustion engines. During electrical integration, the BoP components are connected to the stack. In addition, the system receives its cabling in the process, including a cable harness for integration into the subsequent application. Before the final release of the fuel cell system, it undergoes a final test that checks the functionality of all components and their correct connections to each other.

Intelligent sensor solutions are the basis of highly automated, digitized fuel cell production. In competition with conventional drive and storage technologies, high production output and the fulfillment of high quality requirements are decisive for the competitiveness of fuel cells. With sensors in the areas of detection, identification, quality control and machine safety, plant operators and machine builders are preparing themselves for the automation challenges of fuel cell production.

3. Sensor applications for the production of fuel cell systems

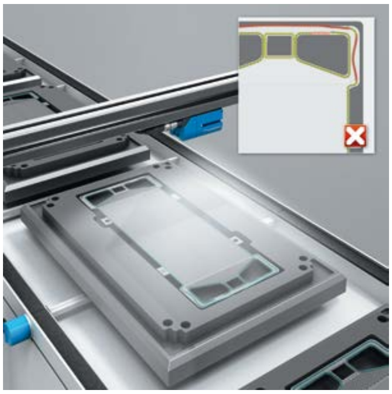
3.1. Monitoring and controlling



Measuring bipolar plates

The configurable TriSpector1000 3D vision sensor allows a reliable 3D measurement of bipolar plates. To ensure the fuel cell has been mounted correctly, it is checked for fractures, bowing, and other defects.
For very precise measurements, the Ruler3000 3D camera offers high accuracy at high speed.

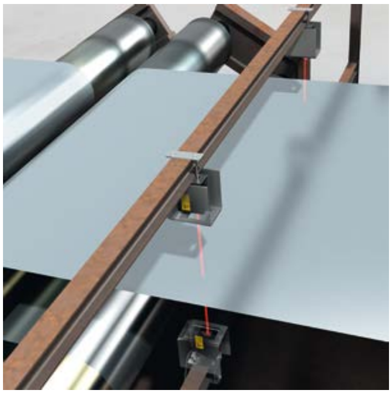
TriSpector1000, Ruler3000



Verifying the seal

Precise application of the sealant is essential for the tightness of the fuel cell. The InspectorP62x 2D vision sensor inspects the adhesive bead. Thanks to its compact design, the sensor can also be installed directly on the dispenser. The integrated image processing tools make commissioning very easy. If necessary, they can be expanded with the help of SICK AppSpace.

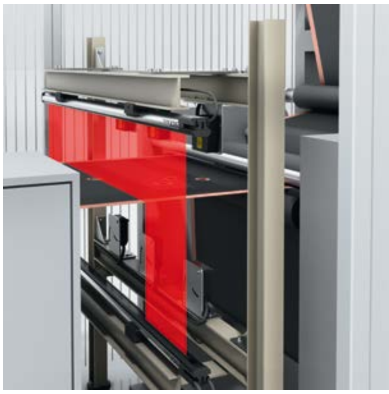
InspectorP62x



Continuous thickness measurement

OD5000 displacement measurement sensors monitor the uniform thickness of bipolar plates during production. With a measuring frequency of up to 80 kHz, the OD5000 achieves very good performance even at high speeds.

OD5000



Crack detection

Handling and transport of film sheets or film tension in the machine can cause rips in the film. Even at high web speeds, the MLG-2 measuring automation light grid detects rips of a few millimeters in size, and precisely determines how large they are and where the films are defective. The dynamic range of the MLG-2 also allows transparent films to be measured.

MLG-2

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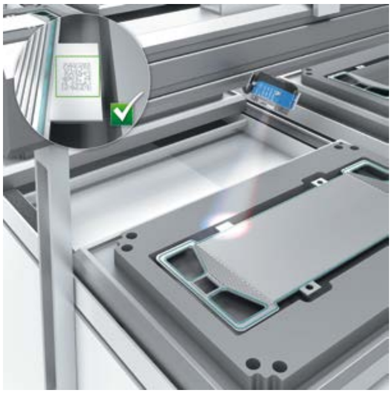
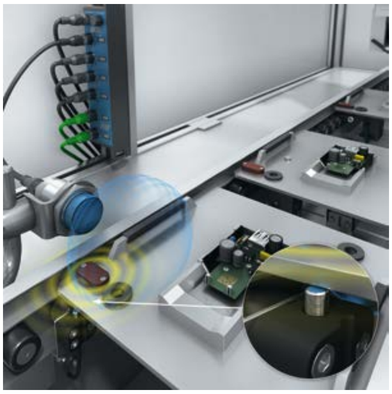
3.2. Identification

	**Identifying bipolar plates** SICK offers a wide range of solutions for tracing fuel cell components throughout the entire production process. The Lector61x image-based code reader can be used to identify bipolar plates using 2D codes. Its reliable illumination concept and extensive range of optical accessories enable lasered Data Matrix codes (DPM) to be read on reflective, metallic surfaces. Lector61x
	**Identification of the workpiece carrier** Using the RFH51x HF write/read device and the transponder on the workpiece carrier, relevant product information and manufacturing commands can be assigned to components. This data can be stored both on the transponder and in the system, making it easy to identify the workpiece carriers. This ensures transparency and a high level of quality throughout the entire mounting process. RFH5xx, SIG200
	**Traceability of production materials** 1D and 2D codes contain important information, such as the type of material and other parameters, for tracing production materials. Mobile handheld scanners from SICK are ideal for reading these codes. Whether wired or wireless, the devices are characterized by reliable and fast code reading and rugged housings. IDM26x, HW199x

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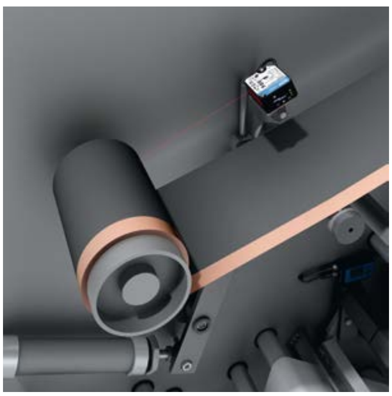
3.3. Role-to-role processes

Edge guiding

In order to manufacture high-quality fuel cells, film sheets must be positioned precisely. That is why the OL1 optical micrometer together with the AOD1 control unit measures the web edge position with micrometer precision. Thanks to its small design, it fits directly in front of the winding unit.
The AS30 array sensor and LL3 array fibers complement the SICK range of solutions for edge guiding and cover different requirements.

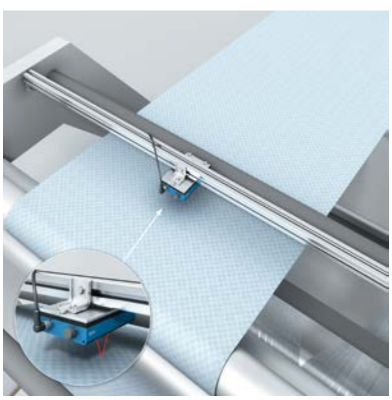
OL1, AS30, WLL190T, LL3, AOD1



Check for unused film

To ensure continuous operation and reduce machine downtime, the film must be changed at the right time. The OD2000 displacement measuring sensor therefore measures the height of the film on the roll as it is unwound. Measuring ranges up to 1,000 mm combined with a high repeatability allows precise monitoring of the remaining film even for larger roll diameters.

OD2000



Non-contact length and speed measurement

The SPEETEC® non-contact motion sensor optically measures the speed and length of a film sheet. Inaccuracies caused by slippage or impairment of the material are no longer a problem thanks to the direct contact, which makes high product quality possible.

SPEETEC®

Identifying the splicing tape

When changing the roll, the beginning and end of two consecutive rolls are joined together using splicing tape. Color, contrast, luminescence and glare sensors from SICK can detect the film tape at this point so that it can be removed later before the film is further processed into the cell. In addition, a SICK encoder increases the accuracy of the splicing tape position determination.

LUTM, KTS Prime, Glare, DBS36

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3.4. Detecting and measuring

Level monitoring of the adhesive cartridge

In the dispensing process, the level of adhesive in the cartridge must be continuously monitored so that the adhesive is properly dispensed and rejects are prevented. This test is performed by the MQ10 magnetic proximity sensor or the CQF16 capacitive proximity sensor. They send a signal to the process control when the cartridge is empty, and the empty status is then displayed on the dispenser station's user interface.

MQ10, CQF16

Robot guided picking

Based on 2D object localization, the PLOC2D robot guidance system distinguishes parts so that the robot can feed them to the assembly fixture in the correct order. The image processing unit of the system locates the exact position of the parts and guides the robot to the correct location.

PLOC2D

Detection of flat objects on conveyor belts

Whether bipolar plates, displays, smartphones or pouch cells, the WTF4F photoelectric proximity sensor with foreground suppression reliably detects very flat objects down to a height of less than 1 mm on conveyor belts. Detection is reliable and certain even for reflective, contrast-rich or jet black surfaces. By adjusting the sensing distance, detection is very accurate even with vibrating conveyor belts.

W4F

Flow measurement

FFU ultrasonic flowmeters monitor the flow rate of liquids. Thanks to the rugged design which does not contain any moving parts, the sensors are even suitable for use in harsh ambient conditions.

FFU

3.5. Protection

Access protection at a robot cell

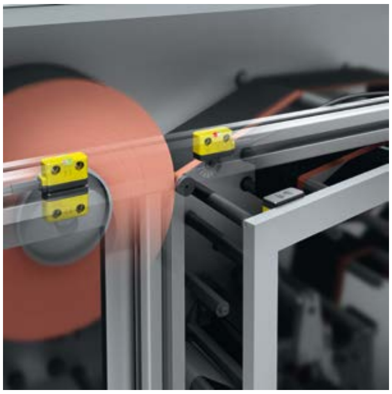
In automated production cells, containers of blanks are provided and trays with finished workpieces are picked up. Two microScan3 safety laser scanners with scanning angles of 275° each are used for access protection around the robot working range. This allows the robot to continue its work unhindered during the provision and collection of parts.

microScan3, deTec

Access protection at the winding unit

The continuous action of winding up a film sheet represents a dangerous movement. The deTec4 Core safety light curtain therefore reliably monitors access to the winding unit. When used in combination with the modular Flexi Soft safety controller, the light curtain offers a complete machine safety solution.

Flexi Soft, deTec4 Core



Protection of safety doors

The STR1 non-contact transponder safety switch has a protective function for monitoring doors. The STR1 can be mounted flexibly and is characterized by high levels of protection against tampering. This ensures that machines stop when doors are opened and only restart when doors are closed.

STR1

Reliable door monitoring for robot-assisted applications

Access doors in robot-assisted applications can be efficiently protected with the TR110 Lock safety locking device and the MB1 mechanical bolt. MB1 prevents sensor damage and thus machine downtime thanks to precise guidance of the actuator. The user-friendly Flexi Compact safety controller and its intuitive Safety Designer configuration software round out this safety solution.

MB1, TR110 Lock, Flexi Compact

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REFERENCES

Automotive
https://www.sick.com/automotive

Battery
https://www.sick.com/battery

Machine vision
https://www.sick.com/de/en/machine-vision/c/g114858?q=:Def_Type:ProductFamily

Identification solutions
https://www.sick.com/de/en/identification-solutions/c/g77989?q=:Def_Type:ProductFamily

Digital Transformation
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Sensor Intelligence.