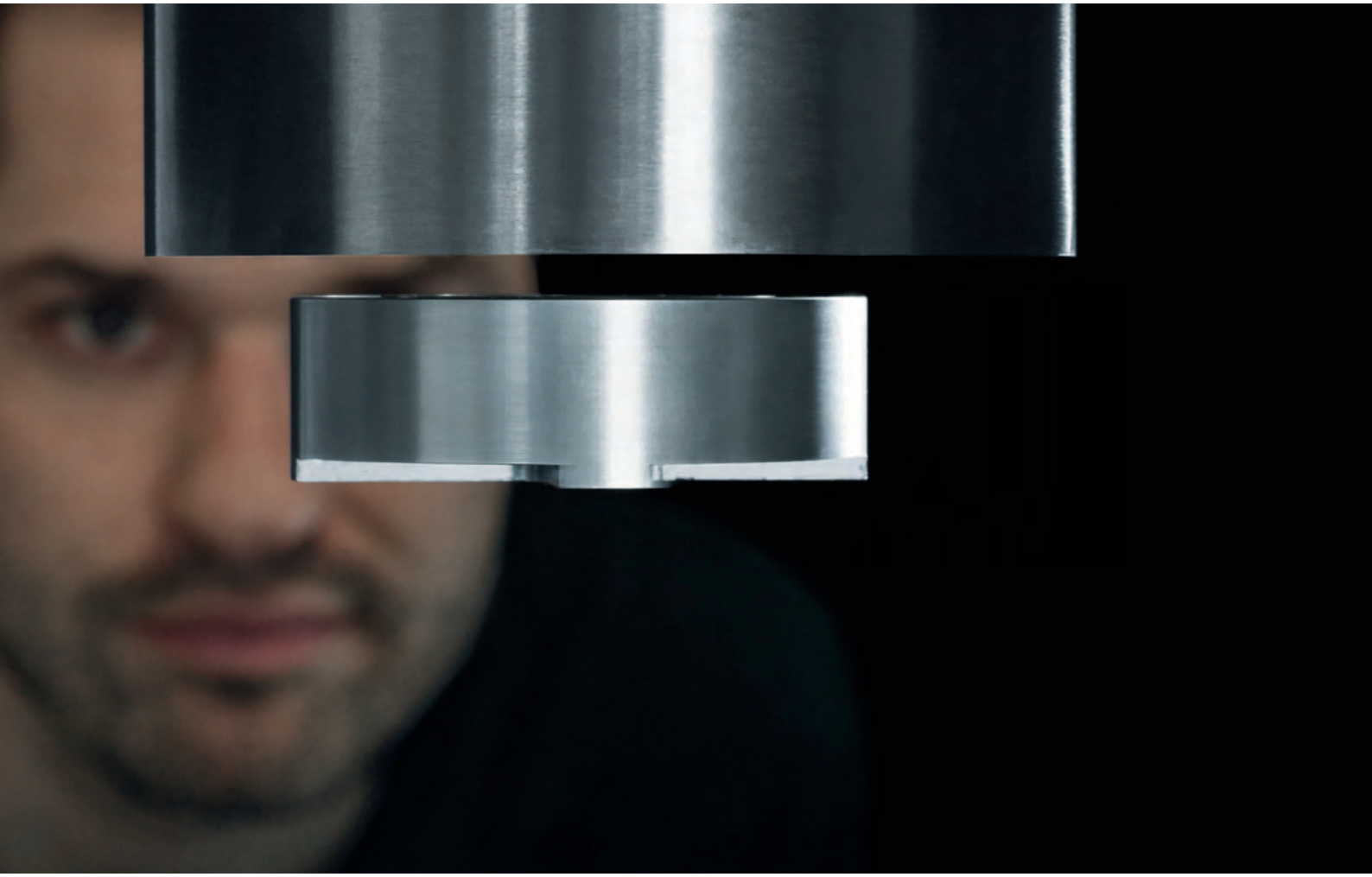
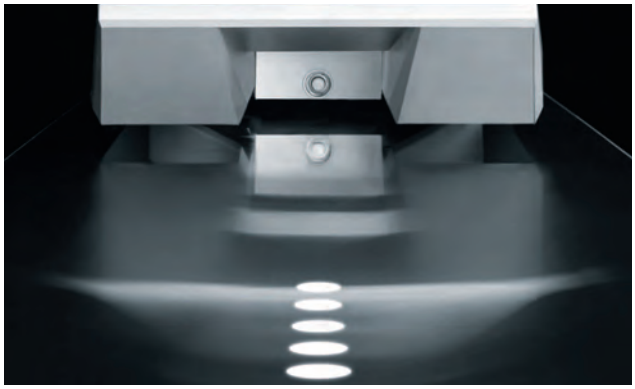
SupraMotion

FESTO



Potential for resource-efficient industrial automation

Frictionless movement, thanks to superconductive bearings



They work by hovering, are resistance-free and energy efficient. Superconductors have been used in medical technology for years. Now, the technology is making its mark in large-scale systems such as marine propulsion systems, wind generators with high power density and loss-free transmission of electricity.

Initial research projects for industrial application
For the first time, a manufacturer of automation technology is testing the application of superconductors to sustainable production of the future. Together with evico, Festo has developed three research projects under the title SupraMotion on superconductive, frictionless bearing systems.

SupraLinearMotion, SupraHandling and SupraPicker demonstrate the technology's potential for the industrial automation of tomorrow, showcasing contactless, linear movement, positioning in the level plane and handling in an hermetically sealed room. On all three exhibits, contactless movement is achieved by maintaining a defined distance between the magnetic field and the superconductor.

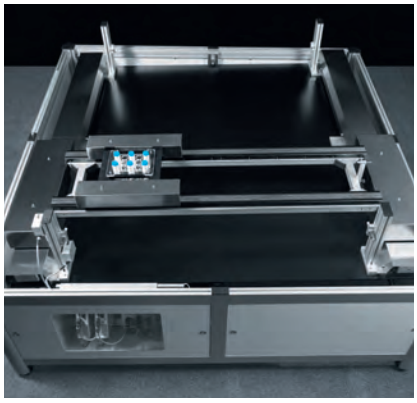
Resistance-free with superconductivity
Superconductors are metals, metal compounds or ceramic materials that have a very special characteristic: their electrical resistance suddenly drops to zero when cooled to below a certain temperature. Once this transition temperature has been reached, mutually repulsing electrons bind to form what are called Cooper pairs.

This cancels out the mechanism of electrical resistance. When a voltage is applied, the pairs conduct the electrical current without any resistance and without losses. Once the electrical current is put into motion, it flows uninterrupted in a closed circuit. The magnetic fields that are generated in this way deliver a very high energy yield.

Steady hovering above and below magnetic bearings
In the three SupraMotion exhibits showcased by Festo, ceramic high-temperature superconductors with a transition temperature of 77 Kelvin (–196 ° Celsius) are used. The superconductor blocks are first cooled down to this temperature. This enables the blocks to store the external magnetic force of a nearby permanent magnet and to independently maintain a defined distance parallel to the magnet, including an air gap. Any attempt to move the superconductor from its stored position is answered with a resetting force, and the superconductor hovers back to its original position.

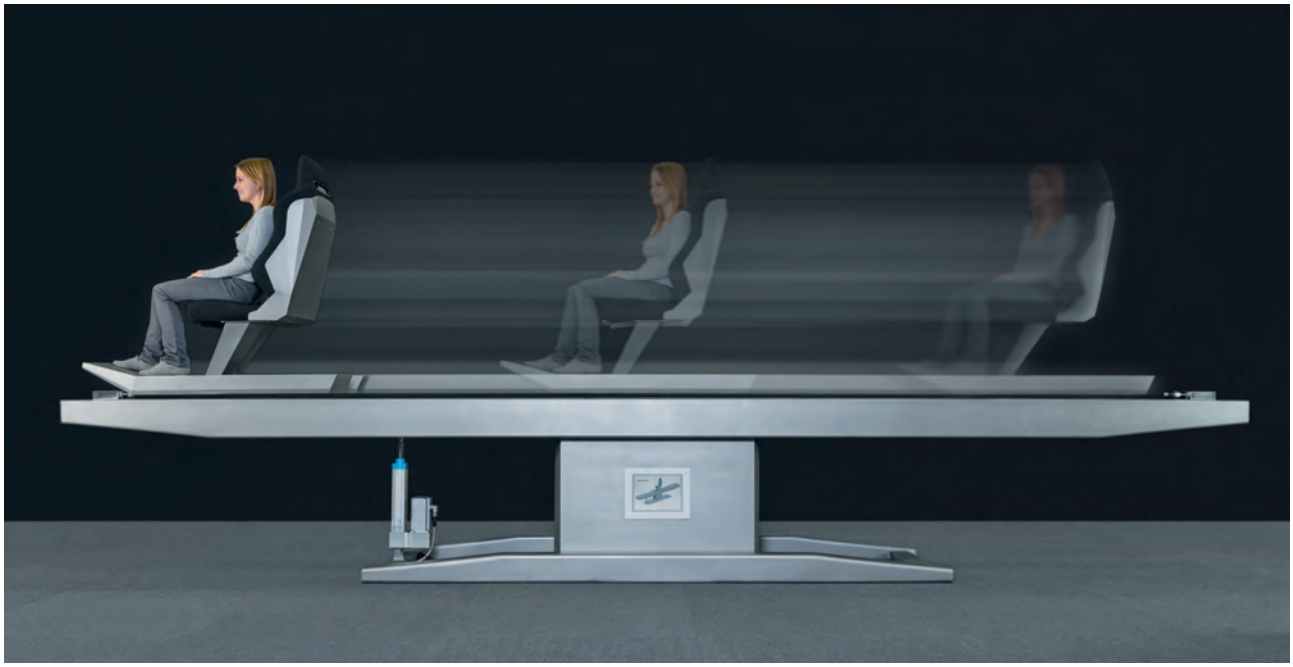
Superconductor cooling
SupraLinearMotion and SupraHandling work on the basis of passive cooling, using liquid nitrogen. It keeps the superconductor blocks in cryostats (the cooling tanks) at operating temperature. On both exhibits, the tanks with the superconductive material are integrated into the slides. On the SupraPicker, the superconductor is actively electrically cooled by a small compressor that keeps the temperature at a constant 73 Kelvin (–200 ° Celsius).

SupraLinearMotion: Linear gliding



SupraHandling: Two-axis movement

SupraPicker: Three-dimensional handling system



SupraLinearMotion: Bringing the technology to life

SupraLinearMotion – frictionless, linear gliding
Festo makes the properties of the technology come alive with SupraLinearMotion: a person takes a seat on the superconductive slide, which hovers at a defined distance above a magnetic rail, thanks to the integrated cooling.

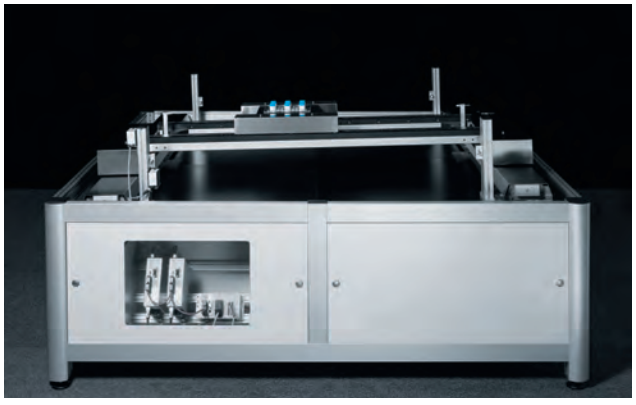
In order to drive it, the rocker is actively taken off balance. It tilts and the passenger glides without friction and noise over the magnetic rail – purely due to the action of gravitational force, carried by the superconductor.

The rocker is tilted by an electric cylinder ESBF. Three pneumatic semi-rotary drives (DRQD) have been integrated into the rail for end-position limiting. In the middle of the rocker, four electric drives (DNCE) raise the seat slide into the rest position so that the passenger can safely climb on and off. These drives hold the slide at the required distance from the magnetic rail while the superconductor is cooling down the magnetic field. A CPX terminal in the base of the rocker coordinates all the electric and pneumatic drives in the exhibit.

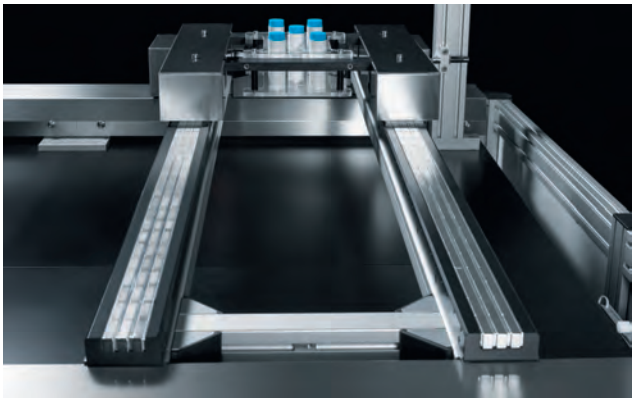
SupraHandling – flexible positioning in a level plane
The developers also put gravitational force to work for them in the second exhibit. The SupraHandling system, an X/Y-table for moving objects in the X and Y direction, works on the principle of the one-dimensional rocker, but on a smaller scale.

The base plate of the table is two metres long by two metres wide and is mounted on a ball joint. The gantry, which comprises four magnetic rails, two superconductive slides and a workpiece holder, is mounted on the base plate. Two servo motors (EMMA-AS) from Festo are attached at right angles underneath the base plate.

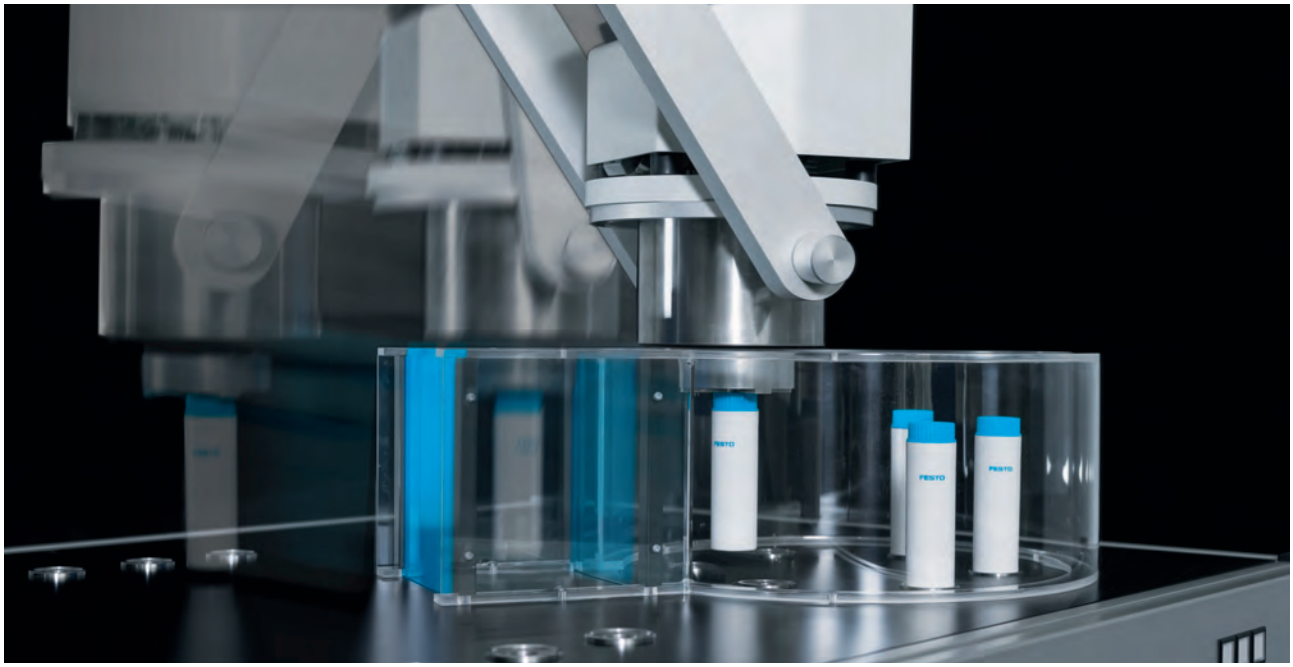
The two drives can, independently from each other, slightly tilt the base plate in the X and Y directions. This enables the two slides to move and hover over the magnetic rails as another example of contactless movement. Two opto-electrical sensors in the corners of the base plate sense the position of the slides during this process. The CPX terminal actuates the two drives to tilt the base plate, as appropriate, to the required positioning of the workpiece carrier.



SupraHandling: Tilting by up to four degrees allows the slides …



… of an X/Y-table to move on superconductive bearings for the first time.



SupraPicker: Contactless handling ...

SupraPicker – new handling opportunities in all directions
The third exhibit shows an hermetically sealed room made from plexiglass in which a handling operation is completed from start to finish. The SupraPicker is therefore not restricted to a horizontal mode of operation. It can execute any solid angle.

The superconductor of the pick & place application is actively cooled electrically using a small compressor. This does away with the need for auxiliary units for cooling, transporting and storing liquid nitrogen, which can make potential industrial use much easier.

Superconductive pick & place application
The vertical movement of the lever arm is realised by an electric toothed belt axis (EGC) and a servo motor (EMMS) from Festo installed beneath the base plate. A further servo motor moves the SupraPicker in both horizontal directions by rotating the arm and the two-armed mount around their own axes. A rotary drive is attached to the end of the mount. It moves the cantilever axis that carries the compressor and the cooling tank containing the superconductive material. A permanently magnetic puck hovers beneath the axis at a defined distance. It picks up the object to be gripped and conveys it into the sealed room.

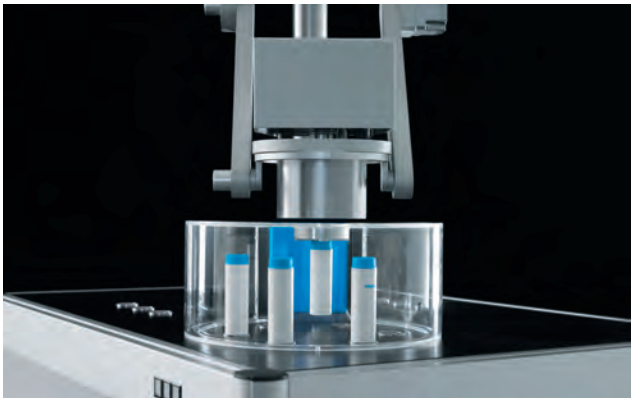
In the room, mounted on the base plate, is an electric rotary drive module of the type (ERMB). This rotary drive enables six different positions to be approached on which the six vials can be placed. Attached beneath the base plate are pneumatic grippers of the type, DHEB, which mechanically take the object from the puck.

The multi-axis movements of the lever arm and the pneumatic drives are coordinated by the CoDeSys controller of the CPX terminal. It also processes all the binary and analogue sensor data as well as the diagnostic information produced by the process.

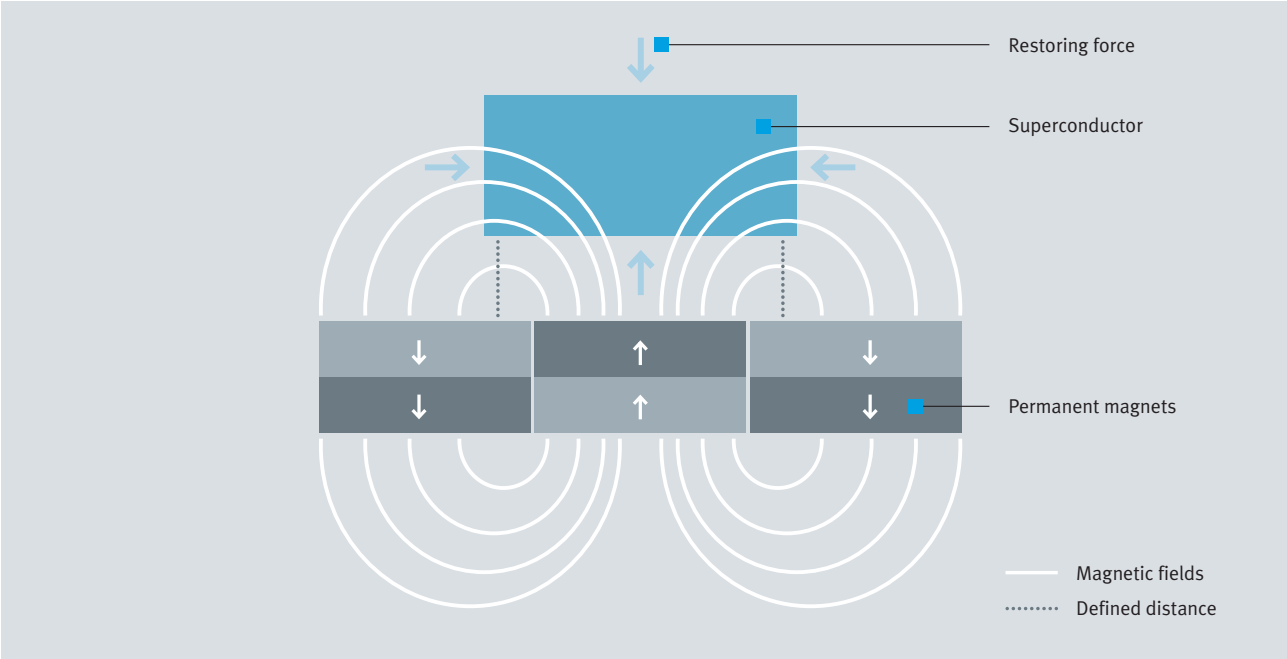
Stable bearing system, even with spatial separation
With the SupraPicker, Festo shows the benefits of contactless, stable bearing systems based on superconductors. The distance between the magnet and superconductor is maintained in all spatial directions and axes. When the magnetic field is stored, the magnet and superconductor can be easily separated.

The superconductive gripper arm magnetically picks up the vials outside of the room using the puck. The gripper arm and gripper (puck) can be separated by the air gap between the puck and superconductor. The puck, together with the object to be gripped, is conveyed through a lock into the closed room, while the superconductor moves in a parallel course outside the room. The handling operation in the closed room can therefore be executed without touching the walls.

The application shows the new handling opportunities that superconductivity can open up for automation; for example, when working with special gases, harmful media or in especially cold or clean environments.



... in an hermetically sealed room



High-temperature superconductors: At a transition temperature of –196 ° Celsius, they store the magnetic field of the permanent magnets at a defined distance.

Great potential for cooling and material
The technology is still at the research stage and is not yet in industrial use in the field of automation. Since 2008, Festo has been working on developing its potential for automation technology in order to identify new fields of application.

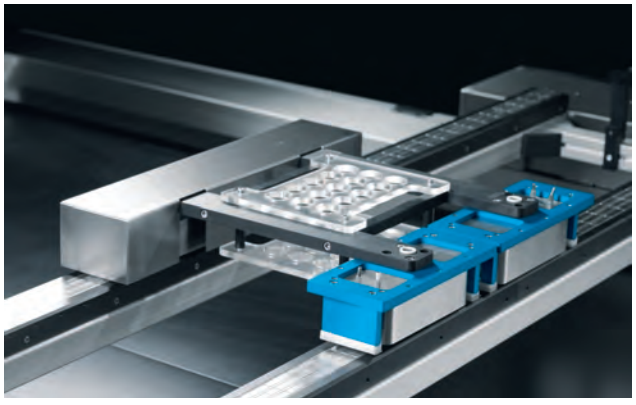
Material development and cooling systems offer huge optimisation potential. The enormous cost of cooling to temperatures near the absolute zero point stood in the way of widespread industrial applications for a long time.

Superconductors with ever higher transition temperatures
High-temperature superconductors whose transition temperature can be above 100 Kelvin (–173 ° Celsius) were discovered in 1986. These are ceramic materials such as yttrium barium copper oxide (YBCO), materials which Festo has used for the three SupraMotion exhibits. Since that time, it has become possible to cool materials directly, using liquid nitrogen, or electrically, which is much cheaper and more practical than with conventional superconductors.

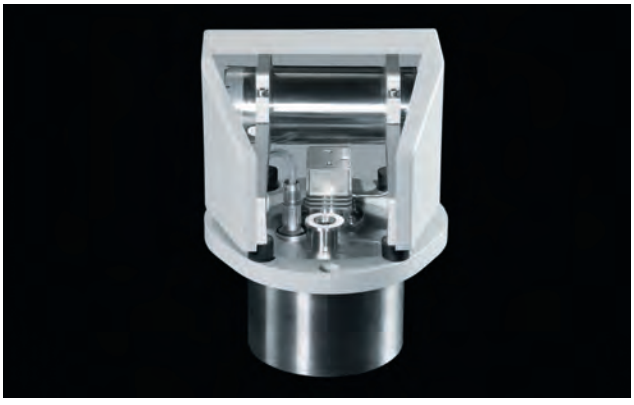
Focus on resource efficiency
The development of superconductive materials allows new key technologies to come on stream for more efficient and environmentally-friendly generation, distribution and utilisation of electrical energy. Festo's goal is to promote the research of superconducting technology together with partners from industry and science.

Advantages of superconductive magnetic bearings
New applications in the field of superconductive magnetic bearings as an alternative to active electromagnetic bearings are offering interesting perspectives for Festo as a provider of automation technology.

The complicated measurement and control technology required to generate the necessary guide forces in electromagnetic bearings are not needed with superconductive magnetic bearings, as superconductors with a simple magnetic path consisting of permanent magnets can achieve frictionless and stable hovering effects.



Passive cooling: Cryostats with liquid nitrogen in the SupraHandling system



Active cooling: Inside view of the electrical compressor of the SupraPicker

Technical data – SupraLinearMotion

- Track length: 6,000 mm
- Track width: 600 mm
- Air gap: 10–15 mm
- Max. height difference: 300 mm
- Max. acceleration: 2.4 m/s²
- Max. speed: 8.6 km/h
- Max. payload: One person, up to 120 kg
- Magnets: 320 NdFeB magnets
- Passive cooling: 4 cryostats
- Superconductor: High-temperature superconductor: yttrium barium copper oxide (YBCO)
- Drives: 1 electric cylinder (ESBF)
  4 electric drives (DNCE)
  3 pneumatic semi-rotary drives (DRQD)
- Controller: 1 CPX terminal

Technical data – SupraHandling

- Dimensions: 2,000 × 2,000 × 1,000 mm
- Tilt angle: 4 degrees
- Max. acceleration: 0.70 m/s² [9.81 * sin (4°)]
- Max. payload: 120 kg (X plane),
  60 kg (Y plane: end load)
- X-axis: 2 large magnetic rails,
  1,800 mm apart
- Max. travel: 1,300 mm
- Passive cooling: 4 large cryostats
- Air gap: 10–15 mm
- Y-axis: 2 small magnetic rails,
  350 mm apart
- Max. travel: 1,100 mm
- Passive cooling: 4 small cryostats
- Air gap: 5–10 mm
- Superconductor: High-temperature superconductors: yttrium barium copper oxide (YBCO)
- Drives: 2 servo motors (EMMS)
  2 motor controllers (CMMP-AS)
- Controller: 1 terminal (CPX-CEC-M1)
- Sensors: 2 laser distance sensors

→ Film

Technical data – SupraPicker

- Dimensions: 1,950 mm (total extended height)
- Active cooling: AIM Linear Stirling Cooler SL 150 with cold fingers, cooling performance: 90 watts for a generated refrigerating capacity of 1.5 watts
- Superconductor: High-temperature superconductor: yttrium barium copper oxide (YBCO)
- Drives: 1 electric heavy-duty axis (EGC)
  2 servo motors (EMMS)
  1 Harmonic Drive rotary drive
  3 24 V DC motors
  1 rotary module (ERMB-25) with servo motor (EMMS)
- Gripper: Permanently magnetic puck, 76 mm diameter for picking
  7 pneumatic grippers
  DHEB for placing
- Sensors: Fork light barriers (SOOF)
  Temperature sensors PT 100
- Controller: CPX-CEC-M1

Project participants

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