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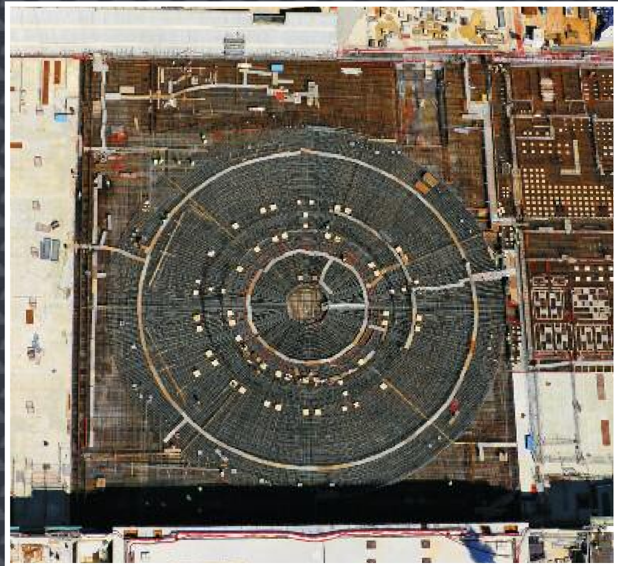
PROGRESS IN PICTURES

June 2014



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A star will be born

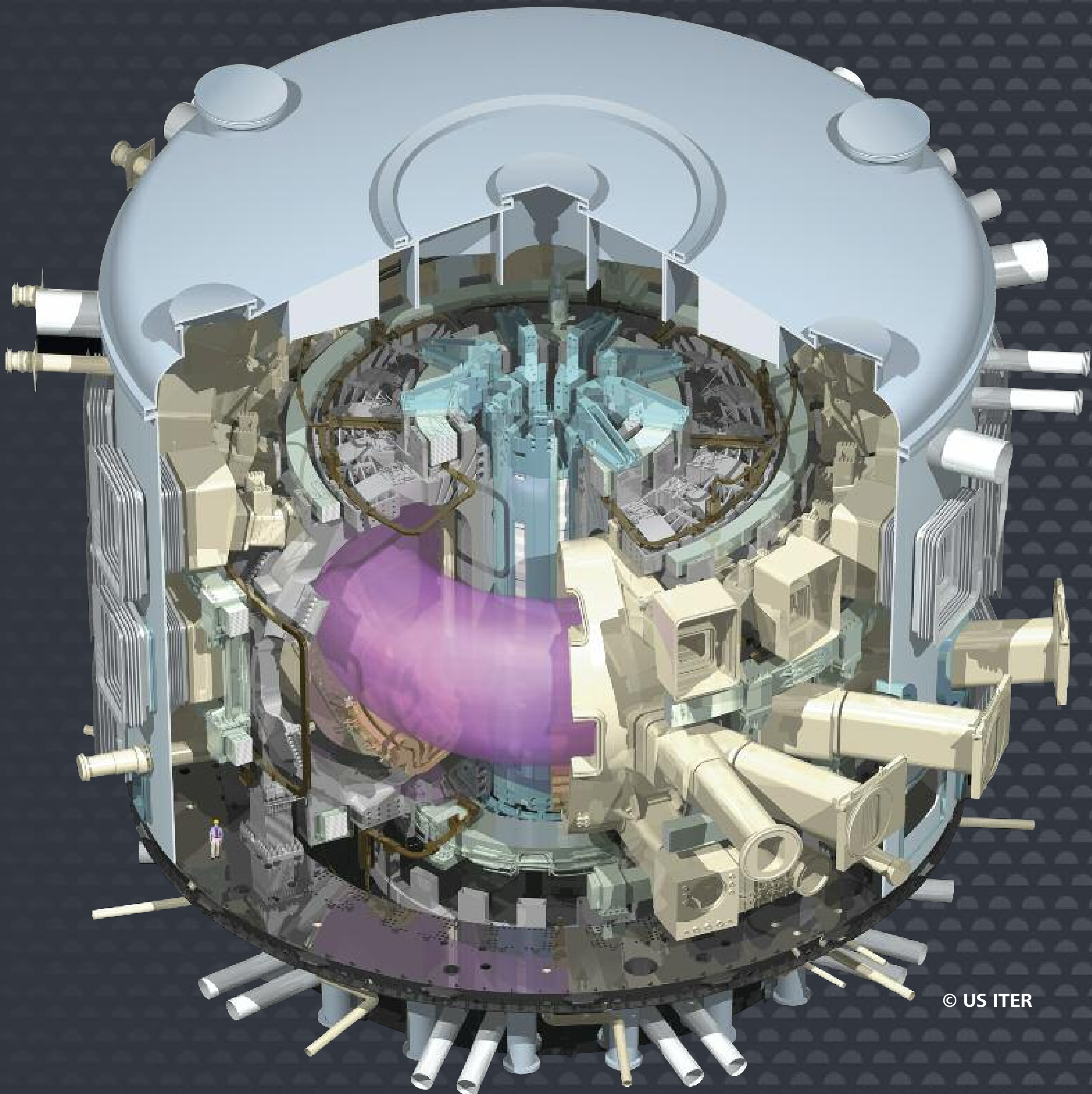
A new star will soon be born, a star unlike any other… a man-made star. ITER – the Latin word for "The Way" – will light up in the early years of the coming decade. From a scientific and technological point of view, it will be one of humankind's historic achievements. The creation of an artificial star and the tapping of the tremendous amounts of energy produced could forever alter the course of civilization.

The ITER Project, an unprecedented international collaboration that brings together China, the European Union, India, Japan, Korea, Russia and the United States, is the culmination of decades of research and years of diplomatic negotiation. What was the aspiration of three generations of physicists is now the reality of the hundreds of scientists, engineers and labourers working in southern France where the ITER installation is under construction.

The seven ITER Members, representing half the world's population, share the responsibility for building the ITER machine and facilities. Every Member, essentially, is involved in every system.

As buildings rise on the ITER platform (part of European procurement, pages 4 to15), component manufacturing advances in ITER Member factories (pages 21 to 41).

This booklet aims to take you into the heart of ITER, from the rolling hills of Provence to factories on three continents, where men and women from 35 nations are bent on realizing one of mankind's most enduring dreams: capturing the fire of the stars and making it available to humanity for the millennia to come.



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The ITER Tokamak

The ITER machine is a tokamak, the Russian acronym for Toroidal Chamber, Magnetic Coils. Tokamaks were developed in the 1960s at a time when nations were experimenting with all kinds of different systems to reproduce the nuclear reactions at work in the core of the Sun and stars.

A tokamak, like a star, is designed to fuse light atoms into heavier ones. A tokamak is a magnificent tribute to Albert Einstein's E=mc2: the tiny loss of mass that results from the fusion process translates into a huge quantity of energy. One gram of fusion fuel (the hydrogen isotopes deuterium and tritium) generates as much power as eight tons of oil.

ITER will be by far the largest and most complex tokamak ever built. Designed from the experience accumulated by hundreds of fusion machines throughout the world, it will demonstrate that fusion energy is scientifically and technologically feasible.

Weight	23,000 metric tons
Height	~30 metres
Diameter	~30 metres
Plasma volume	840m^3
Temperature at plasma core	150 000 000°C
Fusion power	500MW

Site map

On 28 June 2005, the ITER Members unanimously agree on the site proposed by Europe: a 180-hectare stretch of land located in the Durance River Valley some 75 kilometres north of Marseille. Preparation work on the ITER site begins in January 2007. Over two years a 42-hectare platform is cleared, levelled and readied for the construction work that begins in earnest in the summer of 2010.

The ITER site, looking north

Looking north over the ITER worksite. *April 2014*

16 new building projects launched in 2014

No fewer than 16 building projects will be set into motion in 2014. The first projects on the list: the Site Services Building in the northeast corner of the platform and the 60-metre-tall Assembly Building adjacent to the Tokamak Seismic Pit. *April 2014*

Work in progress, June 2014

The heart of activity: the Tokamak Seismic Pit (centre left), the Assembly Building worksite (centre right) and the ITER Headquarters (background). *June 2014*

The Tokamak Pit seismic protection system

The three buildings of the Tokamak Complex will share a common foundation. In case of a seismic event, 493 steel and rubber seismic pads will absorb ground motion and preserve the integrity and safety of the installation. *July 2012*

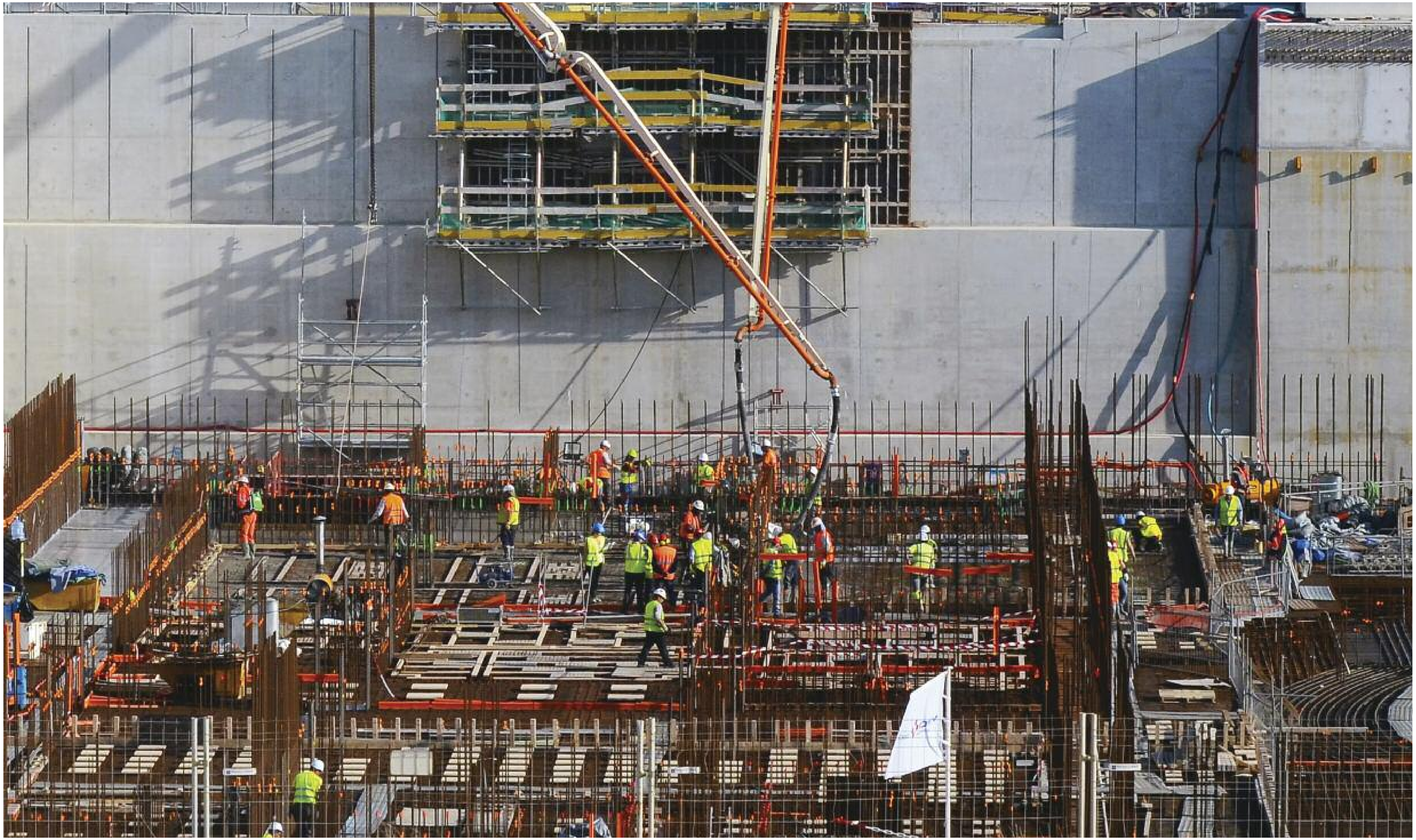
Tokamak Complex slab preparation

The antiseismic columns and pads are hidden from view by the formwork and reinforcement underway for the next-level basemat. The B2 slab will support the 400,000-ton Tokamak Complex. *September 2013*

First concrete for the Diagnostics Building

The Diagnostics Building will be situated at one end of the Seismic Pit. Work begins to pour the first of three basemat segments before dawn on 11 December 2013; the Diagnostics Building slab is completed in February 2014.

First concrete for the Tritium Building

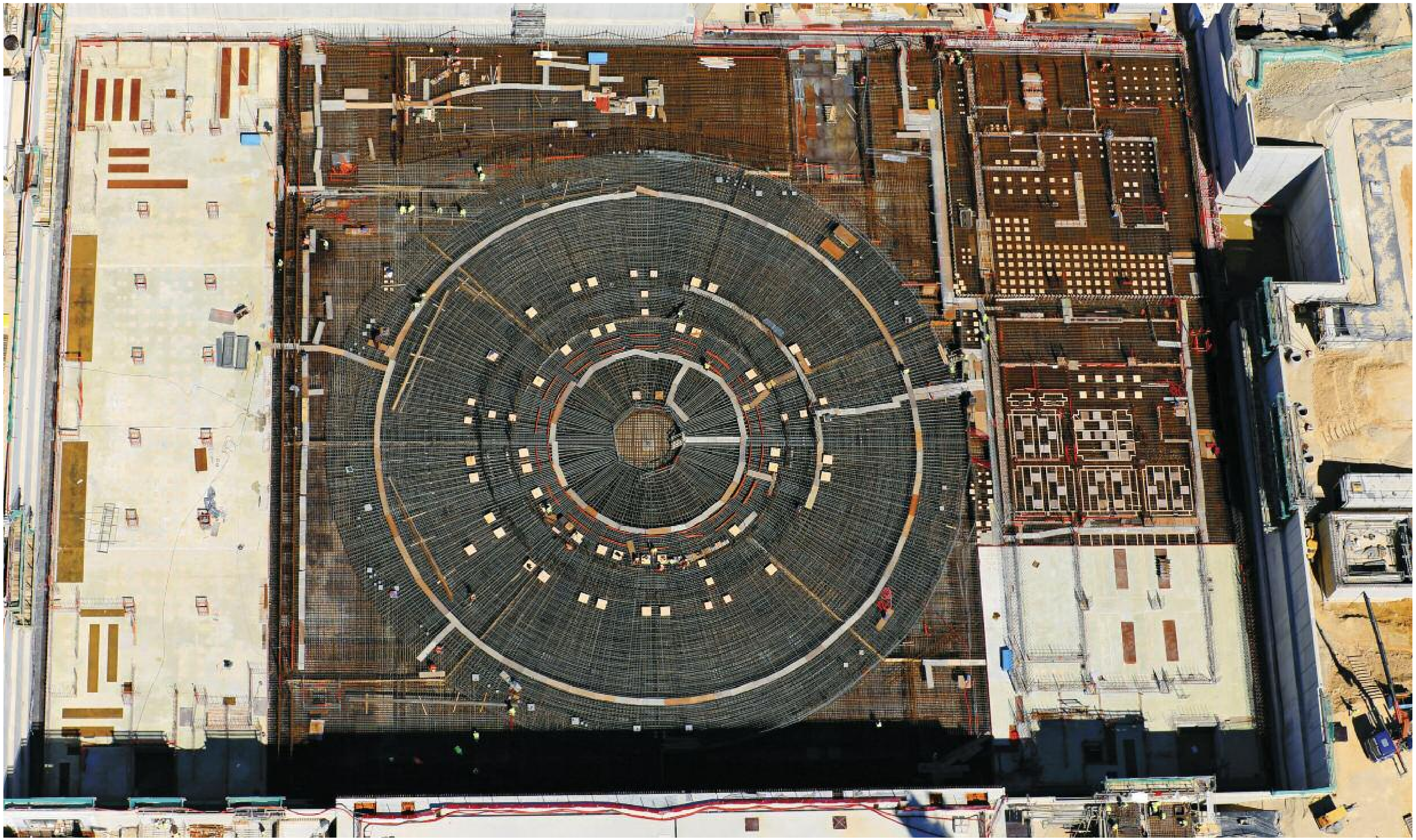


Concrete pouring for the Tritium Building slab (opposite the Diagnostics Building) begins on 19 March 2014. Nearly 1,000 m³ of concrete are employed to fill a 638 m² plot in the northeast corner of the Seismic Pit. *March 2014*

Under the Tokamak

Rebar patterns are at their most complex in the centre of the Seismic Pit, where they will be part of the basemat supporting the ITER Tokamak. There, orthoradial (circular) and orthogonal (right-angled) rebar arrangements interface. *April 2014*

The Seismic Pit from above



The Tokamak Complex is a suite of three buildings on a common foundation. On the left, the finished basemat slab of the Diagnostics Building. On the right, pouring is underway on the Tritium Building slab. In the central area, the circular pattern of rebar that will support the machine. *April 2014*

The Poloidal Field Coils Winding Facility

Too large to travel by road, four out of the Tokamak's six ring-shaped magnets (poloidal field coils) will be manufactured by Europe on site in this 257-metre-long, 49-metre-wide building. *October 2012*

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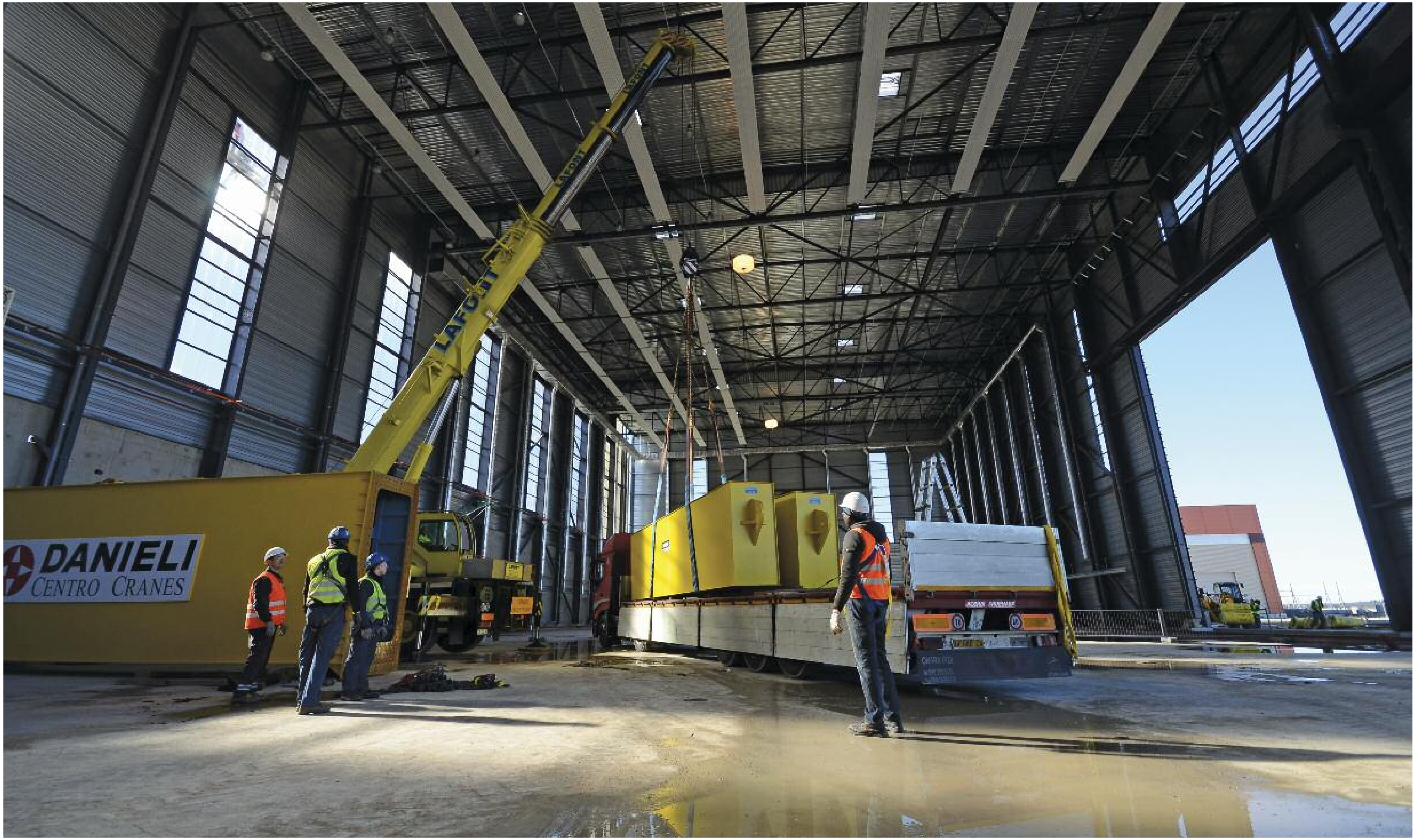
A Sun-like spreader beam

Inside the Poloidal Field Coils Winding Facility, this large, sun-like, spreader beam will permit the very careful and steady transport of the poloidal field coils during the winding and assembly process. It will handle loads up to 50 tons.

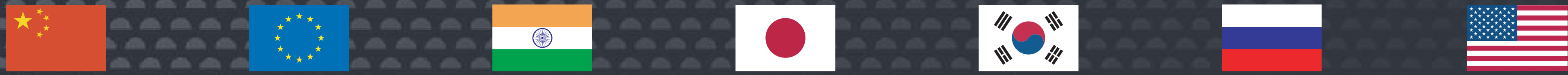
The Cryostat Workshop

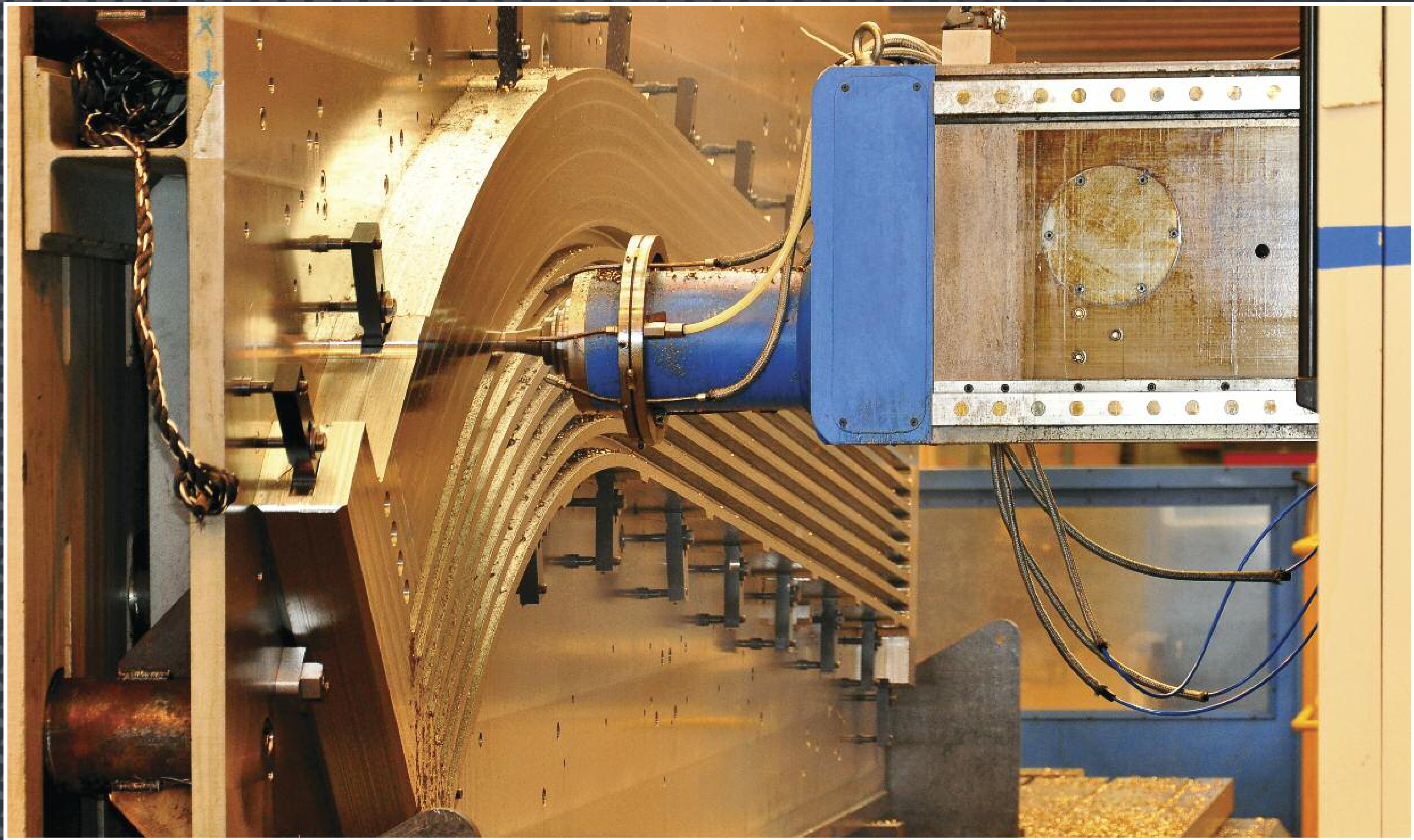
India is responsible for the construction of the large steel-framed temporary Cryostat Workshop where the four main sections of the ITER cryostat – a huge "refrigerator" in which the Tokamak will be enclosed – will be assembled from 54 segments. *January 2014*

Installation of the Cryostat Workshop crane



The first elements of the Cryostat Workshop gantry crane are delivered on site. With a lifting capacity of 200 tons (plus an auxiliary 50-ton hook) the crane will be used to lift and handle the 54 cryostat segments that will arrive from India. *February 2014*





Pre-machining is performed on Europe's first series production radial plate at CNIM, France. *May 2014*

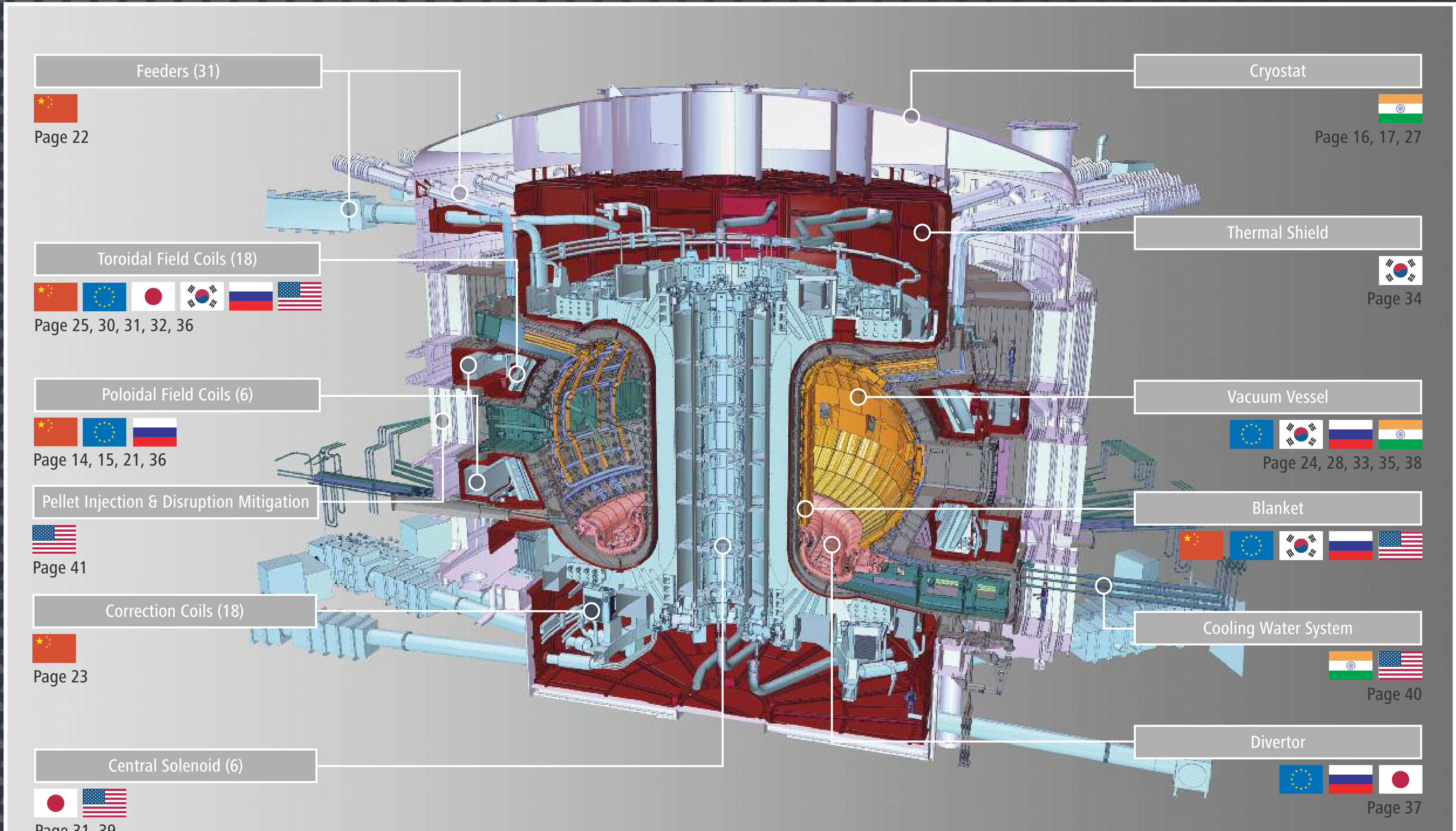
Manufacturing

A unique aspect of ITER implementation is the in-kind procurement system that was established at the onset of the project. Instead of contributing purely financial resources, China, the European Union, India, Japan, Korea, Russia and the United States will be providing 90% of their contributions in the form of machine components, systems and – in the case of Europe – buildings.

Procurement packages are shared equally (~ 9% of the total value) between China, India, Japan, Korea, Russia and the United States; Europe's share, as Host Member, is ~ 45%.

The in-kind procurement process forms the core of ITER founding philosophy, offering the ITER Members invaluable experience in the manufacturing of components for a fusion installation. By contributing to the construction of the experimental machine, the ITER Members are creating the technological and industrial basis for the commercial fusion reactors of the future.

Who manufactures what?



Not all systems and contributions are represented in this illustration.

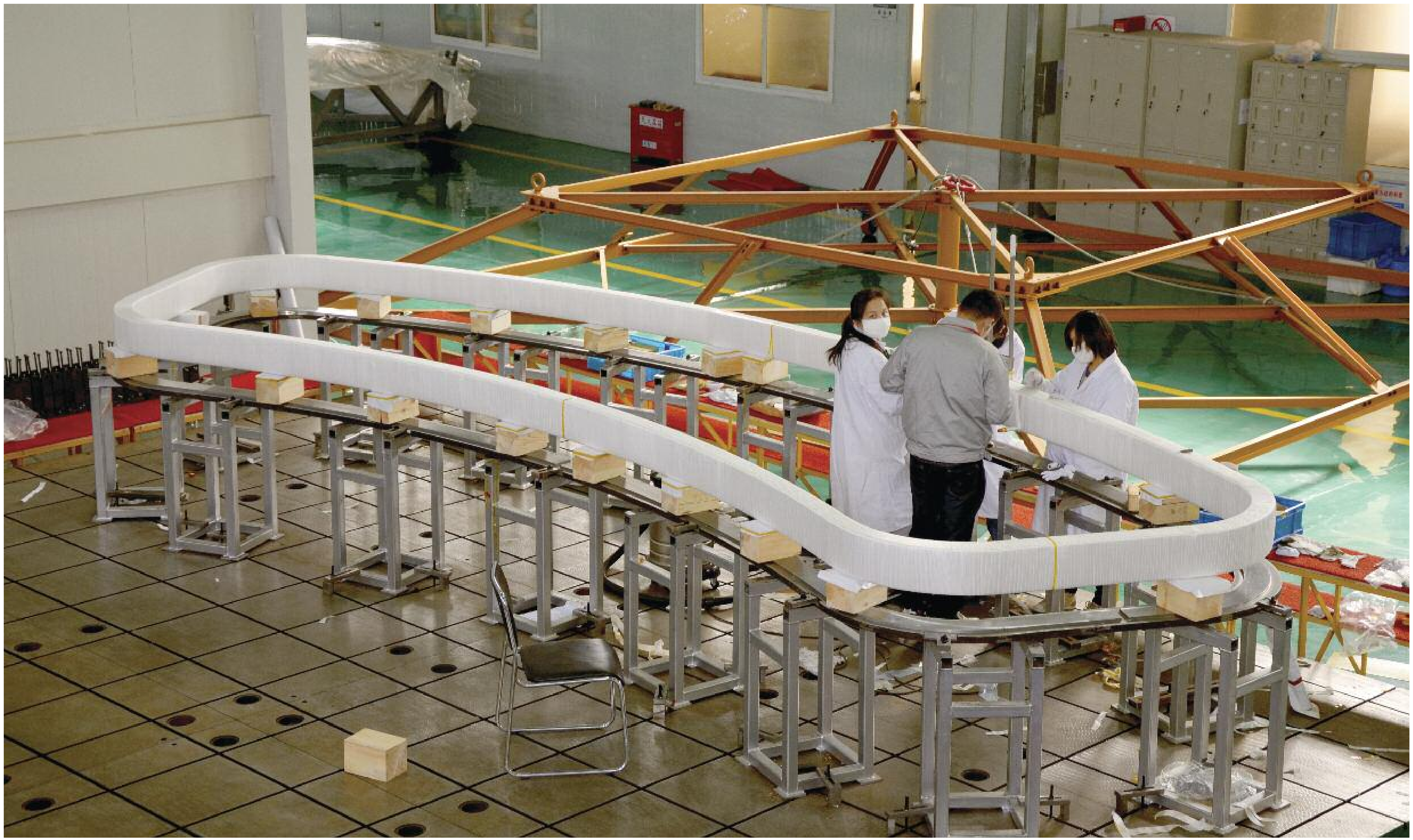
China delivers dummy conductor

The ITER magnet system requires close to 2,800 metric tons of superconducting coils. Before launching actual fabrication, prototypes and "dummies" need to be produced. Here, China delivers a first batch of dummy conductor to the Poloidal Field Coil Winding Facility for fabrication process testing. *June 2013*

Magnet feeders

For the magnet feeders, which bring electrical power and cryogens to the magnets, coil terminal boxes provide housing for the connections of the system. Machining was completed by Shanghai Aerospace Equipment in China for the first of 31 boxes in April 2014. The first box is now undergoing integral testing at the Institute of Plasma Physics, Chinese Academy of Sciences (ASIPP).

Correction coils



Eighteen correction coils will be installed on ITER to correct the local imperfections of the magnetic fields. Following mockup development (pictured), manufacturing is scheduled to begin on the first correction coil in the summer of 2014 at the Institute of Plasma Physics, Chinese Academy of Sciences (ASIPP).

Prototypes for the vacuum vessel

Europe is responsible for seven of the nine sectors that make up the ITER vacuum vessel. A prototype, one-third of the size of the actual component, is currently undergoing bend-testing in Italy. © *Walter Tosto*

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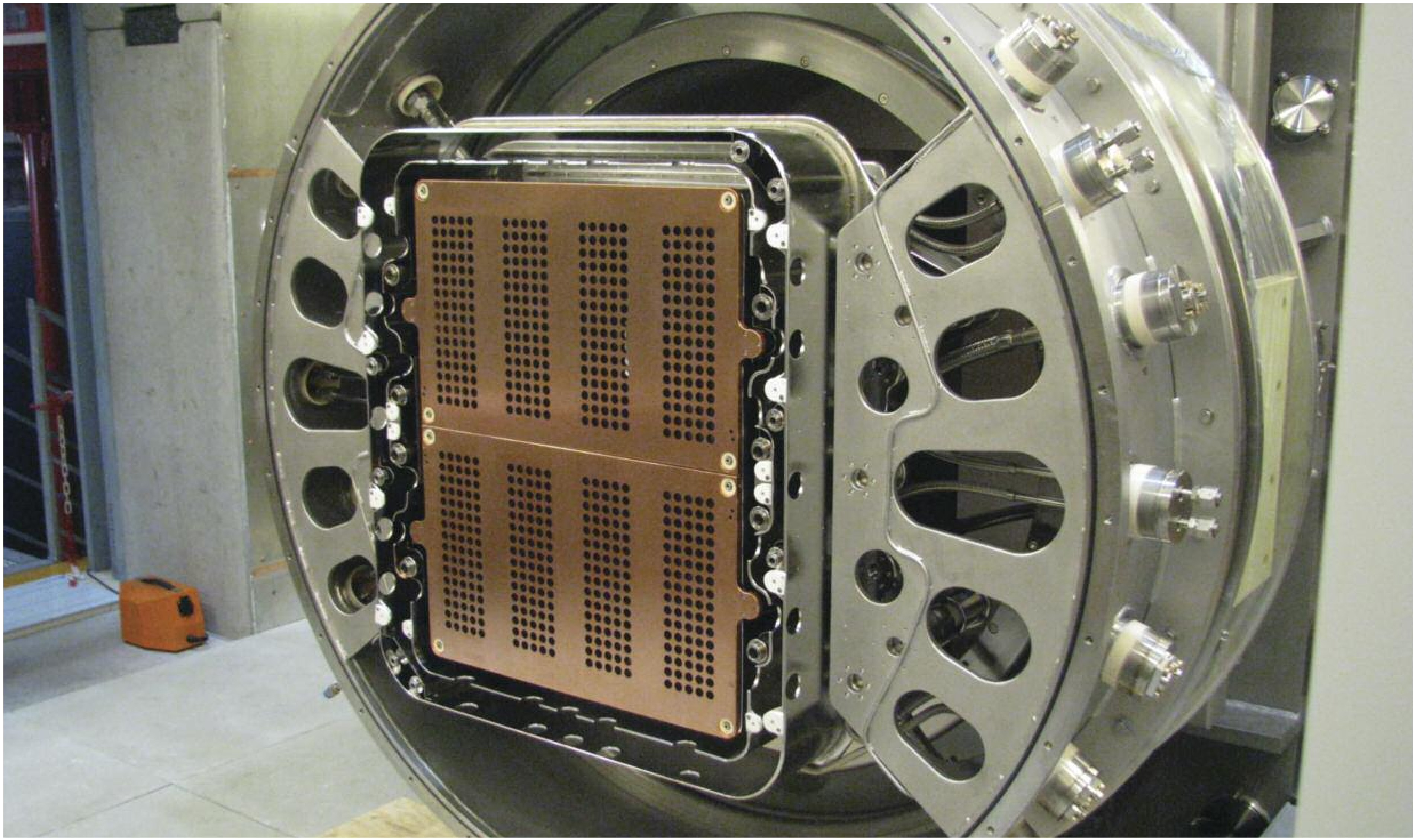
Laser welding robots at work on a “double pancake”

Toroidal field coil conductors will be shaped into layers called double pancakes, seven of which will constitute one toroidal field winding pack. Pictured, three laser welding robots work simultaneously on the double pancake cover plates.

R&D for neutral beam injection

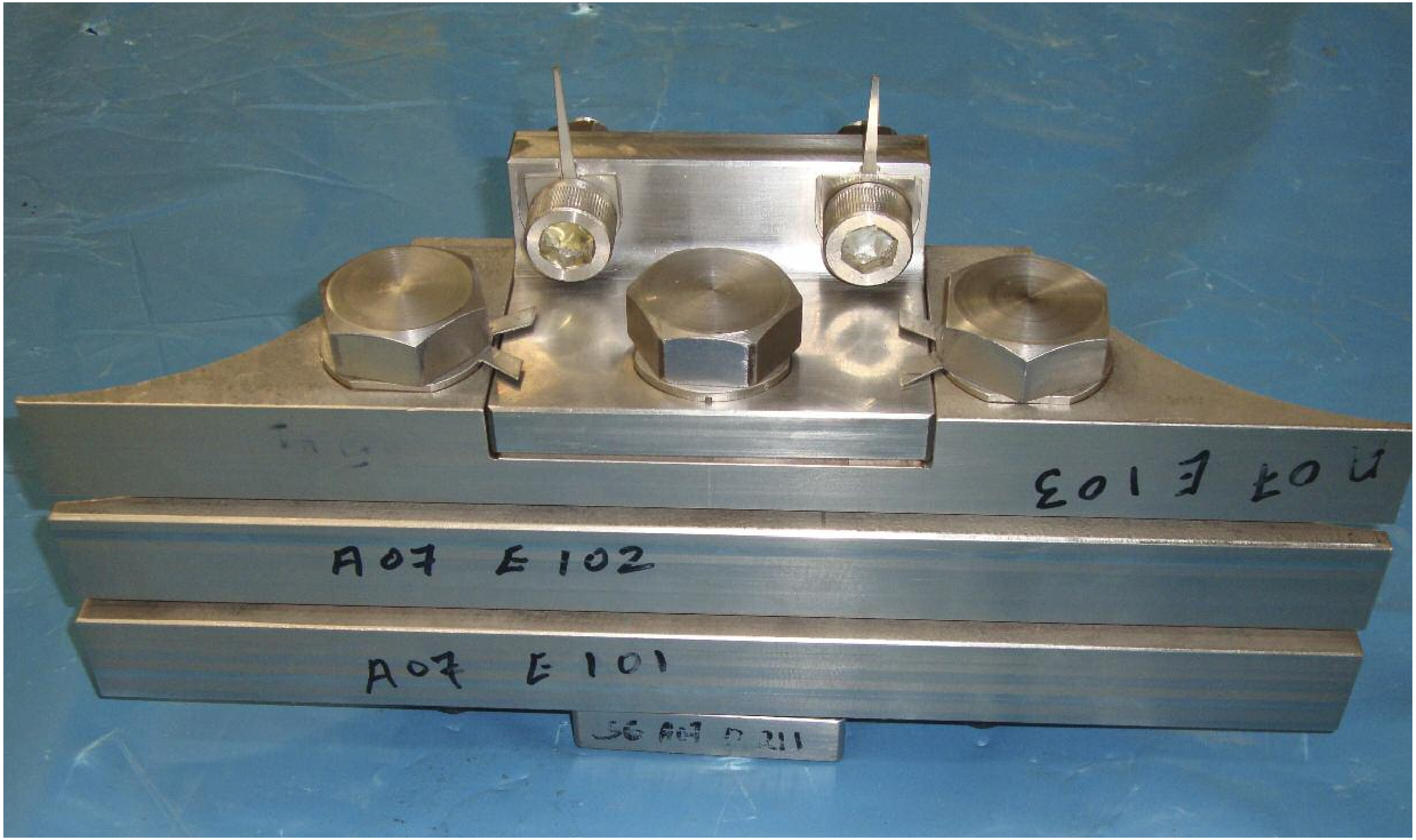


The ELISE experiment in Garching, Germany, is contributing to the development of one of ITER's main heating systems – neutral beam heating – which will inject high energy particles into the plasma in order to heat it up to the temperature necessary for fusion to occur. © *Max Planck Institute for Plasma Physics (IPP)*

Real-scale prototypes for the cryostat

In Hazira, on the northwestern coast of India, fabrication of real-scale prototypes for the cryostat has begun. Pictured here is a portion of the horizontal plate (60° sector) for the cryostat base section, made of 105-mm-thick stainless steel.

8,000 in-wall shielding components



This in-wall shielding block assembly (600 mm long, 180 mm wide and 140 mm high) will be installed in the vacuum vessel. India will produce approximately 8,000 such components of different types and sizes and send them to Europe and Korea for further assembly into the vacuum vessel sectors.

Testing high voltage power supplies

At ITER India, the high voltage power supply for ion cyclotron radio frequency heating (ICRH) is readied for testing.

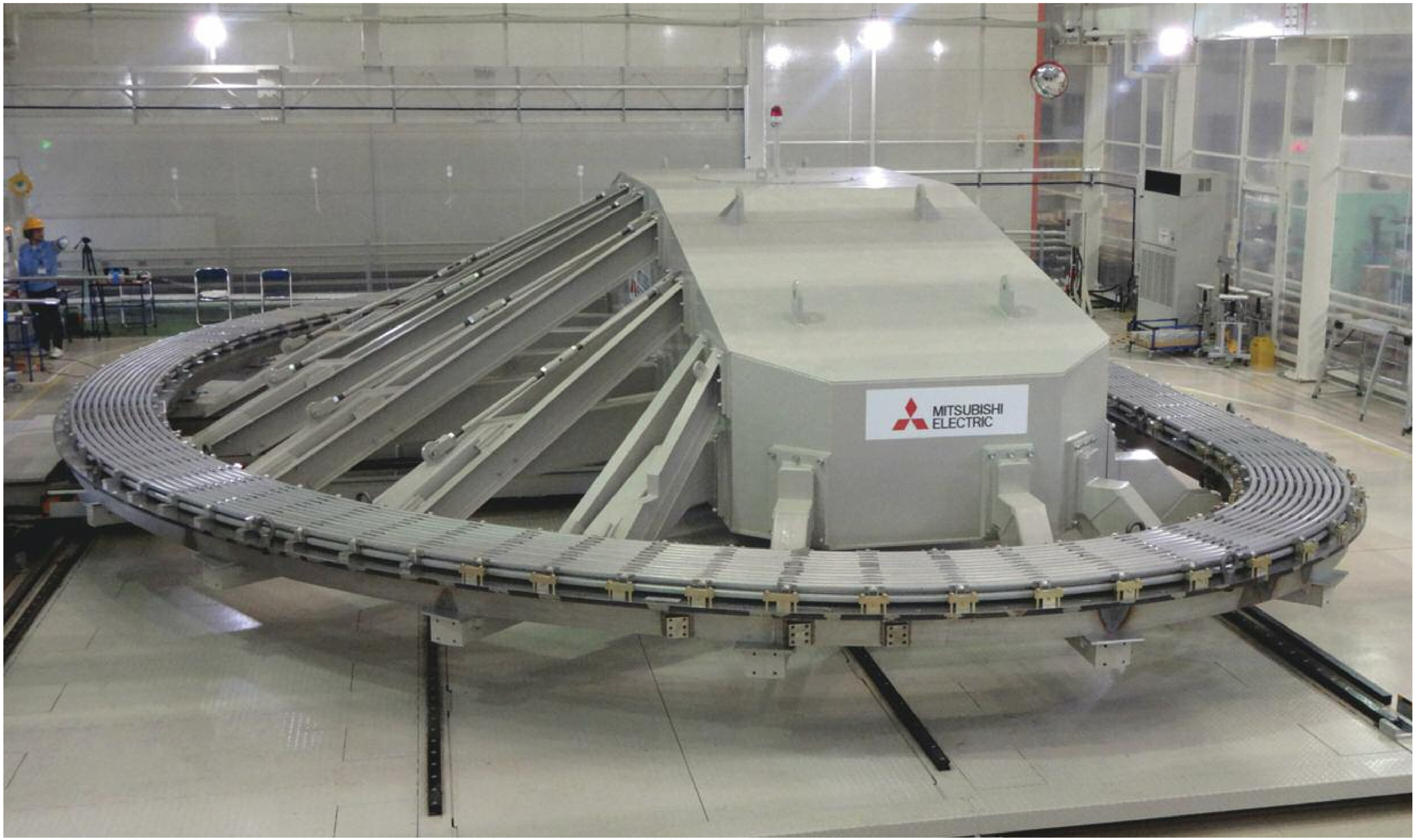
Spooling toroidal field conductor

Upon the completion of jacketing, 760-metre-long toroidal field conductor unit lengths are spooled to facilitate transportation. In the image, three unit lengths are prepared for transport at the Wakamatsu factory, Nippon Steel & Sumikin Engineering.

From billets to strands

The superconducting strands in the ITER central solenoid and toroidal field coils are made of niobium-tin alloy. At JASTEC's Moji factory, workers prepare 40- to 100-kg "billets" that will eventually be transformed into millimetre-thin strands.

Qualifying toroidal field coil winding



ITER's 360-ton toroidal field magnets will be the largest and most powerful superconducting magnets ever manufactured. The magnet coils are made from seven "double pancakes" containing the insulated niobium-tin conductor. Here, at Mitsubishi Heavy Industry's Futami factory, winding is completed on a dummy double pancake – the last qualification step before starting series production.

Vacuum vessel manufacturing underway

Manufacturing of the ITER vacuum vessel sectors is underway in Korea, which is responsible for procuring two sectors out of nine. Pictured is the upper segment of Sector #6, made of special ITER-grade steel, at Hyundai Heavy Industries in Ulsan, South Korea.

Prototype thermal shield under fabrication

Inserted between the toroidal field magnets and the vacuum vessel, the ITER thermal shield system minimizes the thermal radiation to the superconducting magnets. In Korea, prototype fabrication has begun at SFA Engineering Corp.

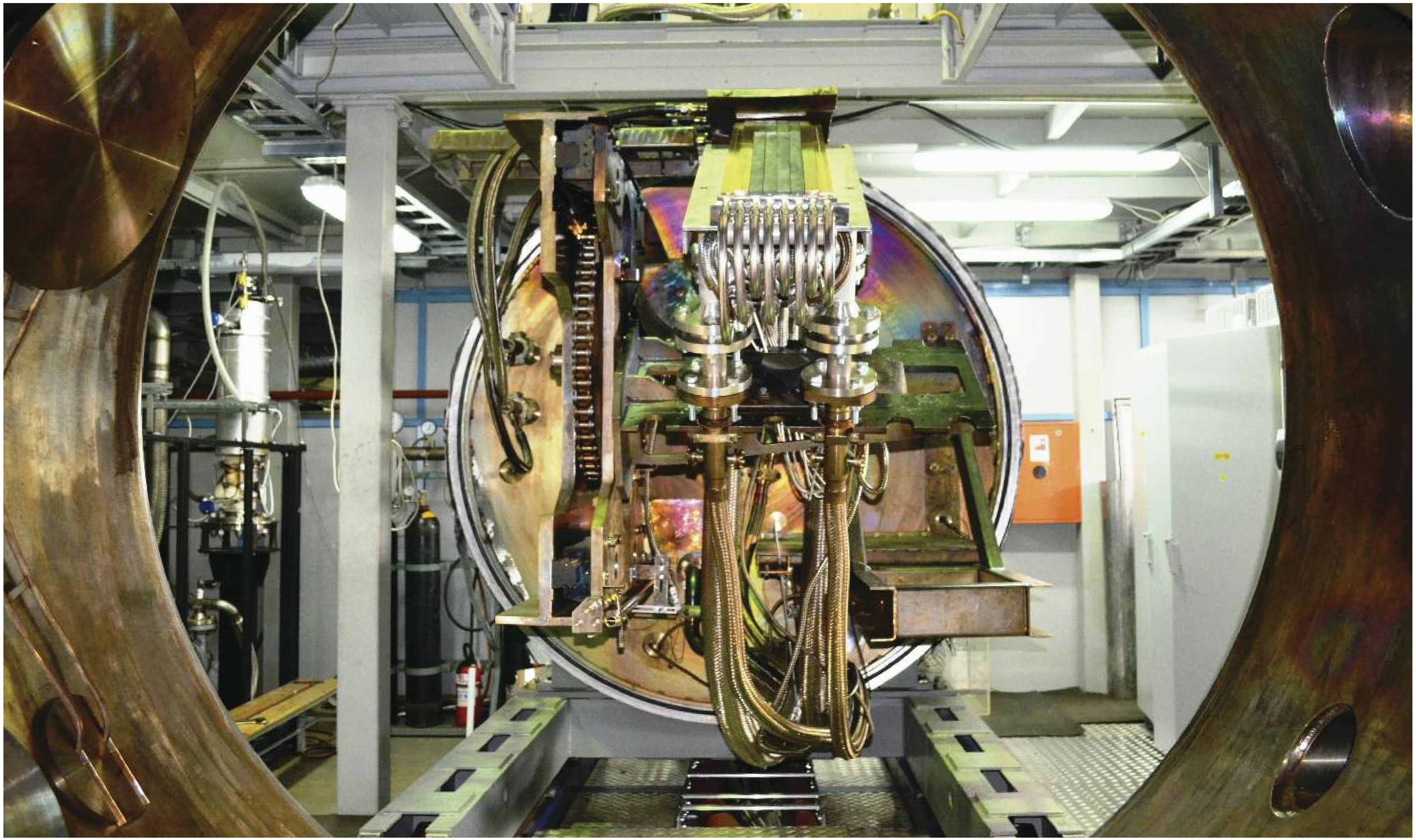
Designing specialized assembly tooling

Korea is responsible for procuring 128 different types of purpose-built tools for the assembly of the ITER Tokamak. Pictured is a four-metre-high sector assembly tool mockup (one-fifth of the actual size) that will be used to handle the vacuum vessel sectors.

A strand manufacturing facility

The Chepetsky Mechanical Plant (Glazov, Udmurtia) provides Russian conductor manufacturers with superconducting strands for the cabling, jacketing and spooling of toroidal field and poloidal field conductors.

High heat flux testing of divertor targets



Located at the very bottom of the vacuum vessel, the ITER divertor will withstand a heat load comparable to that at the surface of the Sun. Pictured: The high heat flux testing of a divertor target prototype at the Efremov Institute in Saint Petersburg.

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Testing the port plugs

In early April, Cryogenmash (near Moscow, Russia) starts a series of gasket tests for the ITER Port Plug Test Facility, where port plugs – the large, leak-tight stainless steel plugs that seal the vacuum vessel's openings and that weigh up to 50 tons – will be submitted to vacuum, heat and functional testing prior to their installation in the machine.

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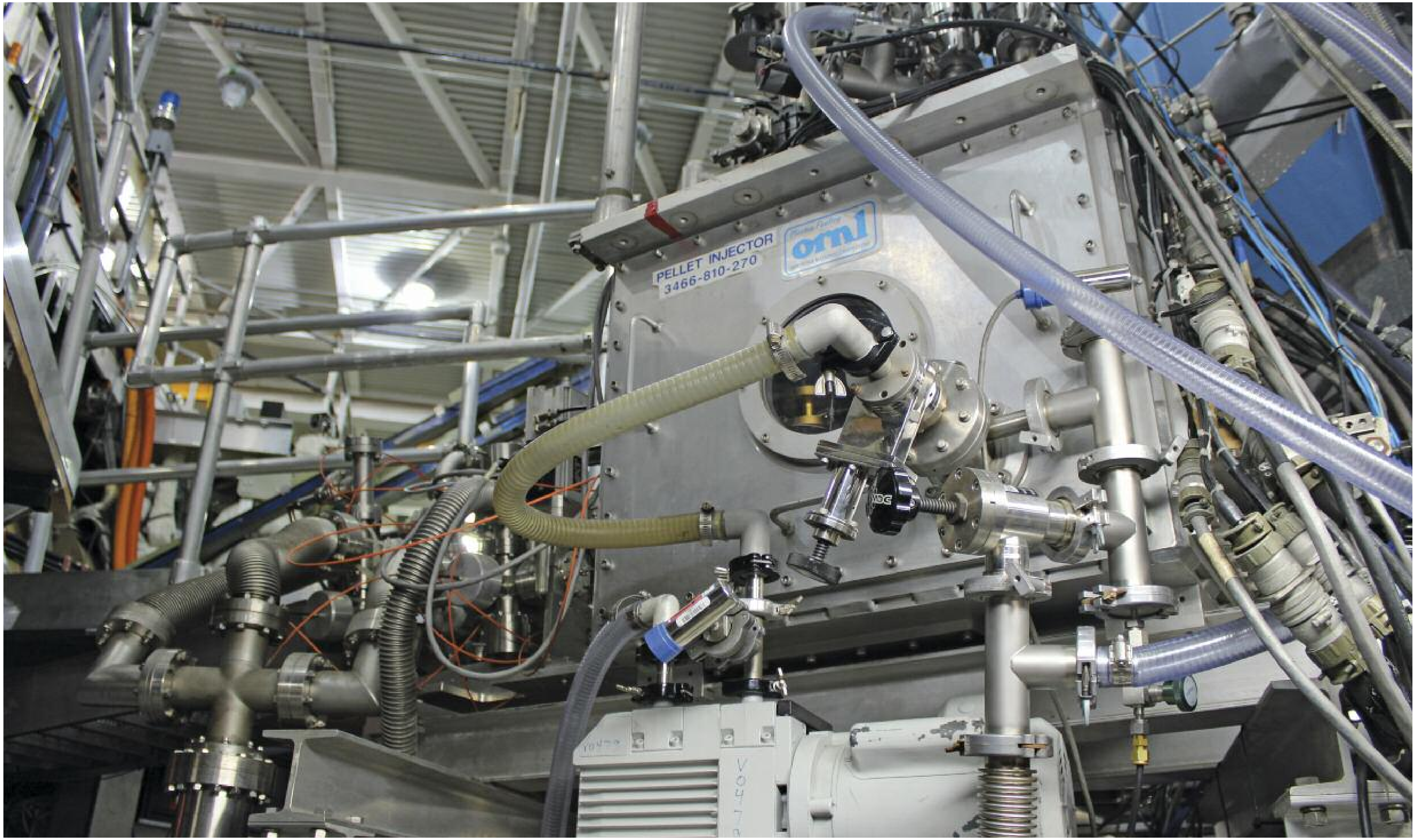
Tie plate for the central solenoid

The 1,000-ton, 13 metre-tall, 4-metre-wide central solenoid will form the backbone of the ITER Tokamak. This one-piece tie plate prototype for the central solenoid structure was forged by Kind, LLC in Gummersbach, Germany and then machined by G&G Steel, Inc. in Russellville, Alabama, USA.

Drain tanks for the cooling water system

In Camden, New Jersey, the Joseph Oat Corporation has begun fabrication activities on four 10-metre-tall, 78 metric ton drain tanks and one 5-metre-tall, 46 metric ton drain tank for ITER's cooling water system.

Fuelling the machine through pellet injection



Heated to temperatures of up to 150 million °C, the plasma will be fed frozen pellets of fuel, fired into the vacuum vessel by pellet injectors. Here, a pellet injector developed by Oak Ridge National Laboratory is installed on the DIII-D tokamak (San Diego, California) for testing. *Photo: US ITER*

Delivering components to the ITER site

The ITER components will travel by sea to the Mediterranean coast of France. Upon arrival, they will be loaded onto a 352-wheel trailer that will travel along a 104-km dedicated itinerary to the ITER site. The transport of a dummy load made of concrete blocks (600 tons), that mimicks the most exceptional dimensions of the ITER loads (10 metres tall, 33 metres long, 9 metres wide), is first tested during the nights of 16-20 September 2013.

Second test convoy takes to the sea

Loaded on a specially designed barge, the trailer carrying the 600-ton dummy load is ferried from the Fos-sur-Mer harbour near Marseille to the northern shore of Étang de Berre where the dedicated ITER Itinerary begins. The operation was part of the second test convoy operation organized on 1-8 April 2014.

An early arrival

In the early hours of Friday 8 April 2014, the second ITER Itinerary test convoy arrives successfully on site. This second week-long test, including the crossing of an inland sea by barge, is the last dry run before the transport of ITER components begins in earnest later this year.

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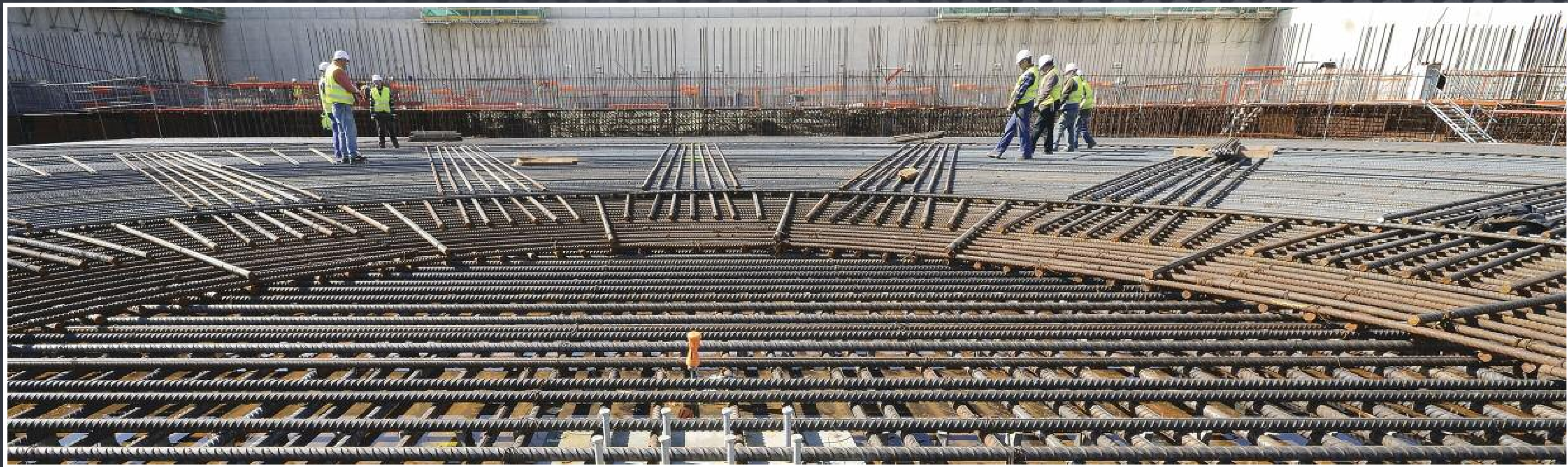

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