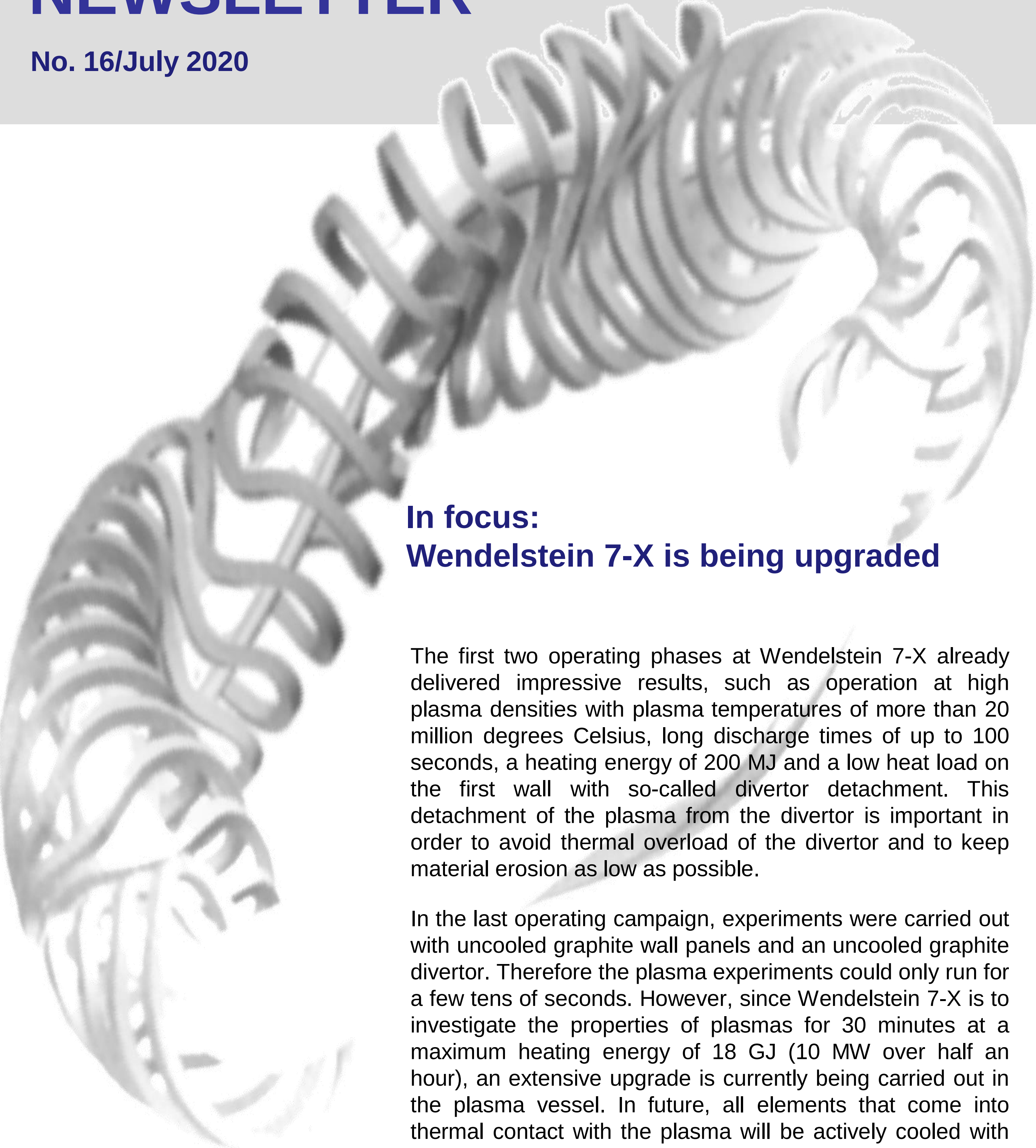
Wendelstein 7-X

NEWSLETTER

No. 16/July 2020



In focus:
Wendelstein 7-X is being upgraded

The first two operating phases at Wendelstein 7-X already delivered impressive results, such as operation at high plasma densities with plasma temperatures of more than 20 million degrees Celsius, long discharge times of up to 100 seconds, a heating energy of 200 MJ and a low heat load on the first wall with so-called divertor detachment. This detachment of the plasma from the divertor is important in order to avoid thermal overload of the divertor and to keep material erosion as low as possible.

In the last operating campaign, experiments were carried out with uncooled graphite wall panels and an uncooled graphite divertor. Therefore the plasma experiments could only run for a few tens of seconds. However, since Wendelstein 7-X is to investigate the properties of plasmas for 30 minutes at a maximum heating energy of 18 GJ (10 MW over half an hour), an extensive upgrade is currently being carried out in the plasma vessel. In future, all elements that come into thermal contact with the plasma will be actively cooled with water, which corresponds to a total area of about 250 m^2. The cooling system required for this consists of more than 600 separate water cooling circuits (see Fig. 1) - a total of about 4.5 kilometres of water pipes will be installed.

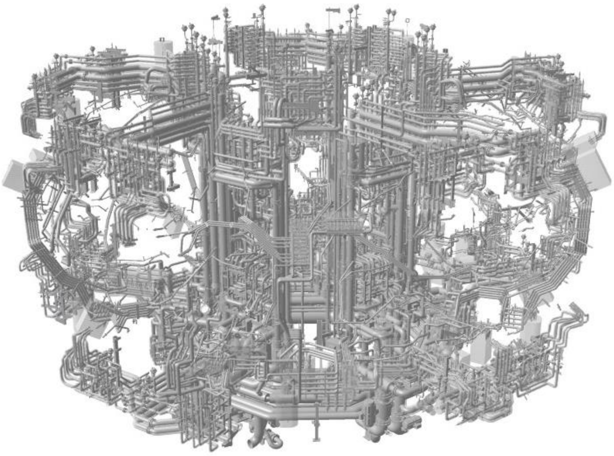


Fig. 1 Cooling-water system around the torus of Wendelstein 7-X, graphic: IPP

The heart of the new in-vessel components is the high-heat-flux divertor, the component with the highest heat load in the plasma vessel. The 120 divertor plates cover an area of 19 m^2 in the plasma vessel and thus protect precisely those wall areas to which the particles and heat fluxes from the edge of the plasma are magnetically directed. The surface of the divertor plates facing the plasma consists of 18,000 carbon-fibre-reinforced carbon tiles that can withstand very high temperatures and dissipate heat well. Since the tiles have to withstand 10 million watts per square meter continuously, they are welded onto plates of a copper-chromium-zirconium alloy interfused with cooling channels. All parts of the new divertor are finished and will be connected to the cooling system in the next few months. The connection of the complex shaped cooling pipe couplings to the divertor is a special challenge due to the extreme space restrictions in the plasma vessel. The welding work on the connections of the water supply lines must meet very high quality requirements in order to prevent leaks in the plasma vessel.

Behind a gap in the middle of each divertor there is a cryogenic pump which removes the impinging gas and impurity particles. Thus, the divertor can be used to control the purity and density of the plasma. Each of the ten cryopumps must be supplied with liquid helium and liquid nitrogen. In the current reconstruction phase, the cryogenic system needs to be upgraded. This involves the installation of a new 55 m long transfer line from the cryogenic system to the new cryovalve box (see Fig. 2) and 10 transfer lines to the cryopumps.

Fig. 2 cryo valve box located in the basement, photo: IPP, B. Kemnitz

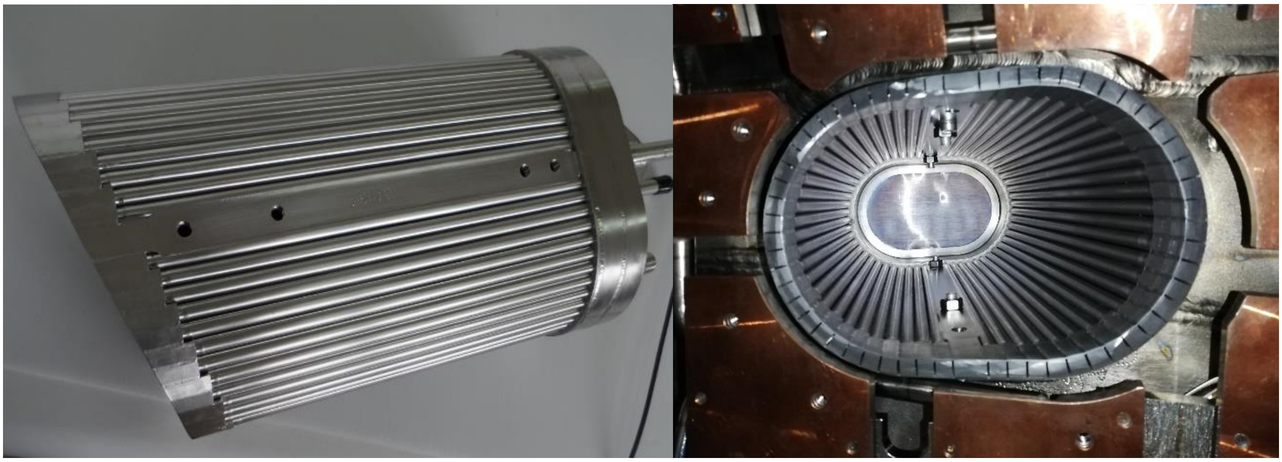


Fig. 3 water-cooled liner before and after the installation in a port, photos: IPP

During operation of Wendelstein 7-X, the ports which connect the plasma vessel to the outside world and which serve for observation, supply and heating of the plasma must also be protected by water-cooled liners against inadmissible heating by radiation from the plasma. The cooling system is designed for a maximum power input of 50 to 100 kW/m^2 and operates according to the heat exchanger principle: cold water flows in 4 mm tubes, which, in turn, are located within 8 mm thick pipes. The return flow then takes place in the space between the two pipes. The actual lining of the ports is constructed from a large number of such pipes. This design allows manufacturing the various port shapes - round, rectangular or oval - that fit precisely into the narrow spaces of 15 to 20 mm.

Electron cyclotron resonance heating (ECRH) is the predominant method for heating the Wendelstein 7-X plasma. Each of the ten 140 GHz microwave senders provides about 0.8 MW.
In the last operating campaign, the first neutral beam injector with two ion sources was used. The total power deposited in the plasma was 1.7 MW. The neutral beam injection system is now being extended to two neutral beam injectors with two sources each and a total heating power of 7 MW (particle energy 55 keV) for the injection of hydrogen ions.
Another new heating system to be used in the next operating phase is ion cyclotron resonance heating with a heating capacity of 1.5 MW.

The range of diagnostics is being expanded by seven new systems. The measuring instruments already available will be extensively enhanced and improved.

The implementation of necessary measures to protect the staff from COVID-19 has inevitably affected the timeline of the Wendelstein 7-X upgrade work. At present, a new assembly schedule and, as a result, a new commissioning schedule are being prepared and agreed with the funding authorities. However, it is already clear that plasma operation will no longer be possible in 2021.

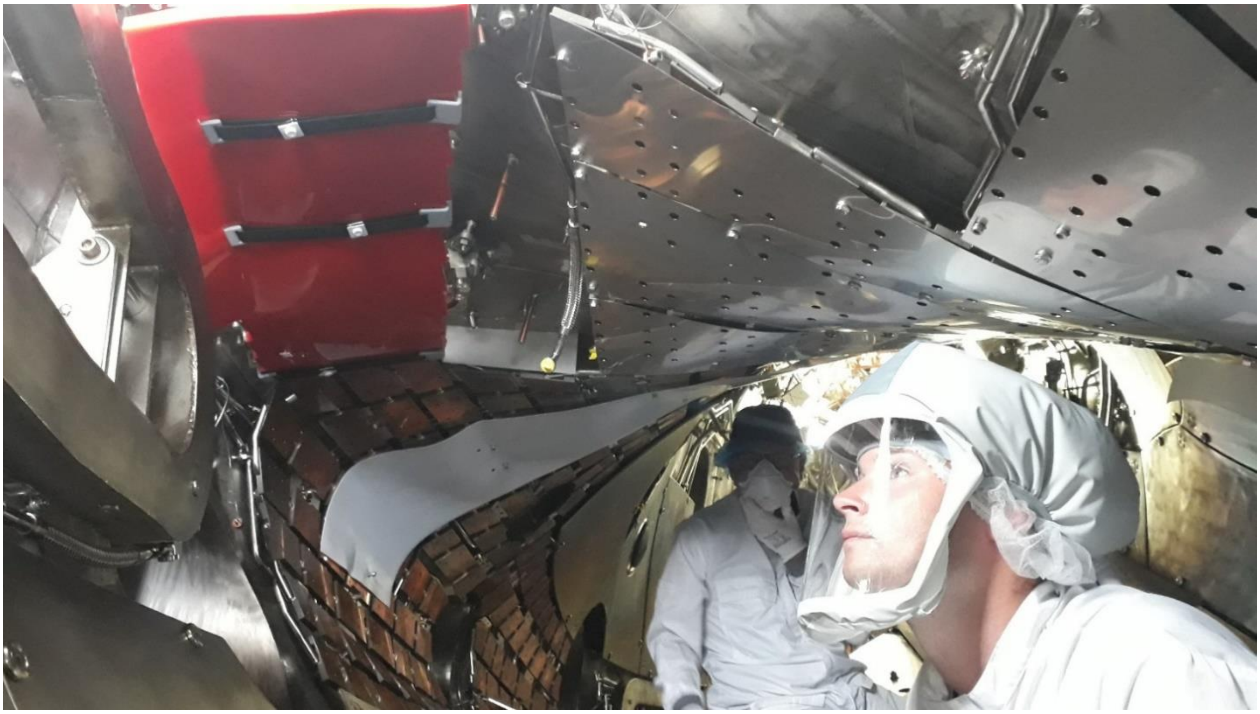


Fig. 4 Work in the plasma vessel in compliance with the infection protection rules, photo: IPP, J. Liebig

When plasma operation starts again after the long break, it will be necessary to carefully approach higher heating powers and longer plasma pulses in order to be able to test all new and upgraded components in operation. The heating power integrated over time or the energy converted in a plasma pulse will then be gradually increased to the maximum of 18 GJ. However, this is a scientific and technical programme requiring several years.

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