Press Release

Linde plays key role in Wendelstein 7-X plasma generation

Munich, 4 February 2016: The Max Planck Institute for Plasma Physics (IPP), developers of the Wendelstein 7-X fusion device in Greifswald, Germany, have reported their success in generating hydrogen plasma for the first time in the fusion experiment Wendelstein 7-X. As part of the experiment, a ground-breaking refrigeration system developed by Linde Kryotechnik, the Swiss-based cryogenic specialist and part of The Linde Group's Engineering Division, was used in the vital low temperature cooling operations.

The objective of W7-X is to demonstrate continuous operation under plasma conditions – a precondition for developing climate friendly power generation which harvests energy from the fusion of atomic nuclei. The IPP suggest that as little as one gram of fusion fuel can deliver the same amount of energy as eleven tons of coal and could potentially power the world's energy needs for an unlimited period. As such, scientists around the world have spent decades trying to deliver this ultimate form of energy production.

For successful plasma creation within the W7-X many significant technological challenges had to be overcome including the development of a pioneering refrigeration system capable of cooling the fifty 3.5 metre magnetic coils to superconduction temperature close to absolute zero with supercritical helium. With fusion running in plasma superheated to around 100 million degrees C, the strong magnetic fields are vital in order to prevent the plasma from coming into contact with the fusion chamber wall and cooling down. Confined by the magnetic fields, the plasma is suspended contact-free in the vacuum chamber interior.

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The unique cooling system, which began with a feasibility study as early as 1997, constitutes a multitude of technological breakthroughs and is one of the most sophisticated and complex refrigeration plants ever built. The pioneering developments lie primarily in the control of the system, especially the starting sequence of the cold compressors and helium pumps. Due to the unique properties of helium, the start- up of the system has been compared to a remote controlled start of a Formula One car on ice, with no latitude given for the slightest error.

For cooling the W7-X, refrigeration needed to be highly efficient across a wide capacity range, servicing the W7-X's multiple consumers of cooling including magnetic coils, coil housings and support structures, cryo-vacuum pumps and shield, current leads, in addition to the cryostat heat radiation shield. An on-site 10,000 litre Dewar allowed for temporary storage of the liquid helium, enabling fast transition between operating modes up to peak demand. The helium refrigeration system, encompassing 15 machines, is also self-adjusting, having the capability to quickly connect or disconnect from each W7-X consumer via 100 control valves and 500 analogue signals from measurement instruments being processed by three programmable logic controllers.

About The Linde Group

In the 2014 financial year, The Linde Group generated revenue of EUR 17.047 bn, making it the largest gases and engineering company in the world with approximately 65,500 employees working in more than 100 countries worldwide. The strategy of The Linde Group is geared towards long-term profitable growth and focuses on the expansion of its international business with forward-looking products and services. Linde acts responsibly towards its shareholders, business partners, employees, society and the environment – in every one of its business areas, regions and locations across the globe. The

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company is committed to technologies and products that unite the goals of customer value and sustainable development.

For more information, see The Linde Group online at www.linde.com.

For further information on the Wendelstein 7-X fusion project, see www.linde-kryotechnik.ch/WENDELSTEIN7X_en

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