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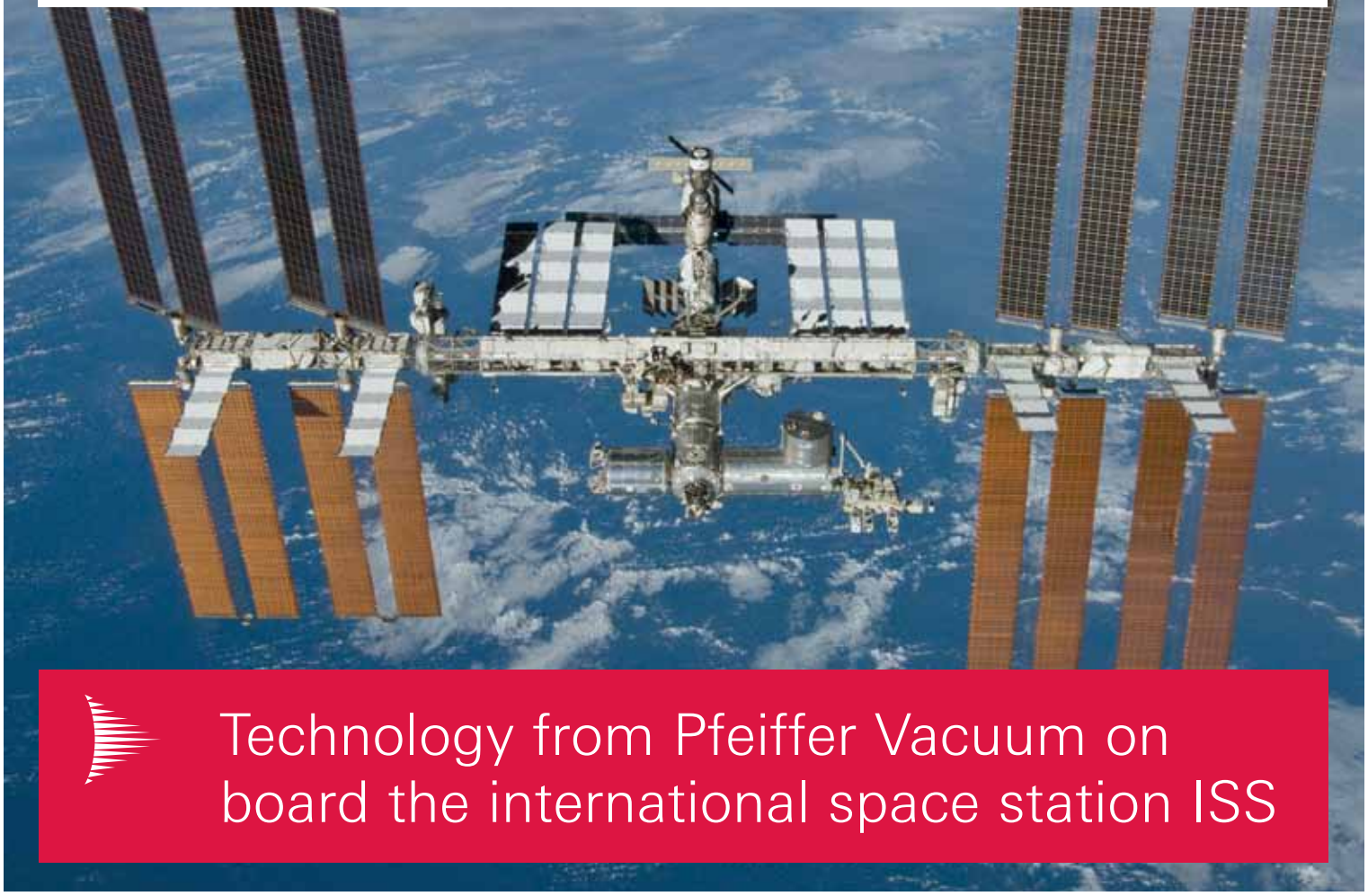
Vacuum Solutions

Resarch & Development



Technology from Pfeiffer Vacuum on board the international space station ISS

Containerless processing in space

In mid 2011, Pfeiffer Vacuum delivered turbopumps and vacuum gauges to EADS Astrium Space Transportation for use in an experiment on board the international space station (ISS)[1)]. The turbopump is based on the HiPace 80 model which, together with the vacuum gauges, was adapted to the special conditions encountered in space through a co-creative process in cooperation with the client. The turbopump and vacuum gauges will be used in the Columbus European Research Laboratory in the MSL-EML module (Materials Science Laboratory - Electromagnetic Levitator). This is where the basic experiment planned for containerless melting of material samples under conditions of weightlessness will take place. The principal aim of the research is to efficiently produce materials with improved properties.

When this project begins, this will be the second Pfeiffer Vacuum turbopump to be used in the ISS space station. In 2001, a specially designed Compact Turbo model was put to work in the Columbus module for investigating plasma crystals.

[1)] The research project is commissioned by the German Aerospace Center (DLR) and is funded by the German Federal Ministry of Economics and Technology under grant no. 50WP0808.

Experiment under conditions of weightlessness

In conventional melting down of materials, substances are heated in a container. Due to the tremendous heat which is generated during this process, foreign matter from the container walls gets into the molten mass. This places severe limits on the level of purity which these samples can achieve.

The experimental set-up designed by the aerospace company Astrium, however, makes it possible to produce particularly pure materials since the use of a container can be dispensed with. But how can materials be melted if they are not in a container?

Under conditions of weightlessness in space, the specimen is held in place in a special chamber under high vacuum by exposing it to an electromagnetic field. This experiment is conditional upon the material being electrically conductive. Under these conditions the substances, will disturb the purity of the sample, do not come into contact with other materials and levitate in the sample chamber without any contact.

Once the sample is held in place, it is heated to up to 2,100°C in one minute using a high-frequency field - similarly to what happens in a microwave - until it has melted. Due to the surface tension, the resulting liquid takes on the form of a perfect sphere in the absence of gravity.

The sample chamber holds up to 18 exchangeable specimens with a diameter of 5 to 8 mm. The chamber is equipped with the modified HiPace 80 and a special vacuum gauge which is also supplied by Pfeiffer Vacuum.

The melting and solidification process is recorded by two high-speed cameras during the experiment, which allows the process itself to be scrutinized, modified and optimized.

Unique conditions in space

The turbopumps used for the experiment were made to meet the special demands of manned spaceflight. Before the pumps receive the approval to work in the ISS, safety considerations dictate that all operating parts must be subjected to extensive testing and documentation that far exceeds the usual industrial standards.

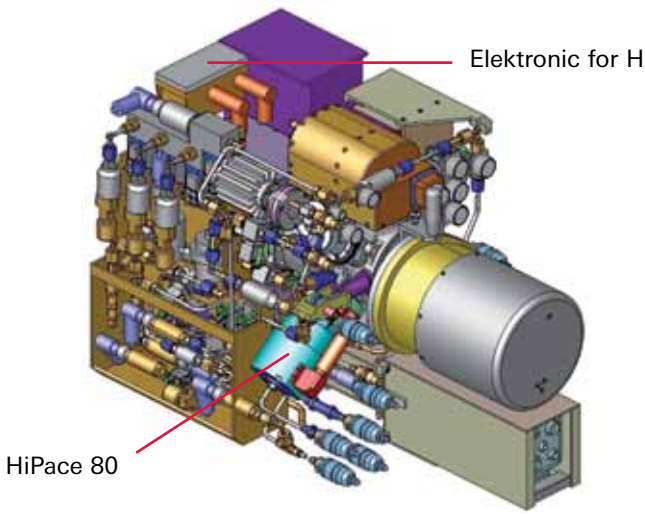
The external screws and housing parts, for instance, underwent non-destructive materials testing to detect microscopic cracks in order to rule out the possibility of premature material fatigue. The housing was electropolished to minimize the accumulation of foreign particles, and was coated and flanged for double seals. This double equipment is mandatory due to safety regulations. In addition, the printed circuit boards are specially treated and any projecting components are fixed in place to ensure they are not damaged by vibrations such as during the rocket launch. Only gold-plated connectors with a limited number of connector operation cycles can be used. This prevents the gold plating becoming corroded and damaged.

For the experiment on board the ISS, the standard pressure in space is not sufficient to evacuate the vacuum chamber sufficiently for the experiment. There are still too many molecules in the environment which could get into the molten mass during the experiment. The vacuum in space is therefore used as a natural backing pump for the turbopump. Using the HiPace, the vacuum chamber is evacuated to a pressure of $1 \cdot 10^{-9}$ hPA, up to two orders of magnitude lower than the pressure in the space station environment.

Outlook

Considerable changes have taken place in manned spaceflight in recent years. The NASA's multiple-use space shuttle missions, for instance, were ended last year. For this reason, the HiPace was sent to the ISS with a conventional launch vehicle in 2014.

The basic materials research experiment at the ISS space station will enable researchers to learn more about the complex thermophysical properties and phase formation of high-purity materials. These unique results can only be obtained under conditions of weightlessness and ultra-high vacuum.



Furnace for containerless melting in space

Modified HiPace 80 turbopump with external drive electronics

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