# Vacuum technology on a research expedition to the Arctic

**Employment of a turbopump on a mass spectrometer.**

Pfeiffer Vacuum, a supplier of custom vacuum solutions, has sent its products to the Arctic to help in research.

Vacuum technology was used on a Swedish icebreaker near 87 degrees north latitude to aid in researching the reasons why Arctic pack ice is melting.

A proton transfer reaction time of flight mass spectrometer (PTR-TOFMS) equipped with innovative Pfeiffer Vacuum turbopumps (SplitFlow turbos) was used in connection with the Arctic Summer Cloud Ocean Study (ASCOS). The study was conducted in the summer of 2008 on board the icebreaker Oden in the far north (up to 87 degrees north latitude). ASCOS was a six-week field study conducted within the framework of the International Polar Year (IPY), which involved a 34-person international team of researchers. Two scientists from the University of Innsbruck, Mag. Markus Müller and Dr. Martin Graus, were invited to participate with a newly developed PTR-TOFMS.
The study includes the fields of marine biology, oceanography, meteorology, aerosol chemistry and physics, as well as atmospheric chemistry. The mission of ASCOS is to provide a better understanding of the primary factors in the development of the aerosol cloud system during the Arctic summer. This multidisciplinary approach provided urgently needed scientific data about the inexplicably rapid melting of the permanent pack ice. In order to refine future climate projections, one of the objectives is to realistically describe the lower cloud levels in climate models. A number of cutting-edge atmospheric measurement units (e.g. mass spectrome-

*SplitFlow™ turbo*

ters) were employed to gather high-quality, unique data. As part of the work on the chemistry of the atmosphere, a PTR-TOFMS from Innsbruck equipped with a Pfeiffer Vacuum turbopump was employed. Organic trace gases were continuously measured throughout a broad mass range with a temporal resolution of one minute. In addition, air samples were taken by helicopter at altitudes of up to 3,000 m and analyzed in order to obtain vertical trace gas profiles. The data that were collected, including aerosol data and meteorological information, are needed in order to provide a better understanding of global, climatically relevant processes.

**The Swedish icebreaker Oden**

The Oden is one of eight icebreakers operated by the Swedish Maritime Administration. The ship is designed for escort duty, icebreaking and arctic research work. With its extremely flexible design, this icebreaker is also used as a research platform, and can transport scientific equipment, containerized/mobile laboratories, frozen storage containers, as well as deep-drilling equipment for taking geological samples.

The Oden is 107.7 meters long and 31.2 meters wide. It has a draft of between 7 and 8.5 meters and a displacement of 13,000 tons. Its engines provide 18 MW of power and a top speed of 16 knots. The Oden can break one-meter-thick ice at a speed for 9 knots and two-meter-thick ice at a speed of 3 knots. With its up to 60 mm thick steel hull, its icebreaking capabilities are well over two meters, depending upon the consistency of the ice. Because of its shape, though, the Oden is highly sensitive to pitching and rolling motions. Considerable low- and medium-frequency vibration occurs when icebreaking or when making way at sea against frontal waves.

Pfeiffer Vacuum turbopump technology can be employed in the field under punishing environmental conditions, such as those encountered on an icebreaker in the Arctic Ocean. The pumps operated perfectly, even under strong vibration when icebreaking or in heavy seas.

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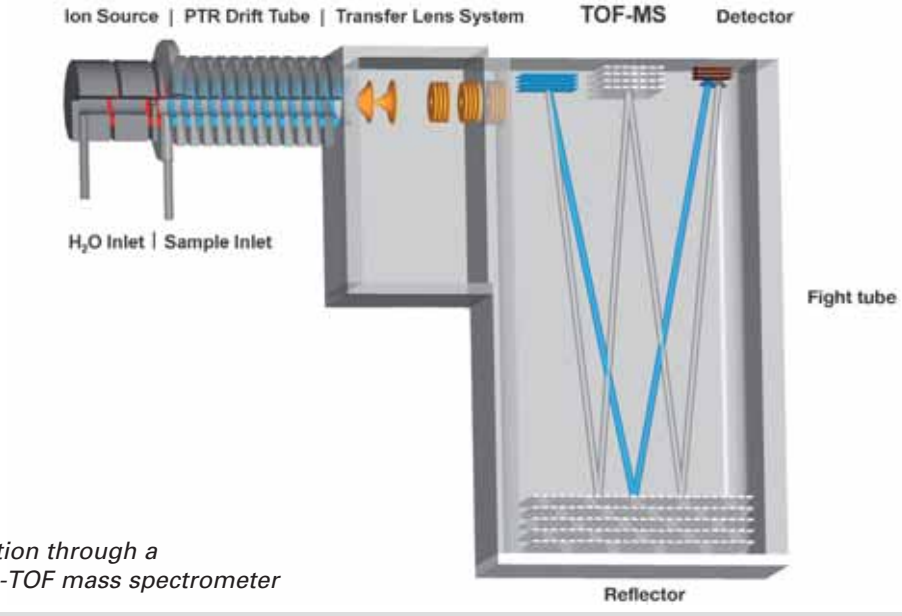
*PTR-TOF mass spectrometer*




*Section through a PTR-TOF mass spectrometer*

**PTR-TOF mass spectrometers**

One way of determining the composition of chemical substances is through the employment of proton transfer reaction time of flight mass spectrometers (PTR-TOF-MS). TOF stands for time of flight.

The fundamental principle of a mass spectrometer is to identify chemical compounds on the basis of their masses, and to draw conclusions about the quantity of substances on the basis of the magnitude of the signal. To do that, the molecules are ionized, which enables them to be manipulated by means of electrical fields, and finally converted to an electrical signal.

In PTR mass spectrometers, ionization is performed in a drift tube. In this process, ionized water ($H_3O^+$ hydrium ions) reacts with the organic constituents of the air that is being analyzed. A proton is transferred from the ionized water to an organic compound – ionizing the molecules of the substance.

In a time of flight mass spectrometer (TOF-MS), the ionized molecules are accelerated by an electrical field in a first step. Molecules having different masses, which achieve the same kinetic energy through the acceleration, fly through the field-free time-of-flight tube at differing velocities. As a result of their differing velocities, the ions of different weight strike the detector at different times. The time of flight enables conclusions to be drawn about the mass of the ionized molecules.

The mass of a molecule can be calculated as follows in a TOF-MS:

After being accelerated by voltage V, the ions have kinetic energy $q \cdot V$ (q is the charge of an ion) when leaving the electrical field, which must be equal to $^1/_2 \cdot m \cdot v^2$

$$q \cdot V = \frac{m \cdot v^2}{2} = \frac{m \cdot L^2}{2 \cdot t^2}$$

$$m = \frac{2 \cdot t^2 \cdot V \cdot q}{L^2}$$

(m = molecule mass; v = molecule velocity; V = field voltage; q = molecule charge; t = time of flight; L = length of flight)

The task of the vacuum system is to gradually bring the MS system to its working pressure. The three sequential chambers (ion source; transfer and focusing stage; time-of-flight tube and detector) require different pressures. In conventional applications, a separate turbopump is attached to each chamber. Pfeiffer Vacuum provides the required vacuum ranges by means of a single SplitFlow turbo. This saves time and money. It would not be possible to conduct this study without vacuum chambers.

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