

10. Safety Guidelines for Handling Magnets made of VACODYM and VACOMAX

Magnetized rare-earth magnets of VACODYM and VACOMAX exhibit high field and exert strong, attractive forces on iron and other magnetic parts in their vicinity. Consequently, they must be handled with care to avoid damage. Owing to their strong magnetic forces there is a risk of injury when handling larger magnets. They always should be manipulated individually or with the aid of jigs. We recommend protective gloves to be worn in this cases as well as for handling of uncoated VACOMAX and Ni-coated parts. This counts especially for persons with allergies to metals.

The high fields can change or damage the calibration of sensitive electronic devices and measuring instruments. Please note that magnetized magnets must be kept at safe distance (e.g.

over 2 m) from pacemakers, computers, monitors and all magnetic data storage media (such as floppy disks, credit cards, audio and video tapes etc.).

On impact rare-earth magnets may develop large sparks. Never handle them in an explosive atmosphere.

Unprotected VACODYM and VACOMAX magnets must not be exposed to hydrogen. Its adsorption destroys the microstructure and leads to disintegration. The only effective protection is gas-proof encapsulation of the magnets.

Machining magnets requires special safety precaution for the grinding slurry. Especially for VACOMAX legal regulations regarding the handling of Co-containing dust have to be observed.

11. Appendix

11.1 Technical Principles and Terms

11.1.1 Hysteresis Loop

The behavior of a magnetic material in a magnetic field is characterized by the correlation between **magnetic flux density (induction B) and magnetic field strength H** (B(H) hysteresis loop). The same correlation can be described by the **polarization J** (J(H) hysteresis loop, Fig. I).

$$B = \mu_0 H + J.$$

The first quadrant of the hysteresis loop describes the magnetization behavior of the material: when applying a magnetic field H the flux density B of a non-magnetized material varies along the virgin curve (cf. Fig. I).

When all magnetic moments are oriented parallel to the external magnetic field, the polarization J is at its maximum value, the **saturation polarization J_s** (J = J_s = const.). The flux density B however, continues to increase linearly with the field strength H.

The minimum field strength required to attain saturation polarization is referred to as the **saturation field strength H_s**. If – in the magnetized state – the magnetic field strength is reduced, the flux density changes in accordance with the hysteresis loop and at H = 0 attains **residual flux density (remanence) B_r** (intersection of the hysteresis loop with ordinate). In the strongly anisotropic RE permanent magnets described here the remanence B_r is in the same order of magnitude as the saturation polarization J_s:

$$B_r \approx J_s$$

11.1.2 Demagnetization Curve

The second quadrant of the hysteresis loop describes the demagnetization behavior of the material. The most important characteristic terms of permanent magnets which are operated

exclusively in opposing fields (see “working point” for further details) are determined from the **demagnetization curve**.

The most important characteristic terms of a permanent magnet are:

– Remanence

This is obtained as described above from the intersection of the hysteresis loop and the ordinate (at H = 0 we have B_r = J_r).

– Coercivity

The field strengths at which the flux density B or the polarization J reach zero are referred to as **coercivities** of flux density H_{cB} or polarization H_{cJ} respectively (intersection of the hysteresis loop B(H) and J(H) with the abscissa).

– Energy Density

The product of the related values from flux density B and field strength H can be attained from any point along the demagnetization curve (see Fig. II). This product represents the energy density and passes through a maximum value between remanence and coercivity, the **maximum energy density (BH)_{max}**. As a rule this value is used to grade permanent magnet materials.

– Working Point

The magnetic field originating from the poles of a permanent magnet has a demagnetizing effect as it is in the opposing direction to flux density B. The operational state of a permanent magnet is consequently always in the range of the demagnetization curve. The pair of values (B_a, H_a) applying to the relevant operational state is referred to as **working point P**. The position of P depends on the geometry of the