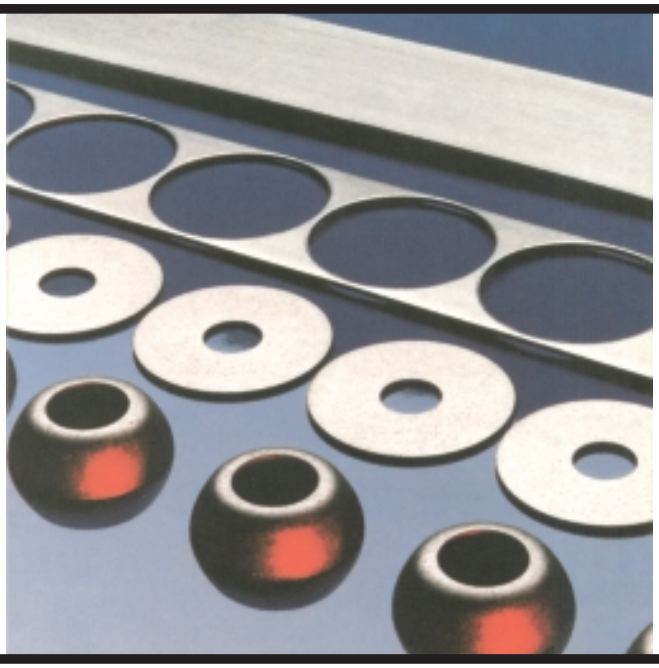
VACUUMSCHMELZE

CROVAC · MAGNETOFLEX · VACOZET SEMIVAC · SENSORVAC

Ductile Permanent Magnet Alloys and Magnetically Semi-Hard Materials



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Ductile Permanent Magnet Alloys and Magnetically Semi-Hard Materials

Permanent magnets are used as functional parts in many fields of application, especially in electrical engineering and electronics, mechanical engineering and high precision technology. The wide variety of demands on properties, shapes and dimensions are met by using our different materials.

Alongside the rare-earth permanent magnet alloys VACODYM*® and VACOMAX® which are produced using powder metallurgical technology and feature extremely high energy densities and coercivities, VACUUMSCHMELZE (VAC) supply ductile permanent magnets and magnetically semi-hard materials.

All applications requiring permanent magnets in the form of strips, rods and wires or those calling for the production of stamped, stamped-bent and machined parts are covered by the VAC ductile permanent magnet alloys CROVAC® and MAGNETOFLEX®, two material groups with different magnetic and mechanical properties.

Magnetically semi-hard materials fall into the category between soft magnetic and hard magnetic materials with respect to coercivity. In the VACOZET® group two alloys whose coercivity can be adapted to the magnetic circuit are offered for each application. In addition, SEMIVAC 90® and SENSORVAC® are available - two materials purpose-developed for EAS (electronic article surveillance) systems.

VACUUMSCHMELZE have considerable experience in designing magnetic circuits and in the production of permanent magnets. Besides magnets of various shapes and sizes our product range includes custom-made magnet systems. By employing our soft magnetic alloys or materials to compensate the temperature effect in magnetic circuits as system components individual specifications can readily be met.

Table 1 gives the most important magnetic and mechanical properties of the ductile permanent magnet alloys and the magnetically semi-hard materials.

Forms of supply and applications are presented under each material description. Information on quality assurance is presented at the end of this brochure. The technical principles and the most important expressions used in connection with permanent magnet materials are explained in our product sheet PD-002 – Rare-Earth Permanent Magnet Materials – which is available free of charge on request. Further details on ordering parts and components are compiled in our product sheet PHT-002.

* under licence from Sumitomo Special Metals
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Table 1: Magnetic and mechanical properties of ductile permanent magnet alloys and magnetically semi-hard materials

Material		CROVAC 12/160	CROVAC 16/160	CROVAC 12/500	CROVAC 16/550	MAGNETO-FLEX 35U	MAGNETO-FLEX 93	VACOZET 258	VACOZET 655	SEMIVAC 90	SENSOR-VAC
Main components		FeCrCoMo				CoFeV	CoFeVCr	CoFeNi		FeCrCoNiMo	FeNiAlTi
Variant	isotropic	●	●								
	anisotropic			●	●	●	●	●	●	●	●
Forms of supply	wire	●	●	●	●		●	●	●	●	
	strip	●	●	●	●	●		●	●	●	●
	wire	●	●				●	●	●	●	
	strip	●	●			●		●	●	●	●
Remanence (T)		0.85-0.95	0.80-0.90	1.15-1.25	1.10-1.20	0.80-0.90	1.00-1.10	1.30-1.50	1.30-1.50	0.90-1.30	1.30-1.60
Coercivity (kA/m)		36-42	39-45	47-55	53-61	25-30	30-35	2.0-3.2	2.5-4.8	4-10	1.5-2.6
Coercivity Tolerance (kA/m)		+/- 2	+/- 2	+/- 3	+/- 3	+/- 1.5	+/- 1.5	+/- 0.15	+/- 0.15	+/- 0.5	+/- 0.5
Energy density $(BH)_{max}$ (kJ/m³)		13	15	35	37	12	20	2.5	4	5	3
Density (g/cm³)		7.6				8.1		8.1		7.85	7.65
Curie temperature (°C)		640				700		800		700	630
Max. application temperatur (°C)		480				500		400		450	300
T_K (B_R) -25°C - 250°C (%/K)		-0.03				-0.01		–		–	–
Therm. expansion (RT-100°C) (10^{-6}/K)		10				11		11		–	–
El. resistivity (Ωmm²/m)		0.7				0.65		0.15		–	–
Vickers hardness HV	as rolled	330				480	520	400	420	–	–
	soft annealed	230				–	–	–	–	–	–
	heat treated	480				900	950	600	650	700	600
Tensile strength R_M	as rolled (MPa)	1150				1850	1900	1700		–	–
	soft annealed (MPa)	620				–		–	–	–	–
	heat treated (MPa)	–				–		1500		–	–
Elongation	as rolled (%)	2				1.5		3		–	–
	soft annealed (%)	20				–		–	–	–	–
	heat treated (%)	–				–		0.5		–	–

The elongation is given for A_{L50} (strip) rsp. A_{L100} (wire).
The above mechanical properties are given as rated values.

CROVAC is a group of ductile permanent magnet alloys on an iron, chromium, cobalt base. One of the main advantages of this group is its low cost shaping quality. Moreover, compared with other permanent magnet materials with similar magnetic properties the raw material costs for CROVAC are lower.

The main fields of application include stamped parts for bistable relays and automotive display instruments, profile parts for residual current relays, rings for hysteresis couplings and deep-drawn parts for pumps.

Production and Forms of Supply

CROVAC is produced as strip, wire or profile material. Parts are shaped by stamping, stamping-bending, cutting or machining processes such as turning, milling or drilling. In the soft annealed state deep-drawing and pressing are possible. In addition to this, semi-finished products like strip, wire or profile wire are available. In the final heat-treated state CROVAC is normally hard and brittle.

The permanent magnet properties are set by homogenizing at temperatures >1000°C as well as annealing in the temperature range between 500°C and 700°C. Depending on the heat-treatment magnetically anisotropic or isotropic properties can be set. As the magnetic properties are highly sensitive to the duration and temperature of the treatment we advise customers to purchase parts and/or semi-finished products after final magnetic annealing.

Typical dimensions of semi-finished material for the production of parts are:

Strip: 0.25 mm - 2.5 mm thickness
up to 240 mm width
Wire: 0.2 mm - 6 mm diameter

Magnetic Properties

The following figure shows the characteristic demagnetization curves for finally annealed magnets for both isotropic heat-treatment (CROVAC 12/160 and CROVAC 16/160) and anisotropic annealing (CROVAC 12/500 and CROVAC 16/550).

On agreement appreciably lower coercivities (>5 kA/m) can be set in isotropic magnets without altering the remanence.

Application Information

The most important physical properties of CROVAC are listed in Table 1. Field strengths of approx. 250 kA/m are required to magnetize CROVAC. In order to fully exploit the magnetic properties and to avoid contamination, especially by magnetic particles during assembly, we recommend that parts made of CROVAC are magnetized in the finished system. It follows that the majority of CROVAC magnets are supplied prior to magnetization.

Examples of application

- telecom relays
- residual current relays
- automotive display systems
- display systems
- hysteresis couplings
- torque magnet systems
- rotary speed controls
- pumps
- flowmeters
- magnetic distance gauges

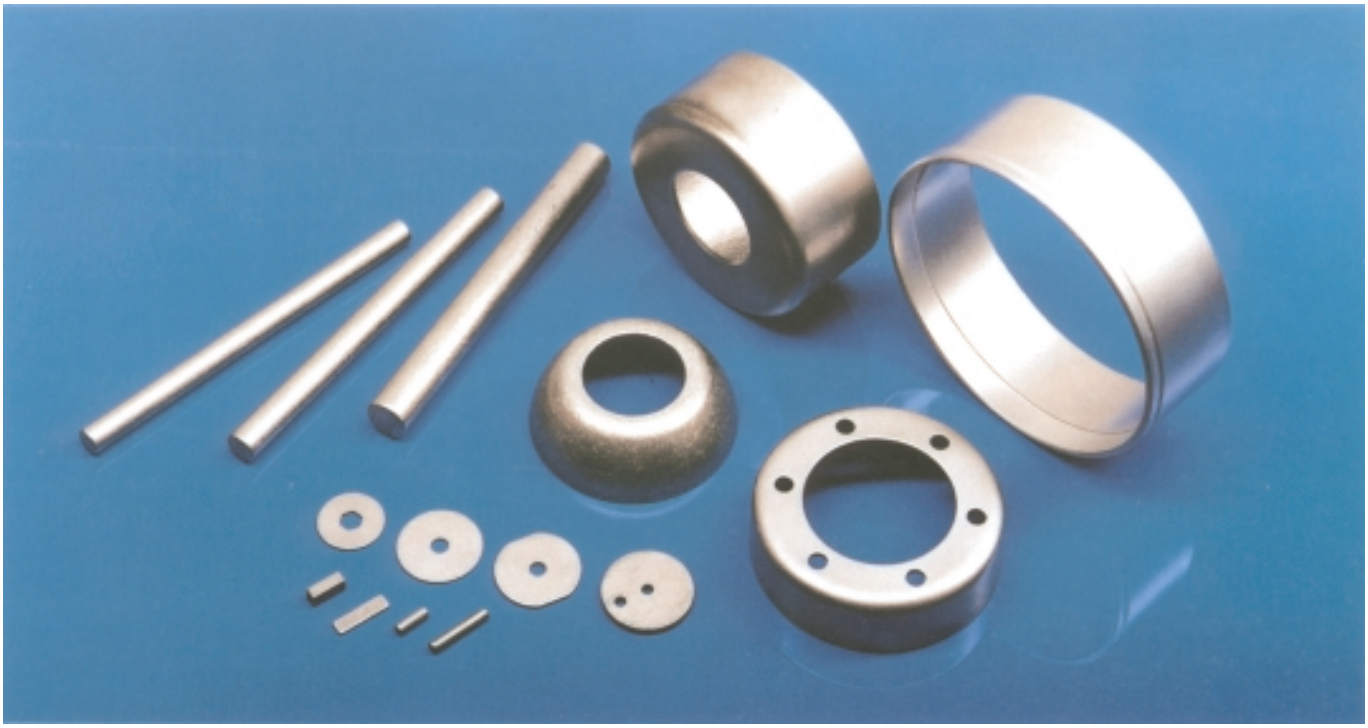

Fig. 1: Parts of CROVAC

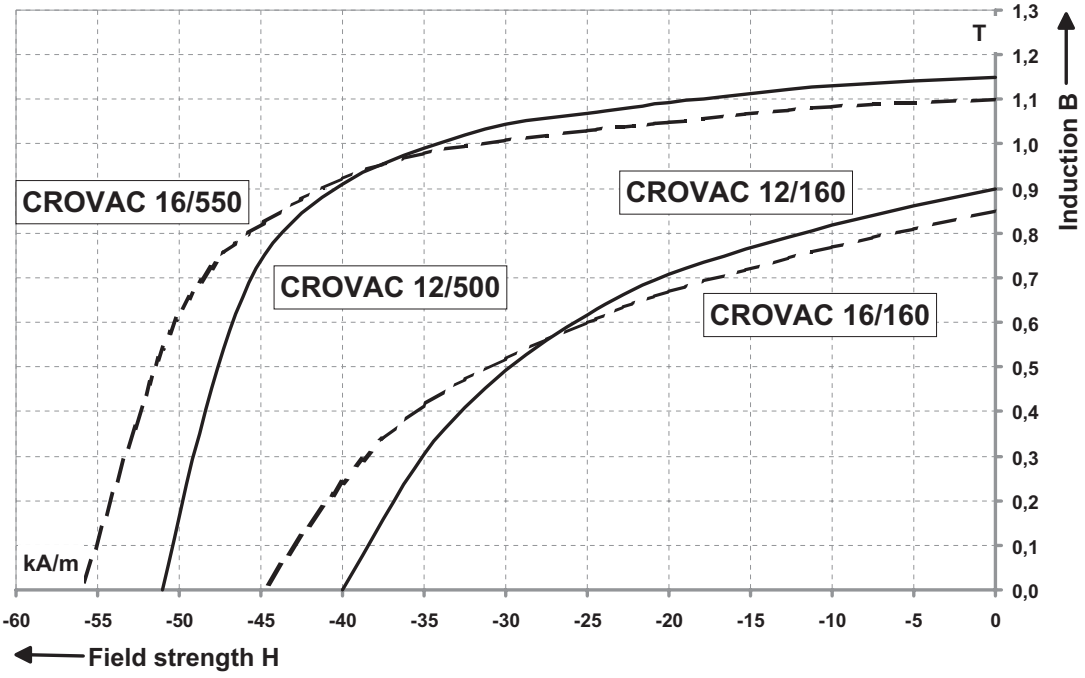

Fig. 2: Demagnetization curves of CROVAC

MAGNETOFLEX is the trade name for our ductile permanent magnet alloys on a cobalt, iron vanadium base. These materials are produced as strip or wire and their magnetic properties set by extreme cold working and subsequent heat treatment in the temperature range between 500°C and 620°C. Shaping by cutting, stamping, bending and rolling must be completed prior to annealing. If MAGNETOFLEX is to be machined, carbide tipped tools must be used. After final heat treatment MAGNETOFLEX can only be ground.

MAGNETOFLEX is particularly suitable for hysteresis rings, other applications include electronic article surveillance systems and colour TV tubes.

Magnetic properties and Forms of Supply

The characteristic demagnetization curves for MAGNETOFLEX can be read off the diagram below. Table 1 gives the typical magnetic values. N.B. lower coercivities up to≥ 5 kA/m can also be set.

MAGNETOFLEX 35U which is produced as strip attains optimum magnetic properties only after the material has been at least 90% cold worked, this automatically limits the maximum thickness to 0.6 mm. Thicker strips have lower magnetic values.

Owing to the degree of cold work MAGNETOFLEX 35U has anisotropic properties. As a result, the preferred magnetic direction should be parallel to the rolling direction. Perpendicular to this, the remanence and coercivity are 10% -30% lower.

MAGNETOFLEX 93 is only produced as wire. As the anisotropy is better in wire, higher magnetic values can be attained.

MAGNETOFLEX is available as final heat treated parts and as semi-finished products, i.e. as strip and wire in the following standard dimensions:

strip (MAGNETOFLEX 35 U): 0.05 mm - 0.6 mm thickness
up to 240 mm width
wire (MAGNETOFLEX 93): 0.3 mm to 4.0 mm diameter

Application Information

The most important physical properties of MAGNETOFLEX are compiled in Table 1.

Field strengths of approx. 200 kA/m are required to magnetize MAGNETOFLEX. Parts should be magnetized in the assembled system whenever possible.

In addition to parts and semi-finished products in the final heat treated state, MAGNETOFLEX can be supplied as pre-material. Any parts made by customers can be returned to VAC for final annealing. On the other hand, should a customer prefer to carry out final annealing at his own works, we will be pleased to advise on the heat treatment. Please note that during final annealing parts shrink by up to 1‰.

Nominal values for annealing are: temperature 500°C - 570°C depending on the magnetic values required, holding time 3 hours. Always anneal under protective gas to avoid oxidation.

Examples of Application

- hysteresis couplings
- hysteresis motors
- electronic article surveillance (EAS) systems
- torque magnets
- focusing in colour TV tubes
- compass needles
- reset magnets
- tachometers

Fig. 3:
Parts of MAGNETOFLEX

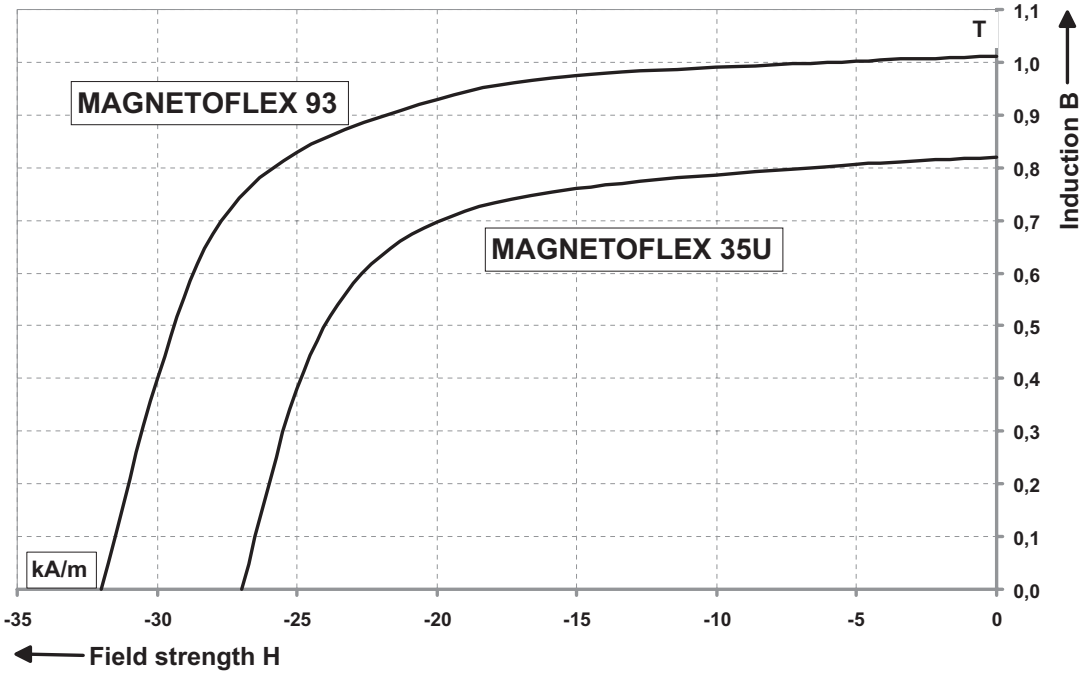

Fig. 4: Demagnetization curves of MAGNETOFLEX

VACOZET refers to magnetically semi-hard alloys on a cobalt, iron, nickel base. They can be produced as strip, wire or profile and their magnetic properties are set by a high degree of cold reduction and subsequent annealing. Shaping of the parts by turning, stamping and bending must be carried out before annealing. Carbide-tipped tools are stipulated for machining.

In the finished heat treated state VACOZET is hard and brittle and can only be ground.

VACOZET is primarily used in bistable relays and display components. In these applications a current pulse causes the system to change from one stable state into another. As no retaining current is necessary, displays are not affected by a power failure. This provides increased safety/reliability and saves electricity.

Magnetic Properties and Forms of Supply

The typical demagnetization curves for VACOZET are presented below, the magnetic values are given in Table 1.

At roughly the same remanence level of 1.4 T the coercivity can be set between 1 and 5 kA/m. To obtain optimum magnetic properties the material must have been cold worked by at least 90% which limits the upper range of dimensions.

VACOZET can be supplied as finished heat-treated parts or as semi-finished products in the form of strip, wire, profile or rods. Standard dimensions are:

Strip:	0.03 mm - 0.6 mm thickness
	up to 240 mm width
Wire or rods:	0.3 mm up to 6 mm diameter

Application Information

The most important physical properties of VACOZET are compiled in Table 1.

To obtain optimum magnetic properties in parts made from strips, ensure that the desired direction of magnetization corresponds with the rolling direction.

The annealing temperature exerts considerable influence on the coercivity. The annealing time should be at least 2.5 hours followed by rapid cooling (approx. 30 minutes down to 100°C or even faster). Slower cooling restricts the reproducibility of the coercivity. Any furnace atmosphere may be selected. However, where the atmosphere contains oxgyen the material surface shows slight oxidation but, please note, that this does not affect the magnetic values.

Parts made from our semi-finished material at the customers can be returned to VAC for final heat-treatment. In such cases, the same tolerance as for parts made at VAC , i.e. +/- 0.15 kA/m can be set in the typical range of coercivities (cf. Table 1) by the heat- treatment. Where other specifications are required, please contact VAC for advice.

VACOZET 655 is used for glass-to-metal sealing and is suitable for all the soft glasses commonly used in reed switch production. To keep changes in the magnetic properties set during annealing to a minimum, we recommend the use of glasses with a low softening temperature and a short heating period followed by rapid cooling.

Examples of Application

- bistable latching relays
- display components
- magnet valves
- reed relays
- electronic article surveillance (EAS) systems

Fig. 5:
Bobbin cores of VACOZET for the Gardena sprinkler computer

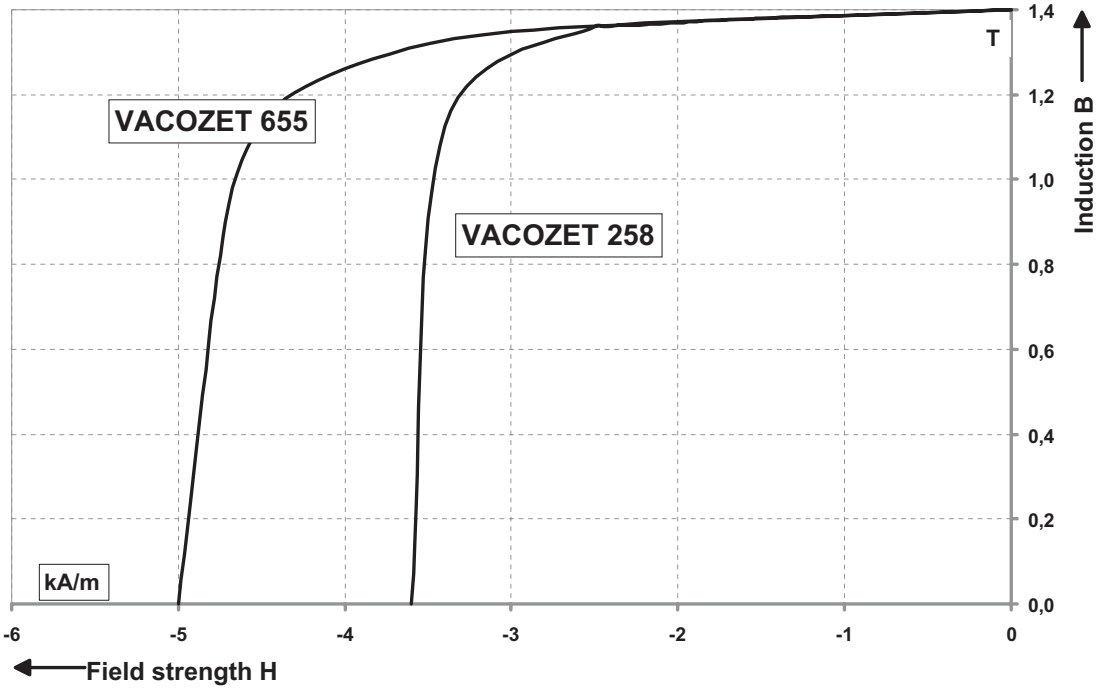

Fig. 6: Demagnetization curves of VACOZET

The tradenames SEMIVAC and SENSORVAC refer to two alloys mainly used in electronic article surveillance (EAS) systems. SEMIVAC 90 is on an iron, chromium, cobalt, nickel base whereas SENSORVAC has no cobalt and is on an iron nickel base. Both alloys can be produced as strip, SEMIVAC is also available as wire. The magnetic properties are set by combining a high degree of cold work with intermediate annealings and final heat treatment.

Parts made of SEMIVAC 90 must be shaped prior to final heat-treatment. Cutting shaping of this material calls for carbide tipped tools. In the final heat-treated state SEMIVAC 90 is hard and brittle and can only be ground.

Both alloys are most frequently supplied for EAS as foils in the thickness range < 100 µm . In these fine dimensions the materials can be cut and stamped in the final heat-treated state.

Magnetic Properties and Forms of supply

The typical demagnetization curves of SEMIVAC 90 and SENSORVAC are presented below, the magnetic values are given in Table 1.

SEMIVAC can be supplied as finished heat-treated parts made from wire as well as the semi-finished products strip or wire. Owing to the high degree of cold work required only thin dimensions are available.

Standard dimensions are:
Strip: 0.045 mm - 0.3 mm thickness
up to 240 mm width
Wire: 0.3 mm up to 3 mm diameter

To date SENSORVAC is only available as strip. Moreover, owing to the required combination of cold work and intermediate annealing steps only thin strips can be realized.
Standard dimensions are:
Strip: 0.045 mm - 0.1 mm thickness
up to 200 mm width

Application Information

The most important physical properties of SEMIVAC 90 and SENSORVAC are listed in Table 1. In order to attain optimum magnetic properties when producing parts from strip, the desired direction of magnetization should coincide with the rolling direction. Perpendicular to the preferred direction both alloys only achieve approx. 70% of their possible magnetic values.

Coercivity in the range 1.5 kA/m to 10kA/m is almost completely covered by these two alloys.

Application Examples

– electronic article surveillance (EAS) systems
– display instruments (SEMIVAC 90 only)

Fig. 7:
EAS-tags with strips of
SENSORVAC and rods of SEMIVAC.

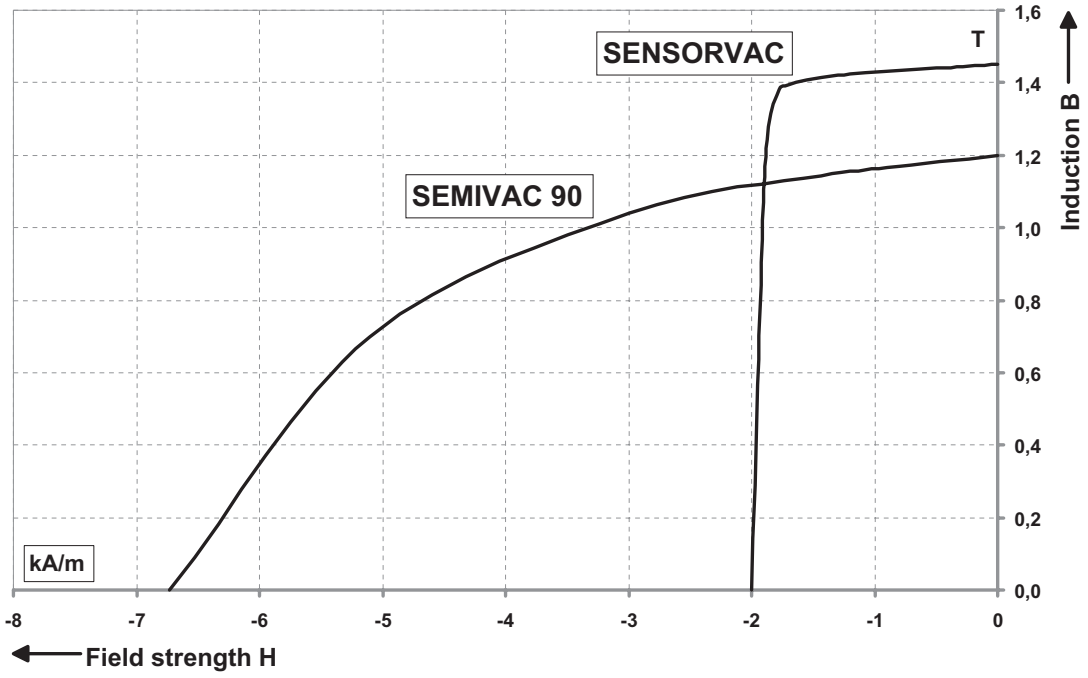

Fig. 8: Demagnetization Curves of SEMIVAC 90 and SENSORVAC

Quality Assurance

Our quality system plays a decisive role in our company policy. Quality is equivalent to offering customers maximum use of our products and service. The framework for our system has been provided by a quality management system certified according to DIN EN ISO 9001 and backed by continuous further development in this field. In the meantime, it is also certified to the stipulations of the US and European automotive industries (QS-9000 and VDA 6.1). Our aim: even less errors, an even better processing capability and even more economic production.

Management begins in determining the requirements and expectations of our customers resp. of the market and extends to careful inter-departmental quality planning. Measures targeted at preventing errors and risk analysis (e.g. FMEA) avoid having to modify products and production processes at a later stage.

Computer aided SPC (statistical process control) and process data evaluation, a calibration control affiliated to the DKD – German Calibration Authority – to ensure internationally comparable measurements, regular staff training sessions, workshops to solve problems and proposals from staff on improvements are only a few of our instruments to ensure a high quality standard.

In 1994 we launched a TQM programme covering the entire company, and based on Business Excellence Models:

- customer satisfaction
- business relevant technical and administrative processes
- integration of personnel and job satisfaction
- corporate figures
- increasing production
- motivating innovative forces.

Our executive staff are responsible for promoting TQM awareness and our entire workforce is committed to TQM awareness.

The main aim of all our quality management measures is customer satisfaction both inside and outside the works.

Product Survey

Semi-Finished Products and Parts

Metallic Semi-Finished Products
Soft magnetic alloys
Magnetically semi-hard alloys
Ductile permanent magnets
Thermobimetals
Spring alloys
Glass/ceramic-to-metal sealing alloys

Parts
Stamped/bent parts
Laminations
Magnetic shielding

Superconductors

Rare-Earth Permanent Magnets

Magnets on Sm-Co and Nd-Fe-B Base

Magnet Assemblies

Cores and Components

Magnetic Cores
Tape-wound cores made of crystalline,
amorphous and nano-crystalline alloys

Inductive Components
for ISDN and switched-mode power supplies,
for current detection and
for driving power semiconductors

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Advanced Materials – The Key to Progress

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