# NEW MnZn FERRITES AND THEIR APPLICATIONS

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**Key words:** magnetic ceramic, MnZn ferrites, magnetic properties, electrical properties, microstructures, applications

**Abstract:** MnZn ferrites, ceramic with special magnetic properties, are widely used as core materials for inductive components in electronics. The demands of future electronic systems require solutions that improve efficiency, reduce weight and not add pollution to the environment. The requirements for component design are a smaller size, weight reduction, performance increase and durability. This paper describes the applications and properties of new designed matireals12Gi, 27G, 55G, 75G and 65G.

# Novi MnZn feriti in njihove aplikacije

**Kjučne besede:** magnetna keramika, MnZn feriti, magnetne lastnosti, električne lastnosti, mikrostruktura, aplikacije

**Izvleček:** MnZn feriti so keramični materiali z magnetnimi lastnostmi in sestavni deli induktivnih komponent namenjeni različnim aplikacijam v elektroniki. Trendi na področju elektronske industrije so usmerjeni v zmanjšanje teže osnovnih kompoment in izboljšanju osnovnih magnetnih lastnosti. Zahteve po zmanjšanju teže in prostornine novih induktivnih komponent narekujejo boljše lastnosti osnovnih materialov in večjo trajnost. V članku so predstavljene lastnosti novih materialov 12Gi, 27G, 55G, 75G in 65G ter njihova uporaba.

## 1. Introduction

Several improved materials will be discussed. It is important to select materials that are suited to specific applications. Some materials with their properties are listed:

1. EMI applications require a current compensated chokes which are very important to eliminate the disturbing interference sources. A ferrite material with a high initial permeability, high impedance over a broad frequency range and high operating temperature is required.
2. Splitter applications in ADSL applications required a plain old telephone system (POTS) splitter used to separate the high frequency data from low frequency voice signals. The core material must have a high reversible permeability at high magnetic field. In addition, a lower number of turns and smaller cores are required. This behavior can be achieved by high initial permeability and high saturation of the ferrite materials.
3. As electronic modules become smaller and lighter, the power supplies must likewise be reduced. The core losses, consisting of hysteresis losses, eddy current losses and residual losses, vary considerably with operating frequency and magnetic flux density. The losses can be reduced by a uniform microstructure and high material resistivity. But low mechanical stress, low magneto crystalline anisotropy and low magnetostriction are also required.
4. DSL applications require a fast data transfer without distortion. Inductive components are used in the customer$^{x}$s premises modem and central office line transformers to realize a distortion free digital signal transmission along the copper wire of the conventional telephone network. The main target for the inductive cores is a long reach (higher than 5 km) at a high data distance.

## 2. Ferrite technology

The first step is the production of granulated ferrite powder. The weighed raw materials iron oxide, manganese oxide and zinc oxide are mixed and then palletized with a small amount of water. The red pellets with a pellet size of 3-5 mm are calcinated in a rotary kiln at about 1000$^{0}$C. Here the oxides react partly to the magnetic ferrite with spinel structure. After that the black pellets, water and some inorganic additives (amount from 0.01 - 0.1wt%) are added into an attritor for fine milling. The inorganic additives are necessary to improve the sintering behavior and/or the magnetic properties. The second part of the technology important to improve properties in associated with core shapes, sintering of them in the temperature range 1200 - 1400$^{0}$C and grinding of final cores.

## 3. Design principles

The performance of ferrites is not determined only by a high initial permeability. Other characteristics such as low losses, high saturation flux density, high sintered density and frequency characteristics are also important. In many cases, these requirements are not satisfied at the same time, so a compromise material has to be selected in such cases.

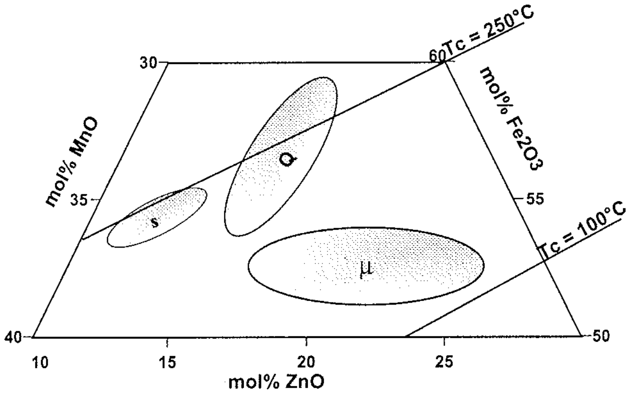


*Fig. 1: Composition diagram for MnZn ferrites*

The high initial permeability of materials depends to a large extent on the mobility of the Bloch's domain walls. To obtain high permeability it is important to lower the anisotropy and the magnetostriction. During the development of high-permeability MnZn ferrites much effort was devoted to the parameters which govern the bulk properties such as composition, microstructure and porosity /1/. To achieve a high permeability the composition of MnZn ferrite must be selected from a relatively narrow composition range, figure 1, region μ, where a zero crystalline anisotropy and a zero average magnetostriction can be expected. Studies of the grain-boundary chemistry in combination with grain-boundary structural analysis revealed that the grain boundaries are characterized by ZnO evaporation and the presence of a glassy phase and the segregation of various cations /2/. Firing conditions and additives are also important for achieving good properties. Well-adjusted sintering conditions support the development of the proper microstructure and the resulting magnetic properties. All these points have to be optimized in order to obtain desired magnetic properties.

Ferrites for power applications must be compositionally batched, figure 1 $B_{sat}$ region, and processed for low losses. Low power loss MnZn ferrites should have uniformly sized grains and high saturation density. The use of additives, a well-controlled process and a suitable sintering profile must be selected to decrease the power loss of ferrites. Additives and impurities are responsible for the grain-boundary chemistry and have a remarkable effect on the grain boundaries properties, particularly on the grain-boundary resistance /3/. In order to obtain a sintered body of uniformly sized fine grains, which would be suitable for achieving low power losses, grain growth should be suppressed especially in the initial stage of sintering process /4,6/. The selection of high-grade raw materials, with a defined low level of impurities, is of special importance in the production of MnZn ferrites for optimized microstructure properties. Addition of Ca and Si are well known to control the micro structural properties. Both ions strongly influence the microstructure of MnZn ferrites. Furthermore, the total resistance of MnZn ferrites increases due to the precipitation of silicate phases at the grain boundaries. This has the advantage that CaO and $SiO_2$ are doped in a defined amount in the ferrite mixture and their effect can be optimized in order to control the grain size and resistivity. In addition to the concentration of impurities, the reactivity of raw materials is a fundamental importance to control and optimize the production process /5/.

The total usable flux, AC + DC, in single ended power supplies is becoming important. The usable flux of a ferrite material is closely connected with the saturation flux density $B_s$, which in turn depends on the composition and density of the ferrite. For practical purposes, the composition of a ferrite material has to be considered as a compromise between application temperature (the position of the secondary permeability maximum corresponding to the position of minimum core losses) and required saturation flux density (which falls as temperature rises). Detailed investigation of core loss mechanisms has made it possible to develop new ferrite materials for various applications.

## High saturation power ferrite 55G

55G is intended for output chokes in power supplies. The requirement of a high saturation level to accommodate a high dc current is necessary to avoid saturating the core. The energy storage value of a choke is proportional to the square of peak flux density and determines the core volume required. Whenever space is limited, this is an important consideration. The new Iskra Feriti material 55G is usable to 500 kHz and above /8/.

***Table 1:*** *55G Material characteristics*

| *Parameter* | *measuring conditions* | *value* |
|---|---|---|
| $\mu_i$ [] | 25 °C, 10 kHz, 0.1 mT | 1800 ± 20% |
| $B_S$ [mT] | 25 °C, 10 kHz, 1200 A/m | ≥ 510 |
| | 100 °C, 10 kHz, 1200 A/m | ≥ 430 |
| | 120 °C, 10 kHz, 1200 A/m | ≥ 400 |
| $T_c$ [°C] | | ≥ 240 |

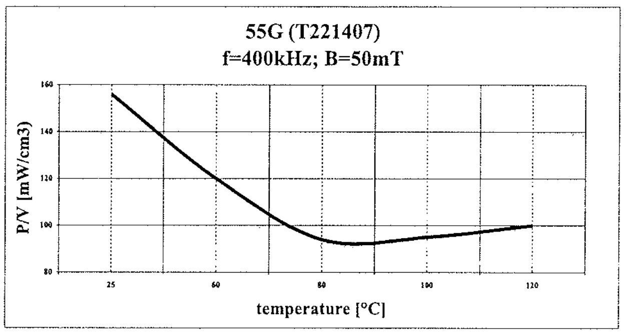


*Fig. 2: Power losses versus temperature*

Preferred applications are:

- High current output chokes – wherever space is at premium like a low profile converter modules, core volume can be reduced. The advantage increases with temperature.

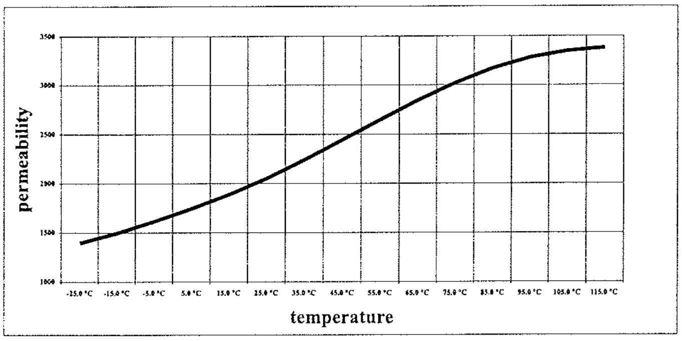


*Fig.3: Initial permeability versus temperature*

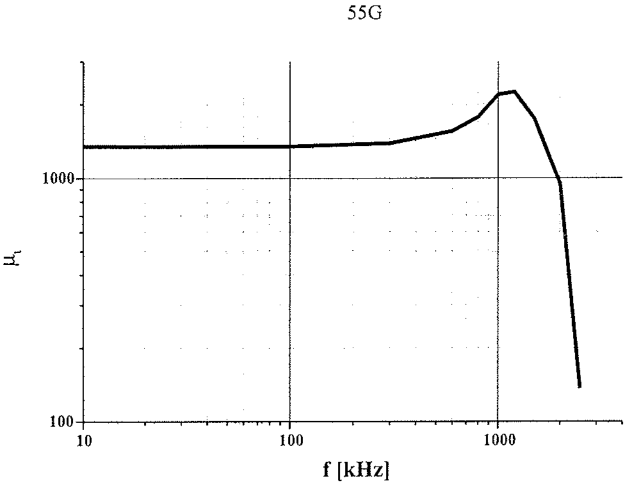


*Fig. 4: Initial permeability versus frequency*

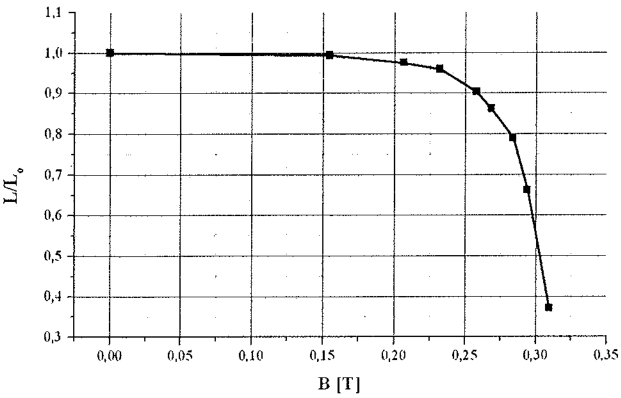


*Fig. 5: Inductance as function of $B_{pmax}$ at 120$^0$C*

- High voltage ignition transformers - for example in electronic lighting ballast where high flux density occurs during ignition, but losses have to be low during steady state operation.
- Gapped toroids where high-energy storage is required.

## High frequency power ferrite 75G

The increase in electrical applications for the automotive market is stressing the 12 volt system. The way to solve the insufficient electrical power is to increase the 12V standard to a 42V standard. The additional requirement to reduce weight and change to a drive by wire concept opens the market for voltage converters. The operating frequency of these converters will be about 500 Hz to 1MHz. The right material is a high frequency power grade, like our 75G, Table2 and Figures 6 to 9. The ferrite components that will be needed for various applications could use 2 planar core sets, one for transformer and one for the output choke for the core solution.

***Table 2:** 75G Material characteristics*

| *Parameter* | *measuring conditions* | *value* |
|---|---|---|
| $\mu_i$ [] | 25 °C, 10 kHz, 0.1 mT | 1300 ± 20% |
| $B_S$ [mT] | 25 °C, 10 kHz, 1200 A/m | ≥ 510 |
| | 100 °C, 10 kHz, 1200 A/m | ≥ 430 |
| | 120 °C, 10 kHz, 1200 A/m | ≥ 400 |
| $T_c$ [°C] | | ≥ 240 |

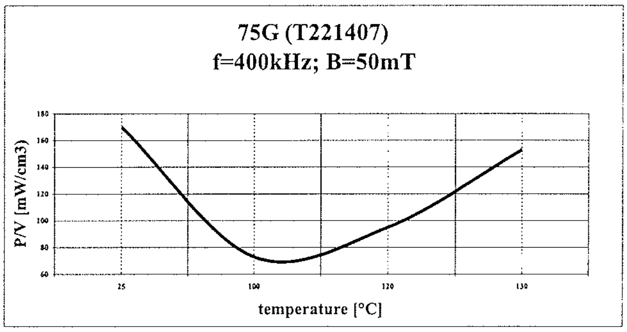


*Fig. 6: Power loss versus temperature*

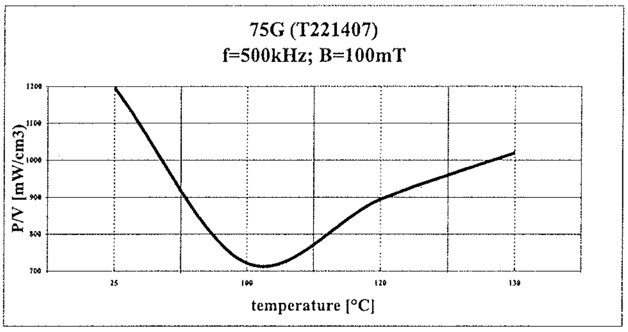


*Fig. 7: Power loss versus temperature*

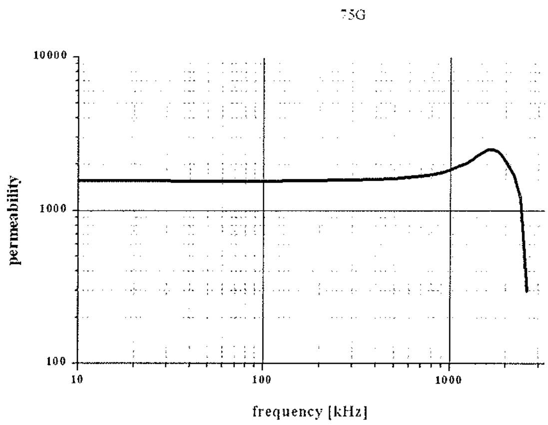


*Fig. 8: Initial permeability versus frequency*

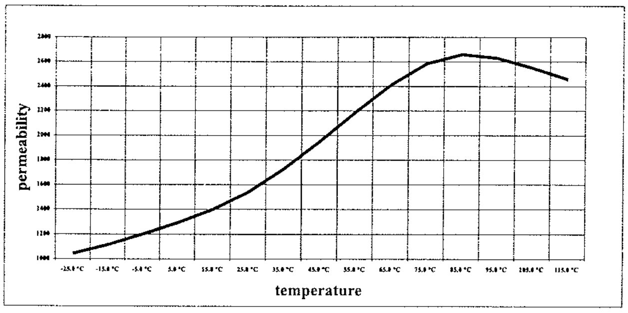


*Fig. 9: Initial permeability versus temperature*

Some potential applications under the 42V system are:

- Lighter, smaller and more efficient air conditioning
- Higher efficiency, longer life, water pump
- Faster starter, superior charging starter/alternator
- Mobile office: fax, PC,....

## Power material 65G – new level of power density

The properties of 65G, a new high flux density power material suitable for frequency up to 400 kHz is shown in Table 3 and Figures 10 to 13. This material is primarily intended for output chokes in power supplies where a high saturation level is required to accommodate DC + AC currents at elevated temperatures. The energy storage volume of a choke is proportional to the square of peak flux density and determines the core volume required. When space is limited, this is an important consideration.

***Table 3:** 65G Material characteristics*

| *Parameter* | *measuring conditions* | *value* |
|---|---|---|
| $\mu_i$ [] | 25 °C, 10 kHz, 0.1 mT | 2300 ± 20% |
| $B_S$ [mT] | 25 °C, 10 kHz, 1200 A/m | ≥ 510 |
| | 100 °C, 10 kHz, 1200 A/m | ≥ 380 |
| | 120 °C, 10 kHz, 1200 A/m | ≥ 360 |
| $T_C$ [°C] | | ≥ 210 °C |

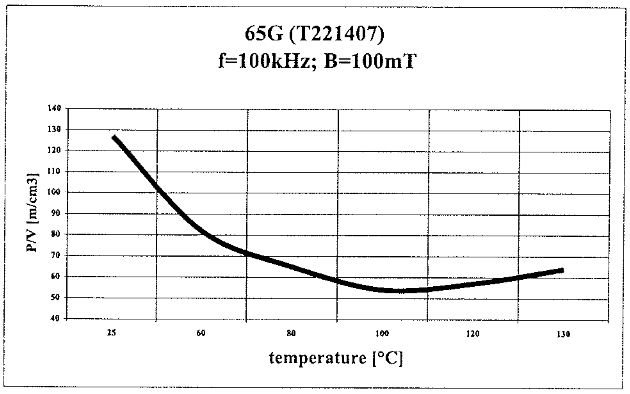


*Fig. 10: Power losses versus temperature*

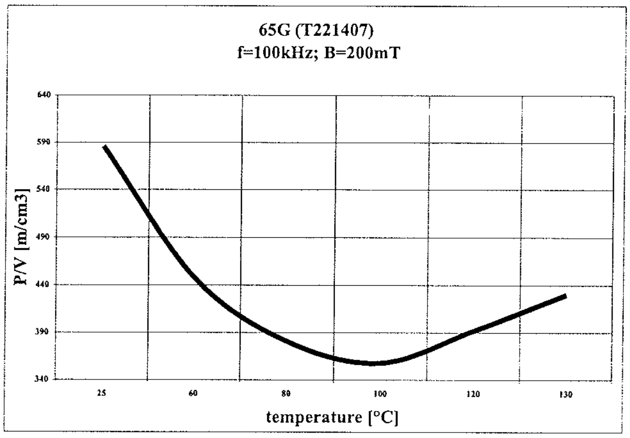


*Fig. 11: Power losses versus temperature*

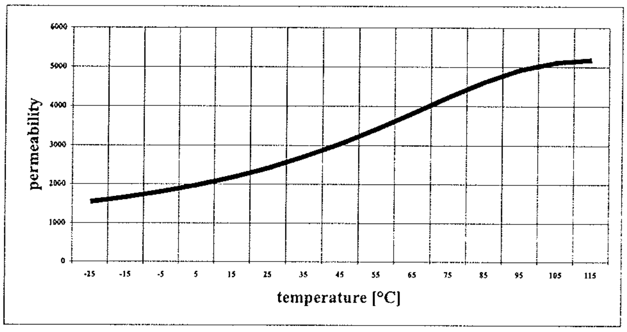


*Fig. 12: Permeability versus temperature*

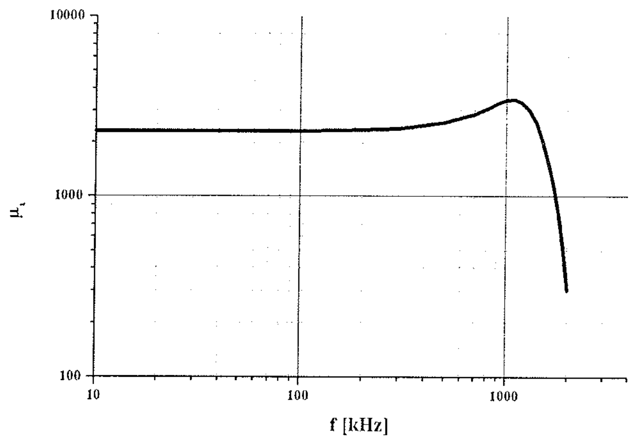


*Fig. 13: Permeability versus frequency*

Some potential applications are automotive electronics and electronic lighting ballasts.

## Innovative material 12Gi for (A) XDSL interface transformers

The ferrite producer Iskra- Feriti has developed an improved 12i ferrite material optimized for (A) XDSL applications. In comparison with conventional 12G ferrite material, the new 12Gi, Table 4 and Figures 14 and 15, allows for increases in the data rate transfer and distance covered by (A)XDSL lines.

The THD, Total Harmonic Distortion, of a ferrite component should be low under operating conditions. THD is a function of flux density (B), frequency (f) and temperature (T). To evaluate the material quality with respect to THD an audio analyzer was used on toroid samples. The improved 12Gi is optimized by low impurity raw materials, the addition of additives and improved processing and sintering conditions.

***Table 4:*** *12Gi Material characteristics*

| *Parameter* | *measuring conditions* | *value* |
|---|---|---|
| $\mu_i$ [] | 10 kHz, 25 °C, 0.1 mT | 10000 ± 20% |
| $\eta_B$ [$10^{-3}$/T] | 10 kHz, 25 °C, 1.5-3.0 mT | < 0.15 |
| tg$\delta/\mu$i [10-6] | 10 kHz, 25 °C, 0.1 mT | ≤ 7 |
| | 100 kHz, 25 °C, 0.1 mT | ≤ 40 |
| $\alpha$F [106/K] | 25 - 55 °C | -1 -+ 1 |
| TC [°C] | | ≥ 130 |

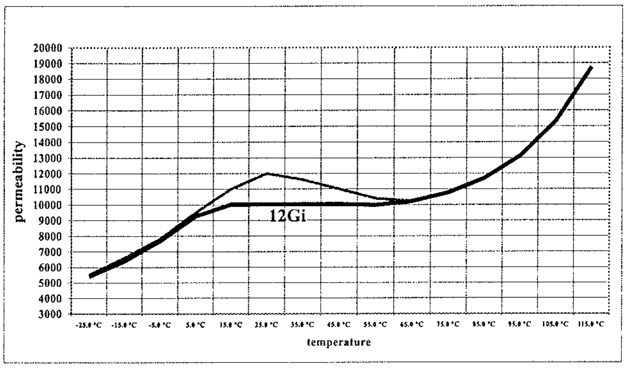


*Fig. 14: Permeability versus temperature*

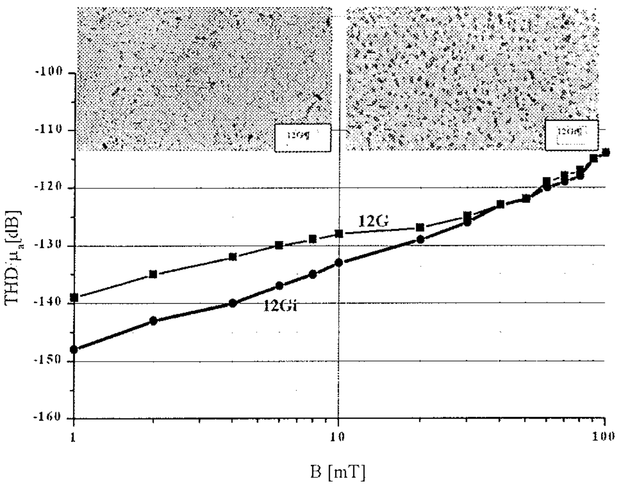


*Fig.15: THD/$\mu_a$ versus B for 12G and new 12Gi at 20 kHz*

## New material 27G for splitter applications

27G material, Table 5 and Figures 16 to 18, replaces 25G material in splitter (POTS) applications. 27G material is the first MnZn-ferrite which is available in production and combines both a high permeability and high saturation,. Both the high permeability and the high saturation at room temperature lead to the improvement of the DC-bias behavior.

This innovative material will also be of interest for interference suppression in automotive electronics and in frequency converters for industrial applications.

Typical industrial applications are found in pumps, fans, conveyer belt drivers, textile machinery and printing presses.

Suppression of this interferences is now a statutory requirement and calls for filters that can cope with high power outputs. The high power outputs inevitably cause high operating and ambient temperatures. The filters therefore require ferrite materials with high initial permeability and high magnetic saturation. The new 27G material is particularly suitable for these extreme requirements.

***Table 5:*** *27G Material characteristics*

| *Parameter* | *measuring conditions* | *value* |
|---|---|---|
| $\mu_i$ [] | 25 °C, 10 kHz, 0.1 mT | 3800 ± 20% |
| $B_S$ [mT] | 25 °C, 10 kHz, 1200 A/m | ≥ 530 |
| | 100 °C, 10 kHz, 1200 A/m | ≥ 410 |
| | 120 °C, 10 kHz, 1200 A/m | ≥ 370 |
| $T_C$ [°C] | | ≥ 210 |

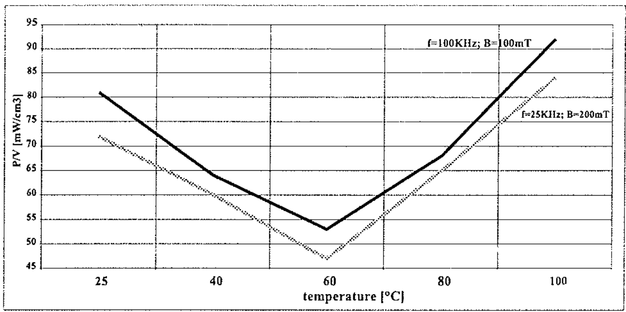


*Fig. 16: Power loss versus temperature*

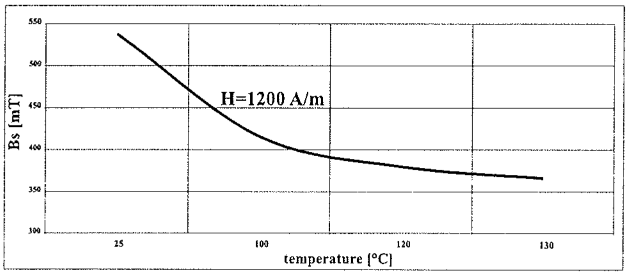


*Fig. 17: Saturation flux density versus temperature*

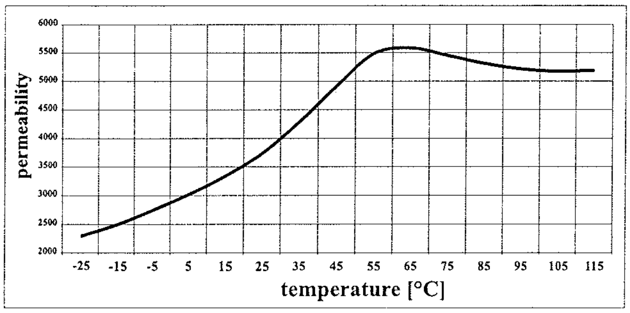


*Fig. 18: Permeability versus temperature*

All materials were successfully introduced on production and available in different core shapes.

## 3. Conclusion

The technical demand for improved soft ferrites has been growing. The technical department at Iskra - Feriti, has been busy developing and improving new ferrites to meet these demands. These materials meet the demands in both quantity and applications requirements that demand improved performance. Raw materials, the improvements in manufacturing technology and the ability to measure the results, play a decisive role in improving the quality and lowering the costs of ferrites. The results of these developments are expected to give new impulses for electrotechnical applications.

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