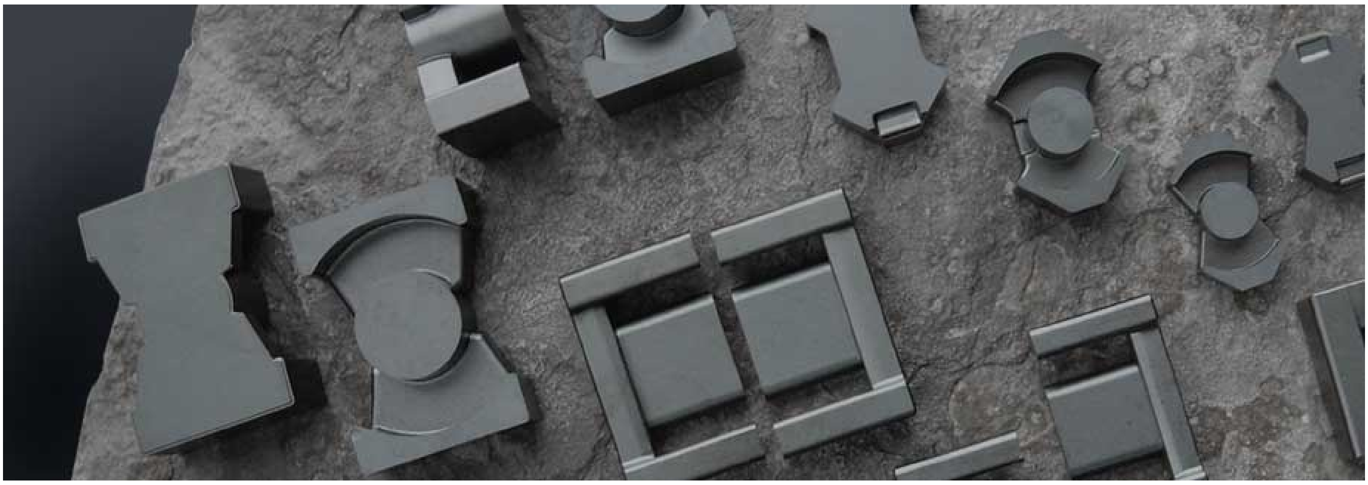


Low-loss And High Saturation Magnetic Flux Density Power Ferrite For Power Transformers And Choke Coils,

PC90 material

Conforming to RoHS Directive

Conformity to RoHS Directive: This means that, in conformity with EU Directive 2002/95/EC, lead, cadmium, mercury, hexavalent chromium, and specific bromine-based flame retardants, PBB and PBDE, have not been used, except for exempted applications.

The industry-leading saturation magnetic flux density was achieved while maintaining the loss in the operating temperature range at a minimum level.

Imagine... an advanced power transformer with low-loss ferrite cores for optimized weight-reduction and downsizing... a small core that is 20% lighter than those cores with minimized general loss by reducing the number of coils on the primary side (copper loss), and with a reduced transformer volume of morethan one third, while maintaining the same drive conditions and specifications... Introducing the cutting-edge power ferrite that can easily undertake these overwhelming tasks of downsizing and efficient improvement previously unfeasible for conventional power ferrites.

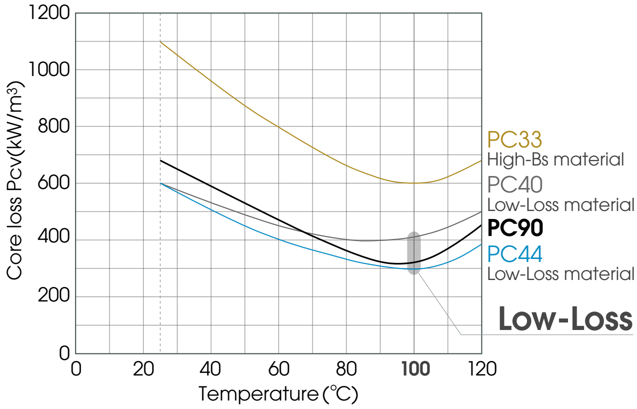
As a transformer core material for diverse power supplies, PC44 proudly offers the ultimate in low-loss characteristics. While the core loss of PC44 is reduced to near 300 kw/m³ between 90 and 110 °C, that of the newly developed PC90 comes very close to the superb level of the PC44 between 80 and 100 °C. PC90 greatly surpasses the widely applied PC40 in low-loss characteristics between 70 and 120 °C.

These are comparison examples of core sizes where "under the same use conditions, the performances are equal".

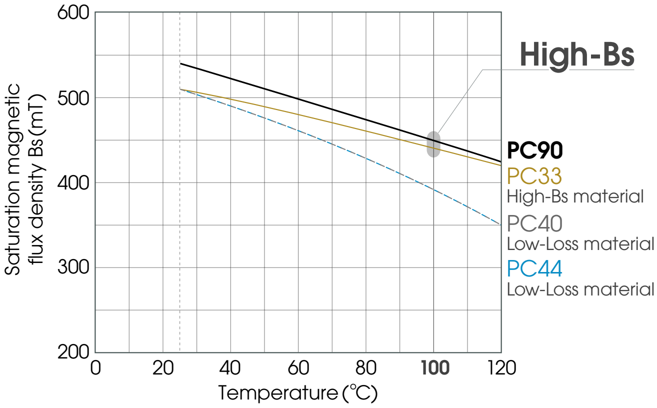
While there's no doubt about PC90's established low-loss quality, the excellent performance of the new material is derived from the innovation applied to the magnetic properties that goes beyond the two major categories of power ferrite: "low-loss material" and "high saturation magnetic flux density".

As well as a superb low-loss material, PC90 is an industry-leading high saturation magnetic flux density material that exceeds PC33 in performance in the wide temperature range between 25 and 120 °C.

Core loss vs. Temperature characteristics



Saturation magnetic flux density vs. Temperature characteristics



Milk cannot be drunk if a cow is sold・・・・・
that's exactly how difficult the technological issues of power ferrite have been.

PC90 material

Basically, the saturation magnetic flux density of the ferrite depends on the amount of magnetic moment per unit volume of ferrite. Therefore, by removing as many defects — such as vacancies and voids — as possible to create an accurate crystal structure, the saturation magnetic flux density can be improved.

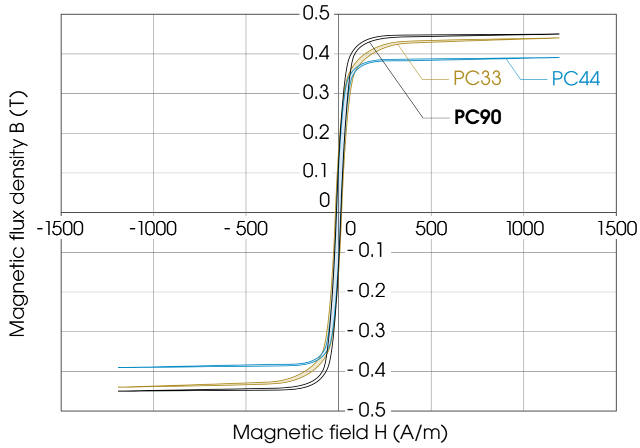
However, if a high sintered density is attempted through a general firing process, the minute crystal grains which constitute the ferrite will tend to become enlarged, increasing eddy current losses, which are proportional to the square of the grain radius. In many cases, the effort aimed at achievng a high saturation magnetic flux density and that aimed at reaching low-loss quality culminate conflict each other.

In short, if conventional theories of ferrite physical property control are followed, it is increasingly difficult to improve the saturation magnetic flux density as a greater low-loss characteristic is sought, so resulting in incompatibility with large excitation conditions of power transformers, etc.

Also, on the contrary, for high saturation magnetic flux density material, in the pursuit of fine structure for maximized Bs value, and composition ratio, it is increasingly difficult to undertake maximized reduction of the eddy current or hysteresis loss compared to low-loss materials. As a result, the issues of unutilized advantages of the high saturation magnetic flux density material — such as high-power drive through gap adjustment — have been left unresolved because of the temperature rise resulting from the loss.

Magnetization curves

(Comparison with conventional materials)



Material characteristics (Comparison with conventional materials)

Features of characteristics			High-Bs	<< Low-Loss <	High-Bs Low-Loss <	Low-Loss
Typical application			Choke coils	Transformers	Choke coils Transformers	Transformers
Material			PC33	PC40	**PC90**	PC44
Initial permeability *1 μ_i		(at 25 °C)	1400±25%	2300±25%	2200±25%	2400±25%
Core loss volume density *2 Pcv (Core loss)	(kW/m³)	(at 25 °C)	1100	600	680	600
		(at 60 °C)	800	450	470	400
		(at 100 °C)	600	**410**	**320**	**300**
		(at 120 °C)	680	**500**	**460**	**380**
Saturation magnetic flux density *3 Bs	(mT)	(at 25 °C)	**510**	510	**540**	510
		(at 60 °C)	**490**	450	**500**	450
		(at 100 °C)	**440**	390	**450**	390
		(at 120 °C)	**420**	350	**420**	350
Remanent magnetic flux density *3 Br	(mT)	(at 25 °C)	220	95	170	110
		(at 60 °C)	150	65	95	70
		(at 100 °C)	100	**55**	**60**	**60**
		(at 120 °C)	100	50	65	55
Coercive force *3 Hc	(A/m)	(at 25 °C)	23	14.3	13	13
		(at 60 °C)	17	10.3	9	9
		(at 100 °C)	14	**8.8**	**6.5**	**6.5**
		(at 120 °C)	14	8	7	6
Curie temperature Tc	(°C)		290 min.	215 min.	250 min.	215 min.
Electrical resistivity ρv	(Ω·m)	(at 25 °C)	2.5	6.5	6	6.5
Density δ	(kg/m³)		4.8×10^3	4.8×10^3	4.9×10^3	4.8×10^3

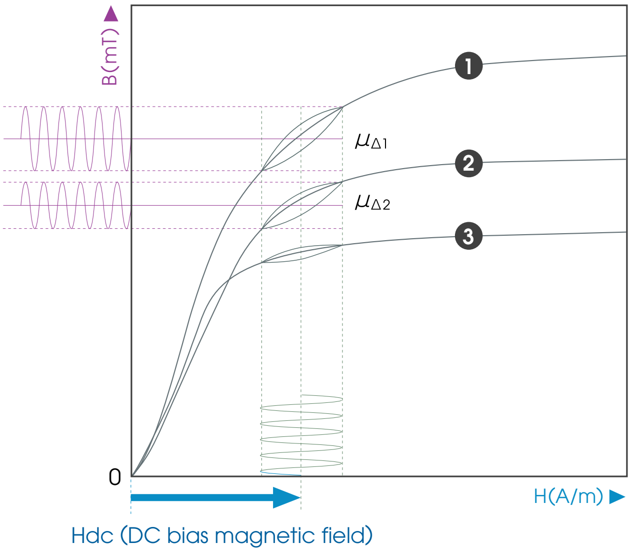
*1. at 100kHz, 0.1A/m *2. at 100kHz, 200mT *3. at 1194A/m

The industry's finest DC superposition characteristic by the "superposition" of low loss and high saturation magnetic flux density.

For choke coils using ferrite cores, how far it can function as an inductor where direct current is impressed — in other words, the quality of DC superposition characteristic — is a major concern in its development.

The deciding factor of this characteristic is the slope of the minor loops (incremental permeability μ_{Δ}) drawn on the magnetization curves(hysteresis loops). The transformer's inductance with direct current impression depends on this minor loop slope, and as the slope becomes more hori-zontal (the onset of magnetic saturation), the inductance decreases sharply.

The relationship between magnetization and DC superposition characteristics



If a core with the magnetization curve shown in ❷ is used, the magnetization curve which actually drives will markedly change slope (because the magnetic flux density is nearing saturation) and the inductance ($\mu_{\Delta 2}$) at this point will swiftly decline.

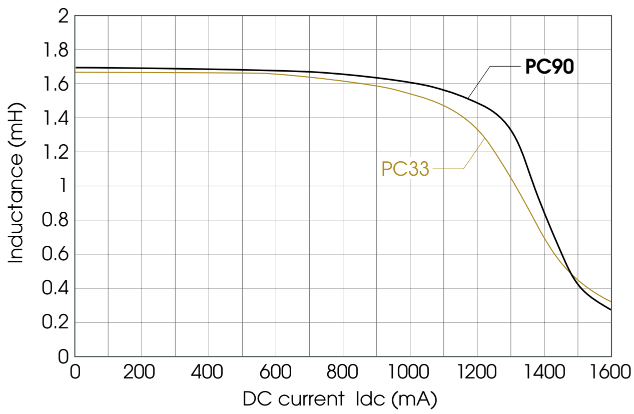
Also, the core of ❸ will reach almost full saturation in the DC bias magnetic field Hdc and will cease to function as a magnetic core.

The magnetization curve with the largest saturation magnetic flux density ❶ can maintain linearity in the DC bias magnetic field Hdc and can provide much greater inductance($\mu_{\Delta 1}$) than that of the core ❷.

The DC superposition characteristic of PC90 exceeds that of PC33's conventional high saturation magnetic flux density by about 8%. However, there is only a small difference between them in saturation magnetic flux density at 100 °C — a difference of about 2%:

PC90 material

DC superposition characteristics

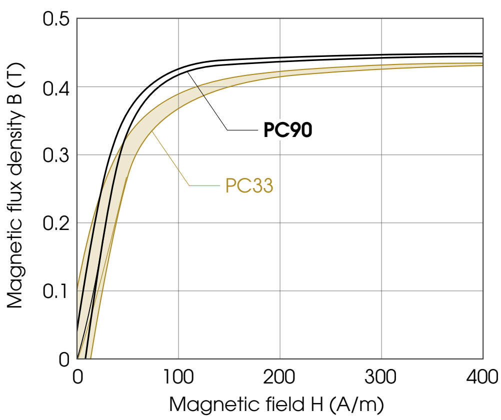


450mT for PC90, and 440mT for PC33. Despite this, PC90 has a DC superposition characteristic superior to that of PC33 by as much as 8%, a clear improvement.

The reason for the difference can be seen by comparing their magnetization curves.

As shown in the core loss vs. temperature characteristics, because PC90's core loss is reduced to a much smaller level than that of PC33, there is a steep formation of magnetic flux density for saturation, and the minor loop is drawn in the vertical direction until it just reaches saturation — an outstanding linearity is maintained.

Magnetization curves



It can be seen that PC90 has an excellent DC superposition characteristic, allowing a drastic downsizing of choke coils by the "shape-up effect" of the magnetization curves which the conventional high saturation magnetic flux density materials have never experienced before.

With drastic downsizing and weight-saving, as well as low-loss/high efficiency design, the volume of the power transformer can be reduced by as much as 36%.

PC90 material

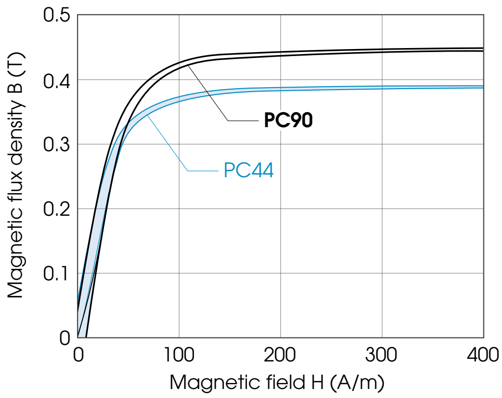
As clearly shown in the characteristic comparison, PC90 surpasses low-loss first-rate materials PC40 and PC44 in the saturation magnetic flux density by about 15%. If driven in the same conditions of magnetic flux density as PC40 and PC44, the cross-sectional area of the core can be reduced. The advantage of taking this step is a weight reduction of about 20%.

Also, because it is high saturation magnetic flux density, the inductance value required for transformers in the gap adjustment can be maintained even if the number of turns of the coil is reduced. This allows setting the copper loss (winding resistance) — which, in general, is a greater disadvantage of power transformers than core losses — at a similar level to the core loss, and then to reduce the gross loss of the transformers to a minimum.

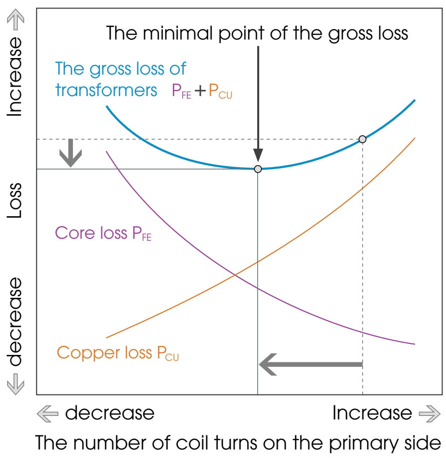
The image on the right shows a power transformer based on those concepts. The smaller one is the latest type using PC90; the larger one is the conventional type with low-loss material PC40. Of course, all of the specifications except for size and weight have been kept intact. Through complete improvement of the loss, better performance is achieved.

The latest power transformers with PC90. By reducing the number of coil turns on the primary side as well as by downsizing the ferrite core, the ratio of the coil loss to the core loss approaches the ideal 1:1. As a result, the conventional type with low-loss material PC40 has been reduced in volume by 36%.

Magnetization Curves



The loss factors of power transformers and control objectives



INFORMATION

Diverse core shapes and sizes optimal for diverse needs are available in EER, PQ, ELT, EPC, RM Series, and so on. We can also support your requests for non-standard shapes. Please feel free to contact us.

Innovations in the composition and development of fine structures that go beyond the limitations of conventional control know-how.

PC90 material

Generally, the saturation magnetic flux density Bs of a ferrite at a temperature T can be expressed by the follow-ing parameters:

$$Bs(T)=Bs(0) \times (\rho/\rho t) \times (1\text{-}T/Tc)a$$

Bs(0) : The saturation magnetic flux density at 0(K)
$\rho/\rho t$: Density / Theoretical density
Tc : Curie temperature   a : Fixed numbers

Among these, Bs(0), Tc, and ρ are the parameters which control high saturation magnetic flux density. Bs(0) is affected by the ratio of the ferrite composition from the sintering process. In the case of Mn-Zn ferrites, this value is determined by the ratio of manganese ferrite ($MnFe_2O_4$), zinc ferrite ($ZnFe_2O_4$), and magnetite (Fe_3O_4). Therefore, general development efforts have been directed to high saturation magnetic flux density where a high generation ratio of magnetite with large Bs(0) is sought.

However, the core materials used for power transformers and choke coils are required to possess high saturation magnetic flux density in the operational temperature range and the control of curie temperature, Tc, is vital here. At Tc, the magnetization process does not function because of thermal disturbance. But if the temperature is set low, the effect of the low temperature on the operational temperature range of the power circuit cannot be ignored. In other words, no matter how much Bs(0) is increased, no benefit of high saturation magnetic flux density can be expected unless Tc is set at the most suitable temperature. However, because Tc is also a parameter that depends entirely on composition, it is not easy to bolster Bs(0) as Tc is optimized.

Thus TDK integrated afourth metal ion to create a controlled composition that optimizes the Curie Temperature, establishing its original process technology for high saturation magnetic flux density that provides stable reproductivity in mass production.

Also, in conventional control knowhow, it is common that the effort to achieve high saturation magnetic flux density hinders reduction of the loss. For example, if the generation ratio of magnetite is increased, magnetostriction will also increase. This in turn will increase hysteresis loss and the electrical resistivity will tend to gradually decrease. In this case eddy current loss will be significant. Plus, the hysteresis loss increases in proportion to the drive frequency of the power supply circuit, and eddy current loss increases in proportion to the square of that. Therefore, for power supplies that drive at a relatively high frequency, such as switching power supplies, a reduction of loss in high saturation magnetic flux density, as well as similar issues, has been difficult.

TDK, as a solution to these opposing challenges, has been revising fine structure control with extremely small amounts of additive, and has been making major improvements of temperature and oxygen concentration conditions when firing. As a result, high-quality fine structure generation technology has been established that can reduce the increase of loss factors under high saturation magnetic flux density that is beyond that achieved by conventional standards, completing "low-loss & high Bs material" with a magnetization curve as sharp as that of PC44 which has an excellent low-loss characteristic.

Main uses of PC90

This will provide an unprecedented design advantage for downsizing, weight saving, low-loss/high-efficiency of diverse transformers and choke coils of power supplies, such as switching power supplies, DC-DC converters, inverters for LCD displays, and power supply circuits of laptop PCs.