



Frequently Asked Questions

It is recognized that courses in magnetic materials and their applications are limited in university offerings. Engineers who are getting into designs that require knowledge in this area often have questions about the science of magnetic materials and geometries that are available. Magnetics has compiled these frequently asked questions for the benefit of those seeking answers to some of the most commonly-asked questions.

We hope these answers are useful in furthering your knowledge of magnetic materials!

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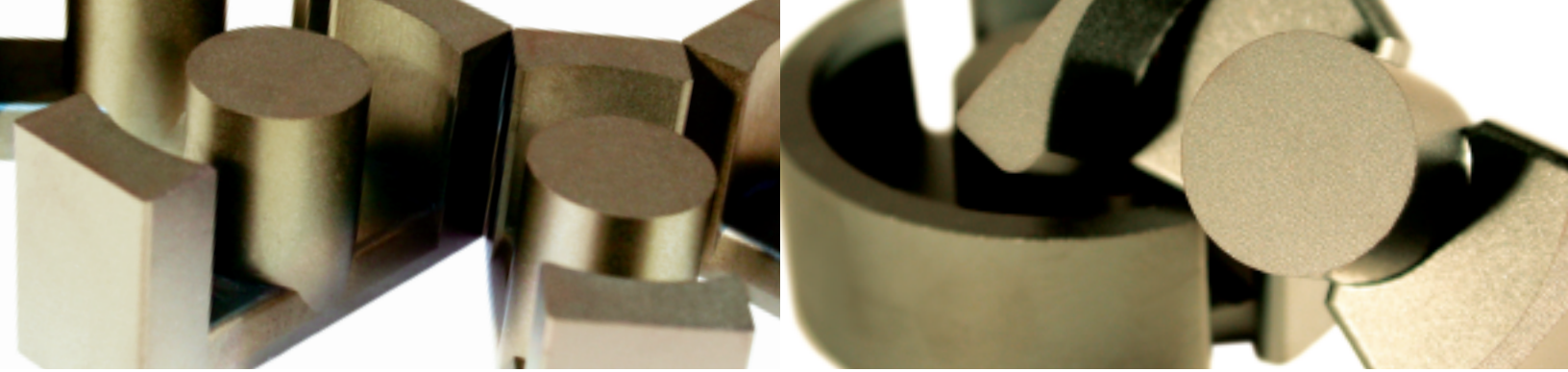
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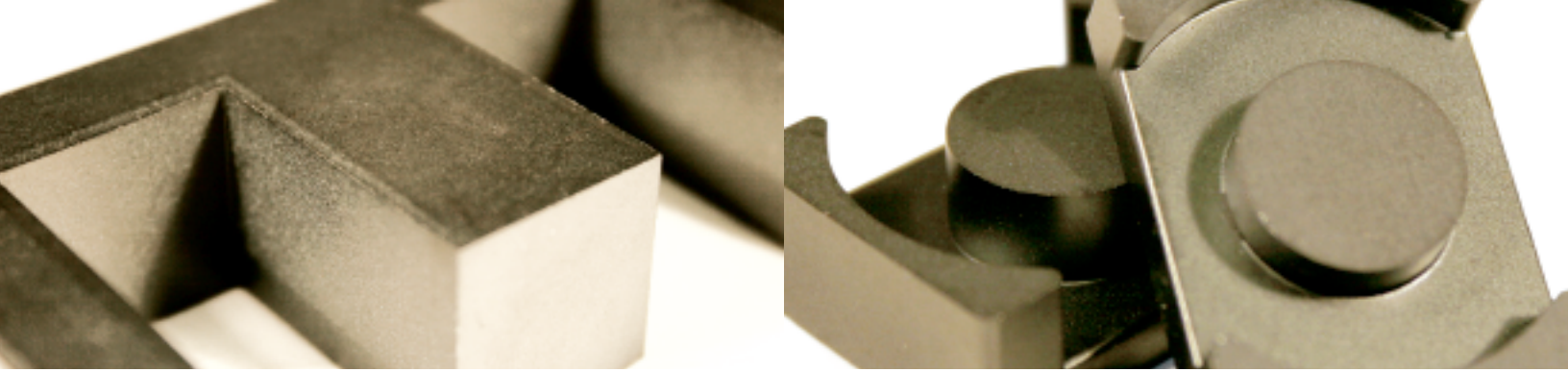
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FAQ

General

**How do you test for A_L ?
Explain why testing at 5 gauss is important.**

Inductance is measured on a bridge with variable voltage and frequency. The flux density should be less than 10 gauss. Cores have to be properly mounted around the measuring coil, or for toroids, wound with the correct number of turns.

Testing at low gauss level is important. Magnetic material characteristics change considerably at higher drive levels. Since all applications are different, it is necessary for manufacturers to normalize characteristics at a low level to insure a degree of consistency in magnetic properties and that "apples are compared to apples."

Why is corner radius important on a toroid?

A radius is important on a toroid because if the core has sharp edges, the wire insulation could be scraped during rigorous winding operations. Magnetics takes special pains to insure that toroids have some radius. Ferrite toroid dies are made with a built-in radius, and cores are tumbled to remove any sharp edges. Powder cores have a radius on one side of the tool and the other side is deburred. Additionally, many cores are painted or coated to provide not only a more blunt corner radius, but also a smoother winding surface. As with ferrites, a coating provides additional edge coverage.

Why do you provide A_L for ferrites and powder cores and not for tape cores?

Tape wound cores are generally used in transformer or square loop applications in which A_L is not critical. The desirable characteristics are high flux density, low core losses, and in some cases high squareness in the B-H loop. In square B-H loop materials such as those used in tape wound cores, the permeability varies widely as the loop is traversed; a consistent and repeatable inductance measurement is not obtainable. In rounded B-H loop materials, such as ferrites and powder cores, the permeability is more constant along the loop. A_L is a measure of permeability at low drive levels, where the permeability is relatively stable in round loop materials.

Can I get tighter dimensional tolerances on cores?

During the sintering operation, ferrite parts shrink to their final dimensions. Different material and processing techniques result in variance in this linear shrinkage which can range from 10 to 20% of the pressed dimensions. The resulting variation in fired dimensions results in final tolerances in the range of 1-4%. Some dimensions cannot be held to a tighter tolerance. But dimensions that can be machined after firing can certainly be held to tighter tolerances. Powder cores generally have the dimensions held to the best available tolerances, though custom dimensions can be quoted on special specification parts.

What is the best core shape?

There is no "best shape". It depends on the application, space constraints, temperature limitations, winding capabilities, assembly, and a number of other factors; this means compromises must be made.

Why are A_L tolerances wide for ferrites and narrow for powder cores?

Ferrites are sensitive to chemistry and kiln conditions. Fired cores have wide inductance tolerances, but machining an air gap in the core provides a tighter A_L . Process control in ferrite manufacturing results in inductance ranges $\pm 20\%$ - $\pm 30\%$ (without 100% selection), in the case of ungapped cores. Process control in powder core manufacturing results in inductance ranges of $\pm 8\%$ to $\pm 15\%$.

FAQ

Can you tighten electrical tolerances on toroidal cores?

While a production batch of toroids may have a wide tolerance, the cores can be graded into narrower inductance bands. Powder cores are all $\pm 15\%$ or better. MPP and High Flux are graded into 2% bands. Due to the equipment limitations, this is not possible on all sizes and permeabilities. Check with MAGNETICS for specific information and costs.

What about availability of parylene core coatings for toroids?

Parylene C® is a vacuum deposited coating providing good resistance to moisture and organic solvents. Electrical characteristics are superior to other coatings. Because this is an expensive coating, the size range is economically limited to an outside diameter of 14 mm or less.

Why are cores not like magnets?

Permanent magnets are considered “hard” magnetic materials because their magnetism is permanently retained, a result that has been achieved by their manufacturing process. Cores are considered “soft” magnetic materials because they are magnetically biased only when wound with current-carrying wire. Hard magnets are fixed at one point on the B-H (or hysteresis) curve. Soft magnetic materials can be cyclically driven along portions of their B-H curves, making them usable for transformers and inductors.

What are effective core parameters?

Magnetic cores, particularly ferrites, come in a variety of geometries. In order to apply the many formulas that are used in calculations for designs, core physical parameters are calculated to minimize geometry effects. These parameters are the magnetic path length, effective area and effective volume.

How does MAGNETICS measure toroid coating insulation and make voltage breakdown guarantees?

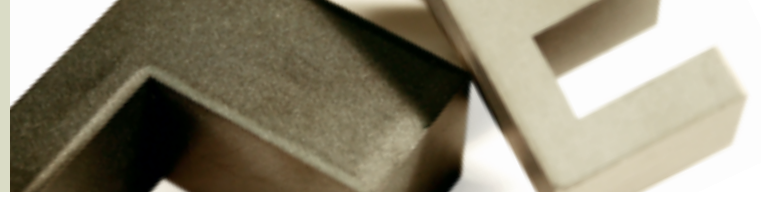
Core finishes on toroids are measured for voltage breakdown by inserting the core between two weighted wire mesh pads. The force is adjusted to produce a uniform pressure of 10 psi, simulating winding pressure. The test is conducted using a 60 Hz r.m.s. or DC voltage. Consult the toroid product catalog for specific finishes and their guaranteed voltage breakdowns. Users should be careful to note that their actual windings, especially when heavy wire is used, can cause mechanical stresses that are not present in the standard breakdown test; excessive stresses here can result in a lower-than-expected breakdown. On the other hand, magnet wire is insulated, unlike the wire mesh test pads.

What is the best material to use?

There is no universal answer to this question, as selection depends on the application and application frequency. Any material selected is subject to tradeoffs. For instance, some materials may keep heat rise to a minimum and are expensive, but if one is willing to put up with more heat, perhaps a larger component or less costly one will do the job. The best material selection first depends on whether you have an inductor or a transformer application. From this point, the operating frequency and cost are important. Different materials are optimal at different frequency ranges, operating temperatures, and flux densities. After narrowing the core selection to particular types, it is advisable to sample the different ones that could fill the bill, then make a final selection. *For additional information, refer to MAGNETICS' All Products Bulletin, Magnetic Cores for Switching Power Supplies, or Ferrite Material Selection Guide.*

How do you demagnetize a core?

Drive the core under 60 HZ conditions (saturating alternately in a positive and negative direction) then slowly reduce the drive level over several cycles until it is reduced to zero. This action will reduce the remanence point to the origin.



What happens to a core if you go above the Curie temperature?

Curie temperature is the temperature at which a material loses all of its magnetic properties. Beyond the Curie temperature, the core loses all useful properties in a circuit. Many cores have an insulated coating which would be ruined long before the Curie temperature is reached. (Coating temperature restrictions can be found in MAGNETICS Design Manuals.)

Strip wound cores can have their magnetic characteristics permanently altered during exposure to the Curie temperatures. Conventional strip wound cores and powder cores generally have such high Curie temperatures ($>450^{\circ}\text{C}$) that the materials may be damaged due to oxidation well below the Curie temperature. Manganese-zinc ferrites, on the other hand, will not be affected, except for the insulated coating on them. This is due to the low Curie temperatures (120°C to 300°C) of ferrites. Exceeding these temperatures is generally not high enough to alter the ceramic material structure. In general, the core's magnetic properties will be restored when the temperature is reduced to below the Curie temperature, as long as the material has not been oxidized or held at high temperature for extended period of times.

What is the maximum frequency at which you can operate a magnetic material?

Primarily, this depends on the type of material. Strip wound cores generally will have a maximum usable frequency lower than, ferrites, because the resistivity is lower, resulting in high eddy currents and higher core losses. The thinner the strip material, the higher the usable frequency. On the other hand, core losses depend on the operational flux density of the design; thus, by reducing the flux density, a higher operating frequency can be achieved. Often in power magnetics, it is not the saturation flux density (B_{sat}) of the material that limits the drive level, but rather the maximum tolerable losses at the specific operating frequency. *Consult the MAGNETICS Design Manuals to see the relationships among core losses, frequency, and flux densities.*

What information does a B-H loop provide?

It defines the flux density of the material, coercive force, the amount of drive level required to saturate the core, and the permeability (or the ability to change the magnetic lines of force). The B-H loop changes with frequency and drive level. How a material reacts to the frequency and excitation level (current and voltage) is very important in determining its effectiveness to meet the needs of a particular application. *Consult the MAGNETICS Design Manuals to see the relationships among core losses, frequency, and flux densities.*

What is the relative cost of different magnetic materials?

Much of the cost is related to the basic cost of raw materials. Magnetic materials containing high percentages of nickel or cobalt have a higher cost than those containing primarily iron. In between these two extremes are the variety of compositions that comprise the many types of materials and geometries. Material cost impacts large cores more significantly than small ones. Relative costs can be compared as follows:

In powder cores, iron powder ranges from x-3x
Kool M μ [®] -----ranges from 4x-5x • High Flux -----approx. 10x • MPP-----approx. 12x

In ferrites, F, L, P, R, and J materials, roughly equivalent (y)
W material -----1.25-1.75 y

Ferrite cost is a function of geometry:
Toroids-----least • E Cores-----Mid • Other Shapes-----Most

FAQ

Why do you put an air gap into cores?

Introducing an air gap into a core, “tilts” or “shears” the B-H loop, making it possible to use the core at higher H levels. It is desirable, for many applications such as inductors, to delay this saturation. Air gaps have an added advantage in allowing for tighter control on inductance.

What is magnetostriction?

When a magnetic material is magnetized, a small change in dimension occurs. The relative change is in the order of several parts per million, and is called “magnetostriction”. For applications like ultrasonic generators, the mechanical motion produced by magnetic excitation through magnetostriction is used to good advantage. In other applications, operating in the audible frequency range, an unwanted audible hum is observed. For this reason, low magnetostrictive materials such as Permalloy 80, Kool M μ ®, and MPP powder cores may be used to limit or remove audible noise.

How do you determine proper core size?

Two elements are useful in determining core size: core window (winding) area and core cross-sectional area. The product of these two elements (area product, or $W_a A_c$) relates to the power handling capability of a core. The larger the $W_a A_c$ the higher the power able to be handled. As operating frequency increases, the area product can be reduced, thus reducing the core size. MAGNETICS publishes the area products as a useful design tool. *Consult the MAGNETICS Design Manuals to see the relationships among core losses, frequency, and flux densities.*

What are the differences between using a distributed gap (powder core) versus a discrete gap (ferrite)?

A distributed gap material such as Kool M μ ® has each alloy grain insulated from the others. This allows for soft saturation over increasing current, giving inherent fault protection. Discrete gap cores hold high inductance out to a knee in the curve resulting in sharp saturation. Distributed gap cores hold better B_{max} and DC bias at high temperatures. Discrete gap cores have fringing flux around the gap adding significantly to the losses.

Where can I find core standards?

The organization recognized for new and existing core standards is the International Electrotechnical Commission (IEC). Specifically the group TC-51 works with core specifications. (www.iec.ch)

Conversion Factors

Multiply	By	To Obtain
Oersteds	2.0213	ampere-turns/inch
Oersteds	0.79577	ampere-turns/cm
Oersteds	79.577	ampere-turns/m
Ampere-turns/cm	1.2566	oersteds
Gausses	10^{-4}	teslas



Application

**What types of cores are used for transformers?
What type for inductors?**

Desirable materials for transformer cores are those that have a high flux density and keep the temperature rise within desirable limits. High permeability materials are desirable to limit the exciting current (air gap minimized). For lower frequency applications (under 20kHz), strip materials have the highest flux density; for higher frequency applications (above 20kHz), ferrites are desirable because the materials are designed to have low core losses (lower heat rise) at these higher frequencies.

For inductors, cores that have discrete or distributed air gaps are desirable because they can maintain their constant permeability levels up to high DC or AC drive levels. Ferrites and strip wound cores can be gapped. Powder cores have a built-in distributed air gap.

See Magnetics All Products Bulletin for Magnetic Core Selection by Application.

Why does one consider single layer windings on toroid cores?

Single layer windings are less costly to wind. The distributed capacitance is kept to a minimum. Temperature rise due to copper loss is minimized. For common mode chokes, symmetry between the opposing windings is much easier to maintain when only one layer is used.

What is a bifilar winding?

Two strands of wire, usually twisted together. The dual wire is then wound on the core or bobbin to produce two equal and parallel windings which take the place of one large single strand.

Assembly

Why does the inductance decrease after winding and potting?

Ferrite materials are susceptible to mechanical stress, both from winding the core and from encapsulation. High permeability materials are particularly affected. Suggested remedies: (1) after winding, bake, and or temperature cycle, (2) thin out epoxy used for encapsulation or dope with an inert material such as sand or ground mica, (3) cushion with tape.

For more details, see MAGNETICS article reprint "Common Mode Inductors for EMI". Page 6 and 7 in that article cover this subject in detail.

How do I know the ferrite hardware will fit on the core?

Cores are manufactured to standards that have been agreed to in the industry. Tolerances have been assigned to the critical dimensions. Generally, hardware fit should not be a problem. When possible hardware and cores should be purchased from the same source.

Powder Cores

Can you press powder cores to different heights?

Many cores can be pressed to different heights. Dies are made so that the cavities can accommodate a range of heights. Height variation is relative to core size. One advantage this offers is the ability to produce alternate core sizes without the expense of additional tooling. Consult MAGNETICS for specific questions on the size of interest.



In powder cores, why is measured inductance different from calculated?

Magnetics measures inductance in a Kelsall Permeameter Cup. Actual wound inductance outside a Kelsall Cup is greater than the value calculated due to leakage flux and flux developed in the winding. The difference depends on the core size, permeability, core finish thickness, wire size, and number of turns, in addition to the way windings are put on the core. The difference is negligible for 125μ and higher and turns greater than 500. The following table is a guide to the differences that one might experience:

No. of Turns	Actual L	No. of Turns	Actual L
1000	0%	100	+3.0%
500	+0.5%	50	+5.0%
300	+1.0%	25	+8.5%

The following formula can be used to approximate the leakage flux to add the expected inductance. This formula was developed from historical data of cores tested at MAGNETICS. Be aware that this will only give an approximation based on evenly spaced windings. You might expect as much as ±50% deviation from this result.

$$L_{LK} = \frac{292N^{1.065}A_e}{l_e \times 10^6}$$

where L_{LK} = leakage inductance (nH/Turn²)

N = number of turns

A_e = core cross-section (mm²)

l_e = core magnetic path (mm)

What is the main advantage of each distributed gap material?

MPP has the lowest losses, and the best Q. HF has the highest DC bias. Powdered Iron is the least expensive. Kool Mμ® is a mix of the advantages of the previous three; lower losses than Iron Powder, near zero magnetostriction, and much lower cost than MPP.

What is the adhesive recommended for Powder Cores?

Bondmaster® ESP 309 is a one part epoxy adhesive that is recommended for use on powder core materials. This adhesive has good strength at room temperature and retains strength at high temperature.

How are properties affected when cores are stacked?

Stacking cores will increase the cross section (A_e) by the multiple of the number of cores in the stack. The magnetic path length (l_e) will remain constant. The A_L can be estimated by the same method as for single sets, where a leakage adjustment is estimated based on the ratio of window area (W_A) to core area (A_e). Because that ratio decreases as cores are stacked, the A_L of n stacked sets are slightly less than n times the A_L of a single set.

What is soft saturation?

Soft saturation is a distributed gap material advantage over a ferrite. The DC bias curve does not have the traditional saturation point that a ferrite core does, rather, as the drive level increases the permeability slowly rolls off in a predictable fashion.



Ferrites

How important is permeability in power materials?

Permeability is flux density, (B), divided by drive level, (H). Power materials are generally used for high frequency transformer applications. Hence, the important characteristics are high flux density and/or low core losses. Permeability is of lower importance because of its variability over an operating flux range.

What is disaccommodation?

Disaccommodation, occurring in ferrites, is the reduction of permeability with time after a core is demagnetized. This demagnetization can be caused by heating above the Curie point, by applying an alternating current of diminishing amplitude, or by mechanically shocking the core. In this phenomenon, the permeability increases towards its original value, then starts to decrease exponentially. If no extreme conditions are expected in the application, permeability changes will be small because most of the change has occurred during the first few months after manufacture of the core. High temperature accelerates the decrease in permeability. Disaccommodation is repeatable with each successive demagnetization; thus, it is not the same as aging.

Why are actual core losses larger than calculated?

When calculating the core losses, it is assumed that the structure is homogeneous. In reality, when core halves are mated, there is leakage flux (fringing flux) at the mating surfaces, and the gap losses contribute to the total losses. Gap losses are caused by flux concentration in the core and eddy currents generated in the windings. When a core is gapped, this gap loss can drastically increase overall losses. Additionally, because the cross-sectional area of many core geometries is not uniform, local "hot spots" can develop at points of minimum cross section. This creates localized areas of increased flux density, resulting in higher losses at those points.

What is the difference between nickel-zinc and manganese-zinc ferrites?

MnZn materials have a high permeability, while NiZn ferrites have a low permeability. Manganese-zinc ferrites are used in applications where the operating frequency is less than 5 MHz. Nickel-zinc ferrites have a higher resistivity and are used at frequencies from 2 MHz to several hundred megahertz. The exception is common mode inductors where the impedance of MnZn material makes it the best choice up to 70 MHz and NiZn is recommended from 70 MHz to several hundred GHz.

Why, in some cases, is only the minimum A_L listed in the core datasheet?

Permeability (and A_L) varies with drive level. For power applications, there is no need to place a limit on the maximum A_L . A minimum A_L translates into maximum excitation current.

What is the proper clamping pressure for ferrites?

Generally, a recommended figure is about 700 kg/m² (100 lbs./sq. in.) of mating surface. *For specific recommended pressures for RM, PQ, EP, and pot cores, consult the MAGNETICS Ferrite Design Manual.*

Why do you flat-grind ferrite cores?

Cores are flat-ground on the mating surface because of the uneven surface produced during the firing process. It is important for cores to mate with a minimum air gap to keep the gap losses low and to achieve optimum inductance.

FAQ



Why do cores get lapped? What is the surface finish?

Lapping is an additional production process used to improve the mating surface. It is typically done on cores with material permeability of 5000 and greater in order to achieve the maximum A_L value for a given material. A mirror-like finish is the result. The surface finish for a normally flat-ground surface is 0.5 to 1.0 microns and for a lapped core is 0.1 to 0.2 microns.

Why is the ferrite gapped tolerance not always $\pm 3\%$?

Due to limitations of the machine performing the gapping, as the gap dimension decreases it is increasingly difficult to hold tight tolerances. As A_L increases the gap gets smaller and the tolerances increase. As the gap gets smaller, the mechanical tolerance becomes proportionately larger, in addition the influence of variation in the material permeability becomes greater. A gap specified by its A_L value yields a tighter tolerance than a gap specified by its physical dimensions.

How do you glue ferrite cores?

Gluing should be done with thermosetting epoxy resin adhesives. The available range is very large. Important factors in the choice are the required temperature and viscosity. The economic curing temperature must not be above the maximum temperature to which the assembly may be safely raised. High viscosity resin can be difficult to apply. Low viscosity resin may run out of a poorly fitted joint or may be absorbed by the porous ferrite material. Follow the manufacturer's instructions for a particular resin. Take care not to thermally shock ferrites; raising or lowering the core temperature too rapidly is dangerous. Ferrites will crack if changes in temperature exceed $5-10^\circ\text{C}/\text{min}$. In addition, care must be taken to match the adhesives' coefficient of thermal expansion (CTE) to that of the ferrite material. Otherwise, the resin may expand or contract more quickly than the ferrite; the result can be cracks that will degrade core properties.

What is MAGNETICS specification for out of roundness on a ferrite toroid?

Out of roundness is controlled by mandating that cores meet overall dimensional tolerances for OD and ID while keeping enough cross section to meet the specified A_L . *Refer to the MAGNETICS Ferrite Design Manual for toroid physical dimension tolerances.*

What is the difference between nylon and epoxy coatings for ferrite toroids?

They are similar. Nylon is thicker, and can stand temperatures up to 155°C . Epoxy is rated at 200°C . Nylon finishes are generally applied to cores ranging in O.D. (outside diameter) from 12.7 mm to 29 mm. Very large and very small cores are coated with a epoxy finish. The voltage breakdown guarantee of nylon and epoxy coating is 1000 volts wire to wire. Nylon cushions better and is more resistant to solvents. Both finishes are held to the same electrical specifications.



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