Dry-Type Transformers

High-Efficiency Dry-Type Transformers

Transformers reduce the voltage of the electricity supplied by your utility to a level suitable for use by the electric equipment in your facility. Since all of the electricity used by your company passes through a transformer, even a small efficiency improvement will result in significant electricity savings. High-efficiency transformers are now available that can reduce your facility's total electricity use by approximately 1 percent. That's good for your company; it's also good for the environment. Reduced electricity use provides cost savings for your company; it also reduces air emissions from electricity generation.

Two types of energy losses occur in transformers: *load* and *no-load* losses.

Load losses result from resistance in the copper or aluminum windings. Load losses (also called winding losses) vary with the square of the electrical current (or load) flowing through the windings. At low loads (e.g. under 30 percent loading), core losses account for the majority of losses, but as the load increases, winding losses quickly dominate and account for 50 to 90 percent of transformer losses at full load. Winding losses can be reduced through improved conductor design, including proper materials selection and increases in the amount of copper conductor employed.

No-load losses result from resistance in the transformer's laminated steel core. These losses (also called core losses) occur whenever a transformer is energized and remain essentially constant regardless of how much electric power is flowing through it. To reduce core losses, high-efficiency transformers are designed with a better grade of core steel and with thinner core laminations than standard-efficiency models. As well, new transformer core designs are emerging that use amorphous metal instead of the traditional silicon steel. These amorphous core transformers, available from major transformer manufacturers including GE, ABB and Howard Transformers, offer up to 80 percent lower core losses than conventional transformers.

Total transformer losses are a combination of the core and winding losses. Unfortunately, some efforts to reduce winding losses increase core losses and vice versa. For example, increasing the amount of conductor used reduces the winding losses, but it may necessitate using a larger core, which would increase core losses. Manufacturers are developing techniques that optimize these losses based on the expected loading.

How Much Will I Save?

Efficiency is the key to determining your savings. That's because the lifetime operating costs from the core and winding losses in an old standard-efficiency transformer are typically about five times the initial transformer purchase price. Table 2 below illustrates how even a small efficiency improvement of less than 1 percent can provide attractive electricity cost-savings.

Table: Comparison of Lifetime Costs and Simple Payback Period for “Typical Pre-Regulation” and “Post-Regulation” 75 kVA Three-Phase Dry-Type Transformers

	Typical Pre-Regulation Transformer	**Post-Regulation Transformer**	**Difference**
Capital cost	$1,500	$3,000	$1,500
Efficiency	97.3 percent	98.0 percent	0.7
Annual cost of losses*	$632	$391	$241
Simple payback (years)	-	6.2	6.2
Lifetime cost of losses**	$5,959	$3,690	
Present value of savings	-	$769	

*Assuming a 35 percent load, an energy cost of $0.08/kWh, and a demand cost of $7/kW month.
**Present value calculation assumes a useful life of 30 years and a discount rate of 10 percent.
Even greater electricity savings are possible with amorphous core transformers, though they typically cost 25 to 30 percent more than comparable transformers with a silicon steel core.

Purchasing High-Efficiency Transformers

The selection and purchase of a high-efficiency dry-type transformer can be a complicated process.

Purchasing Tips

1. **Know your facility's load profile.** Every transformer has its own unique efficiency profile based on its load and no-load losses, so a transformer's energy losses will depend heavily on building and equipment usage patterns. Large transformers tend to be heavily loaded, while transformers that serve smaller industrial and commercial customers tend to be more lightly loaded. The better you understand your facility's load profile, the more effectively you will be able to choose the most efficient transformer for your facility.

2. **Consider what type of equipment the transformer will be powering.** The efficiencies specified for dry-type transformers are calculated under linear load conditions. Examples of linear loads include lighting and motors. Increasingly, transformers are supplying power to non-linear loads, such as adjustable speed drives, computers and electronic equipment. These non-linear loads produce harmonic distortion that increases transformer losses. If your transformer will be supplying power mainly to computers and office equipment (as opposed to motors and pumps), it may be worthwhile considering the transformer's K rating Transformers with high K ratings are specifically designed to be more efficient with non-linear loads. Bear in mind, however, that transformers with high K ratings can cost up to twice as much as a standard transformer and, depending on your load, they may not be necessary. Manufacturers make transformers with K ratings as high as 13, but a recent survey of dry-type transformers found the average K factor to be only 2.7.

3. **Do not be misled by transformers that are rated at full-load efficiency.** It is important to remember that transformers are rarely run at their full-load. In fact, 35 percent is the accepted industry average transformer load. A survey of dry-type transformers actually found the average load factor in manufacturing facilities to be only 14.1 percent. The efficiency of any transformer at this low load is very different from its efficiency at full load.

4. **Do not choose your transformer solely on the lowest temperature rise.** Some purchasers believe that choosing a transformer with a low temperature rise will result in an energy-efficient transformer, but this is not always the case. In general, the lower the temperature rise of a transformer, the lower its internal losses, but when manufacturers design a transformer for a low-temperature rise, they often decrease the load losses but increase the no-load losses. This is due to the cooling method, i.e. fans. If a transformer is running at a very low load, this method of selecting a transformer can actually result in choosing a less efficient model.

Why should we care?

A "transformer" changes one voltage to another. This attribute is useful in many ways.

A transformer doesn't change power levels. If you put 100 Watts into a transformer, 100 Watts come out the other end. [Actually, there are minor losses in the transformer because nothing in the real world is 100% perfect. But transformers come pretty darn close; perhaps 95% efficient.]

A transformer is made from two coils of wire close to each other (sometimes wrapped around an iron or ferrite "core"). Power is fed into one coil (the "primary"), which creates a magnetic field. The magnetic field causes current to flow in the other coil (the "secondary"). Note that this doesn't work for direct current (DC): the incoming voltage needs to change over time - alternating current (AC) or pulsed DC.

The number of times the wires are wrapped around the core ("turns") is very important and determines how the transformer changes the voltage.

- If the primary has fewer turns than the secondary, you have a step-up transformer that increases the voltage.
- If the primary has more turns than the secondary, you have a step-down transformer that reduces the voltage.
- If the primary has the same number of turns as the secondary, the outgoing voltage will be the same as what comes in. This is the case for an isolation transformer.
- In certain exceptional cases, one large coil of wire can serve as both primary and secondary. This is the case with variable auto-transformers and xenon strobe trigger transformers.

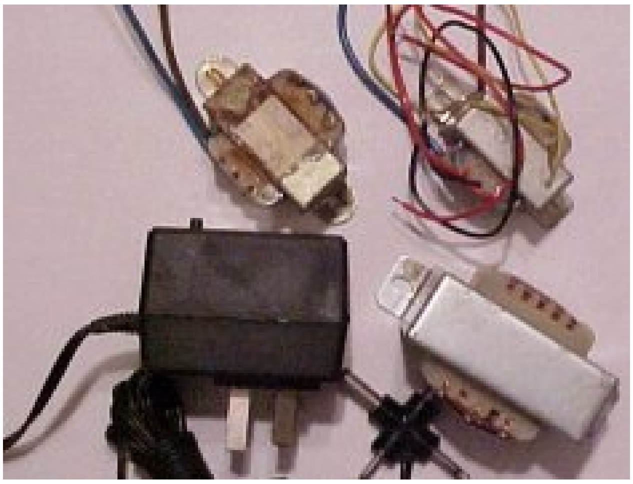
Types of transformers

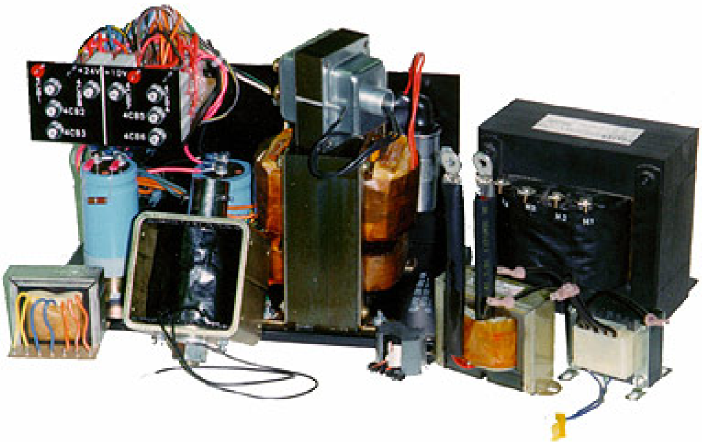
In general, transformers are used for two purposes: signal matching and power supplies.

(a) Power Transformers

Power transformers are used to convert from one voltage to another, at significant power levels.

Some examples of power transformers are shown below.





(b) Step-up transformers

A "step-up transformer" allows a device that requires a high voltage power supply to operate from a lower voltage source. The transformer takes in the low voltage at a high current and puts out the high voltage at a low current.

Examples:

- You are a Swiss visiting the U.S.A., and want to operate your 220VAC shaver off of the available 110 VAC.
- The CRT display tube of your computer monitor requires thousands of volts, but must run off of 110 VAC from the wall.

(c) Step-down transformers

A "step-down transformer" allows a device that requires a low voltage power supply to operate from a higher voltage. The transformer takes in the high voltage at a low current and puts out a low voltage at a high current.
Examples:

- Your Mailbu-brand landscape lights run on 12VAC, but you plug them into the 110 VAC line.
- Your doorbell doesn't need batteries. It runs on 110 VAC, converted to 12VAC.

(d) Isolation transformers

An "isolation transformer" does not raise or lower a voltage; whatever voltage comes in is what goes out. An isolation transformer prevents current from flowing directly from one side to the other. This usually serves as a safety device to prevent electrocution.

(e) Variable auto-transformers

A "variable auto-transformer" (variac) can act like a step-up transformer or step-down transformer. It has a big knob on top that allows you to dial in whatever output voltage you want.

VARIACS

Input: 110 vac
Output: 0 - 130 vac
Fully enclosed variable transformers in ventilated steel cases with 6' power cord, 3 prong grounded receptacle, output voltage meter, on/off switch, fuse and power cord. Portable or mountable.

3 AMP VARIABLE TRANSFORMER
5.35" X 4" X 5.5" high. Weight: 6.5 lbs.
CAT # SC-3M $45.00 each

5 AMP VARIABLE TRANSFORMER
4.75" X 7" X 6" high. Weight: 8 lbs.
CAT # SC-5M $95.00 each

10 AMP VARIABLE TRANSFORMER
6.5" x 9" x 6" high. Weight: 20 lbs.
CAT # SC-10M $135.00 each

20 AMP VARIABLE TRANSFORMER
6.5" x 9" x 7.5" high. Weight: 22 lbs.
CAT # SC-20M $165.00 each

Inverters:

An "inverter" takes a DC power source and boosts it up to a higher voltage. The most common type of inverter takes power from an automobile and cranks out 110 VAC to run appliances and power tools. Inverters are also used to operate fluorescent lamps from battery power. Technically, an inverter isn't a transformer; it *contains* a transformer (and lots of other stuff).

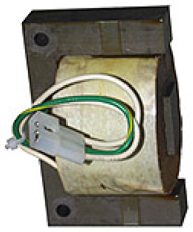
Signal Transformers

"Signal transformers" also take one thing in and transform it to another thing out. But in this case, the power levels are low, and the transformed thing carries some type of information signal.
In most cases, these transformers are thought of as impedance matching.

Custom Transformers

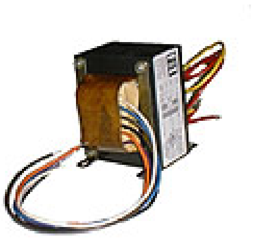
When you need a custom transformer, power supply, inductor, solenoid, or other magnetic component or value added assembly, Foster Transformer Company is the clear choice. Our reputation has been built by consistently and cost effectively meeting the needs of our customers in a timely manner.

- Single and three phase transformers from board level to 5.0 kVA per phase.
- Patented, Inherently Limited, UL 1585 Class 2 transformers to 100 VA.
- Medical Transformers to UL 2601-1, IEC 60601-1, and EN 60601-1
- Ferroresonant Transformers with square wave or sine wave outputs.
- Audio Transformers.
- Ferroresonant and Linear Power Supplies.
- High Voltage Transformers and Power Supplies.
- Solenoid Coils and Assemblies.
- UL Recognized Class 130, 155, 180, 200 and 220 C Insulation Systems.



Electromagnets used in vibrator assemblies for sorting equipment.

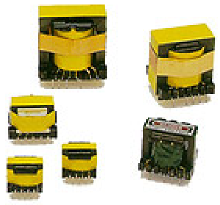
Class 2 transformers as part of value added assemblies.



Isolation Transformers complying with EN 61558-1 and 60601-1

DC solenoids for commercial, industrial, and medical applications.

Hermetically sealed transformers for commercial and military applications.



Ferrite Transformers in all topologies and core shapes.

High voltage power supplies with Class A (105C) to Class H (180C) Insulation Systems.

Constant Voltage Power Supplies for high reliability industrial applications.

Three phase power transformers and line reactors.

Electronic Transformers & Inductor Core Types

Magnetics cores can be divided into many types of categories. These major core categories will then be sub-divided into additional categories.

Further below are a list of core structures and a list of magnetically "soft" core materials. The lists are not intended to be exhaustive lists.

Butler winding can make (and has made) transformers and inductors in a wide variety of core shapes, sizes, and materials. This includes; various standard types of "core with bobbin" structures (E, EP, EFD, EC, ETD, PQ, POT, U and others), toroids, and some custom designs. For toroids, we can (and have done) sector winding, progressive winding, bank winding, and progressive bank winding.

Core Structures

Toroids (rings)

Toroids are the core type geometry of choice for optimizing performance. A toroid of round cross-section offers better performance than one of rectangular cross-section, but for practical and economic reasons toroids of rectangular cross-section are much more prevalent. The symmetry of their circular geometry minimizes the amount of external magnetic flux produced. Consequently they produce much lower amounts of unwanted electromagnetic interference. Unlike other core types, turns can be wound along the entire length of the core thereby allowing more turns per layer. The mean turn length will be shorter than that of other core types of equal power capability hence lower winding resistance and lower winding losses. Compared against other core types, a toroidal coil has a lot of surface area from which it can dissipate heat hence it cools much better than other core types. Cooler windings result in higher efficiency and may allow more utilization of the core's capability.

Because of its circular nature, the magnetic path of a toroid is an unbroken continuous path unless intentionally broken. There is no air gap in the magnetic path (unless intentionally added) hence optimal use can be made of high permeability materials. Ferrite toroids and stacks of stamped lamination rings are examples of this. A tape wound core is the next closest example. The flux in each layer wound on the core can make a full revolution and then continues onto the next layer, but the magnetic flux must eventually pass from layer to layer encountering an air gap between layers in the process. The gap occurs because the tape strip is not perfectly flat. The layer to layer passage is distributed the surface area of an entire revolution, hence the magnetic reluctance of the gap becomes very small and usually can be ignored. A tape wound core can utilize the advantage of grain oriented materials (such as grain oriented silicon steel) while stamped rings cannot.

In some applications it is desirable to have an air gap in the core path. For mechanical reasons, it is cumbersome to add air gap to a toroid. Large air gaps produce undesirable flux fringing. Powdered cores combined the magnetic material with a non-magnetic binder material. Magnetically, the binding material acts like an air gap, but this gap is distributed throughout the entire core. Because of this distribution there are no flux fringing effects. The binder(s) also reduce eddy currents.

Toroids are manufactured in practically all "soft" magnetic materials. Toroid Cores can be coated with insulation to provide electrical isolation between the core and the winding(s). Some toroid cores are "boxed" to provide isolation. Some toroid cores are "boxed" because the core material is sensitive to stresses produced by the winding processes.

Bar, Slab, or Rod:

"Soft" magnetic metal alloys are available in Bar, Rod, or Slab shapes. These core shapes find use in D.C. applications such as D.C. powered solenoids and D.C. relays. They can be used in very low frequency (below 50 Hz) A.C. applications. They do have some limited use at A.C. line frequencies. For a solid core, A.C. core losses per unit weight (or unit volume) become more pronounced as the cross sectional area increases. This is why silicon steel, nickel-iron, and cobalt alloy cores use a stack of laminations. The laminations divide the cross-section into a stack of much smaller cross-sections. D.C. applications are subject to far less core losses. They only experience A.C. core losses (and the heat produced) during transitional events.

Powder Cores extend the useful A.C. frequency range of the materials listed in the previous paragraph. A non-magnetic binding material is used to bind the small magnetic powder particles together. The binding material also serves to insulate the particles from one another thereby reducing eddy current flow in the core. This extends the useful frequency range, but there is a trade-off. The binding material adds a distributed air gap to the core. The distributed air gap reduces the permeability of the core. The core requires more magnetizing VA. Bars, slabs, and rods can be purchased in powder iron materials. The selection of sizes is somewhat limited. Larger sizes can be assembled from smaller sizes.

Ferrites are a magnetic form of ceramics. Ferrite has very high electrical resistivity. Even at high frequencies the eddy currents remain low. With suitable gauss de-rating, some types of ferrite cores can use above 1 megahertz. Bar, slabs, and rods can be purchased in ferrite materials, but the selection of sizes is limited. Larger sizes can be assembled from smaller sizes.

“C” Cores:

“C” Cores are similar to tape wound toroids in that they are made by winding a long strip of electrical steels of desired width and thickness onto a mandrel. They differ from tape wound toroids in two characteristics: it is rectangular with rounded corners, and the wound core is cut in half to form two “C” shaped mating pieces. (One could argue that two “U” shapes are formed.) The mating surfaces are polished to minimize air gap between the two halves. Further reduction in the gap may be achieved by cutting the core at an angle. One “C” core set (or 2 “C” core halves”) can replace a “U-U” or “U-I” laminated structure. Two sets of “C” cores (or 4 “C” core halves) can replace a “E-E” or a “E-I” laminated structure. “C” cores can take full advantage of grain orientation while their laminated counterparts only take about 60% to 80%. Because of this, “C” cores performance is better than that of laminated stacks. The rounded corners also reduce the weight.

“E” Type Cores: “E-E”, “E-I”, “EFD”, “EEM”, “ER”, and “ETD”:

Powdered and Ferrite Cores did not exist In the early development of transformers and inductors. Cores consisted of stacks of laminations; patterns cut or stamped out of thin sheets of electrical steels. Most applications required a lamination pattern (or patterns) that would form a closed magnetic loop when assembled together. Early patterns included rings for toroids, “L” shapes, “U” shapes, “E” shapes and “I” shapes (used with the “E” and the “U”). Patterns were sought that were easy to assemble, could be interleave to minimize gap effects, and would minimize waste. “E” shapes used in “E-E” and “E-I” combinations became popular choices. “Scrapless” “E-I” patterns were developed. The electrical steel stamped out of two adjacent “E” laminations (placed leg end to leg end) to form the winding window area became the two “I” laminations to be placed across the leg ends of the “E” laminations.

In the typical “E” lamination, the center leg (one of three legs) is twice the width of either outer leg. In theory, magnetic flux flowing out of the center leg divides equally and flows into the outer two “E” core legs. Since the outer legs handle half the flux they only need to have half the cross-section that the center leg has. An “E” core structure occupies two outer sides of the coil. This constitutes a “shell” type core structure (not explained in detail here). In contrast, a “U” core or “C” core structure (which has two core legs) only occupies one side of a coil placed over one of its legs. The “E” core structure provides better self-shielding than the “U” core structure (but neither provides good shielding). “E” type cores are easily gapped. For the typical “E” laminations this requires a “butt stacked” core. There is no interleaving of laminations.

Since “E” cores have two open coil sides, they provide substantial room to bring high current lead wires out from the coil. This also permits good heat dissipation but not as good as a toroid. In contrast, the standard pot core has a much more restricted space in which to bring out lead wires and restricts heat flow. It is easier to achieve high voltage electrical isolation with an “E” core than with a pot core.

Because the core stack is a stack of laminations the typical stack has core legs of rectangular cross-section. Typically the inductor or transformer coil is placed over the center core leg. To minimize winding resistance (hence also minimize winding losses) it is desirable to have a round center leg. A round center leg also eliminates the sharp bend encountered when winding wire around a rectangular leg; consequently a round center leg permits use of larger wire. Achieving round center legs with laminations is possible but very impractical. With the development of powdered cores and ferrite cores it became practical to have a round center leg. “EC” and “ETD” are examples of type “E” cores with round center legs. The combined cross section of the two outer legs should equal or exceed that of the center leg. “EC”, “EER”, and “ETD” type ferrite cores were developed for higher power higher frequency switching transformers.

“EFD”, “EEM”, and “ER” ferrite cores are low profile (low height) designs.

“EP” Cores

The “EP” core design combines the self-shielding feature of a pot core with the coil lead accessibility of “E” cores in a small package. The core wraps around the coil on the top, bottom, and three sides of the coil; but leaves one side of the coil open to bring out wires. Although the one side is open, the coil is completely recessed into the core. Because of the one open side, The amount of self-shielding of the “EP” core (by itself) is less than that of the pot core. However, the self-shielding improves when a ground plane is placed over the open side. “EP” cores are usually mounted on a printed circuit board with the open side against the printed circuit board. If good shielding is required, a grounded section of copper is provided on the printed circuit board under the “EP” core and coil. Mounted in this way, the “EP” shielding comes very close to that of a “Pot” core.

Once mounted the coils becomes completely enclosed. Consequently, heat dissipation is poor.

The “EP” core has a round center leg to minimize winding losses.

“F” Lamination Cores

“F” shape laminations are similar in function to “E” laminations. One notable difference is that the “F” lamination can be interleaved at the corners of the stack and have a “butt stack” in the center leg. An air gap can be provided in the center leg during stamping of the lamination. The typical “F” lamination has a hole near each stack corner. A screw is passed through these holes to secure the stack. If the holes are over-sized a bit, there is some play available. This play can be used as a way to provide some gap adjustment in the center leg by sliding the stacked interleaved lamination a bit. The “F” shape is not typically found in cores other than lamination stacks.

“Pot” Cores --- Round, round slab (RS & DS), and Square (RM)

Pot’ cores are known for their excellent shielding capability. This occurs because the core completely surrounds the coil except for two narrow slots which leads are brought through. Pot cores have round center leg and two nearly semicircle outer legs. The center leg is usually hollow but may be solid. Solid ones run cooler because it permits a lower flux density. The center legs may be ground to provide a gapped core. An insert may be placed in a hollow gapped core to provide a means to adjust the inductance of the core (and its windings). There are popular in tuned circuits. The adjustment allows one to compensate for core tolerances and tuning capacitor tolerance.

The round slab “Pot” cores are similar to the standard round “Pot” core but differs because a portion of the core has been removed from the standard round core design. Consequently, the round slab pot cores have better heat dissipation and have more room for wire leads. Double slab (DS) “Pot” cores have two portions of the core removed. In essence the slab “Pot” cores are a compromise design between a standard “Pot” core design and a “E-E” core design.

Square “Pot” core designs differ from standard round “Pot” core at the outer legs. The outer legs have a more “corner-like” appearance to them. This shape permits tighter packing of the cores on a printed circuit board, achieving about a 40% saving in mounting area. The coil is more open hence heat dissipation and lead wire space is better that of the standard round “Pot” cores, but shielding capability is less.

Pot cores are made almost exclusively in ferrite materials.

Planar Cores

Planar cores are low profile cores.   The core material is almost exclusively ferrite material. The core design is intended for use with windings etched on a printed circuit board, thereby eliminating the winding of a separate coil. Etching of the windings puts a limit on the number of available turns hence the operating frequency must be high to avoid core saturation.   If the turns requirement is sufficiently high, some designers might cement a thin coil to the board under the core. Since the typical planar core user does not need a coil, Butler Winding has little experience with planar cores.

“PQ” Cores

“PQ” cores were specifically designed for use in switching mode power supply circuits. The geometry is optimized to provide power with minimal size (including mounting area) and weight. Otherwise, its features are the same as an “E-E” core design. See section above discussing “E” type cores.

“U” and “U-I” Cores

These shapes are available in lamination materials (for stacking), powdered material (typically powdered iron), and ferrite materials. In laminated form, their features are similar to that of the “C” core discussed in a prior section. Heat dissipation is excellent. There is lots of room available for lead wires. Self-shielding is poor. “U” cores have two core legs. Coils can be placed over either or both legs. Using coils on separate legs is great for high voltage isolation between coils. The mean turn length of two coils on separate legs (sharing the whole winding window) is smaller than 1 coil on one leg (occupying the whole winding window), hence the two coils connected in series has less winding resistance. “U” (and “C”) cores may be used for “split-core” current transformers.

Magnetically “Soft” Core Materials

Silicon Steel – laminations or tape wound

Iron has a very high saturation level. It saturates above 20 kilogauss, but requires a lot of magnetizing force above 17 kilogauss. Cobalt has a higher saturation level, but is very expensive. Silicon is added to iron to improve the iron’s electrical resistivity. Processes have been developed with which promote grain orientation in the metal. The grain orientation lowers the losses and extends the boundaries of useful operation. The high saturation level permits the building of smaller transformers. Silicon steel must be used in thin strips to minimize its eddy currents; hence it is used for laminated core stacks or for tape wound cores. Eddy current become excessive as the operating frequency climbs. Eleven to fourteen mil thick strips are used for 50 & 60 hertz and at 100 hertz with some gauss de-rating. Six to seven mils is used for 400 hertz applications. Two to four mils is used near 1000 hertz. Use above 1000 hertz is possible but requires strip thickness below 1 mil and requires operating at lower gauss levels. Silicon steel is very economical within its useful frequency range. Silicon steels can be process to optimize square loop type properties.

Nickel Iron -- laminations or tape wound

Nickel is a higher permeability lower loss magnetic material when compared to silicon steel. It is usually used in combination with iron. Saturation for a fifty-fifty percent combination is around 15 kilogauss. Saturation for an 80% nickel combination is around 8 kilogauss. For the same power rating, a transformer made with Nickel iron will be larger than a silicon steel transformer provided they are operated in the silicon steel’s useful frequency range. At higher frequencies Nickel iron is preferred over silicon steel. Nickel iron is more expensive than silicon steel. Nickel iron, because of its higher permeability and lower losses it preferred over silicon steel for high fidelity applications even at the lower frequencies suitable for silicon steel. Nickel iron can be operated beyond 10 kilohertz with proper choice of strip thickness and kilogauss level. Ferrites can match the lower losses of Nickel iron but cannot match the saturation level or the high permeability.

Nickel iron can be processed to optimize either round loop or square loop properties

Cobalt Alloys – laminations or tape wound

Because of its expense, cobalt is used only in size and/or weight critical applications. It finds frequent use in the aviation industry.

Powdered Iron Cores

Iron alloys are ground and thoroughly mixed with a binding material, then pressed in a press to form a core. The binding material is an insulator; hence it reduces the eddy currents. This extends the useful frequency range of the iron. It can be used up to about five kilohertz depending on the A.C. kilogauss level, above 10 kilohertz at low A.C. gauss levels. The binding material also provides a distributed air gap in the core structure. The distributed gap is useful in D.C. applications. Powder iron is frequently used as ripple filter inductors in D.C. power supplies. The D.C. flux can be high as long as the A.C. flux is sufficiently small.

There are many types of powdered iron materials. Saturation can range from to 14 kilogauss depending on type.

Powdered iron cores are available in “E”, “E-I”, “U” and “U-I” shapes.

Ferrous Alloy(s) Powdered Cores

Ferrous Alloy materials are similar to the “Sendust” material originally develop by Arnold Engineering, but with improvements. Saturation level is 10.5 kilogauss. Like powdered iron, the ferrous alloy is thoroughly mixed with a binding material, then pressed in a press to form a core. It has lower core losses than the powdered iron. It is also used for ripple filter inductors in D.C. power supplies. It becomes the preferred choice over powdered iron at higher A.C. flux levels.

Molybdenum Permalloy Powdered Cores

These cores are composed of a powdered alloy of about 79% nickel, 4% molybdenum, and 17% iron. Saturation is about 7.5 kilogauss. Their high nickel content makes them very expensive. These powdered cores have the lowest losses of all the powdered cores. It has the best A.C. characteristics under heavy D.C. biasing. Because of its expense, its use is limited to the more critical applications that demand its superior properties. D.C. biased High “Q” coils operating at high frequency in tuned circuits is one example.

Nickel-Iron Powdered Cores

These cores are composed of a powdered alloy of about 50% nickel and 50% iron alloy. It has the highest saturation level of the powdered cores mentioned above. Saturation level is 15 kilogauss. Core loss is significantly lower than the core loss of powdered iron cores. Its’ high saturation level permit the smallest D.C biased inductors (assuming sufficiently small A.C. flux).

Ferrites (ceramic structures)

Modern electronic designs demand magnetic devices to operate at ever increasing high frequencies. Higher frequencies permit smaller magnetic devices up to a point; that point being excessive heat loss and its associated temperature rise. Of course sufficiently high temperatures will cause imminent failures. Even mildly excessive temperatures will shorten insulation life and eventually cause the magnetic device to fail prematurely. This can cause a real problem for product manufacturer’s and especially for their customers if the manufacturer’s products fail within a year or two after delivery. Winding losses are one source of heat. The other source is core loss. Core loss is caused by magnetic hysterisis.   The hysterisis produces eddy currents. Eddy currents flow through the resistance of the core material and produce heat. Core materials with high electrical resistivity can be operated at higher frequencies and/or higher flux density levels. Consequently designers sought to discover or develop core materials with high resistivity. Ferrite core materials were a resulting viable solution. Ferrites exhibit high permeability and high resistivity. Ferrites are also reasonably stable (repeatable properties) over time and temperature. Three basic categories of ferrites are discussed below. The manganese zinc and manganese nicker categories can be divided into various grades of ferrites.

Manganese Zinc (MnZn) Ferrites

This general type of ferrite can be manufactured in several different vastly different grades by altering its composition and processing. Initial relative permeability (at 25 degrees Centigrade) can range from several hundred to twenty thousand. Saturation (at 25C) ranges from 3.5 to 5 kilogauss. The curie temperature can range from 100 to 300 degrees Centigrade. Material grades have been developed for particular groups of applications such as power, broadband, E.M.I./R.F.I. filtering, ripple filtering, tuning, and others. The useful frequency range for most of these materials is 1 megahertz and less (with suitable flux density de-rating), but some types approach 9 megahertz. Manganese Zinc ferrites have very low porosity.

Nickel Zinc Ferrites (ceramic structure)

This general type of ferrite can also be manufactured in several vastly different grades by altering its composition and processing. Initial relative permeability (at 25C) can range from about 15 to about 1200. Saturation ranges from 2 to 3.5 kilogauss. The curie temperature ranges from 125C to 500C. Material grades have been developed for particular groups of applications. High frequency E.M.I. suppression is one example. Generally speaking, nickel zinc ferrites grades have significantly lower permeability than the manganese zinc grades. Nickel Zinc ferrites are typically used at frequencies above one megahertz. Manganese zinc ferrites are more economical below one megahertz. The upper frequency limit for nickel zinc ferrites ranges from 30 to 1000 megahertz depending on the grade. Nickel zinc ferrites vary in porosity.

Manganese (Mn) Ferrites

This ferrite material has a unique combination of properties. It is stable with temperature (repeatable properties), it is dense, and it exhibits some square loop properties. It is a good choice for high frequency magnetic amplifiers and other high frequency square loop applications. Its upper frequency limit is 150 kilohertz.

Non-magnetic Cores:

There exist some applications where it is more economical to produce a coil without a magnetic core. A low inductance but high current inductor could be one example. Coil turns are wound on a supporting mandrel and bonded together into a rigid coil or wound on an insulated form which gives the coil support such as a bobbin (or spool), a tube, or a non-magnetic toroidal form. Such coils may be referred to as “air core” coils. The relative permeability of air and most insulators is one. The permeability of air is constant. It does not change with temperature, unless conditions induce formation of corona and/or plasma. Coils wound on insulating forms may have slight inductance changes due to polarization effects on the molecules of the coil form.

Reference:

www.oee.nrcan.gc.ca

http://wolfstone.halloweenhost.com/TechBase/cmptfr_Transformers.html

http://www.butlerwinding.com/core-types/