InduLux Technologies Inc.

Induction Lamp Technology Application Guidelines

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Introduction:

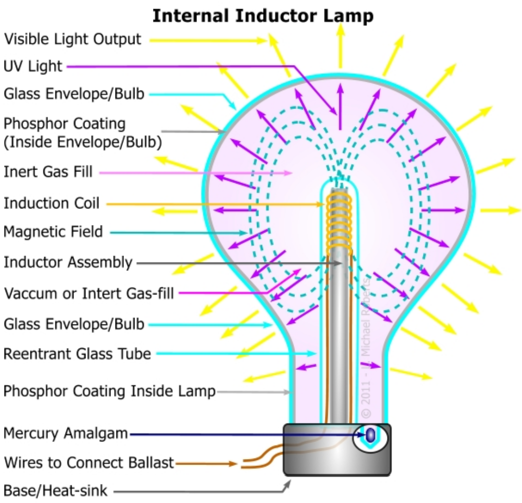
There are internal inductor lamps, external inductor lamps, high frequency and low frequency ballasts available to drive them, and various lamp colour temperatures (Kelvin). It is sometimes confusing to determine which of these is the right choice for a particular application.

This guide attempts to summarize the pros and cons of each technology, in a simplified manner, so as to provide some general guidance for selecting the best technology for your application.

Technology Overview - Lamps:

There are two main types of Magnetic Induction Lamps - Internal Inductor Lamps and External Inductor lamps:

Internal Inductor lamps



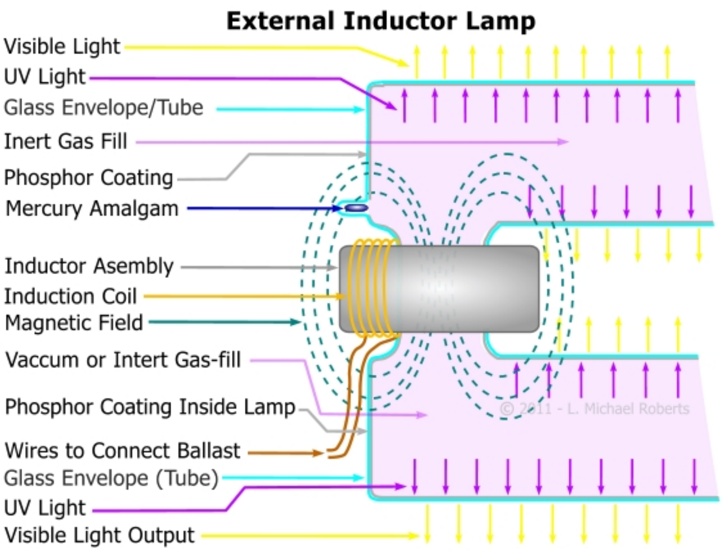
Internal Inductor lamps typically consist of a light bulb shaped glass lamp, which has a test-tube like central re-entrant cavity (glass tube) in the center, and where the interior is coated with phosphors and filled with inert gas, with a pellet of mercury amalgam usually located in a tubule at the bottom of the lamp (see diagram on left).

The induction coil wires are wound around a shaft which is inserted into the central test-tube like cavity. The induction coil is excited (driven) by high or low frequency energy provided by an external electronic ballast, to produce a strong magnetic field. The magnet field couples energy from the inductor into the interior of the lamp in order to produce light.

- The inductor assembly is located inside the lamp bulb/envelope - usually in a test-tube shaped cavity centrally located on the long axis of the lamp;
- Internal inductor lamps generally operate a higher temperatures, thus have shorter lifespan and different lumen maintenance curves, from external inductor type lamps;
- Typical lifespan of an internal inductor lamp is between 50,000 and 60,000 hours;
- Internal inductor lamps require properly engineered heat-sinks, or attachment to an external heat-sink, in order to remove the heat from the inductor inside the lamp to the outside air [or into the fixture housing], in order to maintain proper operating temperature;
- Internal inductor lamps tend to have a lower Lumens/Watt ratio (lower light output) than an external inductor lamp of the same wattage;
- Internal inductor lamps are usually smaller [more compact] than external inductor lamps thus may fit into places which can not accommodate external inductor lamps.
- Internal inductor lamps can be driven by either High Frequency or Low Frequency ballasts according to the needs of the application.

Right: Example of an Internal Inductor type of lamp with High Frequency ballast. In this example, the lamp is mounted on an E40 type base so it can be conveniently screwed into a socket that is connected to the ballast. The inductor is not visible as it is located inside the lamp.

External Inductor lamps



External inductor lamps are basically fluorescent lamps with magnetic induction coils wrapped around a part of the outside of the tube. The interior of the tube is coated with phosphors, and has a small pellet of mercury amalgam usually located in a tubule near the inductor (see diagram on left).

Energy from the electronic ballast, is sent through the induction coil wires of the inductor assembly wrapped around the outside of the lamp tube. The induction coil (or coils) produce a very strong magnetic field which travels through the glass envelope/ tube walls coupling energy into the interior of the lamp to produce light.

- The inductor(s) is/are located externally to the lamp body [wrapped around the outside of the tube];
- External inductor lamps operate at lower temperatures, thus have longer lifespan and better lumen maintenance characteristics than internal inductor lamps;
- Typical lifespan of external inductor type lamps is in the 80,000 to 100,000 hour range;
- Thermal management is more effective in external inductor lamps as removing the heat from the externally located inductor is simpler and more efficient - this can often be accomplished by attaching the inductor assemblies to the fixture housing;
- External inductor lamps tend to have higher L/W output ratios compared to an internal inductor type of the same wattage [more light output for the same energy];
- External inductor lamps can usually only be driven by Low Frequency ballasts as the lamp control circuits in the Low Frequency ballasts are required for stable light output.

Right: Example of a rectangular type of External Inductor type of lamp with Low Frequency ballast. In this example, the inductors with their heat-sinks are clearly visible wrapped around the outside of the lamp tube.

Technology Overview - Ballasts:

There are two main types of electronic ballasts use for driving magnetic induction lamps - High Frequency Ballasts and Low Frequency ballasts:

High Frequency (HF) ballasts

- High frequency ballasts generally operate at around 2.65 MHz - there are variations in this frequency between different manufacturers;

- High frequency ballasts are usually smaller in physical size;
- High frequency [HF] ballasts generally utilize simpler electronic circuitry thus are simpler and cheaper to produce;
- HF ballasts usually have very simple lamp control circuits - lamp light output can vary with input voltage changes (this also varies by manufacturer);
- HF ballasts usually have higher power factors due to the simpler circuitry;
- HF ballasts generally operate at higher temperatures and usually operate the lamps at higher temperatures;
- Higher temperatures in induction lamps can reduce lifespan;
- HF ballasts and lamps can produce Radio Frequency Interference [RFI - see below].

Low Frequency (LF) ballasts

- Low frequency ballasts usually operate at around 230 KHz - there are variations in this frequency between different manufacturers;
- Low frequency ballasts are usually physically larger in size;
- Low Frequency [LF] ballasts utilize more complex electronic circuitry and thus are more expensive to produce;
- LF ballasts usually have microprocessor or servo control circuits - lamp light output is closely controlled meaning there is very little/no change in light output with input voltage changes;
- LF ballasts usually have high power factors thereby saving more energy;
- LF ballasts generally operate at lower temperatures than HF ballasts;
- Lower temperatures in induction lamps provide longer lifespan and improved lumen maintenance characteristics;
- LF ballasts and lamps generally do not produce Radio Frequency Interference [RFI - see below] except under adverse conditions.

Technology Overview - Radio Frequency Interference (RFI):

> Radio Frequency Interference - Noise such as humming, buzzing whistling or chirping on radio devices cased by interference from nearby devices operating in a similar frequency range as the device producing the interference.

Consumer grade 2-way radios, CB radios and low cost AM radios are the most prone to RFI. If you use an AM radio in your kitchen you may hear noise or distortion of the sound when your microwave oven is in operation, due to RFI emitted from the microwave. Even professional grade 2-way radios can experience RFI depending on the frequency they are operating at. Some mobile phones can be affected by RFI - this varies by make, model and the proximity to the source of the RFI.

High Frequency (HF) ballasts

- HF ballasts can produce RFI due to the higher frequency of their operation, which puts them closer to radio bands that other devices use.
- The lower cost of manufacture and generally simpler design of HF ballasts gives more opportunity for RFI to 'leak' from the ballast or the lamp it is driving.
- High frequency radio transmissions [of the same energy level] travel further than low frequency transmissions [of the same energy level].
- The wires between the ballast and the lamp act as an 'antenna' to broadcast the RFI - keeping the wires short and using LF ballasts with their lower radiated energy levels, will reduce or eliminates RFI.

Low Frequency (LF) ballasts

- LF ballasts produce less RFI due to the lower frequency of their operation, which puts them further away from the radio bands that other devices use.
- The better design and generally higher quality of components in LF ballasts gives less opportunity for RFI to 'leak' from the ballasts or the lamps.
- Low frequency radio transmissions [of the same energy level] travel shorter distances then high frequency transmissions [of the same energy level].
- The wires between the ballast and the lamp act as an 'antenna' to broadcast the RFI, but since the energy levels and frequency of LF ballasts are lower, less RFI is emitted by the LF ballasts than the HF ballasts.

Technology Overview - Thermal Management:

Thermal management - the management of heat produced by the lamps (and to a lesser extent the ballasts) - is important in induction lighting [and LED lighting] as operating at high temperatures, or with improper thermal management, can damage the lamp and ballast, and/or shorten the system lifespan.

- Prolonged exposure to high temperatures degrades the efficiency of the phosphors coating the interior of the lamp over time, leading to steeper declines in lumen maintenance.
- Prolonged exposure to high temperatures [especially in internal inductor lamps] "cooks" the insulation on the wires of the inductor coil. Over time the insulation becomes brittle and can crack or fall of, leading to a short circuit in the coil causing lamp and/or ballast failure.
- Magnets are affected by heat and become demagnetized when they reach the "curie point" - the temperature of that point varies with the type of magnet. The electromagnets in induction lamps use ferrite cores which are only magnetized when the lamp is in operation. However, higher temperatures lessen the strength of the magnet field thereby reducing the transfer of energy into the lamp and thus reduce lamp output.
- Properly designed thermal management - heat-sinks, air circulation around the heat-sinks, heat conduction paths from the lamp heat-sink to larger metal masses [such as the fixture housing] - reduce the operating temperature of the inductors and the lamp.
- Reduced inductor and lamp temperatures increase lamp efficiency, improve lifespan, prolong high lumen maintenance curves and insure that the lamp operates within the temperature range in the design specifications.
- Ballast electronics performance is also degraded over time due to heat build up. Excessive heat can cause the thermal protection circuit (if the ballast has one) to 'trip' leading to a condition where the lamp runs for a while, cuts out while the ballast cools, re-starts once the ballast cools, and then repeats this cycle.
- Care should be taken to place the ballast in a location where it is not being heated by the lamp, or where heat transfer from the lamp to the ballast is minimized.
- Ballasts should be installed such that the metal case (chassis) of the ballast is firmly attached to the fixture housing (or another suitable metal mass) to provide a path for heat conduction away from the ballasts case. This insures that the ballast operates within its designated temperature parameters.

General Application Guidelines:

Below is a summary of general guidelines for selecting which technology, internal or external inductor, High or Low frequency ballasts, is most appropriate for use in various induction lighting applications:

Lamp Type - Internal Vs. External Inductor:

Use internal inductor lamps when:

- A compact or 'light-bulb' shaped light source is desirable due to space constraints, or for aesthetic reasons (the lamp is visible such as in decorative post-top fixtures);
- Lamp efficiency [Lumens/Watt] is "good enough" to replace the existing lighting technology and still save energy - this generally means in applications where you are replacing lower wattage High Pressure Sodium (HPS) and Metal Halide (MH) lamps [or even high wattage Mercury Vapour (MV) lamps, which are very inefficient];
- Lamp lifespan is not a major issue as the induction lamp lifespan is already significantly longer than the technology that it is replacing;
- Heat build-up, and the reduced lifespan it produces, is not an issue as the induction lamp lifespan is significantly longer than the lifespan of the lamp it replaces such that the replacement is economically justified;
- The lamp will be used in a fixture that is "open", or that has sufficient air circulation, or that has a thermal management design, which allows the internal inductor lamp to operate within its temperature parameters.

Use External inductor lamps when:

- There is sufficient space to accommodate the larger form-factor of the round or rectangular lamps [and usually a larger ballast].
- Higher lamp efficiency [Lumens/Watt] is desirable to replace the existing lighting technology and still save energy - this generally means in applications where you are replacing higher wattage HPS or MH lamps [as HID lamp efficiency tends to increase in higher wattage lamps].
- Lamp lifespan is a major issue as the induction lamps are replacing lamps in locations where lamp replacement is difficult and thus costly, or where the longer lifespan of the induction lamps significantly minimizes re-lamping costs [replacement lamps and installation labour], increasing the cost/benefit of the induction lamps.
- Heat build-up and the reduced lifespan that produces can be an issue, as the maximum lifespan and lumen maintenance is desired in order to compete with the lamp you are replacing.
- The lamp will be used in a fixture that is "open" or "closed" as long as there is proper thermal management to remove the lower heat levels produced by the external inductor lamps so that they operate within the design temperature parameters.

Ballast Type - High Frequency (HF) Vs. Low Frequency (LF):

In general, Low Frequency ballasts offer better performance, better lamp output stability, higher power factors, and lower operating temperatures than High Frequency ballasts. If a low frequency ballast is available for the lamp model you intend to use, then that is the better choice.

Use High Frequency [HF] ballasts with internal inductor lamps when:

- RFI is NOT an issue due to location of the lamps and ballasts, grounded fixtures are used, and where you have TESTED for RFI problems in advance;
- Cost is an issue as LF ballasts are usually cheaper;
- Lamp stability [variations in light output with voltage changes] is not an important factor;
- Lower power factor is acceptable in the application as there is still sufficient energy savings to economically justify the induction lamps;

- Physical size of the space available for the ballast would not accommodate a LF ballast (if one is available for the lamp model);
- Lifespan is not an issue as the replacement induction lamp & ballast already outperforms lifespan and energy consumption of the lamp it is replacing;
- Higher temperatures of the lamps and ballasts are not an issue as the fixture incorporates adequate thermal managements and has sufficient capacity to remove the heat generated;
- You have no choice as the lamp is only available with an HF ballast - for example, most screw-in self ballasted lamps, which typically use HF ballasts to save space and costs.

Use Low Frequency [LF] ballasts with internal inductor lamps when:

- RFI is an issue due to location of the lamps and ballasts, or if you want to be sure you will not encounter RFI problems and have to switch ballasts later;
- The improved performance of LF ballasts [microprocessor controlled lamp stability] justifies the slightly higher costs;
- High lamp stability [variations in light output due to input voltage changes] is desirable - especially in applications where people are around the lamps all the time and will notice changes in light levels;
- Higher power factor is desirable in the application due to the increased energy savings which helps to economically justify the induction lamps;
- Physical size of the space available for the ballast will accommodate a LF ballast;
- Lifespan IS an issue as the replacement lamp & ballast must significantly outperform the lifespan and energy consumption of the lamp it is replacing for financial viability [best/shortest payback period].
- Lower operating temperatures of the lamps and ballasts are desirable to improve lifespan and lumen maintenance.
- You have no choice as the lamp is only available with LF ballasts.

External Inductor Lamps Ballasts:

Almost all external inductor lamps use Low Frequency ballasts for the best performance and longest lifespan. Thus they fall into the "You have no choice" category and so LF ballasts should be used with external inductor lamps.

Colour Temperature selection:

Induction lamps are available in a range of colour temperatures (Kelvin)- typically from 2,700K to 6,500K. To simplify the guidelines, we will use the designations:

- Warm White - Lamps in the range of 2,600K to 3,600K
- True White - Lamps in the range of 3,800K to 4,250K
- Bright White - Lamps in the range from 4,500K to 5,250K
- Daylight - Lamps in the range from 5,800K to 6,800K

Your choice of color temperature will also be affected by the S/P ratio of the lamps and the increase in VEL (pupil lumens) that produces, while still using the same wattage levels. In general, lamps with higher Kelvin have higher S/P levels, and thus higher VEL, and are the better choice when light levels must match (or exceed) those from existing lamps that are being replaced

Use Warm White type lamps (Lower S/P):

In applications where a "warmer" or more "welcoming" look is required and high visual acuity is not important such as in hotel lobbies, restaurants, lobbies/atriums, entrance ways, washrooms, apartment/hotel hallways, and other domestic/lodging/food-service applications.

Use True While type lamps (medium S/P):

In applications where better visual acuity is required but the lighting should not look "bright" or "cold" such as in offices, office building hallways, elevator lobbies, specialty/boutique stores (where accurate colour rendering is not needed), cafeterias, public/common areas of sports facilities, schools, libraries and other places where bright light, and good visual acuity is required.

Use Bright White type lamps (high S/P):

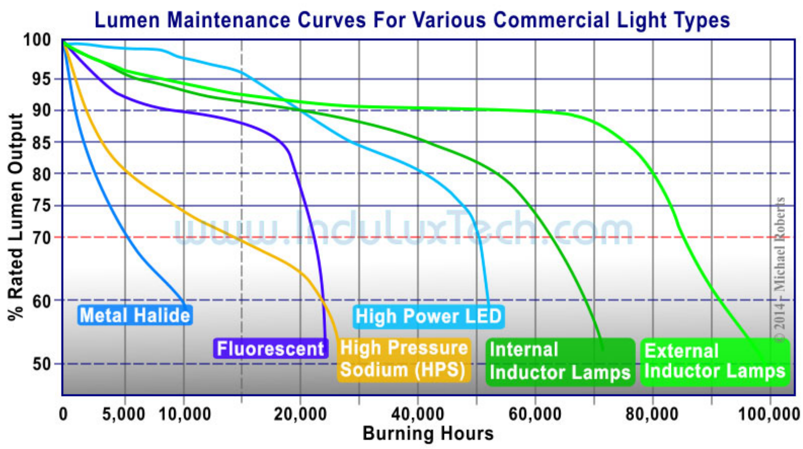
In applications where high visual acuity and more accurate colour rendering is required such as classrooms, library reading areas, product assembly/packing areas, architectural and product design offices, workshops, repair facilities, warehouses, retail and big-box stores, supermarkets, sports facilities (arenas, tennis courts, swimming pools, etc.), billboard illumination, tunnels, subways and pedestrian over/under passes, railway station and airport interiors, shopping malls, underground parking, and other applications where a "bright" look is required.

Use Daylight type lamps (Highest S/P):

In applications where high visual acuity and daylight type colour rendering is required such as auto dealership showrooms/service areas/detailing areas, warehouses, product packing areas, assembly areas for equipment with small components or electronics, supermarkets, retail and big-box stores, arenas, tennis courts, swimming pools, railway station platforms, airport ramp/apron illumination, parking lots, pedestrian over/under passes, and other applications where a "bright" look similar to daylight is required.

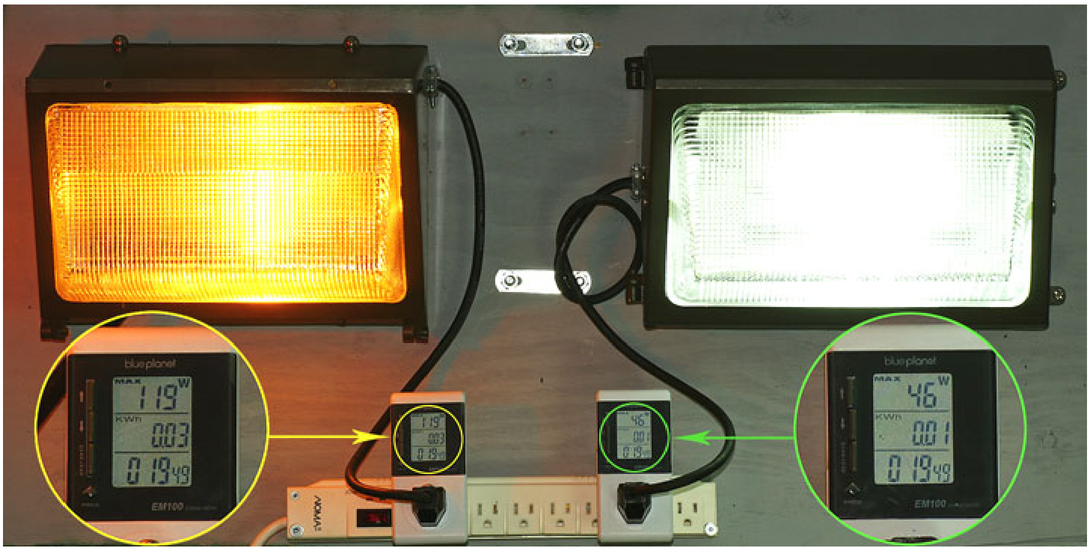
Lumen Maintenance:

Lumen maintenance - the rate at which the light output of a lamp decreases over time - is another important factor in lighting systems. As lamps age, the amount of light they produce decreases, as does their energy conversion efficiency. This is due to various factors such as filament depletion, phosphor ageing, gas-fill "clean up" where the molecules of gas are slowly absorbed into the structure of the lamp over time, changes in internal pressure, etc. This slow decay in output levels can be plotted on a graph as a "lumen maintenance curve" showing how well a particular type of lamp maintains its output.



This chart shows the expected lifespan and rate of decay in the light output of various kinds of lamps including Magnetic Induction Lamps. You will note that the Induction lamps have the highest rate of lumen maintenance (stay brighter, longer) due to the lack of internal electrodes or filaments. You will also note that the internal inductor lamps have a shorter lifespan and steeper lumen decline due to the higher temperatures at which they operate.

Dramatic Energy Savings - Wallpacks



Wallpacks: This photo shows a side-by-side comparison of Wallpack fixtures commonly used on the exterior of buildings as security/perimeter lighting.

Left: A **70W High Pressure Sodium** Wallpack. The insert photo of the watt meter shows that it is consuming 119W of energy (ballast Included) while producing 4,389 Visually Effective Lumens (VEL) of light.

Right: A **40W magnetic induction lamp** Wallpack. The insert photo of the watt meter shows that it is only consuming 46W of energy (ballast included) while producing 5,994 Visually Effective Lumens (VEL) of light. Note the more natural and pleasant colour produced by our Wallpack fixture.

The InduLux magnetic induction lighting technology Wallpack produces over **26% more light** while **using 62.2% less energy!**

Image and Photo Credits:

Induction lamps & ballasts - Photos by Neo Wentao Yang;

About the Author - Michael Roberts

Michael Roberts is the Chief Technology Officer for InduLux Technologies Inc., an R&D and intellectual property company focusing on energy efficient technologies. Michael is presently working on advanced, high efficiency, magnetic induction lamp light sources.

Michael travels to China frequently and visits all of the major induction lighting factories. He has worked with a number of Chinese induction lamp manufacturers on improvements to the technology as well as fixture designs optimized for use with magnetic induction lamps. He has also licensed some of his technology to Chinese manufacturers.

Michael is an inventor with two granted patents in UV water treatment technology. He invented the world's first UVC induction lamp. He has applied for patents for an induction lighting "Daylight Harvesting" system, streetlights and other applications using induction lamps. He presently has various patents pending on induction lighting technology, and specialty induction lighting fixtures. He works as a consultant to manufacturers and distributors of magnetic induction lighting products world-wide, some of whom are also licensees of his Intellectual Property.

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