LUNERA BALLASTLED TECHNOLOGY AND BALLAST LIFE

Magnetic HID Power Factor Compensation

Power Factor (PF) is a measurement of the alignment of the voltage and current waveforms in an AC system, a number from 1.0 (perfect aligned) to 0.0 (90° out of phase). A magnetic High Intensity Discharge (HID) ballast such as those used for Mercury Vapor, Metal Halide (MH) and High Pressure Sodium (HPS) uses a magnetic circuit to achieve constant current operation (fig. 1) and a capacitor to compensate for the Power Factor (PF) loss caused by the magnetic circuit.

CWA (Constant Wattage Autotransformer) Ballast Diagram 1

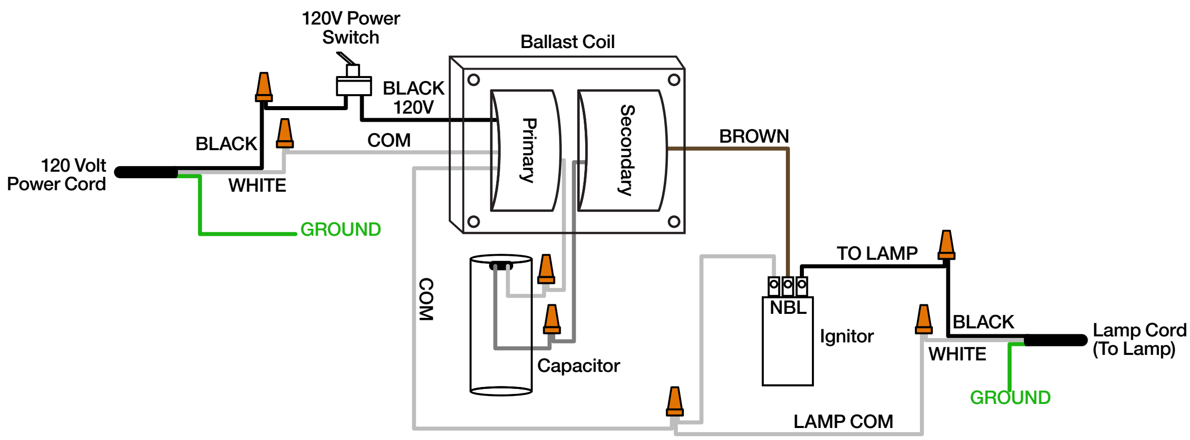
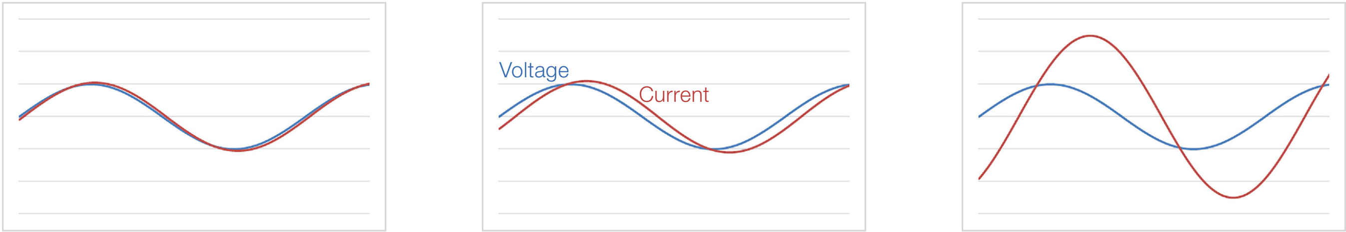


Fig. 1 HID CWA Ballast architecture. The ballast coil is used to regulate the current delivered to the lamp as the capacitor is used to compensate the power factor to achieve high regulation.

Magnetic HID ballast end of life behavior is typically governed by the following parameters:

1. The ballast is heated to an operating temperature by the current it conducts and by convective heating from the HID lamp.
2. Ballast components have a lifespan which is a function of temperature – the weak point typically being the capacitor which lifespan is cut by 2-3x for every 10'C increase in operating temp[1].
3. As the capacitor reaches its end of life at approx. 40k – 100k hrs, its capacitance is reduced resulting in increased current and heating in the ballast.
4. When the capacitor nears failure, heating increases within the transformer and accelerates the thermal degradation in the ballast, resulting in rapid insulation breakdown and eventually failure of the ballast.



Fresh Ballast - 0.99PF | End of design life 0.9PF | End of operational life <0.9PF

Fig. 2 CWA Ballast Operation when fresh and end of design life and during end of life process. At end of life, current increases rapidly with declining PF resulting in thermal run-away and failure of winding insulation.

[1] Philips - http://media.hydroponics.net/productdocs/HID_Pocket_Guide.pdf

Acuity / Holophane - http://www.acuitybrandslighting.com/library/HLP/Documents/otherdocuments/Ballast%20Handbook.pdf

Using HID Power Factor to Project Remaining Ballast Life

The loss in capacitance during a ballasts operating life is linear process[2], therefore the percentage of life remaining in a ballast can be projected by measuring the power factor of that ballast under proper conditions as illustrated below:

1. Install a fresh lamp in the HID ballast – use of an aged lamp will skew results as HID lamp voltages often increase with age.
2. Use a power meter to measure PF on that ballast alone; the meter would need to simultaneously measure voltage as well as current to calculate PF.
3. Use equation #1 below to estimate the remaining life of the ballast if it is continued to be used with an HID lamp.
4. Use equation #2 below to project the increased life of the ballast if used with a Lunera BallastLED lamp such as the Lunera HID LED lamp Lamp.

$$\% \text{ Life Remaining} = (\text{Measured Power Factor} - 0.9) \times 100$$

Equation 1: The Life Remaining in a magnetic HID ballast can be estimated by comparing its measured power factor with a fresh HID lamp to the designed EOL power factor of 0.9. For example for a ballast with designed life of 60,000 hrs and a measured power factor of 0.94:

$$\% \text{ Life Remaining} = (0.94 - 0.9) \times 100 = 40\%$$

$$40\% \times 60{,}000 \text{ hrs} = 24{,}000 \text{ hrs remaining if used with an HID Lamp}$$

Equation 2: BallastLED Lamps such as the Lunera HID LED lamp extend ballast life by reducing ballast operating current, reducing convective heating of the ballast from the lamp and by reducing required compensation capacitors.

If used in a pendant application where lamp is directly below ballast, Lunera's measurements indicate a 12-15'C reduction in operating temps using a Lunera HID LED lamp vs. the HID lamp it is replacing resulting in a 3x improvement in remaining ballast life. If used in a downlight application where the ballast is not directly heated by the lamp, ballast temps are 7-10'C lower resulting in a 2x increase in ballast life.

Following the example above:

$$\% \text{ Life Remaining (Lunera HID LED Lamp)} = 24{,}000 \text{ hrs} \times 3 = 72{,}000 \text{ hrs (Pendant)}$$

$$\% \text{ Life Remaining (Lunera HID LED Lamp)} = 24{,}000 \text{ hrs} \times 2 = 48{,}000 \text{ hrs (Downlight)}$$

If the ballasts in a building are original or have been group replaced, then a measurement of one or two representative fixtures should provide an accurate measure of the site; if ballasts have been individually replaced then a larger sample may be necessary to project site level ballast condition.

[2] http://ti.arc.nasa.gov/publications/5005/download/

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Simplified Calculations Using Current Only

As voltage is relatively constant in these applications, power factor can be estimated by simply measuring the input current of a ballast with a brand new metal halide lamp installed. Below are tables compiled for various voltages, lamp power levels and remaining life states.

If the target ballast measures in between "new" and "end of life" then you can estimate remaining life through a linear interpolation.

$$\%\ Life\ Remaining = \frac{EOL\ Current\text{-}Measured\ Current}{EOL\ Current\text{-}New\ Current} \times 100 = 40\%$$

AC Input Current for New vs. EOL Ballast							
	400W MH		250W MH		175 MH		
Voltage	New	EOL	New	EOL	New	EOL	Units
120V	3.73	4.1	2.36	2.6	1.68	1.9	A
208V	2.09	2.3	1.36	1.5	1.00	1.1	A
240V	1.82	2.0	1.27	1.4	0.82	0.9	A
277V	1.55	1.7	1.00	1.1	0.73	0.8	A
347V	1.26	1.4	0.82	0.9	0.58	0.6	A
380V	0.91	1.0	0.59	0.7	0.36	0.4	A

Current can be measured with a simple AC clamp meter placed across either the hot or neutral input wire to a ballast (not both or they will cancel each other out and current will read zero). For example a 400W MH ballast operating on 277V measures 1.6A of current with a brand new MH lamp installed.

$$\%\ Life\ Remaining = \frac{1.7A - 1.6A}{1.7A - 1.55A} \times 100 = 66\%$$

Assuming a 60,000 hr rated ballast life:

% Life Remaining (Metal Halide) = 60,000 hrs × 66% = 40,000 hrs (Pendant or Downlight)
% Life Remaining (Lunera HID LED Lamp) = 60,000 hrs × 66% × 3 = 120,000 hrs (Pendant)
% Life Remaining (Lunera HID LED Lamp) = 60,000 hrs × 66% × 2 = 80,000 hrs (Downlight)