

**Yttria-Coated Iridium Disc Cathodes ES-535W  
 User Information**

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ES-535W Yttria-coated Iridium Disc Cathode mounted on a Kimball Physics compact CB-104 ceramic base.

**Introduction**

The Kimball Physics ES-535W  $Y_2O_3$  Disc Cathode consists of a 0.84 mm (0.033 inch) diameter yttria coated iridium disc, attached to a 0.08 mm (0.003 inch) diameter tungsten heater wire. This coated cathode is quite sturdy and provides stable and uniform electron emission for a wide variety of electron source applications.

The iridium disc is welded to the tungsten hairpin at a single point and then the disc is coated with yttria which results in a unipotential and planar emission surface. The disc is directly heated by current through the hairpin. Since no heating current passes through the disc, the energy spread is kept to a minimum (<0.7 eV).

The ES-535W cathode structure is available mounted on a standard AEI base and Kimball Physics CB-105 base, and also is available on some custom and non-standard bases.

**Handling**

***Cathodes are fragile and caution must be used in handling. Do not touch the cathode structure itself, only the cathode base.***

The ES-535W  $Y_2O_3$  Disc Cathode is shipped vacuum clean. When handling the cathode, the use of clean-room gloves is recommended to keep surfaces free of fingerprints or other contaminants.



Example of Cathode Transport Container.

To remove the cathode assembly from the purple shipping container:

- a) Place the purple base on a level surface.
- b) Holding onto the lower part (purple) of the shipping container, unscrew the

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- upper cover (plexiglass) and remove it vertically to avoid hitting the cathode.
  - c) Loosen the Philips screws to release clamp on the cathode.
  - d) Carefully lift off the cathode assembly.



Example of cathode with AEI base secured in transport container base.

Care should be taken to avoid exposing the cathode to mechanical or thermal shock. Do not allow anything to come in direct contact with the cathode. The cathode is not harmed by repeated exposure to atmosphere when cold; however, at temperatures above 1300 K, oxidation of the iridium takes place in the presence of water vapor, air or oxygen with a resulting decrease in cathode lifetime.

To preserve the integrity of the cathode structure, the cathode should be allowed to cool to temperatures below which significant oxidation will occur ( $<1300$  K). Cool down times will vary depending upon the gun's structure and its temperature.

### Cathode Mounting / Heat Sink

When mounting the ES-535W, it is important to have adequate heat sink / temperature control for the cathode pins and base, otherwise the cathode may burn out quickly. In the cathode connection, heat sinking is more important than electrical conductivity. For example, heavy copper leads are recommended, the diameter depending upon the length of the leads. Alternatively, copper mounting structures that hold the base may be employed.

### Operating Procedure

The ES-535W  $Y_2O_3$  Disc Cathode is specifically designed to be a low input power device and should be driven by a voltage source rather than

a current source. Due to the relatively small cathode surface area, the predominant avenue for power loss is conduction rather than radiation. A current source will cause an unstable increase in cathode temperature, resistance and voltage which results in premature heater wire burnout. When driven by a voltage source, heater current decreases over time as the cathode temperature and resistance rise, resulting in stable power conditions.

Small changes in electron emission will occur during the first 20-30 minutes of operation, until thermal equilibrium is achieved. As the temperature of the mounting post structure rises, heater current and emission decrease due to increased resistance of the iridium hairpin heater wire. Furthermore, over the entire operating period, physical changes in the cathode such as evaporation and contamination result in a decrease in heating current and emission. Constant electron emission can be achieved by using a feedback control that adjusts the source voltage to maintain a set emission current value. This is the recommended mode of operation for a stable beam current and maximum cathode lifetime. Kimball Physics can supply power supplies with feedback stabilized emission current control. Typical V-I and temperature charts are shown on the next page.

### First Time Cathode Turn-On

This procedure applies to a cathode that is being turned on for the first time or has been exposed to air for a prolonged period, although this cathode is designed such that there is minimal start-up time. Turn on cathode power supply and increase heater current to 1.3 to 1.4 A (amps) while monitoring heater current, heater voltage and vacuum pressure. As the cathode heats up, small increases in vacuum pressure will most likely be noticed, due to out gassing of the cathode and surrounding structure. Maintain vacuum pressure at  $1 \times 10^{-4}$  torr or better. Once the cathode current has reached 1.5 A to 1.6 A and the vacuum pressure has stabilized, an extraction field can be applied, and electron emission should be measurable. Electron emission can be varied by increasing or decreasing cathode source voltage. If the cathode heating current exceeds 1.70 to 1.80 A, cathode failure may occur rapidly.

### Subsequent Turn On and Normal Operation

A cathode that remains in vacuum or is exposed to air for a short time may be brought to the desired operating temperature almost instantly. Normal operation is achieved with a source voltage between 0.8 volts and 1.0 volts or a source current between 1.5 A and 1.7 A. If more emission current is desired, higher source voltages may be applied but a concomitant decrease in cathode lifetime should be expected.

### Turning the Cathode Off:

Heater current may be turned off slowly or instantly. Prior to venting, as mentioned above, the cathode and surrounding structure should be allowed to cool to less than 1300 K. Cool down times will vary from several minutes to over an

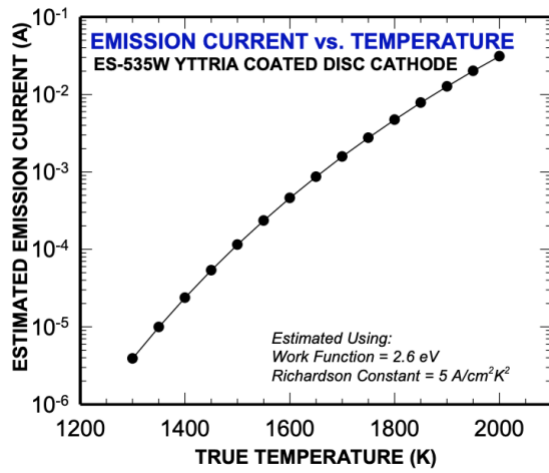
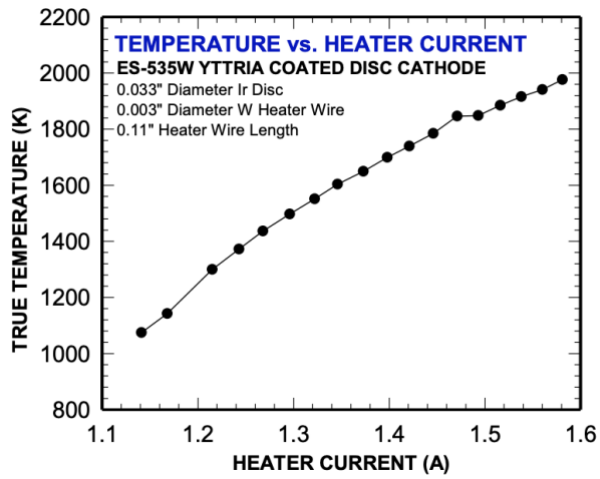
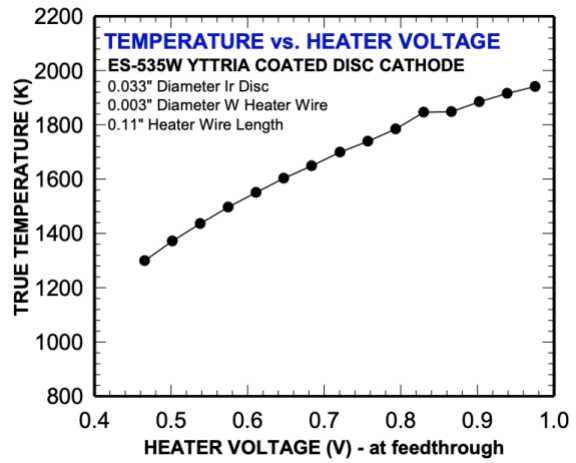
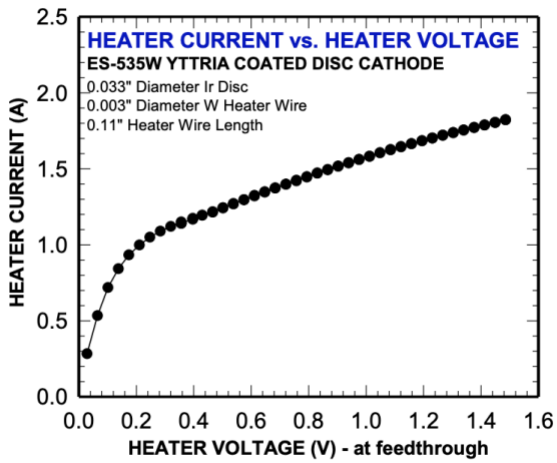
hour, depending on how quickly heat can be conducted out of the structure

### Lifetime Considerations

Some power is lost from the yttria coated iridium disc due to radiation; therefore, in order to obtain the desired disc temperature, the iridium hairpin heater must reach an even higher temperature. The temperature of the disc determines its electron emission density; this relationship can be described by the Richardson-Dushman equation. The expected emission for the ES-535W is shown on the next page. Actual emission currents will vary depending on the applied DC voltage and the geometry of the gun structure. The higher iridium hairpin leg temperatures make the decrease in leg diameter due to evaporation the determining factor in cathode lifetime, assuming lifetime is not foreshortened due to other factors such as

**Yttria-Coated Iridium Disc Cathodes Comparison Table**

	ES-535	ES-535W	ES-526	ES-529
CATHODE DISC MATERIAL	Yttrium oxide coated Iridium	Yttrium oxide coated Iridium	Yttrium oxide coated Iridium	Yttrium oxide coated Iridium
DISC SIZE	0.033 in dia. x .004 in thick (0.84 mm dia. x 0.1 mm thick)	0.033 in dia. x .004 in thick (0.84 mm dia. x 0.1 mm thick)	0.048 in dia. x .004 in thick (1.22 mm dia. x 0.1 mm thick)	0.062 in dia. x .004 in thick (1.57 mm dia. x 0.1 mm thick)
HEATER WIRE SIZE	0.004 in dia. (0.1 mm dia.) Ir	0.003 in dia. (0.08 mm dia.) W	0.005 in dia. (0.13 mm dia.) Ir	0.006 in dia. (0.15 mm dia.) Ir
LEG LENGTH	approx. 0.20 in (5.1 mm)	approx. 0.11 in (2.8 mm)	approx. 0.12 in (3.0 mm)	approx. 0.15 in (3.8 mm)
HEIGHT ABOVE CERAMIC BASE	on AEI base: 0.256 in (6.5 mm)	on CB-104 base: 0.14 in (3.5 mm) on AEI base: 0.256 in (6.5 mm)	on CB-105 base: 0.25 in (6.4 mm) on AEI base: 0.256 in (6.5 mm)	on CB-105 base: 0.27 in (6.9 mm) on AEI base: 0.256 in (6.5 mm)
EMISSION AREA	$5.5 \times 10^{-3} \text{ cm}^2$	$5.5 \times 10^{-3} \text{ cm}^2$	$1.17 \times 10^{-2} \text{ cm}^2$	$1.95 \times 10^{-2} \text{ cm}^2$
EMISSION CURRENT	1-2 mA typical	1-2 mA typical	3-5 mA typical	8-10 mA typical
HEATING CURRENT	1.6A to 1.8A	1.3A to 1.5A	3.8 A to 4.2 A	5.3A to 5.8 A
POWER SUPPLY CAPABILITY	Voltage regulated power supply recommended, 2 V, 2 A	Voltage regulated power supply recommended, 2 V, 2 A	Voltage regulated power supply recommended, 2 V, 5 A	Voltage regulated power supply recommended, 2 V, 6 A
CATHODE BASES	AEI	AEI, CB-104	AEI, CB-105	AEI, CB-105
CATHODE LOADING	0.5A/cm <sup>2</sup> recommended, typical; High loadings result in reduced lifetime			
WORK FUNCTION	Approximately 2.6 eV			
OPERATING TEMP	1800 K typical			
ENERGY SPREAD	Approx. 0.6 eV			
LIFETIME	Hundreds of hours with medium current and proper handling			
VACUUM LEVEL	10 <sup>-4</sup> torr or better, recommended	10 <sup>-5</sup> torr or better, recommended	10 <sup>-4</sup> torr or better, recommended	10 <sup>-4</sup> torr or better, recommended



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contamination, evaporation of the yttria coating, poor vacuum or damage. As the iridium legs evaporate, the resistance of the iridium wire increases; thus small changes in a cathode's V-I characteristic over its lifetime can be expected. The longest possible lifetime is achieved by running the cathode at the lowest possible temperature.

cathode assembly with tweezers, being careful to touch only the base of the cathode. If broken off prior to usage, place the cathode in a capsule or in tissue or secure with double-sided adhesive, and return to Kimball Physics along with the cathode base in the original shipping tube.

### Service for Repair / Breakage

If a problem arises during initial installation, please contact Kimball Physics. Cathodes may be returned to Kimball Physics for evaluation and possible repair with a return authorization number. In case of breakage, handle the

### References

For more information on Cathode Operations, you may download additional detailed technical bulletins (not listed below) from the website Resources Page.

Cathodes- Emitters (Overview)

Yttria Coated Iridium Cathodes / Emitters- Description and Specifications (Overview)

Yttria Coated Cathode (ES-526) Y<sub>2</sub>O<sub>3</sub> Disc Cathode: User Information

Yttria Coated Cathode (ES-529) Y<sub>2</sub>O<sub>3</sub> Disc Cathode: User Information

Yttria Coated Cathode (ES-535) Y<sub>2</sub>O<sub>3</sub> Disc Cathode: User Information

Yttria Coated Cathode (ES-535W) Y<sub>2</sub>O<sub>3</sub> Disc Cathode: User Information

#### Notes:

1. Charts /graphs show typical performance, data is for guidance only
2. It is not necessarily possible to achieve all maximum specifications simultaneously.
3. Specifications Subject to Change Without Notice.
4. DE Altobelli, DT Taylor 10/2/2023

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