Thyratrons & Triggered Vacuum Spark Gaps

High Voltage Switches

Stellant produces a broad line of metal-ceramic hydrogen thyratrons. These devices block voltages up to 100 kV and switch currents up to 20,000 amps. Thyratrons are robust switching devices suitable for a wide variety of pulse power applications, including radars, particle accelerators, broadcast transmitters, medical and industrial lasers.

- Robust high voltage, high peak current switching devices that utilize hydrogen or deuterium as the switching medium.
- They are suitable for a wide variety of pulsed power applications including line type modulator radars, medical and industrial lasers, particle accelerators and broadcast transmitters.
- Thyratrons offer fault tolerance and efficiency advantages over solid state and vacuum (hard tube) technologies. The sub-modulator power necessary to trigger the thyratron is typically 4 orders of magnitude less than the power switched.
- Our Thyratrons block voltages up to 100 kV and switch peak currents up to 20,000 amperes. Devices are available for long life switching at charging supply average power levels up to 250 kilowatts.
- We offer standard models from < 2” to 8” diameter with a variety of optional features. The basic 3 element triode can be equipped with; a second grid for pre-pulsing or DC priming, additional high voltage sections to scale the blocking voltage rating, and reverse conducting anodes.
- Thyratrons are essentially hot cathode high voltage switches that require a heater for thermionic emission.
- Stellant also offers simpler 3 element, 3”- 4” diameter cold cathode triggered vacuum spark gaps.
- These thyratron adjacent devices are indicated when switching peak current and coulomb levels that exceed the capabilities of thyratrons. Spark gaps, as cold cathode devices, do not require the provision of a heater supply.
- Please contact the factory for special requirements including cross references.

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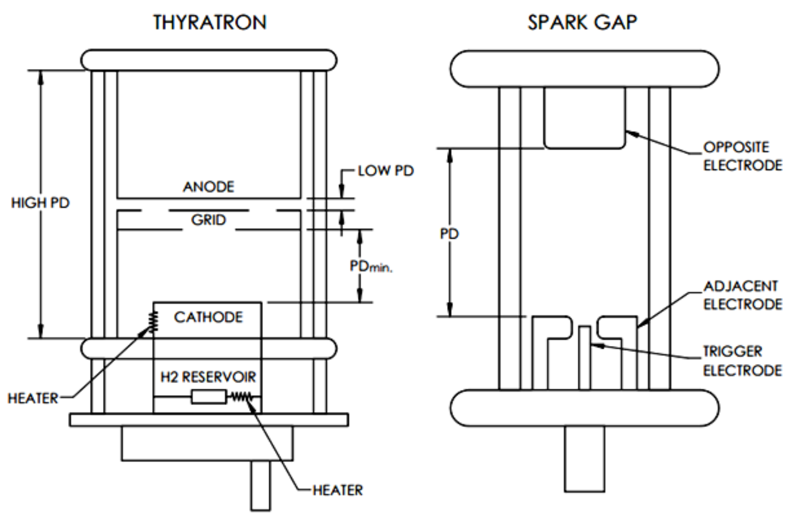
Device Selection Parameters

Key Parameters	Thyratrons	Triggered Vacuum Spark Gaps
Operating Voltage (kV)	1-55kV	.3-50kV
Peak Anode Current (kA)	Up to 20	Up to 50
Coulombs per Pulse (C)	Up to .1	Up to 0.7
Shot Life Order of Magnitude	10^8-10^10	10^3-10^5
Key Advantage	Long Life at High Repetition Rate	High Peak Current and Coulomb Transfer Ratings
Other Advantage	Excellent Pulse to Pulse Time Stability	Lower System Cost (no heater supply required)
Tradeoff	More Complex Ancillary Circuitry (heaters, etc.)	Less Pulse-to-Pulse Time Stability (Jitter), Low Shot Life

Stellant High Voltage Switches



COMPARISON OF THYRATRON AND SPARK GAP STRUCTURES

Note: (P) pressure, (D) spacing

PD product is a critical Paschen's Law parameter

Thyratrons & Triggered Vacuum Spark Gaps

High Voltage Switches

Thyratron Application Note

The hydrogen thyratron was developed to meet the wartime need for a high peak power switch that could repetitively discharge the energy stored in the capacitors of a pulse forming line. Stellant thyratrons have evolved from this legacy application into an extensive product line of robust metal-ceramic devices. Peak anode voltages to 100 kV, peak anode currents to 20 kA, and repetition rates of several thousand pulses per second are achievable. In its conceptually simplest form, the thyratron is a three element hermetically sealed valve containing a thermionic (hot) cathode, a trigger grid, an anode, and hydrogen gas. The incandescent cathode is maintained at the operating temperature by a tungsten filament connected to a 6.3 Volt supply. The hydrogen (or deuterium) gas is utilized as the switching medium.

The gas in the neutral diatomic state is an insulator, thus, the thyratron is capable of blocking voltage as a capacitor is charged (switch is open). Application of a trigger signal to the grid draws electrons from the cathode towards the grid. The consequent collisions of electrons and gas molecules generates an avalanche ionization process that creates a conductive plasma column from cathode to anode (switch is closed). The arc drop voltage is low enough to allow for 98-99% efficient switching. Contrast this to hard tube (vacuum) switches that are 70-80% efficient. Rigid requirements need not be imposed on the pulse shape of the trigger grid signal.

Furthermore, the grid control power is typically 4 orders of magnitude less than the power switched. A critical performance parameter for radar and accelerator pulse modulators is time stability. The time spread of the pulse power current front can be regulated to 2 or 3 nanoseconds with a properly triggered thyratron. The conductivity remains high until the current between anode and cathode drops to a small value for a sufficiently long time to allow the electrons and ions to recombine thereby returning the thyratron to the “open” state. The recovery process time span is on the order of several 10s of microseconds. This allows for pulse repetition rates up to several thousand per second or more.

Hydrogen being a chemically active gas necessitated the development of a technology to maintain the gas pressure. It was determined that titanium had the necessary properties allowing it to store and liberate hydrogen as a function of temperature. Consequently, all modern thyratrons contain a titanium reservoir assembly and a provision for heating it. The reservoir heater can be powered by the same supply as the cathode heater or, more often, by a separate supply. A separate reservoir supply allows for pressure optimization to suit a particular application. Deuterium, an isotope of hydrogen, is sometimes substituted for high peak power applications. Recovery time is increased by approximately 40% with deuterium.

The basic 3 element thyratron discussed above can be equipped with; a second grid for pre-pulsing or DC priming, additional high voltage sections to scale the blocking voltage rating, and reverse conducting anodes.

Stellant sales engineering can discuss how these optional features may add value for your application.

Thyratrons & Triggered Vacuum Spark Gaps

High Voltage Switches

Triggered Vacuum Spark Gap Application Note

Spark gap switches can operate in the 20-100 kV peak and 20 to 1000 kA peak ranges with lifetimes of one to thousands of shots. They are configured as hermetically sealed two or three electrode devices with working gas pressures at either the left hand or right-hand side of the Paschen curve. The switching medium can be vacuum, a fill gas, or even a solid. Applications include voltage surge protection, crowbar circuits, and high energy pulse generators.

Selection of a spark gap is indicated when fast commutation time, high energy transfer, and a simple circuit architecture (no heater supply) is required. The switching efficiency is comparable to thyratrons at 98-99%. Contrasted to hot cathode thyratrons, cold cathode spark gaps tend to have a lesser degree of pulse-to-pulse timing stability, and lower shot life (by orders of magnitude).

The service life of spark gaps will benefit from decreased repetition rate and decreased charge transfer per pulse with respect to the maximum device ratings. Stellant offers robust metal-ceramic three-electrode triggered vacuum spark gaps (TVSG). The TVSG remains in the "open" state as long as the applied voltage remains below its static breakdown voltage rating. The switching action is initiated by a simple low energy pulse applied to the trigger electrode, typically delivered through a step-up transformer.

The trigger pulse causes initially localized ionization of metal vapor. Cathode heating by ion bombardment produces electron emission sufficient to support an avalanche ionization process that spreads through the gap thereby "closing" the switch. Operation at pressures to the left of the Paschen minimum make possible a wide range of operating voltages for the TVGS.

End of life is a consequence of the erosion of electrode material and the consequent condensation of metal onto insulating surfaces thereby lowering the breakdown voltage. This is tradeoff for the spark gaps higher current ratings.

Gas Filled Spark Gaps

Stellant has the manufacturing capacity and engineering resources necessary to develop the equivalents of gas filled two and three element spark gaps. Stellant is also open to custom inquiries.

Thyratrons & Triggered Vacuum Spark Gaps

High Voltage Switches

Thyratron Applications

Stellant has fielded thousands of thyratrons per year. Our thyratron engineering team has extensive experience & our products can support a wide range of applications including:

* Medical: Laser Eye (PRK); Lithotripsy; UVB Laser Skin Treatment; Radiation Oncology
* Industrial Electrically Pumped Gas Laser Equipment: Micromachining; Marking; Pulsed Laser Deposition
* Line Type Modulator Switching for Pulsed Radars, Flash Lamps, Keff Cells, Exploding-Bridge-wire Circuits
* Particle Accelerators: Scientific (Klystron Modulator & Kicker); Industrial; Radiation Oncology
* Crowbar Circuits: Klystron and IOT protection
* Large Motor Testing Instruments

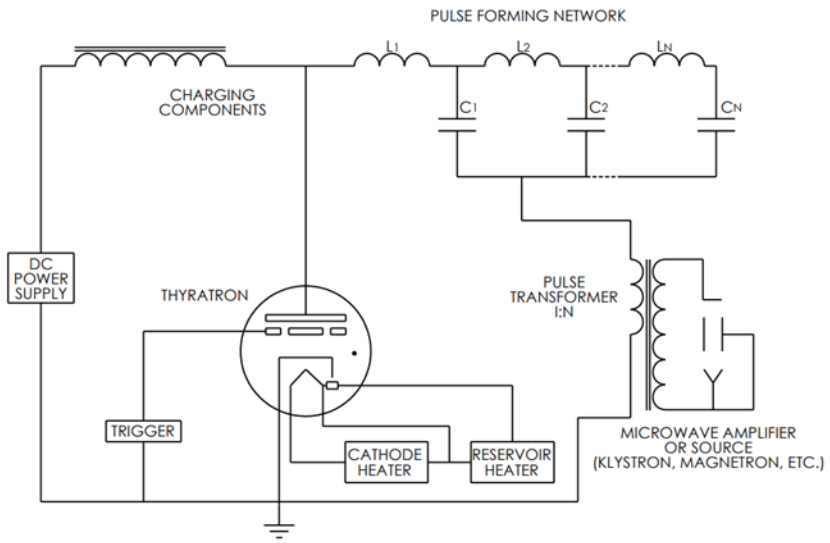
Spark Gaps Applications

* Flash-lamps
* Medical lithotripters
* Crowbar protection devices
* High energy surge protection
* High energy switch for directed energy

Thyratrons & Triggered Vacuum Spark Gaps

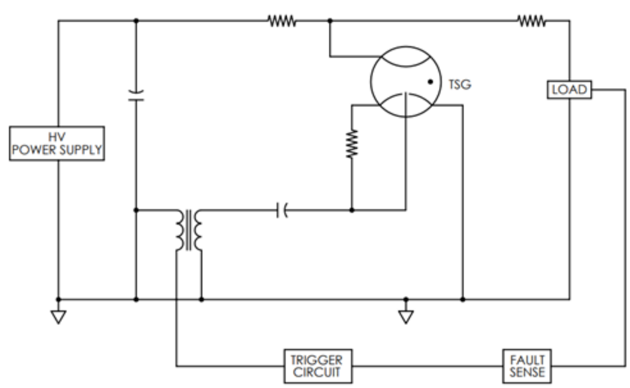
High Voltage Switches

Thyratron: Radar and Accelerator Applications



TYPICAL LINE TYPE MODULATOR CIRCUIT USING A THYRATRON

Spark Gap: Crowbar Circuit



TYPICAL CROWBAR CIRCUIT USING A SPARK GAP

Thyratrons & Triggered Vacuum Spark Gaps

High Voltage Switches

Thyratrons Models and Specifications

Product #	High Voltage Gaps	Tube Diameter (in)	Typical Weights	Outline Drawing (typ)	Peak Anode Voltage (kV)	Peak Anode Current (A)	Avg. Anode Current (ADC)	Cathode Heater (V/A)	Reservoir Heater (V/A)	Cross Reference	Application	Notes
L4668	1	1.38	6 oz	Figure 1	16	350	0.5	6.3/8.0	6.3/4.0	HY-60,	Radar &	
L4669	1	1.38	5 oz	Figure 2	12	350	0.2	6.3/7.0	6.3/2.5	HY-6,KU-71	Radar & Gen'l Purp.	
L4669 C	1	1.38	5 oz	Figure 2	12	350	0.2	6.3/7.0	6.3/2.5		Radar & Gen'l Purp.	
L4884	1	2	13 oz	Figure 3	16	500	0.5	6.3/11.5	NA	FX2522, HY -1A, 8613	Radar & Gen'l Purp.	5, 9 *
L4884A	1	2	13 oz	Figure 3	16	500	0.5	6.3/11.5	NA	FX2522, HY -1A	Radar	5, 9 *
L4884B	1	2	13 oz	Figure 3		500	0.5		NA	CX-8503	General Purpose	5, 9
L4884C	1	2	13 oz	Figure 3	16	500	0.5	6.3/11.5	NA	FX-2522, HY-100		5, 9
L4897	1	2	10 oz	Figure 4	20	500	0.5	6.3/9.0	6.3/2.5	HY-11T, 0265/F-265, FX2541	Radar	
L4897A	1	2	10 oz	Figure 4	20	500	0.5	6.3/8.3	6.3/1.75	HY-11	General Purpose	
L4897R	1	2	10 oz	Figure 4	20	500	0.5	6.3/9.0	6.3/2.5		Radar	
L4898	1	2	10 oz	Figure 4	12	500	0.5	6.3/8.0	6.3/3.5	HY-10, 0261, F-261	Radar & Gen'l Purp.	
L3101	1	3	3 lb 3 oz	Figure 5	35	10000	2	6.3/19	6.3/2.5		Excimer laser	
L4040LD	1	3	1 lb 9 oz	Figure 6	33	1,000	1.25	6.3/24	NA	CX-1140LD	Medical Accelerator	2, 5, 9, 15
L4059	1	3	1 lb 9 oz	Figure 6	33	1000	1.25	6.3/25	NA	CX-1159	Medical Accelerator	2, 5, 9, 15
L4108	2	3	4 lb 2 oz	Figure 7	44	10,000	0.5	6.3/22	6.3/2.5		Excimer laser	1, 2, 4
L4115	1	3	2 lb 6 oz	Figure 8	35	2,000	2.0	6.3/19	6.3/2.5		Excimer laser	
L4189	1	3	2 lb 10 oz	Figure 9	35	2,000	1.25	6.3/19	6.3/2.5	HY-3189, LP -189, F-189	Excimer laser	
L4189A	1	3	2 lb 10 oz	Figure 9	35	2,000	1.25	6.3/19	6.3/2.5	F-189	Excimer laser	
L4189 B	1	3	2 lb 10 oz	Figure 9	35	2,000	1.25	6.3/19	6.3/2.5		Excimer laser	
L4415	1	3	2 lb 10 oz	Figure 10	35	10,000	2.0	6.3/19	6.3/2.5		Excimer laser	11
L4871	1	3	2 lb 10 oz	Figure 11	25	500	1.0	6.3/19	NA	FX-2519A, F -150	Radar & Gen'l Purp.	5, 10

Thyratrons & Triggered Vacuum Spark Gaps

High Voltage Switches

Thyratrons Models and Specifications

Product #	High Voltage Gaps	Tube Diameter (in)	Typical Weights	Outline Drawing (typ)	Peak Anode Voltage (kV)	Peak Anode Current (A)	Avg. Anode Current (ADC)	Cathode Heater (V/A)	Reservoir Heater (V/A)	Cross Reference	Application	Notes
L4885B	1	3	2 lb. 10 oz	Figure 12	35	2,000	2.0	6.3/19	6.3/2.5	7322/1802		6
L4904A	1	3	4 lb 12 oz	Figure 13	35	1,750	2.0	6.3/22	5.8/4.5	CX-1154	Medical Accelerator	2, 4, 15
L4906A	1	3	2 lb 10 oz	Figure 14	35	2,000	1.25	6.3/13	6.3/2.5	F-205	Excimer laser	7
L4915B	1	3	2 lb 10 oz	Figure 15	35	10,000	2.0	6.3/19	6.3/3.0			11
L4945A	2	3	4 lb 2 oz	Figure 16	40	1,500	2.0	6.3/19	6.3/2.5	F229,LS-3229, CX-2608	Laser & Fast Switching	1, 2, 4, 11
L4961	1	3	2 lb 10 oz	Figure 17	35	12,500	2.0	6.3/19	6.3/2.5	0246	Laser & Fast Switching	11, 12
L4883	1	4.5	5 lb 3 oz	Figure 18	40	4,000	8.0	6.3/25	4.5/8.0	HY-5	Radar & Gen'l Purp.	
L4883A	1	4.5	5 lb 3 oz	Figure 18	40	4,000	4.0	6.3/25	4.5/8.0	HY-5G	Radar & Gen'l Purp.	
L4886A	1	4.5	6 lb 2 oz	Figure 19	33	2,000	4.0	6.3/28	4.5/8.0	F-281	Radar & Gen'l Purp.	*
L4022	2	6	25 lb 15 oz	Figure 20	50	15,000	8.0	6.3/75	4.5/30		Industrial Accelerator	1, 2, 4
L4888	2	6	25 lb 15 oz	Figure 20	55	15,000	8.0	6.3/75	4.0/25	CX-1536, CX-1210, F-303	Scientific Accelerator	1, 2, 4
L4888B	2	6	25 lb 15 oz	Figure 20	50	10,000	8.0	6.3/75	4.0/25		Scientific Accelerator	1, 2, 4
L4888D	2	6	25 lb 15 oz	Figure 20	55	10000	8.0	6.3/75	4.0/18.8			1, 2, 4

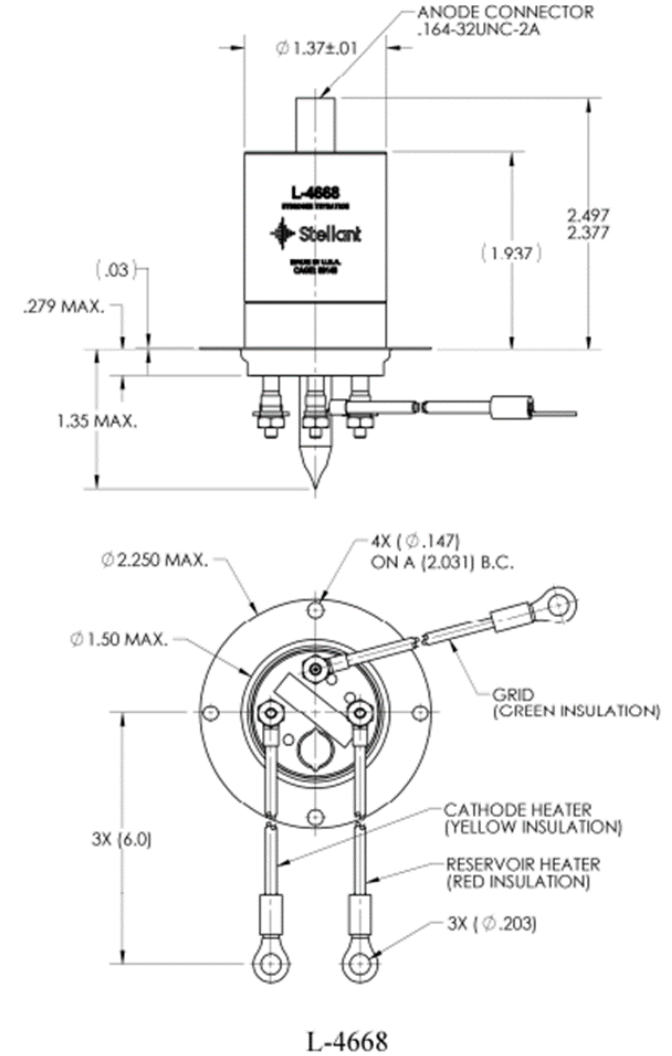
***IMPORTANT STELLANT Thyratron SPEC NOTES:
NOTES: Tubes are single voltage gap triodes, of metal-ceramic construction, flange-mounted unless otherwise indicated. Peak Current (ib) ratings can be appreciably higher for sub-microsecond pulse widths. Control grid drive requirements are given for the minimum open circuit voltage and the minimum peak grid current. Cathode and reservoir heater voltages are nominal operating voltages. Cathode and reservoir heater currents are the maximum required at the nominal voltage.

1. Gradient grids, one or more
2. Auxiliary (preionizing) grid
3. Integral anode cooling chamber
4. Shielded gap for x-ray attenuation
5. Plug-in socket required
6. MT-4 mounting socket
7. Grounded grid (triggered spark gap) thyratron
8. High pulse repetition rate design
9. Reservoir heater & cathode heater internally connected in parallel
10. Metal-ceramic version of glass design
11. Ratings presuppose sub-microsecond pulse widths or single shot/crowbar service
12. Long-grid ceramic to suppress external arc-over
13. Oil immersion recommended
14. Suitable for De-Qing operation
15. During the first 25 microseconds after conduction, peak inverse anode voltage should be limited to 10 kV in order to obtain maximum tube life

Thyratrons & Triggered Vacuum Spark Gaps

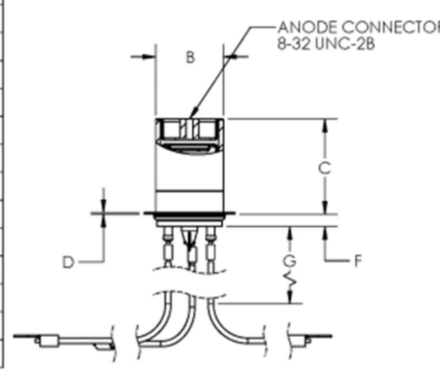
High Voltage Switches

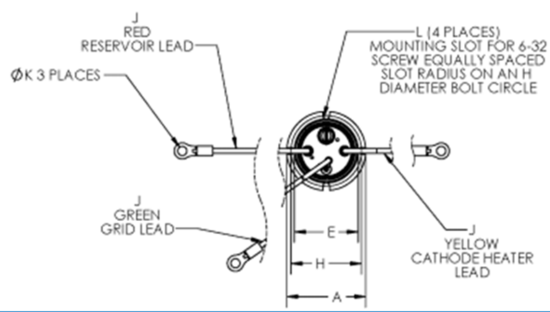
Figure 1



LTR	Dimensions			
	Inches		Millimeters	
	Min	Max	Min	Max
Conformance Inspection, Part 2				
A	1.870	1.880	47.50	47.75
B	1.365	1.385	34.67	35.18
C	1.875	2.000	47.62	50.80
E	1.421	1.453	36.09	36.91
F	0.156	0.280	3.96	7.11
G	-------	1.000	-------	25.40
Reference Dimensions				
D	0.030		0.76	
H	1.656		42.06	
J	6.000		152.4	
K	0.203		5.16	
L	0.150		3.81	

Figure 2

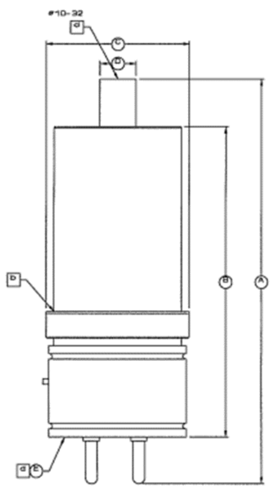


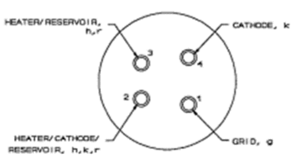


Thyratrons & Triggered Vacuum Spark Gaps

High Voltage Switches

Figure 3

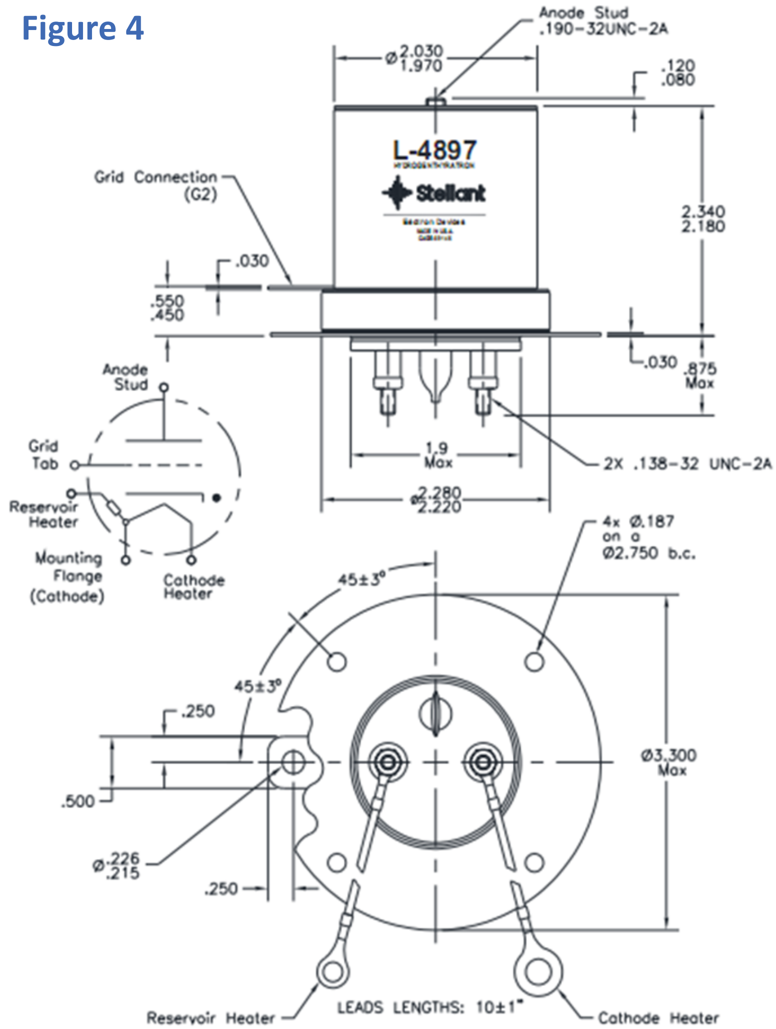




DIMENSIONS				
LETTER	INCHES		MILIMETERS	
	MIN	MAX	MIN	MAX
QUALITY CONFORMANCE INSPECTION - PART 1				
A	6.125	6.625	155.58	168.28
B	4.750	5.150	120.65	130.81
C	2.000	2.375	50.80	60.33
D	.559	.573	14.20	14.55

PIN CONNECTIONS	
PIN NO.	ELEMENT
1	GRID
2	HEATER/RESERVOIR/CATHODE
3	HEATER/RESERVOIR
4	CATHODE
CAP	ANODE

Figure 4



Thyratrons & Triggered Vacuum Spark Gaps

High Voltage Switches

Figure 5

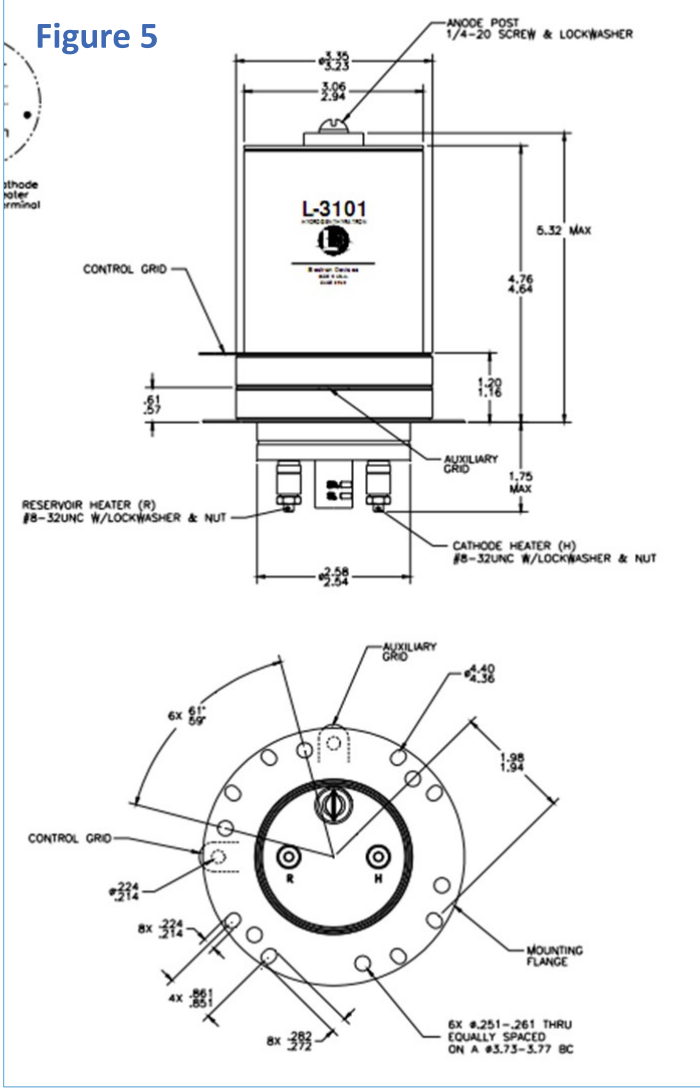
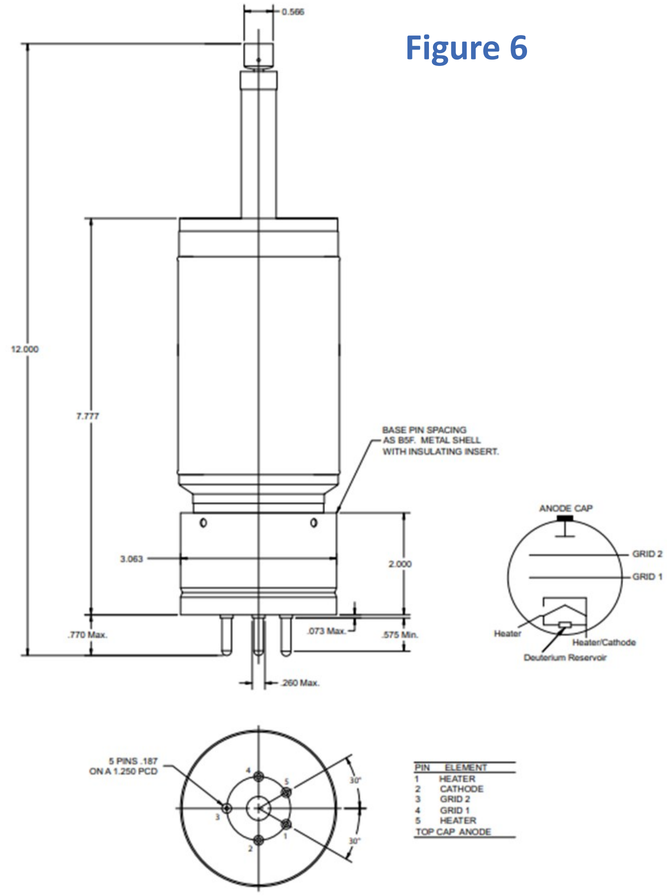


Figure 6



Thyratrons & Triggered Vacuum Spark Gaps

High Voltage Switches

Figure 7

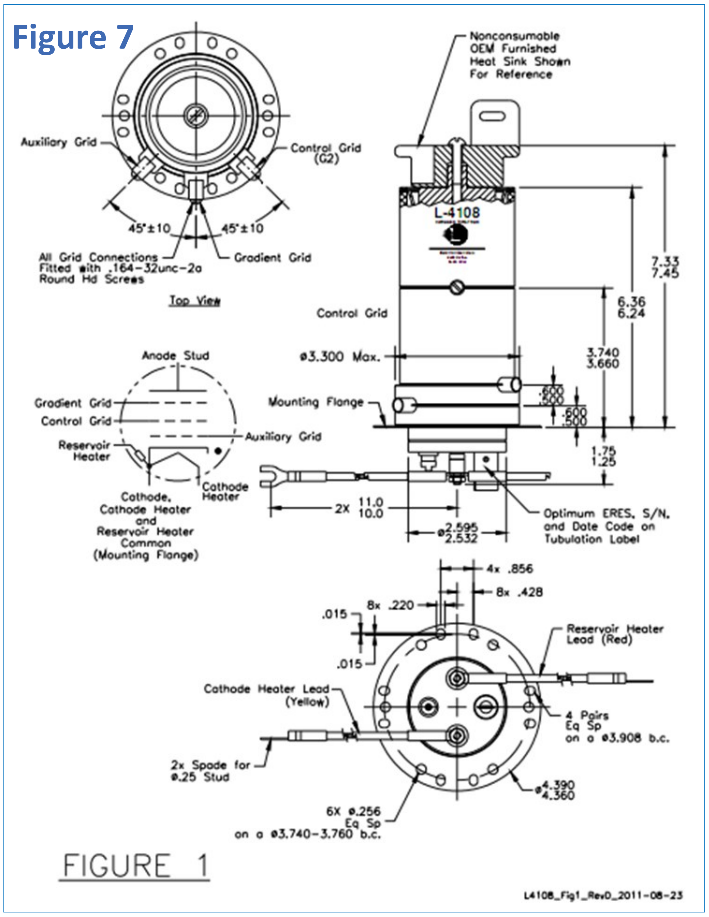
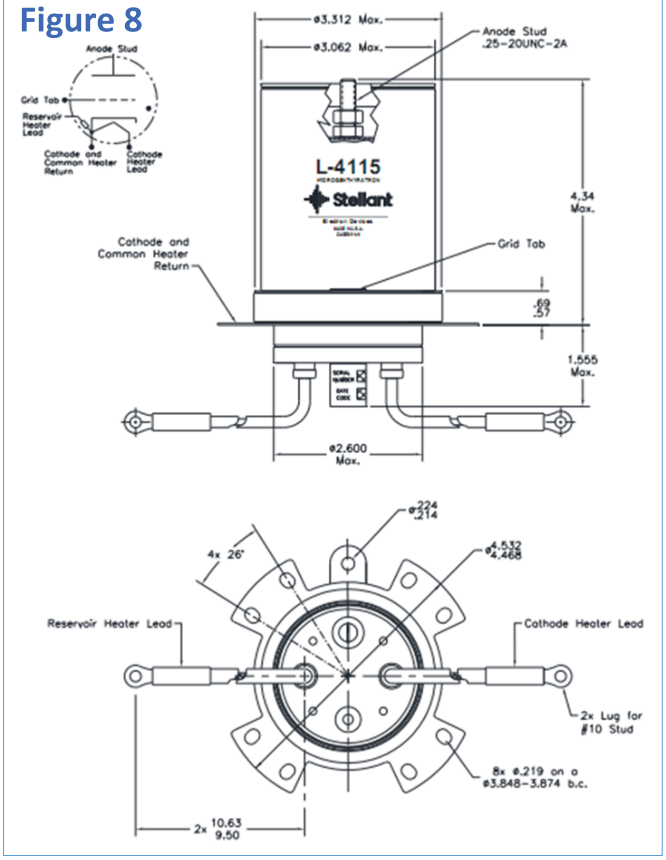


Figure 8



Thyratrons & Triggered Vacuum Spark Gaps

High Voltage Switches

Figure 9

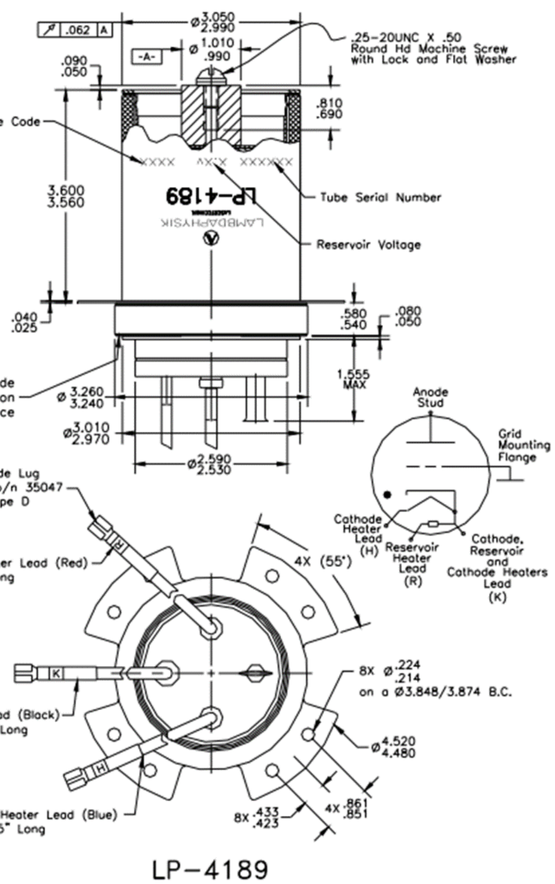
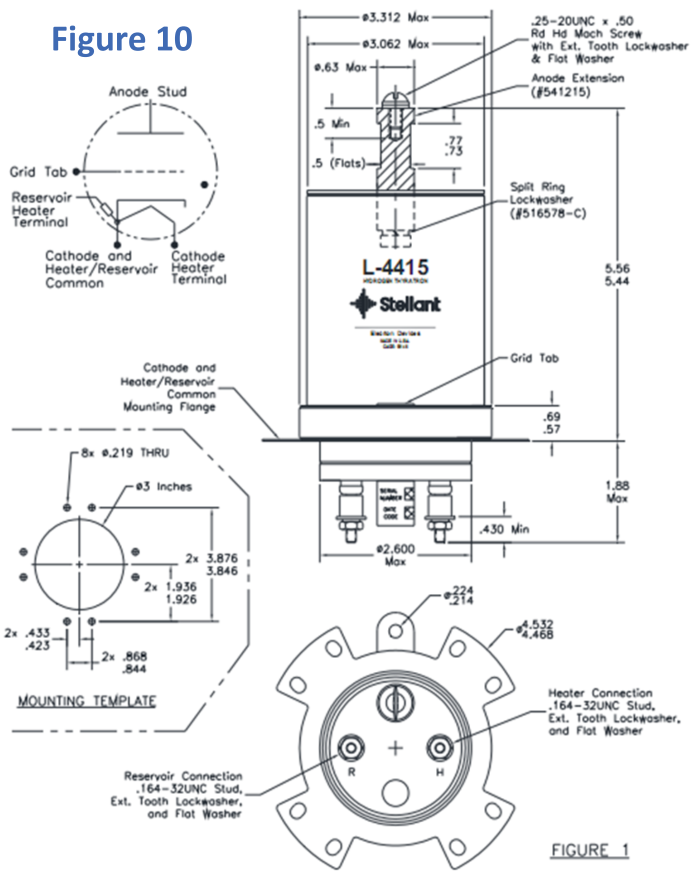


Figure 10



Thyratrons & Triggered Vacuum Spark Gaps

High Voltage Switches

Figure 11

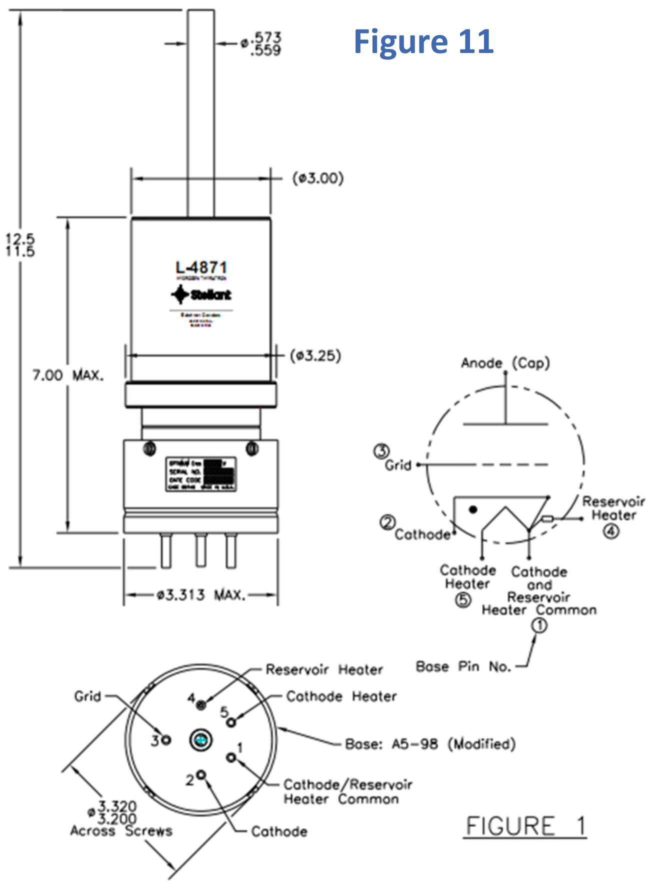
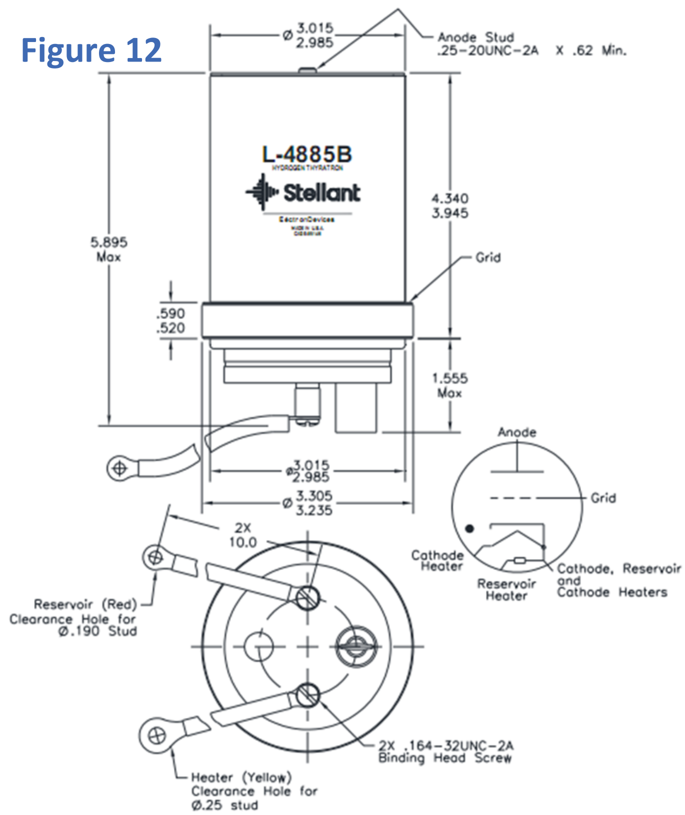


Figure 12



Thyratrons & Triggered Vacuum Spark Gaps

High Voltage Switches

Figure 13

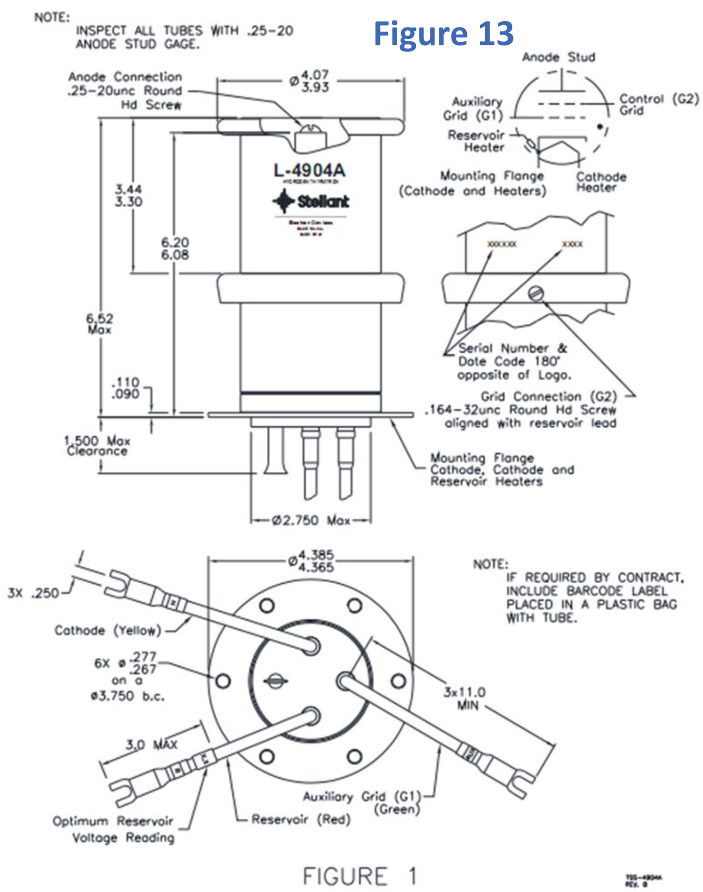
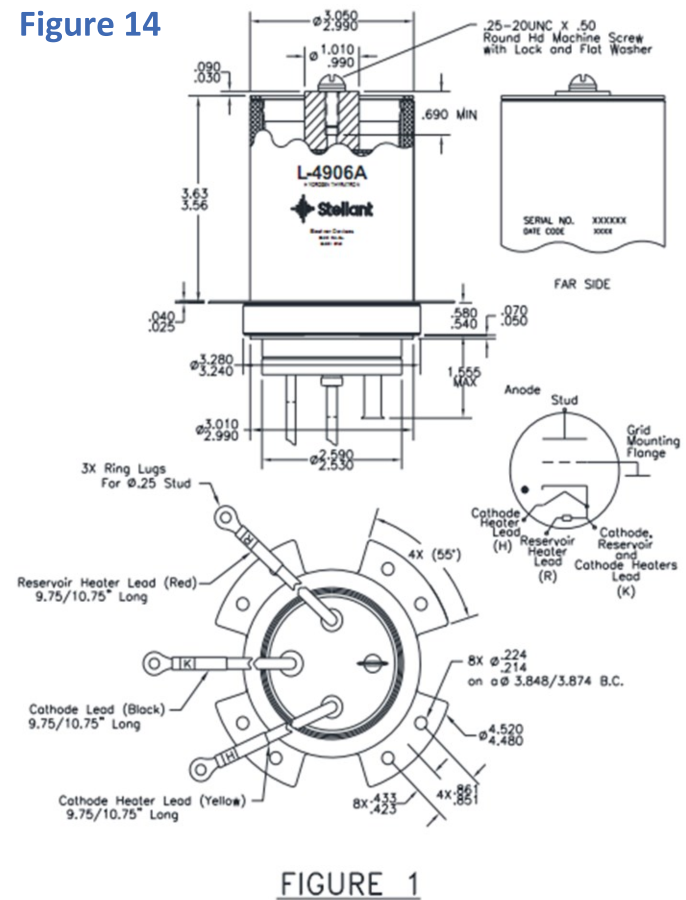


Figure 14



Thyratrons & Triggered Vacuum Spark Gaps

High Voltage Switches

Figure 15

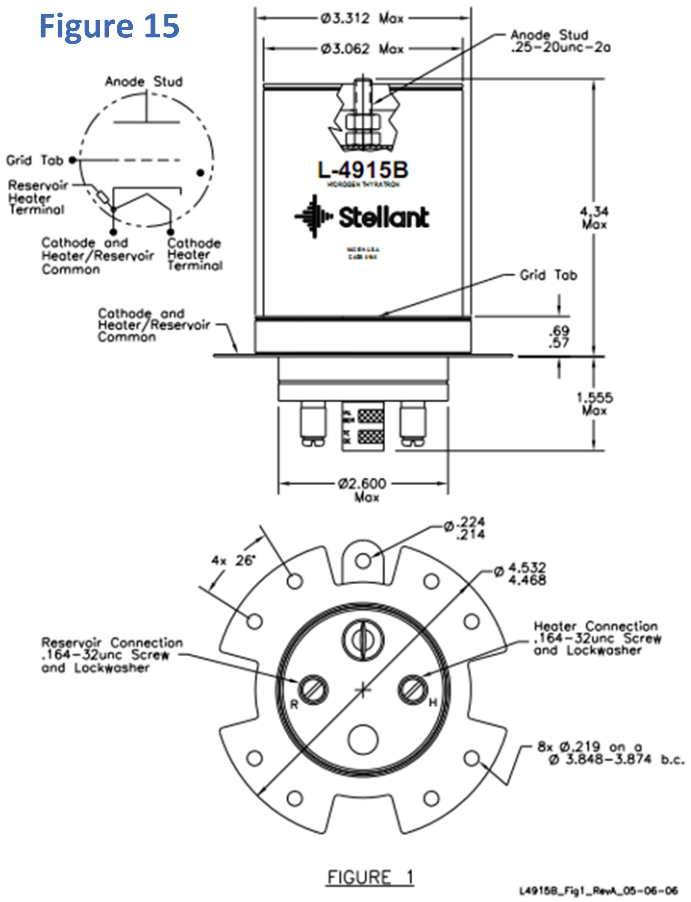
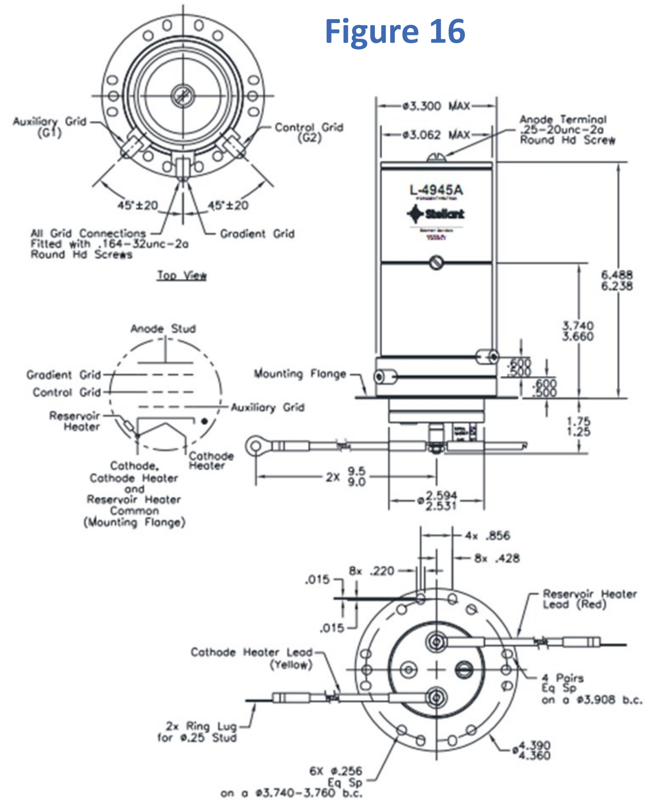


Figure 16



Thyratrons & Triggered Vacuum Spark Gaps

High Voltage Switches

Figure 17

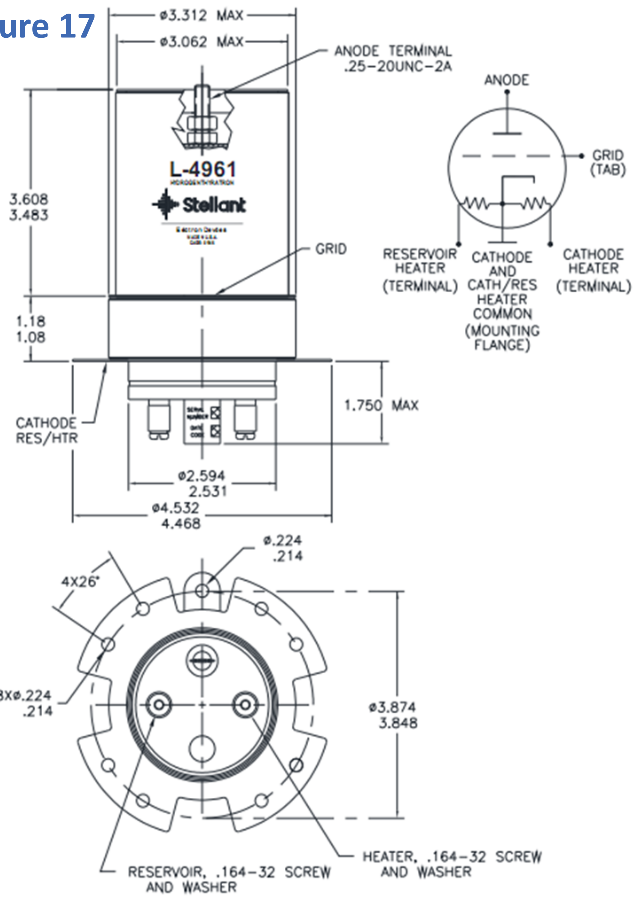
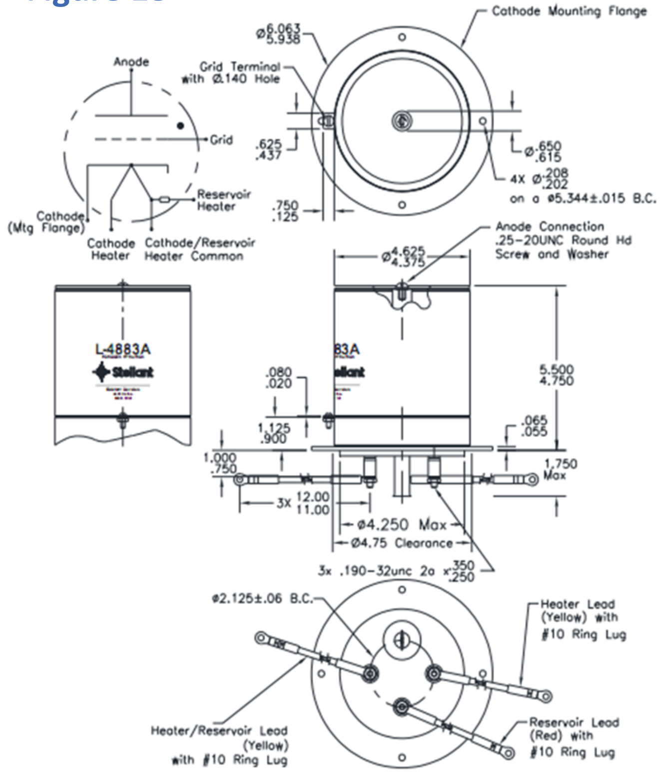


Figure 18



Thyratrons & Triggered Vacuum Spark Gaps

High Voltage Switches

Figure 19

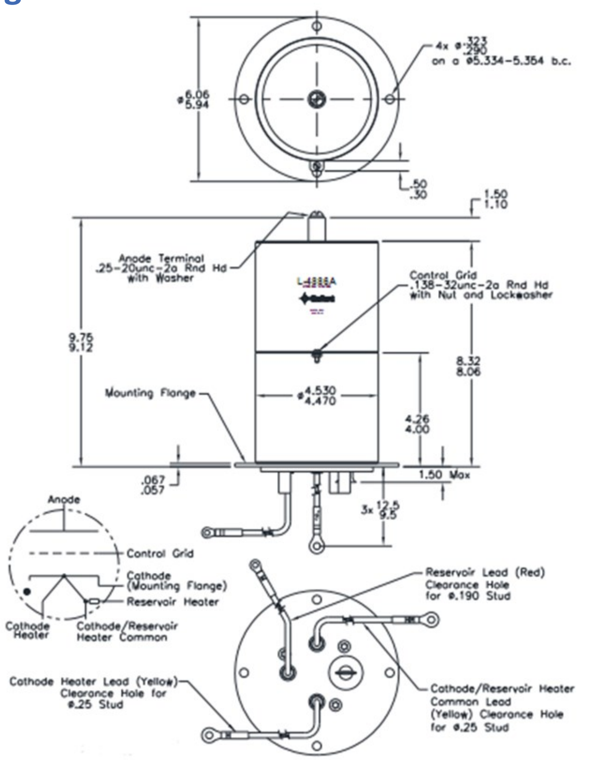
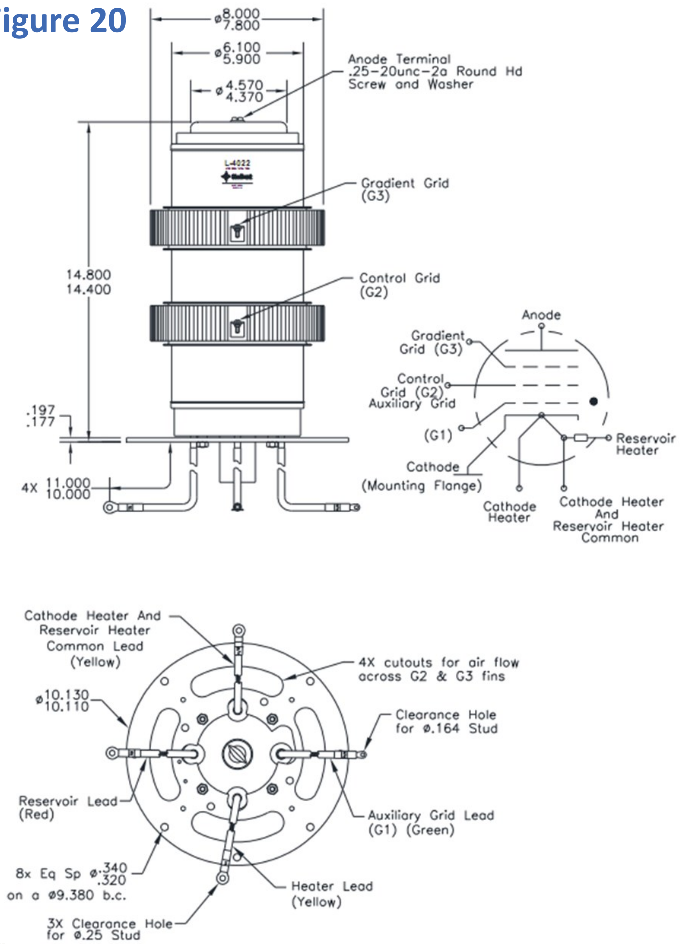


Figure 20



Stellant

Thyratrons & Triggered Vacuum Spark Gaps

High Voltage Switches

Triggered Spark Gap Models and Specifications

Triggered Spark Gap Product #	Tube Diameter (in)	Typical Weights	Outline Drawing (typ)	Breakdown Voltage (kV)	Typical Operating Voltage (kV)	Max Peak Current (kA)	Max Conducted Charge per Shot (Coulombs)	Contains Mercury	Cross Reference	Application	Notes
TVSG-3.50-5050-01	3.5	4 lbs.	Figure 1	55	0.3-50	50	0.7	No	ZR-7512	Surge protection, crowbar, and general purpose switching.	Stell (aka Draft GE ZR-7512)
TVSG-4.25-5050-01	4.25	3 lbs	Figure 2	65	0.3-50	50	0.5	Yes	GPV-63	Surge protection, crowbar, and general purpose switching.	Stell (aka Excelitas GPV-63)

Part # Key: TVSG (Triggered Vacuum Spark Gap) - Diam. (In.) -Operating Voltage (kV) - Max Peak Current (kA) - Configuration #.

***Proposed unit only; parameters not finalized COTS items presently in production.**

Figure 1

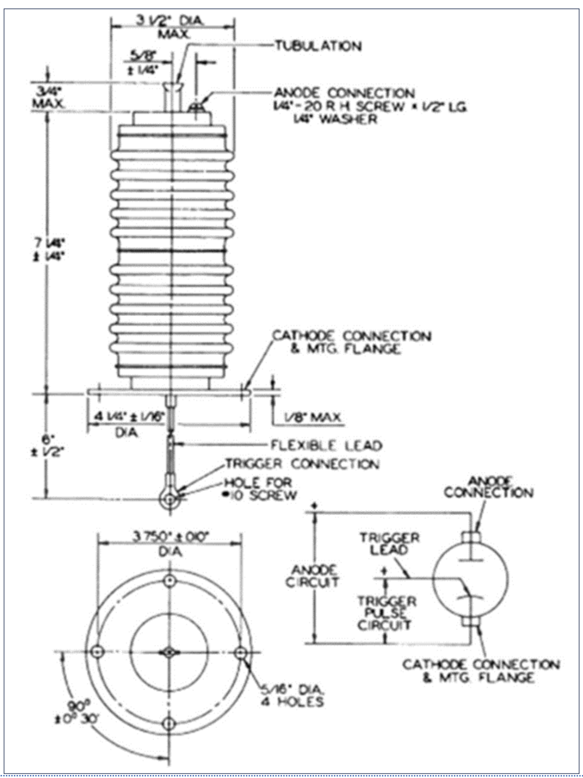
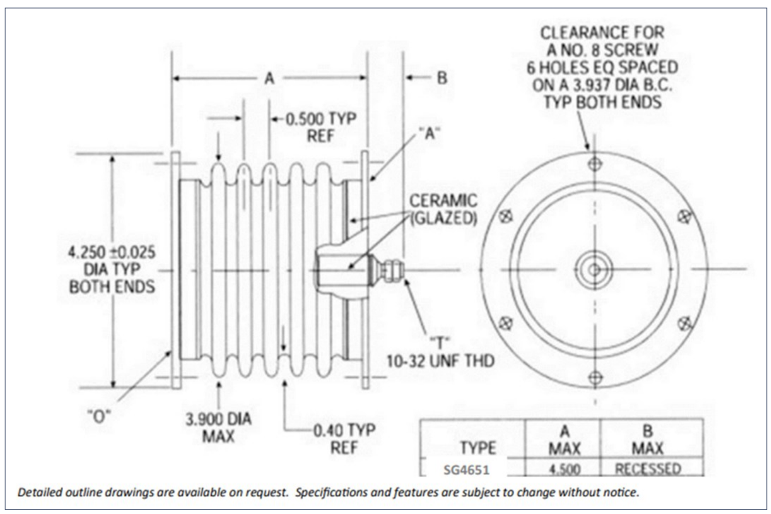


Figure 2



Thyratrons & Triggered Vacuum Spark Gaps

High Voltage Switches

About Stellant Systems

Stellant Systems is a premier manufacturer of critical spectrum and RF power amplification products to the space, defense, medical, science and industrial markets for both domestic and international customers. Stellant has 5 domestic manufacturing facilities and approximately 1100 employees.

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