TB Triggered Gap for Lithotripters
Application Note

Introduction

The TB25.0 ceramic-metal triggered spark gap was designed to fill the need for applications in which high levels of stored energy are discharged rapidly into a load with minimal loss in the transfer process where the electrical energy may be converted to different forms such as heat energy for weapon detonation, laser triggering for generation of light pulses or sonic shock waves for medical lithotripsy.

The significant feature of the TB25.0 is the thin disc shaped ceramic placed between the two main electrodes, which permit short path lengths of current flow resulting in an extremely low level of inductance and dynamic resistance. These are the characteristics needed for the generation of pulses having rapid rise time and least energy loss during the transfer process. The contoured ceramic shape preserves the high level of external surface voltage insulating capability.

Shock Wave Lithotripsy

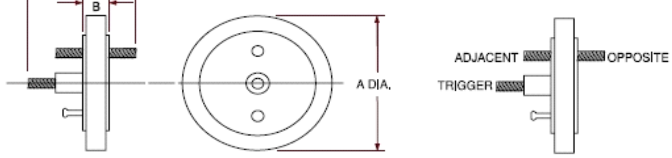
Among the most notable inventions pioneered in the early 1980's was the advancement of a non-invasive alternative to surgery for the treatment of kidney stones. Shock wave lithotripsy was introduced by carefully focusing, high-energy shock waves, generated outside the body, to disintegrate the kidney stones. Once the stones were disintegrated, the sand-like fragments passed out of the body through normal body functions.

The pulse generating circuitry of the lithotripter equipment consists of the energy storage capacitor, a triggered spark gap energy transfer switch and the shock generating transducer. To facilitate the transfer of the electrical energy from the storage capacitors to the shock generating components, a gas discharge triggered spark gap having low inductance, low dynamic resistance and long operating life was required. Based on these performance requirements, the TB25.0 was designed into one of the earliest lithotripsy machines and it soon became the quality standard for triggered spark gaps used for this type of application by providing reliable pulse generation and energy transfer in the sonic pulse generation process.

Conceptual Design and Construction Features

The design of the TB Series was based on new generation application requirements for triggered spark gaps. The degree to which the required electrical performance could be achieved was directly related to overcoming the mechanical limitations inherent in barrel shaped triggered gaps. Major considerations such as nano-second rise time and long life could not be attained by simple modifications of the barrel configuration. As a result, the TB Series saucer shaped triggered spark gap was developed to address the required governing parameters. These parameters included achieving maximum operating life by 1) minimizing effects of erosion deposits, 2) achieving nanosecond pulse formation, 3) reducing levels of inductance and 4) attaining minimum dynamic impedance for maximum energy transfer. In addition, development of a new ceramic-metal sealing technique and the methods needed for processing new materials were incorporated into the component.

TB Series



Operating Conditions

The TB25.0, when operating as a switch, provides very high unfired impedance, high voltage hold-off capability, relatively low level trigger energy requirements and fast follow-through time after application of the trigger pulse. Since the gap operates in the arc mode when conducting current, it acts as a short making it capable of switching high currents limited principally by the circuit in which it is used.

The nature and pressure of the fill gas, electrode geometry and the level of ionization produced within the gap all affect the rate of deionization. After each pulse, the gas within the triggered gap rapidly assumes a neutral state by ion diffusion to the walls and by volume recombination of the positive and negative ions. Although the TB25.0 may be operated at a relatively high pulse repetition rate (>100pps), the thermal limitations and increased rate of erosion of electrode material will require more maintenance procedures. It is necessary to compromise pulse power and the maximum recurrent frequency to limit the thermal accumulation in a given application

Although it is possible to trigger the TB Series with a low energy pulse, greater trigger reliability can be obtained as the trigger current is increased. The amplitude and width of the pulse necessary to trigger the gap depends on the applied voltage to the main electrodes. Required trigger energy decreases as the applied voltage is increased.

Ringing Waveforms

When placed in a typical energy transfer circuit consisting of a storage capacitor, triggered spark gap and cable network terminating in a load such as a sonic generating transducer, a ring wave is generated when the triggered gap is fired due to under damped conditions. By making a study of the ring wave, comparative measurements of the inductance (L) and dynamic resistance (R) of gap designs may be made. The inductance is determined by observation of the ringing period and knowing the storage capacitance, the dynamic resistance is obtained by comparison with an estimated decay time of a RLC ringing waveform.

Comparative measurements of the saucer and barrel shaped gaps have confirmed the inductance value of the saucer gap will be approximately 50 to 75% less than barrel gaps. The resulting decrease in both L & R clearly established the preference for the TB25.0 in lithotripsy applications.

Life Ratings

In lithotripter applications, the size of the storage capacitor and the operating voltage determine, to a great extent, the hours of useful operation of the triggered gap.

For low levels of energy storage (<5.0 Joules with C = 80 nF at 15kVdc), the arc resistance for a current pulse of 4000A is less then 6 mΩ. This low resistance allows nearly all of the stored energy to be transferred to the load. Since the erosion of the spark gap electrode is primarily related to the energy dissipated in the resistive component, slight differences in the dynamic resistance and inductive component of the discharge circuit will affect the discharge life of the spark gap. Additionally, life ratings, estimated from typical operating conditions, are dependent on the pulse amplitude, pulse width and the repetition rate of the pulse. The amount of erosion of the electrodes is typically limited to micro-grams of particles ejected from the surface. This small transfer of electrode material does not of itself affect the DC breakdown voltage. The straight-line trajectories of these particles are deposited on to near-by surfaces, which are within the solid angle purview of the erosion source. The accumulation of these particles result in a continuous electrically conductive film, which for barrel shaped spark gaps, provides a resistive path between the anode and cathode. It is this film, which affects the normal operation of the gap. The TB25.0 saucer shape configuration avoids the film formation since ejected particles traveling in straight lines are not intercepted at the radially oriented ceramic surface. Instead, the eroded particles are returned to the electrode surface and thereby avoid deposit on to the insulating surface.

Conclusion

Shock wave lithotripsy has become the standard non-invasive method for treatment of kidney stones. Since the inception of this technique, the transfer of electrical energy in a pulse mode having extremely fast rise time and low energy loss has been accomplished by incorporating and using the TB25.0 spark gap in lithotripter applications.

TB25.0 SPECIFICATIONS					
Parameter	**Conditions**	**Min**	**Nom**	**Max**	**Units**
Device Specifications @ 25°C					
Main Static Breakdown	100V/s	22.5	25.0	27.5	kV
Applied Voltage	DC	7.5	-	20.0	kV
Trigger Voltage	tr = 0.5µs, PW = 3.0µs	9.7	-	5.2	kV pk
Anode Delay Time	Applied Voltage = 10.4kV	-	< 0.5	-	µs
Insulation Resistance	V = 100Vdc		1,000		MΩ
Mechanical Specifications (See Outline in this Application Note)					
Dimension A	-	-	2.79	-	inches
Dimension B	-	-	-	0.58	inches
Dimension C	-	-	-	2.10	inches
Weight	-	-	5.6	-	ounces
Operating Temperature Range	-55ºC to +85ºC	-	-	-	ºC
Environmental Ratings Mil Std 202G					
Thermal Shock	Method 107 - Condition A				
Shock	Method 213B – Condition J				
Vibration	Method 204D - Condition A (10 - 500Hz/.06DA)				
Barometric Pressure	Method 105C - Condition A (non-operating)				
Life Ratings					
Cumulative Charge	Coulomb Rating	12,000 Note 1			Coulombs (Q)
Charge/Shot	1.2mC/shot	Typical C=80nF/ V= 15,000Vdc			Coulombs/shot (q/shot)
Peak Current	PW<1.0µs	2500 - 5000A peak			Apk
Rep Rate	2-5	4.0 typical			Hz

Note 1: Extrapolated from tests conducted @ E= 12 Joules (C=6.0µF and V=2000Vdc) tested to 2X 10^6 shots.

Contact information:

High Energy Devices, LLC
26 Hollenberg Court
Bridgeton, MO 63044
Tel.: 314.291.0030
Fax: 314.291.8184
E-mail: info@highenergydevices.com
www.highenergydevices.com

HIGH ENERGY DEVICES, LLC MAKES NO REPRESENTATIONS OR WARRANTIES WITH RESPECT TO THE ACCURACY OR COMPLETENESS OF THE CONTENTS OF THIS PUBLICATION AND RESERVES THE RIGHT TO MAKE CHANGES TO SPECIFICATIONS AND PRODUCT DESCRIPTIONS AT ANY TIME WITHOUT NOTICE. NEITHER CIRCUIT PATENT LICENSES NOR INDEMNITY ARE EXPRESSED OR IMPLIED. EXCEPT AS SET FORTH IN HIGH ENERGY DEVICES' STANDARD TERMS AND CONDITIONS OF SALE, HIGH ENERGY DEVICES, LLC ASSUMES NO LIABILITY WHATSOEVER, AND DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY, RELATING TO ITS PRODUCTS INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTY OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, OR INFRINGEMENT OF ANY INTELLECTUAL PROPERTY RIGHT.

THE PRODUCTS DESCRIBED IN THIS DOCUMENT ARE NOT DESIGNED, INTENDED, AUTHORIZED OR WARRANTED FOR USE AS COMPONENTS IN SYSTEMS INTENDED FOR SURGICAL IMPLANT INTO THE BODY, OR IN OTHER APPLICATIONS INTENDED TO SUPPORT OR SUSTAIN LIFE, OR WHERE MALFUNCTION OF HIGH ENERGY DEVICES' PRODUCT MAY RESULT IN DIRECT PHYSICAL HARM, INJURY, OR DEATH TO A PERSON OR SEVERE PROPERTY OR ENVIRONMENTAL DAMAGE. HIGH ENERGY DEVICES, LLC RESERVES THE RIGHT TO DISCONTINUE OR MAKE CHANGES TO ITS PRODUCTS AT ANY TIME WITHOUT NOTICE.

Specification: AN-TG-40

January 2010