



INTRODUCTION

The range of two-electrode spark gaps offered by e2v technologies comprises hermetically sealed gas-filled switches available with DC breakdown voltages from 400 V to 50 kV.

Two-electrode spark gap applications include voltage surge protection, lightning protection, single-shot pulse generators, high energy switches and turbine engine ignition circuits.

PRINCIPAL FEATURES

- No Standby Power Consumption
- Consistent Breakdown Voltage
- High Current Capability
- Fast Switching
- Rugged and Reliable over Temperature Range
- Lightweight

TWO-ELECTRODE SPARK GAP SELECTION

When considering the choice of spark gap, the following factors should be taken into account:

- Application
- Peak Current and Waveform
- Coulombs per Shot
- Maximum Repetition Rate
- Main Gap Voltage
- Environmental Conditions

The e2v technologies two-electrode spark gap preamble should be read in conjunction with the relevant product data sheet to gain a general understanding of the spark gap performance characteristics.

e2v technologies provides a technical customer support service for any queries and assistance.

PRINCIPLES OF OPERATION

A simple two-electrode spark gap is shown in Fig. 1. At low voltages the gap is an insulator. As the voltage increases, the few free electrons (present in the gap as a result of cosmic radiation and other ionising effects) are accelerated to higher velocities, until they are able to ionise atoms of the gas filling. This leads to an avalanche effect as the additional electrons produce further ionisation and as the current builds up, the voltage falls (see Fig. 2). There is a range of current over which emission from the cathode takes the form of a glow discharge and the voltage is almost constant.

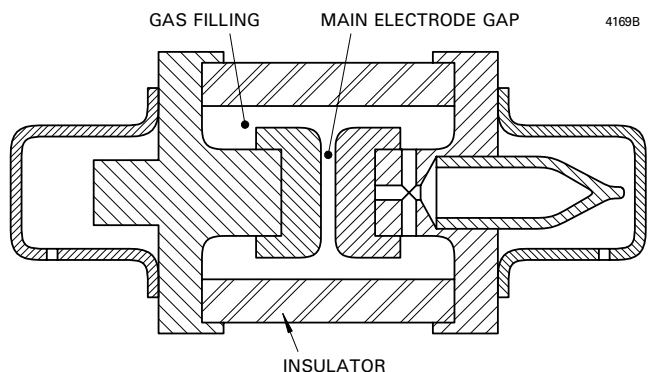


Fig. 1. Basic structure of a typical 2-electrode spark gap

A further increase in current produces cathode heating by ion bombardment, leading to the formation of emission sites and another voltage drop across the gap. The arc discharge formed in this stage is able to carry very high currents at a few tens of volts across the gap and the peak current value is determined by the external circuit.

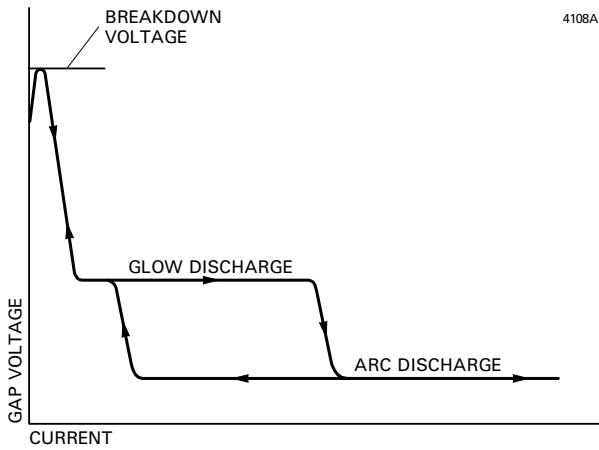


Fig. 2. Voltage-current characteristic of a 2-electrode spark gap

The arc persists until the current falls to a value insufficient to maintain arc conditions; this current is lower than that required to establish the arc initially. Current flow then ceases and the ionisation of the gas decays until the gap has returned to its original state.

The amount of natural ionisation present in the gap described above varies according to the intensity of ionising radiation and should normally be very small. This might cause wide variations in the breakdown voltage; for example the value in darkness might be double that when illuminated. The time taken to establish the arc would also be undesirably long and variable. The performance can be improved and stabilised by providing a consistent source of ionisation within the gas of the gap. One method is to maintain a small corona discharge at the normal operating DC voltage by providing sharp corners on the electrodes or including some high dielectric constant material. Another method frequently used is to include a small quantity of radioactive isotope, normally tritium gas, which emits high energy electrons continuously.

The value of the breakdown voltage is determined by the gap geometry, gas composition and pressure, ionisation conditions and the waveform of the gap voltage. A given type of spark gap can be made to break down at any given voltage selected from a wide range by appropriate adjustment during manufacture. Immediately after a current pulse, the voltage hold-off capability of the tube is limited by the residual ionisation. This decays rapidly by recombination, the recovery time depending on the gas composition, electrode material and pulse energy.

TWO-ELECTRODE SPARK GAP TERMINOLOGY

DC Breakdown Voltage

The voltage at which discharge occurs. This is normally the lowest voltage that will cause breakdown. The spark gap will break down within +10% of the specified voltage unless otherwise stated. A device can be manufactured to any voltage within the range stated.

Impulse Breakdown Voltage

The voltage at which discharge occurs when a rapidly rising voltage is applied across a spark gap. Impulse breakdown voltage normally increases with increasing rate of rise. A rate of rise of 15 kV/ μ s is usually used at e2v technologies.

Impulse Ratio

The ratio of the impulse breakdown voltage to the DC breakdown voltage.

Life

The passage of current through a gap has a cumulative effect, causing a gradual reduction of the DC breakdown voltage. The life of the spark gap can be expressed as the cumulative charge in coulombs that can be passed through the device without changing its breakdown voltage by more than 10%. Life shortens with increasing charge per discharge and increasing repetition rate. For further details see Operating Notes.

Maximum Charge Transfer

The proven charge transfer, single discharge handling capability of the spark gap with a defined pulse wave shape unless otherwise stated. The cumulative charge transfer figure used to express life is based on figures below this value specified at a relative pulse repetition discharge rate.

Recommended Repetition Rate

The maximum repetition discharge rate per second for optimum spark gap performance.

Capacitance

The inter-electrode capacitance is measured across the terminals and typical values for e2v technologies spark gaps are: G XK and GXN series typically 0.5 pF; GXH, GXS and GX2001 series typically 5.0 pF; GXF series 50 pF maximum.

Insulation Resistance

The resistance of a two-electrode spark gap measured at 100 V dc between the terminals is typically >10,000 M Ω .

Radioactivity

Some devices contain tritium to ensure consistency of operation. The activity of the device will not exceed the limit stated.

Gas Content

The gas content of a spark gap might be inflammable when mixed with air. Devices should not be operated if damage to the envelope is evident.

FACTORS AFFECTING LIFE

Life

It might be possible to extend the life of a spark gap by operating the device well below the stated operating characteristics.

Peak Current

The life of a spark gap is governed primarily by the deposition of electrode material on the insulating surfaces. The rate of erosion of the electrodes may be related to peak current as follows:

$$\text{Rate of erosion} \propto (I_{pk})^{1.6}$$

Hence, limiting the peak current can increase spark gap life.

Pulse Duration

For a given peak current, longer life will be obtained with shorter pulses.

Current Reversal

Reasonable life can be achieved with high current reversal, but for maximum life a critically damped circuit is preferred.

Circuit Symmetry

Long life depends on even distribution of the discharge around the electrodes. The electromagnetic fields generated by the discharge may be sufficient to produce a preferred discharge path which in turn might lead to excessive local erosion and reduced life.

Recovery

Recovery time with low duty operation is very short (in the order of microseconds). However, as the charge transferred per discharge increases, thermal effects begin to dominate and the maximum repetition rate decreases. At high charge transfer levels, the recovery time may be many tens of milliseconds.

Charge Transfer

The life of a spark gap increases with decreasing charge transfer. For example, the cumulative charge life for the GXH series is 600 C at 1.0 C per discharge, rising to 6000 C at 0.8 mC per discharge. However, the relative peak currents and other circuit characteristics should be considered also.

For the ringing current pulse conducted by the spark gap (see Fig. 3), the charge transfer is the sum of the shaded areas, not the stored charge CV, where C = capacitance and V = charging voltage.

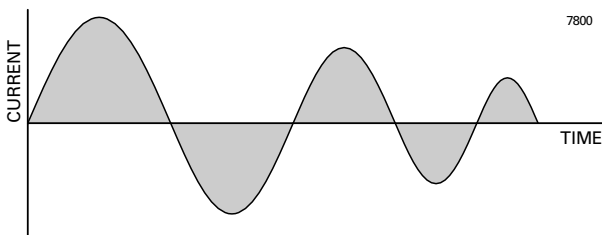


Fig. 3. A typical current pulse (circuit dependent)

Repetition Rate

The life of a spark gap increases with decreasing repetition rate. Burst or higher repetition rates may be acceptable but may shorten life.

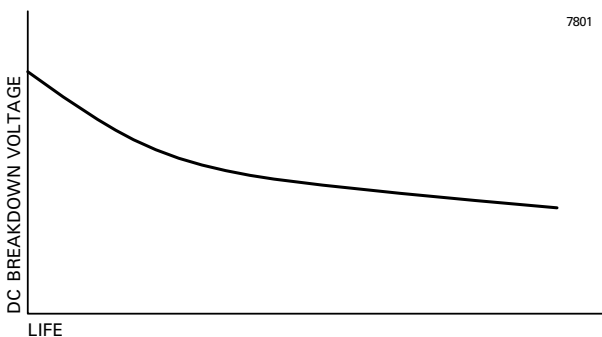


Fig. 4. Typical plot of spark gap breakdown voltage over operational life

End of Life Failure Modes

The DC breakdown voltage of the spark gap reduces slowly over operational life (see Fig. 4). This can be caused by coating the insulator surface with a metallic film. The reduction of the DC breakdown voltage can also be caused by erosion and the deposits of the electrode material onto the opposite parallel electrode surface.

APPLICATION NOTES

- Single-shot Pulse Generators
- Voltage Surge Protection Circuits
- Turbine Engine Ignition Circuits
- Medical Lithotripsy
- High Energy Switches
- Modulator Component Protection

Most types of spark gap, although they may have been developed for one particular set of operating conditions, are very adaptable. The current and energy ratings are related to the life of the spark gap, measured as the number of discharges before the voltage limit is no longer reached; the compromise between life and discharge ratings can be varied over a wide range for any given type.

Surge Protection

Voltage transients are an ever-increasing problem wherever electronic instrumentation and equipment is being used. External voltage transients might be caused by power surges, lightning strikes, general switching, etc. Internal voltage transients arise from arcing, component failures, switching of inductive loads, etc. It is difficult to predict the magnitude, waveform and frequency of these events, and impossible to prevent them, so some form of protection is necessary. One of the simplest and most effective ways is the use of gas-filled spark gaps. Generally, a spark gap will handle more energy than a solid-state component, is more durable and will respond faster to a voltage transient than an electro-mechanical device, thereby giving greater protection.

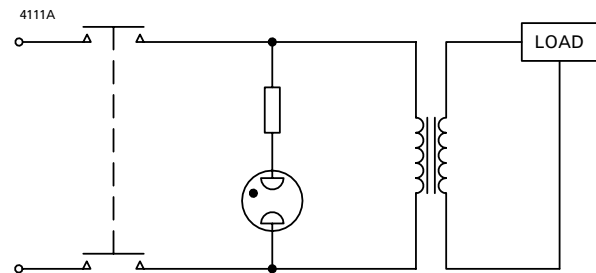


Fig. 5. Protection of a power transformer against voltage transients.

Fig. 5. shows a typical example of a power transformer and its load, protected against transient over-voltages by a 2-electrode spark gap in parallel with the transformer primary. Although a circuit breaker is included, this would not operate rapidly enough to provide protection against voltage surges with short rise times. When the gap is fired by a voltage surge, it will start to recover as the current falls to zero in the AC cycle, but may be ionised sufficiently to break down again in following half-cycles even if the voltage has returned to normal. The contactor must open the circuit before the spark gap can be destroyed, and must not re-close until the gap has recovered its hold-off voltage. The resistance shown in series with the gap

might be necessary for installations where very large currents can be drawn under fault conditions.

A more specialised application is shown in Fig. 6. In a radar transmitter, if the magnetron misfires once, the following pulse from the modulator may be at a much higher energy level than normal and this could cause rapid destruction of the pulse transformer and other modulator components. The spark gap connected across the secondary of the pulse transformer provides the necessary protection. Most pulse magnetrons operate at some thousands of volts, but the short-circuit current of the modulator is relatively small; similar types of gap may be used to protect other types of electron tube and equipment operating under similar conditions.

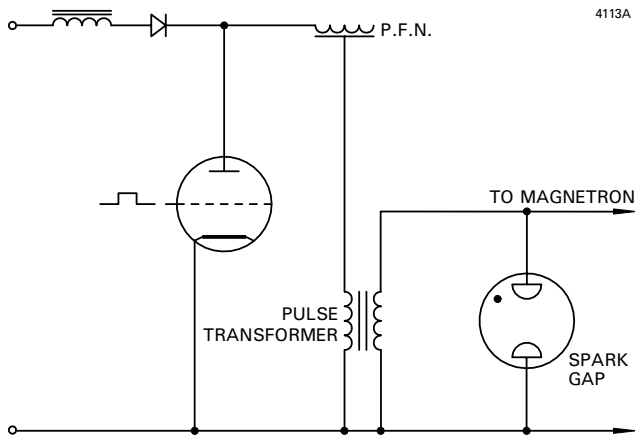


Fig. 6. Protection of a magnetron against misfiring

Pulse Generators

It is possible to use a spark gap as the switch tube in a pulse modulator up to very high peak power levels. The life of the gap will be very much less than that of a thyatron developed for the same conditions, but might still be sufficient for applications requiring only a short or very intermittent operation. The advantages of spark gaps for this purpose include zero standby power, zero warm-up time, a long non-operating life and low cost. Where the output of a modulator must be accurately timed or synchronised, a 3-electrode spark gap is used.

Environmental

The thermal, shock and vibration tolerances of most spark gaps are adequate for normal domestic and industrial applications, but certain types are especially rugged.

Where an industrial application involves a corrosive or abrasive atmosphere, spark gaps will require the same protection as most electronic equipment.

Storage

Spark gaps should be stored preferably in the original packing in a non-corrosive atmosphere. If removed from their packing, they should be protected from dust and industrial atmospheres until required.

The shelf-life is adequate for all normal storage requirements, although it is possible that the characteristics may change as the radioactive content decays. Since tritium has a half-life of twelve years, the change over normal storage periods is negligible.

The radioactive content used in most spark gaps is tritium gas, an isotope of hydrogen. Its emission consists of β particles (electrons) at relatively low energy. The total activity per tube is in the classification category band of <5.5 MBq, class 1 (code of practice Def. Stan. 59-60) and <37 MBq.

The spark gap should not be stored near photographic film and must be in a correctly marked package. There are some limitations on the action to be taken when large numbers of radioactive tubes (e.g. <5.5 MBq) are disposed of, broken or involved in a fire (consult relevant local authorities), but the handling of single tubes requires no special precautions.

Mounting and Connections.

The rise time of the arc current is determined mainly by the inductance of the external circuit and connections; where the fastest possible switching is required, the gap can be built into the end of a coaxial line, matched to the circuit impedance. In general, the connections should be kept short and well-spaced to minimise their inductance. For the same reason, the mounting position will be normally as close as possible to the load or protected equipment. In protection and single-pulse applications, the heat dissipated by the spark gap is not enough to require any assisted cooling, and the maximum temperature rating of the gap will not usually restrict the choice of mounting position.

Most spark gap applications involve high peak currents. Although the mean currents are relatively small, so that small section conductors can be used safely, the connections must be secure. Any poor or loose contacts will be eroded rapidly and are likely to fail completely.

Figs. 7 to 10 show examples of suitable mounting methods for several larger types of gap.

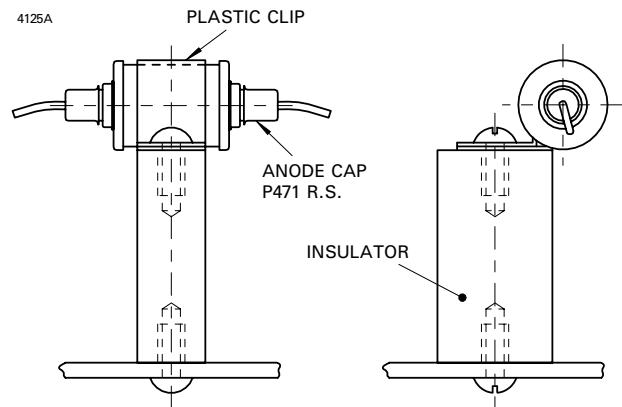


Fig. 7. Typical mounting arrangements for GXX Series

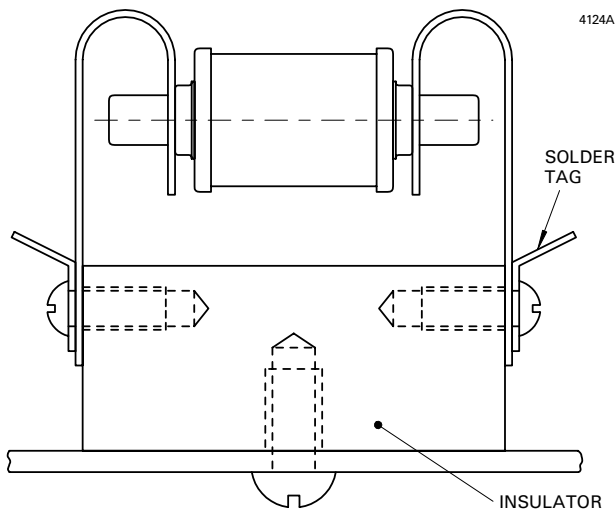


Fig. 8. Typical mounting arrangements for GXN Series

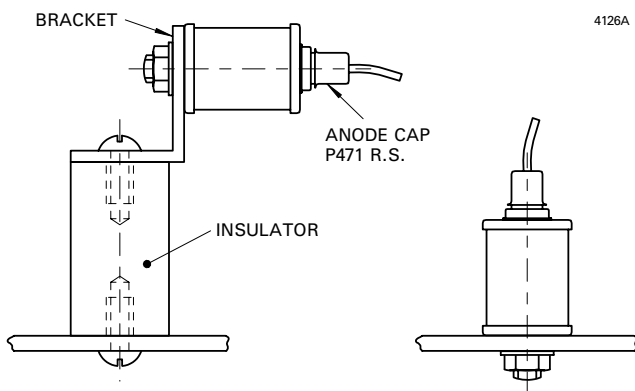


Fig. 9. Typical mounting arrangements for GXS Series

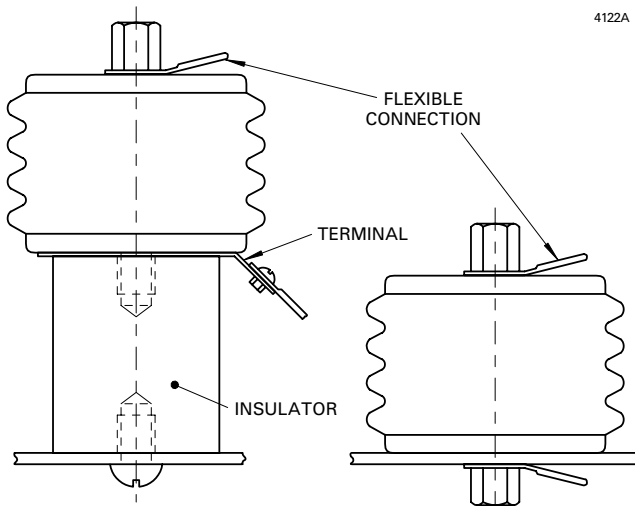


Fig. 10. Typical mounting arrangements for GXF Series

SPARK GAP ENQUIRY OPERATING PARAMETERS FORM

Overleaf is e2v technologies' Spark Gap Enquiry Operating Parameters Form. Please detach or photocopy, then complete and return the form as indicated to the address shown, and e2v technologies will recommend the most suitable spark gap. All information will be treated in the strictest confidence.

INFORMATION CHECK LIST

Answering the following questions will enable e2v technologies to select the most suitable 2-electrode spark gap.

What is/are the:

- application,
- required DC breakdown voltage,
- value of the charge storage capacitor,
- maximum charge transfer,
- cumulative charge transfer,
- typical life shots expected,
- peak current, waveshape and cycle time,
- maximum switching rate per second,
- required dimension limits,
- environmental parameters, e.g. operating temperature, shock, etc?

Whilst e2v technologies has taken care to ensure the accuracy of the information contained herein it accepts no responsibility for the consequences of any use thereof and also reserves the right to change the specification of goods without notice. e2v technologies accepts no liability beyond that set out in its standard conditions of sale in respect of infringement of third party patents arising from the use of tubes or other devices in accordance with information contained herein.

Spark Gap Enquiry Operating Parameters

Please complete as accurately as possible to allow the most suitable spark gap to be recommended. All information is treated in the strictest confidence.

Company Name and Address	
Contact Name Position	E-mail
Telephone No.	Fax No.
Application	
Discharge Circuit and Current Waveform (if known). Please sketch the discharge circuit below or attach a circuit diagram.	
Spark Gap Operating Conditions	
Operating Voltage Range	
Peak Current	
Repetition Rate	
Life Required	
Other Requirements	