■什么是电涌？～电涌对策是不是会造成困扰？～

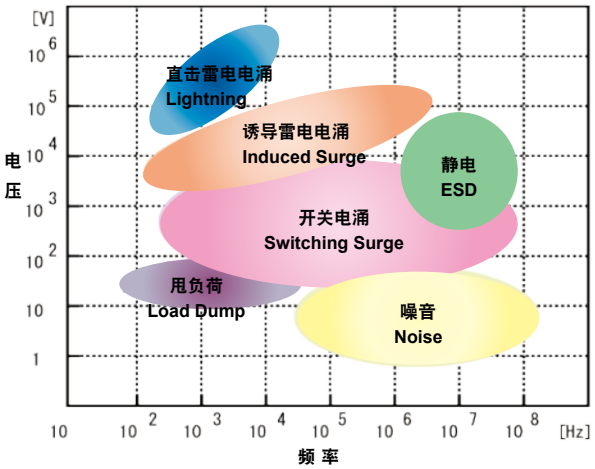


图 1 电涌种类
Fig.1 Surge Types

■What is Surge?

电涌是指瞬间发生的异常电压。如图所示，电涌根据产生的原因，分为多种类型。三菱综合材料（株）提供了针对由雷电引起的诱导雷电电涌和静电放电引起的静电电涌（在电路设计中特别容易成为问题）的相关零件 / 解决方案。

Solving Surge Problems
Surge is abnormal transient voltage and is categorized according to where it is originated. At Mitsubishi Materials, we provide countermeasure devices/solutions for circuitry and ESD surge caused by electrostatic discharge as well as induced surge caused by lightning discharge.

■诱导雷电电涌

■Induced Surge

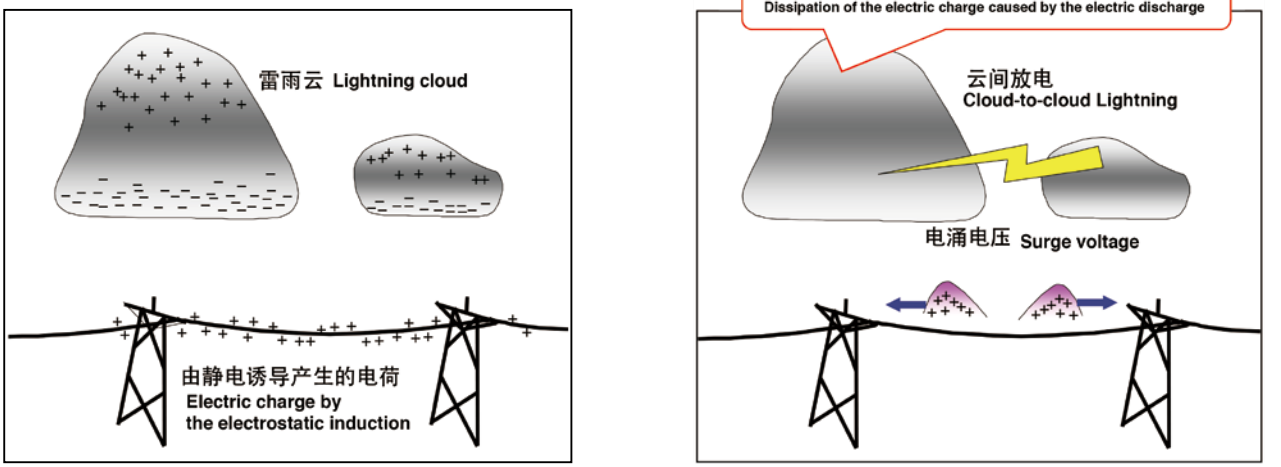


图 2（a）静电诱导电涌
Fig. 2(a) Electrostatic induction surge

在夏天的雷雨季节，雷雨云的上部发生正电荷、下部发生负电荷。
如果在该雷雨云下方存在输电线或通信电缆，电缆的上方也会聚积正电荷，产生高电压。
由于雷雨云之间或雷雨云与大地之间的放电，导致雷雨云的负电荷消失（减少）后，电缆上聚积的正电荷将解除束缚，向两个方向前进，从而产生静电诱导电涌。

When lightning occurs in the summer, a negative charge develops in the upper part of the lightning cloud.
When a power transmission line and a communication line cable exist under this lightning cloud, equilateral electric charges collect on the cable and high voltage occurs. Electrostatic induction surge occurs when a positive charge on a cable develops near a negative charge from a lightning cloud. When the cloud releases its charge to another cloud or the ground, the charge on the cable is released and travels in a wave, advancing in either direction.

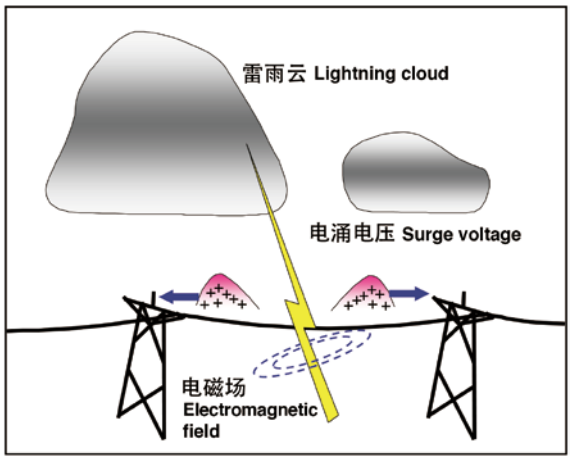


图 2（b）电磁诱导电涌
Fig. 2(b) Electromagnetic induction surge

在雷雨云与大地之间放电（打雷）时，大电流移动，产生电磁场后形成电磁诱导电涌。
如果在落雷点附近存在输电线、通信线等电缆，这些电缆会变为天线，通过电磁诱导，产生异常电压。
在雷雨云之间或雷雨云与大地之间发电时，附近的输电线、通信线等电缆会由于静电诱导或电磁诱导而产生异常电压。上述异常电压被称为诱导雷电电涌。图 2（a）（b）显示了电涌的产生机制。

When electric discharge (lightning) occurs between a lightning cloud and the ground, a severe electric current drifts and the electromagnetic induction surge produces an electromagnetic field.
If a power transmission line and the cable of a communication line exist near a lighting strike, they act as an antenna and electromagnetic induction causes abnormal voltage.
When an electric discharge occurs between lightning clouds or between a lightning cloud and the ground, abnormal voltage occurs by electrostatic induction and electromagnetic induction to the neighboring power transmission line or communication line. This is what is called Induced Surge as illustrated in fig.2 (a) and (b).

■诱导雷电电涌的侵入途径

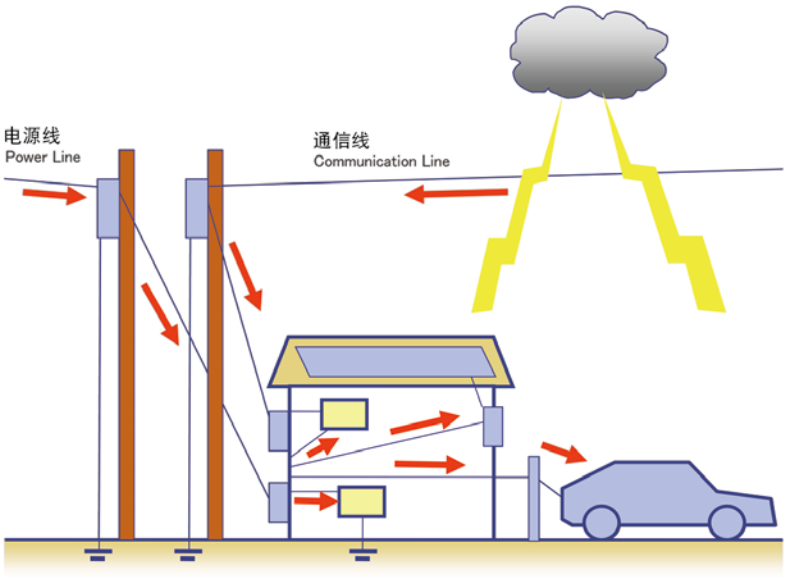


图 3 电涌的侵入途径
Fig.3 Invasion of Induced Surge

■Invasion of Induced Surge

由此产生的诱导雷电电涌通过电源线、通信线等侵入电子设备。

Induced Surge enters electronic equipment through power supply lines or communication lines.

■什么是电涌吸收器

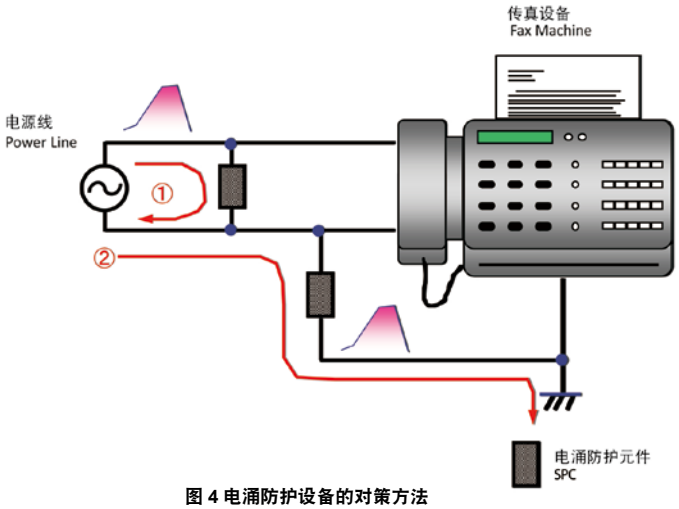


图 4 电涌防护设备的对策方法
Fig.4 Example of Surge Protection

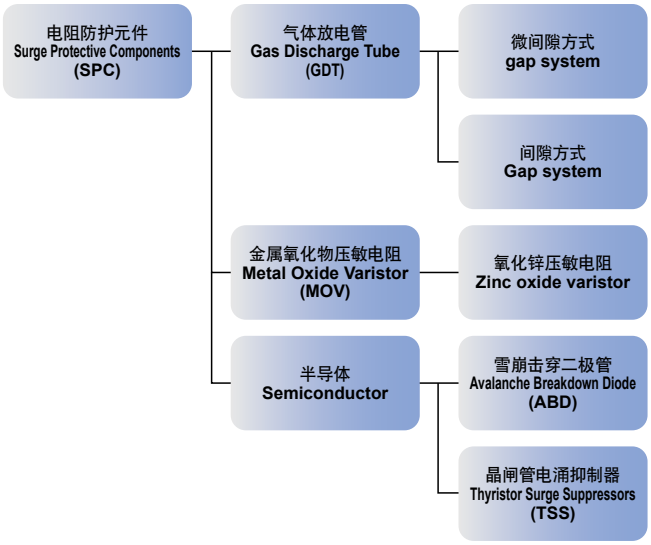
■What is a Surge Absorber?

保护电子设备免受电涌（异常电压）伤害的零件被称为电涌防护元件（SPC:Surge Protective Components）。
电涌防护元件针对电涌的侵入途径，在①线与线之间或②线与云之间进行。
通常，电涌防护元件的电阻较高，几乎没有电流（不会对保护的电子设备造成影响）。
但是，在电涌（异常电压）侵入时，电涌吸收器会在瞬间处于低电阻状态，带走电涌。当电涌消失后，恢复到原来的高电阻状态。

A device protecting electronic equipment from surge (abnormal voltage) is called a Surge Protective Components (SPC). SPC protect from entry of surge between ① the line to line interval or ② the interval from the line to the ground.
SPC typically has a high resistance level and most of the electric currents do not flow (nor influence the electronic equipment). However; when surge (abnormal voltage) enters, the Surge Absorber instantly eliminates surge with low resistance to protect the electronic equipment. When surge is eliminated, the Surge
Absorber returns to high impedance.

■电阻防护元件

■SPC: Surge Protective Components



GDT : Gas Discharge Tube
MOV : Metal Oxide Varistor
ABD : Avalanche Breakdown Diode
TSS : Thyristor Surge Suppressors

图 5 电涌防护元件的种类
Fig.5 Surge Protective Components

■微间隙式电涌吸收器

图 6 微间隙式电涌吸收器（引线式）
Fig.6 Micro-gap Surge Absorber (Lead wire type)

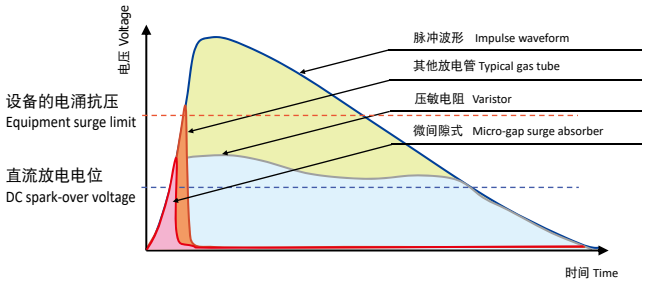


图 8 各种电涌相关零件的电涌应答波形
Fig.8 Surge response waveforms by different surge protections

■关于持续电流

1. 什么是持续电流 ...

持续电流如表面意思，是指持续流动的电流，即放电管中的电流持续流动的现场。

通常，电涌吸收器处于高电阻状态下，电流无法流通。电涌吸收器施加电涌后，则会导电，处于低电阻状态，使电涌通过，保护电路。在电涌消失后，则恢复原来的高电阻状态。然而，在低电阻状态下，如果施加可维持电涌吸收器电流的电压后，会出现如下现象：即使在电涌消失后，也可维持放电，不会回到原来的高电阻状态，电流持续流通。这一现象被称为持续电流。

可观察到持续电流现象的物品是放电管、半导体类开关型电涌吸收器。上述元件的特征包括吸收电涌（通过）时的工作电压（剩余电压）低于工作开始电压等。

吸收电涌时的低电压拥有将施加于被保护设备的压力抑制在较低水平的优点，但同时也存在如下问题：因某种原因，来自电源等的电流流入后，由于电压较低，从而导致无法阻止电流。

根据 JIC C 5381-311，当电流的流动持续超过 150msec. 时，可判断已发生了持续电流现象。

关于持续电流的机制，将在下文进行具体说明。这里将介绍放电管的放电状况、电源特性、持续电流条件。

■放电管的 V-I 特性

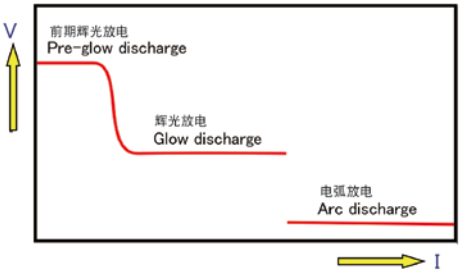


图 9 放电管的 V-I 特性
Fig.9 V-I properties of gas discharge tubes

●前期辉光放电
维持放电的电压与直流放电电位基本相等。是会发出微弱光芒的放电。
●辉光放电
拥有针对电流变化的恒定电压特性。
维持放电的电压因电极的材质、所使用气体的种类而异。
放电光会覆盖部分电极。
●电弧放电
是放电的最终形态，较强的电流流通，发出强光，并放电。
维持放电的电压（放电管的端子间电压）为数十 V。

■Micro-gap Surge Absorber

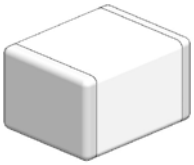


图 7 微间隙式电涌吸收器（表面安装式）
Fig.7 Micro-gap Surge Absorber (SMD type)

【特点】
1）采用微间隙式，可获得出色的电涌应答特性
2）10MΩ 以上的高绝缘电阻特性
3）1pF 以下的低静电容量
4）无明暗之差
5）无极性
6）支持引线式和表面安装式

<Benefits>
1) Excellent surge response
2) High insulation resistance (more than 10MΩ)
3) Low capacitance (less than 1pF)
4) No dark effect
5) Two-directional
6) Lead wire type and SMD type available

■About Follow-On Current

What is Follow-on current?

Follow-on current is electricity that will continue to flow; in this case it is a phenomenon where the current in a discharge tube continues to flow.
Normally, Surge Absorbers are in high impedance. When a surge enters the Surge Absorber, it will drop to low impedance, allowing the surge to bypass the electronic circuit it is protecting. After the surge has passed, the Surge Absorber should return to high impedance.
However, when the Surge Absorber is in low impedance and there is sufficient voltage on the line to keep current flowing, the surge ends and the Surge Absorber remains in discharge. The Surge Absorber fails to return to high impedance and the current continues to flow. This is a phenomenon known as follow-on current.
Surge Absorbers that display this follow-on current are discharge-type and semiconductor switching-type. A characteristic of these absorbers is that during surge absorption (bypass), the operating voltage (remaining voltage) is lower than the starting voltage.
The advantage of these Surge Absorbers is that during suppression, the voltage is held very low, so it reduces stress on the equipment. However, a problem arises when the line current of the equipment is high enough that it continues to drive the Surge Absorber even when the voltage is low.
Follow-on current mechanisms are explained further in the next chapter, along with the discharge tubes.

■V-I properties of gas discharge tubes

微间隙式电涌吸收器属于放电管的一种。该放电管开始放电后，放电形态可逐步变为前期辉光放电、辉光放电、电弧放电，具体如下图所示。

关于该放电管的 V-I 特性，请见显示了放电管的电压与电流的关系的示意图。其特征在于：放电管放电，电流流通后，转变为辉光放电、电弧放电，放电电压下降。相反，放电停止后，从电弧放电转为辉光放电，放电电压上升。

The micro-gap type Surge Absorber is a type of discharge tubes. The discharge in the tube changes from pre-discharge to glow discharge, then to arc discharge as illustrated in Fig.9.
The illustration below also shows the V-I characteristics between voltage and current for the discharge tube.
When the tube is discharging, electric current flows and moves to glow discharge then to arc discharge as the discharge voltage decreases. On the other hand, when the discharge decreases, the voltage increases as it moves from arc discharge to glow discharge.

● Pre-glow discharge
The voltage to maintain the discharge is equivalent to the DC breakdown voltage. A faint light can be seen from at this point.
● Glow discharge
The constant voltage rate remains as the current changes. The voltage to maintain the discharge depends on the electrode material and the gas in the tube. The discharge light covers portion of the electrodes.
● Arc discharge
At the end of discharge and a large current flows through the part and it puts out a bright light. The maintaining voltage at this point (voltage between the discharge tube terminals) is in the 10's of volts range.

关于本资料的处理请阅读【序言】。
Please see【Introduction】for the handling of the products listed in this document.
关于浪涌吸收器的使用注意事项请阅读P.20。
Please see page 20 for precautions when using the surge absorber.

■什么是延续

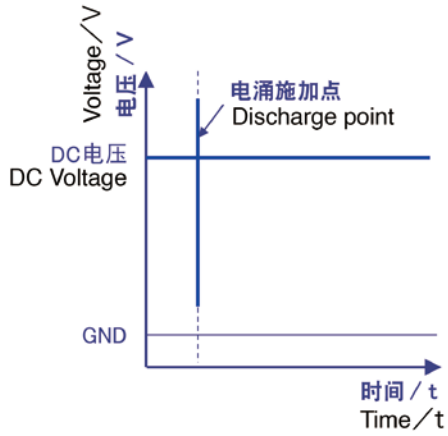


图 10 未发生延续
Fig.10 No Holdover occurring

在 DC 电压重叠的电路中使用放电管时，如果电涌侵入，因电涌电压会导致放电管放电后，来自电源的电流会回流，造成放电无法停止的现象。

发生延续后，例如在 CRT 的驱动电路发生延续时，会出现画面变暗等问题，由于放电无法停止，放电管的玻璃可能会熔化、冒烟、着火。

■What is Holdover?

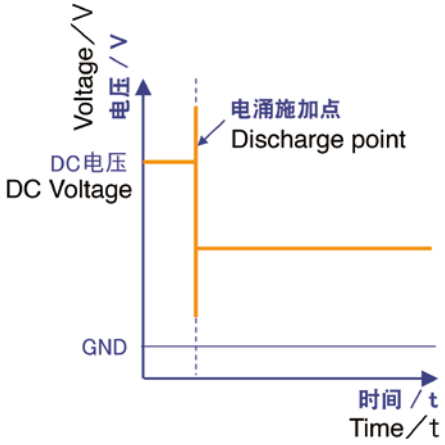


图 11 发生延续
Fig.11 Holdover occurring

When a discharge tube is used on a circuit that has a DC voltage component, there is a phenomenon occurs, called holdover, where the discharge in the tube continues being driven by the current from the power supply even after the surge voltage has subsided. When a holdover occurs, for example when it is occurs in the drive circuit of a CRT, the screen darkens and discharge in the absorber continues, which can lead to the glass tube melting, smoking or burning.

■延续的机制

在直流电源的输出电压和输出电阻状态发生变化，满足了向放电管供电的条件时，会发生延续。

那么，向放电管供电的条件是一种怎样的状态呢？电源的带那样（Vo）、串联电阻（R）、放电电流（I）以及端子电压（V）的关系如下所示，使用图 12 的直线表示。

$$v=Vo-I\cdot R \quad \cdots(1)$$

如果电压 Vo 固定，通过增减电阻，电源的输出特性倾向会发生变化，与放电管的 V-I 特性可能会有交点，也可能没有交点。电源的特性直线显示了电源的可输出电压与电流的关系，放电管的 V-I 特性显示了可获得放电管的电压与电流的关系。

电涌侵入后，放电管处于电弧放电的形态下，电涌会被吸收。电涌消失后，放电形态从电弧放电转为辉光放电，再经过前期辉光放电后，即将消失时，电源的输出特性与放电管的 V=I 特定的关系变得非常重要。

电源的电阻增大，如图 12 所示，电源的输出特性（粉红色）与放电管的 V-I 特性（红色）没有交点时，来自电源的电流不会发生回流，因此不会出现持续电流现象。然而，当电源的输出特性（粉红色）与放电管的 V-I 特性（红色）存在交点时，电源可持续向放电管供电，在电涌消失后，从电弧放电转为辉光放电、前期电弧放电转为辉光放电，电流减少的过程中，电弧放电或辉光放电的交点可持续放电。这被称为延续，电源的输出特性与放电管的 V-I 特性存在交点是电源向放电管供电的条件。

在图 12 中，辉光放电与电源特性的交点或电弧放电与电源特性的交点可能会出现持续电流现象。

为防止延续情况的出现，必须确保电源的输出特性与放电管的 V-I 特性没有交点，这点非常重要。

■Mechanism of Holdover

Holdover can occur when the current is supplied to the discharge tube due to varying conditions of output voltage and output resistance of the DC power supply. What are the conditions that allow current to continue to flow to the discharge tube?
The relation between the power supply voltage (Vo), serial resistance (R), discharge current (I) and the terminal voltage are shown in the linear relation below:

$$v=Vo-I\cdot R \quad \cdots(1)$$

If voltage V0 is fixed, the slope of the power supply output characteristic line increases or decreases according to the resistance and may or may not intersect with the V-I characteristics of the discharge tube. The characteristic linear line of a power supply shows the relation between the output voltage and current of the power supply. Likewise, the V-I curve of a discharge tube shows the relation between the voltage and the current. When static surge electricity is applied to the discharge tube, the shape of the curve shows that the surge is being absorbed during arc discharge.
As the surge ends, the discharge goes from arc discharge to glow discharge and then to a state just prior to glow discharge. At this time, the relationship between the discharge tubes V-I curve and the power supply's output characteristics are very important.
As shown in the figure 12, with a high resistance in the power supply, the output characteristic line (pink) and the discharge tubes V-I characteristic curve (red) never intersect. Therefore, current will not flow from the power supply and follow-on current will not occur.
However, when the output characteristic line of the power supply (pink) intersects with the V-I curve of the discharge tube (red), it is possible for the current from the power supply to flow into the discharge tube. When the surge ends, the current should decrease from arc discharge to the pre-glow state, but instead, the power supply will continue to flow where it intersects in the glow or arc discharge region. This condition where the power supply continues to allow current into the discharge tube is called holdover.
The figure 12 below shows how the power supply continues supplying the current to the discharge tube when its characteristic line intersects the discharge tubes V-I line in the glow or arc discharge sections.
To prevent holdover from occurring, it is important to keep the V-I characteristic line of the power supply from intersecting with the V-I curve of the discharge tube.

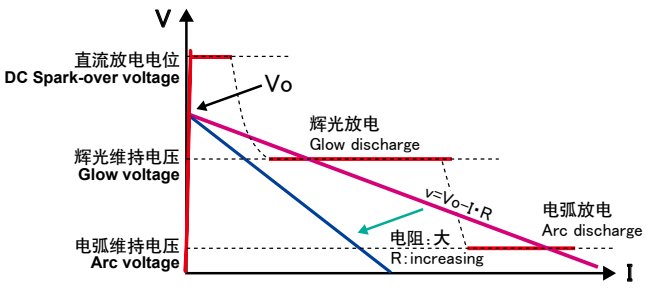


图 12 放电管的 V-I 特性与电源的输出特性的关系
Fig.12 Relations of V-I characteristic of gas discharge tube and output characteristic of the power supply

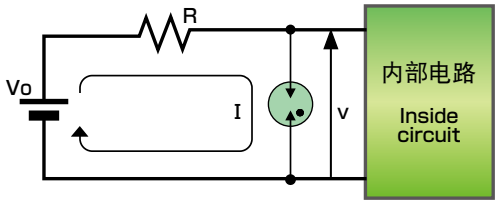


图 13 电源的输出特性
Fig.13 Output characteristic of the power supply

■什么是针对 AC 电源的持续电流

如果将 AC 电源内使用放电管而产生的持续电流应用于 DC 电源，可简单地理解。即图 12 的电源电压（Vo）随时间变化。如前页所述，电源电压显示为 Vo（t）时，该输出特性如下所示。

在输出端显示的电压显示为 v、电路电流显示为 I

$$v = Vo（t）- R \cdot I \quad \cdots (2)$$

由于 Vo(t) 随时间变化，因此 (2) 式如图表所示，为下图左方的斜线。Vo(t) 显示为

$$Vo（t）= Vo\sin\omega t \cdot \cdots (3)$$

时，仅在电源电压为 0 的点（零交叉点）附近的一段时间内，存在电源的输出特性与放电管的 V-I 特性不存在交点的电压范围、时间范围。

如果是 AC 电源，由于电源电压必定会产生零交叉点，因此来自延续的放电很容易停止。零交叉点附近区域成为无法维持放电的领域，供给放电的电流将被阻断，在这段时间内，经过电离的气体分子恢复到原来的绝缘状态，放电停止。

如果放电停止，由于端子电压不会超过直流放电电位，因此不会重新开始放电。

但是，在这段时间内，如果电离的气体分子没有消失，在放电管两端再次施加电压时（进入施加反向电压的周期），再次施加的电压能够确保放电持续下去，而不会消失。这就是交流电压中的持续电流。

发生持续电流后，放电不会停止，放电管的玻璃可能会熔化、冒烟、起火。

■Follow-on current from AC sources

When DC is the power supply, follow-on current occurring in gas discharge tubes for AC sources is easy to understand.

In the figure 12, the only difference is that the power supply voltage (Vo) changes with time. As shown on the previous page, when the power supply voltage is shown as Vo(t), the output power characteristics are displayed as follows:

With “v” being the voltage at the power out terminal, and “I” the current of the circuit,

$$v = Vo（t）- R \cdot I \quad \cdots (2)$$

Vo(t) will vary with time, so when displaying the above equation on a graph, it will appear as in the figures below in the shaded areas. Then when Vo(t) is shown as:

$$Vo（t）= Vo\sin\omega t \cdot \cdots (3)$$

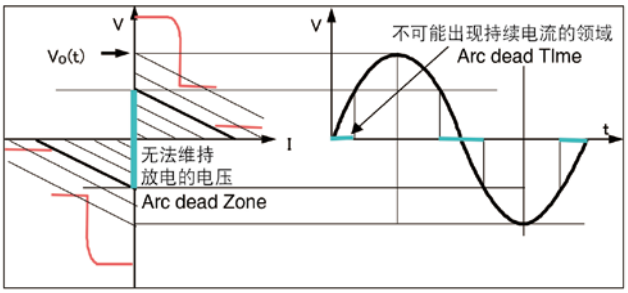
When the power supply voltage becomes 0 (zero cross), there is a short time where the voltage range and time range of the power supply output and discharge tube V-I curve do not intersect.

For an AC power supply, because there is always a zero crossing of the supply's voltage, it is easier to stop the discharge than in the case of holdover. In the vicinity of the zero crossing, it is impossible to maintain the discharge since the current to the discharge is cut off. The discharge is then halted by the ionized gas molecules returning to their normal state.

Because the terminal voltage does not exceed the direct current break down voltage, if the discharge is halted, it will not be able to start again.

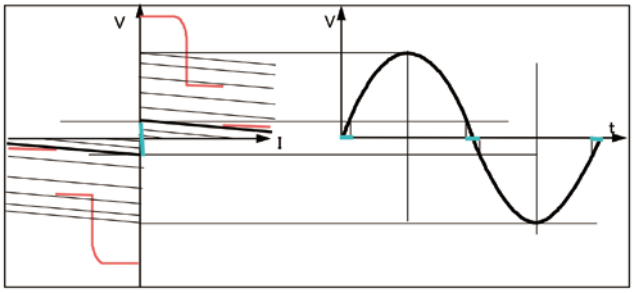
However, if the gas molecules remain ionized during this period and voltage is again applied to both terminals of the discharge tube (enters the cycle of opposite voltage), this newly applied voltage will not allow the discharge to end and it will continue in the discharge mode. This is follow-on current for alternating current.

When this type of follow-on current occurs, the tube stays in a discharge mode and the glass of the tube will begin to smoke, melt and possibly ignite.



(a) V-I 特性上 (b) V-t 特性上
(a) V-I characteristics (b) V-t characteristics

图 14 电阻较大时（不可能出现持续电流的领域较长）
Fig.14 At High Resistance (Long Range of No Follow-on-current)

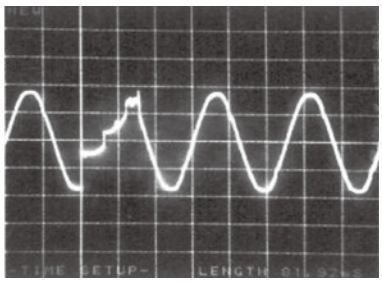


(a) V-I 特性上 (b) V-t 特性上
(a) V-I characteristics (b) V-t characteristics

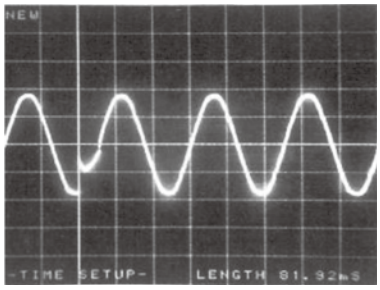
图 15 电阻较小时（不可能出现持续电流的领域较短）
Fig.15 At Low Resistance (Short Range of No Follow-on-current)

在交流电压重叠的条件下，作为不会发生持续电流的条件，将能够完全停止放电的电阻插入串联电路中，这点非常重要。

It is important to utilize a resistance in series that is sufficiently large enough to prevent follow-on-current from occurring according to the conditions of the alternating current.



照片 1 0Ω 时（发生持续电路）
Photo 1 At 0Ω (Follow-on-current occurring)



照片 2 0.5Ω 时（因半波持续电路而停止）
Photo 2 At 0.5Ω (Stopped at half wave Follow-on-current)

当电阻为 1Ω 和 3Ω 时，与照片 2 相同，放电因半波持续电流而停止。如果是 AC 电源，与 DC 相比，放电管与串联电路连接的电阻值可以更小。与串联电路连接的电阻值只要超过 0.5Ω 即可，但如果可能，请设为 3Ω（100V）以上。

此外，也有将变阻器作为电阻与串联电路连接的方法。这是将工作电压高于 AC 电压的变阻器与放电管串联，用作电阻，在放电管不会出现半波持续电流的情况下，停止放电的方法。

变阻器电压的选择方法如下所示。

AC100V……变阻器电压 220V 以上

AV200V……变阻器电压 470V 以上

本公司的电源用吸收器包括 DSANR 系列和 DSAZR 系列，都实施了持续电流对策。

特别可能存在持续电流、延续风险的应用软件如下所示。

1）延续
　使用了 DC 电源的电路
2）持续电流
　使用了 AC 电源的电路

With 1Ω and 3Ω resistance, results are the same as those in photo 2, as follow-on-current is disrupted and discharge is stopped.

For AC power sources, the resistance value that is connected in series with the discharge tube is small in comparison to DC sources.

If the series resistance is 0.5Ω or greater, it should be sufficient; however, for safety, a value of 3Ω (for 100V) or greater is recommended.

In addition, there is a method to use a varistor in series that acts as a resistor. In this case, the varistor must have an operating voltage greater than the AC voltage and be placed in a series with the discharge tube. Unlike the resistor, discharge will be stopped without follow-on current occurring during the first half of the wave.

Selection of varistor voltage:

For AC 100V : $V_{1mA} \geqslant 220V$

For AC 200V : $V_{1mA} \geqslant 470V$

Our DSANR and DSAZR series are made for power supplies and are designed to prevent follow-on current.

At risk applications of holdover or follow-on-current:

1) Holdover
　Circuits using DC power sources
2) Follow-on current
　Circuits using AC power sources