Gas rectifiers

At first an excerpt from "Techn.Grundlagen f. Übermittlungsgerätemechaniker" of the swiss army, 1974). There the fundamental function of a gas rectifier is well explained.

e) Gasgefüllte Gleichrichterröhren

– Definition

Gasdioden sind Gleichrichterröhren mit geheizter Katode. Als Gasfüllung wird Quecksilberdampf oder Edelgas verwendet.

– Symbole

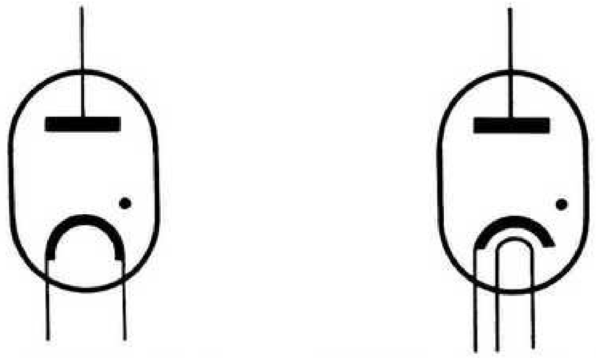


Bild 356

Direkt geheizte Gasdiode Indirekt geheizte Gasdiode

– Aufbau

Die meisten Gasdioden arbeiten mit einer direkt geheizten Katode. Diese besteht aus einem Heizwendel, welcher mit einem emittierenden Belag versehen ist. Die Katode ist einem intensiven Ionenbeschuss ausgesetzt. Alle positiven Gasionen werden von der negativen Katode angezogen. Diese Ionen würden mit einer grossen Geschwindigkeit auf die Katode prallen, die dabei frei werdende Energie würde die emittierende Schicht der Katode zerstören. Die Katode wird deshalb mit einer Abschirmung versehen, welche die Ionen abhält. Die emittierten Elektronen umgehen diese Abschirmung. In Bild 357 ist der Aufbau einer Gasdiode zu erkennen.

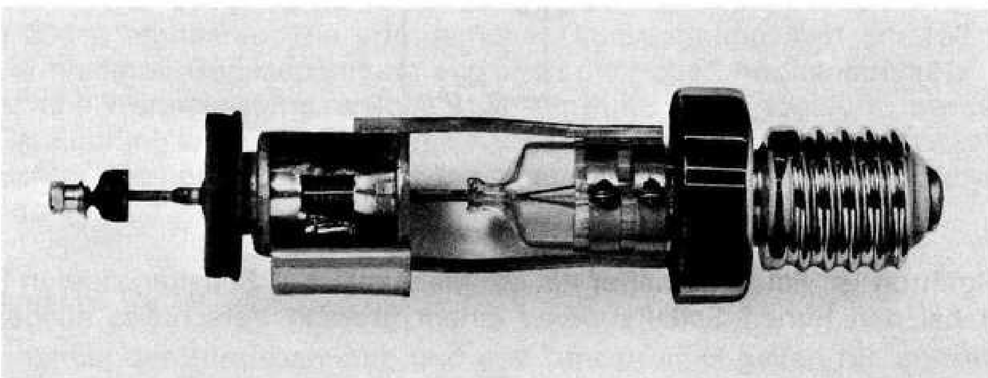


Bild 357

Translation of page 357:

e) gas filled rectifier tubes

- Definition
Gas diodes are rectifier tubes with heated cathode. The filling gas used is either quicksilver steam or inert gas.

-Symbols

directly heated gas diode indirectly heated gas diode

- Construction
Most gas diodes work with a directly heated cathode. The cathode consists of a filament spiral that is coated with an emitting film.The cathode has to endure an extensive ion bombardment. All positive gas ions are attracted by the cathode. These ions would reach the cathode with very high speed. The energy dissipated when impinging the cathode would destroy the emitting coat. For that reason the cathode is surrounded by a shielding that keeps the ions away. The emitted electrons circumvent the shielding. Picture 357 shows the construction of a gas diode.

Translation of page 399

- Principle of operation
The cathode is heated and emits electrons. When the applied voltage exceeds the ignition voltage collision ionization starts. As long as the anode voltage is below the ignition voltage only a small insignificant current of electrons flows in the tube. This is due to the fact that the electrons permanently hit gas ions and are heavily decelerated. When the ignition voltage is reached the electrons have such a high speed that the ionization of the gas begins. The positive ions attracted by the cathode prevent a space charge. For that reason the current of a gas diode rises abruptly when reaching the ignition voltage in contrast to a vacuum tube. Picture 358 shows the difference of the characteristic curves of a vacuum diode and a gas diode. As there are both electrons and ions involved in the current transport a very small inner resistance results; so current limiting is required. There is always a resistive or inductive component in series with the anode. Across the tube the burning voltage is dropped with approximately 15 V for quicksilver steam tubes. The operation conditions of a quicksilver steam tube is strongly influenced by the gas pressure in the tube. The tube temperature in turn determines the gas pressure. Tubes for larger powers therefore must be preheated. The heater voltage is applied before the anode voltage. Preheating requires several minutes. Often the anode voltage is switched on delayed using a relay.

Translation of page 400:

- **Example**

- **Wirkungsweise**

Die Katode wird geheizt und emittiert Elektronen. Überschreitet die angelegte Spannung die Zündspannung, so setzt die Stossionisation ein. Solange die Anodenspannung unterhalb der Zündspannung bleibt, fliesst in der Röhre nur ein sehr kleiner, unwesentlicher Elektronenstrom, da die emittierten Elektronen dauernd auf Gasmoleküle stossen und dadurch stark abgebremst werden. Erst bei Erreichen der Zündspannung wird die Elektronengeschwindigkeit so gross, dass die Ionisierung des Gases eingeleitet wird. Die von der Katode angezogenen positiven Ionen verhindern die Entstehung einer Raumladung, deshalb steigt der Anodenstrom der Gasdiode im Gegensatz zur Vakuumdiode bei Erreichen der Zündspannung schlagartig an.
Bild 358 zeigt den Unterschied zwischen den Kennlinien einer Gasdiode und einer Vakuumdiode.

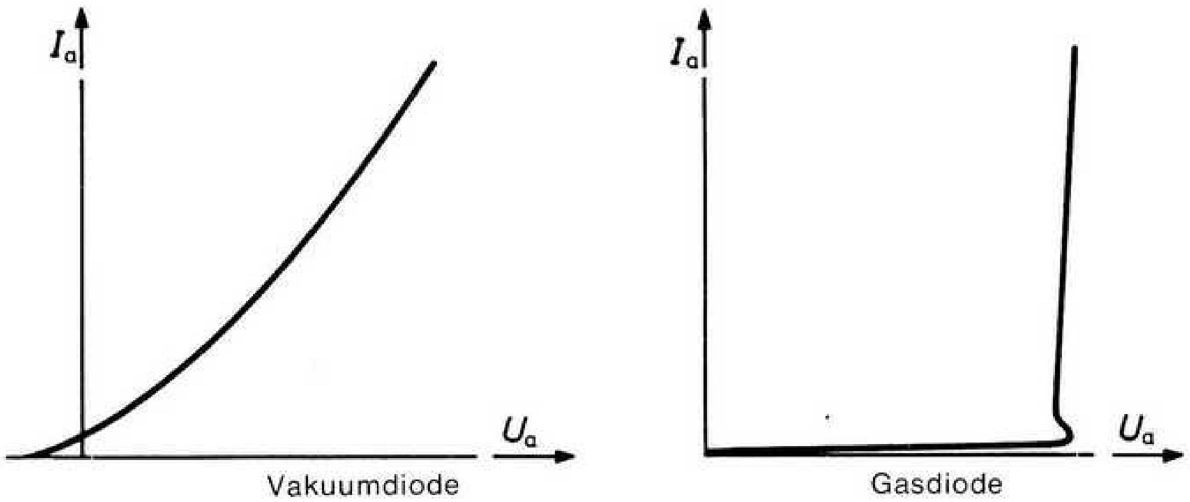


Bild 358

Da an der Stromleitung ausser den Elektronen auch noch Ionen beteiligt sind, ergibt sich ein sehr kleiner Innenwiderstand, wodurch eine Strombegrenzung notwendig wird. Im Anodenkreis der Gasdiode befindet sich deshalb immer ein ohmscher oder ein induktiver Widerstand. Über der Röhre fällt die Bogenspannung ab, diese beträgt bei Quecksilberdampfröhren etwa 15 V.
Das Arbeitsverhalten von Quecksilberdampfröhren wird stark vom Gasdruck in der Röhre beeinflusst. Die Röhrentemperatur wiederum ist mitbestimmend für den Gasdruck. Röhren für grössere Leistungen müssen deshalb vorgewärmt werden. Zu diesem Zweck wird die Heizspannung vor der Anodenspannung an die Röhre gelegt. Die Vorwärmung dauert einige Minuten. Oft wird die Anodenspannung über ein Relais verzögert eingeschaltet.

– **Beispiel**

Eine Gasdiode wird als Gleichrichterröhre zur Ladung von Akkumulatoren eingesetzt. Bild 359 zeigt die Prinzipschaltung.

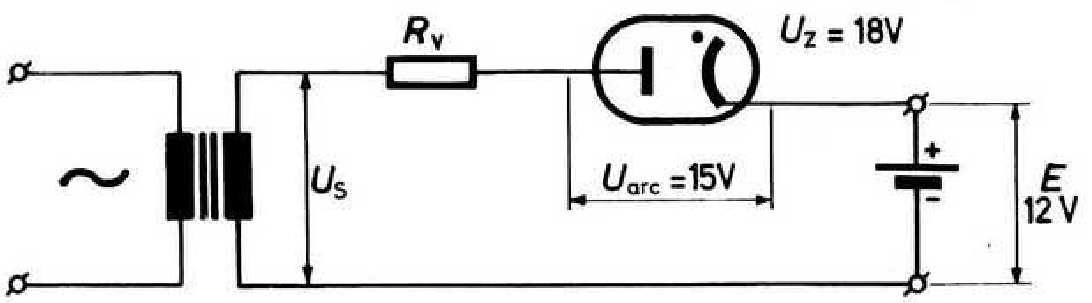


Bild 359

Die Anlage ist für 12 V dimensioniert. Die Zündspannung der Röhre beträgt 18 V, die Brennspannung 15 V. Der Transformator ist so zu dimensionieren, dass die Röhre sicher zündet. Die Sekundärspannung des Transformators ist zu bestimmen. Es ist zu untersuchen, während welcher Zeitdauer innerhalb der positiven Spannungskurve die Röhre Strom liefert und wie gross die Sperrspannung über der Röhre wird.

Vorgehen:

1. Schritt: Bestimmen der notwendigen Sekundärspannung

– Bedingung: Die Sekundär-Spitzenspannung muss grösser sein als die Summe von Zündspannung der Röhre und E.M.K. der Batterie.

– Bedingung in eine Formel kleiden $U_{s_s} > U_z + E$

Zur sicheren Zündung wählen wir einen Sicherheitsfaktor von 1,2. Dieser wird in die Formel einbezogen:

$$U_{s_s} = 1{,}2\,(U_z + E)$$

– Formel für den Effektivwert auslegen: $$U_s = \frac{1{,}2\,(U_z + E)}{\sqrt{2}}$$

– Zahlenwerte einsetzen und ausrechnen $$U_s = \frac{1{,}2\,(18 + 12)}{\sqrt{2}}$$

$$U_s = \mathbf{25{,}46\ V}$$

A gas diode is used as rectifier for loading accumulators. Picture 359 shows the principle circuit.

The arrangement is designed for 12 V. Ignition voltage of the tube is 18 V, burning voltage is 15 V. The transformer has to be designed so that the tube is ignited reliably. The secondary voltage of the transformer has to be determined. It must be evaluated during which time within the positive curve the tube supplies current and how large the reverse voltage is.

Approach:

1. Step: determining the required secondary voltage

- Condition: The secondary peak voltage must be higher than the sum of ignition voltage and the battery's EMK

- Generate a formula from the condition: ….

To assure reliable ignition we choose a safety factor of 1.2. This is inserted to the formula.

- Lay out formula for the RMS value: ...

- Insert number data and calculate the result: ...

2. Schritt: Bestimmen der Stromflussdauer
– Die Ermittlung erfolgt graphisch nach Bild 360:

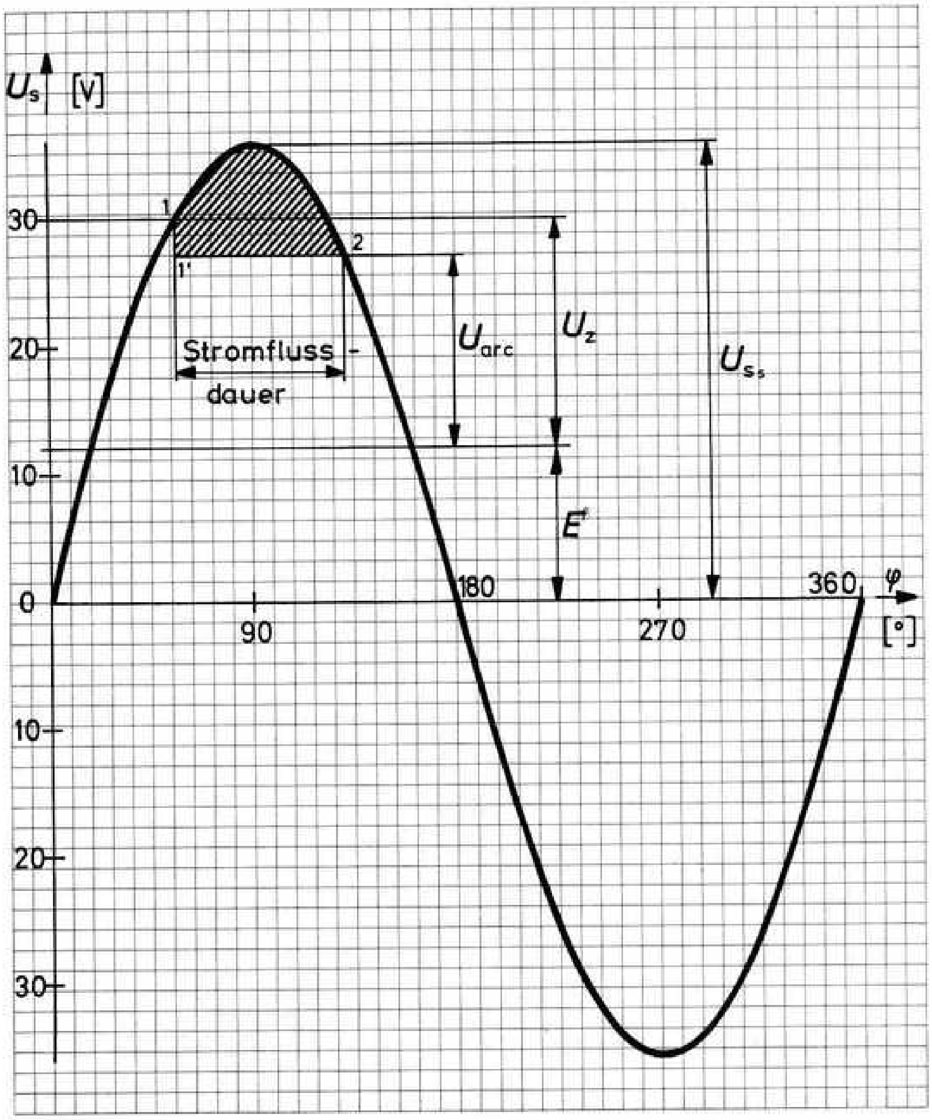


Bild 360

- Aufzeichnen der Sekundärspannung des Transformators
- Einzeichnen der E.M.K. *E* der Batterie
- Addition von Zündspannung und E.M.K. im Diagramm
- Addition von Brennspannung und E.M.K. im Diagramm
- Konstruktion der Fläche, welche dem Stromfluss entspricht.
  Im Zündmoment Punkt 1 fällt die Spannung über der Röhre auf die Brennspannung ab (Punkt 1'). Sinkt die angelegte Spannung unter den Wert der Brennspannung ab, so erlischt die Röhre (Punkt 2). Da die E.M.K. der Batterie während der positiven Halbwelle gegen die Transformatorspannung

Translation of page 401:

2nd Step: Determining the current flow time. This is done graphically using picture 360.
- Draw the secondary voltage of the transformer
- insert EMK E of the battery
- Add the ignition voltage to the EMK in the diagram

- Add the burning voltage and the EMK in the diagram
- Construct the area which correlates with the current flow.

At ignition at point 1 the voltage across the tube drops to the burning voltage (point 1'). When the voltage drops below the burning voltage of the tube the tube extinguishes (point 2). As the EMK of the battery during the positive half wave is opposed to the transformer voltage, ignition and burning voltage are shifted up be the value of the EMK. The drawing shows that there is a current flow only during a short time. The hatched area is small compared to the positive half wave; this indicates a small flow of current. To increase the loading current the secondary voltage of the transformer has to be increased.

Continuation of translation:

3rd Step: Determining the reverse voltage

- Condition: During the negative half wave the reverse voltage appears across the tube. This is the sum of the battery's EMK and the peak value of the negative half wave.
- Put condition to a formula: ….
- Insert numeric values and calculate ….

Picture 361 shows how the reverse voltage is generated.

Conclusions for testing with the RoeTest:

As can be seen from the statements above, the anode current rises abrupt at a certain anode voltage (ignition voltage). So the anode current must be limited.

A normal measurement is not possible using the RoeTest. This would at most be possible – in manual mode - for very small gas rectifiers where ignition voltage and voltage drop during operation are close. But the anode voltage has to be reduced to an agreeable value immediately after ignition.

Apart from that gas rectifiers must **always be operated with a suitable series resistor**. This “suitable” series resistor must be extremely resilient so operating a gas rectifier with the RoeTest eventually is not possible due to lack of a suitable resistor.
Lets have a look at a CK1006 for example: the tube can be ignited with and without heating. The unheated mode of operation is not possible as the ignition voltage is 650 V in this case. When heated the ignition voltage drops to 450 V. This would be possible with the RoeTest. When the tube has ignited about 25 V are dropped across the tube according to the data sheet. The maximal current may be 200mA.
This leads to the following calculation:

Anode operating voltage 450 V – voltage drop across the tube 25 V = 425 V that must be dropped. At 200mA a series resistor of 425V : 0.2A = 2125 ohm, so about 2Kohm would be required. This is not yet critical but:

0.2A * 425V = 85W

So the resistor must have a power capability of 85W! Normally those fat resistors are not at hand. Testing of fat gas rectifiers is therefore not a possibility. With small gas rectifiers testing would be realistic.

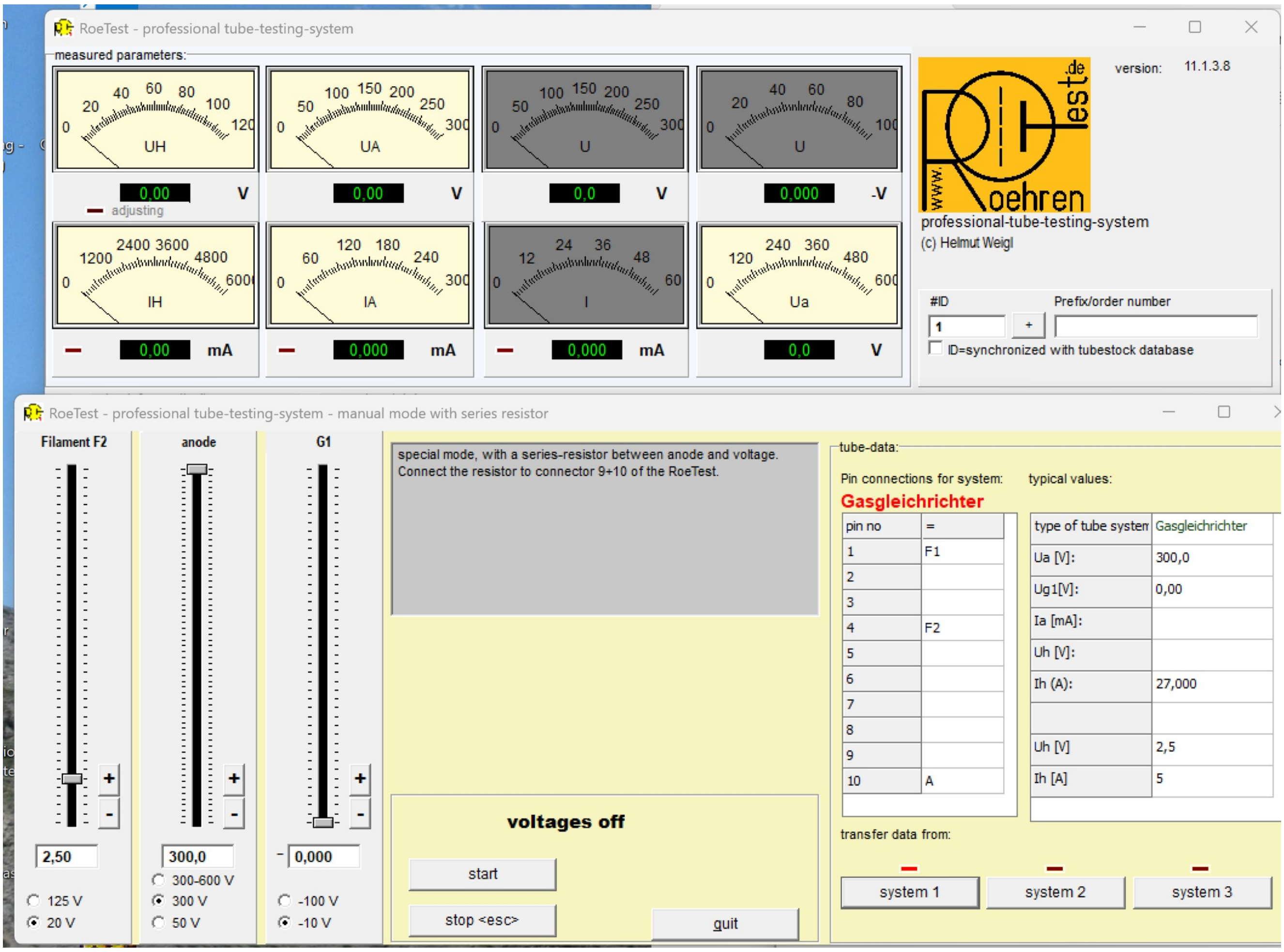
The resistor would have to be connected externally in series between the anode voltage source and the anode. The tube then needs to be heated in manual mode and then the voltage has to be slowly increased until the tube ignites. Caution: do not overload the tube, reduce the voltage if needed (or use a somewhat larger resistor from the beginning so that the maximum value of the RoeTest will not be exceeded).

The burning voltage, this is the voltage that is dropped across the tube, can then be calculated as the value of the series resistor is known. But it is simpler to measure the burning voltage using a multimeter (connected between anode and cathode).

Caution: Never operate larger gas rectifiers without a series resistor. When the gas rectifier ignites a very high impulse current will flow and over voltage is generated. This could damage the gas rectifier as well as the RoeTest.

Realization in the RoeTest:

There is a separate tube type for gas rectifiers. There it is specified that the test is carried out in “manual mode with series resistor”.



The series resistor must be connected **between sockets 9 and 10** of the RoeTest. For an 866A, this would be a series resistor with 10 Kohm/25W.

And yet another tip:

Many gas rectifiers contain quicksilver. Quicksilver is extremely **toxic**. If a gas rectifier cracks quicksilver leaks from the tube. It spreads not only on the floor but can also vaporize. So be careful with such devices. I for myself avoid them and have only very few in my stock.