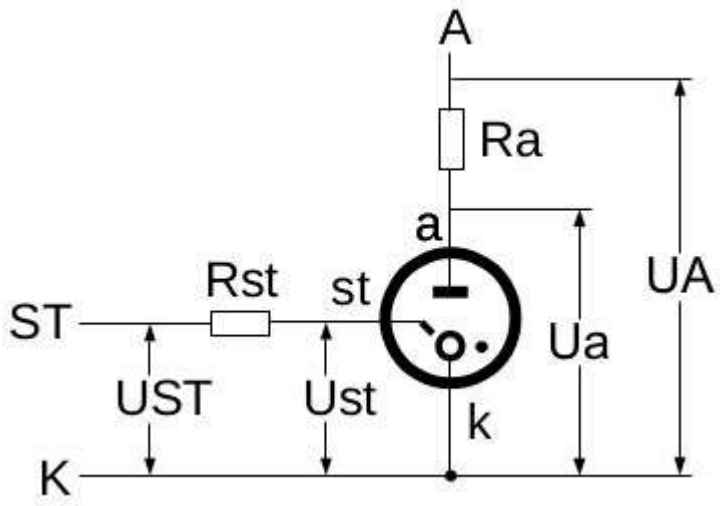
Testing of Relay Tubes, Cold Cathode Thyratrons and Stabilizer Tubes with auxiliary Anode

The tubes discussed in this paper have no heater. They are filled with gas. Most of the gas-filled two terminal tubes belong to the category of glow discharge tubes. Some of those are known as stabilizer tubes (also shortly named stabistors). These glow discharge tubes can be tested with the RoeTest in a special test mode. Therefore they will not be addressed in this article.

How do Relay Tubes work ?



Here we will discuss gas-filled tubes with at least three electrodes. Always present are the **cathode k** and the **anode a**. The third electrode is mostly a **starter st**. A few tubes have instead of the starter electrode an additional grid. There may be additional electrodes like shielding, a helper anode, a helper cathode and/or an additional starter. Relay tubes can only have the two states „blocked“ or „conductive“.
The transition from the blocked state to the conductive state is called „ignition“.

As with glow discharge tubes and also the heated thyratrons **a series resistor Ra must be inserted into the anode line** to limit the anode current in the conductive state. The starter of relay tubes is also operated from a positive supply voltage. So there **must also be a series resistor Rs inserted into the starter line** to limit the starter current.
In the following the voltage between the connection **A** and connection **K** will be named **UA**. In contrast the voltage **Ua** is the voltage between the tube's electrodes **a** and **k**.

When the tube is in the blocked state then UA=Ua. But when the path a-k is in the conductive state then Ua=UA-Ra*Ia.
The same way we define the voltage between the connection ST and the connection K as **UST**. Whereas **Ust** is the voltage between the tube's electrodes **st** and **k**.
When the path st-k is in the blocked state then UST=Ust. When it is in the conductive state then Ust=UST-Rst*Ist.

If the starter electrode is connected to the cathode then we get a normal glow discharge tube.
The voltage Ua when the path a-k ignites is then the ignition voltage **Uza**.
This voltage, Uza, should never be applied to the anode in normal operating mode hence from this voltage on the voltage at the starter electrode has no more influence on the tube.

When the path a-k ignites, an anode current **Ia** can flow. For each of these tubes there exists not only a maximum value **Iamax** but also a minimum value **Iamin** for the anode current.
The tube should not be operated at anode currents below Iamin – it will not work in a reliable state.
After ignition the voltage Ua will drop – due to the series resistor Ra. This voltage is called „running voltage“ **Uba**.

Now lets assume that the anode **a** is not connected.
When the path st-k ignites its voltage drops to its running voltage that we will name **Ubst** in the following. The starter current **Ist** that flows when the path st-k is ignited may be very low. With some tubes it may be even at only 1µA. But there must always be a resistor Rst to limit it.
A common value for the resistor Rst is about 1MOhm.

Now let us again connect the anode.
We apply at the connection **A** a voltage UA that is higher than the running voltage Uba but smaller than the ignition voltage Uza. Now when the path st-k ignites and a medium current Ist flows the path a-k will also

ignite. This will happen even when Ua<Uza. At the Anode the running voltage Uba can then be observed.

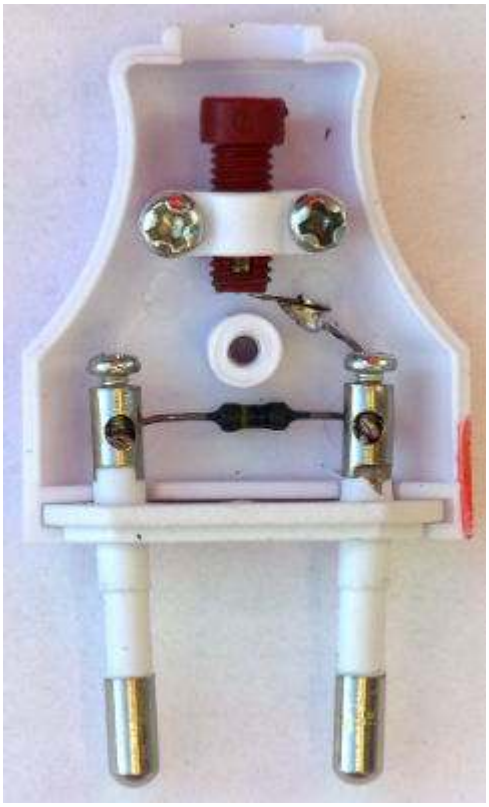
Both of the paths a-k and st-k can only be blocked when both of their voltages are significantly lowered below their respective running voltages.

Like some glow discharge tubes some cold cathode thyratrons may also be operated with AC current.
But this does not hold for all types. Some are actually constructed so that they can act as rectifiers.

More accurate data may be found in the tube's data sheets.

How to test Relay Tubes with the RoeTest

The RoeTest always uses DC when testing tubes. It serves as adjustable voltage source and provides the socket holder for the tests. Therefore you need an **Insertbox** (http://www.roehrentest.de/InsertBox.html) that has a series resistor installed for each electrode (except the cathode or shielding) and the voltage supply. Due to this reason relay tubes **can only be tested in manual mode** with the RoeTest.



I n most cases resistor **Ra** must be a high power type. It must often be capable of 150V at 40mA, i.e. 6W.
A set of such resistors is often available in an already built resistor box. This resistor box will also be required when testing stabilizer tubes and for measuring dynamic characteristic curves of end tubes.

For **Rst** and also the resistors to other electrodes only small resistors with mostly 1MOhm will be sufficient. It is not worthwhile to build a resistor box for those.
So I built **resistor plugs** from Chinese 2-pole Euro-Connectors. See the picture. The red marked side in the picture should point to the tube socket pin. Then the tube's electrode voltage can easily be measured with a multimeter at the 2mm jacket in the top of the Euro-Connector.
These Euro-Connectors can simply be plugged into the **Insertbox**.

The cathode of the tube is always connected to the **RoeTest**'s rail 0 (or Ground) – marked with K in the picture above.
The Anode is connected with a series resistor Ra to rail 2 (300V/250mA) – marked with A. **The RoeTest will show UA and Ia.**
The starter is connected with a series resistor Rst to rail 4 (300V/50mA) – marked as ST. **The RoeTest will show UST and Ist.**

With some tubes a test in reverse direction, i.e. cathode to plus and anode to minus, is permissible. But the RoeTest is not designed for this type of test. (You also cannot test pnp transistors with the RoeTest).

The voltages **Ua** and **Ust** cannot be measured with the RoeTest. The actual value of Ua can be measured with an external digital voltmeter. Alternatively you can calculate Ua from the formula Ua=UA-Ra*Ia.
The value of Ust can also be measured with an external digital voltmeter. In this case the input resistance of the digital voltmeter has to be taken into account.

For testing a relay tube I suggest the following tests:

- The **Uza-Test:**
  The data sheets specify a lowest ignition voltage Uza for the path a-k for a starter voltage Ust=0V.
  The path a-k should not ignite below this voltage Uza.
- The **Uzst-Test:**
  At a given voltage Ua (Uba<Ua<Uza) and Ust=0V the tube should not ignite.
  Now Ust is increased slowly until the path st-k ignites.
  As soon as path st-k ignites the path a-k should also ignite.

Testing an ER21A

This tube was often used in burners of oil-fired heating. The tube has the electrodes cathode, anode and a starter. It also has an additional connection for an internal shielding that need not be connected.When testing with the RoeTest this internal shielding is not connected.
(See also tube type "Thyratron cold cath.": S is not connected to ANY rail.)

In the **window for the manual test mode** there is an **info field** in the upper right edge. There you can see:
Uza-Test: UA<=366V; UST=0V; Ra=24k/10W; Rst=1M; no ignition
Uzst-Test: UA=250V; UST>=120V; Ra=3.6k/6W; Rst=1M; find ignition
Uza=450V(366-593); Ia=6-40mA; Uba=111V(106-115); Uzst=140V(124-162); Ist=200µA(150-500).

These parameters have the following meaning:

- **Uza-Test**: Ust is set to 0V with a series resistor Rst (1MOhm). For Ra a value of 24kOhm/10W should be used (Ra=(Uzamax-Ubamin)/(Iamax/2)). The resistor's value may be higher.
  The path a-k may not yet ignite for the lowest specified ignition voltage (366V for the ER21A).
  Ua is slowly increased up to 300V. Then switch to the 600V range. Now Ua is further increased up to 366V. The tube must not ignite up to this voltage.
  Further increase until ignition of the a-k path is not required.
- **Uzst-Test**: Set Ua to approximately 250V. This is the minimal required anode voltage. Use a Ra value of about 3.6kOhm/6W (or higher resistor value) (Ra=(250-Ubamin)/Iamax).
  Set Ust to a value below the lowest ignition voltage Uzst, 120V for the ER21A or to 0V. Use a Rst of 1MOhm.
  Now slowly increase Ust. The path st-k of the ER21A should ignite in the range from 124V to 162V.
  The path a-k should also ignite when the path st-k ignites. Ua should then be in the range from 106V to 115V. If the voltage Ua is still at 250V the path a-k did not ignite. Tubes that do not ignite or have a higher ignition voltage than Uzst (162V for the ER21A) should be marked as defective.

- The ignition voltage Uza of the path a-k is normally about 450V but it may vary from 366 to 593V.
- When ignited the anode current Ia should be in the range from 6mA (Iamin) to 40mA (Iamax).
- The running voltage Uba of the path a-k is 111V on average. It may be between 106V and 115V.
- The Ignition voltage Uzst of path st-k is normally 140V but may be in the range from 124V to 162V.
- When ignited the starter current should be in the range from 150µA to 500µA. On average it is 200µA.

  As you can see the specified **values in the data sheet have a large variance**. This is true for almost all gas filled tubes.

Settings for the RoeTest.dbf

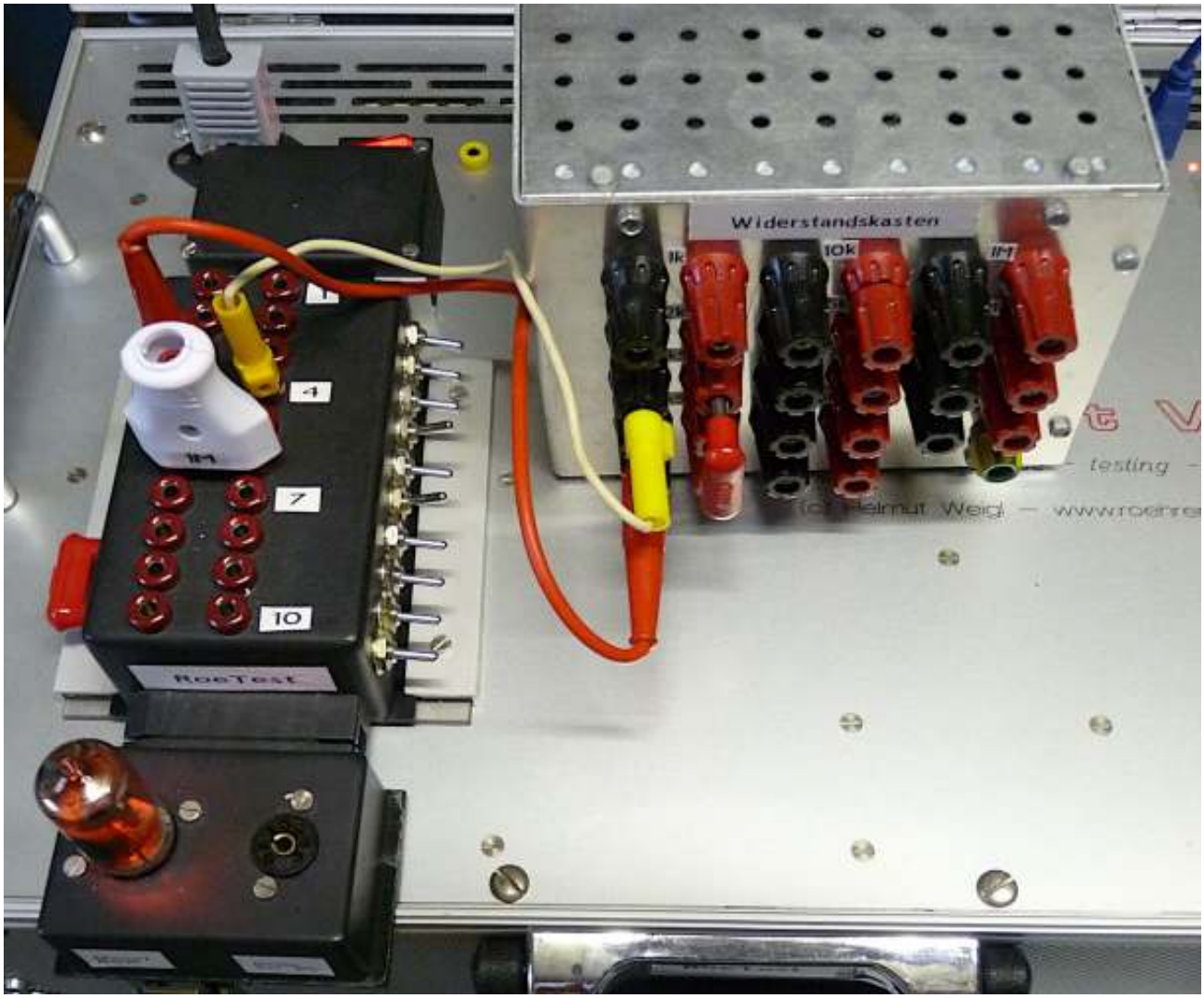
For a new entry you should use an already existing entry in the data base for orientation.
As tube type use "Thyratron cold cath.". For heater type specify "keine" (none).
The socket pin for the starter is associated to entry ST1.
If a tube has two starter electrodes you should create a **second system** with this **second starter**.

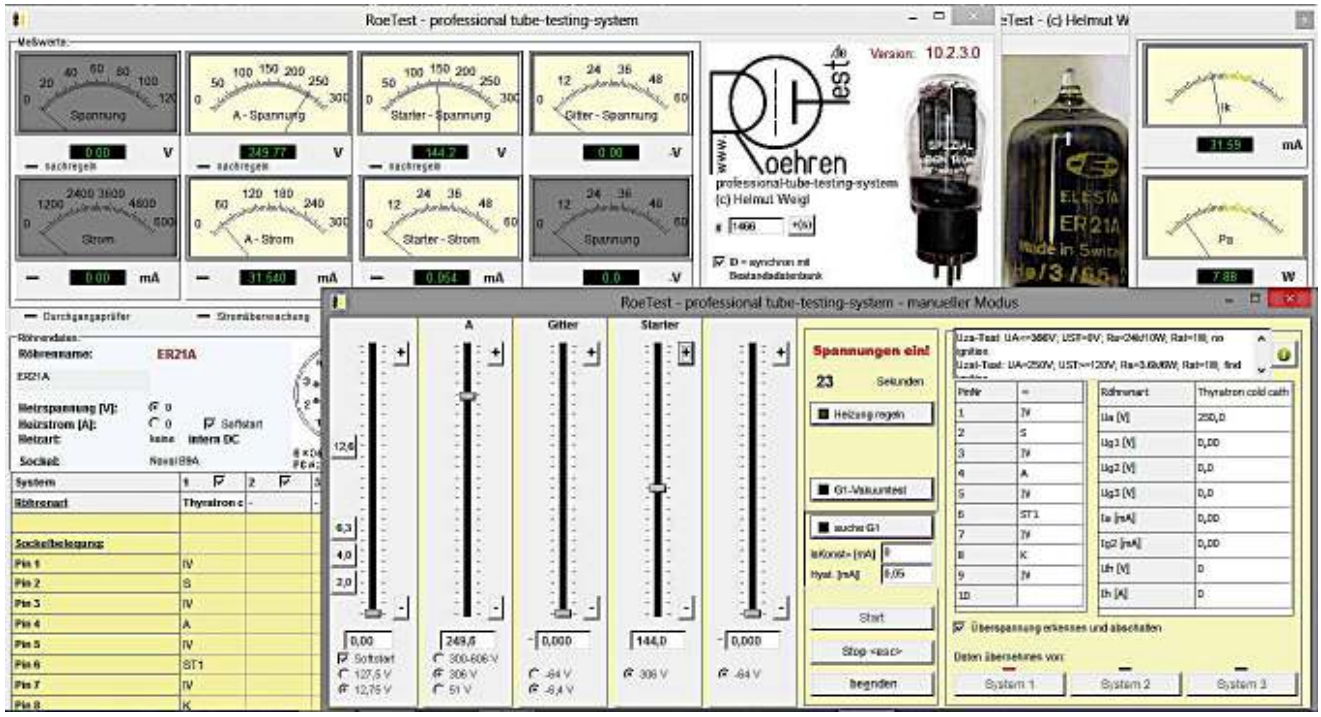
The field "Bemerkungen zur Röhre" (remarks for the tube) should contain the test data for the tube. Unfortunately this field is a little bit small. For this reason the above parameters for the info field were shortened.

In the tab for **typische Werte** (typical values) the initial values for the manual test mode are set. You can specify in the UA/L field the voltage that shall be used for the Uzst test as voltage UA. For the ER21A this should be 250V. This value should be below the minimum Uza but above the running voltage Uba.
For the field UG2/An/Stn specify the value 0V. This value is needed at the start of the Uza test.

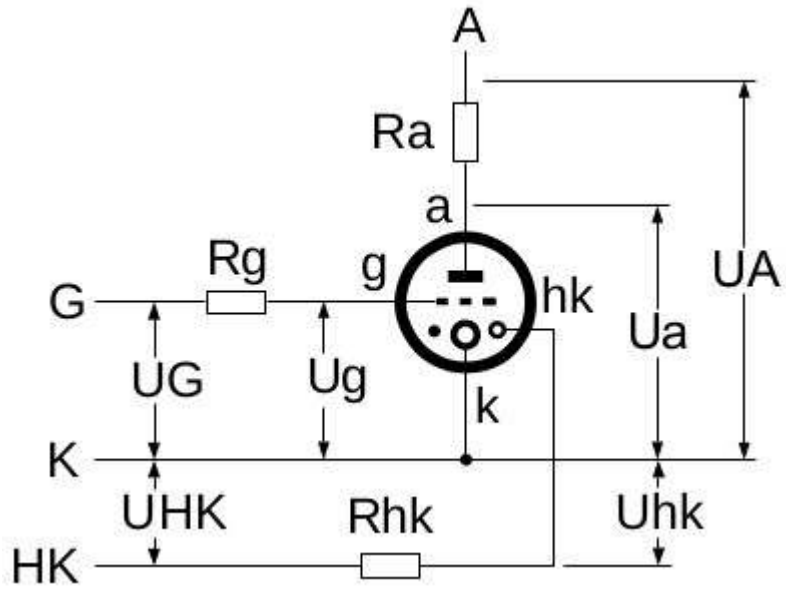
In the tab for **Grenzwerte** (limits) specify for the field UA the highest ignition voltage Uza of the a-k path for the ER21A e.g. 593V.
In the field UG2 specify the highest ignition voltage Ust for path st-k, e.g. 162V for the ER21A. For the value IK specify Iamax of the path a-k, e.g. 40mA for the ER21A.

In the next pictures the ER21A is already glowing. Ra=4.5k. Ust=90V. Uba=108V.





Test of a GT21



The GT21 tube is a cold cathode thyratron. It has no starter but a grid. It is ignited through the grid.
Already a low grid voltage of -0.5V can ignite the tube. So this tube can also be controlled from transistor circuits.

To achieve this low control voltage a helper cathode hk is required. This helper cathode must be supplied with a high negative voltage Uhk related to the cathode.

The most important requirement for the tube to operate at all is an ignited path hk-k.

A resistor Rhk of about 1MOhm is required to supply the path hk-k. Connect a voltage UHK of -250V(<-180V, the maximum ignition voltage of path hk-k) to the connections K and HK; + to K, - to HK.
The current Ihk will be between -100µA and -250µA.

The RoeTest cannot supply such a high negative voltage. You have to use an **external voltage supply** for this purpose.
Connect the positive side of the external voltage supply via the insert box directly to the tube's socket pin k for cathode; do not connect it to the ground of the RoeTest.

Further testing is simple as the tube's manufacturer specifies **two test points**.

In the **manual test mode window** there is an **info field** in the upper right corner. There you can read:
Uza-Test: UA<=370V; UHK=-250V; UG=-6V; Ra=15k/8W; Rhk=1M; Rg=220k; no ignition
Uzg-Test: UA=250V; UG=-6V..-0.5V; Ra=3.6K/5W; Rhk=1M; Rg=220k; ignition
Uza=<450V at Ug=-15V; Ia=10-40mA; Uba=115V; Uzhk>=-180V; Ubhk>=-130V; Ihk=-100..-250µA
Ug=-0.5..+50V for ignition; Ug=-6..-80V for blocking.

The parameters have the following meaning:

- **Uza-Test**: Set Ug to -6V using a series resistor Rg of 220kOhm. Use a resistor Ra of 15kOhm/8W (Ra=(Uzamax-Ubamin)/(Iamax/2)). The resistor's value may be higher.
  Slowly increase Ua to 300V. Then switch to the 600V range. It may happen that the tube ignites when switching to the 600V range due to capacitive impulses.
  In this case disconnect one side of the Ra connection and then reconnect it. The tube should keep blocked after that.
  Now increase Ua up to about 370V. The tube should not ignite up to this value.
- **Uzg-Test**: Set Ua to 250V. Use a Ra with 3.6kOhm/5W (or a higher resistor value) (Ra=(250- Ubamin)/Iamax).
  Set Ug to -6V. This value will keep the tube blocked. Use Rg 220kOhm.
  Now slowly increase Ug. The path a-k should ignite before or when Ug reaches -0.5V.
  Ua should then be about 115V. If Ua is still at 250V the path a-k did not ignite.
- The ignition voltage Uza for path a-k is about 450V for Ug = -15V.
- When in the conductive state the anode current Ia may be in the range from 10mA (Iamin) up to 40mA (Iamax).
- The ignition voltage Uzhk for the path hk-k is around -180V, the running voltage around -130V. The current Ihk will be in the range from -100µA to -250µA.
- The path a-k should ignite when Ug is in the range from -0.5V to +50V and should be blocked if Ug is in the range from -6V to -80V.

Settings for the RoeTest.dbf

Use as tube type "Thyratron cold cath. ". Heater mode is "keine" (none).
There is no starter electrode. But there is a grid that is assigned to G1. The helper cathode should be assigned to A2. This connection to the RoeTest is only needed for testing for electrode shorts.

When later testing in manual mode pin hk MUST NOT be connected to the RoeTest

At pin hk there is only the resistor Rhk connected with it's other side to the negative output of the external helper voltage supply. The helper voltage supply's positive output is connected to pin k of the tube's socket.

The field "Bemerkungen zur Röhre" (remarks for the tube) contains the test data for the tube. Unfortunately this field is a little bit small. For this reason the above parameters for the info field were shortened.

In the tab for **typische Werte** (typical values) the initial values for the manual mode are set.
You can specify in the UA/L field the voltage that shall be used for the Uzst test as voltage UA. For the GT21 this should be 250V. This value should be below the minimum Uza but above the running voltage Uba.
For the field UG1 specify the value -6V. This value is needed at the start of the Uza test.

In the tab for **Grenzwerte** (limits) specify for the field UA the highest ignition voltage Uza of the a-k path for the GT21 e.g. 450V. For the value IK specify Iamax of the path a-k, e.g. 40mA for the GT21.

Testing a Stabilizer Tube with Helper Anode

There exists an own part for testing stabilizers in the RoeTest Software. In this test the helper anode should not be connected to the RoeTest.
You can test the part with the helper anode as a separate stabilizer tube, however. For this test the main anode has to be disconnected. Use a resistor of 1MOhm as series resistor for the helper anode. So it is possible to see if the helper anode works.

This test is also essential if you want to test if a stabilizer tube really implements a helper anode or not. There exist tube tables that show a helper anode for a specific tube in the socket diagram but the tube does not have a helper anode at all.
In case of doubt this can now be tested (an example was e.g. the Osram Te5).

If you want to do a even more thorough test you can test a stabilizer tube analogous like a relay tube.
The helper anode will then be handled as the starter of a relay tube.
You have to create a suitable data set – as required for a relay tube. The helper anode should be assigned to the pin that is marked as ST1 in the socket picture. For more information see above.

The path a-k will ignite with connected helper anode already at a Ua voltage that is significantly below Uza when the helper anode is not connected.

Please do not discard the data base entry for a stabilizer assigned without a helper anode if already present.
Usually a stabilizer with helper anode will be tested as a normal stabilizer tube.
The test as "Thyratron cold cath." is only a supplemental test. Create an additional separate data base entry for this test for the tube and mark it with a name supplement that shows the tube's type.

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