

4. Warranty

All valves manufactured by "Pulsed Technologies Ltd." (The Manufacturer) are guaranteed to be free of defects in workmanship, materials and construction and are designed to give satisfactory service when used under normal operating conditions. The Manufacturer guarantees conformity of thyratrons to the parameters specified in item 1.1 of the thyratrons' certificate within a period of 12 months from the date of delivery, confirmed by shipping documents or within a minimum operating time in terms of total switched charge is 5×10^4 Coulomb, either within a filament life of 1000 hours whichever comes first. The above conditions should be considered provided the thyratrons are treated in accordance with the technical parameters stated in the appropriate clause of the thyratrons' certificate.

For valves failing before expiration of operating time 5×10^3 C, a valve may at the option of Manufacturer be replaced free of charge or credited in full, provided that the filament life guaranteed has not expired. For valves failing with a filament life in excess of the initial period up to operating time 5×10^3 C, but less than the total warranty minimum operating life, replacement or credit will be given on pro rata basis determine by the ratio of the unrealised portion of the warranted operating life to the total warranty minimum operating life. The operating life is considered to start when the valve is first put into service, even though it may subsequently be removed and held as a spare.

Conditions of Warranty. The warranty is valid only if the following conditions are met :

1. The valve is supplied direct from the Manufacturer or via an agency, representative or other selling medium authorized by Manufacturer.
2. The valve is operated within the published minimum and maximum ratings, provided that safety devices for protection against overcurrent in terms of average current are fitted and operation time counter is used.
3. The valve is not subjected to any negligence in use, storage, transportation or handling.
4. The decision of Manufacturer on the cause of failure and on the value and form of any applicable allowances is accepted by the customer.
5. Right of access to equipment for the purpose of checking operating conditions is granted to any representative of Manufacturer where Manufacturer may so require.
6. Manufacturer is notified within 30 days of the valve failure.
7. The valve is withdrawn from service as soon as possible after the failure is alleged to have occurred.

5. Claims Information. In case of a premature failure of a thyatron it should be returned to the Manufacturer within 30 days together with the Certificate stating the following information:

Storage time _____

Date of putting into operation _____

Date of failure _____

Specifications of a mode of operation _____

Operating time in the specified mode _____ of hours (total switched charge).

The reasons for removal of a thyatron from operation _____

The items of information are filled _____

(Date, signature)

In case of absence of the filled passport the claim is not accepted.

Individual № _____, Manufacturing date _____

Address: "Pulsed Technologies Ltd." 5, Yablochkova proezd, 390023 Ryazan, Russia.

Tel: +7(4912)24-0519, **Fax/tel.:** +7(4912)24-9217,

E-mail: pulsetech@mail.ru

Web site: <http://www.pulsetech.ru>



TDI1-200k/25 THYRATRON

Product Certificate. Certificate of Quality.

Thyratron TDI1-200k/25 (Copper Arc Thyatron, Grounded Grid Thyatron) is manufactured in compliance with KBФM 433212.005 Technical Conditions and designed for use as a switch tube in pulse circuits of capacitive storages with sub-microsecond and microsecond pulse duration for domestic as well as export delivery.

1. Basic Technical Data.

The thyatron features a compact, stacked ceramic-metal construction, with hydrogen as a buffer gas under the pressure of 20÷60 Pa in operational mode only. Semiconductor high-temperature ignitor is used for triggering the thyatron. Patented dielectric coating protects envelope of the tube against damage in emergency when anode reverse voltage increases for up to 100% of forward voltage. The tube is environmental-friendly product, has internal shield for minimization of X-Ray emission from the region of anode. In TDI1-200k/25H variant the thyatron comprises hollow anode and is used, for example, for operation in modes with oscillating current (Undamped Circuits), as well as for triggering both from cathode and anode part. Design of the thyatron is covered by Russian Federation patents №№1807798, 2300157, 2418339, International Patents PCT/RU2005/000298, PCT/RU2011/000038 and US Patents No.7,825,595 B2 and US8,735,866 B2.

1.1. Optimal Electrical Parameters.

Parameter	Value	Fact. value
Peak Anode Voltage, kV	3÷20	
Peak Forward Anode Current, kA	150	
Pulse Repetition Rate, Hz	0.5	
Anode Current 1st half-wave width, μ s*	2÷3	
Switching Capacitance, μ F	5.0	
Heater Voltage, V, (not less/not more)	3.0/7.0	
Heater Current (at $U_{\text{heat}} =$ V), A, not more	2.5	
Peak Open Circuit Trigger Voltage, kV, (not less/not more)	3.0/10.0	
Peak trigger current, A, (not less/not more)	60/120	
Trigger Current Pulse Duration, μ s	1÷5	
Readiness Time, min	5.0	

* - damped discharge.

1.2. Absolute ratings (maximus, nonsimultaneous)*

Parameter	Value
Peak Forward Anode Voltage, kV (Notes 1)	1÷25
Peak Reverse Anode Voltage, kV (Notes 2)	20
Peak Forward Anode Current, Ib, kA	200
Maximum anode current rise rate, A/s (Note 3)	$3 \cdot 10^{12}$
Peak reverse anode current, Ibx, kA (Note 4)	up to 20% of Ib
Anode current pulse duration, μ s	0.1÷500.0
Switched energy per shot, J	40 000
Anode Dissipation Factor ($P_b = V \times A \times pps$) (Note 5, 6)	$70 \cdot 10^9$
Root mean square current, $RMS = \sqrt{I_b \times i_b}$ (Note 5, 6)	700
Pulse repetition rate, f, Hz (Note 5, 6)	300
Time Jitter, ns (Note 7)	3-4
Rate of rise of ignition voltage pulse, kV/ μ s, not less	5.0

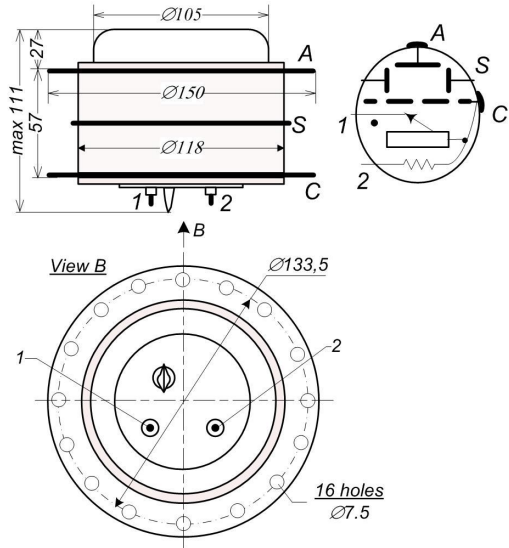
Notes *Operation of the thyatron when two or more parameters listed in p.1.1 are exceeded simultaneously may be permitted upon agreement with the Manufacturer only.

¹⁾ The dwell time at the peak anode voltage should be minimized in order to minimize pre-firing. For operation at the rated peak forward anode current, the dwell time must be less than 0.5 of pulse period, but must not exceed 1 millisecond.

- 2) After the thyatron anode current ceases and before voltage is reapplied to anode, the anode voltage must be kept between minus (100 -5000) Volts for at least 100 μs for buffer gas deionization.
- 3) The ultimate value depends on the external circuit parameters.
- 4) For hollow anode variant TD11-200k/25H Ibx - up to 95% of Ib.
- 5) Use forced air or liquid (oil) cooling providing Pb and RMS below indicated in p. 1.2.
- 6) Pb >10⁹ and RMS >80 can be achieved in burst mode only (ib=CUaf – average current, C – switching capacitance). Burst and pause durations must be agreed with the Manufacturer.
- 7) Pb >10⁹ and RMS >50 can be achieved in burst mode only
- 8) Low-energy, high-rate of rise of trigger voltage pulse trigger system by a cable pulse generator (fig.2).

1.3. Maximum overall dimensions (∅_{cathode flange} × H_{max}), mm, not more - 152×111.

Net weight - not more than 3.5 kg.



2. Diagrams of connections of electrodes to the leads

- A- anode;
- S- screen;
- C- cathode, heater, trigger positive signal input lead;
- 1 - trigger negative signal input lead.
- 2 - reservoir heater (R_{res} ~1Ω).

ATTENTION! It is required in all circuits to observe carefully the polarity of trigger voltage applied to the appropriate leads of the ignitor and to provide symmetry of current pick-off from cathode and anode flanges relative to the axis of the device (J. Slough, et al, «Prospective Pulsed Power Applications Of Pseudospark Switches», 17th IEEE International Pulsed Power Conference (2009, Washington, DC). When switched charge more than 1 Coulomb per pulse the thyatron must be placed in a ferromagnetic screen (V.D.Bochkov et al., "Effect of conductive screens to stabilize the plasma channels with currents of hundreds of

kA" XI International Workshop on Charged Particle Accelerators, Alushta, Rep. Crimea, 2015).

The thyratrons must be handled carefully in order to prevent mechanical effect on the leads 1 u 2 exceeding 3 kgs in axial direction and 1kgs in direction perpendicular to the axes. **It is strictly forbidden to expose the leads 1,2 to impacts.**

3. Operation Guidelines

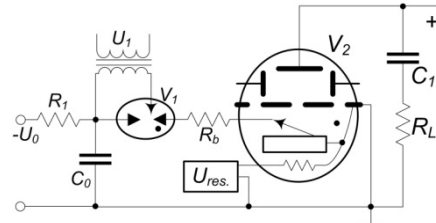
- 3.1. Trigger negative signal must be applied to the tail 1 of the thyatron. Resistance of igniter within warranty period is 5kΩ±200 MΩ.
- 3.2. For reliable operation of the thyratrons use the pulse driver PB-3D providing powering of auxiliary electrodes in conformity with rated parameters. The driver is designed and manufactured by Pulsed Technologies Co. Ltd.
- 3.3. Switching sequence: a) apply heater voltage to the appropriate tail; b) allow the heater to warm up for not less than 5 min; c) apply pulsed ignition voltage to the igniter, apply anode voltage (30-50% of maximum level), smoothly raise the anode voltage to the operating level. It is permitted to simultaneously switch on heater and trigger voltages.
- 3.4. The maximum-allowed temperature of cathode, anode and grid flanges is +120°C. If exceeded, a forced air or liquid (oil) cooling must be used. Air flow rate is to be not less than 2.5 m³/min at 25°C ±10°C of thermofo.
- 3.5. When switching off voltages first switch off anode voltage, then all the rest voltages. It is permitted to switch off all voltages simultaneously.
- 3.6. For ensuring warranty period of operation in modes different from those specified in p.1.1 it is necessary to select voltage of the heater subject to certain mode of thyatron operation. For this

purpose (with nominal load) increase heater voltage by steps of 0.1÷0.3 V from the value specified in the certificate staying at each value for 2÷3 minutes before appearance of signs of unstable operation (transition to higher frequency or to continuous discharge). In appearance of the signs switch off anode voltage, reduce heater voltage of the generator of hydrogen by 0.1÷0.2 V and within a minute switch on anode voltage and maintain it for 5-10 minutes. At steady operation fix the given heater voltage. Further it is desirable to repeat this procedure after every total 10⁴ C of operation.

3.7. After transportation or a long period of storage regulated seasoning at operation conditions within not less than 30 minutes is required. When aging the thyatron, anode voltage must be raised gradually by steps of 3÷5 kV from minimum peak voltage of 10÷15 kV up to peak forward anode voltage. The criteria of successful seasoning at each step will be an absence of misfires within 3-5 minutes.

Recommended Circuits for Ignition Pulse Generator

Fig.1. Principal circuit of a triggered spark gap-based ignition pulse generator. The circuit may be used at high operating temperatures (up to 200 °C).



- U₀=5kV,
- V₁—triggered spark gap RU83;
- R₁=10kΩ, R_b=(0÷50) Ω,
- C₀=(0.01÷0.2) μF

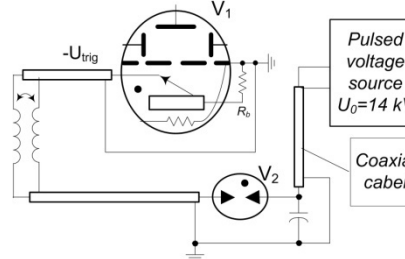
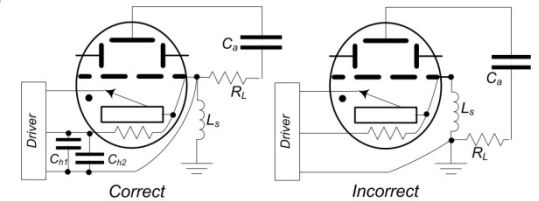


Fig.2. Low-jitter (<5ns), low-energy, trigger system by a cable pulse generator. (V.A.Gribkov, et al, "Pseudosparks in nanosecond range of its operation: firing, jitter, and disconnection", Journal of Physics D: Appl. Phys. 37, 2004, 2107–2111). V₂- sharpening spark gap; cable length = 6 m;

Fig.3. Please make sure that voltage jumps (stray voltage) $U_s = |L_s \cdot di/dt|$ in ground circuit should be minimized. For that heating voltage cable must be connected to the thyatron connectors directly. Also load circuit must be connected right to the thyatron cathode and equipment case directly. Cathode of the tube must be connected with equipment case by a minimum length cable (stray inductance $L_s \rightarrow 0$).



- C₁, C₂: Reservoir protection capacitors with a voltage rating > 500 V;
- C₁ = 1000 pF low inductance (e.g. ceramic), C₂ = 1μF (e.g. polycarbonate).
- Components C₁, C₂ should be mounted as close to the tube as possible.