

#### 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 the appropriate clause of the thyatron certificate within a period of 12 months from the date of delivery, confirmed by shipping documents, or within a minimum operating time equal to  $5 \times 10^4$  pulses, 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 (p.1.1).

For valves failing before expiration of operating time  $10^4$  pulses, 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  $10^4$  pulses, but less than the total warranty minimum operating life, replacement or credit will be given on pro rata basis determined 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 The valve is withdrawn from service as soon as possible after the failure is alleged to have occurred.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 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 \_\_\_\_\_

*information about operating conditions, cause of failure.*

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

The reasons for removal of 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 № 2517, Manufacturing date 01.2018z.

**Address:** "Pulsed Technologies Co. Ltd." 5, Yablochkova Str., 390023 Ryazan, Russia.

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

**E-mail:** [pulsetech@mail.ru](mailto:pulsetech@mail.ru), [info@pulsetech.ru](mailto:info@pulsetech.ru)

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



TDI4-100k/45H-18 THYRATRON

### CERTIFICATE OF QUALITY. MANUAL DESCRIPTION

TDI4-100k/45H-18 thyatron (Copper Arc Thyatron, Grounded Grid Thyatron) is intended for use as a switch tube in pulse circuits of capacitive storages with sub-microsecond and microsecond pulse duration. The thyatron is manufactured in conformity with technical conditions KBФM.433.212.014TY for use in various installations for domestic as well as export delivery. Numbers 18 designate 18 flange holes pattern.

#### 1. Basic Technical Data.

Pulse thyatron has a ceramic/metal envelope, two high-voltage sections, filled with hydrogen (deuterium) as buffer gas at 20÷60 Pa in operational mode only. Semiconductor igniter is used to trigger the switch. Special dielectric coating protects internal surface of the envelope against damage in cases when anode reverse voltage achieves 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 TDI4-100k/45H variant the thyatron comprises hollow anode and is used, for example, for operation in modes with oscillating current (Underdamped 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. Electrical Parameters in Optimum Operation Mode

Parameter	Value	Fact. value
Forward anode voltage, kV	5÷35	32
Peak forward anode current, kA	50	50
Anode current 1st half-wave width, $\mu$ s	5.0	4.8
Pulse repetition rate, Hz	0.5	0.5
Heater voltage, V. (not less/not more)	3.0/7.0	4.25/5.5
Heater current (at $U_h = 5.25$ V), A, not more	2.5	1.95
Peak open circuit trigger voltage, kV. (not less/not more)	3.5/6.0	4.0
Peak trigger current, A, (not less/not more)	80/120	100
Trigger current pulse duration, $\mu$ s	2÷5	2
Tube warm-up time, minutes	5.0	5.0

#### 1.2. Absolute ratings (maximus, nonsimultaneous)\*

Parameter	Value
Peak forward anode voltage, kV' (Notes 1, 2, 3)	2÷45
Peak reverse anode voltage, kV' (Notes 3)	35
Peak forward anode current, Ib, kA	150
Peak reverse anode current, Ibx, kA (Note 4)	up to 95% of Ib
Maximum rate of anode current rise, A/s (Note 5)	$5 \cdot 10^{12}$
Anode current pulse duration, $\mu$ s	0.1÷100.0
Pulse repetition rate, f, Hz (Note 6)	300
Switched energy per shot, J	20 000
Anode Dissipation Factor ( $Pb = I \times A \times pps$ ) (Note 6)	$70 \cdot 10^9$
Root mean square current, RMS $\sqrt{I_b \times I_b} (I_b = C \cdot U \cdot f)$ (Note 6)	700
Peak open circuit trigger voltage, kV. (not less/not more) (Note 7)	3.0/10.0
Peak trigger current, A, (not less/not more) (Note 7)	50/150
Rate of rise of ignition voltage pulse, kV/ $\mu$ s, not less (Note 7)	5.0
Time Jitter, ns (Note 7)	3

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

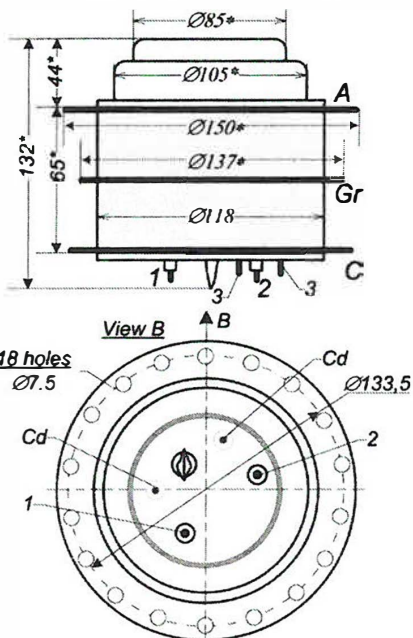
<sup>1)</sup> Immerse the tube into SF<sub>6</sub>, N<sub>2</sub> or oil when operating at voltages over 35 kV.

<sup>2)</sup> The dwell time at the peak anode voltage should be minimized 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.

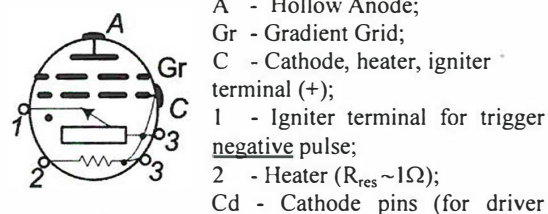
- <sup>3)</sup> After the thyatron anode current ceases and before voltage is reapplied to anode, the anode voltage must be kept between minus (100 -5000) Volts for at least 100  $\mu$ s for buffer gas deionization to recover hold-off.  
<sup>4)</sup> For hollow anode version (TD)4-100k/45H). For flat anode TD)4-100k/45 reverse current <10% of Ib.  
<sup>5)</sup> The ultimate value depends on external circuit parameters.  
<sup>6)</sup> Pb >10<sup>6</sup> and RMS >50 can be achieved in burst mode only (Ib=CUaf - average current, C - switching capacitance). Burst and pause durations must be agreed with the Manufacturer.  
<sup>7)</sup> High rate of rise of trigger voltage pulse trigger system by a cable pulse generator (fig.2). More trigger energy and dV/dt - less jitter.

1.3. Maximum overall dimensions ( $\varnothing_{\text{cathode flange}} \times H_{\text{max}}$ ), mm - 152x136.

1.4. Weight - not more than 4.0 kg.



## 2. A diagram of electrodes connection



- A - Hollow Anode;
- Gr - Gradient Grid;
- C - Cathode, heater, igniter terminal (+);
- 1 - Igniter terminal for trigger negative pulse;
- 2 - Heater ( $R_{\text{res}} \sim 1\Omega$ );
- Cd - Cathode pins (for driver common only).

common only).  
 \* - reference dimensions.

**ATTENTION!** It is required in all circuits to carefully observe polarity of ignition voltage applied to the appropriate terminal of the igniter 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, 2015).

The thyatrons must be handled carefully in order to prevent mechanical effect on pins 1, 2 exceeding 3 kgs in an axial direction and 1 kgs in direction perpendicular to the axes. It is strictly forbidden to hit the valve pins.

## 3. Operation Guidelines

3.1. Trigger negative signal must be applied to the pin 1 of the thyatron. Resistance of igniter within warranty period is 5k $\Omega$ -200 M $\Omega$  (reference value only).

3.2. For reliable operation of the thyatrons driver PB-3D or PB-3DV, providing powering of auxiliary electrodes in conformity with rated parameters, is recommended. The driver is designed and manufactured by Pulsed Technologies Ltd.

3.3. Switching sequence: a) connect heater voltage power supply to the appropriate pin 2; b) allow the heater to warm up for not less than 5 min; c) apply pulse trigger voltage to igniter, apply anode voltage (30-50% of maximum level), then smoothly increase anode voltage to the operating level required. It is allowed to simultaneously apply both heater and trigger voltages.

3.4. The maximum-allowed temperature of cathode, anode and grid flanges is +100 $^{\circ}$ C. If exceeded, a forced air or liquid (oil) cooling must be used. Air flow rate is to be not less than 2.5 m<sup>3</sup>/min at 25 $^{\circ}$ C  $\pm$ 10 $^{\circ}$ C of thermofoir.

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 consistent with a certain mode of thyatron operation. For this purpose (with nominal load) increase heater voltage by steps of 0.1 $\pm$ 0.3 V from the value specified in

the certificate staying at each value for 2-3 minutes until signs of unstable operation (transition to higher frequency or to continuous discharge) appears. In case the signs appear please switch off anode voltage, reduce heater voltage of the generator of hydrogen by 0.1 $\pm$ 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 10<sup>4</sup> C of operation.

3.7. After transportation or a long storage period a regulated conditioning under operating conditions within not less than 30 minutes is required. When conditioning the thyatron, anode voltage must be raised gradually by steps of 3-5 kV from the minimum anode voltage of 10-15 kV up to the maximum forward anode voltage. The criteria of successful conditioning at each step will be the absence of pre-fires within 3-5 minutes.

### Recommended Circuit for Trigger Pulse Generator

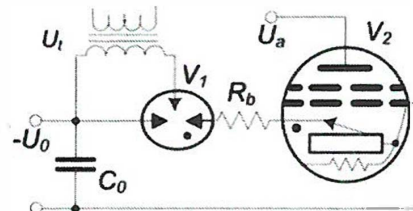


Fig.1. Electrical schematic of a triggered spark gap based trigger pulse generator (driver).  
 V<sub>1</sub> - RU83 Trigger Spark Gap.  
 R<sub>1</sub>=10k $\Omega$ , R<sub>b</sub>=(0-50) $\Omega$ ,  
 C<sub>0</sub>=(0.01-0.2)  $\mu$ F,

### Options for Triggering of Thyatron.

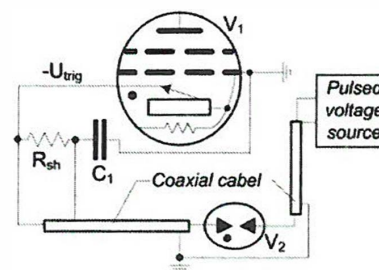


Fig.2. Electrical schematic of low-jitter (<5 ns), low-energy, cable- system trigger pulse generator. (V.A.Gribkov, et al, Pseudosparks in nanosecond range of its operation: firing, jitter, and disconnection, Journal of Physics D: Appl. Phys. 37, 2004, 2107-2111.)  
 U<sub>0</sub>=8-12 kV, C<sub>1</sub>=(0.01-0.2)  $\mu$ F  
 V<sub>1</sub> - spark gap; cable length ~ 6 m;

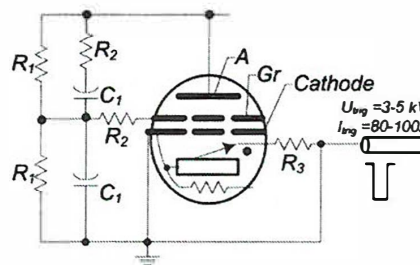


Fig. 3. Principal circuit of gradient grid feed.  
 C<sub>1</sub>=(0.3-0.5) nF, R<sub>1</sub>=(5-20)M $\Omega$ ,  
 R<sub>2</sub>=470 $\Omega$

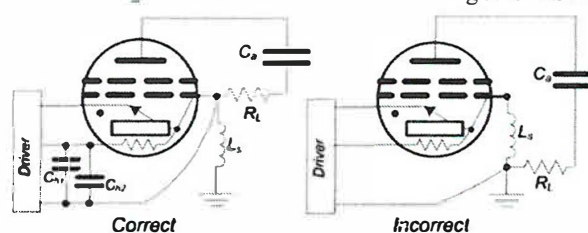


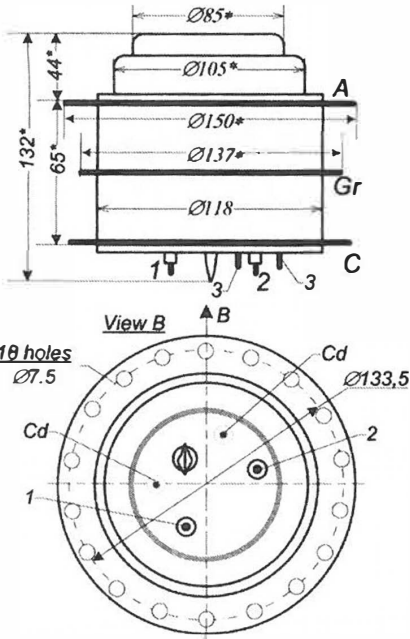
Fig.4. Please make sure that jumps stray voltages (transient voltage spikes)  $U_s=L_s \cdot dI/dt$  in ground circuit are minimized. For that heating voltage cable must be connected to the thyatron terminals directly. Also load circuit must be connected to the thyatron cathode and equipment case directly. Cathode of the tube must be connected with equipment case by a minimum length cable (stray inductance  $L_s \rightarrow 0$ ).

C<sub>1</sub>, C<sub>2</sub>: Reservoir protection capacitors with a voltage rating > 500 V;  
 C<sub>1</sub> = 1000 pF low inductance (e.g. ceramic), C<sub>2</sub> = 1 $\mu$ F (e.g. polycarbonate).  
 Components C<sub>1</sub>, C<sub>2</sub> should be mounted as close to the tube as possible.

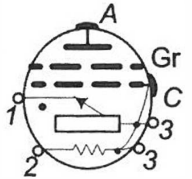
- 3) After the thyatron anode current ceases and before voltage is reapplied to anode, the anode voltage must be kept between minus (100 - 5000) Volts for at least 100  $\mu$ s for buffer gas deionization to recover hold-off.  
 4) For hollow anode version (TD14-100k/45H). For flat anode TD14-100k/45 reverse current <10% of I<sub>b</sub>.  
 5) The ultimate value depends on external circuit parameters.  
 6) P<sub>b</sub> >10° and RMS >50 can be achieved in burst mode only (I<sub>b</sub>=CU<sub>af</sub> - average current, C - switching capacitance). Burst and pause durations must be agreed with the Manufacturer.  
 7) High rate of rise of trigger voltage pulse trigger system by a cable pulse generator (fig.2). More trigger energy and dV/dt - less jitter.

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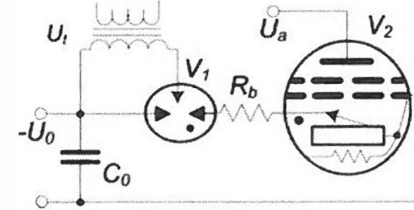


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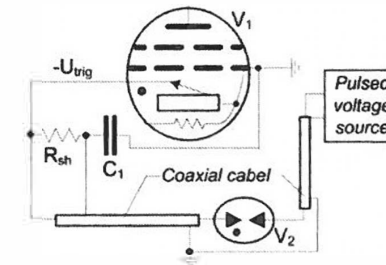
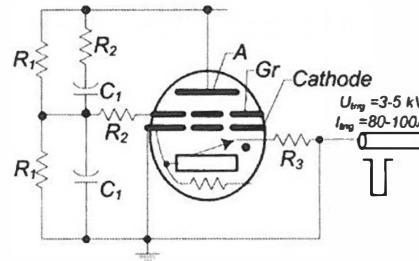


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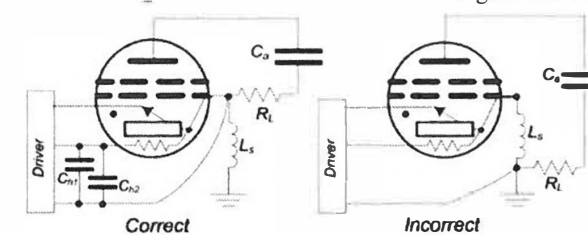
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3. The valve is not subjected to any negligence in use, storage, transportation or handling.
4. The decision of Manufacturer on the cause of failure and on the value and form of any applicable allowances is accepted by the customer.
5. Right of access to equipment for the purpose of checking operating conditions is granted to any representative of Manufacturer where Manufacturer may so require.
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Specifications of a mode of operation \_\_\_\_\_

*information about operating conditions, cause of failure.*

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

The reasons for removal of 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 № 2518, Manufacturing date 01.2018.

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

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

E-mail: [pulsetech@mail.ru](mailto:pulsetech@mail.ru), [info@pulsetech.ru](mailto:info@pulsetech.ru)

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



TDI4-100k/45H-18 THYRATRON

### CERTIFICATE OF QUALITY. MANUAL DESCRIPTION

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#### 1.1. Electrical Parameters in Optimum Operation Mode

Parameter	Value	Fact. value
Forward anode voltage, kV	5÷35	32
Peak forward anode current, kA	50	50
Anode current 1st half-wave width, $\mu$ s	5.0	4.8
Pulse repetition rate, Hz	0.5	0.5
Heater voltage, V, (not less/not more)	3.0/7.0	4.5/5.25
Heater current (at $U_h = 5; 0$ V), A, not more	2.5	1.7
Peak open circuit trigger voltage, kV, (not less/not more)	3.5/6.0	4.0
Peak trigger current, A, (not less/not more)	80/120	100
Trigger current pulse duration, $\mu$ s	2÷5	2
Tube warm-up time, minutes	5.0	5.0

#### 1.2. Absolute ratings (maximum, nonsimultaneous)\*

Parameter	Value
Peak forward anode voltage, kV (Notes 1, 2, 3)	2÷45
Peak reverse anode voltage, kV (Notes 3)	35
Peak forward anode current, $I_b$ , kA	150
Peak reverse anode current, $I_{bx}$ , kA (Note 4)	up to 95% of $I_b$
Maximum rate of anode current rise, A/s (Note 5)	$5 \cdot 10^{12}$
Anode current pulse duration, $\mu$ s	0.1÷100.0
Pulse repetition rate, f, Hz (Note 6)	300
Switched energy per shot, J	20 000
Anode Dissipation Factor ( $P_b = V \times A \times pps$ ) (Note 6)	$70 \cdot 10^9$
Root mean square current, $RMS = \sqrt{I_b \times I_b} (I_b = C \cdot U \cdot f)$ (Note 6)	700
Peak open circuit trigger voltage, kV, (not less/not more) (Note 7)	3.0/10.0
Peak trigger current, A, (not less/not more) (Note 7)	50/150
Rate of rise of ignition voltage pulse, kV/ $\mu$ s, not less (Note 7)	5.0
Time Jitter, ns (Note 7)	3

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

<sup>1)</sup> Immerse the tube into SF<sub>6</sub>, N<sub>2</sub> or oil when operating at voltages over 35 kV.

<sup>2)</sup> The dwell time at the peak anode voltage should be minimized 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.