Technical Information Techsem Capsule Device

1. Introduction

Techsem is the only publicly listed enterprise in China with more than 47 years of experience in the production of power electronic components. Techsem has expertise in all aspects of the production process, from wafer and chip processing to power device manufacturing. The power capsule devices made by Techsem include phase-control thyristors (KP series), fast turn-off thyristors (KK series), and rectifier diodes (ZP series), with chip diameters ranging from 0.5 inches to 5 inches. The output current range is 200A to 8500A, and the reverse voltage range of the capsule devices is 400V to 6500V. Techsem is the leader in the Chinese power capsule device market. Techsem products are widely used for metal smelting, high-power conversion, AC/DC motor control, AC/DC switching, phase-controlled rectification, active and passive inversion, and other applications in many industries.

1.1. Features

All Techsem capsule devices have CE marking and comply with European RoHS directives. The devices are packaged in hermetic metal cases with ceramic insulators, and they are in full compliance with international standards, providing excellent versatility and substitutability to customers. The capsule devices are categorized according to chip type and electrical characteristics as follows:

- **Phase-Control Thyristors (KP series):** The chips are processed with Complete Diffusion Technology and have internal amplifying gate structure. The devices are suitable for single- or double-sided cooling. At the case temperature of 55^{o}C, the forward current rating I_{FAV} ranges from 400A to 5200A, and the range of reverse blocking voltage is 400V to 6500V. The typical applications for phase-control thyristors are high-power inversion, AC and DC motor control, AC/DC switching, phase-controlled rectification, active/passive inversion, among others. The following capsule housing types are offered for the different I_{FAV} and V_{RRM} of the devices:

I_{FAV}（A）	V_{RRM}（V）	Housing Type
400	1200 — 1800	KT19
400	6000 — 6500	KT38
500	600 — 1000	KT19
600	400	KT19
600	1200 — 1800	KT25
900	6000 — 6500	KT50
1000	400 — 1000	KT25
1000	1200 — 1800	KT33
1200	3000 — 4200	KT50
1500	400 — 1000	KT33
1600	6000 — 6500	KT60
1800	1200 — 1800	KT50
1900	3000 — 4200	KT73
2200	6000 — 6500	KT84
2400	3000 — 4200	KT60
2500	600 — 1000	KT50
2800	1200 — 1800	KT33
3500	6000 — 6500	KT100
4000	600 — 1800	KT73
5200	6000 — 6500	KT125

Fig. 1: Relation of I_{FAV} / V_{RRM} to capsule type for phase-control thyristors

- **Fast Turn-off Thyristors (KK series):** The chips are processed with Complete Diffusion Technology and have internal amplifying gate structure. The thyristors can operate under conditions of fast turn-on and high rate of rise of on-state current (di/dt), and they possess excellent electrical dynamic characteristics such as low switching loss and fast turn-off time. The devices are suitable for single- or double-sided cooling. At case temperature of 55°C, the forward current rating I_{FAV} ranges from 400A to 4800A, and the range of reverse blocking voltage V_{RRM} is 1200V to 2800V. The typical applications for fast turn-off thyristors include inversion, chopping, inductive heating, and various types of conversion. The following capsule housing types are offered for the different I_{FAV} and V_{RRM} of the devices:

I_{FAV}（A）	V_{RRM}（V）	Housing Type
400	1200 — 1800	KT33
800	1200 — 1800	KT33
1300	1200 — 1800	KT50
2000	1200 — 1800	KT60
2100	2000 — 2800	KT60
2700	1200 — 2800	KT73
3800	2000 — 2800	KT84
4800	2000 — 2800	KT100

Fig. 2: Relation of I_{FAV} / V_{RRM} to capsule type for fast turn-off thyristors

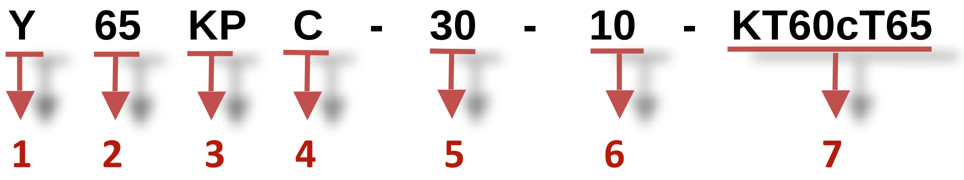
- **Rectifier Diodes (ZP Series):** These devices are diffused-junction diodes. They are suitable for single- or double-sided cooling. At the case temperature of 55°C, the forward current rating I_{FAV} ranges from 600A to 8500A, and the range of reverse blocking voltage V_{RRM} is 400V to 2000V. The typical applications for rectifier diodes are high-power inversion, welding, motor control, drive and charging, among others. The following housing types are offered for the various I_{FAV} and V_{RRM} of the devices:

I_{FAV}（A）	V_{RRM}（V）	*Housing Type*
600	1200 —2000	ZT19
1000	400	ZT19
1310	1200 — 2000	ZT25
1460	400	ZT25
1680	1200 — 2000	ZT33
1990	400	ZT33
3000	1200 — 2000	ZT50
6000	1200 — 2000	ZT73
6300	400	ZT44
8500	400	ZT60

Fig. 3: Relation of I_{FAV}/ V_{RRM} to capsule type for rectifier diodes

1.2. Type Designation

The type designation of capsule devices can be explained with a product example:



1: Code for capsule devices (“Y” for conventional devices / “H” for high-voltage devices with pressure contact technology)

2: Chip diameter (mm)

3: Chip type (KP / KK / ZP, please refer to 1.1)
4: Code for wafer specifications
5: Rating for forward current: I_{FAV} / I_{TAV} = Code x 100A
6: Rating for reverse voltage: V_{DRM} / V_{RRM} = Code x 100V
7: Housing designation

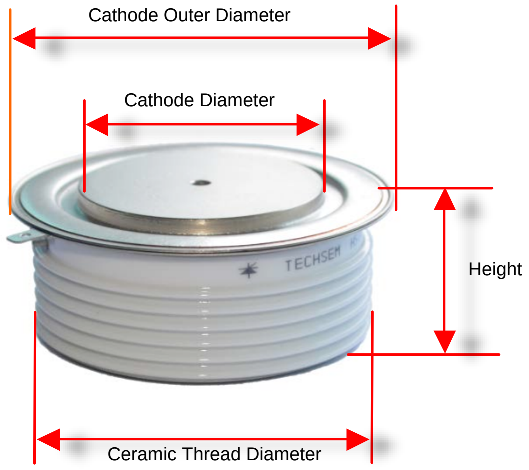
1.3. Capsule Housing

1.3.1. Explanation of housing code

K	T	60	cT	65
K: capsule housing for thyristor Z: capsule housing for diode	T: protruding surface A: concave surface	Surface diameter code for cathode and anode (close to but not necessarily equal to the value of chip diameter)	Height of housing aT: 14mm cT: 26mm dT: 35mm	Optional: Diameter of the alternative applicable chip

Fig. 3: Explanation of housing code

1.3.2. Key Indicators of capsule housing



Key Indicators of Capsule Housing

Housing Type	Chip Type	Ceramic Thread Diameter (mm)	Maximum Cathode Outer Diameter (mm)	Mounting Force (KN)
KT19aT	Thyristor	37	42	3.3 —3.5
KT25aT	Thyristor	40.5	42	5.3—10
KT33	Thyristor	53	59	10—20
KT50	Thyristor	66	74	19—26
KT60	Thyristor	88	100	27—34
KT73	Thyristor	98	110	35—47
KT100	Thyristor	132	142	81—108
ZT19aT	Diode	37	42	3.3—3.5
ZT25aT	Diode	40.5	42	5.3—10
ZT33	Diode	53	59	10—20
ZT50	Diode	66	74	19—26
ZT60	Diode	88	100	30—40
ZT73	Diode	98	110	35—47
ZT100	Diode	132	142	81—108

Fig. 4: Key indicators

Note:

1. Except for KT19aT and KT25aT, all other thyristor housing types have different heights (aT/cT/dT).
2. Except for ZT19aT and ZT25aT, all other diode housing types have different heights (aT/cT/dT).
3. The housing types KT60 and ZT60 are also applicable for chips with diameter of 65mm.
4. For Techsem capsule devices, standard tolerance of catalogue drawings is +/-0.5mm.

1.3.3. Reserve Voltage Selection

In Fig. 5, the relation between the input line voltage (AC) and the recommended repetitive peak off-state and reverse voltage (V_{DRM}/V_{RRM}) of the devices are shown.

Input Line Voltage (V)	V_{DRM}/V_{RRM} (V)
60	200
125	400
250	800
380	1200
400	1400
440	1400
460	1600
500	1600
575	1800
660	2000
690	2200

Fig. 5: Recommended reverse voltage

Note: The maximum permissible continuous voltage on a diode V_R or SCR V_D/V_R should be $0.7V_{DRM}/V_{RRM}$.

2. Technical Parameters

In the following paragraphs detailed explanation of the electrical parameters on the datasheet will be given.

2.1. Mean Forward Current $I_{F(AV)}$ (Diode) / Mean On-State Current $I_{T(AV)}$ (Thyristor)

This refers to the maximum average current that the diode/thyristor is able to conduct in forward-bias mode under the defined heat sink temperature T_{HS} or case temperature T_C. This value depends on the current characteristics, the current conduction angle, and the cooling conditions. Thus, the maximum current represents the upper limit of junction temperature. Therefore, current overload is not permissible under normal operation. With consideration of changes in cooling conditions and environmental temperatures, it is recommended that the diode/thyristor operate at no more than 80% of the maximum rated mean forward current. On the datasheet, the relation of $I_{F(AV)}$ / $I_{T(AV)}$ to the heat sink temperature T_{HS} or case temperature Tc is indicated so that the suitable device for certain current can be determined.

2.2. Surge Forward Current I_{FSM} (Diode) / I_{FSM} (Thyristor)

This refers to the maximum permissible peak value of a single half sine wave 50Hz current pulse (10ms). These values on the datasheet are specified at turn-on at maximum permissible junction temperature with 80% of V_{RRM} (repetitive peak reserve blocking voltage). The number of withstanding of surge forward current during the lifetime of a device is limited. Current overload should be avoided if possible.

2.3. Peak Load Integral i^2t

The peak load integral can be calculated from the surge forward current $I_{T(F)SM}$ as follows:

$$\int_0^{t_{hw}} i_{FS}^2 \, dt = I_{FSM}^2 \cdot \frac{t_{hw}}{2}$$

t_{hw} represents the duration of the half sine wave under I_{FSM}. The maximum rated $\int i^2 dt$ value serves to determine the limit of short-circuit protection.

2.4. Repetitive Peak Off-state Voltage V_{DRM} / Repetitive Peak Reverse Voltage V_{RRM}

V_{DRM} is the maximum value of repetitive voltages in the forward off-state direction, including all repetitive peak voltages.

V_{RRM} is the maximum permissible instantaneous value of repetitive voltages in reverse direction, including all repetitive peak voltages.

These values should not be exceeded in any application.

2.5. Peak Value of Reverse Drain Current I_{DRM} / Peak Reverse Recovery Current I_{RRM}

These values are determined as off-state or reserve leakage currents at the V_{DRM} or V_{RRM} on the device under the maximum permissible junction temperature.

2.6. Threshold Voltage V_{TO}

V_{TO} is the voltage at the point of crossover between an approximation line of the forward characteristic and the voltage axis.

2.7. Forward Slope Resistance r_F

The equivalent line is an approximation for the on-state characteristic of a thyristor or a diode to calculate the on-state power dissipation. The value r_F is calculated from the rate of increase of the equivalent line. To calculate the forward power dissipation, the following formula is used: $V_F = V_{TO} + r_F \times i_F$.

2.8. Peak Forward Current I_{FM} (Diode) / Peak On-State Current I_{TM} (Thyristor)

This refers to the peak value of the current a diode/thyristor is able to conduct in forward-bias mode under the defined heat sink temperature T_{HS} or case temperature T_C.

2.9. Forward Peak Voltage (Diode) V_{FM} / On-State Peak Voltage V_{TM} (Thyristor)

These values represent the voltages at the peak forward current I_{FM} (diode) or the peak on-state current I_{TM} (thyristor). They directly reflect the on-state characteristics and they impact the forward current load of the device. The forward (on-state) peak voltage can be represented approximately by the threshold voltage and slope resistance: $V_{TM} = V_{TO} + r_T \times I_{TM}$; $V_{FM} = V_{FO} + r_F \times I_{FM}$.

2.10. Current Commutate Turn-Off Time *t*q (Thyristor)

This value represents the time interval between the instant when the decreasing on-state current passes through zero and the earliest reapplication of off-state voltage, after which the thyristor does not turn on again. The measured value of *t*q depends on the applicable testing conditions. The testing conditions at Techsem are as follows:

- On-state peak current $I_{TM} = I_{TAV}$ of the device
- Critical rate of rise of on-state current di/dt = -20A/μs
- Rate of rise of reapplication voltage dv/dt = 30A/μs
- Reserve voltage $V_R = 50$V
- Junction temperature $T_j = T_{jm}$

2.11. Critical Rate of Rise of On-State Current di/dt

On the datasheet, this value is indicated as the maximum rate of rise of on-state current without damaging the thyristor. The value can be strongly impacted by the gate trigger conditions. Therefore, it is recommended to use stronger trigger signals such as current pulse amplitude ≥4～10 x I_{GT} or pulse rising time ≤1μs.

2.12. Critical Rate of Rise of On-State Voltage dv/dt

This value represents the maximum rate of rise of the on-state voltage at which the thyristor is not triggered. On the Techsem datasheet, the minimum values of dv/dt are given for all thyristors. Special requirements pertaining to the value of dv/dt are met for certain applications.

2.13. Gate Trigger Voltage V_{GT}

V_{GT} is the voltage that occurs across the gate terminal and cathode. At the specified gate voltage, all thyristors will trigger. The V_{GT} value indicates the voltage across the main terminals and the junction temperature. The gate trigger voltage decreases with increasing junction temperature and is thus specified at 25^oC.

2.14. Thermal Resistance Junction to Case $R_{th(j-c)}$

The thermal resistance between chip and module case is an important parameter representing the heat dissipation capability of the device. The value also indicates the on-state characteristics. On the Techsem datasheet, the thermal resistance of capsule components with double-sided cooling and the value for one-sided cooling of power modules are given. The values of capsule devices can be ensured only when the device is assembled on the heat sink with the mounting force indicated on the datasheet.

2.15. Thermal Resistance Case to Heat Sink $R_{th(c-hs)}$

Another important parameter pertaining to heat dissipation is the thermal resistance case to heat sink. The measure of contact surface between capsule device and heat sink or the mounting force will determine this value. The value shown on the datasheet can be ensured only by using the indicated mounting force.

3. Quality-Control Principles

To ensure the highest level of product quality, Techsem adheres to the following principles：

3.1. Techsem guarantees that all business processes, including product design and production, are in accordance with the requirements of the ISO 9001:2008 Quality Management System.

3.2. Techsem guarantees that in-process inspections and product testing will be carried out throughout the production process.

3.3. In-process inspection includes assessment of the appearance and parameters of the procedures from the wafer diffusion stage to chip and module / capsule assembly.

3.4. Product testing involves four test categories:

Group A: Routine Testing for all manufactured devices
Group B: Lot Control Testing
Group C: Qualification Maintenance
Group D: Qualification Approval Testing

3.4.1 Group A: Techsem guarantees 100% testing with the following parameters for all products before delivery:

Parameters	T_j	Reference Documents	Inspection Requirements
V_{DRM} V_{RRM}/ I_{DRM} I_{RRM}	25°C / T_{jm}	IEC60747-6, IEC60747-2 Individual test specification per article	100%
dv/dt	T_{jm}	IEC60747-6 Individual test specification per article	100%
Qrr trr (on request)	T_{jm}	IEC60747-6, IEC60747-2 Individual test specification per article	100%
V_{TM} /V_{FM}	25°C / T_{jm}	IEC60747-6, IEC60747-2 Individual test specification per article	100%
I_{GT} V_{GT} I_H	25°C	IEC60747-6 Individual test specification per article	100%
tq (on request)	T_{jm}	IEC60747-6 Individual test specification per article	100%

Fig. 6: Group A testing

3.4.2 Group B:

To ensure reliable quality, Techsem regularly carries out spot testing (Group B Testing). The purpose of the testing is to inspect the AC blocking voltage of the products.

Examination or Test		Reference Documents		
Sub-Group	Test Category	IEC & Internal Standard	Condition	Note
B1	Endurance: AC blocking	IEC60747-6 V	24 h at T_{vj} max sine wave 50 Hz V_D = 0.7...0.8 V_{DRM}	Note1

Fig.7: Group B testing

3.4.3 Groups C and D:

In addition, Techsem carries out annual Group C testing to evaluate the long-term stability of the products.

For new products or modified production processes, Techsem carries out Group D testing to confirm the appraisal before release of the products.

Group C:

Examination or Test		Reference Documents and Conditions		
Sub-group	**Test Category**	**IEC & Internal Standard**	**Conditions**	**Notes**
C1a	I_L	IEC 60747-6	$T_j = 25^oC$	
	I_H	IEC 60747-6	$T_j = 25^oC$	
C1c	I_{TSM}/I_{FSM}	IEC 60747-6	T_{jm} 10ms half sine wave, $V_{RM} = 0.6V_{RRM}$	
C1d	R_{jc}	IEC 60747-6		
C2	V_{GD}	IEC 60747-6	T_{jm}, $V_D = V_{DRM}$	
C3	V_{RGM}	IEC 60747-6	$T_j = 25^oC$	
C4	P_{GM}	IEC 60747-6	$T_j = 25^oC$	
C5	di/dt	IEC 60747-6	T_{jm}, $V_D = 0.5V_{DRM}$, $I_{TM} \geq 2I_{T(AV)}$, $t_r \leq 0.5$ µs, $I_{GM} =$ (3~5) I_{GT}， tw ≥20 µs, 50 Hz, 60 s	
C6	Endurance: AC blocking	IEC 60747-6	1000 h at Tvj max sine wave 50 Hz $V_D = 0.7...0.8\ V_{DRM}$	Note 1
C7	Endurance: Storage at high temperature	IEC600 68-2-2 1031.4 7021 B-10	1000h at Tstg max	Note 1
C8	Sealing (capsule package only)	IEC 60068-2-17	Helium mass spectrum	

Fig. 8: Group C testing

Group D:				
Examination or Test		Reference Documents and Conditions		
Sub-group	Test Category	IEC & Internal Standard	Conditions	Notes
D1	Endurance: Storage at low temperature	IEC60068-2-1 Aa7021 B-12	500 hours at Tstgmin	Note 1
D2	Endurance: Thermal cycling load (thermal fatigue)	IEC60747-6 IV, 41037.1 7021 B-18	ΔT_{vj} = 80°C ... 100°C 10000 cycles	Note 1
D3	Thermal cycling	IEC60068-2-14 Test Na	Tstgmax~Tstgmin 10 cycles	Note 1
D4a	Shock	IEC60068-2-27 Ea2016.2 7021 A-7	Internal Standard	Note 2
D4b	Vibration (sinus)	IEC60068-2-6 Fc2056 7021 A-10	Internal Standard	Note 2
D5	Salt mist	IEC60068-2-11 Ka1046.2	35°C, 5% NaCl, 7 days	Note 3
D6	Robustness of terminations	IEC60068-2-212036.3A 7021 A-11	Tension, 40 N, 10s	

Fig. 9: Group D testing

Testing methods and test materials can differ among various products and applications. For details, please refer to the product specifications or datasheets.

Notes:

1) Failure criteria for diodes: I_{RRM} ($T_{vj\ max}$) <1.1 USL
V_{FM} <1.1 USL
Failure criteria for thyristors: I_{RRM}, I_{DRM} ($T_{vj\ max}$) <1.1USL
I_{GT}, $V_{GT\ (25°C)}$ <1.1 USL
V_{TM} ($T_{vj\ max}$) <1.1 USL

2) Failure criteria for all devices: Integrity of package materials, wafers, sealing (for capsule types), lead connections.
The device must meet requirements listed under Note 1.

3) Failure criteria for all devices: no significant corrosion.

4. Mounting and Assembly Instructions

4.1. Mounting Requirements

In order to obtain the maximum possible current from a capsule thyristor or diode, double-sided cooling (DSC) is normally used. In this case, the device is clamped between two identical heat sinks. It is also permissible to have single-sided cooling (SSC) only. In the case of DSC, the thermal resistance figures are related to both heat sinks together. Either air-cooled or water-cooled heat sinks can be used. For air-cooled, the heat sinks should be mounted so that their cooling fins are parallel to the flow of cooling air, and located near to an air inlet so that the air is not preheated by other components.

In order to guarantee good electrical and thermal contact, the contact areas of the heat sinks must be cleaned to a metallic shine. The flatness remaining after machining these areas should be 50 µm per in, and the roughness should be less than 10 µm. The contact areas should be coated with a thin (100 µm) layer of thermal compound, such as Penetrox A or A13.

4.2 Instructions for Mounting onto Heat Sink

4.2.1 Air-Cooled Heat Sink

In order to attain the required clamping force specified on the datasheet for the capsule devices, a spring-type clamp that employs either Bellville washers or a flex-spring bar, should be used. The clamp design should provide an even force to the two mounting surfaces. Care must be taken to neither exceed nor fall short of the specified mounting pressure.

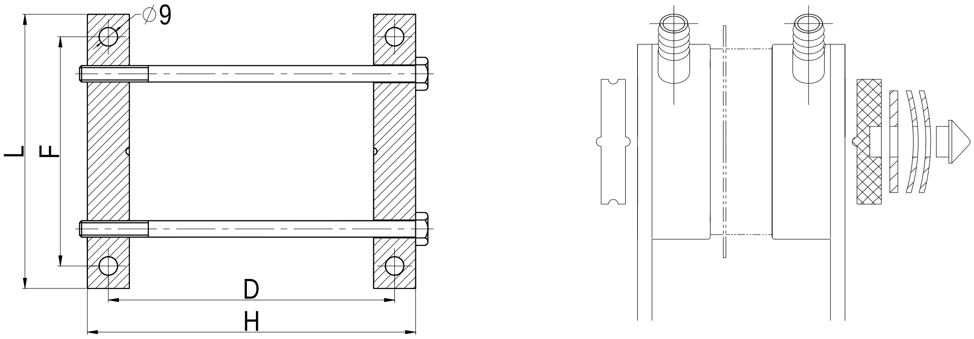


Fig. 10: Sketch of spring-type clamp for air-cooled and water-cooled heat sink

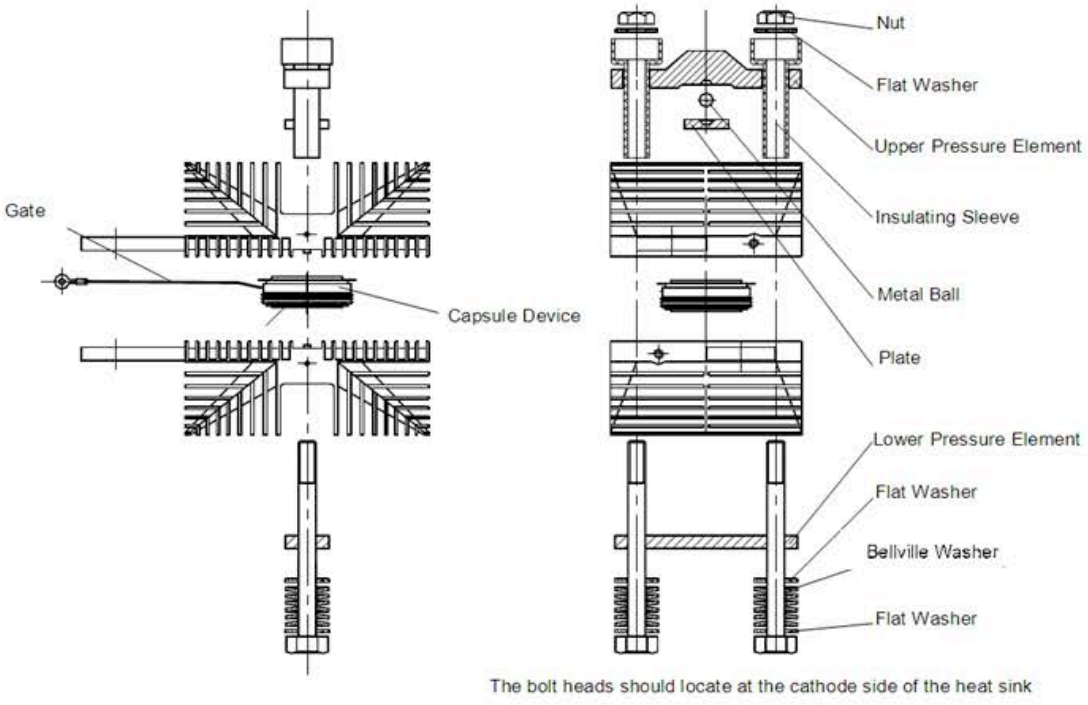


Fig. 11: Drawing of air-cooled heat sink assembly

Example of a capsule thyristor heat sink assembly (for diodes, the same assembly procedure can be used, but without the cable connection with gate):

Step 1: Put the flat washer into the bolt, followed by the superimposed three Bellville washers (spherical upward). Then, put the three reversed Bellville washers into the bolt to form a composite.

Step 2: Insert the two composites under the lower pressure element. Then, insert it into the holes on the heat sink of anode.

Step 3: Place the protruding device on the heat sink of anode (the anode side toward the table, and placed into the pre-reserved hole). Attach the heat sink of cathode.

Step 4: Center the plate on the heat sink connected to cathode. Place the metal ball inside the socket of the plate. Attach the upper pressure element, so that the metal ball targets the socket on it.

Step 5: Insert the insulating sleeve into the holes on the pressure element and insert onto the bolt. Put one flat washer into each upper hole of the insulating sleeve. Then, place the nuts on the bolts.

Step 6: Tighten the two nuts evenly by using torque wrenches so as to achieve the specified torque.

Step 7: Check to make sure the two mounting surfaces remain parallel. Tighten each bolt an additional 1/10th turn. Do not tighten beyond this point.

Fig. 12: Capsule device with air-cooled heat sink

4.2.2. Water-Cooled Heat Sink

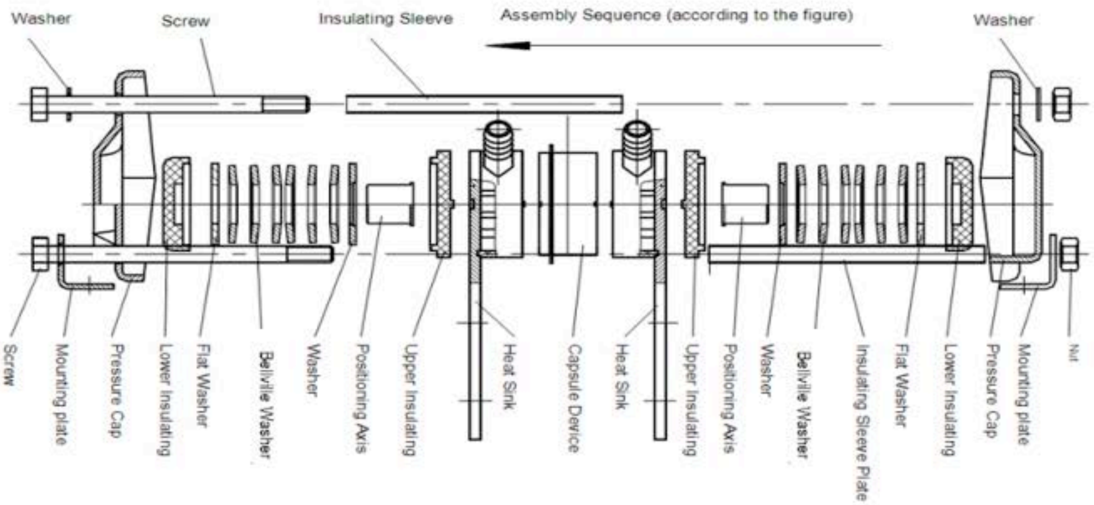


Fig. 13: Drawing of water-cooled heat sink assembly

The required elements and the sequence of parts assembly are shown in Fig. 13. The cathode surface should be flush with the bolt head and should be aligned in that position when assembled. During the assembly, it should be tightened with regular force according to the size of the contact surface (usually 30N per square millimeter), so as to achieve the specified pressure.

It is important that the surface of the heat sink must match the surface of the device. In case of askew or crooked placement, the device can be damaged when pressure is applied. The surface of the device must be completely parallel, concentric to the two heat sinks.

4.3. Using Environmental Conditions

4.3.1. The quality of the cooling water should meet certain requirements: the electrical resistance of the circulating water should not be less than 2.5KΩ and the PH value should be between 6 and 9; the inlet water temperature should not be higher than 35ºC, and the water flow 4-7L/min.

4.3.2. For water-cooled heat sinks, measures for anti-blocking and anti-condensation should be taken along with measures to avoid leakage.

4.3.3. Air-cooled heat sinks should be mounted so that their cooling fins are parallel to the flow of cooling air. The inlet air temperature should not be higher than 40ºC. The inlet air- flow speed should be at least 6m/s.

5. Accessories

The auxiliary connection wires on gates and cathodes should comply with the following requirements:

- The wire will sustainably withstand at least 5A gate current
- The insulation of the wire will be able to resist a temperature of 60ºC
- The tensile strength of the connectors will be >80N. The force required to separate the wire and the device after connection by plug-in or solder will be >16N.

Below is the schematic of a gate and cathode connection wire with standard length:

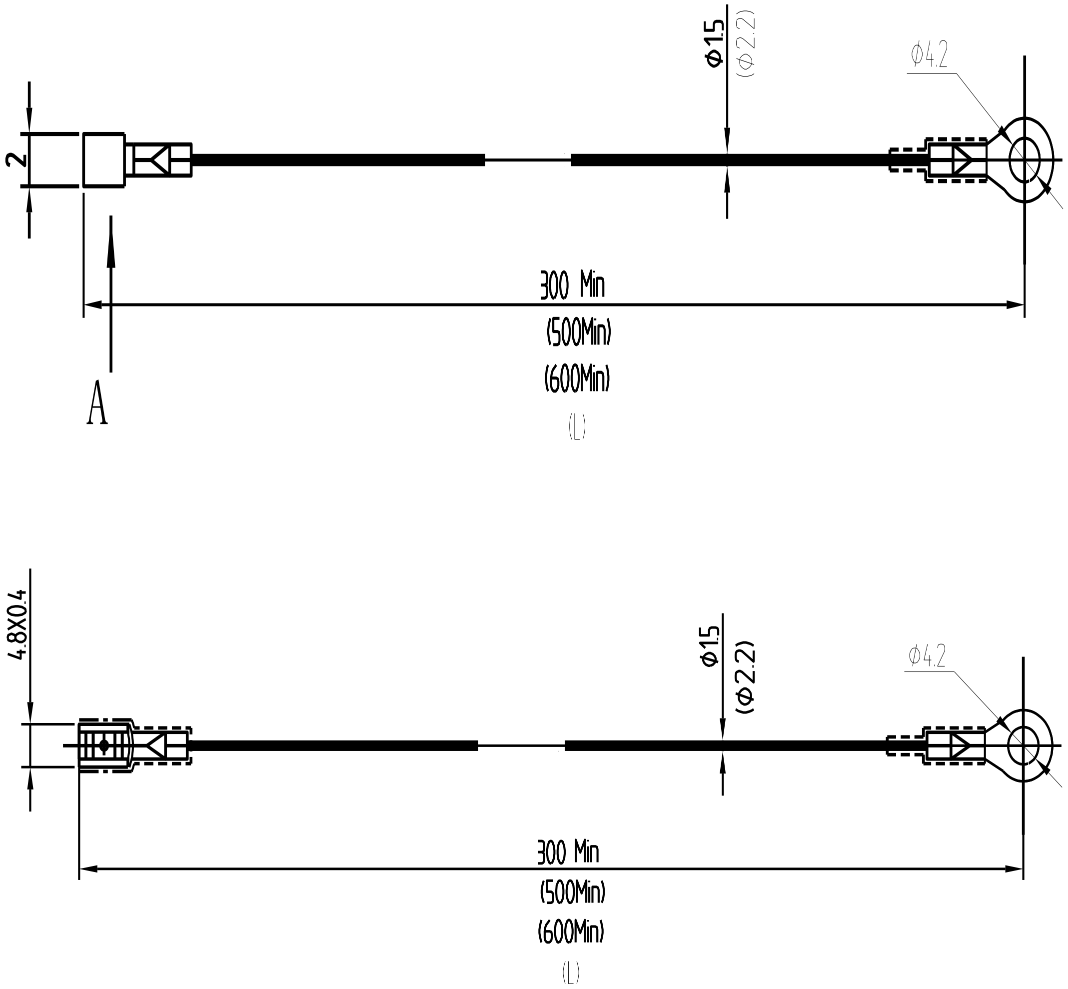


*Fig. 14: A*uxiliary *connection wire for capsule devices*

6. Packaging

6.1. Markings on Product

Fig. 15: Markings on capsule housing

1: Code for capsule devices

2: Chip diameter (mm)

3: Chip type (KP / KK / ZP, please refer to Section 1.1)

4: Code for wafer specifications

5: Code for forward current rating: I_{FAV} / I_{TAV} = Code x 100A

6: Code for reverse voltage rating: V_{DRM} / V_{RRM} = Code x 100V

7: Date code

8: Data matrix code

The Data matrix code contains following information:

- Type description
- Part number
- Measurement line number
- Production tracking number
- Data code
- Continuous number

6.2. Packing Box

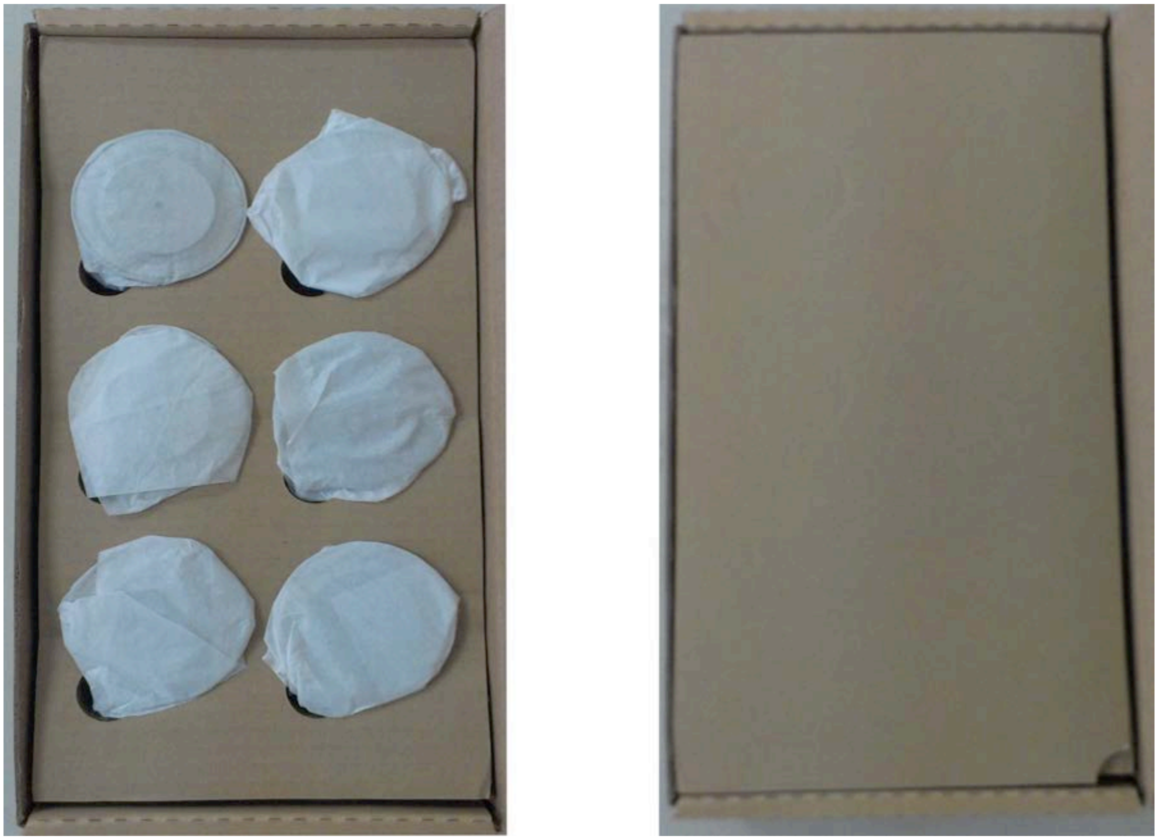


Fig. 16: Packing box for capsule device

Product Name	Minimum Package Quantity (piece)
H89 / H100 / H125 / Y89 / Y100	1
Y76 / H76	2
Y65 / Y70	3
Y38 / Y50 / H38 / H50	6
Y24 / Y30	12

Fig. 17: Quantities per package

A white-colored gate lead cable (to be soldered) for each capsule device is included in the packing box.