High Power Pulse Klystron
E3772A,A
Operating Instructions

* We are appreciating your purchase of our klystron product.
* Please read carefully this instruction manual before operating the klystron tube to use it properly.
* Please keep this instruction manual carefully not to lose.

April, 2019

CANON ELECTRON TUBES & DEVICES CO., LTD.

Contents

1. SAFETY PRECAUTIONS

This operation manual describes important information for preventing injury to users, personnel at manufactures employing this electron tube, and other personnel, as well as for preventing property loss and ensuring safe operation. Fully understand the meanings of the following indications and symbols before reading this manual and observe all precautions to ensure safe operation.

[Description of indications]

Indication	Meaning
DANGER:	Indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury.
WARING:	Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.
CAUTION:	Indicates a potentially hazardous situation which, if not avoided may result in minor or moderate injury or extensive property damage (e.g. damage to machinery, units, and accessories or occurrence of a fire).

[Usage limitation and exception clause]

This electron tube is intended and designed for use in combination with amplifier for industrial devices and scientific equipment. If this electron tube is to be used with equipment other than the above, contact CANON ELECTRON TUBES & DEVICES CO., LTD. (CETD) in advance. CETD will not be held responsible for malfunction or damage caused by the use of this electron tube in applications other than those specified without prior approval.

When designing or operating equipment employing the electron tube, do not attempt to modify the electron tube and do not allow the electron tube to be operated beyond its ratings. CETD will not be held liable if these precautions are not observed.

[Warning labels]

(1) Warning labels as described in this instruction manual are attached to the electron tube. Confirm that they are attached correctly before operating the electron tube. If incorrectly attached or missing labels are found, Contact CETD.
(2) Read all the labels and fully understand their meanings to ensure safe operation of the electron tube.
(3) Maintain the labels so that they can be seen easily. Do not remove any labels or allow them to become dirty, covered, or otherwise obscured.

[Manufacturing equipment, warning indications for equipment, use of the electron tube]

(1) All equipment incorporating this electron tube must be equipped with safety mechanisms as described below.
(2) All equipment incorporating this electron tube and their operations manual must include the warning indications described below to ensure safe operation of the electron tube.
(3) To ensure safe operation of this electron tube, observe the precautions described below.
(4) For any questionable points, consult with CETD before operating this electron tube.

DANGER

(High voltage)

High voltage is supplied to the electron gun section and the ion pump section of this electron tube.

(1) The main body (body terminal) of this electron tube is used as the circuit return wire (ground wire). Securely connect it with the circuit return wire (ground) of the equipment together with the focusing coil to ensure proper grounding.
(2) Place a cover or cage around the high-voltage section to prevent it from being touched. The circuit must be designed so that a switch on the door cuts off high voltage and discharges the capacitor of the high-voltage section when the cover or cage is opened.
(3) Before replacing or performing maintenance work on the electron tube, be sure to turn OFF the power switch and discharge all residual charge by touching each electrode of the electron tube with a ground rod. Pay particular attention to the charge in the capacitor of the high-voltage section.
Never disable the door switch when the cage is open. At least two workers are required for replacement or maintenance work to ensure safety. (A person who has received training in cardiopulmonary resuscitation should be present.)
(4) When connecting / disconnecting the ion pump, be sure to turn OFF the ion pump power supply and confirm safety.

(Electromagnetic radiation)

Observe the following precautions to prevent exposure to harmful high-frequency electromagnetic radiation (in particular, to avoid the risk of eye damage) and to prevent telecommunication devices from being adversely affected:

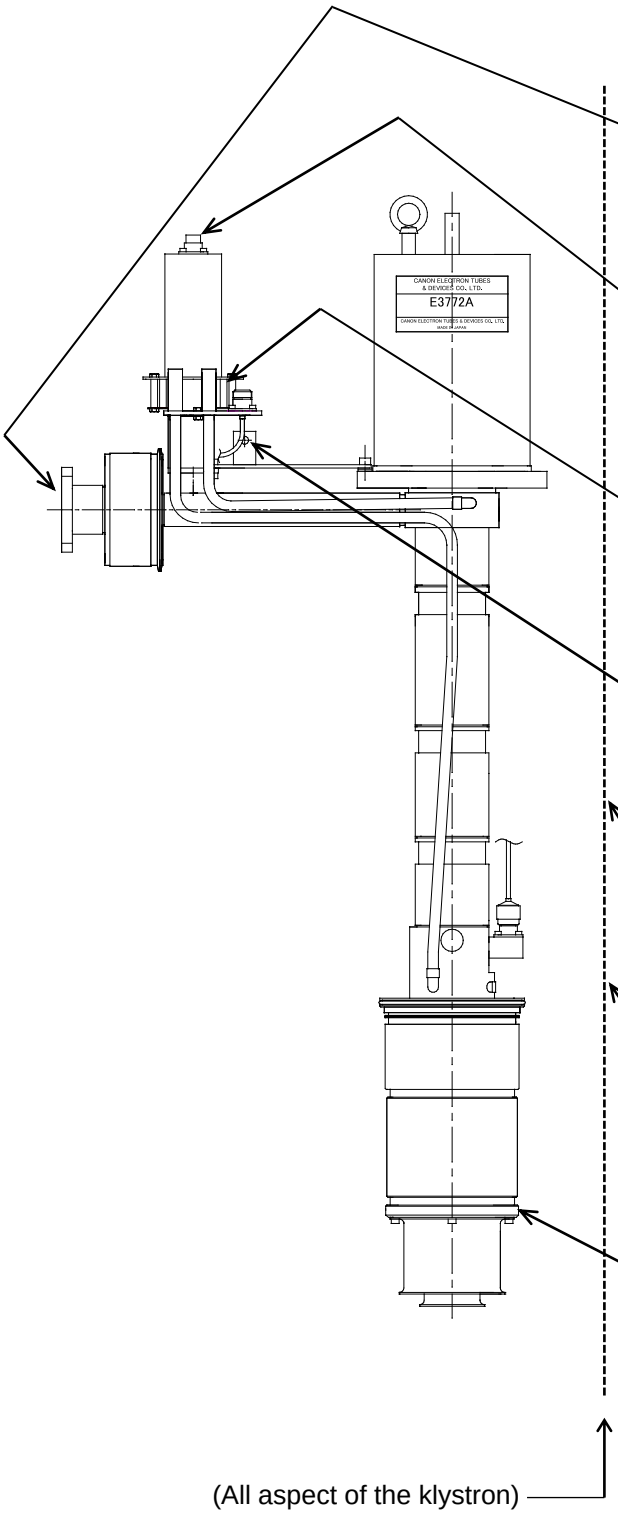
(1) Never supply high voltage when the high-frequency load (output waveguide) is not connected to the high-frequency output section.
(2) To prevent high-frequency leakage due to connection failure in the high-frequency output section and the high-frequency load, securely connect the coaxial tube, the waveguide, and the shield cover.
(3) Do not modify or remove the high-frequency contact elements such as the gasket of the cavity/output sect ion, the finger, etc. of the electron tube.
If an electromagnetic shield is mounted, do not remove or modify it.
(4) Evaluation of electromagnetic radiation leakage must be performed with the electron tube and the high-frequency load mounted in the equipment.

WARNING	
 **(X-ray radiation)**	An electron tube with a tube voltage of more than 10 kV will generate X-rays. X-ray generation increases as the voltage and current are increased. (1) Perform thorough evaluation for X-ray leakage for the equipment used in combination with this electron tube. Add shielding appropriate for the installation and operating conditions as required. Checks for X-ray generation must be performed both when high frequency output operation is performed and when it is not performed. (2) If an X-ray shield is already mounted, do not remove or modify it. (3) Since the amount of X-ray generation may change over time, perform X-ray checks periodically.
 **(Magnetic field)**	About 0.3-tesla intense magnetic field is used for this electron tube. The ion pump magnet used in this electron tube generates 0.13-tesla intense magnetic field. (1) Persons with cardiac pacemakers must not engage in the handling, operation, or maintenance of this electron tube. (2) The magnetic field of the focusing coil has been precisely adjusted. Do not allow any permanent magnets or magnetic objects to come near the electron tube or focusing coil. They will be attracted by the magnetic field, possibly resulting in personal injury or damage to the electron tube. (3) Do not place magnetic cards, hard disk drives, etc. near the electron tube.

CAUTION	
(Handling)	Only qualified engineers or persons who have received the specialized training listed below are permitted to handle this electron tube. The types of specialized training required are as follows: (1) High-voltage work (4) Slinging work (2) X-ray work (5) Crane operation (3) High-frequency work (6) Electrical device work Read the operation manual carefully and fully understand the contents before handling the electron tube.
 **(Temperature, Heat)**	The following sections of the electron tube become very hot during operation: Surface of the output waveguide : about 60 degrees centigrade Surface of the focusing magnet : about 60 degrees centigrade (Room temperature of 20 degrees centigrade) (1) Do not touch any of the sections listed above during operation or immediately after operation. (After operation is stopped, the above parts will remain hot for a while.) The high temperature of these sections may cause a burn. (2) In tubes with evaporative cooling, the cooling water in the cooling-water tank is very hot, reaching temperatures near 100 degrees centigrade. Be extremely careful when handling it. Before disconnecting tubing, confirm that the cooling water has cooled sufficiently.

CAUTION	
(Weight)	Weight of this electron tube is about 35 kg. Be careful when handling this electron tube because it is very heavy. (1) Be extremely careful to ensure safety when shifting, moving, or installing this electron tube. (2) Be careful not to subject this electron tube to excessive vibration or shock because it is a precision device. (3) Use the standard packing case provided by CETD to carry or store the electron tube.
(Caution)	Use the frequency specified by laws, regulations, or standards.
(Caution)	Note the following when handling damaged or used electron tubes: (1) When handling a tube that has fractured, wear protective gloves, protective glasses, etc. because the ceramic or metal fragments are sharp and very dangerous. (2) Dispose the scrapped products according to the requirement of local regulation. If you have any questions, please contact to our local sales representatives for further information. (3) The main materials used in this electron tube are as follows: Copper, Stainless steel, Malleable iron, Nickel/iron alloy, Tungsten, Molybdenum, Alumina ceramics Note that no radioisotopes or beryllia porcelain are used. (4) Lead is used for the X-ray shield of this electron tube. Do not abrade or melt the lead because lead powder or vapor is harmful if it comes into contact with the skin or is ingested. For lead disposal, consult with specialized disposal personnel.
(Caution)	Before operating this electron tube, confirm that the cooling unit operates normally. (1) Excessive temperatures due to interruption of cooling air or water may result in damage to the tube, smoking, or a fire. (2) It is recommended that various sensors such as an airflow sensor, a water flow sensor, a pressure sensor, a thermometer, and/or a smoke sensor be provided to protect the tube.
(Caution)	Perform periodic inspection. (1) Dust from the air may build up on the electron gun section or collector section over time, leading to deterioration of withstand-voltage characteristics and interfering with cooling. (2) For devices in which insulation oil is used, dirty oil may lead to deterioration of the withstand-voltage characteristics. Ensure that the insulation oil is always clean.

Fig.1 Explanation diagram concerning safety



⚠ Danger Electromagnetic wave

Do not operate the klystron tube with the output waveguide disconnected. Output power of high frequency is about 7.5 MW and it can cause death or serious injury.

⚠ Danger High voltage

Do not remove the safety cover and touch while operating. DC voltage of 3.5 kV can cause death or serious injury.

⚠ Warning Magnetic field

The magnetic field of 0.13 tesla generated by the permanent magnet can cause to suck an iron product and scissors.

⏚ Ground

Please connect a ground line surely.

⚠ Warning X-ray radiation

X rays are radiated from all aspects of the klystron. There is fear of injury caused by the X-ray radiation.

⚠ Warning Magnetic field

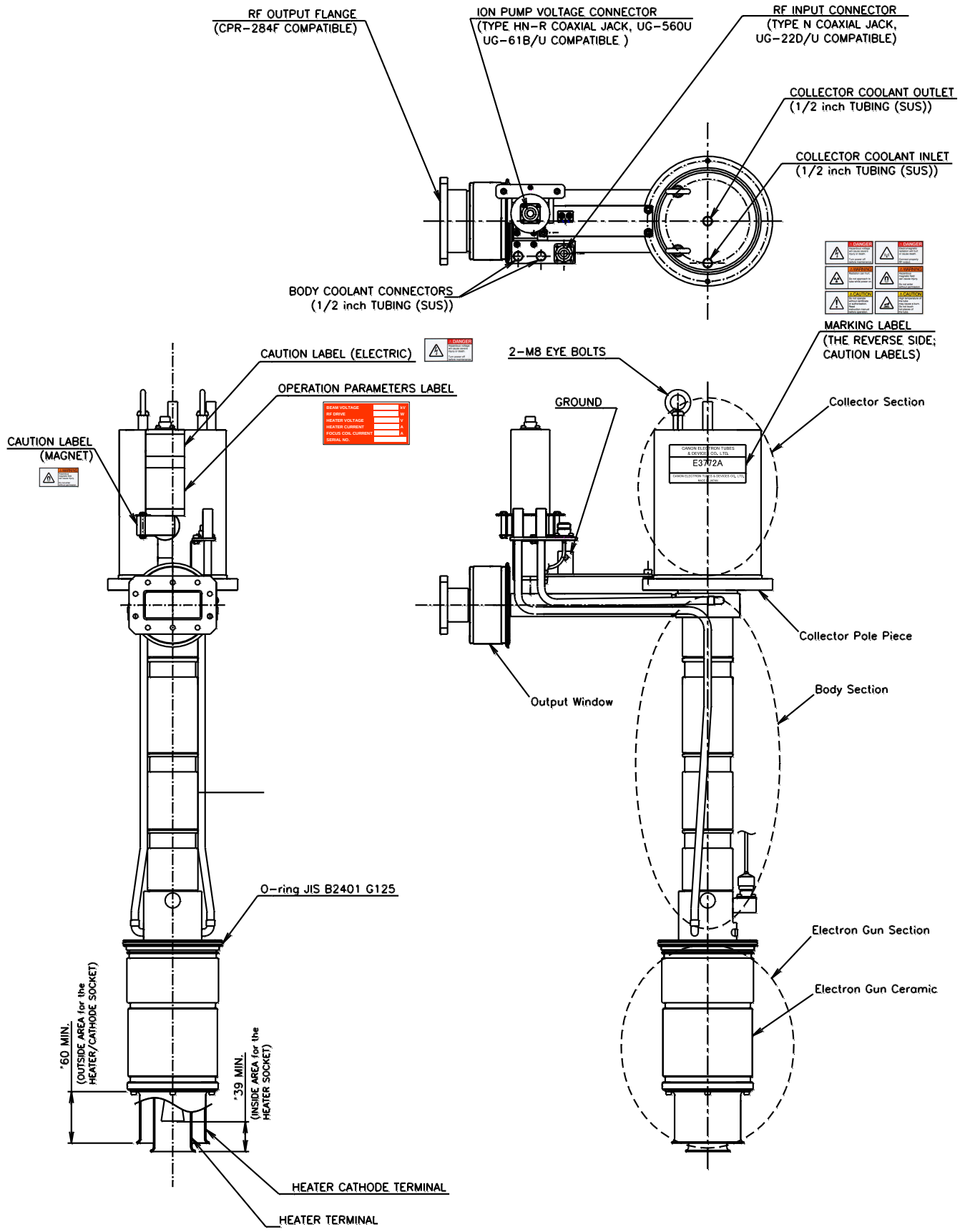
The magnetic field of 0.3 tesla generated by the focusing magnet can cause to suck an iron product and scissors.

⚠ Danger High voltage

Do not remove the safety cover and approach and touch this section. Pulse voltage of 155 kV can cause death or serious injury.

2. EACH PART NAME OF KLYSTRON TUBE

UNIT : mm



3. Marking labels

(1) Caution labels (Collector side)

Dimension : 125 x 95 mm

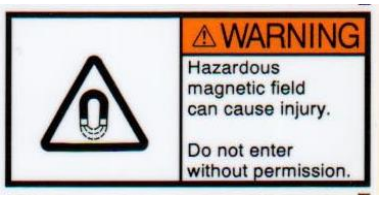
Material : Aluminum film

(2) Caution label (Terminal for the ion pump power supply)

Dimension : 63 x 32 mm

Material : Aluminum film

(3) Warning label (Magnet of the ion pump)



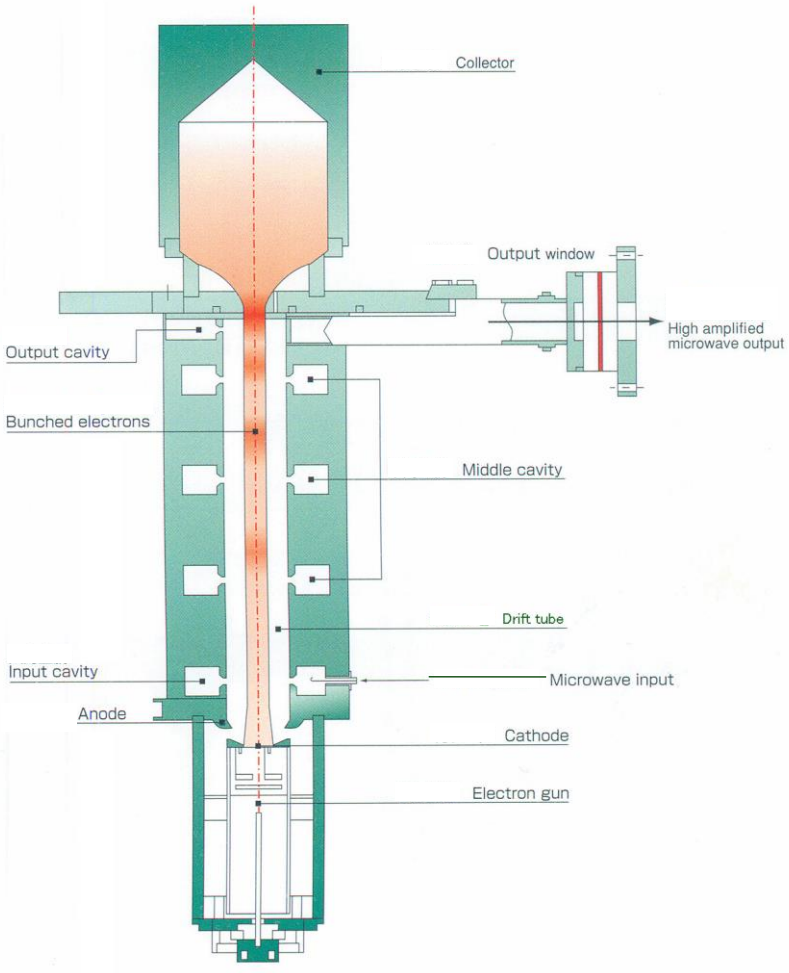
Dimension : 48 x 24 mm

Material : Aluminum film

4. Structure and theory of operation

4.1 Theory of operation

A high-power klystron with multi cavities consists of an electron gun, interaction cavities for Radio Frequency (RF), a collector, an output window and an ion pump. At the electron gun section, a heated cathode emits electrons and high voltage which is applied between the cathode and an anode generates an electron flow called an electron beam. The electron beam is focused by the electric field formed by the cathode and the anode electrodes under the influence of the magnetic field formed by a focusing magnet. Interaction section of RF consists of a drift tube and some cavities. When RF drive power is inputted into the input cavity which locates near the electron gun section, amplified RF power is outputted from the output cavity near the collector section. When RF drive is inputted into the input cavity, voltage is generated at the gap of the input cavity. This voltage modulates the velocity of the electrons. The electrons go forward in the drift tube and then density of the electrons is modulated by difference of the velocity. Resonant frequency of the intermediate cavity is tuned to frequency of the density modulation. The electrons reach next cavity and velocity is modulated further by voltage at the gap of the intermediate cavity. The electron beam has ingredient of RF power much higher than the drive power consequently. The electron beam passes through the output cavity finally and RF power of the modulated electron beam is outputted at this cavity. The amplified RF power passes through the waveguide and is outputted to outside. The electron beam which passed interaction cavities reaches collector section and the energy of the electrons is absorbed at this section. A large amount of heat is generated in the collector caused by the energy of the electron beam. Therefore, the collector needs to be cooled. According to amount of the loss, cooling method is selected to air-cooled, water-cooled, evaporation-cooled and so on.



4.2 Outline of the design

This klystron tube consists of following sections.

a. Electron gun section

The electron gun section consists of a cathode electrode, an anode electrode, and an insulating ceramic. An impregnated cathode (Iridium-coated M-type dispenser cathode) is adopted for E3772A,A.

b. RF interaction section

The RF interaction section consists of five resonant cavities and a drift tube. The cavities and the drift tube are cooled by water.

c. Collector

The collector is cooled by water.

d. RF Output section

The RF output section consists of an output waveguide and a pillbox type output window made from alumina ceramic.

e. Ion pump

The ion pump keeps high vacuum degree in the klystron tube.

4.3 Characteristics of the tube

E3772A,A is a high power pulse klystron especially designed to be used as a high power microwave source for a linear accelerator. E3772A,A can deliver peak output power of 7.5 MW with a pulse width of 5.0 micro-seconds at frequency of 2856MHz. The focusing magnet of VT-68934,E is available.

4.3.1 Mechanical characteristics

Dimensions	See outline drawing
Weight	Approx. 35 kg (without the X-ray shielding kit)
Mounting position	Vertical, cathode down
Cooling	Liquid

4.3.2 Connections

RF input connector	Type “N” 50 ohms coaxial; UG-22D/U compatible
Output waveguide	WR284
RF output flange	CPR-284F compatible
Ion pump	HN-R, UG-61B/U compatible
Filament/Cathode	
Heater/Cathode	Mate with socket
Heater	Mate with socket
Cooling water	
Collector	1/2-inch metal tube
Body	1/2-inch metal tube

4.3.3 Electrical characteristics

Frequency	2856 MHz
Pulse width (RF)	5.0 μs
Peak RF output power	7.5 MW
Average RF output power	8.5 kW
Peak forward beam voltage	160 kV
Peak cathode current	116 A
Peak drive power	80 W typ.
Efficiency	40% min.

Heater voltage	15.5 V typ.
Heater current	12.5 A typ.

4.3.4 Absolute ratings

Parameters		Symbol	Units	Max.	Min.
Frequency		f	MHz	2858	2854
Heater voltage		Ef	V	20	---
Heater current		If	A	18	---
Heater current (surge)		If (surge)	A	20	---
Cathode warm-up time		tk	minutes	---	30
Peak forward beam voltage		epy	kV	165	---
Peak inverse beam voltage		epx	kV	20	---
Peak cathode current		ik	A	120	-10
Peak drive power		pd	W	120	---
Peak RF output power		po	MW	8.5	---
Average RF output power		Po	kW	10	---
Collector dissipation		Pcol	kW	20	---
Pulse width(duration) (epy)		tp(epy)	μs	8.5	---
Pulse width(duration) (rf)		tp(rf)	μs	6.0	---
Pulse repetition rate		prr	pps	250	---
Ion pump voltage		V ip	kV	3.8	3.2
Load VSWR		σL	VSWR	1.4	---
Coolant flow	Collector	Qw,c	L/min	---	25
	Body	Qw,b	L/min	---	10
Inlet coolant temperature		Tw,i	centigrade	40	5
Coolant pressure	Collector	Pw,c	MPa	0.8	---
	Body	Pw,b	MPa	0.8	---
Waveguide pressure		PW/G	MPa	0.3	0.1
(Gauge pressure)			(kgf/cm^2	3.0	1.0)

5. Related device and notes

5.1 Accessories

E3772A,A includes following accessories.

Magnet for the ion pump

5.2 Related devices

The following devices are needed to operate E3772A,A besides the accessories.

Focusing magnet VT-68934,E (Optional)

X-ray shielding kit VT-69133 (Optional)

Ion pump power supply and cable (Optional)

5.2.1 Devices necessary for installation

a. Carrying device such as a hoist etc.

A crane whose height of lifting up is more than 1.5m plus the height of the oil tank is necessary for installing the klystron tube.

b. Stand for the klystron tube

5.2.2 Devices necessary for operation

a. RF Driver

Frequency: 2856 MHz, Output power: more than 120 W (measured at the input terminal of the klystron tube)

b. DC power supply for the focusing magnet

Main electromagnet: DC voltage 160 V, DC current 40 A

Counter electromagnet: DC voltage 5 V, DC current 30 A

Stability of current: +/-2% max.

c. Ion pump power supply

Voltage: 3.5 +/-0.3 kV

d. Heater power supply

Voltage: 20 V max. Current: 18 A max.

e. High voltage power supply

Voltage of the High voltage power supply must be continuous from 80 kV to the rating voltage. The accelerating electrode (tube body) must be connected to ground since accelerating electrode and output waveguide are same potential in the klystron tube. The cathode electrode must be connected to high voltage with negative polarity. Inverse voltage of HV pulse must be less than 20 kV.

5.2.3 Measurement item

To operate the klystron tube, measure following items.

a. Heater voltage, Heater current

Measure the voltage and current for the heater by using a voltmeter and an ammeter.

b. Waveforms of the HV pulse

Measure the peak voltage, peak current and width of the HV pulse imposed to the tube.

c. RF pulse

Measure peak power of the input RF pulse, peak power of the output RF pulse and pulse width of the input and output RF pulse.

d. Vacuum

Measure current of the ion pump.

e. Gas pressure in the waveguide

Measure pressure of the SF_6 gas in the output waveguide.

5.2.4 Load condition

Pressurize the output waveguide with SF_6 gas. The voltage standing wave ratio (VSWR) must be less than 1.4 : 1. A Protection interlock which detects discharge or reflection power and stop inputting RF power or applying the high voltage is necessary to prevent the VSWR from exceeding 1.4 : 1. Output power of the klystron is measured under the condition of the VSWR with 1.2 : 1 or less at the factory test.

5.2.5 Oil tank

The electron gun section must be operated in insulating oil with insulation voltage of 30kV/2.5mm or more. Be sure that oil level exceeds the regulated level.

5.2.6 Cooling

The cooling circuits are two (2) for the tube and they cool the collector, the body. Coolant shall be LCW (Low Conductivity Water). When coolant flow is less than the regulated value, the interlock should stop applying the high voltage and the heater voltage. If there is a risk of freezing, drain the coolant. Please follow the following ratings about cooling the klystron tube and the focusing magnet. Cool the output waveguide if necessary.

	Collector	Body	Focusing magnet
Coolant flow min.	25 L/min.	10 L/min.	10 L/min.
Coolant temperature max.	40 degrees	40 degrees	40 degrees
Coolant pressure max.	0.8 MPa	0.8 MPa	0.8 MPa

The coolant water requires the following quality.

pH factor	7 - 9
Dissolved oxygen	max. 1 - 6 ppm
Resistivity	min. 10 kΩ-cm
Particle-matter size	max. 50 μm (325 mesh)

5.3 Operating hazards

E3772A,A is a klystron operated with high output power and high voltage. Therefore, please note the following points for safety and protection of the tube.

5.3.1 High voltage

This tube operates at high voltage. So that, equipments, electromagnet and klystron must be designed so that personnel cannot come in contact with operation voltages.

5.3.2 X-ray radiation

Operating personnel must be protected by appropriate X-ray radiation shielding. Adequate X-ray shielding should be installed for this tube. X-ray signs or labels must be permanently attached on the equipment to notify operating personnel never to operate this device without X-ray shielding in place.

5.3.3 Microwave radiation

Exposure of the human body to microwave radiation in excess of 1mW per square centimeter is unsafe and can result in blindness or other injury. Personnel must be fully protected from the microwave energy which radiates from this device. All input and output RF connections, waveguide flanges, and gaskets must be RF leak proof and properly engaged. Never operate this device without a microwave-energy-absorbing load. Personnel must be prevented from looking into open waveguide or antennas while this device is energized. Equipment must be designed to protect all the personnel from the hazards. The label and caution notices must be provided on the equipment and tin the manuals warning clearly of these hazards.

5.3.4 Protecting instrument

The following protection interlock is necessary to protect the klystron tube from change of the power-supply voltage, breakdown of the focusing magnet and the cooling system, and unexpected abnormal circumstances.

Item	Protection action value	Point of action	Action Speed
Cathode warm-up time	Within specified time	No application by high voltage	–
Oil level	Oil surface is under the specified surface level	Beam high voltage application paused	Medium
Ion pump current	More than a specified value（Regular operation value plus 2 μA）	Beam high voltage application paused	High
Water-coolant Flow （Collector and body）	Less than maximum ratings	Heater high voltage application paused Bean high voltage application paused	Medium
Inlet coolant Temperature	Maximum rate more than（40℃）	Heater high voltage application paused Beam high voltage application paused	Medium
Heater Voltage	Out of the specified rate ±5% for each klystron	Beam high voltage application paused	Medium
Heater Current	Out of the specified rate ±5% for each klystron	Beam high voltage application paused	Medium
Beam Voltage	Exceed the normal value plus 5% or the maximum rating	Beam high voltage application paused	High
Beam Current	Exceed the normal value plus 10% or the maximum rating.	Beam high voltage application paused	High
Beam Inverse Voltage	Exceed the rated value（20kV）	Beam high voltage application paused	High
Load Waveguide Arc	Discharge within waveguide	RF application paused	High
Focusing magnet current	Out of the specified rate ±5% for each klystron	Beam high voltage application paused	High
Focusing magnet voltage	Out of the normal value ±10%	Beam high voltage application paused	High
Water-coolant flow for focusing magnet	Less than the specified value	Beam high voltage application paused Power supply for magnet paused	Medium
Inlet coolant temperature for focusing magnet	Less than the specified value	Beam high voltage application paused Power supply for magnet paused	Medium
Load waveguide pressure	Degradation of waveguide pressure	RF application paused	High

(Attention) The definition of action speed indicated in the table is as following.

Medium Speed - Have a high velocity with about 100 ms

High Speed - Activate as fast within 30 ms（possibly next pulse will not be applied）

6. Explanation of operation and maintenance

6.1 Installation

A crane whose height of lifting up is more than 1.5 meter is necessary for installing the klystron tube. Following instruments are necessary to set up the tube.

Focusing magnet VT-68934,E	1 pc
Ion pump power supply and cable	1 set
X-ray shielding kit VT-69133	1 set

6.1.1 Unpacking

A carrying device such as a hoist is necessary since the weight of the tube is approximately 35 kg. The klystron tube is packed with a double box. The weight of the whole packing is approximately 100 kg. The tube should be unpacked with following procedure.

1. Remove the outer-box lid.
2. Remove the two cushions on the upper side of the inner-box.
3. Lift up and take out the inner-box from the outer-box by using a hoist etc. Or, remove the sideboard of the outer-box and take out the inner-box.
4. Stand the inner-box with the collector-side up.
5. Remove the lid and the front board of the inner-box.
6. Remove the holding board on the electron gun section.
7. Remove the two fixed screws (M6 bolts) on the pole piece of the collector. In this case, prevent the tube from falling down by lifting the tube lightly from two eyebolts on the collector.
8. Lift up the tube from the hanging part (two eyebolts) on the collector and take out the tube from the inner-box by moving the tube to horizontal direction. At this time, the tube is lifted with a hoist from the upper part of the collector. Lift up the tube perpendicularly with care so that the electron gun section does not touch the surroundings. The electron gun section, the output waveguide, the ion pump and the cooling pipes are weak part. Therefore, take care of not knocking them.
9. Put the tube on the stand with fixing at the pole piece of the collector. Or install the tube to the socket according to the procedure written in next clause.

6.1.2 Installation

The klystron tube unpacked from the inner-box should be installed according to the following procedure.

1. Put the focusing magnet on the oil tank.
2. Remove the upper flange (divided to two) of the focusing magnet. Remove the flange before inserting the tube into the magnet since the tube cannot be inserted.
3. Lift up the tube from the hanging part on the collector and carry the tube over the center of the magnet hole. Insert the tube into the focusing magnet. In this case, pay attention to the position of the tube and the focusing magnet. It is necessary to set the phase between the position of the output waveguide and the cut part of the focusing magnet. Set the X-ray shielding around the output cavity and the output waveguide. Set the upper flange of the focusing magnet with the tube lifting up after inserting the tube. In this case, confirm the flatness between the pole piece of the tube and the upper surface of the focusing magnet. Set the X-ray shielding kit on the collector.
4. Make sure that the level of the insulation oil is higher than the regulated level.
5. Remove the cover of the output flange on the tube and connect it with output circuit. In this case, take care of not applying excessive force to the output waveguide of the tube. Furthermore, make sure that there is no dust and stain in the waveguide that cause discharge or deterioration of vacuum. Put a contactor between the flanges since it is necessary that both flanges contact each other electrically. Make sure no leakage on the joint part of the flanges since inside of the waveguide should be pressurized by SF_6 gas.
6. Connect a cable to RF input.

7. Connect the ion pump to the power supply. After connecting, confirm that the current of the ion pump is less than 5 micro-amperes. If the tube is not used for long time, the current of the ion pump may be several tens of microamperes. In this case, wait a minute and then confirm that the current of the ion pump is decreased to be less than 5 micro-amperes.
8. Connect coolant circuit to the tube and the focusing magnet.
9. Wire the electrical terminal of the focusing magnet. The electrical terminal is at the side of the focusing magnet.

6.1.3 Check

After installing the tube and before starting operation, check the following items.

1. Current of the ion pump
   Check the vacuum degree. Over current relay which stop applying the high voltage should be set as the regular operation value plus 2 micro-amperes.
2. Pressure of the output waveguide
   Confirm that the output waveguide is pressurized with SF_6 gas of regulated pressure.
3. Coolant flow
   Confirm that the coolant flow is the regulated rate or more. Set the interlock level to stop the power of the heater and the focusing magnet when the coolant flow is less than the regulated rate. The coolant temperature should be 40 degrees centigrade or less.
4. Heater
   The heater current should be within +/-2% of the specified value for each tube. Surge current of the heater must not exceed 20A. Set point of the protection unit motivated by the heater current should be within +/-5% of the specified value for each tube.
5. Current of the focusing magnet
   Confirm that stability of the power supply for the focusing magnet is within +/-2%. The current of the focusing magnet should be within +/-2% of the specified value for each tube. Set point of the protection unit motivated by the current of the focusing magnet should be within +/-5% of the specified value for each tube.

6.2 Operation

6.2.1 Start

When operate a new tube or a tube stored for a long time, start the operation according to the following method.

1. Preheating of the cathode
   After applying the heater voltage, preheat the cathode for the specified time. (Preheating for 1.5 times long of the specified time is preferable to use the klystron with stably.) Immediately after applying the heater voltage, the current of the ion pump may be increased to several tens of microamperes. In this case, it is not abnormal situation if the current of the ion pump is decreased after preheating. Confirm that the current of the ion pump is less than 10 micro-amperes after preheating even if the increase of the current of the ion pump is seen.
2. RF output from the output waveguide
   There is a possibility to arcing in the output waveguide which newly outputs the RF. Therefore, the RF output power should be increased from peak power of several hundred kW to ratings value gradually. The high voltage or the input RF power should be changed to adjust the output RF power.
3. Applying of the high voltage
   When applying the high voltage to a new tube, apply the high voltage from 80kV to specified value each 5kV with confirming no arcing for 5 minutes. Though the tube has already processed for high voltage proof, there is a possibility of arcing by using a tube stored for a long time. In the case of arcing, decrease the beam voltage and then increase the beam voltage to specified value gradually. If the durability of high voltage is deteriorated, conduct the high voltage process. The high voltage process is same manner as for a new tube described above. In the case of the arcing, the vacuum degree in the tube will be deteriorated

and then the possibility of the arcing by the next pulse rises. Therefore, a protection unit which stops applying the high voltage is necessary when the arcing occurs.

6.2.2 Normal operation

Start operation according to the following procedure.

1. Apply the voltage to the ion pump.
2. Flow coolant of the cooling system for the collector and the body. (Specified flow rate or more.)
3. Apply the heater voltage Ef of the specified value and preheat for more than the specified time. When the heater voltage is applied to the tube, the heater current must not exceed the surge current specified in the absolute ratings. In this case, the heater voltage is gradually raised to a specified value so as not to exceed the surge current and then preheat the cathode for the specified time after the heater current reaches the specified value. Ef should be set within +/-2% of the specified value.
4. Flow coolant for the focusing magnet (Specified flow rate or more) and apply the current specified for each tube. The current of the focusing magnet should be set within +/-2% of the specified value
5. Apply the high voltage pulse to the cathode and rise to specified value gradually. When operating with a new tube or a tube stored for a long time or a new output waveguide, RF output power should be raised from several hundred kW to the specified value gradually so as not to damage the tube by arcing
   (Note) In any case of applying the high voltage to the cathode, make sure a load whose VSWR is specified value or less is connected to the RF output part.

6.2.3 Acton of the protection unit

When the protection unit acts, check the following items.

Interlock	Check
Ion pump current	Check the current of the focusing magnet and tube cooling are correct. Make sure that the ion pump current has returned to the normal value.
Coolant flow	Make sure there is no leakage in the circuit.
Heater current	Make sure there is no open or short circuit.
Focusing magnet coolant flow	Make sure there is no leakage in the circuit.
Focusing magnet current	Make sure there is no open or short circuit.
Waveguide pressure	Check the gas pressure level is in the proper range.
Beam current	Make sure the ion pump current has returned to the normal level. Check the applied high voltage is in the normal operation range.
VSWR in waveguide	Check the pressure gauge is in normal operation range.

6.2.4 Stop

Stop the operation according to the following procedure.

1. When stop the operation, follow opposite of the starting procedure.
2. After stopping the heater voltage and the current of the focusing magnet, continue to flow the coolant for 10 minutes or more and to operate the ion pump for 60 minutes or more since the tube and the focusing magnet have a latent heat. We recommend that the ion pump be operated at all the time except for an unavoidable case.

6.2.5 Notes in handling

Please note the following point in the handling of this klystron tube.

1. Use the formal package and cushions for storage and transportation of the tube.
2. Do not apply an excessive vibration or impact to the tube.
3. Do not make the ceramic for the electron gun and the output window dirty. Keep inside of the pill-box clean without dust. The ceramic of the electron gun insulates the high voltage. Therefore, stable operation may be difficult if the ceramic is polluted.

4. Shield the X-ray properly to prevent X-ray exposure.
   It is possible that leakage of the X-ray radiation at the point 1 meter from the center of the tube is decreased to be less than 20μSv/h by using the focusing magnet (VT-68934,E) and the X-ray shielding kit VT-69133 under the condition of po=7.5 MW, tp(rf)=4.5 microseconds, prr=200pps. However, this value does not mean the X-ray intensity which is harmless for the human body. Also, this value does not mean the assured intensity of X-ray leakage for the device. Considerable amount of leaking X-ray radiation is possibly generated from the opening parts at the X-ray shield for leading the coolant pipes at the collector and the output port for the output waveguide on the focusing magnet.

6.2.6 Heater operation

Klystron E3772A,A is no risk to operate once a day ON/OFF of the heater.

To avoid a thermal shock by ON/OFF of the heater, the black heating operation is available. In the black heating operation, 75%(example) of heater voltage is possible as the stand-by mode. Decreasing the heater power at the stand-by mode is effective to reduce the evaporation of the emitter from the cathode. When decreasing the heater power for switchover to the stand-by mode, slow change of the heater voltage is recommended.

6.3 Maintenance

6.3.1 Check

Check the insulation strength of the insulation oil periodically. Check the purity of the coolant periodically.

6.3.2 Maintenance

In case of shutting down operating the device for a comparably long period, prevent the coolant from freezing. If there is fear that the coolant freezes, remove the coolant from the tube. Please operate an ion pump power supply at all the time except for an unavoidable case. Cover the output flange to avoid soiling the ceramic window by dust.

If the focusing magnet is not used during a long period, prevent the coolant from freezing. If it is fear that the coolant freezes, remove the coolant from the focusing magnet.

6.4 Storage

For storage of the klystron tube, store the tube in the transport case or put it in a stand for storage. Operate an ion pump power supply at all the time except for an unavoidable case. When putting the tube to the stand for storage, support the tube at the pole piece flange on the collector. Furthermore, fix the tube to the stand at the pole piece of the collector to prevent falling down. Remove the coolant in the tube and the focusing magnet completely. Cover the output flange of the tube. Be careful contamination and oxidization at the electron gun and the electrode by dust and humidity.

For storage of the focusing magnet, store the magnet in the transport case or put it in a stand for storage. Remove the coolant in the focusing magnet completely and dry the cooling pipe sufficiently before the storage. A little coolant remaining in the cooling pipe causes corrosion of the cupper.

6.5 Transportation

Use the formal package and cushions for transportation of the klystron tube.

6.6 Environment

The klystron tube should be operated and stored in an air-conditioned room in which there is no dust and no vibration and no oil dispersion. Do not operate or store the klystron tube in the following environment:

1. Environment with a lot of caustic gases such as sea breeze, Cl_2, HCl, H_2S, NH_3, SO_2, and No_x
2. Environment with dispersion of water, oil, chemicals, and organic solvent, etc.
3. Environment with strong static electricity
4. Direct sunshine and outdoor exposure environment

7. Inquiries

For further information, please contact CETD at following address.

CANON ELECTRON TUBES & DEVICES CO., LTD

1385, SHIMOISHIGAMI, OHTAWARA-City, TOCHIGI-Ken, 324-8550 JAPAN
PHONE: +81-287-26-6345 FAX: +81-287-26-6060

OVERSEAS SUBSIDIARIES AND AFFILIATES

For Sales & Technical Services, please contact the following representative:

- **SUMITOMO DEUTSCHLAND GMBH**

  GEORG-GLOCK-STRASSE 8, 40474 DUSSELDORF,
  FEDERAL REPUBLIC OF GERMANY
  PHONE +49 (211) 4570-0 FAX+49 (211) 4570-236

- **SUMITOMO CORPORATION OF AMERICAS**

  NORTH RIVER ROAD, SUITE 700, ROSEMONT, ILLINOIS 60018, U.S.A.
  PHONE +1 (847) 384-5200 FAX +1 (847) 384-0560

- **CANON ELECTRON DEVICES & MATERIALS TRADING (SHANGHAI) CO., LTD. (CEMS)**

  RM1606, SH-PLAZA, No.336, XIZANG ROAD (MIDDLE), SHANGHAI, 200001, CHINA
  PHONE 86-21-6361-0077 FAX 86-21-6351-5760