

Operating procedure for a new E3772A,A klystron at the customer site

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When customer operates a new tube or a tube stored for a long time, there is a possibility of arcing in the tube if high voltage of the rated value is applied to the tube from the first pulse. Also, there is a possibility of arcing in the output waveguide which is newly passed through the RF power. Therefore, please start the operation according to the following instructions.

1. Operation procedure for a new tube

Operate by the following order.

Prepare of operation → DC aging operation (Diode mode) → RF aging operation

2. Preparation of operation

Before starting the operation, confirm the following matter.

- a. The klystron and focusing magnet are installed correctly.
- b. The oil level in the tank is higher than the specification limit.
- c. Connect a power supply to the focusing magnet and ion pump and apply the rated voltage and current.
- d. Connect a load with VSWR of 1.2:1 or less to the klystron output port.
- e. Connect a coolant circuit to the klystron and focusing magnet and flow coolant of the specified value or more.
- f. X-ray shields are installed on the upper flange of the focusing magnet correctly.

3. DC operation

a) Preparation

- a. Connect a 50 ohms terminal or the RF amplifier cable to the klystron RF input to prevent noise mixture.
- b. Apply the specified power to the klystron heater. After the heater voltage and the heater current reach the specified value, preheat the heater for the specified time. When the heater power is applied to a cold tube, the heater voltage shall be adjusted from zero to prescribed value so that the heater current should not exceed the specified surge value (20 A). The prescribed value of heater voltage shall be maintained for at least 30 minutes prior to the application of beam voltage.

- c. Confirm that the settings of each item are the following values.
 - 1) Current of klystron heater : Specified value
 - 2) Current of focusing magnet : Specified value
 - 3) Flow rate of coolant
 - Klystron : Specification limit or more
 - Focusing magnet : Specification limit or more
 - 4) Interlocks
 - Refer to table 3.
- b) Schedule of DC aging operation

There are two types of aging manner described below.

 - a. Step type
 - 1) Conduct the DC aging according to the schedule of Table 1 with pulse repetition rate of 20 pps.
 - 2) When step number reaches last number, decrease the beam voltage to around 80 kV and increase the pulse repetition rate to 50 pps and then restart the step form number 1.
 - 3) Repeat the manner, increase the pulse repetition rate to 100 pps.
 - 4) Repeat the manner, increase the pulse repetition rate to 200 pps.

Table 1: Schedule of DC aging (Step type)

No.	Holding time [min.]	Beam Voltage [kV]	Beam Current [A]	Ion Pump Current [μ A]	Step up condition
1	> 5	Approx. 80	Confirm that perveance is within the range from 1.7 to 1.9 μ P.	< 2 μ A	Iion is less than 1 μ A. Holding time is completed.
2	> 5	90			
3	> 5	100			
4	> 5	110			
5	> 5	120			
6	> 5	125			
7	> 5	130			
8	> 10	135			
9	> 10	140			
10	> 10	145			
11	> 10	150			
12	> 10	155			
13	> 10	Target Value			

Note: When increasing the beam voltage, change voltage slowly with confirming that Iion does not increase rapidly.

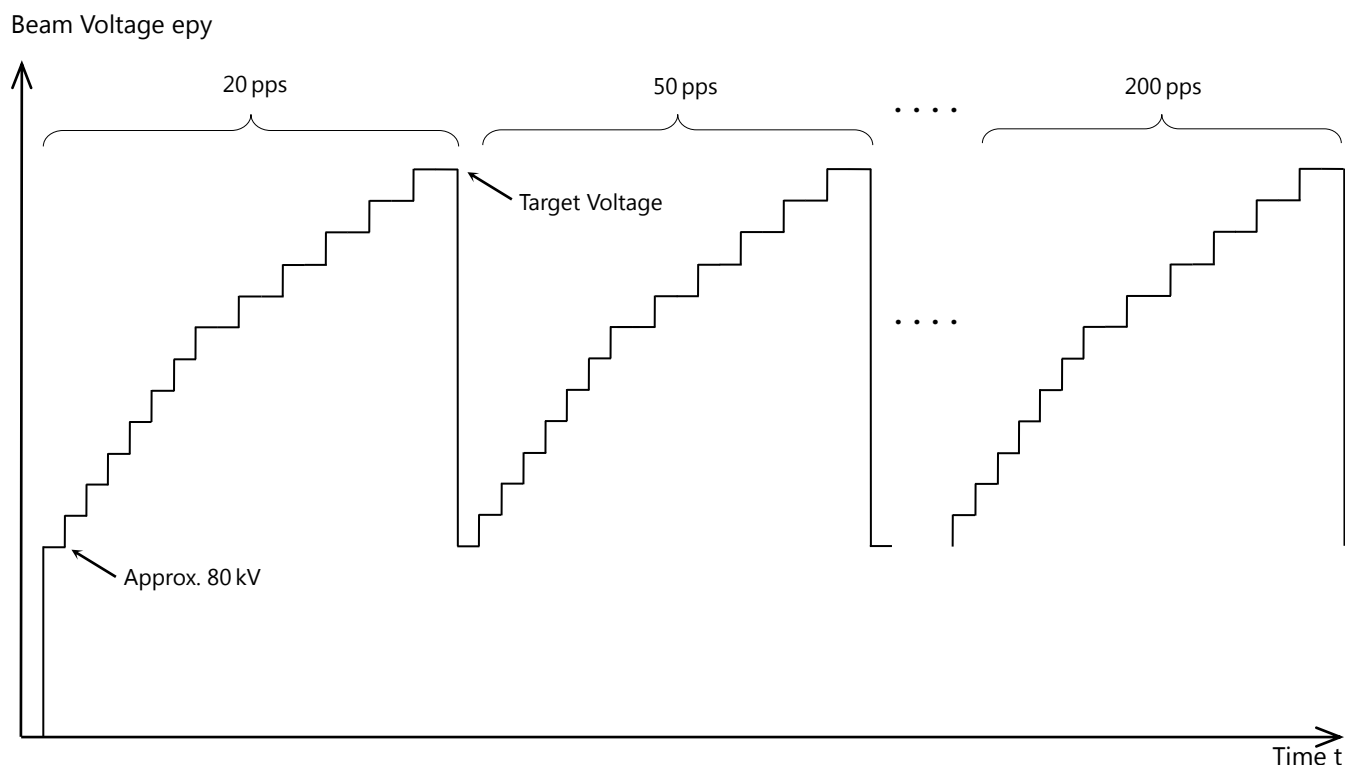


Fig.1: Step up image of DC aging (Step type)

In case of arcing in the tube, stop the operation immediately (The speed on which a next pulse isn't applied is desirable.) After stopping operation, wait a few minutes, confirm stable in the tube vacuum (Ion pump current is less than $1 \mu\text{A}$.), then restart operation of the HV modulator. Set the target beam voltage as 90% of the voltage at which arcing occurred, and increase voltage from 0 kV to the set value with the rate of about 1 minute. Increase voltage from the set value to the voltage at which arcing occurred with the rate of 1/2 holding time in table 1. After beam voltage reaches the voltage at which arcing occurred, resume aging operation with the schedule in table 1.

b. Continuous type

- 1) Start applying at the beam voltage less than 80 kV and gradually raise the beam voltage up to 120 kV. (1-2 hour(s))
- 2) Increase beam voltage from 120 kV to target voltage ($\leq 165 \text{ kV}$) by 10 kV/60 min. When arcing occurs, stop high voltage immediately and set beam voltage to 90% of arced voltage (70% is preferred at the first operation).
- 3) Increase beam voltage to voltage of arcing by 10 kV/10 min.
- 4) Increase beam voltage to target voltage by 10 kV/60 min.

Low repetition rate is better for aging the electron gun. For example, it is recommended that first operation is conducted by 20 pps and then 50 pps and then 100 pps, and then 200 pps, repeatedly.

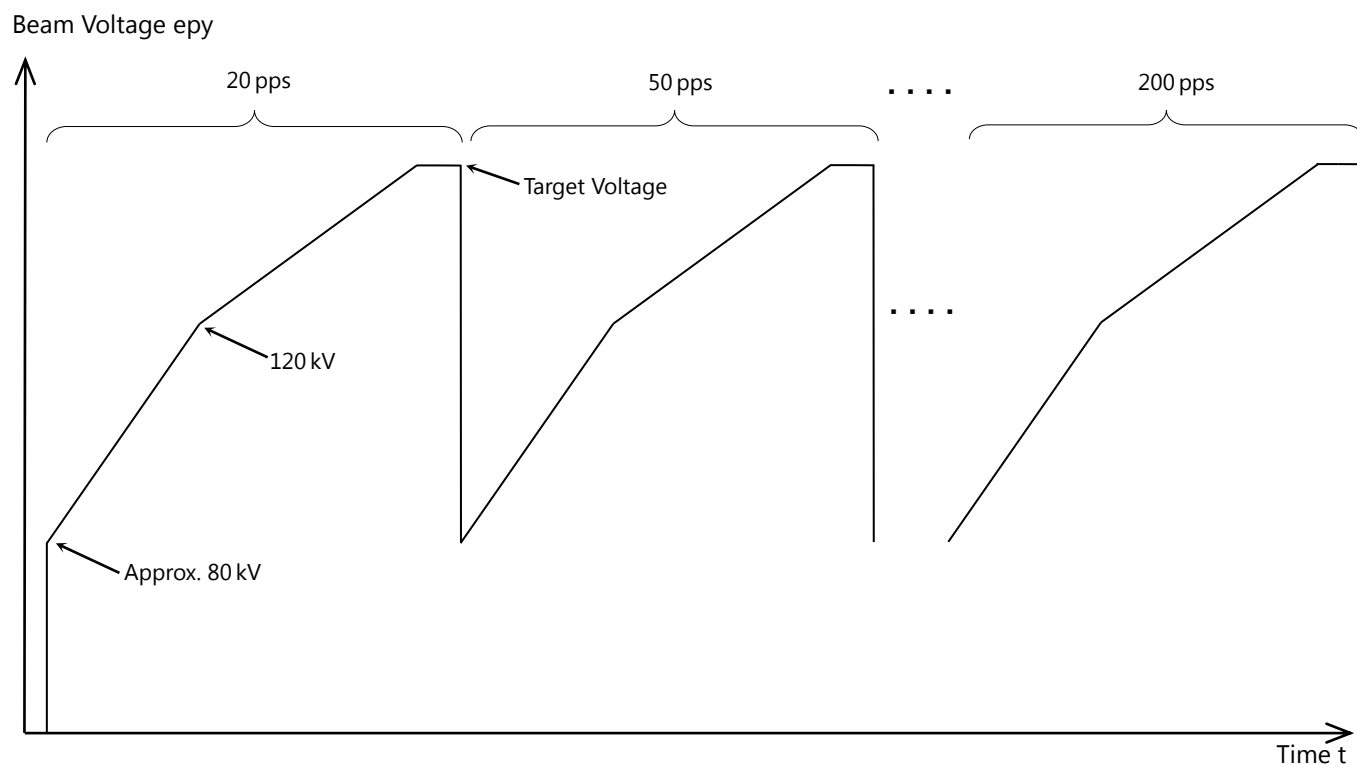


Fig.2: Rising image of DC aging (Continuous type)

4. RF operation

a) Preparation

- a. Connect an RF input and RF monitoring system.
- b. Calibrate the RF input power of the RF monitoring system in order to measure the RF input power correctly.
- c. Confirm each interlock (Ion pump, Arc sensor, Flow rate, Current of focusing magnet, etc.) works correctly.
- d. Pressurize inside of the output waveguide by SF₆ gas. Pressure in the output waveguide must be between 0.1 MPa to 0.3 MPa (Gauge pressure).
- e. Apply the specified power to the klystron heater. After the heater voltage and the heater current reach the specified value, preheat the heater for the specified time. When the heater power is applied to a cold tube, the heater voltage shall be adjusted from zero to prescribed value so that the heater current should not exceed the specified surge value (20 A). The prescribed value of heater voltage shall be maintained for at least 30 minutes prior to the application of beam voltage.

b) Schedule of RF aging operation

Conduct the RF aging according to the schedule of Table 2. Peak power of the input RF should be adjusted to the level at which the output power is saturated. When arcing in the output waveguide occurs, stop the RF input immediately. Shorter the RF pulse width and resume aging operation. If the output waveguide and the load are passed through high power RF at first time, start the aging operation with shorter pulse width and less pulse repetition rate than written in table1 according to the load condition. (0.2 μ s, 10 pps are recommended.)

Table 2: Schedule of RF aging (Example of the factory process)

No.	Beam Voltage [kV]	Step Voltage [kV]	Holding Time [min.]	RF Repetition Rate [pps]	RF Pulse Width [μs]
1	$80 \leq epy \leq 120$	5	10	20	0.5
2	$120 < epy \leq \text{Target}$	2	10	20	0.5
3	$80 \leq epy \leq 120$	5	10	20	1.0
4	$120 < epy \leq \text{Target}$	2	10	20	1.0
5	$80 \leq epy \leq 120$	5	10	20	2.0
6	$120 < epy \leq \text{Target}$	2	10	20	2.0
7	$80 \leq epy \leq 120$	5	10	20	3.0
8	$120 < epy \leq \text{Target}$	2	10	20	3.0
9	$80 \leq epy \leq 120$	5	10	20	4.0
10	$120 < epy \leq \text{Target}$	2	10	20	4.0
11	$80 \leq epy \leq 120$	5	10	50	1.0
12	$120 < epy \leq \text{Target}$	2	10	50	1.0
13	$80 \leq epy \leq 120$	5	10	50	2.0
14	$120 < epy \leq \text{Target}$	2	10	50	2.0
15	$80 \leq epy \leq 120$	5	10	50	4.0
16	$120 < epy \leq \text{Target}$	2	10	50	4.0
17	$80 \leq epy \leq 120$	5	10	100	1.0
18	$120 < epy \leq \text{Target}$	2	10	100	1.0
19	$80 \leq epy \leq 120$	5	10	100	2.0
20	$120 < epy \leq \text{Target}$	2	10	100	2.0
21	$80 \leq epy \leq 120$	5	10	100	4.0
22	$120 < epy \leq \text{Target}$	2	10	100	4.0
23	$80 \leq epy \leq 120$	5	10	200	1.0
24	$120 < epy \leq \text{Target}$	2	10	200	1.0
25	$80 \leq epy \leq 120$	5	10	200	2.0
26	$120 < epy \leq \text{Target}$	2	10	200	2.0
27	$80 \leq epy \leq 120$	5	10	200	4.0
28	$120 < epy \leq \text{Target}$	2	10	200	4.0

Table 3: Interlocks

Item	Protection action value	Point of action	Action speed
Heater warm-up time	Within specified time	Klystron high voltage	Medium
Oil level	Oil surface is under the specified surface level	Klystron high voltage	Medium
Ion pump current	More than the specified value (Regular operation value plus 2 μ A)	Klystron high voltage	Fast
Tube water flow	Less than minimum ratings	Heater power supply	Medium
Tube water temperature	More than maximum rating (40°C)	Heater power supply	Medium
Heater voltage	Out of the specified rate $\pm 5\%$ for each klystron	Klystron high voltage	Medium
Heater current	Out of the specified rate $\pm 5\%$ for each klystron	Klystron high voltage	Medium
Beam voltage	Exceed the normal value plus 5% or the maximum rating	Klystron high voltage	pulse-to-pulse
Beam current	Exceed the normal value plus 10% or the maximum rating.	Klystron high voltage	pulse-to-pulse
Inverse beam voltage	Exceed the rated value (20 kV)	Klystron high voltage	Pulse-to-pulse
Waveguide pressure	Out of the specified rating	Klystron high voltage	Fast
Load Waveguide Arc	Discharge in the waveguide	RF drive or Klystron high voltage	Pulse-to-pulse
Electromagnet current	Out of the prescribed value $\pm 5\%$ for each klystron	Klystron high voltage	Medium
Electromagnet voltage	Out of the normal value $\pm 10\%$	Klystron high voltage	Medium
Electromagnet water flow	Less than minimum rating (10 L/min.)	Electromagnet supply and Klystron high voltage	Medium
Electromagnet water temperature	More than maximum rating (40°C)	Electromagnet supply and Klystron high voltage	Medium

The "medium" action speed indicates the monitoring system can be based on average value measurements. It should be around 100 ms.

The "fast" action speed indicates the klystron high voltage must be cut off as soon as possible within 20 ms. Usually, this can be done by cutting off the thyatron triggering signal.

The "pulse-to-pulse" action speed indicates that the monitoring device must detect the first single irregular pulse and interlock system must cut off the next pulse to the irregular pulse detected. For this purpose, peak measuring devices and comparators with references, which can be adjustable, are necessary.

In order to protect the ceramic windows, an ion pump should be equipped within 1 m from the windows. Monitor waveguide pressure with a cold cathode gauge and interlock at fast speed.

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