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Operating procedure for a new E3730A klystron at the customer site

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When you operate 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 operation (Diode mode) → RF 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 ohm terminal or an 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 (40 A). The prescribed value of heater voltage shall be maintained for at least 60 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 2.
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 100 kV and increase the pulse repetition rate to 20 pps and then restart the step form number 1.
　　3) Repeat the manner, increase the pulse repetition rate to 40 pps.
　　4) Repeat the manner, increase the pulse repetition rate to 50 pps

Table 1: Schedule of DC aging (Step type)

No.	Holding time [min.]	Beam Voltage epy [kV]	Beam Current ik [A]	Ion Pump Current Iion [μA]	Step up condition
1	> 5	Approx. 100			
2	> 5	120			
3	> 5	140			
4	> 5	160			
5	> 5	180			
6	> 5	200	Confirm that perveance is within the range from 1.9 to 2.1 μP.	< 2 μA	Iion is less than 1 μA. Holding time is completed.
7	> 5	220			
8	> 10	240			
9	> 10	260			
10	> 10	280			
11	> 10	290			
12	> 10	300			
13	> 10	310			
14	> 10	Target Value			

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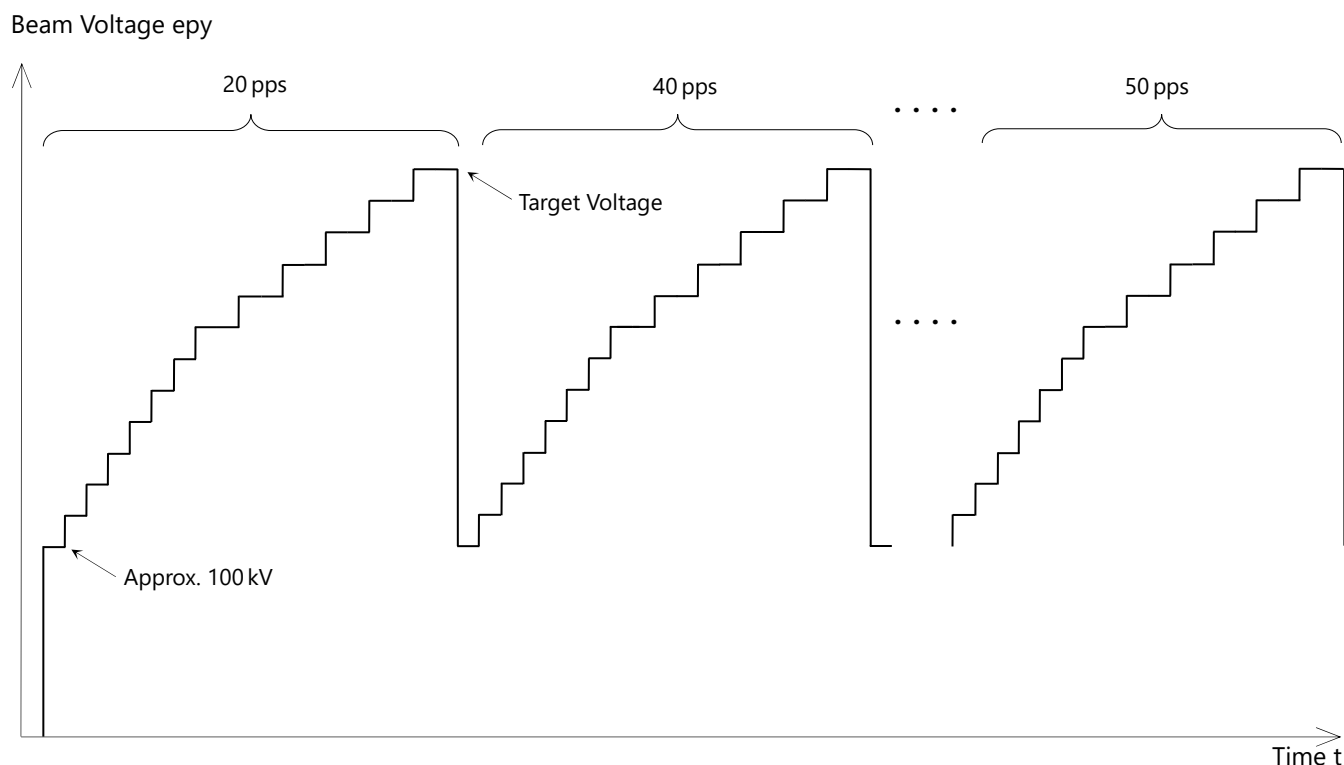
Beam Voltage epy

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 μA.), 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 100 kV and gradually raise the beam voltage up to 280 kV. (1-2 hour(s))
    2) Increase beam voltage from 280 kV to target voltage by 10 kV/60 min. When arcing occurs, stop high voltage immediately and set beam voltage to 70-90% 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 40 pps and and then 50 pps, repeatedly.

Beam Voltage epy

20 pps　　　　　　　40 pps　　. . . .　　　50 pps

Target Voltage

280 kV

Approx. 100 kV

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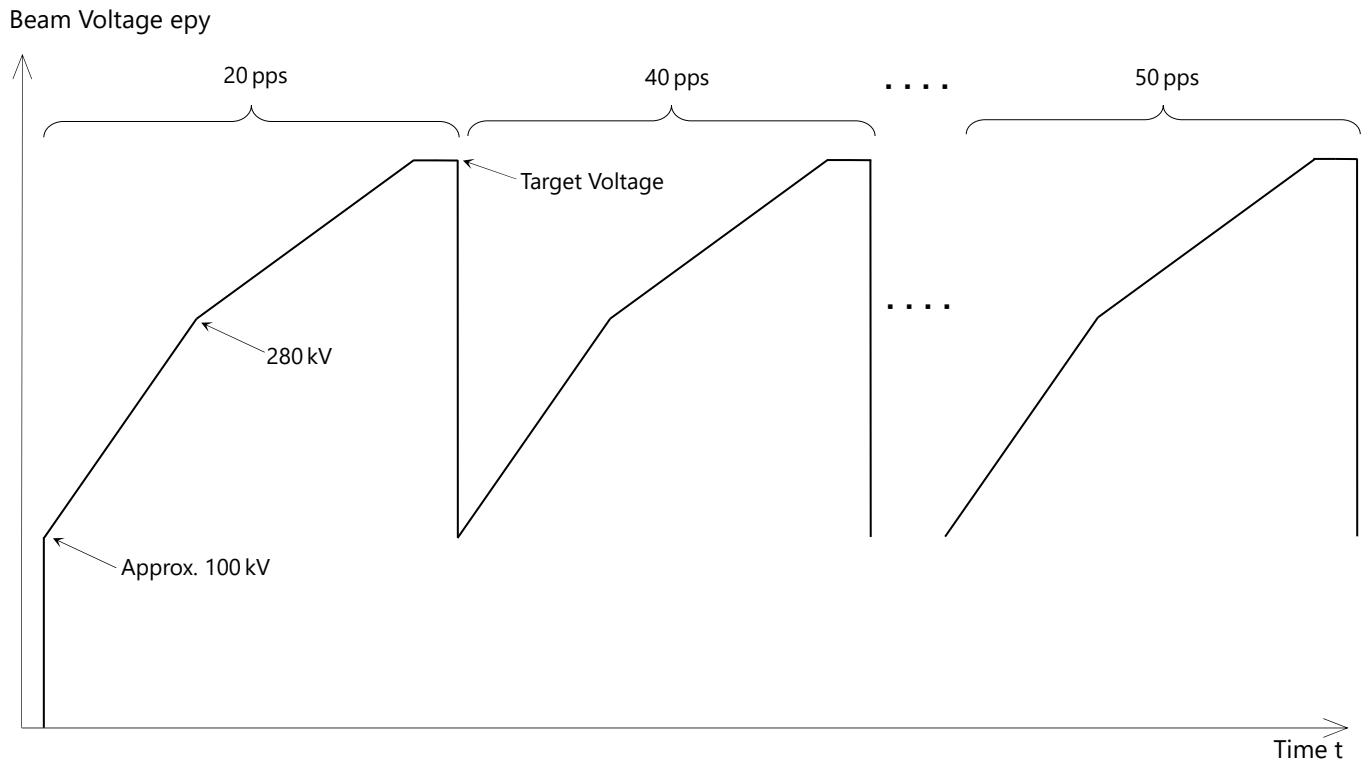
Fig.2: Rising image of DC aging (Continuous type)

4. RF conditioning
   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. Be the inside of the output waveguide vacuum. Pressure in the output waveguide must be less than 6.7×10^{-5} Pa.
      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 (40 A). The prescribed value of heater voltage shall be maintained for at least 60 minutes prior to the application of beam voltage.

b) (Reference) Schedule of RF aging at CETD process
Conduct the RF aging according to the schedule of Table 1. When arcing in the output waveguide occurs, stop the RF input immediately and shorter the RF pulse width.
Resume aging with keeping the pressure in the output waveguide less than specification limit.

Table 1: Schedule of RF aging (example)

No.	Beam Voltage [kV]	Step Voltage [kV]	Holding Time [min.]	RF Repetition Rate [pps]	RF Pulse Width [μs]
1	200≦epy≦280	5	10	20	0.5
2	280＜epy≦Target	2	10	20	0.5
3	200≦epy≦280	5	10	20	1.0
4	280＜epy≦Target	2	10	20	1.0
5	200≦epy≦280	5	10	20	2.0
6	280＜epy≦Target	2	10	20	2.0
7	200≦epy≦280	5	10	20	3.0
8	280＜epy≦Target	2	10	20	3.0
9	200≦epy≦280	5	10	20	4.0
10	280＜epy≦Target	2	10	20	4.0
11	200≦epy≦280	5	10	40	2.0
12	280＜epy≦Target	2	10	40	2.0
13	200≦epy≦280	5	10	40	3.0
14	280＜epy≦Target	2	10	40	3.0
15	200≦epy≦280	5	10	40	4.0
16	280＜epy≦Target	2	10	40	4.0
17	200≦epy≦280	5	10	50	2.0
18	280＜epy≦Target	2	10	50	2.0
19	200≦epy≦280	5	10	50	3.0
20	280＜epy≦Target	2	10	50	3.0
21	200≦epy≦280	5	10	50	4.0
22	280＜epy≦Target	2	10	50	4.0

Table 2: Interlocks

Item	Protection action value	Point of action	Action speed
Oil level	Oil surface is under the specified surface level	Klystron high voltage	Medium or Manual
Ion pump current	More than a specified value (Regular operation value plus 2μA)	Klystron high voltage	Fast
Tube water flow	Less than maximum ratings	Heater supply	Medium
Tube water temperature	More than(35℃)	Heater supply	Medium
Heater voltage	Out of the specified rate ±5% for each klystron	Klystron high voltage	Medium
Heater current	Out of the specified rate ±5% for each klystron	Klystron high voltage	Medium
Beam voltage	Exceed the normal value plus 5% or the maximum rating	Klystron high voltage	Medium and pulse-to-pulse
Beam current	Exceed the normal value plus 10% or the maximum rating.	Klystron high voltage	Medium and pulse-to-pulse
Klystron inverse voltage	Exceed the rated value (100kV)	Klystron high voltage	Pulse-to-pulse
Klystron inverse current	Exceed the rated value (55A)	Klystron high voltage	Pulse-to-pulse
Waveguide pressure	Exceed the specified value (6.7×10^{-5} Pa)	Klystron high voltage	Fast
Waveguide SWR	Exceed the load VSWR 1.2:1.0	RF drive or klystron high voltage	Pulse-to-pulse
Electromagnet current	Out of the specified rate ±5% for each klystron	Klystron high voltage	Medium
Electromagnet voltage	Out of the normal value ±10%	Klystron high voltage	Medium
Electromagnet water flow	Less than the specified value	Electromagnet supply	Medium
Electromagnet water temperature	More than (40℃)	Electromagnet supply	Medium
Electromagnet temperature	Thermal relay open	Electromagnet supply	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 thyratron 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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