

JIS

JAPANESE INDUSTRIAL STANDARD

**General rules for
high potential generators of
medical X-ray apparatus**

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In the event of any doubt arising,
the original Standard in Japanese is to be final authority.

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General rules for high potential generators of medical X-ray apparatus Z 4702-1991

1. Scope

This Japanese Industrial Standard specifies high-voltage generators of medical X-ray apparatus (hereafter referred to as "high-voltage generators") which generate and control a high voltage to be applied to the X-ray tubes to be accommodated in X-ray tube assemblies complying with JIS Z 4704 (hereafter referred to as "X ray tubes"). However, high-voltage generators of inverter systems and those for used in the mono-tank X-ray units for diagnostic use specified in JIS Z 4711 and in reproductive tomography (X-ray CT) equipment are excluded.

For the matters other than those specified here, the provisions of JIS Z 4701 shall apply.

Remarks 1. The Standards cited in this Standard are as follows:

- JIS C 1302-Insulation Resistance Testers (Battery Operated)
- JIS C 8303-Plugs and Receptacles for Domestic and Similar General Use
- JIS C 8308-Knife Switches with Cover
- JIS C 8313-Particular Requirements for Link-Fuses
- JIS C 8314-Particular Requirements for Low-Voltage Cartridge Fuses
- JIS C 8370-Molded Case Circuit Breakers (MCCB)
- JIS H 4000-Aluminium and Aluminium Alloy Sheets and Plates, Strip and Coiled
- JIS T 1005-Style Manual for Instruction Manuals
- JIS Z 4001-Glossary of Terms Used in Nuclear Energy
- JIS Z 4004-Graphical Symbols for Medical Radiological Equipment
- JIS Z 4511-Methods of Calibration for Exposure Meters and Dose-Equivalent Meters
- JIS Z 4701-General Rules for Medical X-Ray Equipment
- JIS Z 4704-General Rules on Medical X-Ray Tube Assemblies
- JIS Z 4711-Mono-Tank X-Ray Units for Diagnostic Use
- JIS Z 4731-High Voltage Cable Plug and Socket for Medical X-Ray Equipment
- JIS Z 4921-Measuring Devices for X-Ray Tube Voltage
- JIS Z 8601-Preferred Numbers

- 2. In this Standard the units and numerical values given in { } are based on the traditional metric system and are appended for informative reference.

2. Definitions

For the purpose of this Standard, in addition to the definitions given in JIS Z 4001 and JIS Z 4701, the following principal definitions shall apply:

- (1) high voltage generator A combination of a high-voltage transformer assembly and a control assembly.
- (2) high voltage transformer assembly An assembly of electrical devices which transform the voltage from the control assembly to a necessary voltage to apply the X-ray tube and supply the transformed voltage to the X-ray tube.
- (3) control assembly An assembly of electrical devices which control all the necessary auxiliary functions for regulating the X-ray. However, components in high-voltage side circuits are included in the high voltage transformer assembly.
- (4) two-peak high-voltage generator A high-voltage generator for operation on a single-phase supply that delivers a rectified output voltage with two peaks during each cycle of the supply.
- (5) six-peak high-voltage generator A high-voltage generator for operation on a three-phase supply that delivers a rectified output voltage with six peaks during each cycle of the supply.
- (6) twelve-peak high-voltage generator A high-voltage generator for operation on three-phase supply that delivers a rectified output voltage with twelve peaks during each cycle of the supply.
- (7) constant potential high-voltage generator A high-voltage generator with an output voltage waveform not exceeding 4 % in the percentage ripple of X-ray tube voltage.
- (8) capacitor discharge high-voltage generator A high-voltage generator in which the electric energy is stored in the radiographic capacitor to be supplied to the X-ray tube by discharge, the radiographic capacitor has a capacitance up to and including 2 μF and the switching for X-ray irradiation is done on high-voltage side. However, high-voltage generator employing a capacitor for smoothing its output voltage is excluded.
- (9) X-ray tube voltage The voltage applied between both electrodes of an X-ray tube during X-ray irradiation. The X-ray tube voltage is expressed by its peak value (kV). In the case of a capacitor discharge high-voltage generator, the voltage equal to the charged voltage of radiographic capacitor minus the voltage drop due to the discharge resistor.
- (10) nominal X-ray tube voltage Nominal value of highest X-ray tube voltage at which the high-voltage generator can be used.
- (11) X-ray tube current The anode current which flows through a X-ray tube during X-ray irradiation. The X-ray tube current is expressed by its average value (mA). However, in the case of radiography using a capacitor discharge high-voltage generator, the current is expressed by the peak value (mAp).

- (12) nominal X-ray tube current Nominal value of maximum X-ray tube current at which the high-voltage generator can be used.
- (13) long-time rating The rating when radioscopy is carried out. It is expressed by the highest X-ray tube voltage at which the X-ray tube can be loaded continuously for 5 min or more, and the maximum X-ray tube current at the said X-ray tube voltage.

Remarks: The "rating" means the value not including the tolerances, and when the tolerances are included the value is called "nominal".

- (14) short-time rating The rating when radiography is carried out. It is expressed by the combination of the X-ray tube voltage at which the X-ray tube can be loaded for 1 s or more and the maximum X-ray tube current at that X-ray tube voltage. However, in the case of a capacitor discharge high-voltage generator it is expressed by the highest X-ray tube voltage (kV) at which the X-ray tube can be loaded and the capacitance of radiographic capacitor (μF).
- (15) power supply equipment The power supply equipment starting from the distribution transformer to the control switch or plug in connector via low voltage lines, low voltage lead-in wires, service entrance switch and indoor wiring.
- (16) apparent resistance of supply mains The impedance of the supply mains equipment on the supply side of the supply terminal of the operating switch or plug-in connector for connection to the high-voltage generator which is measured by means of resistance loading. The measurements are carried out at a power not exceeding 30 kW and the apparent resistance is obtained from the following formula:

$$R = \frac{U_N - U_L}{I_L}$$

where, R : apparent resistance of supply mains (Ω)

U_N : supply voltage at no-load (V)

U_L : supply voltage at loading (V)

I_L : supply current at loading (A)

- (17) percentage average error The rate of difference between the set value or indicated value and the average value of the measured values to the set value or indicated value in percent. The percentage average error is obtained from 10 measured values successively obtained by means of the following formula.

$$PAE = \frac{X_p - \bar{X}}{X_p} \times 100$$

where, PAE : percentage average error (%)

$\bar{X}$: average value of measured values

X_p : set value or indicated value

- (18) coefficient of variation A coefficient which represents the reproducibility of X-ray output. The reproducibility is obtained from 10 X-ray doses successively measured using a specified⁽¹⁾ X-ray tube assembly by means of the formula given below.

Note (1) The "specified" means that the assembly is specified in the instruction for use.

Remarks: The X-ray dose is the air kerma measured in air, the unit is gray (Gy). Air kerma 1 Gy (1 J/kg = 29.7 mC/kg) corresponds to 115 R.

$$C = \frac{S}{\bar{X}} = \frac{1}{\bar{X}} \left[\sum_{i=1}^{10} \frac{(X_i - \bar{X})^2}{9} \right]^{\frac{1}{2}}$$

where, C : coefficient of variation
 S : standard deviation by 10 measurements
 $\bar{X}$: arithmetic mean by 10 measurements
 X_i : i -th measured value

- (19) nominal electric power The product of the maximum current which can be passed at an X-ray tube voltage of 100 kV and the X-ray tube voltage. The nominal electric power is expressed in kW and it is obtained from the formula given below, for transformer high-voltage generators.

$$P = U \times I \times f \times 10^{-3}$$

where, P : nominal electric power (kW)
 U : X-ray tube voltage (100 kV)
 I : X-ray tube current (mA)
 f : coefficient determined by rectifying system

Remarks: The values of f shall be those given below according to the rectifying system (percentage ripple of X-ray tube voltage).

$f = 1$ twelve-peak or constant potential high-voltage generator (percentage ripple ≤ 10 %)

$f = 0.95$ six-peak high-voltage generator (10 % < percentage ripple ≤ 25 %)

$f = 0.74$ two-peak high-voltage generator (25 % < percentage ripple)

The percentage ripple of X-ray tube voltage is obtained from the following formula:

$$\frac{U_{\max} - U_{\min}}{U_{\max}} \times 100 \text{ (%)}$$

where, $U_{\max}$: maximum value of X-ray tube voltage waveform during each cycle of the supply
 $U_{\min}$: minimum value of X-ray tube voltage waveform during each cycle of the supply

- (20) current time product The quantity of electricity resulting from loading of an X-ray tube which is the product of the X-ray current (average value) expressed in mA and the duration of radiography expressed in s. The mAs is used as the unit of current time product.
- (21) reference current time product The current time product determined at 0.1 s or a specific duration of photography specified in the instruction for use, used as a reference value to verify the linearity of X-ray output in X-ray generators.
- (22) stand-by state The state of equipment after a preconditioning which is necessary before initiation of X-ray emission.
- (23) ready state The state of equipment in which all the conditions necessary for initiation of X-ray emission are completed and all the interlocks are released so that the intended operation can be initiated by a single action. As for X-ray emission when two consecutive positions are controlled by one control in starting of the rotating anode such a control may be considered as one operation.
- (24) minimum radiography duration in automatic exposure control
The minimum radiography duration in automatic exposure control at which the reproducibility and safety are satisfactory.
- (25) loading factor The factor influencing by its value the X-ray tube load. For example X-ray tube voltage, X-ray tube current, radiography duration and percentage ripple.
- (26) X-ray source assembly A combination of an X-ray tube assembly and a beam limiting system.

3. Classification

High-voltage generators are classified into two classes i.e. transformer system and capacitor discharge system.

- (1) Transformer high-voltage generator Transformer high-voltage generators are classified according to the use, kind of supply mains, nominal X-ray tube voltage and nominal X-ray tube current, and the standard classification is shown in Table 1.

Table 1. Standard classification of transformer high-voltage generators

Standard type designation ⁽²⁾	Nominal X-ray tube voltage kV	Nominal X-ray tube current mA	Use
RDP-20-100	100	20	Mainly for dental radiography
RDP-100-100		100	
RF-320-100		320	For radiography and radioscopy of single-phase equipment
RF-500-100		500	
RF-500-125	125		
RF-500-150	150		For radiography and radioscopy of three-phase equipment
TRF-800-150		800	
TRF-1000-150		1000	
TRF-1250-150		1250	
TRF-2000-150		2000	

Note ⁽²⁾ The type designation denotes the standard one in that group, all the high-voltage generators are included in these standard type designations, and the performances shall be as specified for each type designation.

The type designation shall be made as prescribed in Tables 1 and 2, and the standard type designation appropriate to the equipment shall be clearly stated in the instruction for use.

Example: For high-voltage generator for radiography and radioscopy with nominal X-ray tube voltage 150 kV and nominal X-ray tube current 1300 mA employing three-phase a.c. supply mains.

Type designation: TRF-1300-150

In this case, the standard type designation viewed from the supply mains equipment and nominal electric power is TRF-1250-150.

Remarks: The meaning of the letters and numerals used in the type designation is as given below.

Example: RDP—20—100
 | |
 First Third
 item item
 |
 Second
 item

First item RDP: mainly used for dental radiography (including dental panoramic tomography) employing single-phase a.c. as the supply mains.

RF: used for radiography and radioscopy employing single-phase a.c. as the supply mains.

TRF: used for radiography and radioscopy employing three-phase a.c. as the supply mains.

Second item 20, 100, 320, 500, 800, 1000, 1250, 2000: value of nominal X-ray tube current

Third item 100, 125, 150: value of nominal X-ray tube voltage

- (2) Capacitor discharge high-voltage generator Capacitor discharge high-voltage generators are classified according to the use, nominal X-ray tube voltage and nominal capacitance of radiographic capacitor and the standard classification is shown Table 2.

Table 2. Standard classification of capacitor discharge high-voltage generator

Standard type designation ⁽²⁾	Nominal X-ray tube voltage kV	Nominal capacitance of radiographic capacitor μF	Use
CR-0.5-100	100	0.5	Radiography
CR-1-100		1	
CR-1-125	125		
CR-1-150	150		
CR-1.5-150		1.5	
CRF-0.5-100	100	0.5	Radiography and radioscopy
CRF-1-125	125	1	
CRF-1.5-125		1.5	
CRF-1-150	150	1	
CRF-1.5-150		1.5	

Remarks: The meaning of letters and numerals used in the type designation is as given below.

Example: CR—0.5—100

First
item

Second
item

Third
item

First item CR: used for radiography only

CRF: used for radiography and radioscopy

Second item 0.5, 1, 1.5: value of nominal capacitance of
radiographic capacitor

Third item 100, 125, 150: value of nominal X-ray tube
voltage

4. Ratings

The ratings of high-voltage generators classified according to the
provision of 3. shall be as given in Table 3.

Table 3. Ratings

Standard type designation	Supply mains			Long-time rating		Short-time rating				
	Number of phases	Frequency Hz	Nominal rated voltage V	X-ray tube voltage kV	X-ray tube current mA	X-ray tube voltage kV	X-ray tube current mA	Capacitance of radiographic capacitor μF		
RDP- 20-100	1	50 or 60	100 or 200	—	—	80 100	20 10	—		
RDP- 100-100			200	—	—	80 100	100 63			
RF- 320-100				100	4 max.	80 100	320 200			
RF- 500-100						80 100	500 320			
RF- 500-125				120	100 125	500 320				
RF- 500-150			200 or 415		125 150	500 320				
TRF- 800-150				3			100 125 150		800 500 250	
TRF-1000-150	100 125 150	1 000 630 320								
TRF-1250-150	100 125 150	1 250 800 400								
TRF-2000-150	100 125 150	2 000 1 000 320								
CR-0.5-100	1	100	—				—	100	—	0.5
CR- 1 -100								125 150		1
CR- 1 -125										1.5
CR- 1 -150										
CR-1.5-150				100 125 150	0.5					
CRF-0.5-100			95		2 max.	100	0.5			
CRF- 1 -125			120			125	1			
CRF-1.5-125						150	1.5			
CRF- 1 -150			1							
CRF-1.5-150			1.5							

5. Power supply equipment

In this clause the power supply equipment of lower limit under which transformer high-voltage generators and capacitor discharge high-voltage generators exhibit their performances sufficiently is specified, because the said generators demand a large power instantaneously different from general electrical machinery and equipment.

It is desirable to prepare one supply main for one transformer high-voltage generator of large power. If two or more such high-voltage generators are connected to one supply main a means to prevent simultaneous loading or a means to eliminate the influence of supply voltage drop shall be employed.

- (1) Power supply The number of phases, frequency, nominal rated voltage and its allowable voltage range, apparent resistance of supply mains and recommended capacity of distribution transformer shall be as given in Table 4 and 5.

Table 4. Power supply equipment (for 100 or 200 V distribution)

Standard type designation	Number of phases	Frequency Hz	Nominal rated voltage V	Allowable voltage range at no-load V	Apparent resistance of supply mains $\Omega^{(1)}$	Recommended capacity of distribution transformer kVA	
RDP- 20-100	1	50 or 60 $\pm 1\%$	100	90to110	0.5	2 min.	
			200	180to220	2.0		
RDP- 100-100					0.40	10	
RF- 320-100					0.12	20	
RF- 500-100					0.080	30	
RF- 500-125					0.064	50	
RF- 500-150					0.051		
TRF- 800-150	3					0.054	75
TRF-1000-150						0.043	100
TRF-1250-150						0.035	150
Capacitor discharge type	1		100	85to110	0.5 ⁽⁴⁾	3 min.	

Note (3) This indicates the apparent resistance of supply mains which causes voltage fluctuation not exceeding 10 % even in the X-ray irradiation which results in the maximum value of short-time rated load. It is desired that this value is as small as possible.

The voltage fluctuation (%) is obtained from the following formula:

$$\frac{U_N - U_L}{U_L} \times 100$$

where, U_N : supply voltage at no-load (V)
 U_L : supply voltage at short-time rated load (V)

- (⁴) For capacitor discharge high-voltage generators, the effective sectional area of the power supply cord shall be 1.25 mm² or more.

Further, if a radiographic stand is also used, the apparent resistance of supply mains shall not exceed 0.3 Ω .

Remarks: It shall be avoided to use a transformer high-voltage generator by connecting it directly to a generator. If such use is unavoidable, detail specification shall be previously agreed between the parties concerned with acceptance.

Table 5. Power supply equipment (for 415 V distribution)

Standard type designation	Number of phases	Frequency Hz	Nominal rated voltage V	Allowable voltage range at no-load V	Apparent resistance of supply mains $\Omega^{(5)}$	Recommended capacity of distribution transformer kVA
RF- 500-150	1	50 or 60 $\pm 1\%$	415	374to457	0.12	(50) ⁽⁶⁾
TRF- 800-150	3				(75) ⁽⁶⁾	
TRF-1000-150					0.09	100
TRF-1250-150					0.07	(150) ⁽⁶⁾
TRF-2000-150					0.04	200

Notes (⁵) This indicates the apparent resistance of supply mains which causes voltage fluctuation not exceeding 5 % even in the X-ray irradiation which results in the maximum value of short-time rated load.

(⁶) This is not produced as the standard product of 415 V distribution transformer, but the capacity is given assuming such a case that it may be necessary when installed individually.

- (2) Low voltage line When a transformer high-voltage generator is installed, the capacity of exclusive transformer and the relationship between the nominal sectional area and the one-way length of the wire, in the low voltage line from the distribution transformer to the control switch shall be such that the sectional area and the capacity shall have at least the relevant value shown in Table 6 in the case of 200 V conduit wiring or in Table 7 in the case of 415 V conduit wiring.

Table 6. Nominal sectional area of wire in low-voltage line
(of 200 V conduit wiring)

Standard type designation	Capacity of distribution transformer kVA	Nominal sectional area of wire mm ² Cu									
		One-way length of wire									
		10 m max.	20 m max.	30 m max.	40 m max.	50 m max.	60 m max.	70 m max.	80 m max.	90 m max.	100 m max.
RDP- 100-100	10	3.5	3.5	5.5	5.5	8	8	14	14	14	14
RF- 320-100	15	8	14	22	30	38	50	50	60	60	80
	20	8		14	22	22	30	38	38	38	50
RF- 500-100	20	22	38	60	80	100	—	—	—	—	—
	30	8	22	30	38	50	50	60	80	80	80
RF- 500-125	30	14	30	50	60	80	80	100	—	—	—
	50	8	14	30	38	38	50	60	60	80	80
RF- 500-150	50	14	22	38	50	60	80	80	100	100	100
TRF- 800-150	75			30	38	50	60	60	80	80	
TRF-1000-150	100	22						80		100	125
TRF-1250-150	150		30	50	60	80	100	100	125	150	150

Table 7. Nominal sectional area of wire in low-voltage line
(of 415 V conduit wiring)

Standard type designation	Capacity of distribution transformer kVA	Nominal sectional area of wire mm ² Cu									
		One-way length of wire									
		10 m max.	20 m max.	30 m max.	40 m max.	50 m max.	60 m max.	70 m max.	80 m max.	90 m max.	100 m max.
RF- 500-150	(50) (°)	8	14	14	22	22	30	30	38	38	50
TRF- 800-150	(75) (°)	5.5	8				22		30		38
TRF-1000-150	100	8	14	22		30	38	38	50	50	60
TRF-1250-150	(150) (°)								38		50
TRF-2000-150	200	14	22	30	38	50	60	60	80	80	100

- (3) Safety device The control switch and fuse, molded case circuit breaker, or plug and receptacle specified in Tables 8 and 9 shall be mounted at a place capable of being operated immediately from the position of the X-ray control assembly as the safety device to protect the equipment. However, in the case specified in 8.2.2 is excluded.

When plug and receptacle are used, the fuse or molded case circuit breaker installed in the equipment may serve as the safety device.