



Cardiac Epsilon™ High-Voltage Generator

PRODUCT SPECIFICATION

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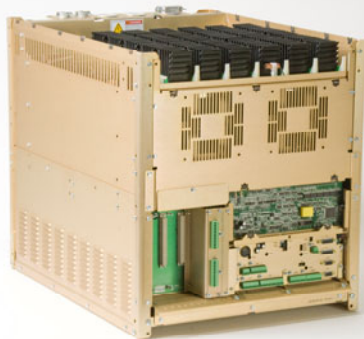
1.0 INTRODUCTION TO CARDIAC EPS HIGH-VOLTAGE GENERATORS

The **Cardiac High-Voltage generator** is an *Advanced High Frequency X-ray Generator* designed with a unique power inverter technology, the beating heart of the Epsilon Pulsing System.

Thanks to its modular conception, more power or custom features are simply added when needed, using plug-in modules quickly inserted to the generator's main core made out of an electronic controller that drives an oil-free encapsulated high-voltage unit. The generator comes in different configurations, best suited to conventional cardiac applications, special vascular procedures and latest digital procedures.

Table 1- Main Configurations of EPS Cardiac High-Voltage Generator

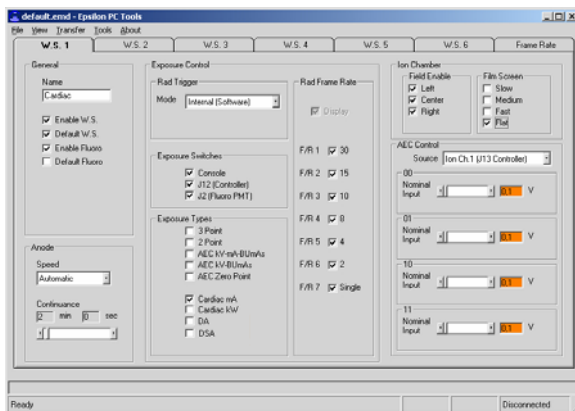
Configuration	Cardiac	Vascular	Cable Discharge	90 f/s	SPD	Power
EPS “C”	✓	–	–	Option	Option	From 50 kW to 100 kW
EPS “CV”	✓	✓	–	Option	Option	
EPS “CX”	✓	–	✓	Option	Option	
EPS “CVX”	✓	✓	✓	Option	Option	



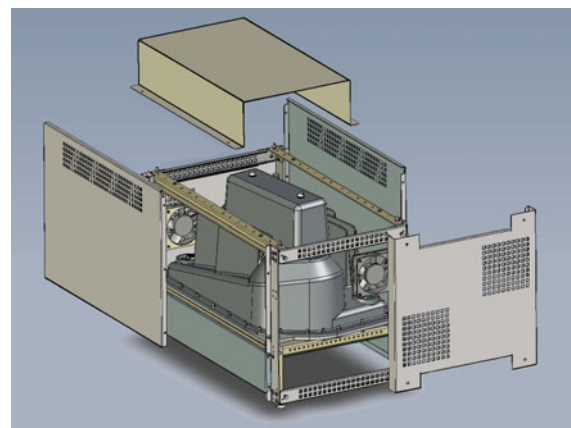
Epsilon High-Voltage Generator
(Includes a decorative cabinet not shown)



Epsilon Operator Console



Epsilon PC Tools program



Optional Cable Discharge Unit
(Shown here with fans for increased duty cycle)

1.1 Technological Landmark

The Epsilon™ technology achieves variable frequency operation at up to 240 kHz. This produces kV flatness waveform, with outstanding quick rise time. This realization embodies important technological achievements designed with innovative power switching inverter modules and a cascaded series of high frequency power transformers embedded in a solid dielectric high voltage unit.

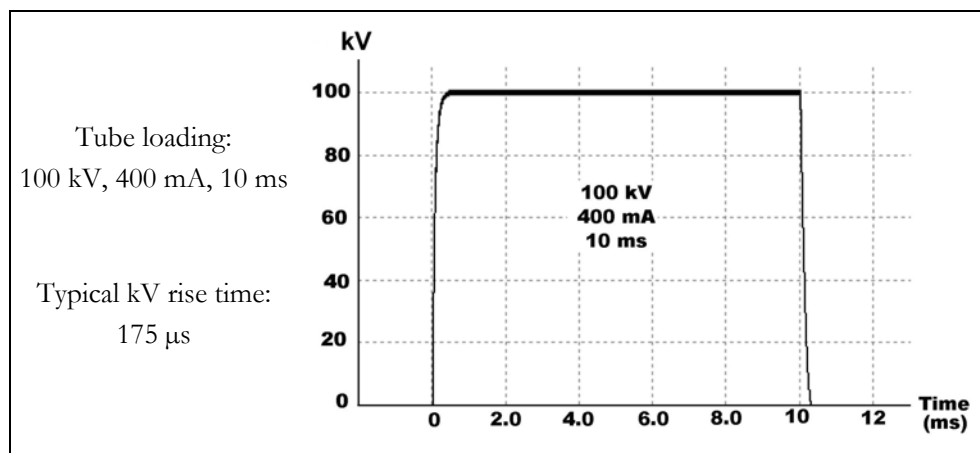


Figure 1 – Typical kV Waveform.

1.2 Cardiac Main Features

1. A **Cardiac modality** providing fully automatic exposures performed at either *constant-kW* or *constant-mA* mode;

- Constant-kW exposure mode aims at improving the image contrast;
- Constant-mA exposure mode aims at the reduction of the patient dose;

Other features in Cardiac modality:

- **High frame rate**, permitting up to 90 frames per second, in RAD & Fluoro.
- A **record lock** function permits the physician to perform special procedures such as left ventricular grams.
- An optional **cable discharge unit**, which is an electronic crowbar mechanism that permits precise exposure times using very fast rise and fall times.
- **Auto-Focal Spot** mode lets the generator decide of the image resolution.

2. **Vascular exams** performed in either *DA* or *DSA* semi-automatic AEC modes.

- DSA angiographic serial exposures with AEC-Lock and image subtraction ;
- DA angiographic exposure mode with AEC-Lock ;

3. High Performance Pulsed Fluoroscopy performed in either *Dose Reduction* or *Image Enhancement* mode.

- **Dose reduction** lowers average patient dose at slower pulse rates while keeping the same dose per pulse (the pulse count is reduced).
- **Image enhancement** provides clearer, less noisy images at slower pulse rates while keeping the patient dose about constant.

High Performance Pulsed Fluoro is done on standard X-ray tubes (no grid), using a *programmable* surface dose rate and a *variable* pulse width.

Continuous Fluoro is available using the service mode, for example to troubleshoot the Fluoro imaging chain.

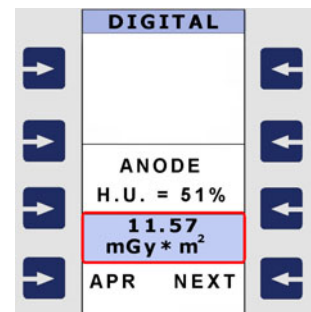
4. Multi-zoom Functionality

With multi-field image intensifier, the source of image brightness control or Fluoro stabilization can be switched in-between runs.

1.3 Optional Features

1. DAP Interface P/N 10028.000

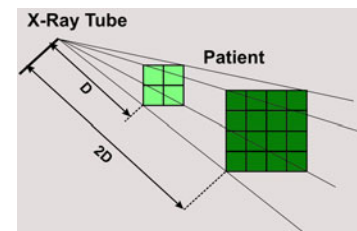
The DAP Interface option allows interfacing a DAP measurement device on the Epsilon Operator Console to display the radiation level a patient is exposed to in radiological exams. Cumulative dose area product (**DAP**) would also be printed when an optional DAP printer is connected to the generator.



2. Source to Patient Distance Integrator

The generator adjusts the X-ray beam to compensate for the source-to-patient distance (SPD) when the gantry position varies during an exam. This provides constant surface dose along the full SPD span.

$$\text{mAs/pulse} \propto (1/\text{SPD})^2$$



3. High Frame Rate

Typically dedicated for high grade special procedures, this option allows image acquisition at up to 90 frames per second, in Cardiac & RAD/Fluoro.

4. Auxiliary Power Supplies P/N 10023.xxx

This option provides a medical grade power supply rated 24 VAC, 150 VA (2.7 A) and 24 VDC, 65W.

5. Cable Discharge Unit P/N 10027.000

The **Cable Discharge Unit** provides the EPS 45-80 High-Voltage generator with an electronic crowbar mechanism that permits multiple exposures at precise exposure times using rapid rise and fall times along a broad spectrum of tube mA, on standard (no grid) X-ray tubes.

The quick turning on and off of the high-voltage output dramatically improves the quality of images acquired from cineradiography, digital subtraction angiography, digital radiography and Pulsed Fluoro.

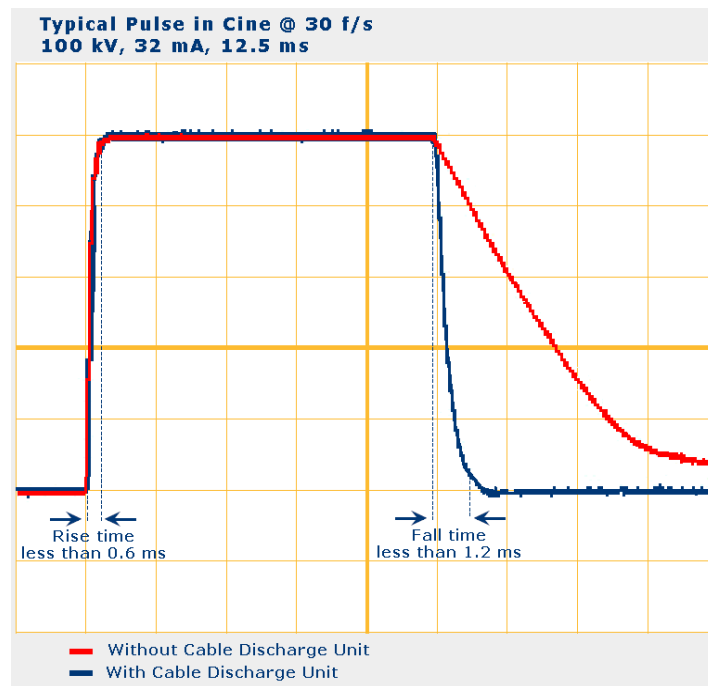


Figure 2 – Typical kVp waveforms, with and without Cable Discharge unit.

6. Falling Load P/N 10013.000

This option allows the generator to initiate an AEC-mAs exposure at a higher tube current value, after which the mA drops as the exposure proceeds.

7. Universal Chambers Interface Board P/N 11002.000

Consists of a plug-in board and the necessary software to perform AEC exposures on up to three (3) solid state AEC chambers. This board includes also an additional interface for standard ion chamber.

8. Custom Pedestal Stand P/N 10003.000

An elegant stand for the Epsilon Operator Console.

Custom Pedestal Stand >



2.0 TECHNICAL SPECIFICATIONS

2.1 Power Specification

2.1.1 X-ray Power Range

Table 2- Maximum Power Outputs versus Tube mA (Intermittent Mode)

EPS Configuration	Tube mA							
	200	250	320	400	500	630	800	1000
EPS 50	150 kV 30 kW	150 kV 37 kW	150 kV 48 kW	125 kV 50 kW	100 kV 50 kW	79 kV 50 kW		
EPS 65	150 kV 30 kW	150 kV 37 kW	150 kV 48 kW	150 kV 60 kW	130 kV 65 kW	103 kV 65 kW	81 kV 65 kW	
EPS 80	150 kV 30 kW	150 kV 37 kW	150 kV 48 kW	150 kV 60 kW	150 kV 75 kW	127 kV 80 kW	100 kV 80 kW	80 kV 80 kW
EPS 90	150 kV 30 kW	150 kV 37 kW	150 kV 48 kW	150 kV 60 kW	150 kV 75 kW	127 kV 80 kW	112 kV 89.6 kW	90 kV 90 kW
EPS 100	150 kV 30 kW	150 kV 37 kW	150 kV 48 kW	150 kV 60 kW	150 kV 75 kW	127 kV 80 kW	113 kV 90.4 kW	100 kV 100 kW
Nominal power values (kW) are given for a loading time no less than 100 ms.								

2.1.2 Power Ratings / Line Requirements

The generator requires a three-phase electrical line with a protective earth ground (4 or 5 wires ^(*)). Standard line regulation from no load to full load will provide full power output, at maximum kV.

Table 3- Power Ratings and Electric Line Requirements

Epsilon Configuration	Mains Voltage $V_{AC} \pm 10\%$ (3 Phases) ^(1,2)	Apparent Resistance of Supply Mains (Ω) ⁽³⁾	Over-current Releases ⁽⁴⁾ (A)	Nominal Electric Power			
				Short Term		Long Term ⁽⁶⁾ RAD/Fluoro	
				(A) ⁽⁵⁾	(KVA)	(A)	(KVA)
EPS 50	400V	0.17	100	102	68	5.0/7.0	2.0/3.4
	480V	0.24	100	85	70	5.0/7.0	2.4/4.1
EPS 65	400V	0.17	150	124	85	5.0/7.0	2.0/3.4
	480V	0.16	100	105	88	5.0/7.0	2.4/4.1
EPS 80	400V	0.11	150	150	102	5.0/7.0	2.0/3.4
	480V	0.16	150	125	105	5.0/7.0	2.4/4.1
EPS 90	400V	0.11	150	170	116	5.0/7.0	2.0/3.4
	480V	0.16	150	145	122	5.0/7.0	2.4/4.1
EPS 100	400V	0.09	150	200	136	5.0/7.0	2.0/3.4
	480V	0.12	150	165	138	5.0/7.0	2.4/4.1

Notes

- (1) Automatic mains line selection (no transformer tap configuration required). Automatic kW derating when mains line voltage drops below -12%.
- (2) Line Frequency tolerance from 47 to 63 Hz.
- (3) With lower (better) impedance lines, expect approx. 15% more current in Epsilon input current.
- (4) Circuit breaker mandatory, supplied by customer. Thermal breaker recommended. The over-current releases values are suggested figures only. The selected value should have current rating versus time curve characteristics higher than the ratings specified. Consult a qualified electrical contractor to comply with local electrical bylaw and site electrical installation.
- (5) Nominal line current values; if electric line goes to minus 10%, the input current will then increase by 10%.
- (6) Values based on Continuous Fluoroscopy at 125 kV @ max. 10 mA for **EPS RF** configurations and on standby mode for **EPS RAD** configurations (no continuous X-ray for RAD High-Voltage generators). For High Performance Fluoro optional configuration (140 kV @ max. 20 mA), the long-term current nominal values are 9.2A/6.4KVA (@ 400 VAC) and 7.7A/6.4KVA (@ 480 VAC).

(*) Maximum wire gauge : 0 AWG (50 mm)

2.2 System Configuration

WORKSTATIONS : 5 or 6 workstations, depending on configuration.

APR EXAMS : Programmable technique chart consisting of up to 2000 fully customizable exams, stored in the **Epsilon** Operator Console. Every single step on the APR program leads to a new set of parameters, every time more fitted with the intended exam. This reduces the number of key strokes. The APR can be programmed to behave as a traditional APR with 7 regions per workstation, 8-10 exams per region and 4 patient sizes.

AEC MODE : Ion chamber, photomultiplier tube, photodiode or flat panel.

2.3 X-ray Tube Loading

2.3.1 Cardiac Cineradiography

kV : Auto-kV exposure, from 40 to 125 kV.

MAS : Auto-mAs exposure, from 10 to 1000 mA.

Table 4- X-ray Tube Loading Factors in Cardiac

Loading mode	Description
Cardiac-mA	Exposures performed using constant mA algorithm (variable kW). This method aims to reduce the patient dose.
Cardiac-kW	Exposures performed using constant kW algorithm (variable mA). This method aims to improve the image contrast.
Frame rate	7 pulse rates available at the operator console and service programmable from 0.25 up to 30 f/s ⁽¹⁾ . Operative frame rate selected by the operator, by APR, or by remote selection using a digital input to the generator.
Run length	1, 2, 5, 10, 20, 30, 40, 50 and 60 seconds ⁽²⁾
Tube kW	The operative frame rate and run length combination for a given exposure impacts on the allowed tube kW load. The generator ensures the X-ray tube operating parameters are within safe limits.
<p>(1) Up to 90 f/s available as an option.</p> <p>(2) The run length corresponds to the maximum total duration of repeated tube loadings allowed by the generator for a distinct exposure switch actuation</p>	

2.3.2 Radiography & Vascular

kV : From 40 to 150 kV, with 1-kV steps.

MA : From 10 to 1000 mA, with 25% increment steps (up to 21 stations).

10;	12.5;	16;	20;	25;	32;	40;	50;	63;	80;	
100;	125;	160;	200;	250;	320;	400;	500;	630 [Ⓞ] ;	800 [Ⓞ] ;	1000 [Ⓞ] .

- (1) For 50 kW and above configurations only (3) For 80 kW and above configurations only
 (2) For 65 kW and above configurations only

IRRADIATION TIME:

From 1.0 ms[Ⓞ] to 10 seconds, with 25% increment steps (41 stations).

1.0 [Ⓞ] ;	1.25;	1.6;	2.0;	2.5;	3.2;	4.0;	5.0;	6.3;	8.0;	ms
10;	12.5;	16;	20;	25;	32;	40;	50;	63;	80;	ms
100;	125;	160;	200;	250;	320;	400;	500;	630;	800;	ms
1.0;	1.25;	1.6;	2.0;	2.5;	3.2;	4.0;	5.0;	6.3;	8.0;	10.0 seconds.

- (1) Minimum irradiation time in AEC = 5.0 ms

MAS:

From 0.4 to 1000 mAs[Ⓞ], with 25% increment steps (up to 35 stations).

0.4;	0.5;	0.63;	0.8;	1.0;	1.25;	1.6;	2.0;	2.5;	3.2;
4.0;	5.0;	6.3;	8.0;	10;	12.5;	16;	20;	25;	32;
40;	50;	63;	80;	100;	125;	160;	200;	250;	320;
400;	500;	630 [Ⓞ] ;	800;	1000.					

- (1) Maximum mAs in the optional *High Performance Radiography*: 10 000 mAs.
 (2) 600 mAs max. in AEC mode

Table 5- X-ray Tube Loading Factors in Radiography & Vascular

RAD Technique	Loading Mode
Three-point	Loads the tube at specific kV, mA and irradiation time factors.
Two-point	Loads the tube at specific kV and mAs factors.
AEC mode	Loads the tube ...
AEC-mA	<ul style="list-style-type: none"> At specific kV & mA factors and adjustable backup time (for a given kV);
AEC-mAs	<ul style="list-style-type: none"> At specific kV & backup mAs factors;
AEC-Zero Point	<ul style="list-style-type: none"> At specific backup mAs factor and automatic kV selection based on Fluoro stabilization (ABS or manual); <p>... and uses the feedback of an external exposure time pickup device to stop the tube loading.</p>
AEC-Lock	Loads the tube as in normal AEC mode for the first frame, and uses the measured mAs factor for the remaining tube loadings.
Serial Tube Loading Mode	
D.S.A./D.A.	Automatic serial exposure mode that combines pre-selected parameters with auto-kV mode and AEC feedback.
Frame rate	7 pulse rates available at the operator console and service programmable from 0.25 up to 30 f/s (1,2). Operative frame rate selected by the operator, by APR, or by remote selection using a digital input to the generator.
Run length	1, 2, 5, 10, 20, 30, 40, 50 and 60 seconds (2)
Tube kW	The operative frame rate and run length combination for a given exposure impacts on the allowed tube kW load. The generator ensures the X-ray tube operating parameters are within safe limits.
<p>(1) Up to 90 f/s available as an option.</p> <p>(2) The run length corresponds to the maximum total duration of repeated tube loadings allowed by the generator for a distinct exposure switch actuation.</p>	

2.3.3 High Performance Pulsed Fluoroscopy

High Performance Pulsed Fluoro allows doing pulsed fluoroscopy on standard X-ray tubes, with no grid, using a *programmable* surface dose rate and a *variable* pulse width.

Table 6- X-ray Tube Loading Factors in Fluoroscopy

kV range	40 to 125 kV, in one-kV steps, with programmable kV range.										
mAs range	From 0.025 up to 5.0 mAs. <i>Variable Pulse width:</i> The pulse width is not fixed and adjusted live during Fluoro. This provides better and quicker image stabilization.										
Pulse rate	0.25 up to 30 p/s (7 pulse rates available at the operator console). 0.25 up to 90 p/s with High Frame Rate option.										
mA range	In Continuous Fluoro : 0.2 to 12.5 mA.										
	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	
	1.3	1.4	1.6	1.8	2.0	2.2	2.5	2.8	3.2	3.6	
	4.0	4.5	5.0	5.6	6.3	7.1	8.0	9.0	10.0	11.0	12.5

The High Performance Pulsed Fluoro can be performed in 2 modes, Dose reduction & Image Enhancement (Table 7).

Table 7- High Performance Pulsed Fluoro (Typical Setup)

I -Dose Reduction Mode			
	p/s	Dose to Patient	mAs/min
Reduces the total Fluoro dose to the patient by decreasing the pulse rate operation.	30	Total dose to patient	(mAs/min) x 1
	15	One half total dose to patient	(mAs/min) ÷ 2
	10	One third total dose to patient	(mAs/min) ÷ 3
	7.5	One fourth total dose to patient	(mAs/min) ÷ 4
	5.0	One sixth total dose to patient	(mAs/min) ÷ 6
	3.75	One eighth total dose to patient	(mAs/min) ÷ 8
II -Image Enhancement Mode			
	p/s	Image Enhancement	mAs Factor
Improves the image contrast (greater mAs/pulse) at lower Fluoro speeds using a mAs correction factor.	30	No	mAs <input type="text" value="x 1"/>
	15	Yes	mAs <input type="text" value="x 2"/>
	10	Yes	mAs <input type="text" value="x 3"/>
	7.5	Yes	mAs <input type="text" value="x 4"/>

PULSE RATE: Up to 7 frame rates are selectable at the operator console or remotely selected from the Fluoro table.

ABS CURVES: 4 service programmable kV/mA tracking curves are provided to improve the contrast during ABS stabilization. The current ABS curve can be changed from the operator console.

ENTRANCE EXPOSURE RATE:

Two distinct Fluoro entrance exposure rates are supported. The generator controls the Fluoro surface dose rate as a function of the kV, pulse rate and, optionally, of the source-to-patient distance. Before using the generator clinically, the maximum Fluoroscopic entrance exposure rate must be adjusted by the service representative using **Epsilon** PC Tools.

ALARM : Continuous alarm every 5-minute Fluoro interval. The alarm is shut down by pressing a key on the Epsilon console or by using a digital input to the generator.

TIMER : Cumulative timer display resettable by pressing a key on the Epsilon console.

SHUTDOWN: Fluoro shutdown after 10 minutes of uninterrupted Fluoro.

2.3.4 Audible Alarms

Table 8- Audible Alarms

Alarms in Fluoro	
Fluoro Alarm	Tone
"Fluoro beam-on" alarm (1)	Pulsed tone: Low Fluoro=> 1 beep/2 seconds High Fluoro => 1 beep/second
"Fluoro 5-minute elapsed" alarm (2)	Continuous tone
"Anode H.U. over 80%" alarm	Pulsed tone (2 <i>beeps</i> per second)
"System Fault" alarm	4 consecutive beeps
<p>1. This alarm is heard in the X-ray room only and requires the presence of an external buzzer (not provided with the generator).</p> <p>2. The alarm is shut off by pressing the Alarm Reset key at the Epsilon Operator Console.</p>	
Alarms in RAD/Cardiac	
Exposure Alarm	Tone
"X-ray beam-on" alarm	Continuous tone
"80 % of maximum run length" alarm	Pulsed tone (2 <i>beeps</i> per second)
"Anode H.U. over 80%" alarm	Pulsed tone (2 <i>beeps</i> per second)
Exposure Fault and B.U.T. alarms	4 consecutive beeps

2.4.2 ABS Interfaces

Different ABS sensors can be interfaced for Fluoro image automatic stabilization, depending on the generator configuration.

Pulsed Fluoroscopy

- **Photomultiplier tube;** Requires the Fluoro PMT board P/N 9822.00. Gain is adjusted via a high voltage bias supply which can be varied from about -200V to about -950V.
- **Photodiode;** Requires the Photodiode Ion Chamber Fluoro board P/N 11030.000. Usable input signal range is from about 12.5 mV to 9 V or from about -12.5 mV to -9 V.
- **Ionization chamber:** See “Ionization chambers” in Section 2.4.1.

Continuous Fluoroscopy

- **Photomultiplier tube;** Requires the Fluoro PMT board P/N 9822.00. Gain is adjusted via a high-voltage bias supply which can be varied from about -200V to about -950V.
- **Photodiode;** Requires the Photodiode Ion Chamber Fluoro board P/N 11030.000. Usable input signal range is from about 5 mV to 1 V or from about -5 mV to -1 V.
- **CCD camera or flat panel detector;** Usable input signal range is from 0.1V to 10V or from - 0.1V to - 10V.

3.0 MISCELLANEOUS

3.1 X-ray Tube Interface

3.1.1 X-ray Tube Specification

NUMBER: One dual focal spot standard X-ray tube supported.

MODELS: Most popular X-ray tube models are supported through a *built-in* X-ray tube chart. Other X-ray tube models may be added by field service representative.

> Current range : Up to 8.1 amperes (A_{RMS})

> Filament power : Maximum 100 watts

TUBE DERATING: The tube can be derated to extend its usable lifetime, to troubleshoot specific conditions or for other reasons.

ANODE DRIVE : Integrated Low or Dual Speed Rotor Controller.


3.1.2 Focal Spot /Anode Rotation

Manual and automatic focal spot selections available.

Anode rotation set in service mode to low, high or automatic in RAD, and low, high or RAD speed in Fluoro.

Auto Focal Spot in Radiography

In *auto focal spot* selection, the filament is determined as a function of the technique kW and the anode speed. Table 9 below shows the generator algorithm for the selection of the focal spot and anode rotation speed when *auto speed* and *auto focal spot* are enabled. The anode speed is not user alterable as it is set in the workstation configuration.

Table 9- Focal spot and anode speed selection as a function of technique kW	
kW	Focal spot/Anode speed
	
kW	
	Small/Low
	Small/High
	Large/Low
	Large/High

Auto Focal Spot in Cardiac mode

In cineradiography auto focal spot mode, the generator selects the focal spot in RAD as a function of the stabilization kV in Fluoro versus a pre-determined kV-threshold value. When Fluoro stabilizes above the kV threshold value, the next cardiac run uses the large filament. When Fluoro stabilizes below the kV threshold value, the next cardiac run uses the small filament.

Focal Spot in Fluoro

Continuous Fluoro: Small filament (large filament if small filament opens);

Pulsed Fluoro : Small or large filament, as a function of the tube mA.

Anode Rotation : Low, high or RAD speed.

3.2 Environmental Conditions

TEMPERATURE

- Storage : - 25 to + 70°C
- Operating : + 10 to + 40°C

HUMIDITY

- Storage : 30 to 95 %, non-condensing
- Operating : 30 to 75 %, non-condensing

SYSTEM BTU

200 BTU/hr in idle

ATMOSPHERIC PRESSURE

700 hPa to 1060 hPa (hectoPascal)

AUDIBLE NOISE Less than 52 dbA @ 1 m

VIBRATION SHOCK Product packaged to meet air-sea-ground transportation requirements

PRODUCT DISPOSAL



At the end of its usable lifetime, no particular action is necessary for the disposal of the product except those locally in force at the installation site. If the EPS generator is fit with the optional cable discharge unit (high-end Cardiac configurations), the latter contains approximately 30 liters of dielectric oil. When comes the time to dispose of the cable discharge unit, it must done in a way that respects the local environmental regulations in force.

3.3 Physical Dimensions

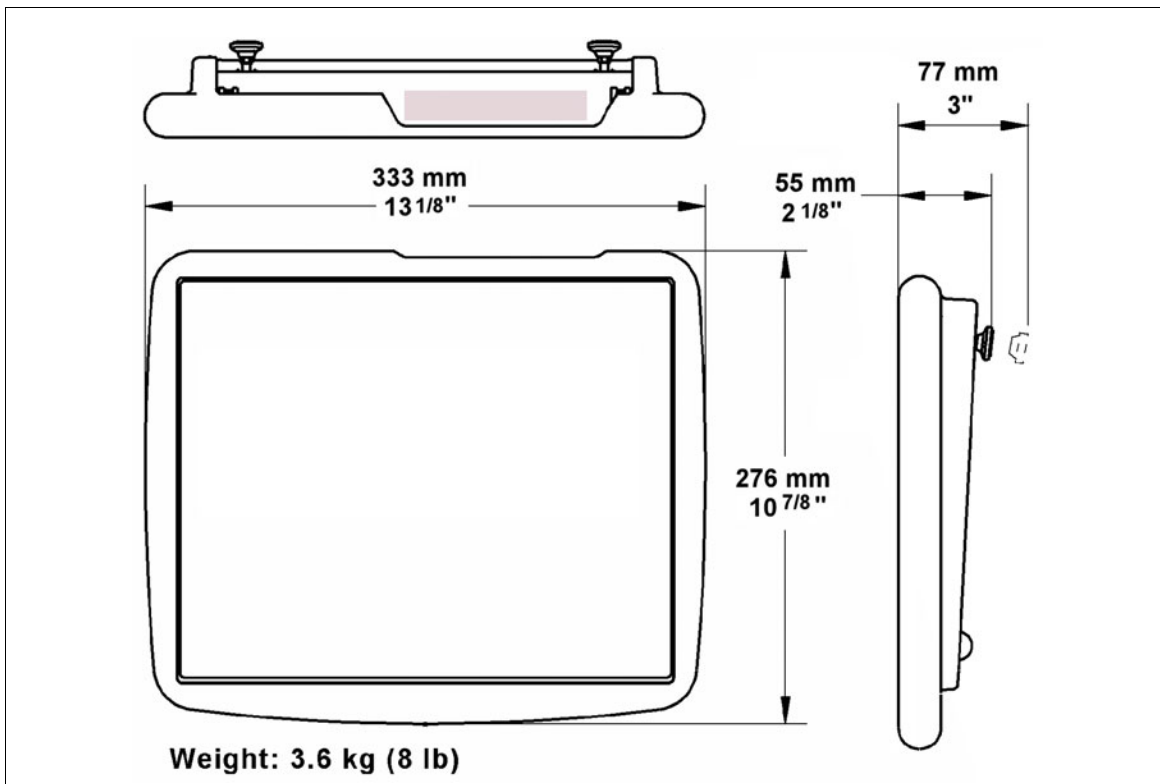
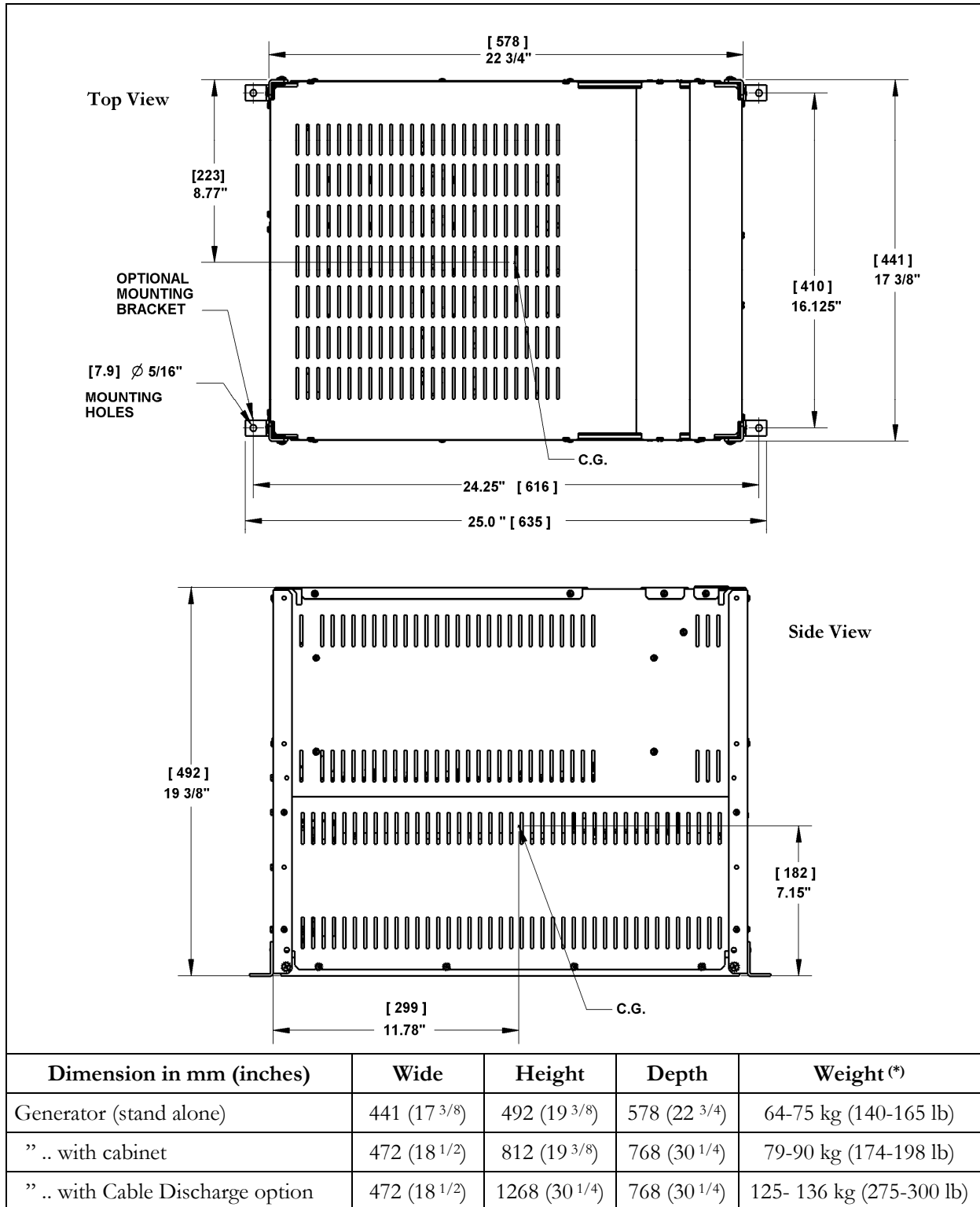


Figure 4 – Operator Console Dimensions.



(*) Approximately, as a function of power configuration

Figure 5 – Epsilon Dimensions; Center of Gravity (C.G.)

Cardiac Epsilon High-Voltage Generator

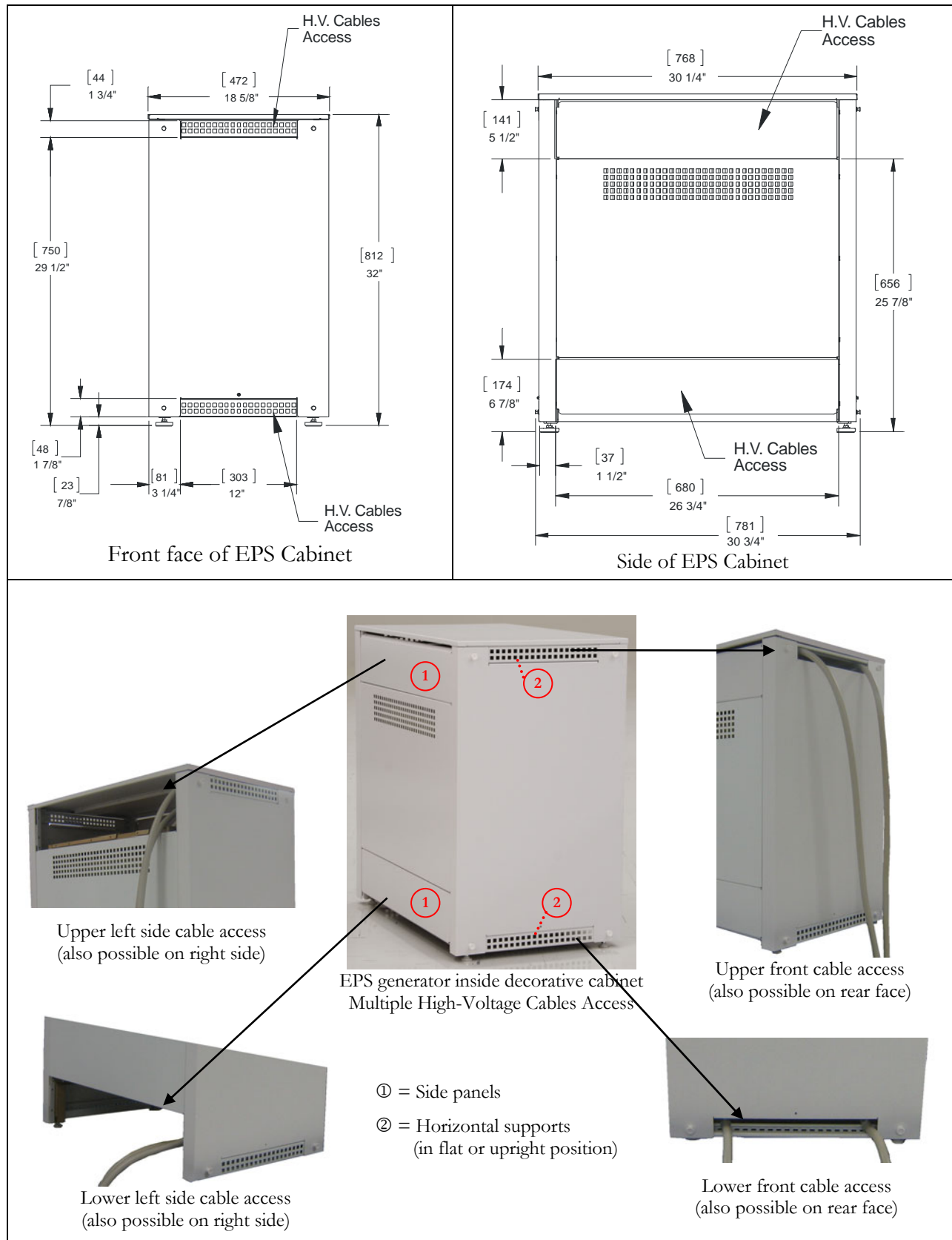


Figure 6 – Decorative Cabinet dimensions and different possible cable access.

3.4 Regulation and Quality Approvals

Table 10- Regulatory Standards

Market	Type	Standard
Canada		CSA C22.2 No. 601-1
USA	Safety	UL 60601-1 IEC 60601-2-7
	Health	This equipment complies with the Radiation Performance, 21CFR, Subchapter J.
Europe		EN 60601-1; EN 60601-1-2; EN 60601-1-3 EN60601-2-7; EN 60601-1-4 Based on the Declaration of Conformity, this unit complies with European harmonized standards for the application of the CE Mark.
<p><u>Note</u> The conformity is based on the equipment configured and interconnected as described in the Technical Manual. Changes or modifications to this equipment not expressly approved by emd technologies could void its conformity to applicable standards.</p>		