Mobile and Portable Radiography Overview:A

Definitions:

Mobile radiography equipment both for radiography and fluoroscopy, radiographic equipment that has wheels that enable it to be moved to a specific location to be used.
Exclusions to this definition for this lecture include sets housed in lorries and vans to provide radiographic services at different sites, i.e. mobile C.T. Scanners and breast screening units.

Portable radiography equipment is taken to be radiographic equipment that may be carried to a destination to be used.

A review of equipment characteristics

- **Portable Radiographic Equipment.**
- **Mobile Radiographic Equipment.**

A review of equipment characteristics and Electrical Characteristics:

1. Portable Radiographic Equipment.

Uses of portable radiographic and mobile/fluoroscopy equipment.

Domicilliary, the practice of taking X-Ray equipment to sites that cannot be reached by conventional mobile radiographic equipment in order to take X-Ray images. Typically these may include a patient's house or region of the hospital or an outlying hospital or ward where the call for radiographic examinations is small and unable to justify the cost of a machine permanently sited there.

Physical Features:

- Size
  Often heavy but have the ability to be taken apart into major parts and carried about.
  The major units include tube stand, control unit, tube head that contains the HT transformer.
- Weight
  Each composite part is usually light enough to carry but the composite weight may be too heavy to carry, the major weights are the support stand and the tube head containing the HT transformer. Care must be taken when assembling to ensure fixations are secure in order to prevent staff and patient injuries. Typical tube head may weigh 30 Kg and the stand a similar amount.
- Wheels
  Small castors aid positing and movement but the small wheel diameter limits the ability to traverse and obstacles.
- Range of movements
  Usually limited to vertical and tube rotation at 90^0 to the long axis of the tube movements controlled by friction locks and or rack and pinion movement.
- Electrical supply
  No special supply is required the unit being operated from a standard domestic 13 Amp socket. Typical maximum power consumption is 240 volts at 14 Amps peak for an exposure of 70 KVp at 10 - 15 mA. There may be a special earth lead to connect the all exposed metal parts.
- Maintenance & safety
  Care must be taken with electrical safety due to the fact that damage may occur when the unit is being transported, visual inspection of electrical cables and the support structure must be undertaken whenever the equipment is set up or taken down.
- Cost
  Units range from £6000 for a very basic unit up to £20,000 for a more sophisticated set.
- Advantages Disadvantages & Limitations.
  Major advantages include, these units permit radiographic examination in locations only limited by the availability of a standard electrical supply.
  Disadvantages include, low output a typical maximum is 80 KVp at 15 mA for 1 second.
  Difficult to control X-Ray safety aspects of radiation protection.

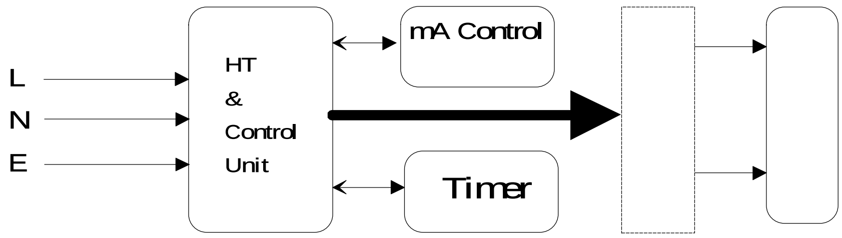
Electrical Characteristics:

- Electrical supply

A 240 Volt single phase alternating current household supply.

- Circuit description

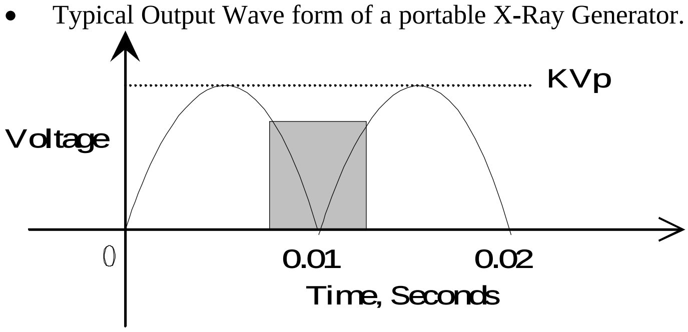
Basic X-Ray Unit Block Diagram



(Most portable sets are self rectified or have two rectifiers)

The Auto transformer has the following controls located within its construction.
Line voltage compensation
KVp selector
mA selector controlling the filament circuit
A basic timer unit, early models clockwork now solid state.
The auto transformer is connected to the high tension transformer and the X-Ray tube is connected to the high tension transformer directly or via a rectification circuit.
Generally a single focus stationary anode tube.

- Typical Output Wave form of a portable X-Ray Generator.



The importance and implications of this output wave form are that unless there is some form of exposure phasing to ensure that the exposure encompasses a full cycle the exposure if less than 0.01 seconds may not achieve the maximum output voltage. (Shaded section)

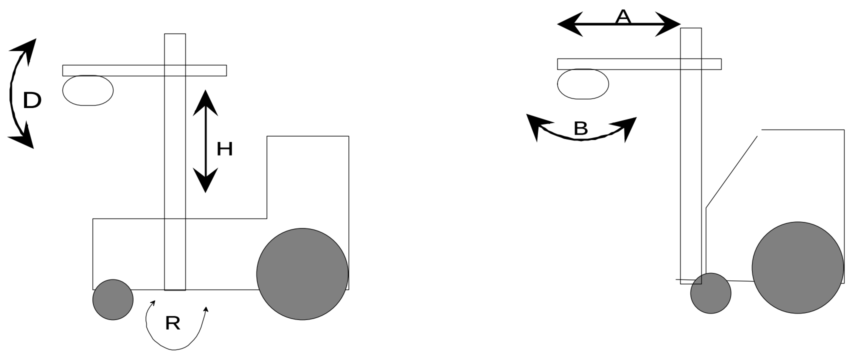
A review of equipment characteristics

- **Mobile Radiographic Equipment.**

Physical Features:

- Size
  Mobile equipment must be so designed as to be easily accommodated in limited space, i.e. ward side rooms and alongside beds and in the often limited space of an operating theatre. The generator and base unit may be of low design or waist high design.

Typical Mobile Chassis Designs



- **Range of movements**

The range of movements available is one of the most important factors governing ease of use of mobile equipment. The range of movements can be split into five major components. In order to prevent damage to cables that is a safety hazard all movements should have mechanical stops.

i) Rotation around the centre of the column, (R)
ii) Cross arm movements the extension of the tube head away from the centre of the column,(A)
iii) Rotation around the axis of the cross arm, (D)
iv) Angulation across the long axis of the tube head.(B)
v) Vertical movement up and down main column (H)

An important point in the usefulness of the range of movements is the maximum distance obtainable from the centre of the tube column to the tube head. (A) As this determines how close alongside a bed or operating theatre table the mobile can be placed. If the distance is short accurate positioning becomes awkward, and in an operating theatre creates difficulty in maintaining a sterile field.

One of the limitations to the range of movements is dependent on the centre of gravity of the design, if the centre of gravity is low then the distance the tube head can be moved away from the centre of the column is higher than if the centre of gravity is raised.
The centre of gravity of a mobile is determined by how low the components of major mass can be positioned. Mobiles with battery packs that tend to be heavy and large HT. transformers positioned low down tend to be more stable, as in the "low design".

Some machines (IGE Explorer and D38) have an extending column to increase the range of height movement (H) whilst at the same time allowing the column to fit under a normal door height.

Movement locks and limiters, all movements of the tube head must have some form of lock in order to maintain the position, there are four main types.
i) Friction locks
These are generally a clamp type design and are hand operated at the site of locking, they have the advantage of being cheap effective and simple but suffer from sometimes being inaccessible in use.
ii) Electromechanical locks
Consist of a solenoid operated friction clamp operated by switches, sometimes remote from the site of operation often on the tube head handles making for easier operation during use. Disadvantages include non operable when the machine is switched off or not connected to the electrical supply.

iii) Counterbalance systems
These systems employ either gas/oil filled struts or cables and counterbalance weights to apply an equal and opposite force to that caused by the mass of the tube head only requiring the effort of the operator to overcome friction to position the tube head. Counterbalance systems should be locked during transport, gas struts can be bulky and limit the range of movements.
iv) Rack and pinion electrical drive locks
Some mobiles have a variety of movement aids including a motor driven column system that reduces radiographer strain and simplifies positioning especially in difficult locations, there is usually a manual override system in case of failure, remember to disconnect drive when operating manually.

- **Wheels and Drive**

There are two types of motive power for mobiles,
i) Radiographer power here the motive power is provided by human effort.
ii) Motor driven or motor assisted, here the rear wheels are driven by an electric motor with power supplied by either batteries when it is available all the time or from the mains when the mobile is "plugged in". With battery powered drive the drive batteries are separate from any batteries used for X-Ray production. Drive may be provided at a single speed, continuously variable speed, or a two speed system where the first position on the switch usually a hand switch is low speed for positioning and a higher speed for moving around the building plus either a single speed or two speed reverse. As a safety measure the speed / drive control needs continuous human pressure to operate and is designed so it cannot be operated accidentally.
A motion brake is generally provided and may be interlocked with the speed control, there may also be interlocks to prevent full transport speed when the tube is not parked safely and or the machine is "plugged in".
Motor assisted mobiles require less effort but adds to the weight and cost of mobiles.
In general mobiles have two larger drive wheels at the back and two small steerable castors or wheels at the front. Some mobiles have a drive warning sound that is a safety requirement in some countries.

Typical drive statistics: (Picker Explorer) At full charge.
Fast speed 2.5 mph max.
Slow speed 1.2 mph.
Reverse 0-1.25 mph.
Distance ability 10 Mlles
Incline ability 1.2 miles at 10°
Braking within 3/4 inch
Ability to climb steps 1 inch max.
Turning circle 54 inches

- **Weight**

The weight of a mobile is important when considering old lifts and floors and manouverabilty.
Examples: (typical person 70 Kg.)
400 Kg. Picker Explorer battery driven self powered.
380 Kg Deans D38 self propelled mains operated.
330 Kg Wolverson Tanka battery driven mains powered capacitor discharge.
140 Kg Philips Practix 30 Medium frequency mains powered.

- **Light beam diaphragm and collimator**

Most mobiles have a light beam collimator with fully adjustable collimation and a central line light indicator as in the GEC "Care" system.
Capacitor discharge mobiles have an extra lead shutter that closes when the capacitors unused residual charge is being discharged through the tube after use.
Older mobiles may have no light collimator, some have a pointer arrangement some may have a lens and mirror 'periscope viewing arrangement with an adjustable collimator.
Another option is the use of fixed cones and diaphragms.
Many incorporate a retractable tape measure for measuring F.F.D. modern equipment may have an ultrasonic distance measuring device with audible indications at standard distances.

- **Cable storage**

All mobiles have some form of mains cable, either a heavy duty type if the X-Ray circuits do not use either a discharge capacitor or an inverter, or a thinner lightweight cable to supply battery charging functions.
Some equipment has a special retracting cable drum that minimises cable damage in storage others have simple hooks to wind the cables round.
Care must be taken with mains leads to prevent damage that may compromise earthing arrangements.

- **Electrical supply**

Most mobile require a standard 240 volt single phase 13 Amp supply.
The exceptions to this are the mobiles that are single phase full wave rectified units, e.g. Deans D38 Mobile.
These mobiles usually are operated by a special mains circuit in the buildings they are to be used in. These special low resistance circuits are characterised by using a large three pin round plug or the special 'X-Ray' only red plug that has no fuse. The special X-Ray wall sockets are special low resistance circuits with a measured line resistance that corresponds to a numbered scale on the control panel and the socket number, which the line resistance scale selector has to be matched to during use.

- **Maintenance & safety**

All mobile equipment should be serviced as per the manufacture's schedule as due to there mobility extra mechanical stresses are imposed on them that increases the possibility of electrical and mechanical failure.
Mobiles should be charged in a well vented atmosphere as hydrogen is given off along with oxygen during the charging of lead acid batteries.
Most mobiles contain a warning that they are not to be used in explosive anaesthetic atmospheres.
Mobiles should be kept 'clean' as they represent a contamination risk due to be moved between wards and coming in contact with patients' beds etc. which increases the likelihood of cross infection.
Particular attention should be paid to radiation safety and all local rules governing their use should be adhered to.
When moving mobiles the tube head should be parked as per the manufactures instructions to minimise damage to the anode rotor bearings.
Brakes must be applied when travelling in the lift.

- **Cost**

Typical Approximate Costs
£36,000 Picker Explorer battery driven self powered.
£21,000 Hitachi Sirius 125B Capacitor discharge.
£12,000 Philips Practix 30 Medium frequency mains powered.

Mobile and Portable Radiography Overview:B

Definitions:

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Portable radiography equipment is taken to be radiographic equipment that may be carried to a destination to be used.

A Review of Generator Types.

1. **Single phase, full wave rectified.**
2. **Constant Potential.**
3. **Capacitor discharge.**

Block Diagram of a Single phase, full wave rectified, Generator

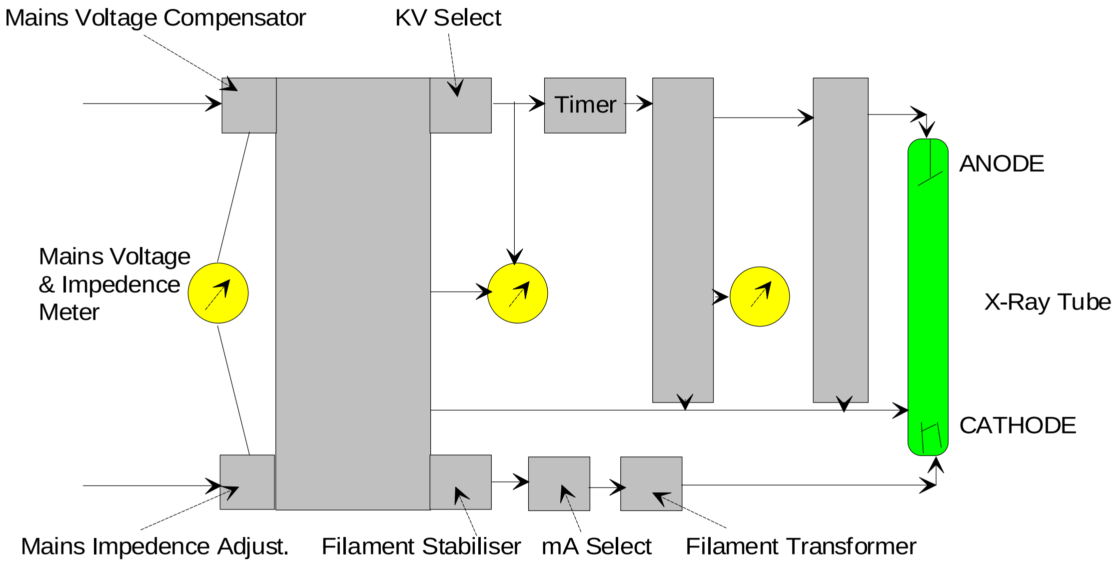
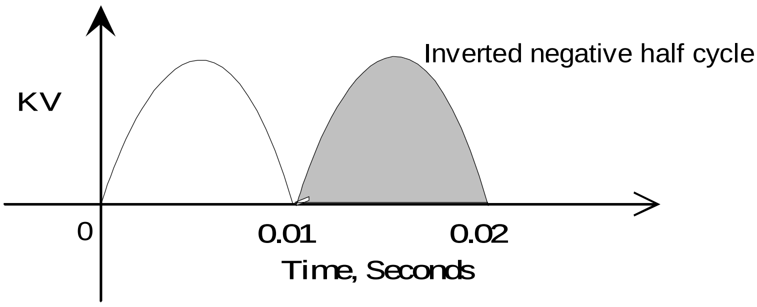


Diagram of a Theoretical Wave form from a Single phase, full wave rectified, Generator



Single phase, full wave rectified, Generator
Operation Notes

The essential feature of these machines is that they are powered from the typical domestic mains 240V at 13A Max., in some machines it is necessary to set a main's voltage compensator and possibly a frequency compensator, with the values indicated on a dual scale panel meter.
An auto transformer with pre-set tappings supplies the preselected KV and mA values supplied to the high tension transformer, the secondary voltage of which is rectified and fed to the X-Ray tube.
Tube current mA is controlled by the tube filament heating current supplied by the filament transformer and a set of current limiting resistors.
During exposure the actual voltage delivered to the primary of the HT transformer depends not only on the main's voltage but also the mains impedance, and it's correction circuit. The higher the main's impedance the greater the voltage drop during exposure.

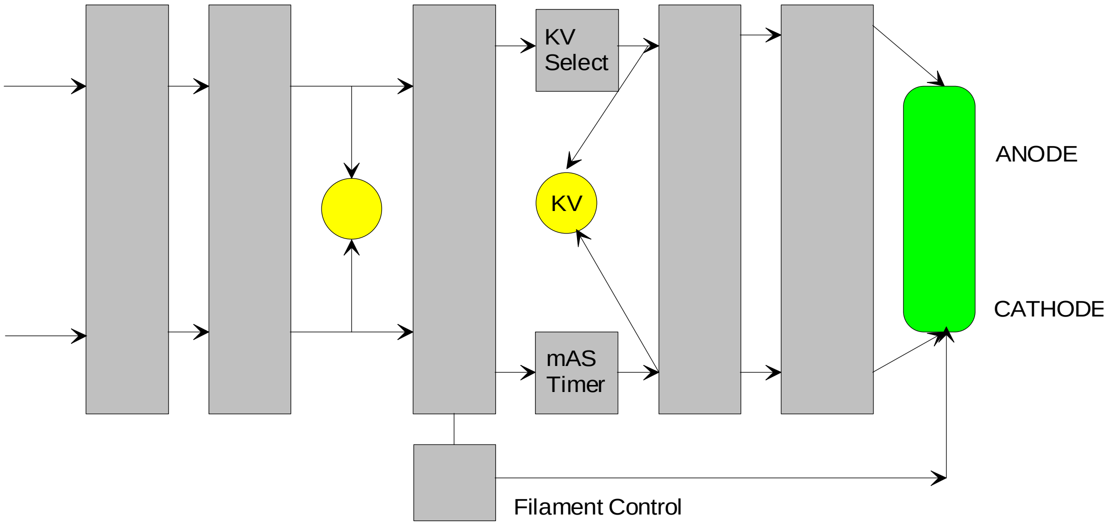
The major problem with a single phase full wave rectified circuit is that there is 100% ripple and useful radiation is only produce for 66% of the exposure time and only instantaneously reaches the peak value. This peak exposure voltage reduces the effectiveness of the output compared with a constant potential unit by 10% so when transferring exposure values between machines the values used by this type of mobile need to be set 10% higher than constant potential units.

The range of exposure times available on a single phase mobile is determined by the main's frequency because it is necessary to begin and end the exposure (Zero voltage switching) at zero voltage. Hence exposure times are multiples of the half cycle time, half cycle as the negative half cycles are inverted.
Thus the theoretical minimum exposure time is 0.01 S. This is more usually limited to 0.02S.

The nominal power output is limited to below 15 kW.
The tube is normally a low speed rotating anode type with a bi focus.

Block Diagram of a Constant Potential Generator.

Type 1 NiCad



Type 2 Primary Capacitor

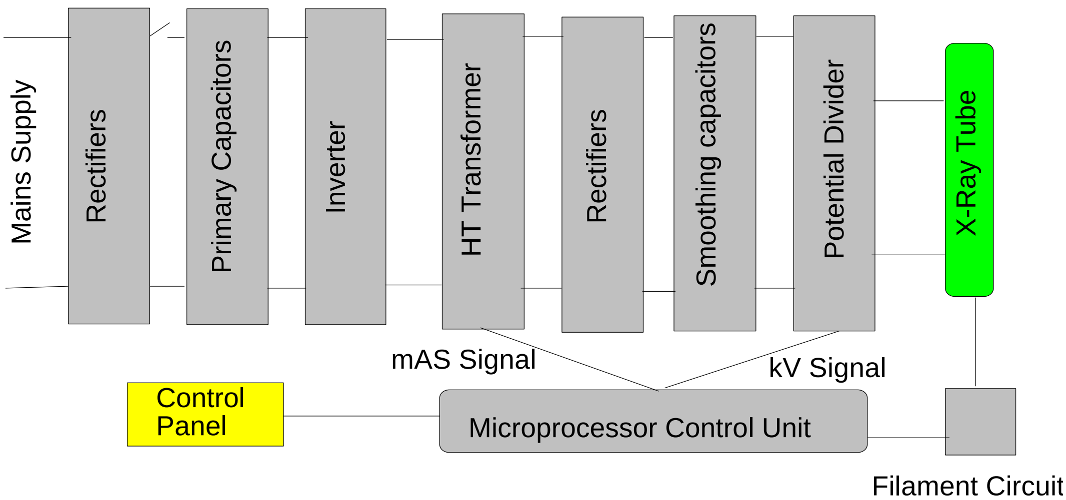
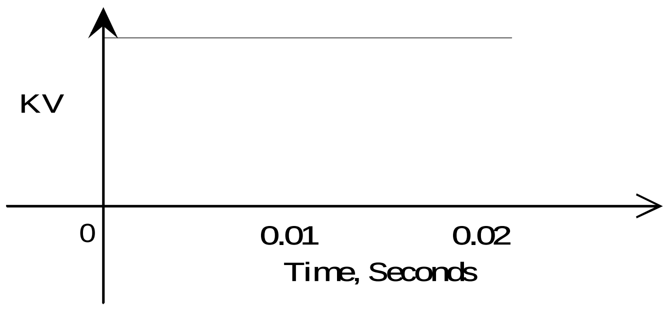


Diagram of a Theoretical Wave form from a Constant Potential Generator



Operation Notes
Constant Potential Generators.

Type 1 NiCad
This is a mains independent mobile using rechargeable batteries for all it's functions both radiographic and motor drive. There may be a control for adjustment to compensate for the voltage drop of the batteries during use but Nickel cadmium batteries have a very low voltage drop during normal usage.

The essential feature is a 500Hz inverter powered by a 130 volt Nickel Cadmium battery with a capacity of 10.000 mAS.
The 130 Volt DC supply is converted to an alternating voltage by the inverter unit that supplies the High tension transformer, running at 500Hz it is more efficient than a 50Hz transformer so the windings and core can be made smaller and lighter than a similar unit operating at 50Hz.
The 500 Hz is not ripple free but the ripple is reduced to less than 5% by the smoothing capacitor sited in the secondary circuit.
The exposure timing is controlled by monitoring the 500Hz wave form and using subdivision of this frequency down to 0.001 seconds.
The operating current mA is fixed at 100mA.
The X-Ray tube is normally a bifocal rotating anode design.
The machines have a nominal power of 10kW

Type 2 Primary Capacitor
This is a high powered and sophisticated design.
Energy for exposure is stored in a large primary capacitor that is charged either from the mains or from a battery.
An inverter is used to convert the D.C. output from the capacitor that is charged between exposures into a 4.5kHz A.C. supply for X-Ray generation by the HT transformer.
High tension transformer, running at 4.5kHz it is more efficient than a 500Hz transformer so the windings and core can be made smaller and lighter than a similar unit operating at 500Hz.

The voltage across the tube is monitored by microprocessor and constant potential is ensured by contiguously adjusting the tube current during exposure.

Block Diagram of a Capacitor Discharge Generator.

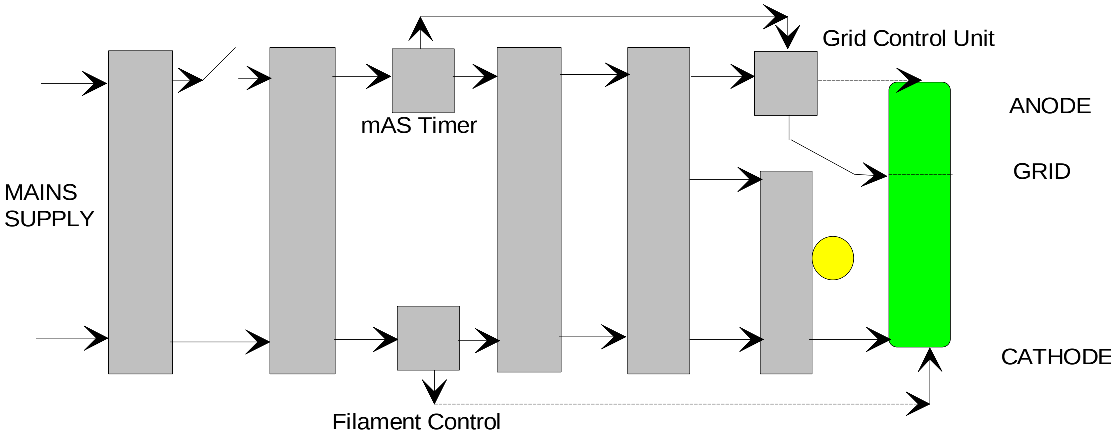
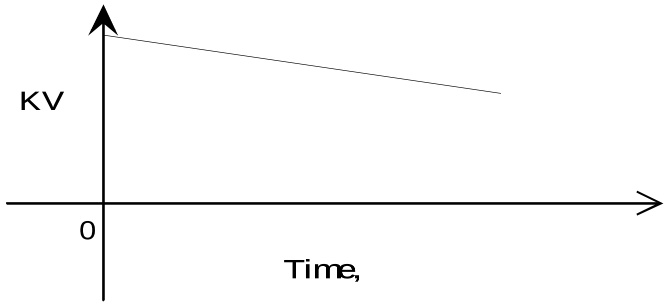


Diagram of a Theoretical Wave form from a Capacitor Discharge Generator



Operation Notes
Capacitor Discharge Generator

The fundamental of these machines is that the tube voltage is stored in a one microfarad capacitor a is discharged through a grid controlled X-Ray tube. In the previous example the charge stored in the capacitor was discharged into a semi conventional high tension circuit not across the tube so is not a true capacitor discharge mobile.
The capacitor discharge mobile must be connected to the mains but does not require and compensation circuit, and the radiographic output is not affected by the mains supply.
The machine only requires a small amount of mains current to charge the capacitor so requires no special mains supply.
The capacitor is charged to the required voltage after selection and gradually after a few seconds reaches the set voltage. The actual voltage is indicted by the kV meter, charging stops when the capacitor voltage is the same as the kV selected.
The mAS selected is the amount of charge delivered by the capacitor when exposure is terminated.

When the exposure is instigated after the prepared sequence is completed the grid bias of around -2kV is removed and the tube makes an exposure until the set mAS is delivered. This is monitored by the control circuit so the machine has no timer as such, the tube operates in saturated condition and the mA is constant at around 100mA. When the desired mAS has been delivered the tube's grid bias is reapplied and exposure is halted.

In a 1µf design the kV drop is around 1 kV per mAS used and the effective voltage is 1/3 of the voltage drop lower than the starting voltage.
Hence the equivalent kV=Starting kV-1/3 x mAS used.

Example for an exposure of 87Kv and 20mAS
87-(1/3 x 20)=

87-6.6 = 80Kv Effective.

The starting exposure must be such that the end exposure contributes to the image, in practice any end exposure of less than 50 kv will contribute little to image formation but will cause excessive skin dose.

When the exposure has been made there is still a residual charge in the capacitor.
To remove this a special discharge circuit is employed, the capacitor is discharged through the tube but a special lead shutter closes the exposure aperture to protect the operator and patient. This operation has to be performed if the kV selected needs to be lowered the charge cycle has to be reduced to zero and then reset.

The X-ray tube is a grid controlled single focus rotating anode tube.

Table 1 Equivelent Set and Departmental Kv values for a capacitor discharge mobile at a selection of mAs values.

mAs	2		5		10		20		30		40		50	
Kv Drop	**1**		**2**		**3**		**7**		**10**		**13**		**17**	
Dept KV	**Equiv Kv**	**End Kv**	**Equiv Kv**	**End Kv**	**Equiv Kv**	**End Kv**	**Equiv Kv**	**End Kv**	**Equiv Kv**	**End Kv**	**Equiv Kv**	**End Kv**	**Equiv Kv**	**End Kv**
50	51	49	52	47	53	43	57	37	60	30	63	23	67	17
60	61	59	62	57	63	53	67	47	70	40	73	33	77	27
70	71	69	72	67	73	63	77	57	80	50	83	43	87	37
80	81	79	82	77	83	73	87	67	90	60	93	53	97	47
90	91	89	92	87	93	83	97	77	100	70	103	63	107	57
100	101	99	102	97	103	93	107	87	110	80	113	73	117	67
110	111	109	112	107	113	103	117	97	120	90	123	83	127	77
120	121	119	122	117	123	113	127	107	130	100	133	93	137	87
Dept KV	**Equiv Kv**	**End Kv**	**Equiv Kv**	**End Kv**	**Equiv Kv**	**End Kv**	**Equiv Kv**	**End Kv**	**Equiv Kv**	**End Kv**	**Equiv Kv**	**End Kv**	**Equiv Kv**	**End Kv**

Equivelent Kv = Department Kv + 0.33 x mAS

End Kv = Equivelent KV – mAS value

Example of Exposure Calculations for a typical

Capacitor Discharge Mobile X-ray Unit

Adult Chest Exposure

Departmental Exposure = 80 kv @ 4 mAs

Question 1a. *What would be the equivelent exposure using a Capacitor discharge mobile?*
Question 1b. *What would the start and end kv values of the exposure?*

Answer 1a
kv (Equivelent) = kv (dept) + (0.33x mAs)

kv (Equivelent) = 80 kv + (0.33 x 4 mAs) = Kv(Equivelent) 81.2

Answer 1b
Kv drop = 1 kv per mAs of exposure
The start and end kv values of the exposure 81.2 - 4 = 77.2

Adult Abdomen Exposure

Departmental Exposure = 80 kv @ 40 mAs

Question 2a. *What would be the equivelent exposure using a Capacitor discharge mobile?*
Question 2b. *What would the start and end kv values of the exposure?*

kv (Equivelent) = kv (dept) + (0.33x mAs)

kv (Equivelent) = 80 kv + (0.33 x 40 mAs) = Kv(Equivelent) 92

Answer 2b
Kv drop = 1 kv per mAs of exposure
The start and end kv values of the exposure 92 - 40 = 52 kv

Adult Lateral Lumbar spine Exposure

Departmental Exposure = 90 kv @ 100 mAs

Question 3a. *What would be the equivelent exposure using a Capacitor discharge mobile?*
Question 3b. *What would the start and end kv values of the exposure?*

kv (Equivelent) = kv (dept) + (0.33x mAs)

kv (Equivelent) = 90 kv + (0.33 x 100 mAs) = Kv(Equivelent) 123

Answer 3b
Kv drop = 1 kv per mAs of exposure
The start and end kv values of the exposure 123 - 100 = 23 kv

This is clearly unacceptable….

(Ref. Mobile X-Ray Generators: a review By Evans, Harris, Lawinski & Hendra Radiography March/April 1985Vol. 51 No: 506)