National School of Healthcare Science

NHS Health Education England

Competency: Critically evaluate the function of the ionisation chamber in the Linear Accelerator and its importance for correct treatment delivery

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Trainee: Trainee

Module: Radiotherapy Physics

Competency:
D2.5: Critically evaluate the function of the ionisation chamber in the Linear Accelerator and its importance for correct treatment delivery.

Date of Review: 30/04/2012

Evidence:
20/04/2012 I attach a document describing the function and importance of the ionisation chambers in a linac.

Files: (one attached document)

Reviewer: Assessor

Feedback: 30/04/2012: Very good summary

Outcome: Satisfactory

Ionisation chambers in the linear accelerator

D2.5 - Critically evaluate the function of the ionisation chamber in the linear accelerator and its importance for correct treatment delivery

- Function of a general ionisation chamber
- Varian clinac ionisation chambers
- The ionisation chamber's importance for correct treatment delivery
- References

Function of a general ionisation chamber

Ionisation chambers make use of the fact that radiation of sufficiently high energy, such as the x-ray and electron beams used in radiotherapy, can knock electrons off atoms and molecules, which is the process of ionisation. This creates ion pairs of opposite charge in what was an electrically neutral environment.

An ionisation chamber can be open or closed (in a linac head they are closed), but in either case the chamber contains a sensitive volume in which ion pairs are created by the action of incoming radiation. A voltage is applied across the volume, with oppositely charged electrodes. The negative ions are attracted towards the positive electrode (anode) and the positive ions to the negative electrode (cathode), so the ion pair is split and the electrodes receive a tiny signal (current) for each pair created. The current per pair is very small, but it is still an order of magnitude easier to measure than the temperature rise in a calorimeter from the same radiation [2].

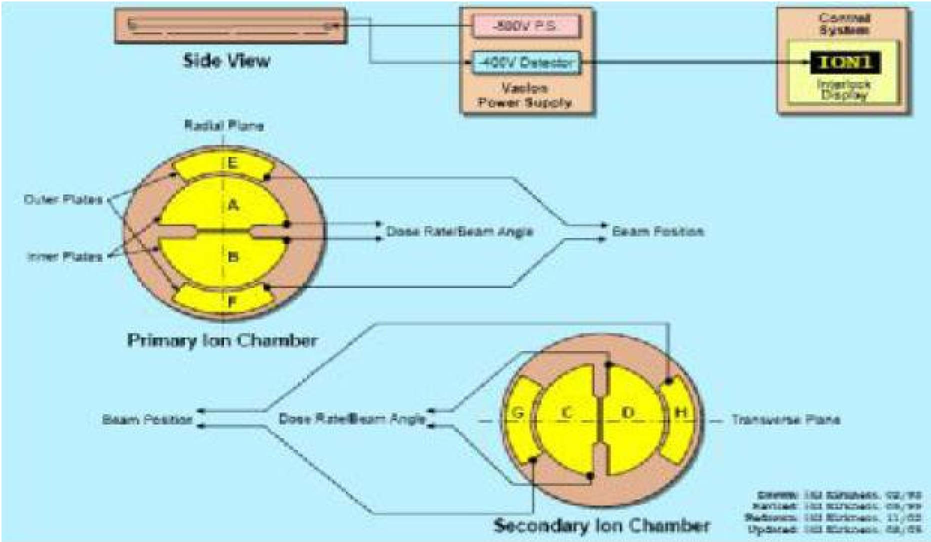
The amount of ionisation is proportional to the mass of the sensitive volume, so in an open ionisation chamber filled with air, measurements must be corrected to a standard temperature and pressure to account for density variations [2]. There is a small correction required for relative humidity, but it is so small as to be negligible under normal conditions (relative humidity between 20% and 70%), and a more significant correction for recombination of the ions (reduced by having a greater voltage) [2].

Varian clinac ionisation chambers

For further details, see reference [1]

There are two independent ionisation chambers found in a Varian Clinac, each consisting of two pairs of plates. The primary chamber is denoted MU1, and has plates aligned along the radial axis of the beam. For MU2, the secondary chamber, the plates are aligned along the transverse axis. In monthly tests, MU1 and MU2 are tested to check that they match. If not, they must be recalibrated.

The two chambers are shown in the diagram below:



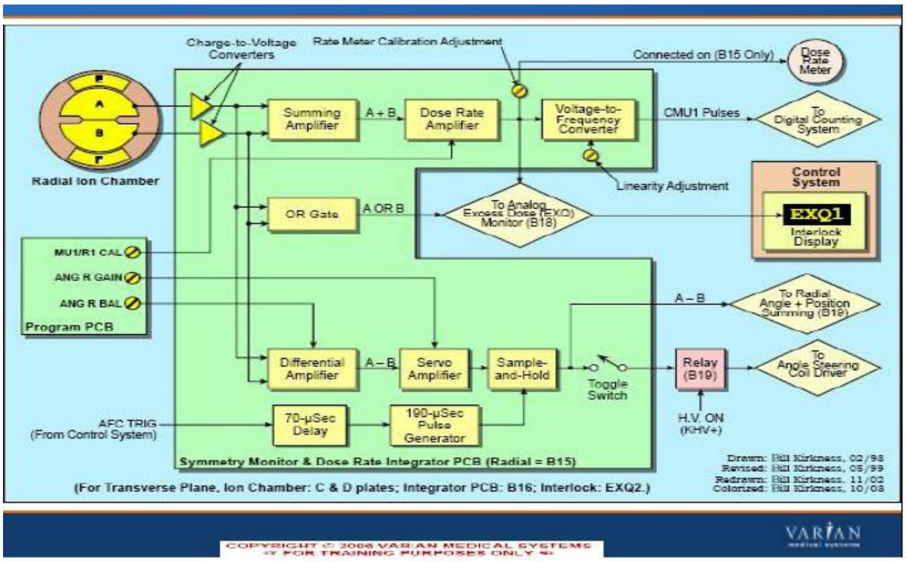
The chambers are used to monitor dose rate and symmetry. The small currents are converted to voltages and summed, forming pulses which are proportional to the dose rates on the inner plates. Each pulse is proportional to 1 cMU, so by recalibrating MU1, the ratio of cGy to MU can be set.

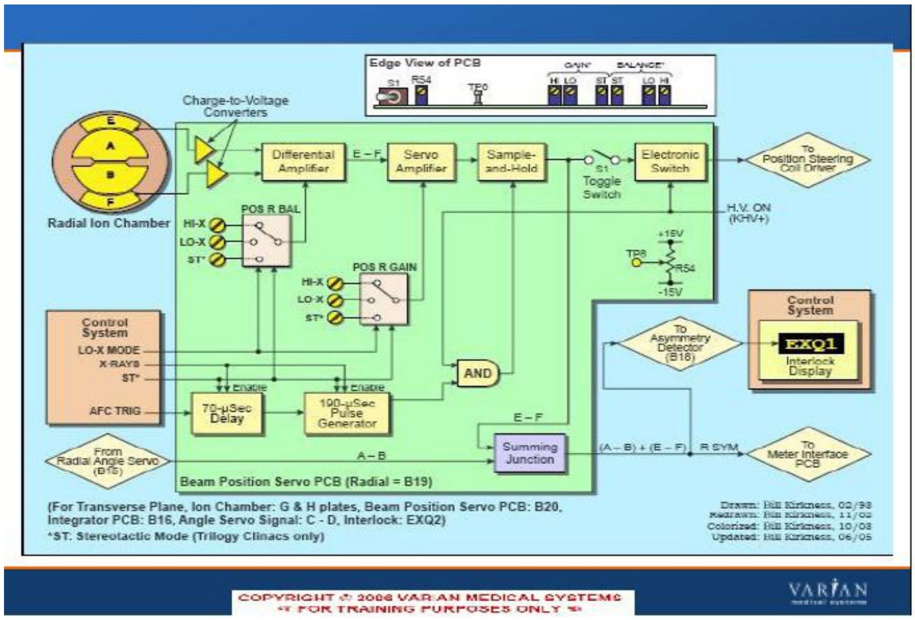
- The inner plates (e.g. A and B) are completely within the beam.
    - Their summed output current is therefore proportional to dose rate.
    - The difference in their output currents reveals beam angle symmetry errors. An interlock is generated for a difference of more than 8V.
- The outer plates (e.g. E and F) are partially within the beam, on its edge.
    - The difference in their output gives the beam position symmetry errors.

For these measured angle and position errors, there are feedbacks to correct the beam. Actually, the position and angle error signals are summed together to give R and T symmetry signals which are then monitored by asymmetry level detectors. The ion chamber charge is also monitored, and excess of either charge or asymmetry generates the EXQ1 or EXQ2 interlock (primary or secondary chamber), causing instantaneous termination of the gun current.

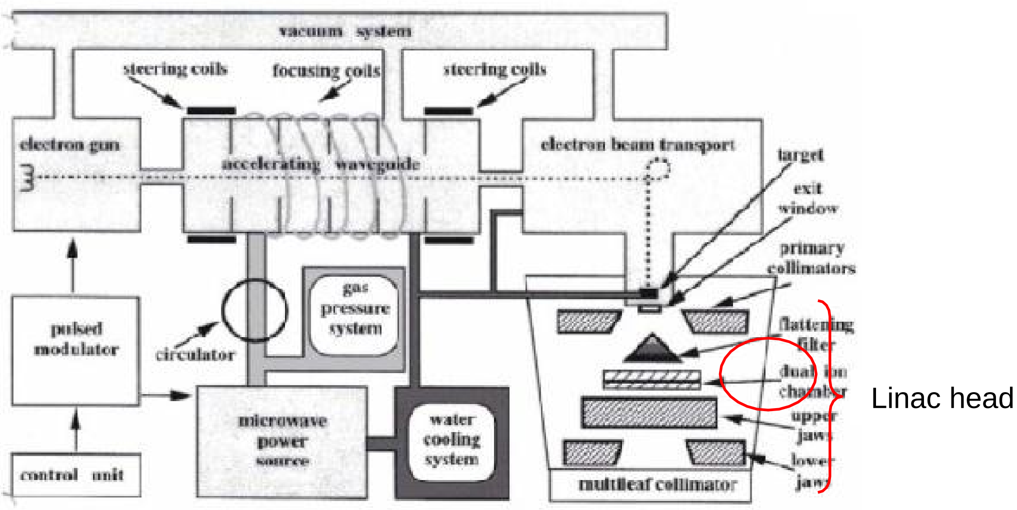
The DOS1, DOS2 and DS12 interlocks are directly controlled by the ionisation chamber inner plate measurements. DOS1 refers to the output measured by MU1, with DOS2 the equivalent for MU2. DS12 is the interlock affected by the difference in output measured by the two chambers.

The pathways for signals from the inner and outer plates are shown in the following diagrams:





The two ionisation chambers, MU1 and MU2, are located in the treatment head of the linac. A schematic diagram of a linac shows this [3]:



The ionisation chamber's importance for correct treatment delivery

The ionisation chambers in the linac are vital for ensuring that the correct dose is given to the patient. Complete tolerances and action levels are given in WORK INSTRUCTION, and are based on IPEM 81 [5]. I describe action and tolerance levels in more detail in reference to another evidence document produced by TRAINEE

The IPEM Report 81 (chapter 1) states that "a figure of 3 per cent can be taken as the currently recommended accuracy requirement on dose…changes will be likely to be clinically observable for dose changes at twice this level" [5]. It also states "Variation in the dose distribution across the target volume may also be expected to affect treatment outcome". In other words, the values of output (dose, dose rate) and beam angular and positional asymmetry are key to the success or otherwise of radiotherapy treatment, and must be closely monitored. Incidentally, the uncertainty of up to 3% (2% is used as a tolerance level at the HOSPITAL, with 3% forcing treatment to stop) must be combined with other uncertainties, such as patient movement and change in shape, to give an overall uncertainty of around 5%. For a palliative patient, up to 10% might be permissible.

While tests of output using equipment such as a Linacheck occur every day, and monthly and annual QA measures output as well as beam flatness and asymmetry, MU1 and MU2 are the only means of measuring flatness, symmetry and output for each individual patient and while treatment is in progress. As such, the existence and correct functioning of the ionisation chambers in the linac are essential to the treatment of patients.

References

[1] *Customer Clinac HE Training* Craig Phillips, Varian Medical Systems

[2] National Physical Laboratory Practical Course in Reference Dosimetry, *Overview of Dosimetry*

[3] www.emitel2.eu, accessed 19/4/12 [4] WORK INSTRUCTION

[5] IPEM Report 81, *Physical Aspects of Quality Control in Radiotherapy*