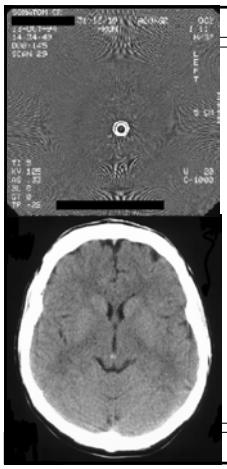
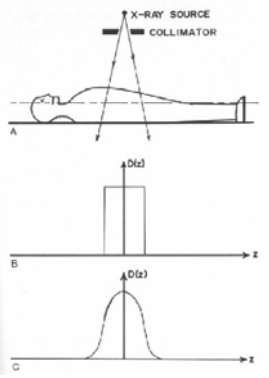


Basis of QC in Computed Tomography

Dr Slavik Tabakov

Dept. Medical Eng. and Physics
King's College London

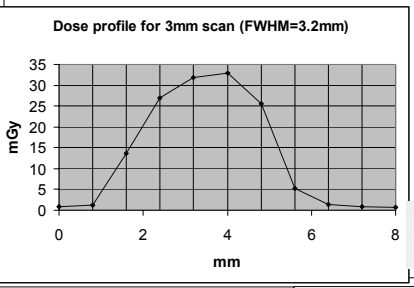
E-mail: slavik.tabakov@kcl.ac.uk

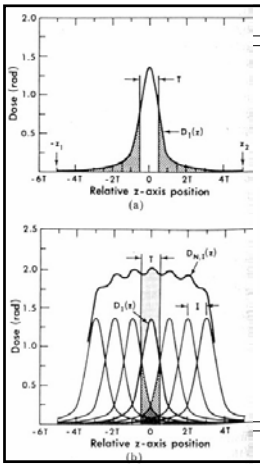


The beam width is determined by the tube collimator. Ideally it would be with steep sides, in practice it is spread (bell shape dose distribution). When numerous contiguous slides are made, the spread overlap. This creates an overall dose increase

Dose profile (for each slice thickness)

measured over one scan with TLD chips or film





Computed Tomography

Dose Index - CTDI

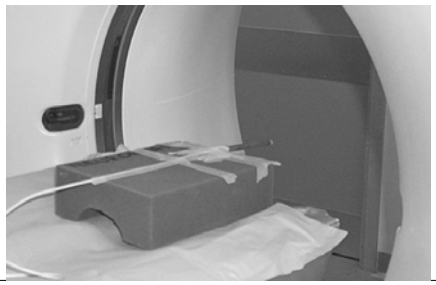
Originally the integration is over 14T

$$CTDI = \frac{1}{n.T}\int_{z1}^{z2} D(z)dz \quad \textbf{mGy}$$

z1,z2	= the limits of integration
D(z)	= the single slice dose profile
T	= the nominal slice thickness in cm
n	= the number of slices irradiated simult

Measurement of **CTDI** $_{\textbf{10cm, air}}$ (here - at the centre of rotation)

The scan is aligned at the centre of the ionisation chamber (at 5cm)



CTDI measured in air with 10 cm ionisation chamber, using a single scan. The measurement is normally at two positions - one at the centre of rotation and one in the periphery (10cm off axis).

UK ImPACT measurement

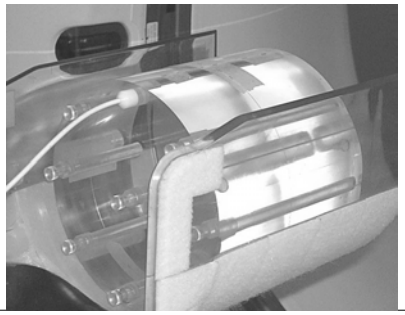
The 10 cm ionisation chamber should be calibrated with 125 kV X-ray beam with extra filtration (equivalent to HVL ~ 7-9 mm Al) - equivalent to effective energy ~ 50-59 kV for monoenergy beam

$$CTDI_{10cm,air} = R \times cf_E \times 8.76 \times 10^{-3} \times \frac{L}{T} \quad \textbf{mGy}$$

R	= ion chamber reading in 'mR'
cf_E	= calibration factor of ion chamber at appropriate energy (55 k
8.76×10^{-3}	= factor to convert exposure (mR) to dose in air (mGy)[21]
L	= length of ion chamber (= 10 cm)
T	= nominal slice thickness (in same units as L; cm)

Measurement of **CTDI $_{10cm, CTPX}$** (here - at the phantom periphery)

The scan is aligned at the centre of the ionisation chamber (at 5cm)



The FDA/ImPACT CTDI difference comes from the dose integration distance (respectively 14 cm and 10cm). Also the UK ImPACT group uses 10 cm ionization chamber, irradiated with one scan in the middle; FDA uses TLD chips arranges in an long insert, placed in the phantom, also irradiated with one scan in the middle, and sum of all TLD doses .

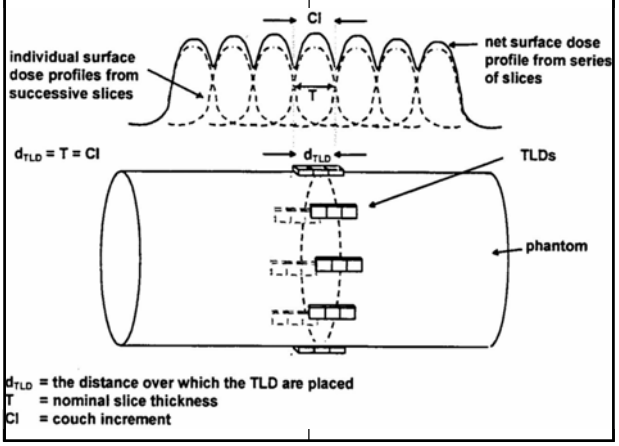
Example $CTDI_{14cm,FDA}$ /$CTDI_{10cmCTPX}$ = 1.1(centre); = 1.05(periphery)

A comparison Table for the Ratio $CTDI_{14cm,FDA}$ and $CTDI_{10cmCTPX}$ can be taken from the UK MDA ImPACT Report 98/25 (blue report)

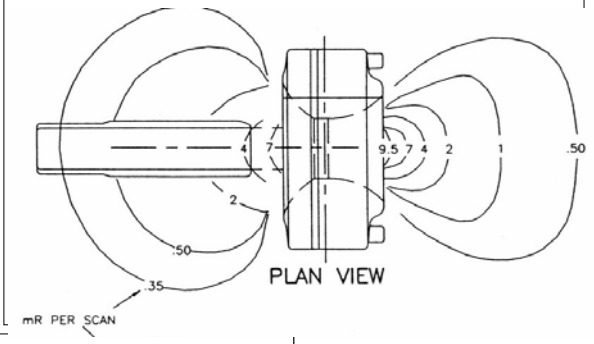
http://www.sghphy.demon.co.uk/impact.html

The new EU protocol for CT QC is also based on 10cm ion.chamber:

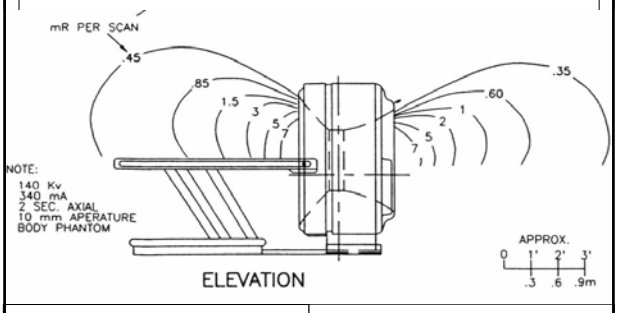
http://www.drs.dk/CT/document/



Scattered Radiation around CT scanner (body phantom) - top view
Rothenberg, Pentlow



Scattered Radiation around CT scanner (body phantom) - side view
Rothenberg, Pentlow



Repeating the Dosimetry in air with different kV, mA (mAs), projections (scan time), slice thickness is used for further assessment of Dose consistency, dependence on various parameters, accuracy,etc

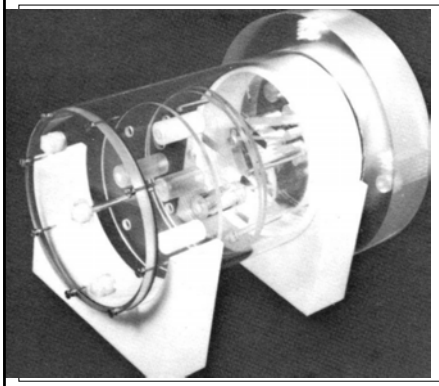
Commonly assessed X-ray Generator parameters:

- X-ray tube output consistency
- Variation with slice thickness
- Variation with mA
- Variation with scan time
- Variation with kV

In principle it is possible to perform these measurement with other ionisation chamber. The common calculation of consistency is used.

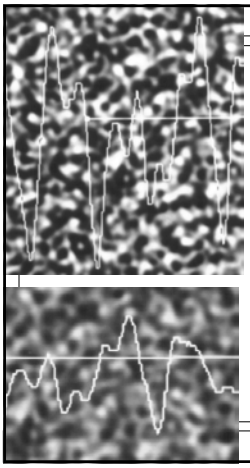
X-ray Generator assessment (centre, air) with 6cc thimble chamber

Read kV	Read mAs	SetT sec	Setsl.th. mm	Air kerma (mR)	(mGy)	Relat.dose mGy/(mAs*mm)	Meas.T sec
120	170	3	10	1350	11.73	0.00230	2.96
120	170	3	10	1320	11.47	0.00225	2.96
120	170	3	10	1310	11.38	0.00223	2.95
120	170	3	10	1320	11.47	0.00225	2.95
120	170	3	5	659	5.73	0.00225	2.95
120	170	3	2	280	2.43	0.00239	2.96
120	170	3	1	280	2.43	0.00477	2.95
120	240	3	10	1800	15.64	0.00217	2.95
120	330	3	10	2340	20.33	0.00205	2.96
120	420	3	10	2920	25.37	0.00201	2.95
120	600	3	10	4200	36.50	0.00203	2.96
120	100	1.8	10	826	7.18	0.00399	1.83
120	220	4	10	1880	16.34	0.00186	4.19
120	330	6	10	2750	23.90	0.00121	6.11
120	1200	6	10	8740	75.95	0.00105	6.13



AAPM TO

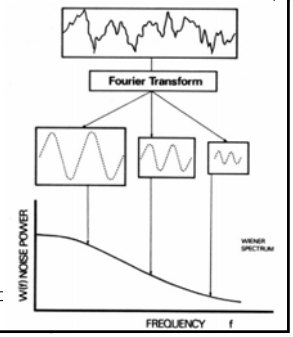
The "noise ring" contains inserts for assessment of peripheral spatial resolution

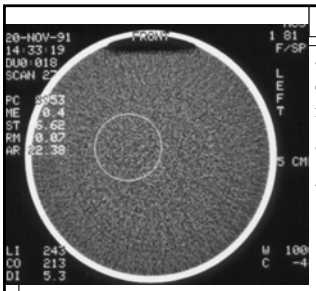


Assessment of CT Noise

-Enlarged image of water phantom (high and low noise level)

- Wiener noise spectrum calculation

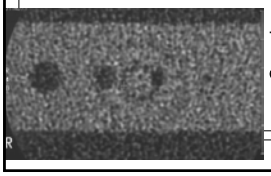




- CT noise as standard deviation of mean CT values (HU) varies most often between 1 and 10 HU

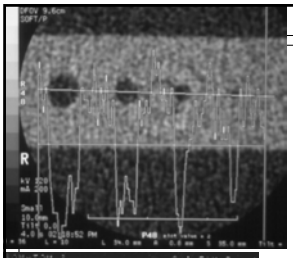
-Main limitation of contrast resol.

- Min. contrast > noise level (HU)



- Standard deviation (noise):

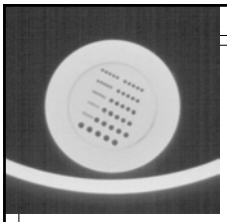
$$\sigma = [\Sigma(CT_i - CT_{mean})^2 / (n-1)]^{1/2}$$



Low Contrast Resolution

<<<Method 1 : using the Partial Volume Phenomenon (artefact), the insert is thinner than scan slice (on the image GE TO assessed with density profile)

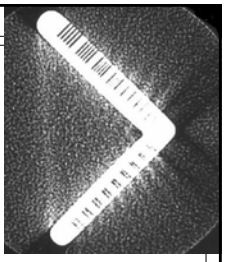
<< Method 2 : using inserts (details) with different size and variable radiographic density (contrast) - SIEMENS TO

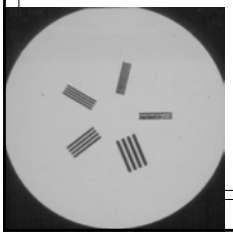


High Contrast Spatial Resolution

<< ImPACT TO

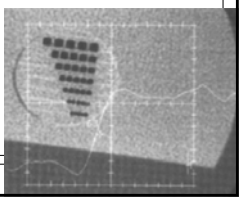
CATPHAN TO >>



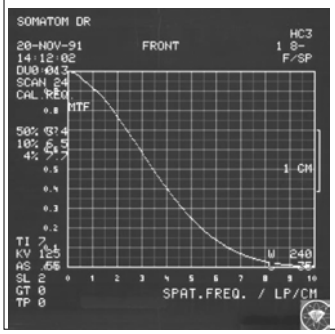


<< SIEMENS star TO

AAPM TO >>



Assessment of PSF of thin Tungsten wire - SIEMENS DR

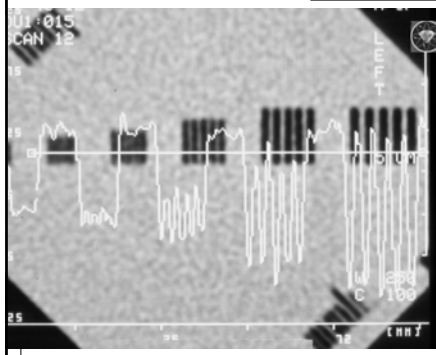


Contemporary CT scanners have normally limiting spatial resolution up to 12 lp/cm

(*1024 matrix, max. projections, min. FOV, HF filter*)

$MTF_{sys}(f)=MTF_{geom} \times MTF_{alg}$

High Contrast Spatial Resolution

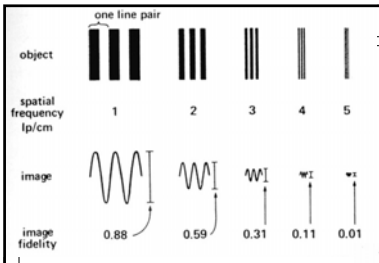


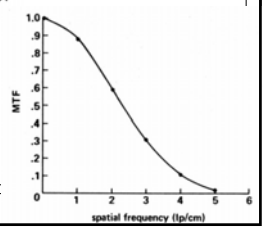
Density Profile

- Assessment of contrast decrease
- CTF - Contrast Transfer Function

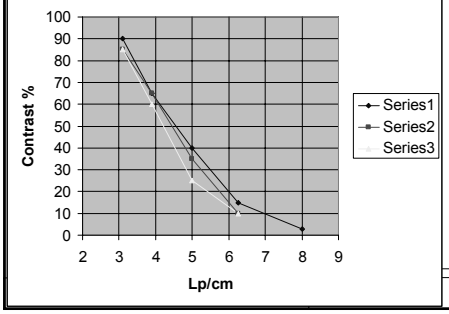
** Slightly different from MTF, but easy to perform, easy comparison*

CTF concept



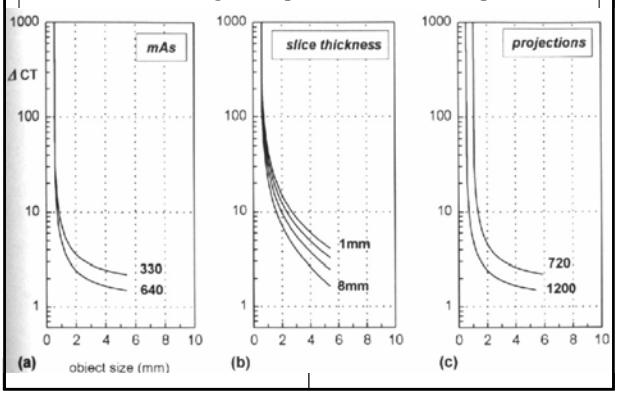


kV/mAs	Reconstr filter	Scan tim sec	% decrease of contrast with spatial resolution 3.1	3.9	5	6.25	8	->Lp/cm
140/600	edge	3	90	65	40	15	3	ser.1
120/600	stand.	3	85	65	35	10		ser.2
120/100	stand.	1	85	60	25	10		ser.3



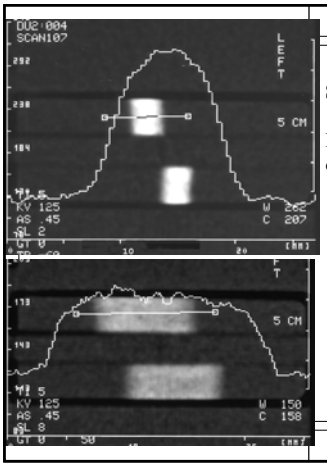
Real example of CTF from GE scanner

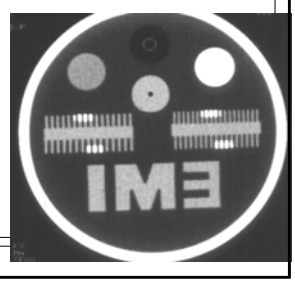
Contrast-Detail diagram dependence on some CT parameters



Slice thickness measurement

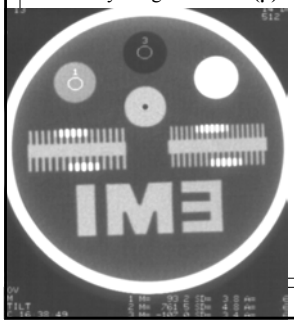
Measured FWHM of the image of two angulated plates

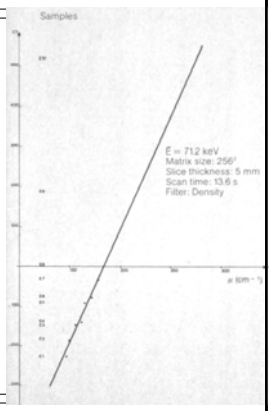


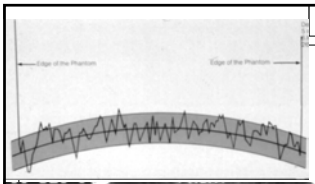


CT Densitometry assessment

- Inserts with specific densities
- Linearity Diagram **HU=F(μ)**



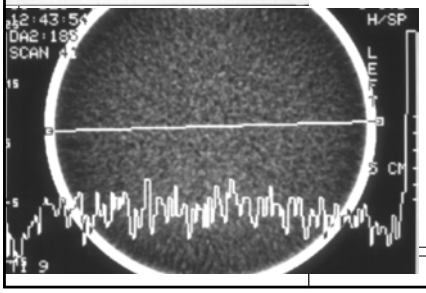




Spatial non-uniformity OR

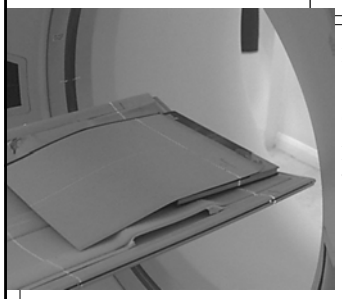
Cross-field Uniformity OR

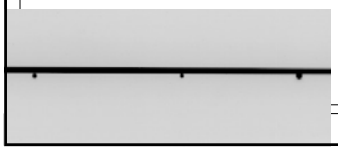
Homogeneity



Related to correction for beam hardening (cupping effect) with ***beam shaping filter***

- Minimal with new CT tubes, with beam filtration between 0.25 and 0.4 mm Cu



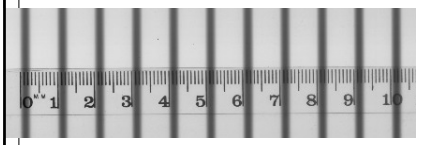


Patient Table positioning and increment

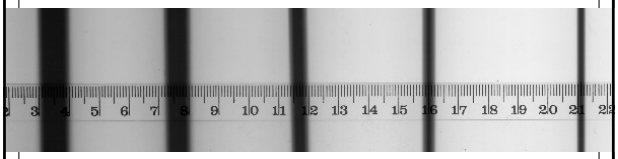
(Localiser accuracy)

Easy assessment with wrapped X-ray film

CT Assessments with X-ray film



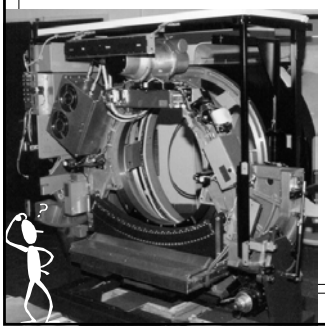
1. Dose profile (microdensitometer)
2. Patient table
3. Slice thickness
4. Gantry tilt



Frequency of CT Quality Control

- Preferably at 6 months (at least once per year) +
- After each major servicing (X-tube, etc.) +
- After each change of software
- Normally one QC test takes ~ 5-6 hours
- Acceptance testing takes 2-3 days
- Calculate the results on the next day takes ~ 3 h.
- If not sure in some findings - seek consultation
- Always discuss with the medical staff past or occasional problems

1. Check very carefully the CT patient dose, as it is quite high



2. Remember - the CT scanner is extremely complex equipment, designed and tested by highly skilled people with excellent equipment.

Always double check your measurements before accusing the CT scanner in incorrect adjustment.