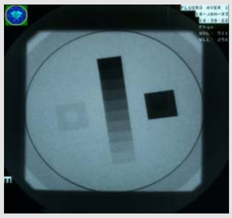
Need and Effectiveness of QA in X-ray Diagnostic Radiology



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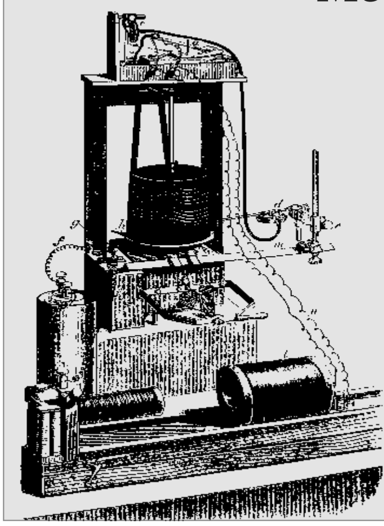
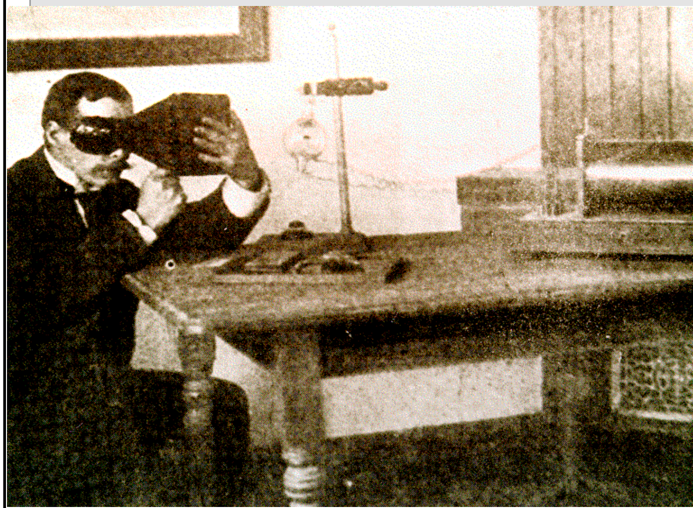
Medical Physics before 1895



Mainly related to medical application of optics, electricity, acoustics, etc.

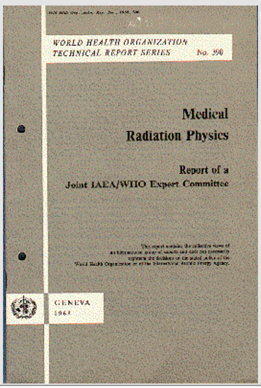
Short university courses and research, but not a separate profession

Medical Physics after 1896

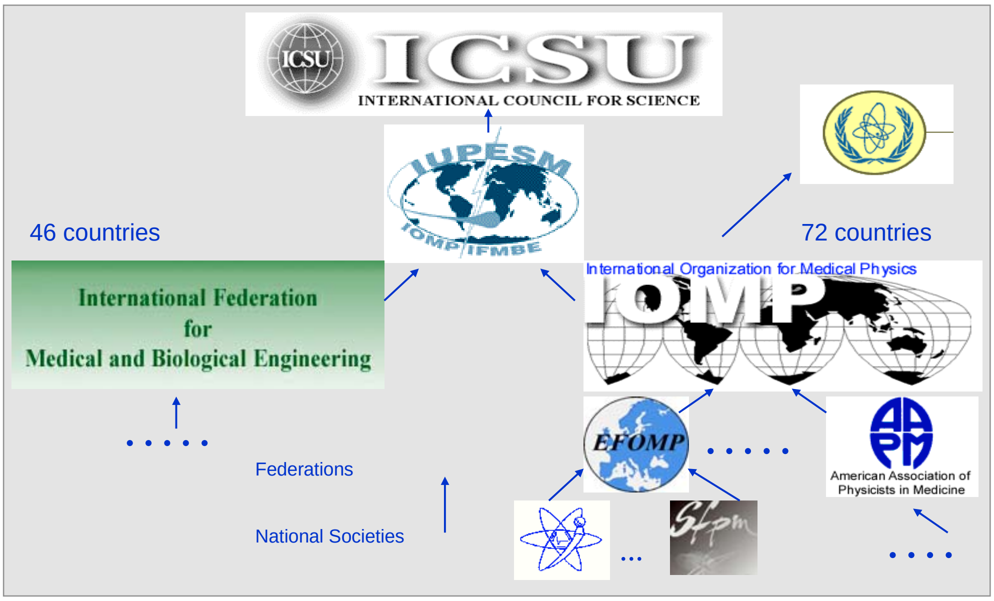


Related mainly to the medical use of radiation:
- X-rays
- Isotops
- Radiotherapy
- Physiol. measur.
- Imaging

Joint IAEA/WHO Expert Committee on Med.Rad.Phys.
<u>Recommendations</u>



- Medical Physics should be recognised in all countries as a scientific discipline with full professional status in universities, medical schools, hospitals and allied institutions.
- Medical Schools should appoint teachers in medical physics to their faculties..
- In all countries, and especially in those with few or no medical physicists, the government authorities responsible for the health services and for education should initiate or expand medical physics activites..
- Hospitals requiring medical physics services should be provided with adequate space/equip.
- IAEA and WHO should provide support for seminars/training on medical physics..



Minimum staffing of the Medical Physics support of:

Radiotherapy

1 high energy accelerator - 0.8

1 major item of equipment (simul.,Co unit,Plan.sys) - 0.4

1000 new courses of treat. p.a. with ext. beam therapy - 1.2

100 new courses of treat. p.a. with brachytherapy - 0.25

Academic commitments - 0.5

Radiation Protection (Adviser) 1

Nuclear Medicine

1 Gamma camera - 0.5

5000 exam. p.a. - 0.5

500 dynamic studies p.a. - 0.25

250 SPCET studies p.a. - 0.25

50 new courses of treat. p.a.- 0.25

Diagnostic Radiology

Rad. Dept. with complex equip.-1

Rad.Dept. serving 500,000 pat. -1

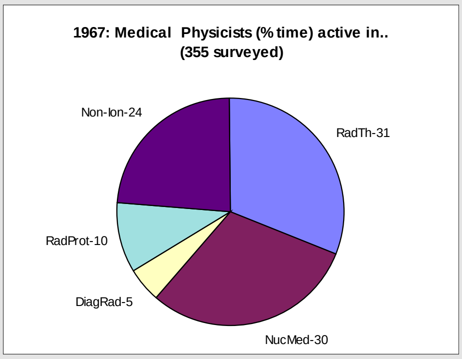
(depending on the QA program)

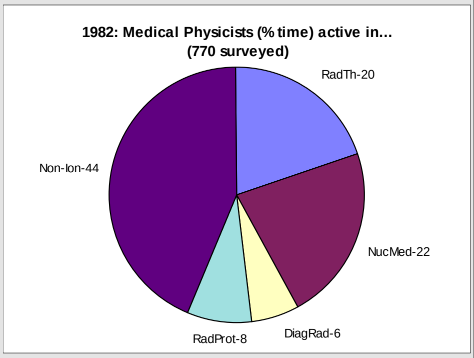
EFOMP Policy Statement

Number of qualified physicists at Dept. *(ex.-Sweden,~10 mil)*	Number of Departments	Total number of qualified physicists
1 (at Central Hosp.)	13	13
2 - 7 (Central Hosp.)	10	42
7 - 9 (at Univ. Hosp.)	4	32
15-17 (Univ. Hosp.)	3	48
TOTAL	30	135 (+approx.110 n.q)

- Turkey(~ 60 mil.) - 21 Public + 7 Private Dept. with MP (Total number - approx 120 Med.Rad.Phys+30 others)
- Romania(~23 mil.) - spread in many Hosp. Dept. (Total number - approx. 60 Med.Rad.Phys. + 100 others)
- UK(~57 mil) - Tot. approx.1200 Med.Phys. in 125 Dept.

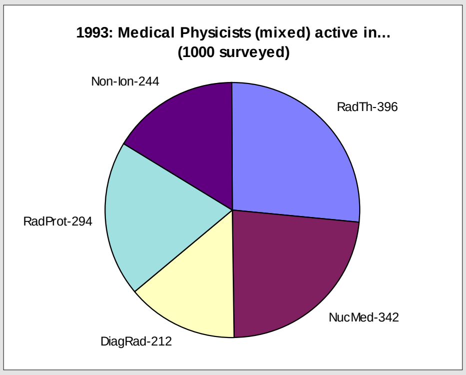
Medical Physicists activity (relative data, UK: 1967, 1982)





Scope, V.2 No.3

Medical Physicists activity (relative data, UK: 1993)



<u>Increased activity in:</u>

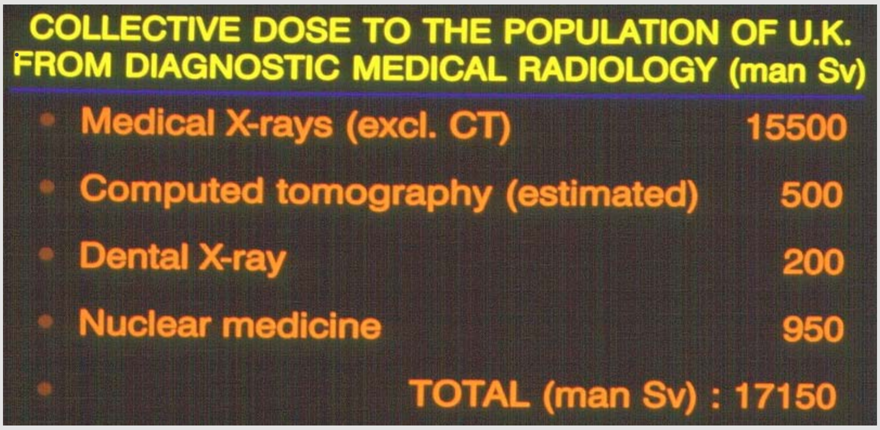
Diagnostic Radiology

Radiation Protection

Physiological Measur.

Non-Ionis. Med. Imaging

Scope, V.2 No.3



COLLECTIVE DOSE TO THE POPULATION OF U.K. FROM DIAGNOSTIC MEDICAL RADIOLOGY (man Sv)

Medical X-rays (excl. CT)	15500
Computed tomography (estimated)	500
Dental X-ray	200
Nuclear medicine	950
TOTAL (man Sv) :	17150

Data for mid-1980

NRPB, 1989

Estimated annual collective dose to UK population from Diagnostic Radiology for 1990 is approx. 20,000 manSv. On the basis of risk estimate this could be responsible for up to 700 cancer deaths/year !

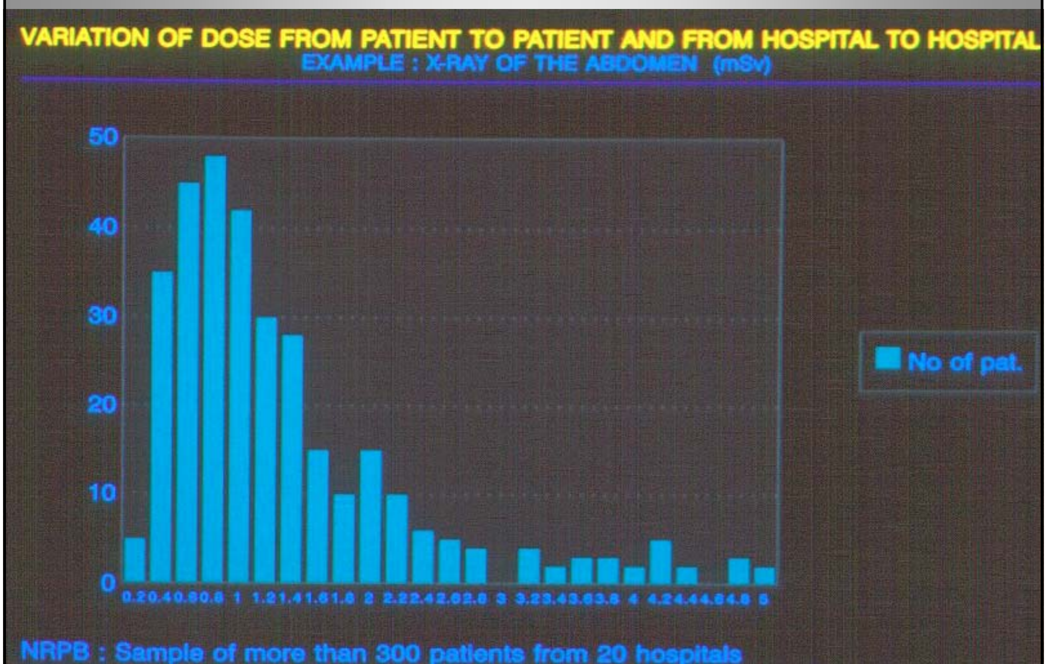
Safety in Diagnostic Radiology, IPEM, 1995

Approximately 90% of the total collective dose to UK population from man-made radiation sources arises from Diagnostic Radiology Safety in Diagnostic Radiology, IPEM, 1995

In most industrialised countries there are between 300 and 900 X-ray examinations for every 1000 inhabitants every year. Over half of these are chest examinations (these figures does not include dental X-ray examinations or mass screening programs).

Doses varies widely from hospital to hospital, even in the same country, sometimes by a factor of 100.

Radiation and You, EU, Luxembourg 1990



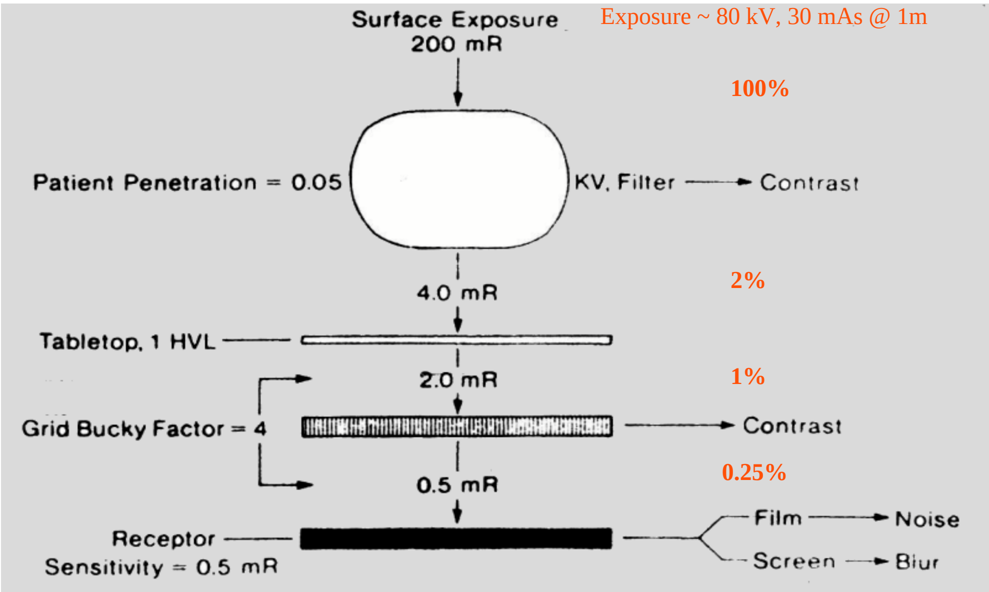
Introducing Quality Assurance programmes, which includes Quality Control surveys of X-ray equipment

Quality Control (QC) in X-ray Diagnostic Radiology includes regular (yearly) tests of various parameters - accuracy and consistency of X-ray tube output, kVp, timer, variation of output with the mA, Half Value Layer, image resolution and contrast, noise, etc.

These parameters are directly related to equipment performance, image quality and patient dose.

Now QC is the main job of most Medical Physicists in Imaging

X-ray Dose distribution: from tube > through patient > to film



Revised radiation doses for typical X-ray examinations

B F Wall, D Hart, BJR, May **1997**, p.437-439

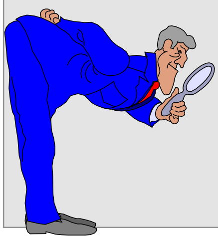
- For most non-CT procedures the new (1990-ties) typical effective doses to standard adult patient are between **25 and 60% lower** than the old ones (1980-ties);

- For abdominal and pelvic CT examinations the doses are about 35% higher (while head CT are with lower dose than before);

As an overall picture the collective effective dose in the UK has increased during late 90-ties, but large part of this is related to contrast examinations and CT examinations (these are ~4% of all examinations, but deliver ~40% of the collective dose)

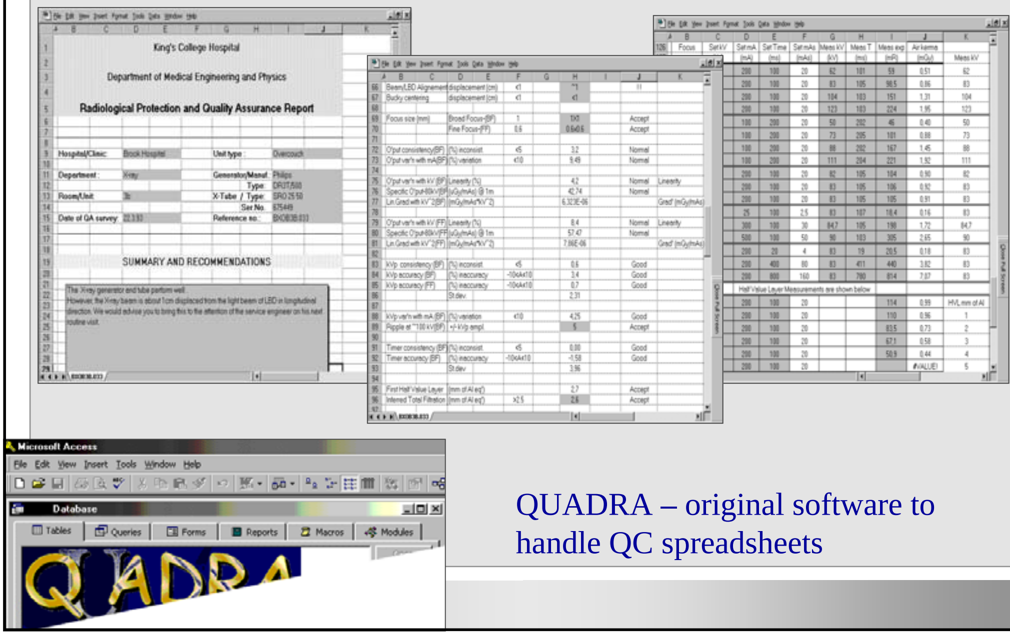
Often Hospital management accepts Quality Control (QC) of X-ray equipment as just a necessity linked to specific Regulations.

This might reflect in a superficial attitude to the QC tests linked mainly to "bureaucratic" collection of QC records



Our study shows the effect of regular QC tests on the X-ray equipment performance and image quality, based on long term statistics, and compared with a period when no QC tests had been made

QC Protocols based on MS Excel



QUADRA – original software to handle QC spreadsheets

QC statistics (Radiography) made on the basis of :

- 63 X-ray generators&tubes (surveyed over 3 years) - from 1992-1995 (no QC have been carried out to these equipment for some 2 years before 1992)

-During the following 5 years 12 of those equipment have continued to be surveyed and analysed

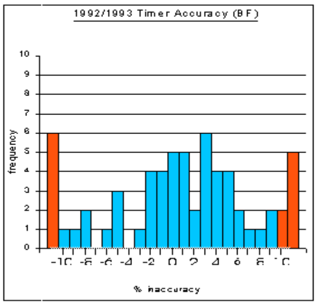
- All equipment had been in use for less than 15 years

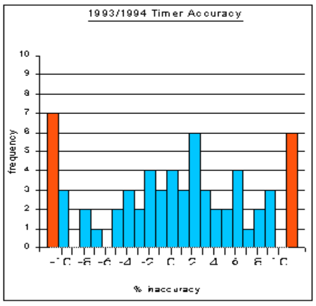
- 27 new X-ray generators&tubes have been surveyed and analysed over 3 years (1997-2000)

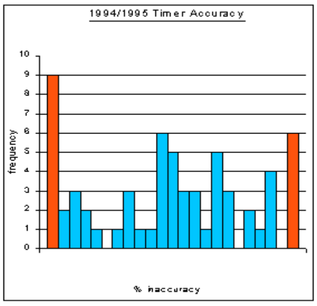
- All equipment has been surveyed with identical tests (IPEM and Emerald) and all data presented to the X-ray service

- The analysed parameters (statistics with SPSS package) are presented on the slides to follow

Timer Accuracy

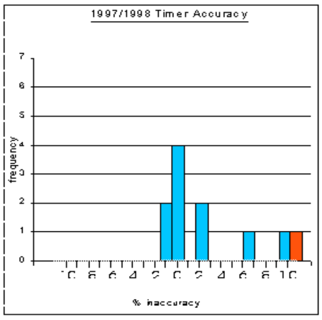


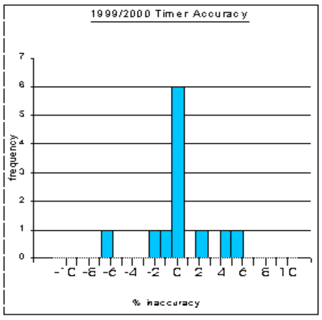




Timer accuracy:

almost no reaction, often deteriorates





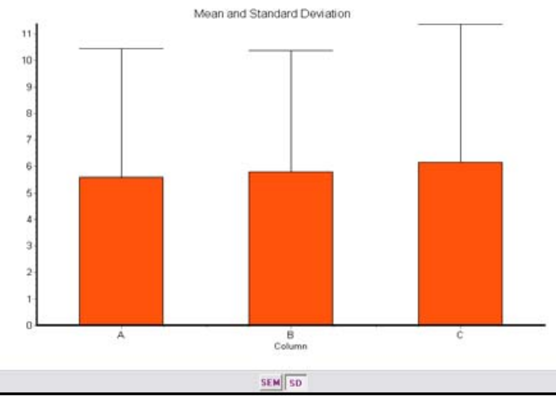
Timer Accuracy (abs. values) -100*(mean error)/(real value):

Year 1 >> Year 2 : P >0.05 (not significant)

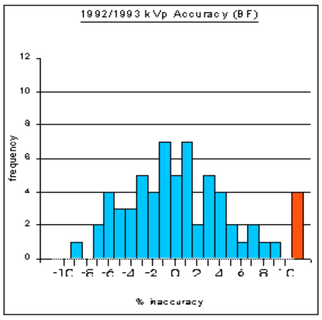
Year 1 >> Year 3 : P >0.05 (not significant)

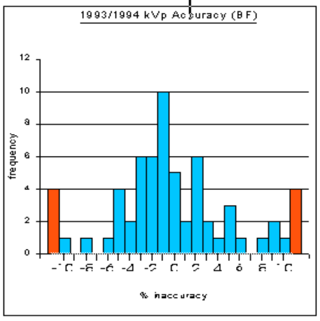
Years 1 >2>3 : P >0.05 (not significant)

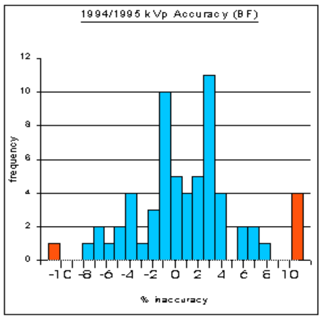
The parameter often deteriorates (equipment defects) and perhaps due to this reason the overall reaction (as a group) is not significant. Only some of the observed equipment show slow positive reaction.



kVp Accuracy

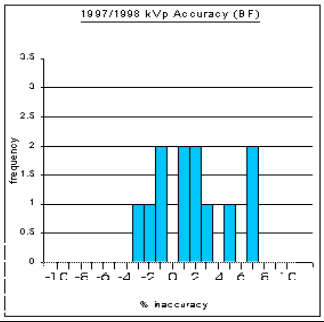


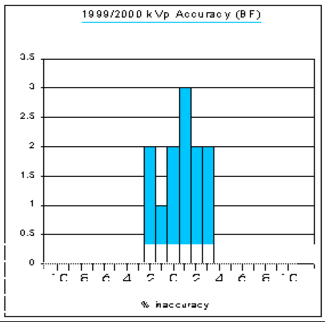




kVp Accuracy:

Slow reaction, often deteriorates





kVp Accuracy (abs. values) -100*(mean error)/(real value):

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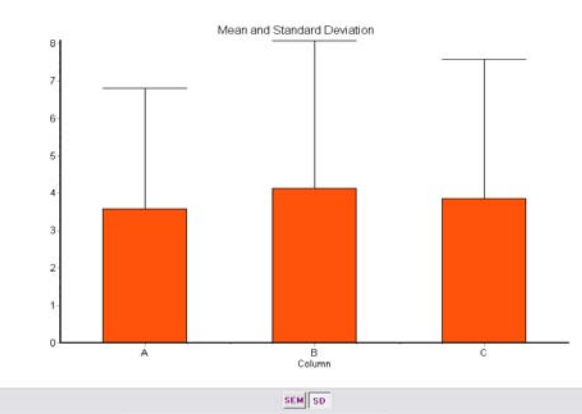
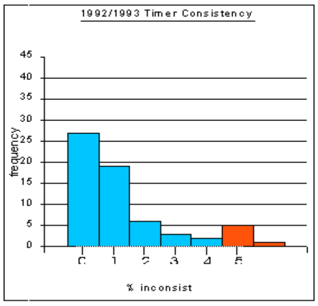
Year 1 >> Year 3 : P >0.05 (not significant)

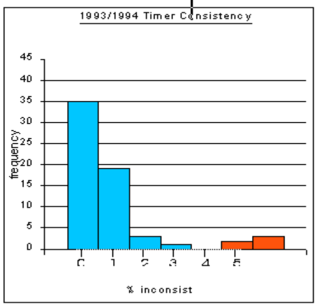
Years 1 >2>3 : P >0.05 (not significant)

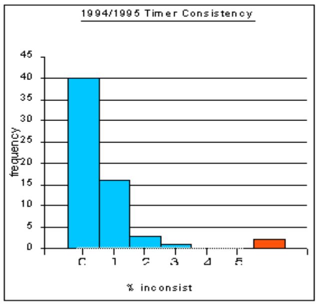
The parameter often deteriorates (equipment defects) and perhaps due to this reason the overall reaction (as a group) is not significant. However observing equipment without defects shows slow positive reaction.

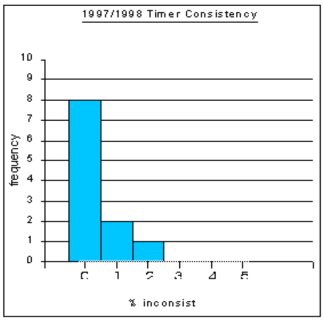


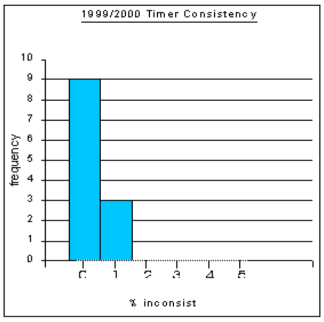
Timer Consistency











Timer consistency:

reacts slowly, but stabilises with time

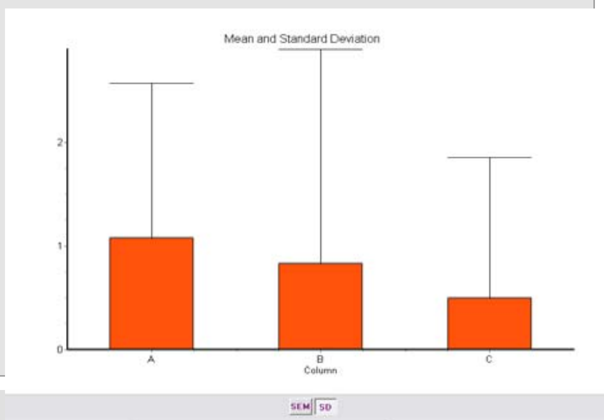
Timer Consistency - 100*(st.dev)/(average) :

Year 1 >> Year 2 : P >0.05 (not significant)

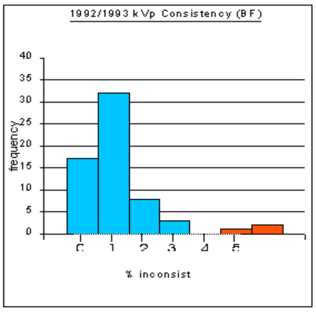
Year 1 >> Year 3 : P<0.01 (very significant)

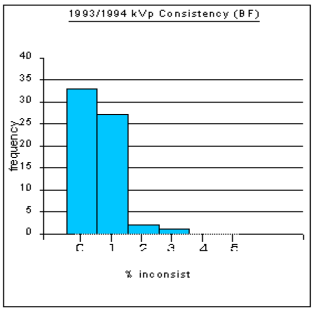
Years 1 >2>3 : P <0.05 (significant)

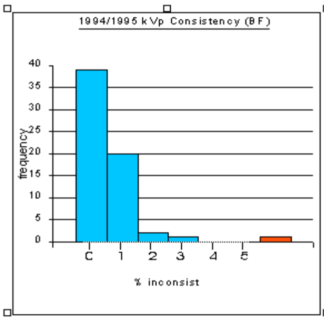
The parameter stabilises after the second QC test - both in terms of mean value (small inconsistency) and in terms of concentration of results (small SD).

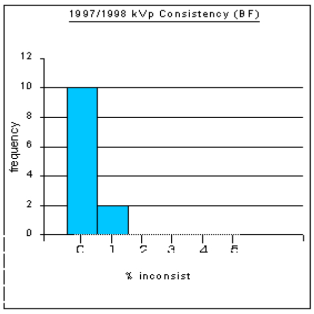


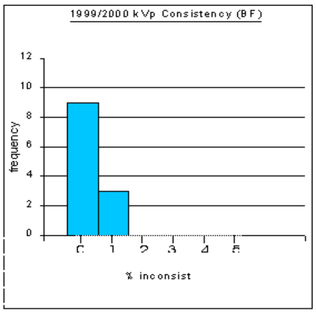
kVp Consistency











kVp Consistency:

reacts quickly and stabilises with time

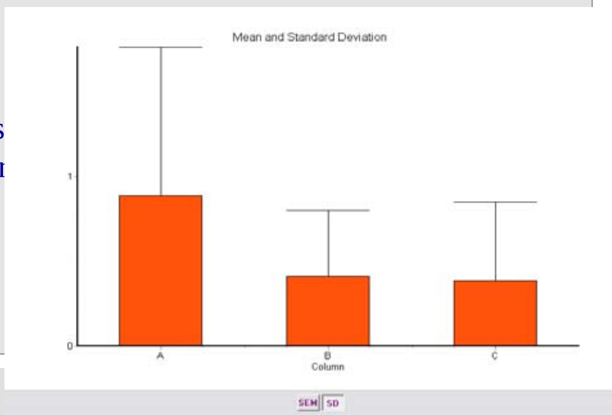
kVp Consistency - 100*(st.dev)/(average) :

Year 1 >> Year 2 : P<0.01 (very significant)

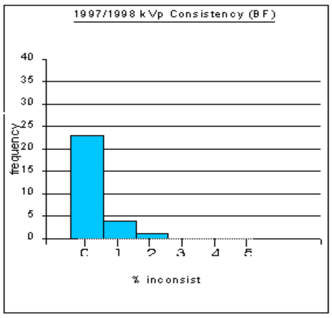
Year 1 >> Year 3 : P<0.01 (very significant)

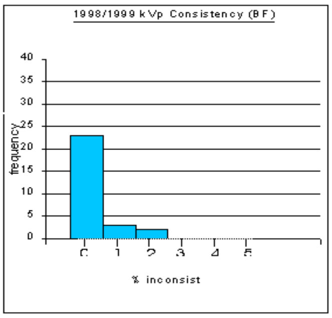
Years 1 >2>3 : P<0.01 (very significant)

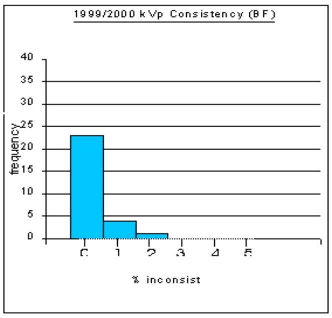
The parameter stabilises after the first QC test - very fast reaction. The consistent results does not exclude absolute error (to be seen with the accuracy tests).



kVp Consistency



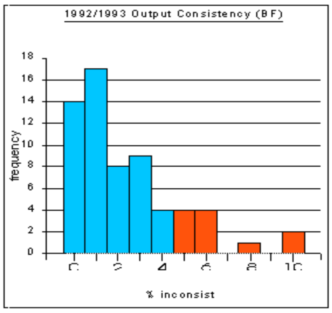


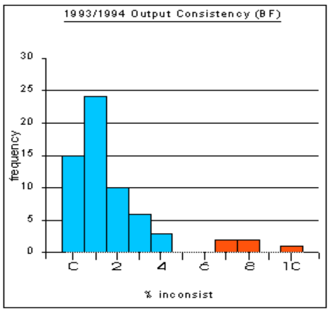


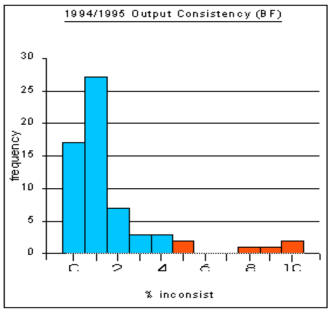
kVp consistency:

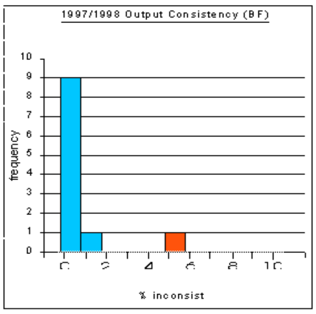
in new X-ray equipment (with regular QC) the parameter maintains stable low values.

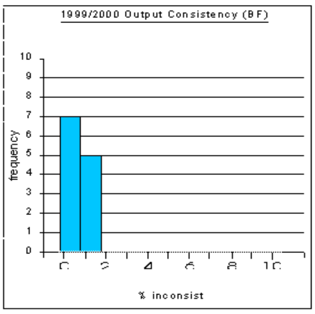
Output Consistency











Output Consistency:

reacts quickly and stabilises with time

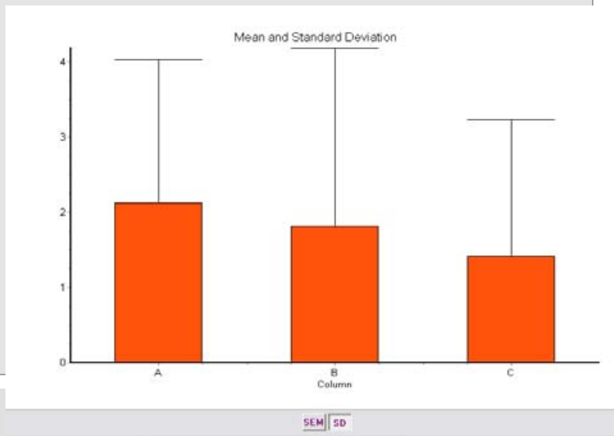
Dose Output Consistency - 100*(st.dev)/(average) :

Year 1 >> Year 2 : P~0.05 (close to significant)

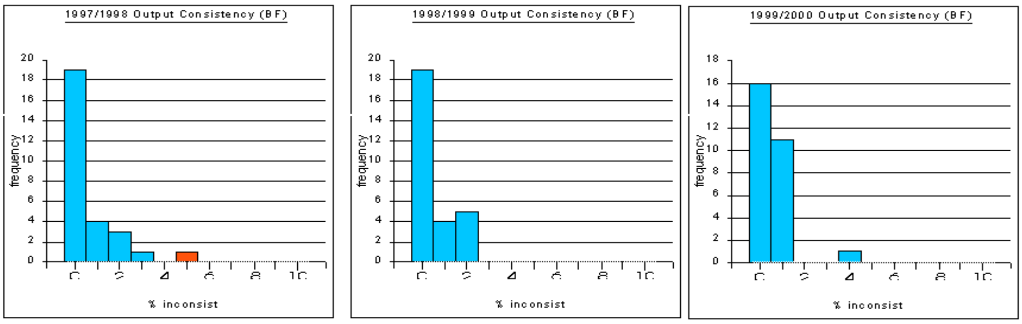
Year 1 >> Year 3 : P<0.05 (significant)

Years 1 >2>3 : P~0.05 (close to significant)

The parameter improves with time (statistically observed after the second QC test).



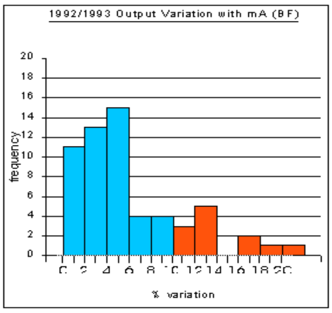
Output Consistency

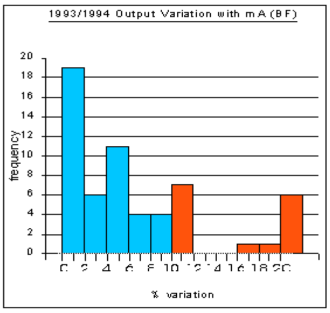


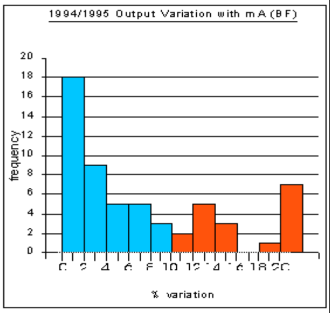
Output consistency (as overall parameter):

in new X-ray equipment (with regular QC) maintains stable parameters

Output Variation with mA

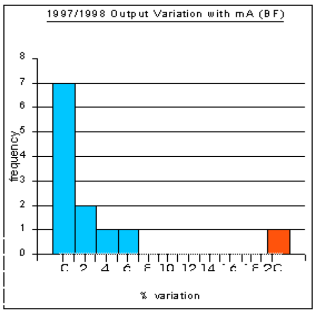


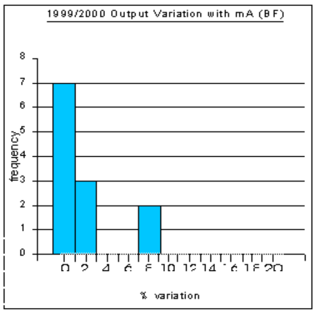




Output var with mA:

No visible reaction, often deteriorates





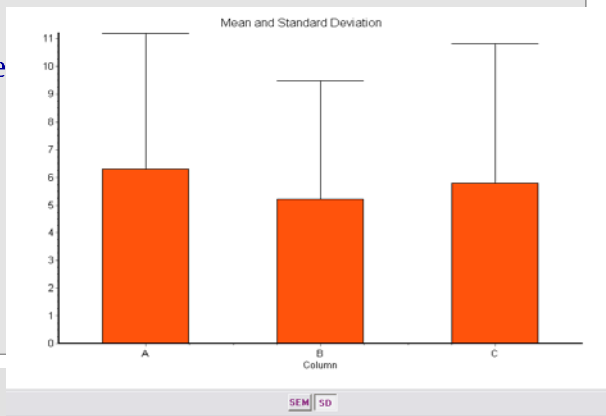
Output variation with mA - 100*(st.dev)/(average) :

Year 1 >> Year 2 : P>0.05 (not significant)

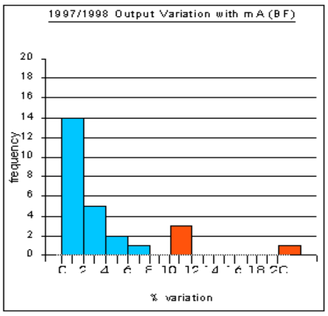
Year 1 >> Year 3 : P>0.05 (not significant)

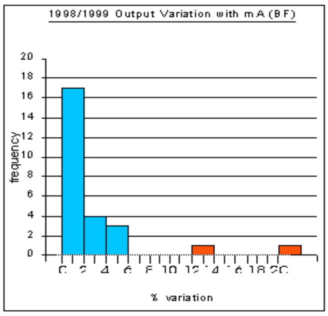
Years 1 >2>3 : P>0.05 (not significant)

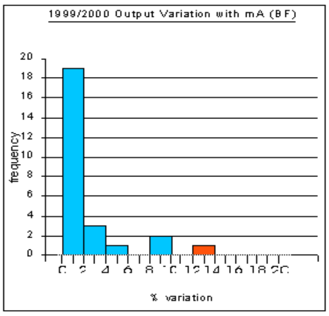
The parameter is linked not only to equipment performance but also to stability of the electrical supply. Significant faults observed at mobile equipment (perhaps tested in different rooms). No trend for improvement observed.



Output Variation with mA







Output variation with mA:

in new X-ray equipment does not show reaction of stabilising the parameter

QC statistics (Fluoroscopy) made on the basis of :

60 X-ray non-digital fluoroscopic units (surveyed over 3 consecutive years) – in the period 1992-1999 (no QC made to these equipment for some 2 years before 1992)

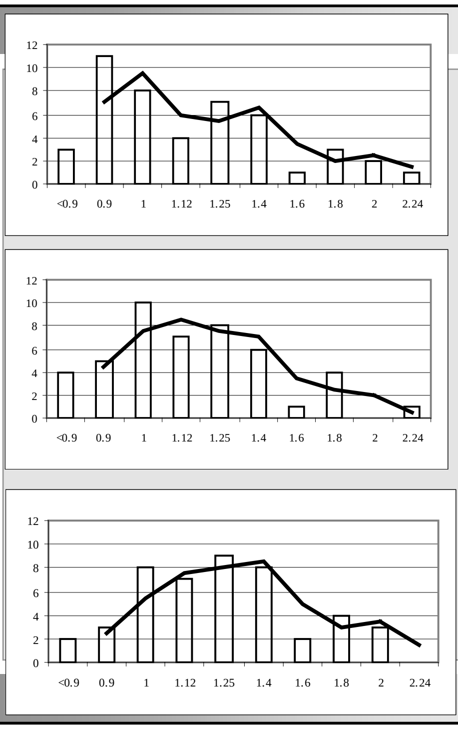
- The equipment has been tested using normal protocols (Emerald and IPEM recommendations) and Leeds Test Objects

-All equipment had been in use for less than 10 years

- Image Intensifiers are grouped in 2 FoV groups: “normal” (18-23 cm) and “magnified” (12-17 cm)

- All QC data had been presented to the X-ray service engineers

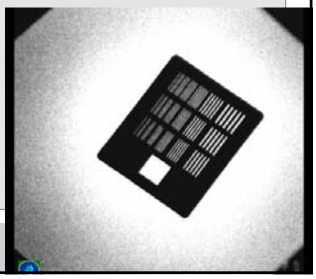
- The analysed parameters (statistics with SPSS package) are presented on the slides to follow



Spatial Resolution of "normal" II (45 equip.) - TREND

(lp/mm measured with Huttner Test Object)

Slow improvement (increased sp. res.)



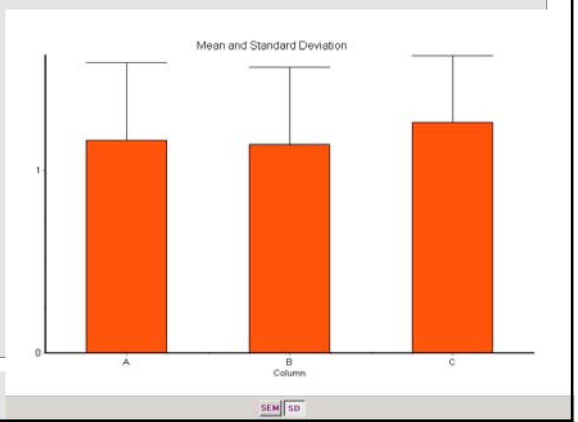
Spatial Resolution of "normal" II (45 equip.)

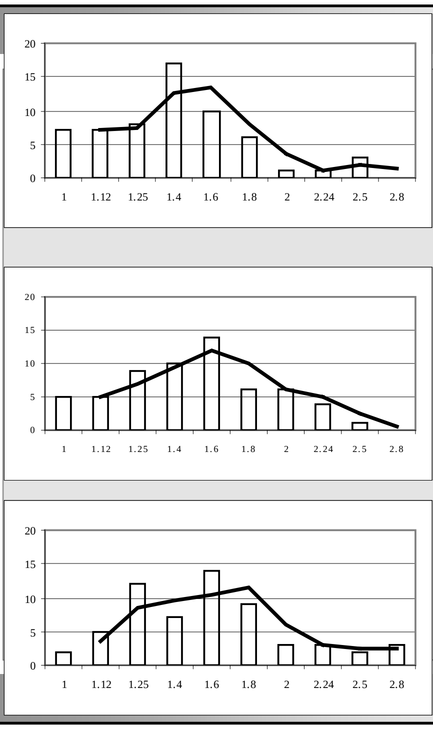
(lp/mm measured with Huttner TO)

Years 1 >2>3 : P<0.01 (very significant)

Spatial resolution shows slow increase with time.

Friedman Test (Nonparametric Repeated Measures ANOVA)

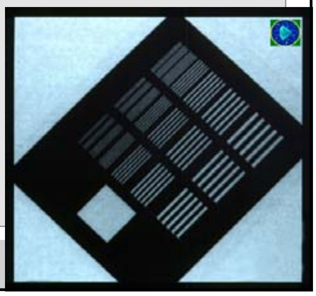




Spatial Resolution of “magnified” II (59 equip.) - TREND

(lp/mm measured with Huttner Test Object)

Slow improvement (increased sp. res.)



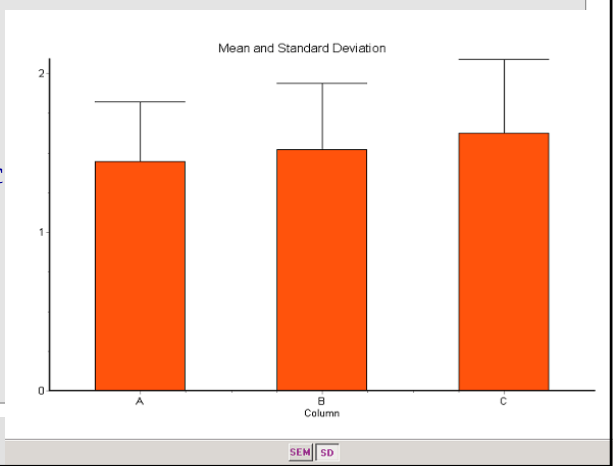
Spatial Resolution of “magnified” II (59 equip.)

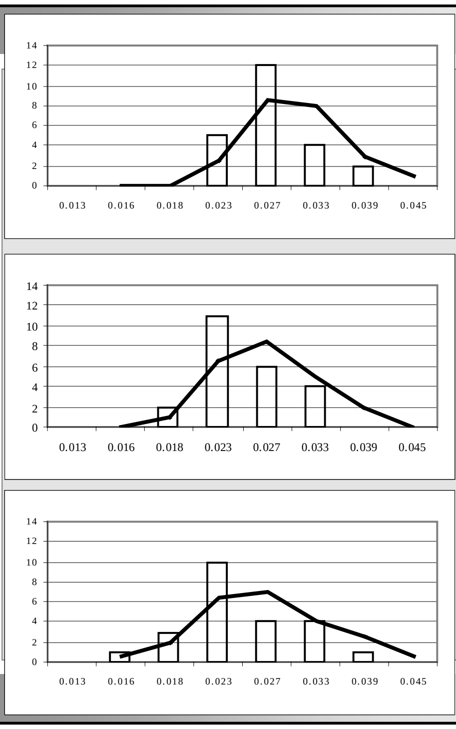
(lp/mm measured with Huttner TO)

Years 1 >2>3 : P<0.01 (very significant)

Spatial resolution shows more noticeable increase with time.

Friedman Test (Nonparametric Repeated Measures ANOVA)

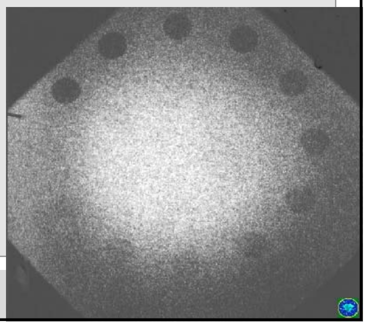




Noise of “normal” II (22 equip.) - TREND

(% contrast measured with N3 Leeds Test Object)

Slow improvement (decreased noise)



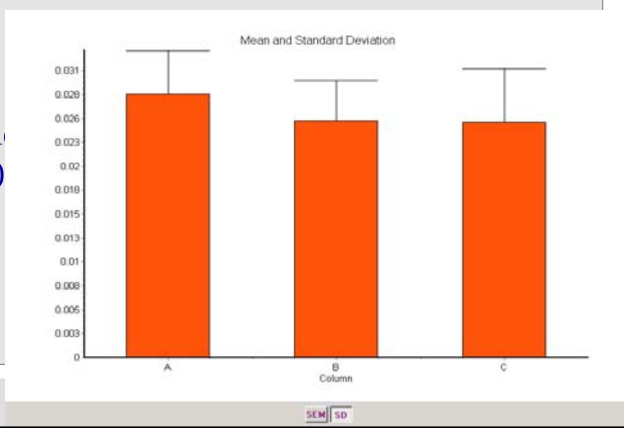
Noise of “normal” II (22 equip.)

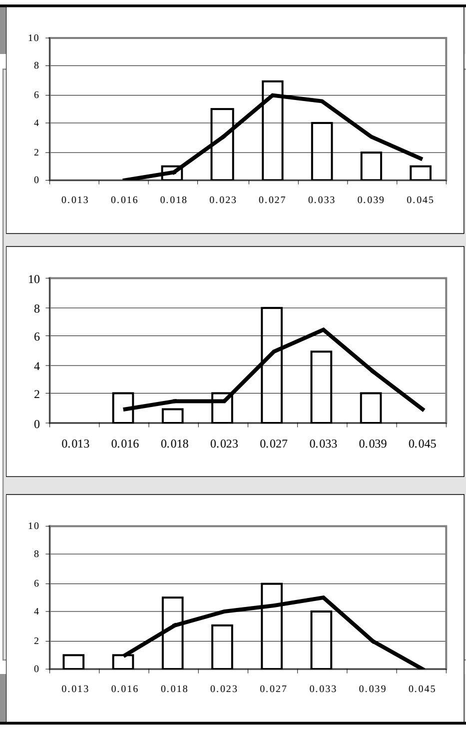
(% contrast measured with N3 Leeds TO)

Years 1 >2>3 : $P<0.05$ (significant)

Noise level shows decrease with time.

Friedman Test (Nonparametric Repeated Measures ANOVA)

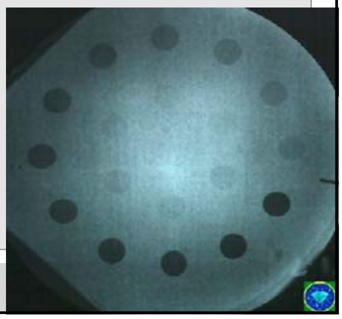




Noise of “magnified” II (20 equip.) - TREND

(% contrast measured with N3 Leeds Test Object)

Slow improvement (decreased noise)



Noise of “magnified” II (20 equip.)

(% contrast measured with N3 Leeds TO)

Years 1 >2>3 : P<0.01 (very significant)

Noise level shows decrease with time.

Friedman Test (Nonparametric Repeated Measures ANOVA)

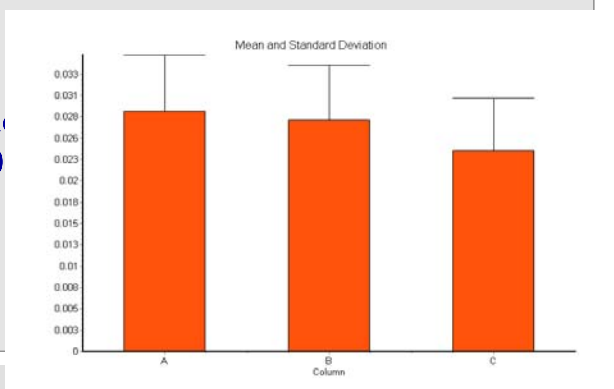


Image Intensifier entrance dose for "normal" and "magnified" II

(mR/min measured with 1mm Cu)

3 Years ("normal", 27 equip) : P~0.05 (not very significant)

3 Years ("magnified", 30 equip) : P>0.05 (not significant)

In most 3 years periods measurements of II entrance doses have been made at different distances from Image Intensifier and re-calculation of the results is not possible.

Due to this reason pairs of two consecutive years (measurements) have been used.

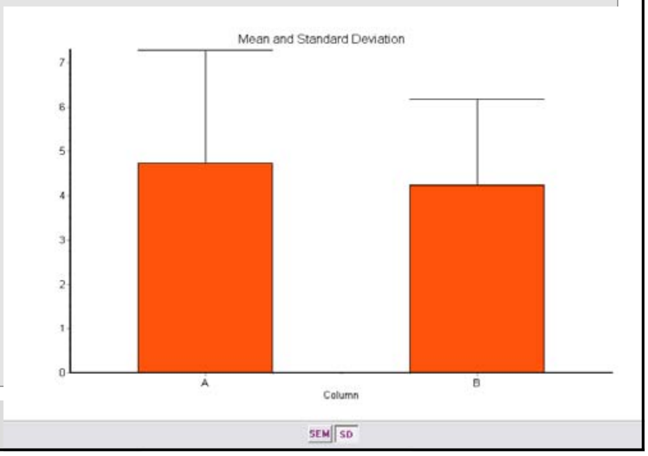
II entrance dose "normal" II (34 equip.)

(mR/min measured with 1mm Cu)

2 Years : P~0.05 (not very significant)

II entrance dose slowly decreases.

Paired t test



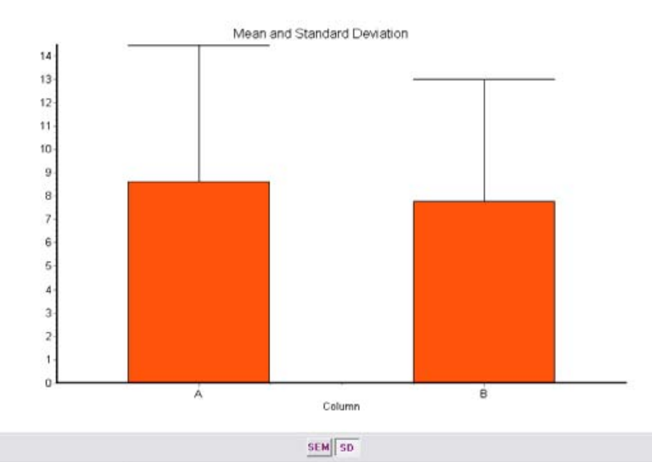
II entrance dose “magnified” II (39 equip.)

(mR/min measured with 1mm Cu)

2 Years : P<0.05 (significant)

II entrance dose slowly decreases.

Paired t test



Conclusions

- The pre-1991 data (without regular QC) shows significant inconsistency and inaccuracy of the performance of the X-ray systems PLUS deteriorated image quality - lower resolution and higher noise and Image Intens. entrance dose
- Regular QC tests help to maintains the consistency of X-ray systems parameters and image quality within specification
- The improvement is small (perhaps just keeping a stable acceptable level) as it relates to equipment specifications.
- Close collaboration with the service engineers is essential.
- QC statistics is difficult as often colleagues do not follow strictly the protocols

- IOMP - EFOMP - IAEA – AAPM -

Summer schools, courses, meetings with various national societies (including special sessions on QC)

International Medical Physics College ICTP, Tieste