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College on Medical Physics:
Imaging and Radiation Protection

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D.M.Q.
Quality Control for
a Film-Screen Mammography

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D.Q.M.

QUALITY CONTROL FOR

A FILM-SCREEN MAMMOGRAPHY

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QUALITY CONTROL OF MAMMOGRAPHIC EQUIPMENT

Mammographic equipment is a special category of X-Ray units, that is dedicated to the X-Ray examination of the breast.

BREAST COMPOSITION : ADIPOSE, FIBROUS and GLANDULAR TISSUE

INHERENTLY LOW SUBJECT CONTRAST

Changes of composition and structure with age and degenerative changes as INDUCED CYSTS or FIBROUS TUMORS.

POSITIVE DIAGNOSIS DEPENDS ON EARLY DETECTION AND EVALUATION OF SIZE, NUMBER AND SHAPE.

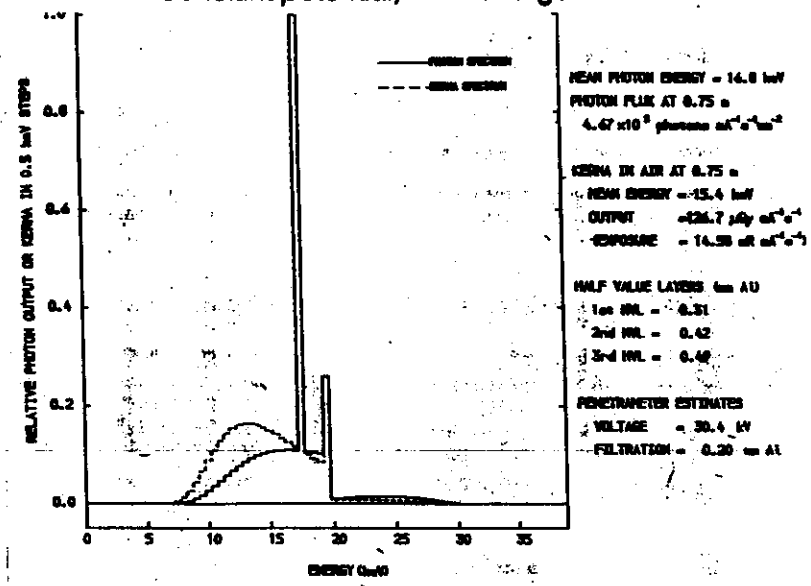
A DEDICATED MAMMOGRAPHIC UNIT REQUIRES

HIGH CONTRAST AND HIGH SPATIAL RESOLUTION

LOW ENERGY SPECTRUM FOR MAMMOGRAPHIC UNITS

30 kV , 1.0 mm Be (window) and 0.03 mm Mo (filter)

Constant potential, 17° Mo target

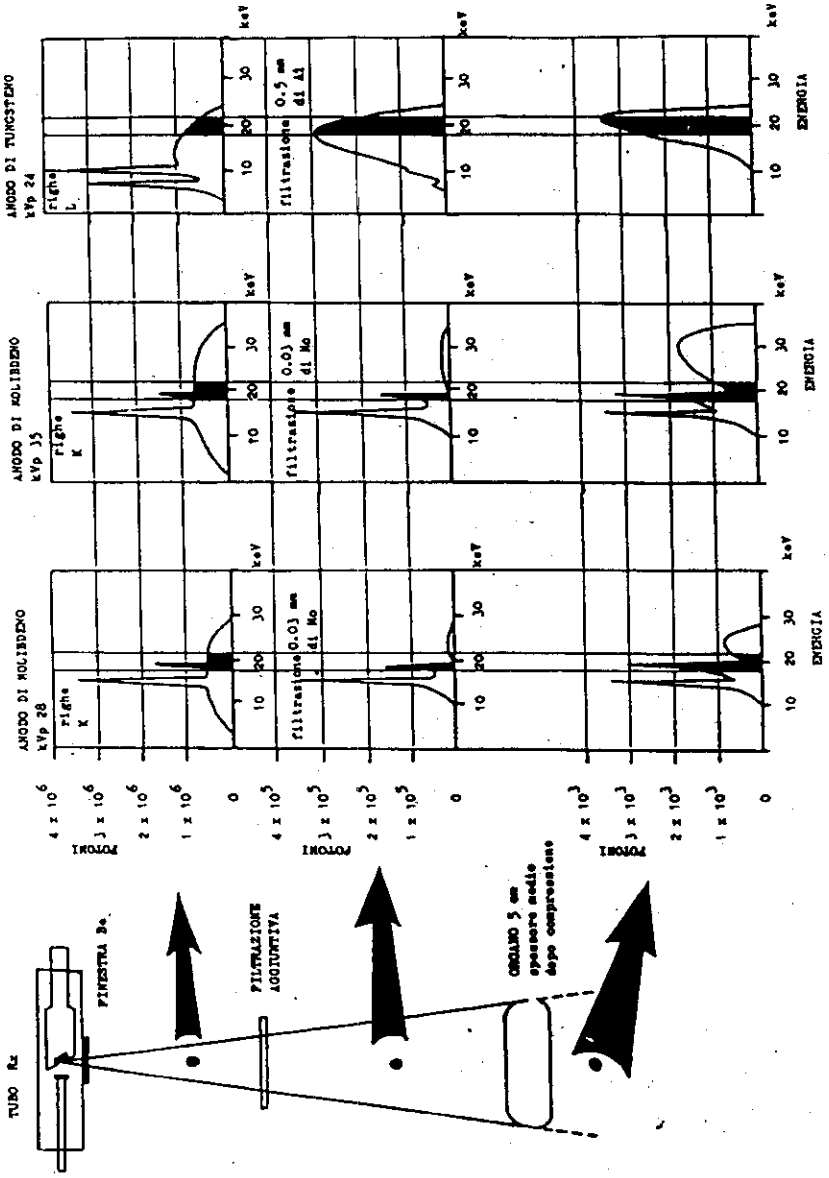


Catalogue of spectral data for diagnostic X-Ray

R.Birch, M.Marshall

The Hospital Physicists' Association

Scientific Report Series n. 30



PARAMETERS AFFECTING CONTRAST

LOW ENERGY SPECTRA WITH THE PEAK AROUND 20 keV

BREAST COMPOSITION AND THICKNESS

GEOMETRICAL SITUATION

IMAGE RECEPTORS (FILM - RARE-EARTH-SCREEN)

CONTRIBUTION OF SCATTERING RADIATION

PARAMETERS AFFECTING SPATIAL RESOLUTION

PHYSICAL AND GEOMETRICAL SITUATION:

*- FOCAL SPOT DIMENSIONS (large focal spot : 0.5*0.5 cm)*

- DISTANCE FOCUS FILM (high F.F.D. around 60-65 cm)

- DISTANCE OBJECT FILM

- GRIDS

IMAGE RECEPTOR (HIGH SENSITIVITY)

DOSE TO THE PATIENT

RISK OF A MAMMOGRAPHIC EXAMINATION
- RADIATION-INDUCED CARCINOGENESIS

BENEFIT OF A MAMMOGRAPHIC EXAMINATION
- EARLY POSITIVE DIAGNOSIS

PARAMETERS AFFECTING ABSORBED DOSE:

- ***BEAM QUALITY***
- ***ENTRANCE EXPOSURE***
- ***BREAST COMPOSITION AND THICKNESS***

The depth dose within the breast decreases rapidly with increasing tissue depth

The use of a firm compression device and of a very sensitive receptor system may reduce the absorbed dose.

The use of grids and the low energy spectra involves an increase of the dose delivered to the patient.

THE REFERENCE ABSORBED DOSE IS "MEAN DOSE TO THE GLANDULAR TISSUE"

(NCRP 1986, ICRP 1987)

THIS ABSORBED DOSE IS LESS INFLUENCED BY THE CHANGES OF BREAST COMPOSITION AND SIZE AND THE GLANDULAR TISSUE IS BELIEVED TO BE THE MOST SENSITIVE TO RADIATION-INDUCED CARCINOGENESIS

FINALLY TO COMPARE DOSES IT IS NECESSARY TO DEFINE A STANDARD BREAST WITH A STANDARD COMPOSITION: a central region of 50% adipose and 50% glandular tissue with a 0.5cm-thick superficial region of adipose tissue

D.Q.M. I

DOSE AND QUALITY IN MAMMOGRAPHY

This program was planned by P.L. Indovina (Istituto Superiore di Sanita') and O.Rimondi (Department of Physics in the University of Ferrara).
It is mentioned in the Circular n.62 of the Ministry of Health (1984) and adopted by SIRMN.
In Trieste it was applied indipendently in 1985-1986, involving 12 mammographic centers of Friuli Venezia Giulia.

THE AIMS OF D.Q.M.

A) COLLECTION OF THE WORKING PARAMETERS
B) DOSE AND IMAGE QUALITY EVALUATION
C) COMMUNICATION OF THE RESULTS AND SUGGESTIONS FOR CORRECTIVE ACTIONS

PHYSICAL PARAMETERS EVALUATED

A) IMAGE QUALITY

- "performance phantom"

B) MEAN BREAST DOSE

- plexiglass phantom simulating the standard breast
- group of TLD chips to measure the entrance exposure and the quality of the beam

C) FOCAL SPOT and MTF-FOCAL SPOT

- star pattern device

All data were collected and elaborated by the HEALTH PHYSIC SERVICE OF TRIESTE.

D.Q.M. II

The program of Quality Control was subsequently developed and again applied by the Health Physics Service of Trieste in 1990/1991, being inspired by:

**** the Working Parting of CEE : "CEC quality Criteria for diagnostic radiographic images and patient exposure trial". Commission of the Europian Communities EUR 12952, Luxembourg 1990***

**** the guidance of O.M.S. : " Quality Assurance in diagnostic radiology ". World Health Organization, Geneva 1982***

**** the results and experience of the first DQM in Italy and in Trieste and of the voluntary program for the accreditation of mammographic screening sites by the American College of Radiology. (R.E. Hendrick "Standardization of the Image Quality and Radiation Dose in Mammography". Radiology,174, 648-654 1990)***

20 mammographic film-screen systems, situated in different places in Friuli Venezia Giulia were investigated.

PHYSICAL PARAMETERS MEASUREMENTS AND EVALUATIONS

* IMAGE QUALITY *

number of visible details

Net Optical Density

* TUBE OUTPUT *

consistency of output

variation of output with tube voltage (Linearity)

* X-RAY QUALITY *

Half Value Layer (H.V.L.)

* FOCAL SPOT *

effective sizes, width and length

PHYSICAL PARAMETERS MEASUREMENTS AND EVALUATIONS

* PATIENT DOSE *

exposure at entrance

H.V.L.

mean glandular dose

* AUTOMATIC EXPOSURE CONTROL *

reproducibility with exposure

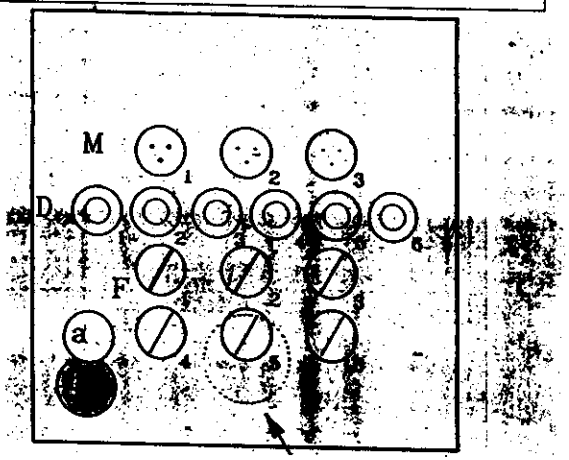
object thickness compensation

tube voltage compensation

* SENSITOMETRIC FILM CHARACTERISTICS *

characteristic curve

* PERFORMANCE PHANTOM *



*The test object simulates a 5cm thick compressed breast consisting of 50 % adipose and 50 % glandular tissue It's a block of Lucite (4.5*10*10 cm) and contains :*

- ***3 microspheres of 300, 200, 100 um diameter***
- ***6 aluminium disks of size 6 mm and thickness 15, 30, 45, 60, 75, 90 um***
- ***6 nylon wires, 10mm in length of cross-sectional diameter 0.70, 0.60, 0.50, 0.45, 0.38, 0.33 mm***
- ***(A) lead tablet for fog-plus-base density***
- ***(B) wax tablet for reference density***

* IMAGE QUALITY *

A) Necessary Equipment:

- *performance phantom*
- *densitometer*
- *mammographic film*

B) Measuring Conditions:

- *normal working conditions*
- *large focal spot*
- *compression device*

C) Quantities to be measured and calculated:

- *N.O.D. = D_b - D_a*
- *number of visible details*

IMAGE QUALITY WORKING CONDITION

Image quality evaluation is performed under the "optimum" working condition, that means:

Net Optical Density = 1.0

Phantom images are assessed indipendently by 3 physicists and 3 radiologists

IMAGE QUALITY IS QUANTITATED BY THE NUMBER OF TEST OBJECTS OF EACH TYPE VISUALIZED BY THE REVIEWERS IN THE BEST PHANTOM IMAGE

NB : CEE Protocol recommends a number of details greater than 8 and a N.O.D. in the range 0.8-1.2

* X - RAY QUALITY *
MEASUREMENTS OF HALF VALUE LAYER

The H.V.L. should be assessed by adding thin Aluminium filters to a collimated X-RAY beam and measuring the attenuation.

A) Necessary equipment:

- *VICTOREEN 660 ionization chamber*
- *5 Aluminium foils (thickness of 0.2 mm)*
- *an exponential fitting software*

B) Measuring conditions:

- *manual mode*
- *no compression device*
- *no beam limiting device*
- *28 kVp and 40 mAs*

C) Quantities evaluated:

- *exposure in entrance for different thickness*

N.B. FOR A MAMMOGRAPHIC UNIT WITH A MOLYBDENUM TARGET AND MOLYBDENUM ADDED FILTRATION, THE H.V.L. WILL BE TYPICALLY BETWEEN 0.3-0.4 MM OF ALUMINIUM

* DIMENSIONS OF FOCAL SPOT *

Three techniques may be used to measure characteristics of the focal spot:

*** SLIT CAMERA**

*** PINHOLE METHOD**

*** STAR RESOLUTION GRID OR "STAR PATTERN"**

The British Standard 6530 (BSI, 1984) recommends the use of slit camera, but recognises that a star resolution and a pinhole camera are also useful. The first method have to be used on installation of a mammographic system, but for routine measurements the other two methods are simpler and suitable.

* STAR PATTERN METHOD *

The focal spot dimensions can be estimated from the first 'blurring diameter' on the image of the star pattern. This diameter refers to the distance between the outermost blurred regions on the image along each direction of evaluation : normal to and parallel to the X - Ray tube anode - cathode axis.

Suitable spoke angles are 1.5 for focal spot values > 0.2 mm and 0.5 for focal spot values < 0.2 mm.

* STAR PATTERN METHOD *

A) Necessary equipment:

- lead star pattern, 1.5 degree
- no compression device
- no beam limiting cone
- distance film - star pattern 40 cm

B) Quantities evaluated:

- dimensions of the imaged focus in two direction:

$$f = \frac{\vartheta}{180} \frac{D}{M-1}$$

$\vartheta = 1.5'$
M = magnification factor
D = diameter of the blurred area

* AUTOMATIC EXPOSURE CONTROL *

In 17 of 20 screen-film mammography, the radiation exposure is controlled by an A.E.C. system.

One or more detectors located after the image receptor monitor the X-rays transmitted by the receptor. The exposure is terminated when the radiation dose reachs a predeterminated level, corrisponding to the desired optical density. The dose rate at detector will depend on the tube current, voltage and filtration as well as the size and composition of the breast.

To check the A.E.C. compensation to these different parameters, it is used a perspex phantom simulating breasts of different thickness, under different working conditions.

* AUTOMATIC EXPOSURE CONTROL SYSTEM *

A) Necessary equipment:

- densitometer (X-Rite model 301)
- 3 perspex labs of thickness 2cm

B) Measuring conditions:

- automatic mode
- beam limiting cone
- compression device

C) Measurements:

*** REPRODUCIBILITY**

- 4 exposure at 28 kVp with 4cm phantom

*** COMPENSATION FOR THICKNESS AND KVP CHANGE**

- 3 serials of exposures for 26,28,29,30 kVp on the phantom of 2, 4, 6 cm thickness

D) Quantities evaluated:

- optical density in the middle point of developed image
- density variations from mean value

MEAN GLANDULAR DOSE

A) Necessary equipment:

- entrance exposure and air kerma (without backscattering
- X-Ray quality (H.V.L.)

B) Measuring conditions:

- exposure of performance phantom in normal working condition (in cranio-caudal view)

C) Estimation with the following expression(*):

$$D = k\,g\,p$$

k= air kerma in entrance of the phantom

p= factor converting the incident air kerma at the entrance of the lucite phantom into that for the standard breast

q= factor converting the incident air kerma on the standard breast into mean glandular dose

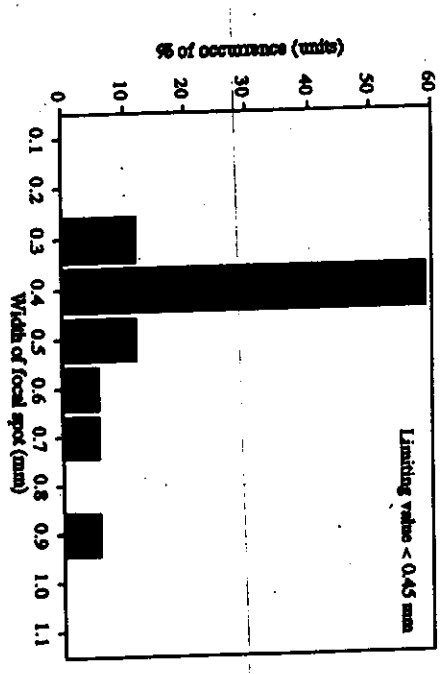
- value of p and g depend on radiation quality

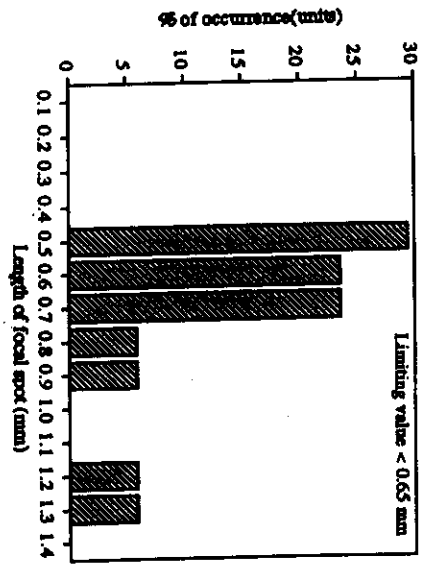
* Dance D.R., "Monte Carlo calculation of conversion factors for the estimation of the mean glandular dose" Phy. Med. Biol. 35, pag. 1211-1219 (1990)

PHYSICAL PARAMETERS	DQM PROTOCOL limiting value	DUTCH PROTOCOL limiting value	CEE PROTOCOL limiting value
Tube Voltage (kVp)	25 - 28	25 - 32	25 - 32
Focus-film distance (cm)	≥ 50		60 - 65
HVL at 28 kV (mm Al)	0.26 - 0.29	0.26 - 0.33	> 0.28
Focal Spot (mm)	< 0.6 * 0.6	< 0.45 * 0.45	< 0.45 * 0.45
Entrance Exposure (R)	< 1		< 2
Mean Glandular Dose (mGy)	< 3		< 3
Net Optical Density	1 - 1.5	0.9 - 1.1	0.8 - 1.2
Visible Details	> 8		
A.E.C. Parameters			
Coefficient of density variation (%)			
Reproducibility	< 20	< 10	< 10
Voltage compensation	< 20	< 10	< 10
Thickness compensation (28kV)	< 20	< 20	< 20
Thickness compensation (30kV)	< 20	< 20	< 20

RESULTS

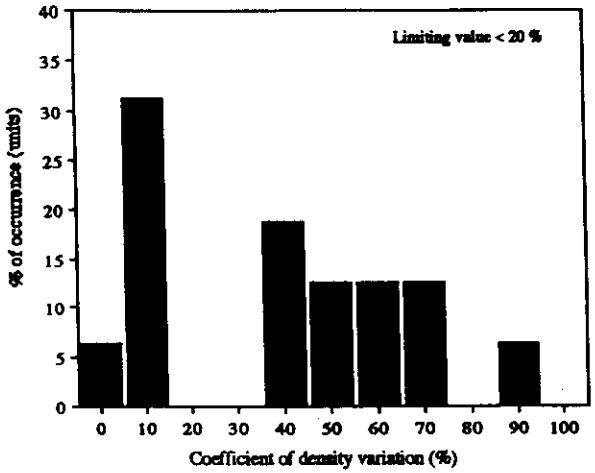
FOCAL SPOT DIMENSIONS

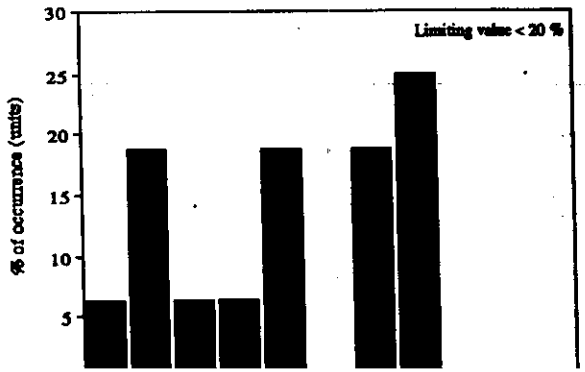




RESULTS

OBJECT THICKNESS COMPENSATION AT 28 kV AND 30 kV

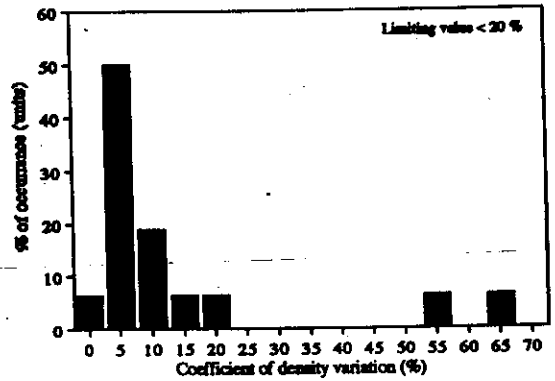




RESULTS

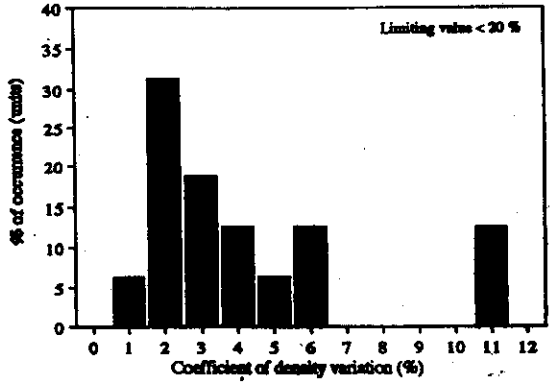
COMPENSATION FOR TUBE VOLTAGE

(4 cm plexiglass phantom)



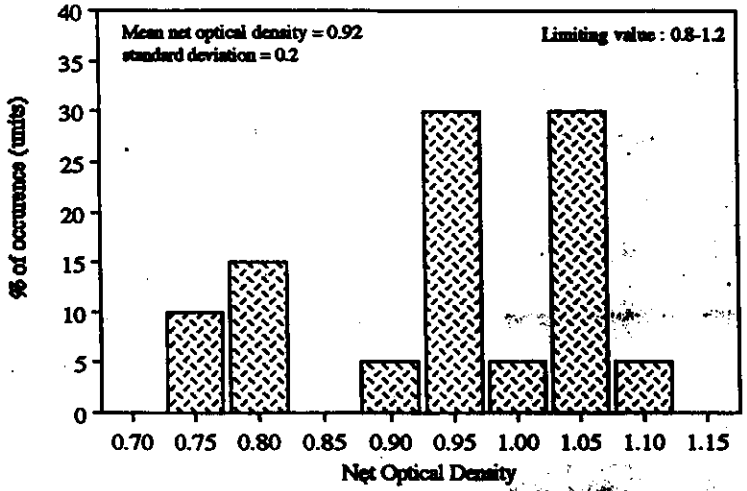
REPRODUCIBILITY

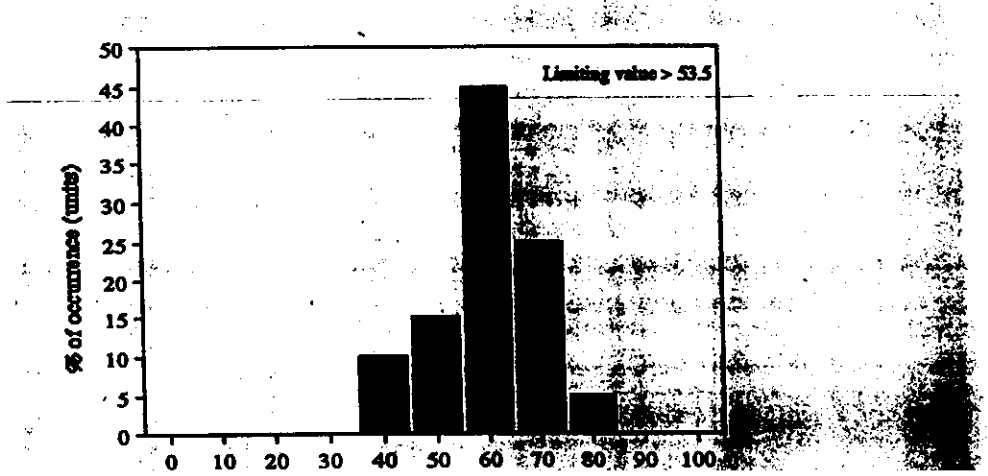
(4 cm plexiglass phantom at 28 kV)



RESULTS

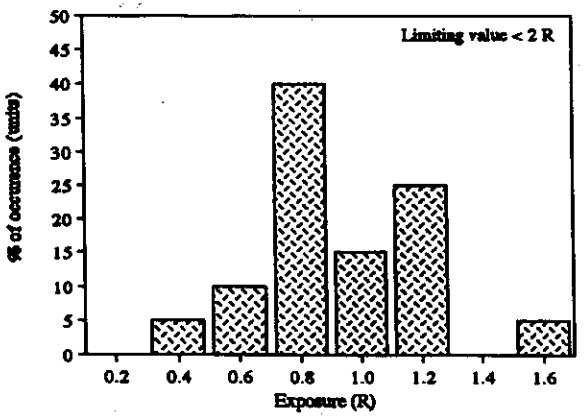
IMAGE QUALITY

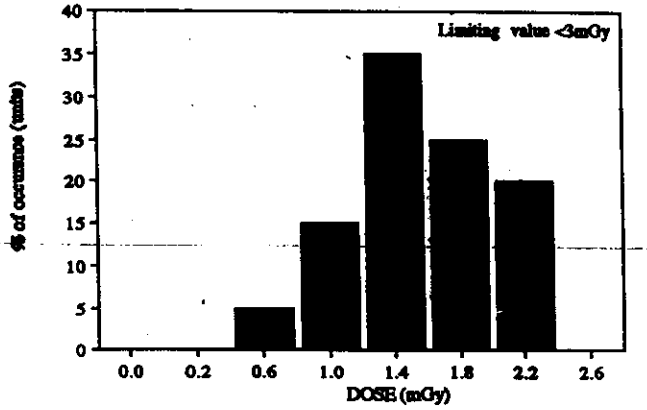




RESULTS

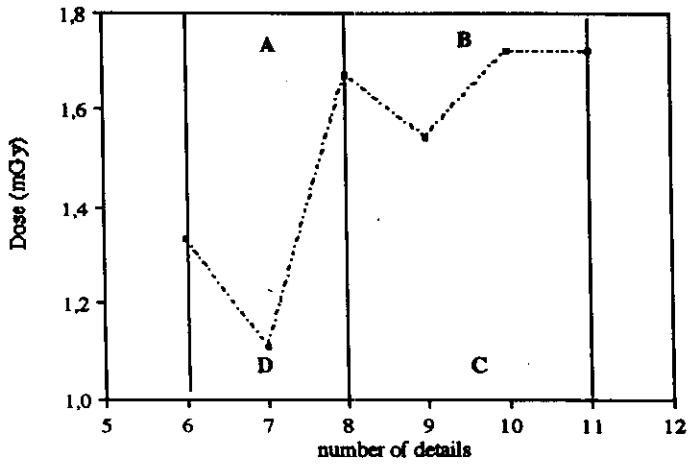
ENTRANCE EXPOSURE AND MEAN GLANDULAR DOSE





DQM 90 / 91 DATA

Mean glandular dose related to detected visible details



A: 1 unit

B: 7 units

C: 10 units

D: 2 units

LIST OF REFERENCE PROTOCOLS

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