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TECHNICAL SPECIFICATIONS FOR THE WORLD HEALTH IMAGING SYSTEM FOR RADIOGRAPHY - THE WHIS-RAD

This document is based on the *Report from the consultation meeting on the WHO Basic Radiological Systems,* Lund, Sweden, June 1993, and on subsequent comments from the partcipants and other professionals and experts.

1. BACKGROUND AND INTRODUCTION

In **1975** a meeting on *A Primary Care Radiological System* was held at the Pan American Health Organization (PAHO) in Washington, DC, USA, with radiologists, radiophysicists, administrators and technical representatives of manufacturers. The report from this meeting contained the first *Proposed specifications for a primary care radiological unit.* The unit was called the **WHO Basic Radiological System (WHO-BRS).**

These early specifications were further developed at several World Health Organization (WHO) advisory group meetings. In **1985** the *Technical specifications for the x-ray apparatus to be used in a basic radiological system* was published by WHO.

The WHO-BRS was originally intended for use in regions deprived of radiodiagnostic services for economic or geographic reasons. The WHO-BRS concept has been developed further, however, and use of the new system, presented in these technical specifications, would improve image quality in most large x-ray departments.

Since 1985 the WHO-BRS has been further developed, improved and clinically tested worldwide with active participation of the WHO Collaborating Centre for BRS in Lund and other members of the WHO-BRS Advisory Group. In December **1992** a new **World Health Imaging System for Radiography (WHIS-RAD)** was ready for presentation.

The guiding principles in the design of the WHO-specified radiographic unit have been:

1. The x-ray image quality must be excellent.
2. The equipment must be safe for patients and personnel.
3. The equipment must be easy to install and use.
4. The equipment must be usable also when the electrical mains supply is not reliable.
5. Equipment maintenance should be minimal.

The WHIS-RAD Unit can perform more than 80% of all general radiographic procedures, required at teaching hospitals. It is easier to operate than most conventional x-ray equipment and can be powered from batteries, which may be charged from any suitable power source. It is possible to manufacture the WHO-specified radiographic equipment at low cost and it functions extremely well in the front line of any health care system.

A consultation meeting on WHO Basic Radiological Systems was convened in June **1993** in Lund, Sweden, with 25 participants (10 radiologists, 2 radiophysicists, 5 radiographers and 8 representatives of manufacturers). The International Society of Radiology, the International Society of Radiographers and Radiological Technologists, and the International Organization for Medical Physics were represented in this group.

The technical specifications of the existing

WHO-BRS were reviewed at this meeting, taking into consideration the concerns and advice from all professionals present.

It was recommended to use a new name for the new unit: the WHIS-RAD. The old specifications of the Basic Radiological System will be referred to as the WHO-BRS/85.

General information about the WHIS-RAD

More than 95% of all x-ray examinations made in the world today can be made with the WHIS-RAD. All bone examinations can be made, including skull examinations. The WHIS-RAD is a first choice chest unit, much superior to common chest wall stands and wall buckles. Abdominal examinations, including urography (IVP), cholecystography and (if ultrasound is unavailable) obstetric examinations can be made.

The price of a WHIS-RAD unit is low, when compared with conventional equipment for general radiography. The price is high, only when compared with the cost of substandard, low-powered, single-phase x-ray units.

Purchasing agencies should be encouraged to buy the equipment described in these specifications, developed by a task force within the WHO, and should avoid cheap, underpowered, "well-tried" x-ray units, especially mobile units (which require much more professional skill for acceptable clinical results).

These specifications of the new *World Health Imaging System for Radiography* are published after 15 years of practical clinical use worldwide of several early WHO-BRS models, and that includes teaching hospitals as well as remote primary care polyclinics.

It is important that regional offices and other sections within the WHO do not initiate their own versions of the WHO-BRS or WHIS-RAD, or authorize purchase of substandard equipment, creating confusion as to the correct specifications. Alterations in the specifications should be initiated only by the WHO Headquarters or a WHO unit dedicated to radiographic equipment.

2. DESCRIPTION OF THE WHIS-RAD

The WHIS-RAD is a further development of the WHO-BRS. It is designed to be used by qualified radiographers or by radiographer's assistants, supervised by qualified radiographers.

The WHIS-RAD is intended for use in primary care and at first level referral hospitals. It is especially suited for use in small rural hospitals and large health care centres but serves well also in x-ray departments of large hospitals, especially as a first choice unit for examinations using a horizontal x-ray beam.

The *examination stand* is designed to assure optimum imaging geometry, eliminating the negative influences of a variable focus-film distance and angulation of the antiscatter grid. Thus the unit operates with a *single x-ray tube* in *fixed geometry* in relation to the cassette holder, using the pendulum principle to vary the direction of the x-ray beam.

The new specifications include a standard, multilevel light-beam *collimator* with reliable format indications for an FFD of 140 cm. The *cassette holder* must accept any standard cassette format, used in the country where the equipment is installed.

It may be possible to angulate the x-ray tube away from the cassette holder *should a qualified radiographer be operating the machine.* The elimination of the built-in radiation protection in the cassette holder must be kept in mind, when this possibility is used.

Only *multipulse x-ray generators* are considered. It must be possible to operate the generator from a grounded 2.3 kW AC source (e.g. 230 V, 10 A). Thus some kind of energy storage must be used. The stored energy is converted into multipulse high-voltage AC, and rectified to high voltage DC with very low ripple (<4 %).

The total energy available for a single exposure shall be 23-30 kWs, to permit the use of screen-film combinations with a nominal speed of 200 (e.g. calcium-tungstate screens and blue-sensitive film). With screen-film combinations in the speed range above 400 the upper energy limit of the generator may be as low as 12.5 kWs.

The replacement of an *x-ray tube* is often a major economic and administrative problem. The

tube must have an expected life of no less than 50,000 exposures in normal clinical use at the first referral level (see item 3.2.1).

3. TECHNICAL SPECIFICATIONS FOR THE RADIATION SOURCE OF THE WHIS-RAD:

These specifications were developed after 15 years of clinical testing at the WHO Collaborating Centre for Basic Radiological Systems in Lund, resulting in more than 1 million clinical x-ray films, and after numerous consultation meetings.

The radiation doses are lower than with most other equipment. Many testing reports from x-ray departments in developing countries have shown that the WHO-BRS is easy to handle, and the image quality is outstanding.

The specifications should be a guide for manufacturers, purchasing agents and users. *They are not an international standard.*

3.1. HIGH-TENSION GENERATOR

3.1.1. Mains connection

A wall outlet or a separate 50/60 Hz AC generator, which can deliver 2.3 kW within 10%, is required. This corresponds to nominal values of 10 A at 230 V or 20 A at 115 V.

NOTE: Solutions without mains connection, using a battery with other type of charging, e.g. solar cells or a small AC generator, are also acceptable.

3.1.2. Energy storage

The power rating of the x-ray generator will be much higher than the instantaneous power (2.3 kW) available from the AC source described above. The high tension generator therefore must have an integrated energy storage unit. An individual exposure of a very dense object may on rare occasions require close to 30 kWs (kilowatt-seconds) at 90 kV. Generators without energy storage, intended to operate directly from the mains, are not recommended (*unless a 380-400 V, 0.2 - 0.3 Ω power line is avalable*). Peak power loads in the range of 12 - 30 kW for 0.1 s and 12 - 15 kW for 2 s may be expected.

NOTE: The energy storage unit shall be maintenance-free and carry a 5 year pro rata temporis *warranty. It is preferable to use a* **battery** *for energy storage but other methods may also be acceptable, such as a large* **capacitor** *on the primary side of the high-tension transformer or a* **fly-wheel.**

3.1.3. High-tension transformer frequency

Only high-tension generators using **multipulse inverter technology** are acceptable. Frequencies from a few kHz to 100 kHz are used with satisfactory results. The high-tension voltage ripple shall be no larger than 4%, measured at 100 kV (kVp) and 100 mA.

3.1.4. Generator control panel

Only the following switches or controls shall be available: ON/OFF, kV-selector, mAs-selector, anode rotation, and EXPOSURE. The exposure switch should be mounted on the control panel, so that the operator must stand behind a protective screen or wall during exposures. The selected values for kV and mAs shall be shown before and after the exposure (= *tube loading*). A light signal shall indicate if the generator is READY for the selected tube loading. The actual tube loading shall be indicated with a sound and/or a light signal.

3.1.5. Nominal x-ray tube voltage

The nominal x-ray tube voltage (highest available kV) shall be 120 kV.

NOTE: The high-tension generator must have circuits which automatically protect the x-ray tube from overload (tension and temperature) and the high-tension circuit from damage by flash-over.

3.1.6. Available x-ray tube current

The tube current shall be or exceed 100 mA.

3.1.7. Electric power rating

The *nominal electric power* rating (kW) shall be stated as the highest constant electric power in kilowatts, which the high-tension generator can deliver for a loading time of 0.1 s in the voltage range of 90 - 100 kV. The minimum acceptable power rating for a WHIS-RAD generator is 12 kW at 100 kV.

3.1.8. Electric energy rating

The *nominal electric energy* (total energy available for one single exposure), measured at 90 kV and a tube loading time not exceeding 2.5 s, shall be in the range of 23 - 30 kWs (kilowattseconds). (See below and under item 3.1.9.d.) The measurement at 90 kV (instead of at 100 kV, which is customary) depends on the fixed selection of kV-values used in the WHIS-RAD philosophy. Typical peak load situations, using current and peak loading time values available in the Renard-10 series (see item 3.1.9.d), are 90 kV + 160 mA + 2 s, resulting in 28.8 kWs, or 90 kV + 100 mA + 2.5 s, resulting in 22.5 kWs.

NOTE: This type of electric energy rating (not yet applied by the International Electrotechnical Commission - IEC) is necessary if the generator uses power storage or falling tube current during the tube loading (exposure).

EXCEPTION: The electric energy rating specified above, presumes that the image recording medium (screen-film combination) used has a nominal speed of at least 200 in the 70 - 120 kV range, corresponding to an exposure requirement of 0.5 mR (air kerma of close to 5 μGy) at the input side of the film cassette. When a recording medium is used, which has a nominal speed of 500, requiring 0.2 mR/exposure (air kerma close to 2 μGy) at 90 kV (retaining acceptable image quality), the nominal electric energy, measured as above, may be as small as 12 kWs.

For the time being this requires the use of green-emitting intensifying screens and green-sensitive x-ray film (see item 6.1). The use of such film requires special attention to the darkroom lighting and the film development. Free access to green-sensitive (orthochromatic) x-ray film is also required, which may be a problem in some remote areas.

3.1.9. Selection of loading factors

The selection of loading (exposure) factors is optimized in the WHIS-RAD Unit and limited to kV- and mAs-values. Exposure times and mA-values shall not be set separately, but only selected as current-time products (mAs-values). The shortest possible exposure time and the highest possible mA-value shall be automatically selected in the x-ray generator control for each mAs-value used.

Adequate information shall be available to the operator before, during and after the loading of the x-ray tube about which loading factors (kV and mAs) that are used.

a) **Values of x-ray tube voltage** shall be measured as kVp but indicated as kilovolts (kV) because the voltage ripple is no more than 4%. The concept of kVp shall not be used in the manual or on the control panel.

   For didactic reasons the choice of **kV-values** is limited to a small number of fixed steps. This does not impose a limitation in the practical use of different radiation qualities in radiography.

Recommended values of x-ray tube tension:
46 - 53 - (60) - 70 - 80 - 90 - (100) - 120 kV

   NOTE: 60 kV and 100 kV are required for testing purposes, but not needed for clinical use. A larger number of kV-steps or continuously variable tube tension are not acceptable.

   The selected kV-value must not fall more than 5% from the initial value during the tube loading (corresponding to about 10% in air kerma loss).

b) **Values of x-ray tube current** shall be selected automatically and not displayed. If the tube current is constant during the tube loading its minimum value shall be 100 mA. If the tube current is falling during the tube loading, the initial value should be in the range of 200 - 320 mA.

   NOTE: If exposure times and mA-values are selected from ranges of fixed values, these must be taken from the Renard-10 series, thus resulting in mAs-values according to item 3.1.9.d below.

c) **Values of loading time** (exposure time) need not be displayed. Shortest reproducible loading time (measured as the time during which the kV is 75% of the selected value) shall be 5 ms or shorter. Loading times longer than 2.5 s are not permitted.

d) **Values for current-time product** shall be indicated in milliampere-seconds (mAs) and shall be chosen as decimal multiples and submultiples from the rounded values of the Renard-10 series (R'10) shown on the following page (ISO Standard 497/1973).

R'10 = the Renard-10 Series

1	1.25	1.6	2	2.5	3.2	4	5	6.3	8
1.0000	1.2589	1.5849	1.9953	2.5119	3.1623	3.9811	5.0119	6.3096	7.9433

The minimum range of fixed mAs-values to be used in the WHIS-RAD is:

							0.5	0.63	0.8
1	1.25	1.6	2	2.5	3.2	4	5	6.3	8
10	12.5	16	20	25	32	40	50	63	80
100	125	160	200	250	(320)				

NOTE: It is not required that the entire range of mAs-values is available at all tube tensions. Thus it is acceptable that only 20 kWs is reached at 80 kV (with 250 mAs) and that only 12 kWs is reached at 120 kV (with 100 mAs).

The combination of 250 mAs and 90 kV (= 22.5 kWs) is usually enough as the peak output. The combination of 320 mAs and 90 kV (= 28.8 kWs) is rarely needed in a population with an average weight of individuals around 80 kg and never in a population with an average weight of 70 kg.

e) **Precalculated current-time products** shall be shown by the control panel. The lowest mAs-value should be stated, which is within the specified ranges of compliance for linearity and constancy (see below).

NOTE: This information is very important. The energy loss in the high-tension circuit may be in the order of magnitude of 0.06 kWs at each exposure, which corresponds to 0.5 mAs at 120 kV (= the lowest possible combination of loading factors used in chest radiography).

3.1.10. Reproducibility, linearity and constancy of radiation output

Multipulse x-ray generators with energy storage inherently have much better reproducibility and linearity than required in the IEC Standard 601-2-7/1987 *(Medical electrical equipment, part 2: Particular requirements for the safety of high voltage generators of diagnostic x-ray generators).* This standard does not apply to battery-operated generators.

a] **Reproducibility of air kerma:** The coefficient of variation of measured values of air kerma shall not be greater than 0.1 (10%) for any combination of loading factors within the available range.

b] **Linearity of air kerma:** Within the available x-ray tube voltage range (46 - 120 kV) the quotient of the measured values of air kerma divided by the indicated *precalculated* value of current-time product (μGy/mAs) shall not differ from the quotient of the measured value of air kerma and indicated current-time product at 10 mAs by more than 0.1 (10%) of that latter quotient.

Comment: **Measurements of air kerma** shall be made with a minimum added filtration on the x-ray tube of 20 mm Al or equivalent.

Measurements of mAs inside the x-ray tube are not made and measurements in the grounded centerpoint of the high-tension transformer are of no value. The linearity requirement is only related to the magnitude of the steps in the precalculated mAs-scale, representing 26% increments of air kerma.

The linearity requirement is stricter than the corresponding IEC requirement for mains-connected x-ray generators. Practical experience at the old WHO Collaborating Centre for BRS and the new WHO Collaborating Centre for Radiological Education in Lund, Sweden, has shown, however, that multipulse x-ray generators using energy storage can easily be modified to give a μGy/mAs quotient, which does not differ more than 2-5% from the reference value (at 10 mAs) over the entire mAs-range.

c] **Agreement between indicated and measured values of loading factors.**

At a given measurement date, using the same measuring instrument, the permissible *average error* of the indicated value of x-ray **tube voltages** shall not be greater than 0.025 (2.5%), approximately corresponding to the requirements for air kerma given above.

Under the same conditions the permissible *average error* of **current-time products** shall not exceed the value 0.05 (5%) or 0.1 mAs, whichever is larger.

3.2. THE X-RAY TUBE

Due to the long time usually required to change an x-ray tube at a remote location and the very high tube replacement costs, longevity of the x-ray tube is a very important characteristic. An x-ray tube for a WHIS-RAD Unit benefits from design features which promote a long tube life such as a large anode diameter and renium/tungsten alloy in the anode surface.

3.2.1. Expected lifetime

An x-ray tube for a WHIS-RAD installation should have an expected lifetime of 10 years or more with the types and mixture of examinations to be found in an x-ray department at primary-care or first referral level (see box). This may correspond to a total of about 50,000 exposures in normal use.

Distribution of examinations to be expected in primary care or at first referral level:	
35-40% chest	**38-42% extremities**
8-10% abdomen	**10-15% spine and pelvis**
	3-4% head and neck

The anode of an x-ray tube develops small cracks in the target surface due to heat variations. These cracks lead to reduction in the output of the x-ray tube. When the output reduction reaches 20%, corresponding to one tube loading step in the Renard-10 series, the demand on the x-ray generator power output has increased with 25%, which may prove critical for some examinations.

The average tube load at this type of work is around 3 kWs/loading, corresponding to 10-13% of the permitted maximum load. However, the actual tube load varies within a very wide range: from 0.25 kWs for a normal PA chest to 30 kWs for a lateral view of the lumbo-sacral junction of a heavy person.

3.2.2. Focal spot

A rotating anode must be used. The **focal spot** of the x-ray tube shall have a nominal size no larger than 1 mm, measured according to IEC 336.

NOTE: A new IEC standard for focal spot measurements is anticipated in 1995/96. In this the nominal figure for focal spot size is dimensionless and specified in terms of detail resolution in lines/mm at a specified geometric magnification. This practice, however, is not yet in general use by manufacturers, users or purchasing agents and its introduction is beyond the scope of this publication. For practical purposes the nominal values may still be interpreted as representing millimeters.

> *ADDITION (November 1995): Focal spots with a nearly gaussian intensity distribution (e.g. created by simultaneous use of two superimposed focal spots of different size) may be about 40 larger, when measured according to IEC 336.*

3.2.3. Anode angle

The **anode angle** should be in the range of 12-15^{O}. No special recommendations are given about anode diameter or rotation speed.

NOTE: An anode angle in the range of 12-15^{O} is compatible with a nominal focal spot size of 0.8 - 1.0 (mm) and a tube rating of 23 - 30 kW (at 0.1 s).

An anode angle of 12^{O} easily permits an x-ray field of 45 x 45 cm without visible heel effect at the expected working conditions.

Comments: The **aging of the anode** is very dependent on how it can withstand heat. Anodes made of pure tungsten may not live up to the requirements stated in this paragraph. Reliable figures for the drop in anode output with normal clinical use are not available. The output from a tungsten target containing 90% tungsten and 10% renium drops at a rate which is about 25% of the rate for a pure tungsten target. The overall lifetime of a 90/10% tungsten/renium target is about 4 times longer than that of a pure tungsten target.

3.2.4. Tube rating

- The **high-tension rating** of the x-ray tube shall be 125 kV (low-ripple high tension).

- The **nominal power rating** shall be in the range of 23 - 30 kW at a loading time of 0.1 s.

- The **long time power rating** shall be in the range of 12 - 15 kW at an exposure time of 2 s, corresponding to a total energy load of 24 - 30 kWs.

3.2.4. Tube filtration

The **total filtration** (inherent + added) shall be within the range of 3 - 4 mm Al. The filtration shall be determined by Half Value Layer (HVL) measurements of the emerging radiation, which may be performed with a penetrameter.

3.2.5. X-ray beam collimator

It is recommended to use a standard, multilevel light-beam collimator. Special attention should be paid to the following features:

- The controls should have reliable format indicators (e.g. for 12, 18, 24, 35 and 43 cm) for a focus-film distance of 140 cm, so that the collimator can be used also in case of mains power failure or a light-bulb blow-out.

- It is advantageous if the collimator controls are no more than 110 cm away from the front wall of the cassette holder, enabling a person not taller than 155 cm to reach them, when the x-ray tube is in normal position for examination of a recumbent patient on a 70 cm high patient trolley.

- The collimator should be designed in such a way that the light bulb can be replaced with retained exact position without the use of special tools. The position of the centre of the light field shall not vary more than 14 mm (1% of the FFD) from the point, where the central x-ray beam reaches the cassette holder. The limits of the light field may not vary more than 1% of the FFD from the limits of the x-ray field.

- Spare collimator bulbs, sufficient for an estimated 10 year's consumption, should be provided.

4.0. SPECIFICATION FOR THE WHIS-RAD EXAMINATION UNIT

4.1. GENERAL DESCRIPTION

The examination unit consists of a support for the x-ray tube and the cassette holder, usually called *the stand,* and a *patient trolley,* which can be used as a floating-top table.

The examination unit combines the functions of a chest unit, a vertical bucky, and a floating-top table with an x-ray tube stand. It must permit the use of horizontal, vertical and angulated x-ray beam on lying, sitting and standing patients, also in emergency situations.

4.2. THE SUPPORT FOR X-RAY TUBE AND CASSETTE HOLDER

It is necessary to use a design of the stand which will ensure that the x-ray tube can always be connected to the cassette holder in a rigid and stable way, providing precise and simple centering of the x-ray beam.

The focus-film distance (FFD) shall be fixed at 140 cm. The x-ray tube and the cassette holder shall be mounted in such a way that also a recumbent patient can be examined with a horizontal x-ray beam. The arm assembly shall be perfectly balanced (with a 24 x 30 cm cassette in place) in two basic positions: horizontal and vertical.

It must be possible to angulate the arm +/- 30^{o} from both these positions, retaining the balance, and to use a horizontal central x-ray beam in the minimum range of 50 - 170 cm above the floor. No individual tube angulation is acceptable in a standard installation.

Comment: If a WHIS-RAD unit is extensively used in traumatology, e.g. in an emergency room, it should be possible to create a horizontal x-ray beam, which is *not* directed towards the cassette holder. It should also be possible to tilt the x-ray beam 90^{o} downwards, when the tube arm is horizontal, for radiography of patients which cannot be moved from the bed or strecher, on which they have arrived. This use implies taking away the radiation protection included in the cassette holder and should be applied only under the supervision of a qualified radiographer.

4.3. CASSETTE HOLDER

The cassette holder shall be fixed at right angles to the central x-ray beam and shall accept any standard cassette format in longitudinal and

transversal position. Critical dimensions are given in Table 4.6.

NOTE: The largest format may be different in different parts of the world, depending on the size and constitution of the individuals to be radiographed. In many parts of the world the 35.6 x 35.6 cm format ("35 x 35") is satisfactory for PA chest, abdomen and pelvis due to the advantageous imaging geometry of the WHIS-RAD (the FFD is 140 cm and the skin-film distance is 2.5 cm in chest radiography). However, the 35 x 43 cm format is required in large parts of Africa and in most parts of Australia, Europe, and North America.

It must be possible to change cassettes with minimal difficulty also when the x-ray beam is used in the vertical direction, with the trolley in place above the cassette holder.

The cassette holder may be used as a small horizontal examination table without using the trolley. It must permit a load of at least 15 kg without unwanted downward movement or disalignment of the focussed grid.

The **centre** of the x-ray beam and **vertical film format dimensions** for the four most used film formats shall be indicated on the *front wall* of the cassette holder. If the 35x43 cm format is anticipated to be used also in the transverse position, this must be indicated on the cassette holder.

The *front wall* of the cassette holder shall contain a fixed **anti-scatter grid** (see below).

The *back wall* of the cassette holder shall contain a protective screen with a density equivalent to 0.8 mm of lead and outer dimensions not smaller than 49 x 49 cm.

4.4. ANTI-SCATTER GRID

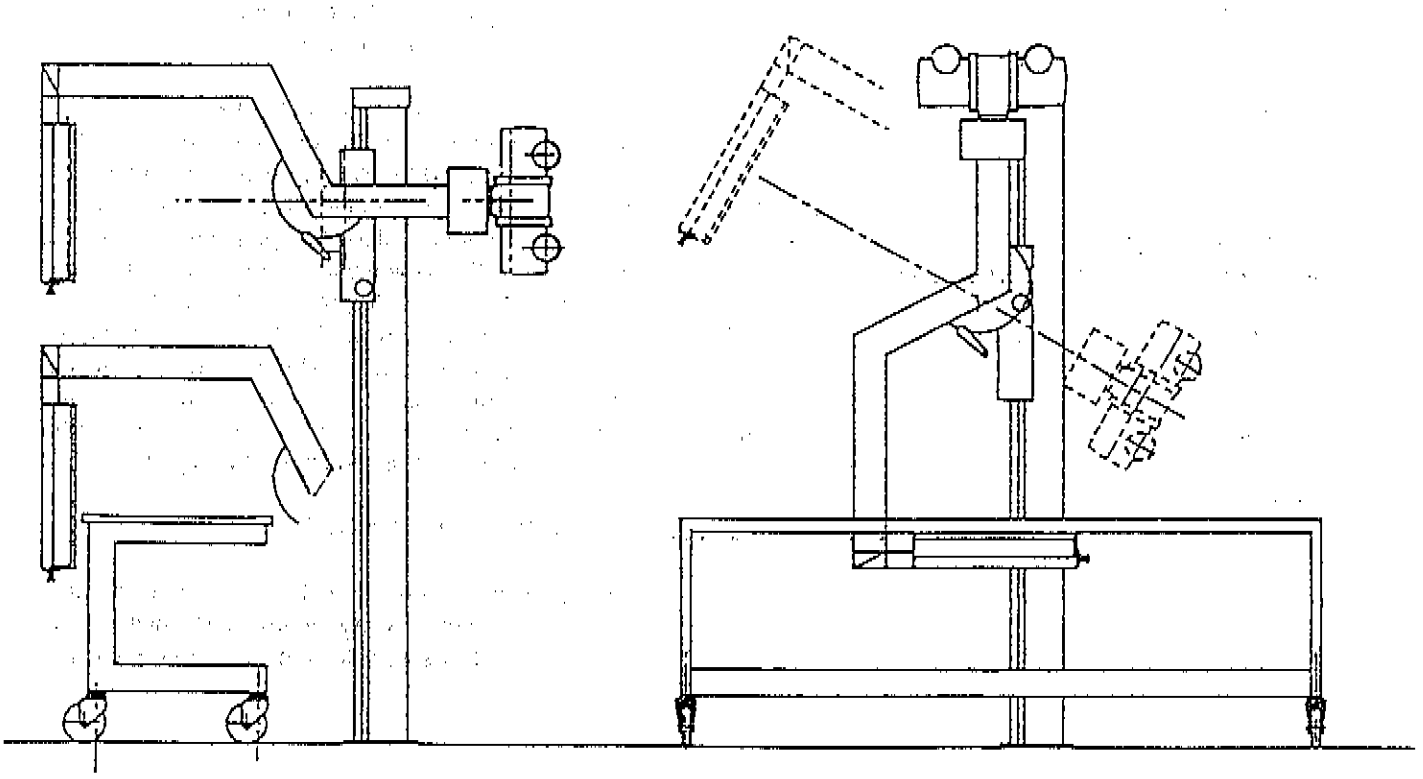
The anti-scatter grid must be focused at a distance of 135 - 140 cm. The grid ratio shall be 10:1 with a line density of 40 - 60 lines/cm. The grid shall be large enough to cover a vertical film format of 35 x 43 cm. If the 35 x 43 cm format will be used in transversal position, the grid must be 43 x 43 cm.

NOTE: Practical experience has shown that a grid with 40 lines/cm is satisfactory and practically invisible, when correctly focused and when the resulting film is viewed at a distance longer than 30 cm. Lead with interspacing aluminium is advantageous in the 90 - 120 kV-range and acceptable in the 70 - 80 kV-range.

Grids using carbon fiber as interspacing material usually come with at least 60 lines/cm. They are advantageous in the 53 - 70 kV range but not equally effective (resulting in lower contrast) in the 90 - 120 kV range.

4.5. EXAMINATION TABLE

The **examination table** shall be a trolley, which can be used as a floating-top table. The table top shall be rigid and be able to support a patient weighing 110 kg, sitting on the middle of the table, without appreciable (<1 cm) distorsion. The equivalent density of the table top should not be more than 1 mm Al.



The design of the trolley must permit the use of the cassette holder in horizontal position under the trolley in such a way that the distance between the table top and the film plane does not exceed 8 cm. In this position it must be possible to use the trolley as a floating-top table, so that the longitudinal midline of the trolley can be offset no less than +/- 12 cm from the midline of the cassette holder.

The trolley shall have large wheels, with locks on at least two of them. A central lock for the wheels is preferred. The table surface should be flat. Dimensions are given in the table below.

4.6. Table:

SUMMARY OF CRITICAL DIMENSIONS OF THE EXAMINATION UNIT:		
Focus-film distance (fixed, not variable) Distance between arm pivot and x-ray film	140 cm 80 - 100 cm	
Space available for trolley with patient a. minimum trolley clearance at a level 8 cm below the central horizontal x-ray beam: b. minimum possible lateral movement of the patient trolley with vertical x-ray beam: c. space under cassette holder arm for patient lying in lateral decubitus position:	trolley width + 5 cm (min 70 cm) +/- 12 cm from central x-ray beam minimum 25 cm from arm to central x-ray beam	
Tube/cassette-holder arm angulation from vertical and horizontal position: - Brake for arm rotation - Brake for height adjustment (additonal option) - Distance from pivot to central x-ray beam	+/- 30° mechanical mechanical (electro-magnetic brake) 0 (or *very* short)	
Height above floor for horizontal beam:	variable: min 50-170 cm	
Optional tube angulation of horizontal arm for use in traumatology by qualified operator:	30° down and 90° down	
Cassette holder - Cassette holder height (= length): - Distance between front wall and film: - Largest distance between front wall and floor at vertical x-ray beam:	maximum 50 cm 2 - 3 cm 90 - 100 cm	
- Film cassette formats:	recommended	alternate
small format	18x24cm	-
intermediate format	24x30cm	-
long format	18x43cm	15/20x40
large format	35x43cm	35x35
Patient trolley: table width	65 - 70 cm	
table length	200 - 210 cm	
table height	70 cm +/- 1 cm	
table top density equivalence	1 mm Al or less	
diameter of wheels	10 - 15 cm	
distance from table top to film with no angulation of the x-ray beam:	maximum 8 cm	

5.0. CASSETTES AND FLUORESCENT SCREENS

5.1. RECOMMENDED SCREEN TYPES

Calcium tungstate intensifying screens emit **blue light** and are available in three speeds:	
Detail/50 Universal/Parspeed/100 Fast/HiPlus/200	for hands and feet for head & extremities for everything else
The speed (light/μGy) is almost kV-independent.	

Gadolinium-oxysulphide intensifying screens emit **green light** and come in four speed groups:	
Fine/100 Medium/200 Regular/400 Fast/600-800	for hands and feet for chest for everything else for *very* dense objects
The speed (light/μGy) varies with kV used.	

The speed (= sensitivity) of gadolinium-oxysulphide screens is highest in the upper end of the clinically used kV-range (90 - 120 kV), reducing exposure times for very dense objects (90 kV) and chest (120 kV). The speed approximately doubles, when the tube tension is changed from 50 to 100 kV. This is advantageous, because the sensitivity to scattered radiation is then lower than to primary radiation. The nominal speed is usually given for 70 - 80 kV.

All speed information refers to the use of standard x-ray film (blue- or green-sensitive).
It is recommended to choose the **basic screen system** described below in *Section 6.2*, if the choice of intensifying screens and x-ray film is limited in the area, where the WHIS-RAD is going to be used. If the choice of screens and film types is unrestricted, or if the energy rating of the x-ray generator is below 23 kWs, the **advanced screen system** is preferred. The detail resolution of the advanced system is considerably better than that of the basic system in all screen types except in the Detail/Fine category.

Speed groups of blue-emitting calcium-tungstate and green-emitting gadolinium-oxysulphide intensifying screens

Calcium-tungstate screens with **blue-sensitive** film at 46 - 120 kV
Detail/50 Univ./Parspeed/100 Fast/200

Gadolinium-oxy-sulphide screens used at kV:	Rel. speed with **green-sensitive** film					
	no grid		with Pb/Al grid, ratio 10:1			
	46	53	60	70	80	90 - 120
Fine/100	50	63	80	**100**	-	-
Medium/200	100	125	160	**200**	225	250
Regular/400	-	-	320	**400**	450	500
Fast/600-800	-	-	-	**630**	700	800

5.2.

CHOICE OF X-RAY CASSETTES	format (cm)	designation	speed grp	use
Basic screen system:	18x24	Detail	50	no grid
A minimum supply of cassettes should	18x24	Fast	200	grid
include those listed to the right,	24x30	Fast	200	grid
intended for **blue-emitting**	18x43(15x40)	Fast	200	grid
calcium-tungstate screens:	35x43(35x35)	Fast	200	grid
* Alternative choice for extremities	18x24*	Universal*	100*	+/- grid
Advanced screen system:	18x24	Fine	50-80	no grid
If green-sensitive, orthochromatic	18x24	Regular	320-500	grid
film is available, it is better to	24x30	Regular	320-500	grid
choose **green-emitting intensifying**	18x43(15x40)	Regular	320-500	grid
screens as shown to the right:	35x43(35x35)	Regular	320-500	grid
(speed varies with kV)	35x43(35x35)	Medium	200-250	chest+gr
* Alternative choice for extremities	18x24*	Medium*	100-160*	+/- grid

Cassettes must be marked on the back with **speed** of the screens, **type of film** to be used (blue- or green-sensitive), and **date** of initial usage.

All intensifying screens, used in the same room, must belong to the same type and generation. It is therefore recommended to provide at least 3 cassettes of each type, even if 2 of each would be satisfactory for the anticipated workload.

5.3. OPTIONAL LOOSE ANTI-SCATTER GRIDS

Some projections make use of a loose cassette on top of the cassette holder or the trolley. Separate anti-scatter grids with a ratio of 6:1, mounted on these cassettes, may then be required. WHO recommends the use of two separate grids: for 24 x 30 cm and 35 x 43 cm cassettes.

6.0. PROTECTIVE DEVICES

It is recommended that the x-ray generator control panel is installed behind a protective wall or screen, separating an area from the x-ray room, large enough for two people (e.g. operator and interpreter or parent). The lead equivalence of the wall/screen should be 0.5 mm Pb or more. The wall or screen must have a lead glass window, adjusted to the average height of a standing radiographer, thus providing a good view of the patient being examined. The lead glass window may be as small as 30 x 30 cm in a screen but should be at least 40 x 50 cm in a brick wall.

The back wall of the cassette holder contains 0.8 mm lead (or equivalent). Thus 12 cm thick walls of solid, baked bricks or concrete may be satisfactory for radiation protection around the x-ray room, if the room is at least 18 square meters in size and no more than 2000 examinations are made per year.

At least two full length (shoulder to knee, adjusted to the size of a normal person) radiation protection aprons and two pairs of radiation protection gloves with 0.25 mm Pb equivalence should be offered with the x-ray equipment.

7. FINAL COMMENTS

7.1. MANUALS

One set of WHO manuals on radiographic technique, film processing and film interpretation should be delivered with the equipment. Equipment manufacturers are required to supply adequate manuals for installation, use, maintenance and repair of their own equipment.

7.2 OPERATIONAL ACCESSORIES
(to be offered with the WHIS-RAD Unit)

a) Two 15 x 32 cm lead **rubber sheets** (0.5 mm Pb equivalent) to cover cassettes, when used on the table top. This will allow two exposures on the same film: For example two times 12 x 18 cm for the wrist on an 18 x 24 cm format or two times 12 x 30 cm for the forearm on a 24 x 30 cm format.

b) A parallel-sliding **measuring caliper**, graduated in cm, to determine body part thickness at exposure factor calculations.

c) A standard set of **foam-plastic wedges** and **sandbags**, used for radiographic positioning of patients.

d) Two **viewing boxes**, approximately 40 cm wide and 50 cm high, mounted side by side, or one lightbox about 80 cm wide and 50 cm high, should be delivered with the WHIS-RAD Unit. Use standard "warm-white" fluorescent tubes (not "daylight" tubes) behind milky-white glass. The luminance of the light surface should be in the range of 1800 - 2500 candela/square meter.

7.3. FILM PROCESSING

It is anticipated that film processing will be manual, using strict time/temperature control *(without visual control of the development).* In certain conditions, however, there may be a case for the use of a small automatic processor, but this requires a totally reliable mains connection and access to maintenance service.

A separate WHO publication deals with questions related to film processing.

8. TESTING AND FIELD TRIALS

Upon request, WHO is prepared to arrange for evaluation of prototype WHIS-RAD equipment and organization of field trials of such equipment in cooperation with the WHO Collaborating Centre for Radiological Education, Department of Radiology, Lund University Hospital, S-22185 Lund, Sweden.

Further technical information concerning these specifications may be obtained directly from Dr Thure Holm, Department of Radiology, Lund University Hospital.

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