ANNEX 8

USE AND SPECIFICATIONS OF THE WHO BASIC RADIOLOGY SYSTEM (BRS) AND THE WORLD HEALTH IMAGING SYSTEM FOR RADIOGRAPHY (WHIS-RAD)

For the past 20 years, WHO has been supporting the development. of the Basic Radiology System (BRS). This system provides good quality images, and is easy to use and maintain. Since 1993, the system has been further improved and called the (WHIS -RAD). The difference between the two systems is summarized at the end of this Annex by Dr Thure Holm, of the WHO Collaborating Centre for Radiological Education in Lund, Sweden.

Potential users of these X-ray units should be aware that there are low quality copies of such units on the market. Ask your potential suppliers to provide you with references from current users of their products, and enquire yourselves directly with the current users.

1. Introduction

The World Health Organization has developed a concept of diagnostic radiology that has been named the Basic Radiological System (BRS). The BRS is primarily intended to be used in communities currently deprived of radiodiagnostic services. Long practical experience has shown, however, that the BRS is equally applicable in industrialized countries. The BRS concept comprises X-ray equipment, as well as equipment for film processing and viewing of X-ray films, and manuals for radiographic technique, darkroom technique and film interpretation.

The BRS is aimed at providing:

(1) better radiographic coverage of the population in the entire world;

(2) an adequate radiographic system capable of performing at least 80% of all radiographic examinations required at university level;

(3) radiographic equipment which can be operated by personnel who have had shorter training than fully qualified medical radiology technicians (MRT);

(4) better radiodiagnostic facilities to physicians working in less accessible places of the health care system.

The attainment of these objectives will result in:

- better diagnosis and prognostication of disease;
- improved therapeutic decisions and consequent management of patient care;
- reduced cost to patient, community and government due to the shortened period of disability and bed occupancy, and the reduced need for patient transportation;

- lowered radiation dosage per examination.

The development of such a BRS requires an X-ray apparatus with the following major characteristics:

(i) Utilization restricted to general X-ray examinations not requiring fluoroscopy, tomography or serial film changers.

(ii) Simplified design and increased reliability permitting:

- operation by persons with less training than that of an MRT;
- operation under adverse climatic conditions;
- operation in places where no electrical power line is provided or where it is undependable due to frequent power cuts, wide fluctuations in voltage and frequency, etc.
- simplified procedures for faultfinding and repair in case of breakdowns, thus increasing the viability of the equipment as much as possible;
- operation at a reasonably low level of radiation exposure to patients and operating
- personnel, in compliance with international standards.

(iii) The cost of the X-ray equipment has to be reasonably low, so that large numbers of complete installations can be made available to national health authorities even in developing countries with limited resources.

2. Place of use

The BRS equipment with the characteristics described above is intended for use in:

(a) small rural hospitals covering the needs of rural populations;

(b) large health centres and polyclinics with many outpatients;

(c) larger hospitals (rural or urban), as additional equipment in the casualty department, thus sparing the more sophisticated and expensive X-ray equipment for special X-ray diagnostic procedures, fluoroscopy, etc. Another utilization will be in private medical practice, where such equipment will bring acceptable radiodiagnostic quality within reach of privately financed practices.

3. Examinations to be performed

This list of examinations to be performed by the BRS equipment should serve only as a guide.

The more common indications and examinations include:

Skeleton	:	fractures, bones and joint diseases
Head	:	trauma and infections
Chest	:	tuberculosis, pneumonia and other respiratory infections, heart enlargement, tumors, trauma

Abdomen : intestinal obstruction, calcifications, trauma and possibly intravenous urography, cholecystography, and problems in pregnancy

Soft issue : Foreign bodies, calcifications

Contrast medium examinations are only recommended when an experienced person is available, able to carry out and interpret such examinations and treat possible complications of contrast injections. Several of the above-mentioned examinations require special consideration of horizontal beam utilization on the recumbent patient.

4. Technical characteristics of the BRS apparatus

4.1 X-ray generator

The power output of the X-ray generator is critical for two of the examinations specified above:

(a) the chest, which requires a very short (<50 ms) radiographic exposure, and therefore a high power output for a very short time;

(b) lateral view of the lower lumbar spine, which requires a very large amount of radiation to penetrate a considerable thickness of tissue and thus high power for a longer time.

The output of the X-ray generator should be high enough to produce a minimum exposure of the 0.5 mR (within .10%) at a focus-film distance of .140 cm and a tube tension of 120 kV:

(a) behind a 12 cm water phantom in 50 ms or less, and

(b) behind a 30 cm water phantom in I second or less. The exposure conditions include the employment of a focused lead/aluminum grid with 40-50 lines per centimeter and a ration of 10: I and an irradiated field at the position of the cassette collimated to 400 square centimetres. The X-ray generator must also be capable of delivering a maximum total output of 25 kWs. (This may be produced by a converter generator with an output at the X-ray tube of 10-12 kW at 120 kV).

Recent developments indicate that in the future most X-ray generators with be using the converter principle. These generators use a DC source and convert the DC to AC with higher frequency than regular mains frequency (50/60 Hz). The higher frequency AC utilizes very small and often inexpensive components. The power source may consist of batteries or rectified low impedance AC mains.

Generators using batteries are to be preferred because the main supply will often be unreliable in the working locations to be expected. Preference is given to lead-acid batteries because of the experience from practical tests conducted by WHO working groups. For the same reason, preference is given to X-ray generators using AC frequencies above 2 kHz and automatic control of X-ray tube voltage (kv) at a present value, preventing voltage drop during exposure.

Generators directly connected to the mains have different requirements on the mains impedance for good performance. A mains-operated generator should be considered only when it could be shown that the mains impedance is consistently lower than 0.5 ohm.

4.2 Choice of exposure factors

The choice of exposure factors needs to be restricted to simplify the operation. If the "two-component" system (kV and mAs) is used, the number of available kV-values should be restricted to 4 fixed values: 55-70-90-120 kV + 2%.

The minimum range of mAs-values, usable in the entire kV -range, is 0.8-200 m As in 25 steps for converter generator. The increments between the steps should be 26%. If a single-dial technique is used, changing kV and mAs at the same time and approximately following an iso-watt curve, the number of steps must be increased to more than 30.

4.3 Control panel

This should indicate the state of the electricity supply (mains or battery) before exposure and the chosen values of kV and mAs or object thickness in centimetres of water.

The exposure switch should be mounted on the control panel, so that the operator must stand behind the protective screen during exposures.

The protective screen, large enough to protect a standing operator, should be available as an integral part of the control panel. The lead equivalent needed is 0.5 mm if the X-ray beam is never directed towards this screen. The screen must have a lead glass window not smaller than 30 x 30 cm, placed in a convenient position to give a good view of the patient.

4.4 X-ray and collimator

The X-ray tube should be able to handle at least 20 kW during 0.1 second and 10 kW during 1 second. The focal spot should be smaller than 1 mm. This requires a tube with rotating anode. The anode angle may be as small as 100.

The total permanent filtration in the useful beam shall be equivalent to not less than 2.5 mm A1 and not more than 3 mm A1.

The tube must be provided with an adequate collimator enabling restriction of the size of the beam to that of each of the film formats. A movable pointer or other reliable system for centering of the beam must be provided. The collimator design should enable its easy replacement by an adjustable light-beam collimator in countries whose regulations make these mandatory .The smallest format of the collimator may not be larger than 18 x 24 cm. The collimator design must also prevent any part of a patient from being closer to the radiation source than 30 cm.

4.5 Support for X-ray tube and cassette holder

It is necessary to have a design which will ensure that the X-ray tube is always 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 should be fixed at 140 cm. A stationary, focused lead/aluminium grid having 40-50 lines per centimetre and a ration of 10:1 must be incorporated in the cassette holder and must cover the full area of the largest film. The cassette holder must include a lead screen in the back wall with a minimum thickness of 0.5 m Pb. This requirement may obviate the need for further radiation protection of the walls of the examination room if the floor dimensions are 3 x 4.5 m or larger and no more than 2000 X-ray examinations are made per year.

The design of the examination stand must permit:

(a) the use of horizontal beam for examinations of recumbent patients;

(b) the use of the patient trolley as a "floating" table top in such a way that the longitudinal midline of the trolley can be offset at least + 12 cm from the midline of the cassette holder;

(c) the use of angulated beam + 300 from the vertical and horizontal beam directions;

(d) the use of horizontal beam in the range of 50-170 cm above the floor;

(e) the use of the cassette holder as a small horizontal examination table at a distance from the floor not less than 90 cm. The cassette holder, when used as a table top must permit a I load of at least 15 kg without misalignment of the focused grid or slipping of the brake for the vertical movement of the arm carriage;

(f) the design of the stand should also permit the use of horizontal boom in two opposite directions unless a "mirror image" version of the stand is available.

The film sizes to be used should be standardized and not more than four film sizes are recommended. The cassette holder must accept at least the following formats: 35.5 x 43 cm, 18 x 43 cm and 24 x 30 cm.

4.6 Patient support

The patient support should be rigid, with an X-ray permeable top, approximately 2.0 x 0.65 m in size and approximately 0.7 m from the ground. It must be able to support a weight of 110 kg without appreciable distortion, should be easy to keep clean, impervious to fluids and resistant to scratching. The design of the trolley must permit positioning of the cassette holder in such away that when the vertical beam is used the distance between table and film plane must not exceed 8 cm. The distance between the front wall of the cassette holder and the film plane should be not more than 2.5 cm. When the beam is angulated + 300 from the vertical direction, the distance between the tabletop and the film plane should not exceed 25 cm in the central beam. The wheels must be of a size to permit easy movement of the trolley with all 0 kg patient, and the locking mechanism should preferably be central and immobilize at least one wheel at either end.

5. Selection and Use

5.1 Choice of power supply

In many rural areas and some towns and cities, the main electrical supply is unreliable, both in continuity and voltage control. Marked variation in line voltage can severely damage X-ray equipment. Where variation is known to occur, an additional line voltage regulator should be installed to protect the X-ray generator. If the power line is weak or unreliable, it can be replaced by a power storage system. The simplest and most reliable is a set of lead-acid batteries (96-120 V, 25-60 Ah); it is also possible to use a large capacitor on the primary side of the high-voltage transformer, provided it meets the energy requirements (12-25 kWs) given above under 2 (ii).

Battery-powered generators have several advantages for small hospitals:

- it is very easy to reach a power output of about 15 kW and an energy output of 30 kWs within 2-3 s.
- Work can continue for 1-3 weeks without recharging the batteries (depending on their size).
- Batteries are not affected by variations in voltage or frequency.
- Batteries can be recharged by solar power or by an intermittent power source such as a weak or otherwise unreliable power line or a small independent petrol- or kerosene-powered electricity generator.

Sealed and maintenance-free lead-acid batteries are the best to use with an X-ray generator. They tolerate well the near-short-circuiting which occurs during an X-ray exposure. They may last for more than five years and require practically no maintenance.

The alternative, nickel-cadmium batteries, require sophisticated maintenance and recycling once or twice a year. This cannot be done at the hospital. Nickel-cadmium batteries are not recommended.

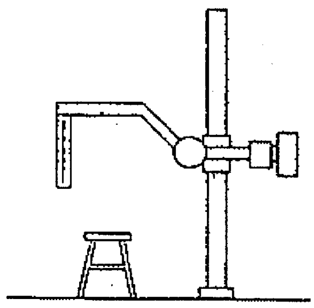
X-ray generators with a large capacitor for power storage are a very attractive alternative, if the following conditions are fulfilled:

- The capacitor is connected on the primary side of the high-voltage transformer.
- The X-ray tube voltage is maintained constant and the tube current is falling during the exposure.
- A reliable low-power source (0.8-1.2 kW) is available.
- The X-ray exposure does not require more energy than 10-12 kWs.

A capacitor discharge X-ray generator that fulfils the above requirements may be connected to any household wall-outlet of 220-250 V. It is the best choice for a chest X-ray unit.

5.2 Choice of X-ray tube support and patient support

The X-ray is supported on a column with a tube-arm. The WHO-BRS design (Fig. 108) stipulates a single floor-column with a rotating arm that supports the X-ray tube and the cassette holder. This model requires minimal attachment to the wall and is easy and quick to install. No separate chest stand is needed. The patient support is a mobile trolley, which can also be used to fetch patients from the ward or emergency area. There is no weight on the ceiling.



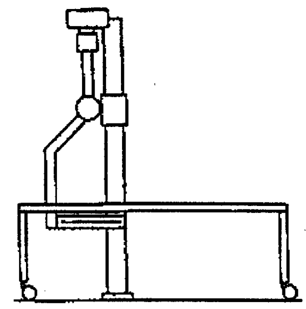


Fig. 108a. BRS unit with horizontal X-ray beam

Fig. 108b. BRS unit with vertical X-ray beam and patient trolley

The alternative is a tube-column which runs on floor rails (Fig. 109) and also has a ceiling track. The two sets of rails must be exactly parallel, and the intervening distance must not vary. This requires a level floor and a strong ceiling. The X-ray table is fixed, and an additional, separate chest-cassette holder is required. Tube-columns are available that run on two floor rails, without ceiling support (Fig. 110); these are unstable and are not recommended.

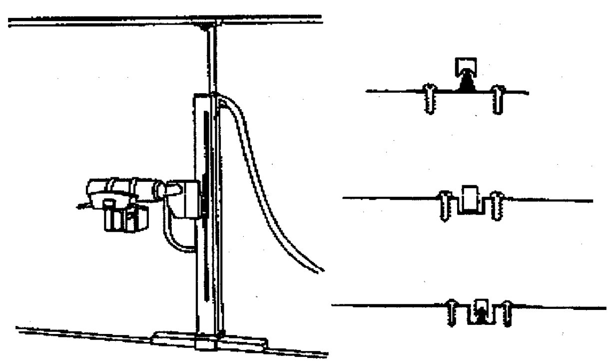


Fig. 109. Column X-ray tube support mounted on floor rails with a ceiling rail: three possible types of rail

The WHO-BRS tube and patient supports are strongly recommended. This design has been well tested in rural hospitals, is very easy to use and, with the WHO-BRS Manual of Radiographic Technique; can be used to provide all the X-ray examinations required in hospitals where there is no specialist radiologist (and will even be satisfactory when there are fully trained radiological staff).

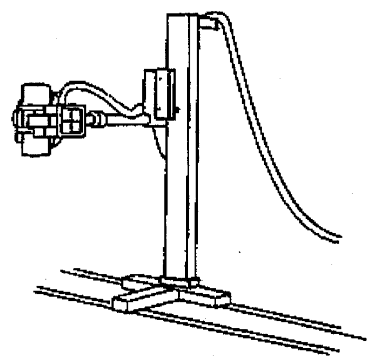


Fig. 110. Column X-ray tube support mounted on floor rails

5.3 Secondary radiation grids

When X-rays pass through a part of the body, some are scattered within the tissues. This reduces the contrast in the radiographic image. A so-called "grid", interposed between the patient and the film cassette, will greatly reduce the amount of scattered rays that reaches the film (Fig. 111). A grid appears as a 2-3 mm thick, flat plate and contains very thin strips of lead (about 0.05 mm wide and 2 mm high), supported by interleafing strips of an X-ray-translucent material (about 0.2 mm wide and 2 mm high), arranged as a venetian blind.

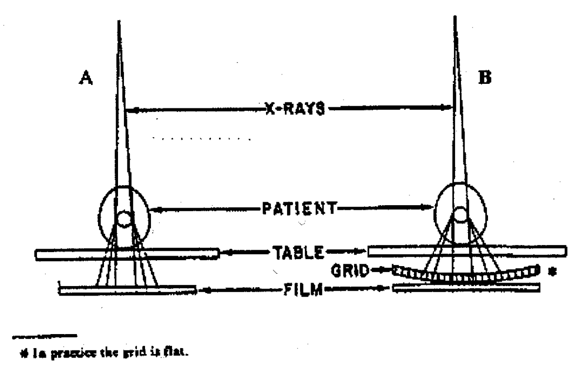


Fig. 111. Scattering of radiation: A, without a grid; B, with a grid

The grid lines will be visible on the film if it is viewed at a very short distance (<30 cm) or if the grid is not correctly focused. The lead strips of focused grids are arranged in such a way that each line is imaged practically without magnification, permitting nearly 80% of the direct radiation to pass through. A focused grid must be used, however, at only one distance from the X-ray tube. If this cannot be done, or if the grid lines are wider than 0.05 mm. the grid can be moved (oscillated) during the exposure to blur the image of the lead strips. Such a moving grid is called a "bucky". Bucky mechanisms are complex mechanical devices and are also expensive.

If different focus-film distances are used in radiography, different grids must be used in different imaging geometrics. Grids are expensive items. WHO recommends the use of a single standard focus-film distance, which permits the use of a single focused, high-quality grid for all examinations.

5.4 X-ray films and screens

X-ray films, which have photographic emulsion on both sides, are placed between two fluorescent "screens" inside a light-proof cassette. When X-rays pass through the patient and the cassette, the screens give off light, which exposes the film emulsions, recording an image. Screens vary in their response to X-rays and their capacity to reproduce details of the image.

X-ray-intensifying screens are currently rated in four main groups by the manufacturers (Table 13). Unfortunately, there is no clearly defined nomenclature, and the "fast" screens from one manufacturer may be similar to the "medium" screens from another.

Table 1.3. Main groups of X-ray intensifying screens

Group	Resolution (lines/mm)	Relative speed Blue/UV systems	Green systems
Fine/detail	8-12	80-125	80-125
Medium/universal	6-8	100-200	200-250
Regular	4-6	160-250	320-400
Fast	3-4	200-500	500-800

Intensifying screens emit ultra-violet/blue or green light. They must be used in combination with film that has the appropriate colour sensitivity. Use of a blue-sensitive film with green-emitting screens, or the reverse, results in a loss of speed of about 50% and must be avoided.

Green-emitting screens are considerably more expensive than most blue/ultra-violet-emitting screens, but they in general reduce the patient dose by a factor of 2 or more, for the same quality of image. Green systems are also much less likely to show "film graininess". This effect almost always depends on quantum noise and frequently appears in blue systems when the speed exceeds 250 and in green systems when the speed is over 500. Green-sensitive (orthochromatic) film has a longer shelf-life (is less sensitive to ageing); however, it is not yet generally available and may be more expensive in some markets.

Note: Never mix cassettes or film for blue and green systems.

Provided the X-ray generator meets WHO requirements for a BRS generator (converter generator with minimum 11 kW, 25 kWs), a "medium" speed of about 200 is the safest choice because such screens and films are universally available.

Note: The traditionally used amber-coloured filters for blue-sensitive X-ray film cannot be used with green-sensitive film. Green-sensitive film requires a filter of a rather dark ruby-red colour.

To ensure a constant supply of X-ray processing chemicals, it is advisable, but not essential, to buy film and chemicals from the same supplier. Most chemicals can be used to process any make of film. Note that three essentially different types of developer are available. One is used for large automatic processors at high temperature and needs special "starter" and "replenisher" solutions. Another is used for automatic processors with low capacity and small tanks at high temperature and does not require "starter" and "replenisher". The third type is used for manual processing at 20-25°C and is less aggressive; no "starter" or "replenisher" is used.

5.5 Processing X-ray films

After exposure, X-ray films are taken in the cassette to the darkroom, where they are removed for processing, which can be done manually or automatically.

(i) All automatic processors require a constant electrical supply and can be used only with good-quality X-ray film. Small, "table-top" processors are reliable, easy to install and provide well-processed, dry X-ray films within 3-4 min. If more than 15-20 patients are X-rayed every day, an automatic processor is desirable; if the electrical supply is unreliable, however, back-up manual processing is essential.

(ii) Manual processing tanks should be made of high-quality, chemical-resistant stainless- steel. Plastic tanks are cheaper but will warp, crack and leak (although manufacturers claim otherwise). Specifications are given in paragraph 6. Most metals, including regular stainless-steel, are rapidly destroyed by X-ray chemicals.

Both manual and automatic film processors must be connected to running water, preferably both hot and cold. There must also be adequate drainage: plastic, porcelain or other chemical-resistant pipes are essential, as the water running off contains chemicals (Fig. 112).

5.6 Safe lights and other darkroom accessories

Details are given in paragraph 6. The following information is also important:

(i) X-ray chemicals cannot be mixed in the darkroom, as good ventilation (e.g., open air) is required during mixing. Designated buckets for developers and fixer are essential equipment.

(ii) Do not install a film-viewing box in the darkroom, as it will interrupt and delay processing. Provide a carrying tray to catch the wet drips if films are processed manually, and carry the films to a viewing box in the office (not in the X-ray room).

(iii) The switch that controls the filtered safe light should be located immediately inside the entrance door at the regular height for light switches used in other rooms. The switch for the white ceiling light should be placed above the safe-light switch but at a somewhat "inconvenient" height above the floor: 180 cm is recommended. This arrangement averts the possibility that the white light will be turned on by mistake, which would fog or completely destroy the X-ray films.

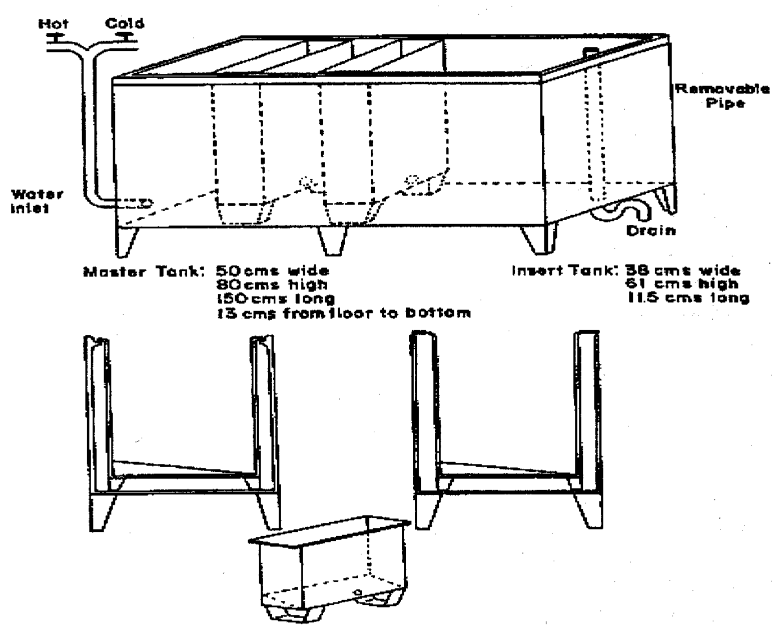


Fig. 112. Processing tank

(iv) The normal entrance to the darkroom, through a maze, a light trap or a narrow, light-tight door, cannot be used for bringing in processing tanks and other large pieces of furniture. A door wide enough for this purpose must be available. This door must be closed or boarded over to be made light proof when the darkroom is used.

(v) Adequate light proof ventilation is essential in the darkroom (Fig. 113), and the floor must be chemical proof. Ordinary wooden floors are not satisfactory; concrete or tiles are preferable.

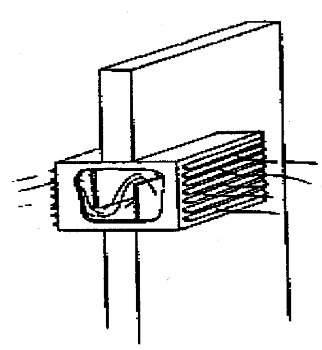


Fig. 113. Lightproof darkroom ventilator

5.7 Radiation protection and safety

Ionizing radiation, such as X-rays, is harmful to human (and animal) tissues. All people who work with X-ray equipment must constantly be aware of the danger. A regular radiation monitoring service for personnel should be established.

Lead-protective clothing must be provided and worn when appropriate. X-ray personnel should never hold or support patients during examination. All protective clothing must be checked regularly and the results documented.

Detailed information regarding radiation protection and personnel monitoring is given in the *WHO Manual on Radiation Protection in Hospitals and General Practice* (Volume 1, *Basic Protection Requirements;* Volume 3, *X-ray Diagnosis;* and Volume 5, *Personnel Monitoring Services).*

Building specifications are described in Annex 6.

6. Installation

Location of the X-ray unit

The location of the X-ray unit must be chosen primarily for ease of access for all patients. With the BRS, radiation protection is not a critical factor in the choice of location.

The majority of patients will be ambulatory outpatients but some patients will arrive on trolleys or in wheelchairs. The X-ray unit should be located close to the hospital entrance, preferably on the first floor. There must be no steps, thresholds or other obstacles which would impede trolleys and wheelchairs.

Space required for the X-ray department

A minimum of three rooms are required examination room (X-ray room), darkroom and office/viewing room. Some additional storage space must also be available and a special film file is required if the processed X-ray films are to be filed within the X-ray department.

The X-ray room must be at least 12 m^2, not including the control area, where the operator is standing during the exposures. The minimum work area for a BRS stand is 2.9 x 4.2 m. See Fig. 114a.

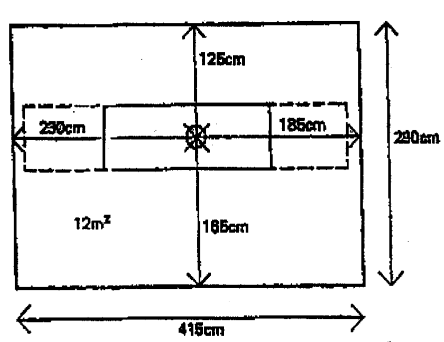


Fig. 114a. BRS examination room

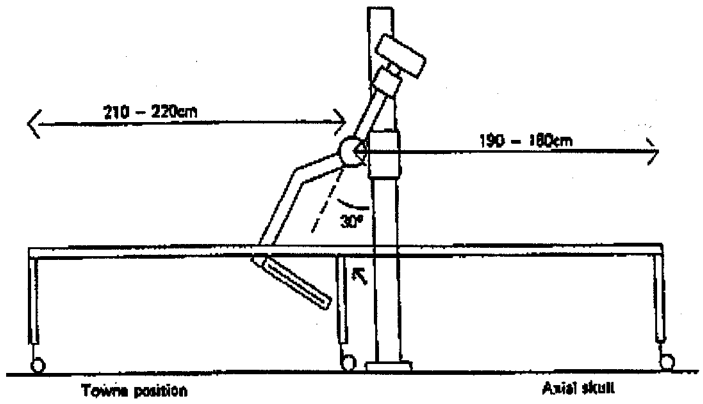


Fig. 114b. Working range of BRS stand

The control of the X-ray generator may be located behind a lead screen inside the X-ray room. A better solution is to have the control in a small separate space outside the examination room. The total area of the examination room including the control should be at least 18 m^2.

The amount of radiation absorption needed in the room walls depends upon the size of the room and the number of examinations per year. If the walls are made of concrete or clay-bricks with an effective thickness of 5 cm, the following conditions are valid for a maximum of 5 mSv (0.5 rem) per year outside the room:

Room size	Distance to nearest wall from vertical central beam	Ceiling height*	Max. number of exams/year
3 x 4 m	1.5 m	2.5 m	2 000
4 x 5 m	1.8 m	2.8 m	3 000
4.6 x 5 m	2.1 m	3.0 m	4000

*if floor above is occupied

The *darkroom* should be at least 5 m^2 for manual processing. No dimension of the room should be smaller than 2 m. If an automatic processor is used and the room is not continuously manned, the room may be as small as 1.5 x 2m.

The *office/viewing room* should at least be 8 m^2. If a film file is maintained in the office, the room must be considerably larger with dimensions depending upon the anticipated size of the film archive. Also if the room is to be used for film-viewing in groups, the room must be larger.

Storage space is required for chemicals, unexposed X-ray film, linen, film envelopes, etc. Unused chemicals may be stored in the darkroom. Unused X-ray film must be stored standing in the original light-tight boxes away from heat, humidity and radiation.

Relationship between the rooms

Several complete floor plans for small BRS departments are shown in figures 115a-115c. The larger ones contain storage and utility rooms and a small area for waiting. It is important that the darkroom is close to the control area of the examination room. It is also vital that the darkroom is not too close to the radiation source.

Design of the X -ray room

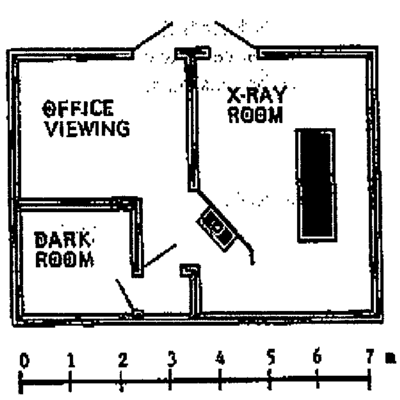
Unless the X-ray room is very small or the number of examinations is very large, it is unlikely that special arrangements will be necessary for radiation protection. Walls made of wood or fibre-board are not suitable, however. Brick, concrete or gypsum plate are usually satisfactory. The walls should have a protection capability equivalent to that of 0.25 mm of lead or more and the distances mentioned in the table above should be observed. A shorter distance may be compensated for by an increase in the lead equivalence but more than 0.5 mm of lead is never needed with the BRS unit.

If the X-ray room has windows, no part of the window may be less than 2 m from the outside ground.

The X-ray room floor must be strong to support the weight of the stand column and the X-ray generator. The weight of the stand column will be in the range of 250-500 kg and the support area may be very small (about 400 cm^2). The X-ray generator has a wider base and may weigh as much as 350 kg if it contains lead/acid batteries.

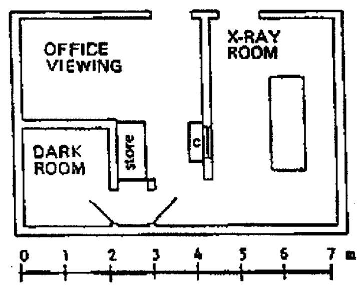
It is essential that the floor is completely level because patient trolleys will have to move over it. It should be waterproof, washable, and free of dust. The best construction material is concrete covered with vinyl.

The ceiling height should be at least 2.5 m. The ceiling will not be required to support any weight.



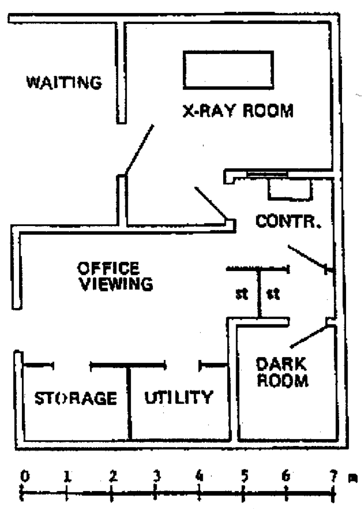
Radiography	16 m^2
Darkroom	5 m^2
Office/viewing	8.5 m^2
total net area	29.5 m^2
gross area	35 m^2

Fig. 115a. Minimum BRS department



Radiography	13m²
Control	2.5m²
Darkroom	5m²
Office/viewing	9m²
total net area	29.5m²
gross area	35m²

Fig. 115b. Minimum BRS department 2



Radiography	19m²
Control	4.5m²
Darkroom	7m²
Office/viewing	13m²
Storage	4.5m²
Utility	4m²
Waiting	10m²
total net area	62m²
gross area	70m²

supporting walls = double lines
screen walls = single lines

Fig. 115c. Small BRS department

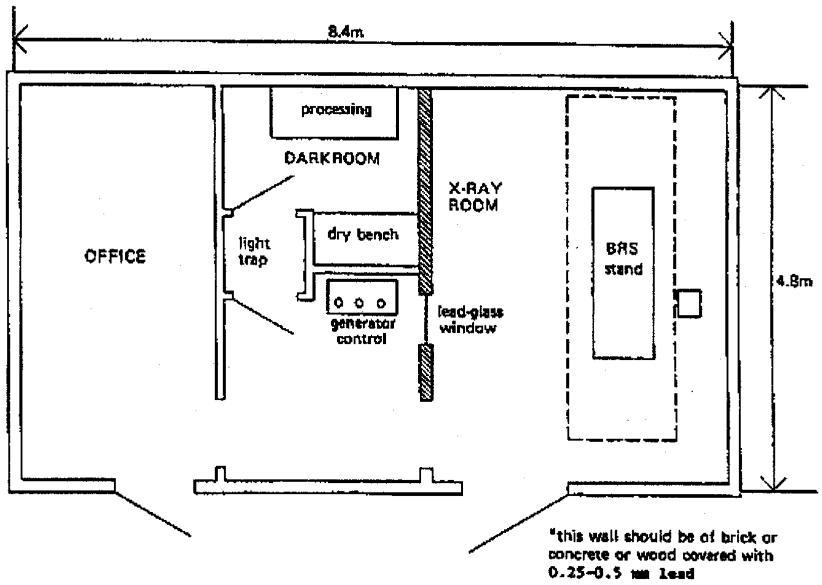


Fig. 116. Small X-ray department showing working area for BRS stand

The walls should be painted with washable semi-gloss paint in a very light (pastel) colour or be almost white (cream). The ceiling should be white. It is preferable to use subdued indirect light when supine patients are examined. Separate fluorescent light sources should be available in the ceiling for cleaning and service needs.

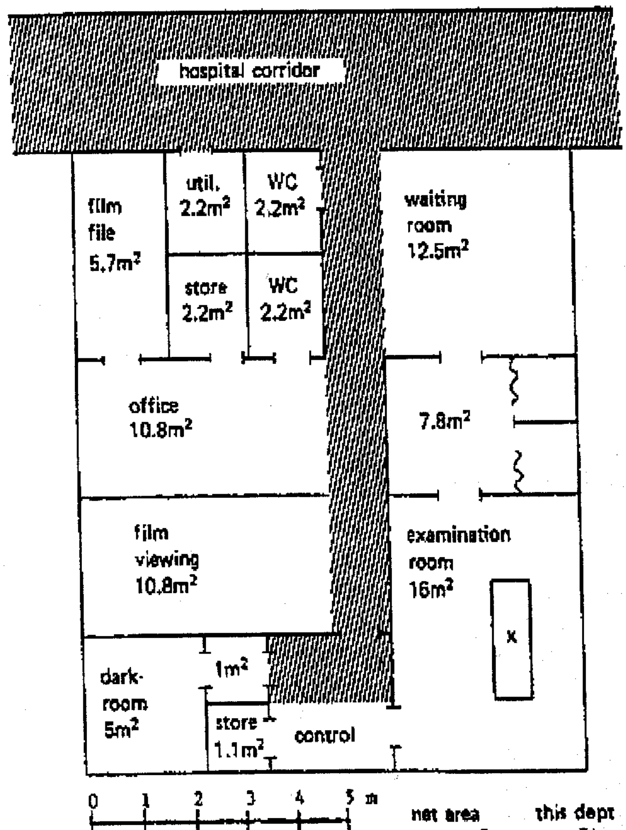
The door between patient corridor and examination room must be wide enough to admit a bed-usually 110-120 cm. There should be no step or threshold. It is preferable to use a steel door but if the distance to the radiation source is long (more than 3 m) or the patient load is small (less than 10 examinations per day), a wooden door may suffice. It must be possible to lock the door from the inside.

If the X-ray room is large enough (18 m^2 or more), the X-ray generator may be located behind a panel inside the room. The panel must permit full protection of the operator and of cassettes with unexposed film and should contain at least 0.5 mm lead or the equivalent thickness of bricks (Fig. 116). It is often more convenient to have a separate small room for the generator control. The design of this room must prevent primary or secondary radiation from reaching the BRS operator or the X-ray cassettes even if the opening between the examination room and the control room does not have a door.

Design of darkroom

The important factors in the design of the darkroom are the size of processing equipment and the need to work in almost total darkness with only safe-light illumination. There must be separation of a wet area and a dry area.

The darkroom must be entirely lightproof, however bright the outside sunlight. Light-tightness of door, window and ventilation ducts must be tested carefully. No light leak from outside may be visible to someone who has spent 10 min inside the room in total darkness.



		net area range (m^2)	this dept (m^2)
Patient area	Waiting room	10 - 20	12.5
	Dressing cubicles	2 - 4	7.8
	Space for trolley	2 - 4	
	Patient toilet	2 - 3	2.2
Examination room (incl. control)		16 - 20	18.5
Personnel area	Darkroom	6 - 8	6.0
	Viewing room	8 - 12	10.8
	Office	8 - 12	10.8
	Film file	5 - 10	5.7
	Storage and supply	2 - 4	3.3
	Utility	2 - 4	2.2
	Personnel toilet	2 - 3	2.2
	Total net area	65 - 104	82.0m^2

Fig. 117. Floor plan for primary care radiography 4000 or more examinations per year

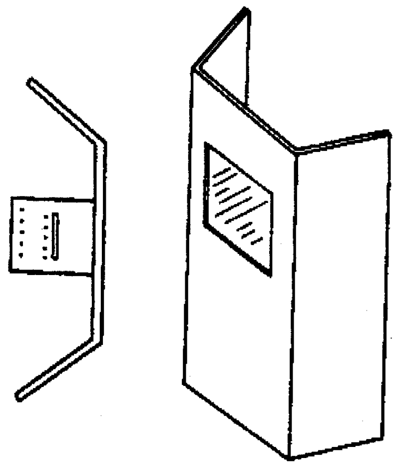


Fig. 118. Control protective screen and control panel

The entrance to the darkroom should be close to the X-ray generator control but it need not be directly from the X-ray room. If the workload is small (one examination per hour or less), and floor space is a problem, it may be sufficient to use a simple light-tight door.

The darkroom floor should be waterproof, level and washable. A floor drain is very useful. Ceiling and walls should be painted with a semi-gloss chrome-yellow colour with no white pigment added. A pure chrome-yellow paint does not reflect any blue light which might expose the X-ray film. Also, the walls should be washable.

Three separate light sources are needed in the darkroom.

(1) General white light: a 4-watt incandescent bulb in the ceiling (a fluorescent tube gives afterglow and is not acceptable)

(2) Indirect filtered light: a 25-40 watt incandescent Indirect filtered light filtered light in a reflector directed upward towards the ceiling (Fig. 119a)

(3) Direct filtered light: a 15-watt incandescent filtered light in reflector directed downwards towards surface of the dry-bench. Distance between bulb and table surface, 120 cm. The reflector must have the words "MAX 15 WATT" written in large letters on the outside 3 (Fig. 119b).

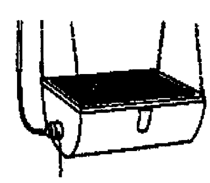


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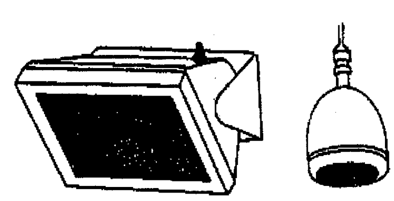
Fig. 119a. Indirect filtered light



2 3

Fig. 119b. Direct filtered light

All light sources must have separate switches located so that confusion is impossible.

The darkroom must have a dry side with a dry-bench for unloading and loading of cassettes and a wet side with processing tanks. Separation of wet side and dry side becomes unnecessary if an automatic processor is used. The darkroom must also have a regular sink, preferably of stainless-steel.

The minimum equipment for film processing is a 26-litre developing tank, a fixing tank of the same size or 50% larger and a rinsing tank which can handle at least the expected film production from one hour of work: usually 15 cm or more in length.

Design of office/viewing room

Several different activities will go on in the office and will affect the design of the room:

1. reception and dismissal of patients;
2. keeping of records;
3. drying of X-ray films;
4. viewing of X-ray film, sometimes by several people;
5. filing of X-ray films and reports in envelopes.

The room must have viewing boxes with fluorescent light for viewing of several films at the same time. A minimum is one viewing box with alight area of 43 x 72 cm for wet films (with a drip tray) and one with a minimum light area of 43 x 100 cm for dry films.

The room should also contain a drying rack or drying cabinet for film, a regular office desk with room for typewriter, telephone, etc., and shelves for film and records.

Storage

Storage space should be provided for unexposed X-ray film, processing chemicals, envelopes, office supply, linen, etc.

Electrical supply

If the generator is dependent on a mains connection, the manufacturer of the X-ray generator will specify the power requirements. Some generators may require as much as 150 A for up to 3 seconds from a 220 V source with a small impedance (0.5 ohm or less). In this case a 50 slow fuse usually will suffice, however. Generators using batteries or large capacitors may operate from standard grounded 220 V outlet and do not require more than 3 A during operation.

If an automatic processor is used, its power consumption may be as much as 5 kW for short periods.

The electrical supply for room lighting and viewing boxes can be standard grounded wall outlets for 220 V, 10 A.

For further information, specific questions may be sent to:

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St. Lars Roentgen
Lund University Clinics
S-220 06 Lund, Sweden (Tel: 046-16 45 09)

7. Summary of differences between WHO-BRS/85 and WHIS-RAD/

This summary is following the layout of WHO document WHO/RAD/TS/95.1: "Technical specifications for the World Health Imaging System for Radiography"

WHO-BRS 1985	WHIS-RAD 1995	Comments
Mains supply An x-ray generator directly connected to the mains supply should be considered only when the impedance is lower than 0.5 ohm. (Assuming a 230 V AC source; the amperage needed is not mentioned.	**Mains supply** Assuming the use of energy storage (23-39 kWs available per exposure), a supply mains for 2.3 kW (230 V/10 A or 115 v/20 A) is sufficient. The value of the mains impedance becomes un-critical.	Generators without energy storage, operating directly from the mains, are not recommended, unless a 3-phase, 380 - 400 V, <0.3Ω (ohm) power line is available. Peak power loads of 23 - 30 kW for 0.1 s and energy loads of 23 - 30 kWs are to be expected.
X-ray generator Multipulse generators using inverter technology and energy storage in lead/acid batteries are recommended.	**X-ray generator** Multipulse generators using inverter technology and energy storage are required. Lead/-acid batteries are preferred.	Multipulse generators are now generally available. Maintenance-free, sealed lead/acid batteries (≥ 2 kWh) have an expected lifetime of 5-8 years and are the best energy source. The wider selection of kV-values is an important improvement, making it easier to programme the mAs-values and easier to work clinically.
Available kV-values: 55 - 70 - 90 - 120 kV (+ / - 2%).	Available kV-values: 46 - 53 - 60 - 70 - 90 - (100)-120 kV (+ / - 2%), 100 kV for testing purposes only.	
Tube current values: Not mentioned, but at least 100 mA is needed to reach the specified electrical power rating.	Tube current values: The tube current shall be or exceed 100 mA.	Unless "falling load" is used, fixed tube current values of 100, 125, 160, 200 and 250 mA are required to reach the shortest possible exposure times at different tube loads.
Time-current product: Minimum range 0.8 - 200 mAs (in 26% increments).	Time-current product: Required range: 0.5 - 250 mAs (in 26% increments).	Extension of the mAs-range upto 250 mAs is often important. Values <0.8 mAs are seldom needed.
The exposure time range is not specified.	Exposure time range: 0.005 - 2.5 s	Exposure times <5 ms are difficult to reach with linear µGy/mAs response, times > 2.5 s are unacceptable.
Electric power rating: minimum 11 kW at 90 kV.	Electric power rating: minimum 12 kW at 100 kV.	Comparison of power ratings: 125 mA at 90 kV = 11.25 kW and 125 mA at 100 kV = 12.5 kW
Electric energy rating: minimum 25 kWs.	Electric energy rating: 23-30 kWs at 90 kV.	NOTE: Use of green-emitting screens and green-sensitive x-ray film with nominal speed >400 may compensate for an energy rating below 23 kWs.
Linearity and reproducibility are not mentioned	Linearity (µGy/mAs) and reproducibility are expected to be close to + / - 2% in the entire mAs range	Linearity and reproducibility of multipulse generators are very much better than required by IEC for 50/60 Hz generators.

X-ray tube (rated at 125 kV) Focal spot: 1 mm or less. Anode angle: >10. Nominal power rating: 20 kW (at 0.1 s) Long time power rating: 10 kW at a loading time of 2 s (= 20 kWs). [10 kW for 1 s= 10 kWs is incorrect!]	**X-ray tube** (rated at 125 kV) Focal spot: 0.8 - 1mm Anode angle: 12 - 15° Nominal power rating: 23 -030 kW (at 0.1 s) Long time power rating: 12 - 15 kW at 2 s (=24 - 30 kWs) = energy rating).	A 0.8 mm focus is available with a power rating of 23 - 30 kW. A power rating f 30 kW and an energy rating of 30 kWs are required when the "reference man" is 78 kg/178 cm. (It is possible to use 20 kW/24 kWs x-ray tubes in many parts of the world, e.g. South East Asia.)

WHO-BRS 1985	WHIS-RAD 1995	Comments
Expected lifetime not mentioned	Expected lifetime (loss in efficiency around 20%): at least 50 000 exposures at normal distribution of examinations.	"Normal examination distribution" = 35-40% chest, 30-42% extremities, 10-15% spine and pelvis, 3-4% head and neck, and 8-10% abdomen.
Total tube filtration: 2.5 - 3 mm Al.	Total tube filtration: 3 - 4 mm Al.	Increased filtration saves dose without increasing the tube load.
Collimator (to limit the irradiated area): minimum requirement: fixed formats 18x24, 24x30, 18x43 and 35x43 cm in longitudinal direction plus a mechanical backpointer to indicate the central beam. A variable light-beam collimator is available as an option.	**Collimator** (for selection of irradiated area): A standard, multi-level, light beam collimator, which can give any format up to 43x 43 cm, and has reliable format indicators for 12, 18, 24, 35 and 43 cm for a focus film distance of 140 cm. No backpointer.	The possibility of a free selection of correctly centered film sizes and formats is an important improvement. The first level of the collimator must be a square diaphragm (beam stop), limiting the irradiated field to 43x43 cm at the film position.
Examination stand with cassette holder for use with horizontal, vertical and angulated x-ray beam. Trolley on wheels. Cassette formats: min. 24x30, 18x43 and 35x43 cm in longitudinal direction.	Same BRS examination stand and trolley on wheels (12 - 15 cm diam.) but with a cassette holder for free choice of film formats:) Minimum 18x24, 24x30, 18x43 (or 20x40), and 35x43 (and/or 35x35) cm.	The examination stand has a new cassette holder with free choice of cassette formats, which is an important improvement. Any format can be used, longitudinally and transversally.
Swivel arm angulation: + / -30° from vertical and horizontal beam directions with retained balance.	Swivel arm angulation: Same as for BRS, but added optional possibilities to create horizontal and vertical x-ray beams, NOT directed towards the cassette holder.	The added optional angulation possibilities make the stand usable in emergency rooms for immobile patients, arriving at the x-ray department in bed or on a stretcher.
Impossible to angulate the cassette holder separately.	Lead shield in the cassette holder back wall: 0.8 mm thick, covering a minimum area of 49x49 cm.	NOTE: This emergency use (for qualified radiographers only) takes away-the radiation protection by the lead screen in the back wall of the cassette holder.
Lead shield in the back wall of the casstte holder: 0.5 mm pB, outer dimensions not specified.		

CHOICE OF RADIATION QUALITIES

WHO-BRS 1985			WHIS-RAD 1995			Comments
KV	grid	examined body parts	KV	grid	examined body parts	
53	no	extremities	46	no	extremities 1-7 cm thick	
70	yes	skeleton, abdomen, iodine contrast	53	no	extremities 7-12 cm thick	
90	yes	skeleton, abdomen, child chest	60	+/-	testing and special use	
120	yes	adult chest	70	yes	skeleton, skull, abdomen	very dens
			80	yes	spine, IVP, paranasal sinuses	obj.: + 10 kV
			90	yes	lateral lower spine, child chest	
			100	+/-	for testing purposes only	
			120	yes	chest, (GI with barium contrast)	

This comparison was prepared in October 1997 (replacing the earlier one by Dr Thurne Holm, Consultant Radiologist at the WHO Collaborating Centre for Radiological Education, University Hospital, Lund, Sweden, Fax: +46-46-211-6411.