
ANNEX 1

The WHO Basic Radiological System (WHO-BRS)

Scope

The rugged, high-quality X-ray equipment specified for the WHO Basic Radiological System (BRS) is ideally suited for small clinics, health stations, first-referral hospitals, and general practices under the supervision of a general practitioner. In these situations, the population served is often in the range 10 000–100 000. At this level, no fluoroscopy should be undertaken.

Clinical indications for radiographic examination with the WHO-BRS (partial list)

Skeleton: fractures, bone and joint infections.

Chest: Suspected tuberculosis, pneumonia and other respiratory infections, cardiac enlargement, tumours.

Abdomen: intestinal obstruction, calculi or other indications for intravenous urography or oral cholecystography.

Soft tissue: foreign bodies, calcification.

Intravenous contrast media examinations are only recommended when an experienced physician is available, and able to carry out and interpret such examinations.

The X-ray equipment and accessories

Specifications for the X-ray machine

The current WHO specifications for the BRS X-ray unit, with accessories, are summarized below. The complete specifications are given in a WHO unpublished document.¹

The BRS X-ray equipment consists of a high-quality X-ray generator and an X-ray tube, together with a high-quality focused grid, and a unique tube stand, all of which are linked together in a sophisticated manner to produce an optimum X-ray system.

- The output of the generator must be sufficient to produce (a) a minimum exposure of 0.5 mR (5 μ Gy) in 1 second or less, at a focus–film distance of 140 cm, behind a water phantom of 30 cm thickness; and (b) 0.5 mR (5 μ Gy) in less than 50 ms at 140 cm behind a water phantom of 12 cm thickness.
- There should be a rotating anode X-ray tube, with a focal spot of less than 1 mm, capable of handling 20 kW during 0.1 s.
- The total permanent filtration of the tube must be equivalent to at least 2.5 mm of aluminium.
- The control panel should indicate the status of the electricity supply and the chosen values of kV and mAs, or anatomical thickness. Only four kV values are required: 120, 90, 70, and 55 kV. The minimum range of mAs values, all of which must be usable in the entire kV range, is 0.8–200 in 25 steps.

¹ *Technical specifications for the X-ray apparatus to be used in a basic radiological system.* Geneva, World Health Organization. 1985 (unpublished document RAD/85.1; available on request from Radiation Medicine. World Health Organization, 1211 Geneva 27, Switzerland).

- The design must ensure that the tube is always connected to the cassette holder in a rigid and stable manner, providing precise centring of the X-ray beam. A fixed focus–film distance of 140 cm must be used.
- A stationary, focused lead/aluminium grid with 40–50 lines per cm and a ratio of 10 : 1 must be incorporated.
- The tube must be provided with a collimator that allows restriction of the X-ray beam to the sizes of the films used (see below).
- The film sizes should be standardized, and not more than 4 sizes of film should be used. The cassette holder must accept at least the following three formats: 35.5 × 43 cm, 18 × 43 cm, and 24 × 30 cm. The addition of 18 × 24 cm is desirable.
- A movable pointer or other reliable system of centring the beam must be provided.
- The patient support must be rigid, with an X-ray permeable top, and it must be able to support a weight of 110 kg without appreciable distortion.
- Darkroom equipment must be provided with the X-ray equipment.
- A standard range of patient protection devices must be provided with the X-ray machine.
- The back wall of the cassette holder must incorporate a lead shield of at least 0.5 mm thickness.
- At least one protective apron and 1 pair of protective gloves, with lead equivalence of at least 0.25 mm must be provided.
- A protective screen, large enough to shield a standing operator, must be an integral part of the control panel, unless there is a similar permanent shield with equivalent radiation protection. The lead equivalence must be at least 0.5 mm. A leaded-glass window, no smaller than 30 × 30 cm, must be incorporated in the screen.

X-ray generator

The X-ray generator should use the frequency-converter principle. These generators convert a direct current (DC) source to alternating current (AC) at a higher frequency than the regular mains frequency (50–60 Hz). The higher frequency AC uses very small and often inexpensive components. The power source may consist of batteries or rectified AC mains.

Generators using batteries are preferred, as in many locations the mains supply is unreliable. Preference is given to lead–acid batteries, because the maintenance of nickel–cadmium batteries requires particular knowledge and skills, as well as expensive equipment (see page 144).

The exposure switch must be an integral part of the control panel, so that the operator must stand behind the protective screen during exposures.

X-ray tube and collimator

A movable mechanical pointer or other reliable system for centring the beam must be provided. The collimator design must prevent any part of a patient from being less than 30 cm from the X-ray tube focus. It should be designed so that it can easily be replaced by an adjustable light-beam collimator in countries where regulations make these mandatory.

Tube stand

A fixed focus–film distance, without angulation of the tube and the cassette holder, ensures the accurate direction of the primary beam so that the exposure of the patient and the staff is reduced.

Examination table

The examination table (patient support) should be easy to keep clean, impervious to fluids and resistant to scratching. There must be easily operated and reliable brakes on all wheels. The wheels must be large.

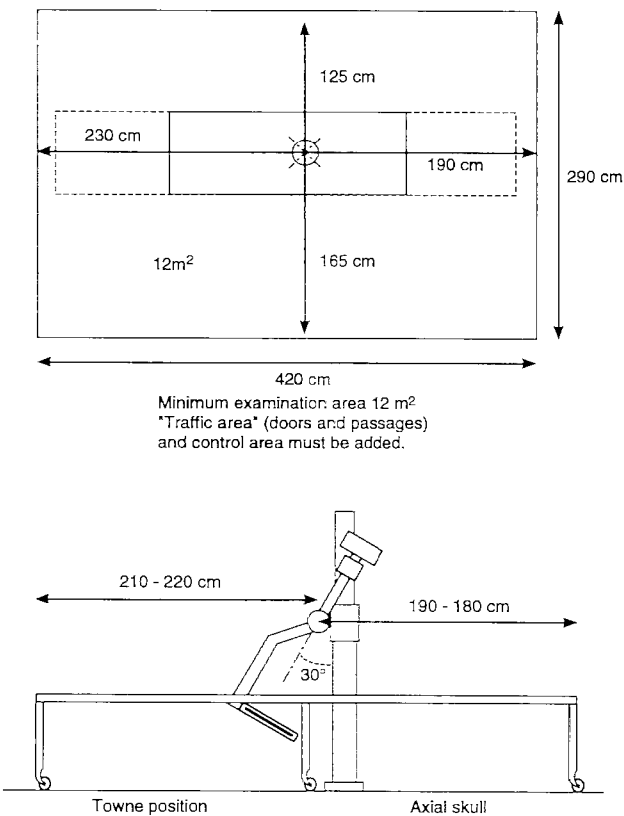
Cassette holder

The cassette holder, with its lead shielding of at least 0.5 mm, serves as a primary beam absorber and greatly reduces the need for shielding in the walls of the room. With a vertical beam, and without the regular examination table in place, it also makes an excellent small examination table for infants and for the wrists, hands, forearms, and feet of adult patients.

Premises and installation of the equipment

Two rooms, the X-ray room and the darkroom, are the minimum required. Three rooms are desirable: an examination room (X-ray room), a darkroom, and an office/viewing room. Storage space must be available, with room for a film file if the exposed X-ray films are to be filed in the X-ray department.

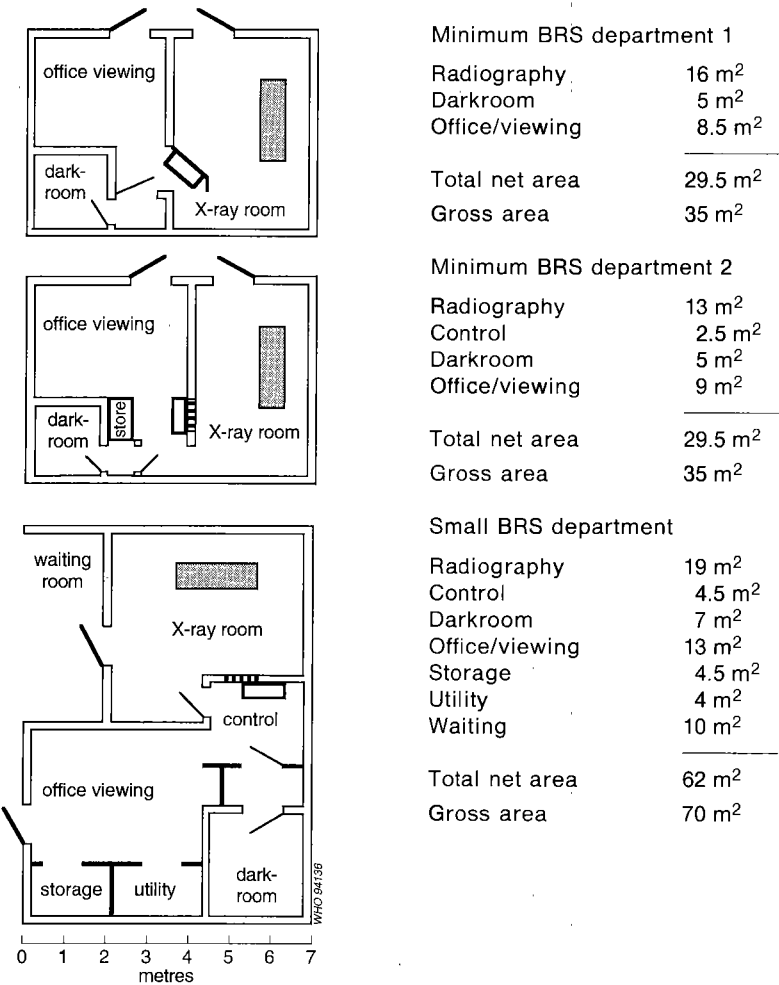
Fig. A1.1. BRS examination room.



X-ray room

The minimum work area required for a BRS stand is shown in Fig. A1.1 and three possible floor plans are shown in Fig. A1.2. Additional information is provided in a WHO unpublished document.¹

Fig. A1.2. Three typical BRS floor plans.

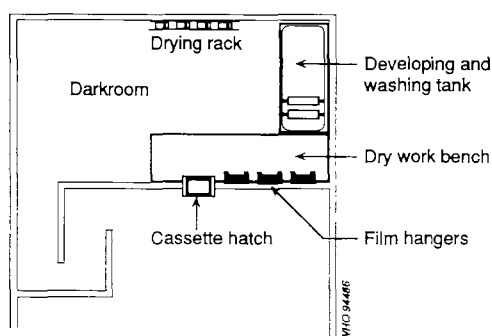


Darkroom

The darkroom should have a floor area of at least 5 m² when manual processing is used; no dimension of the room should be less than 2 m. If an automatic processor is used and the room is not continuously occupied, it may be as small as 1.5 × 2 m. A plan of the darkroom layout is shown in Fig. A1.3. Additional information is provided in the WHO unpublished document mentioned above.¹

The darkroom must be entirely light-proof, even with the brightest sunlight outside. The light-tightness of doors, windows, and ventilation ducts must be tested carefully. No light from outside must be visible to anyone who has spent 10 minutes inside the room in total darkness.

¹ *Guidelines for the installation of WHO Basic Radiological Systems (BRS)*. Geneva, World Health Organization, 1986 (unpublished document RAD/86.1; available on request from Radiation Medicine, World Health Organization, 1211 Geneva 27, Switzerland).

Fig. A1.3. Plan of a darkroom.

Three separate light sources are needed in the darkroom:

- General white light: a 40 watt incandescent bulb in the ceiling. (A fluorescent tube gives afterglow and is not acceptable.) The control switch must be **inside** the darkroom, 180 cm above the floor.
- Indirect filtered light: a 25–40 watt incandescent light directed upwards towards the ceiling, through a darkroom light-filter.
- Direct filtered light: a 15 watt incandescent light, with a darkroom light-filter, directed downwards toward the surface of the dry bench. The distance between the light bulb and the table surface must be at least 120 cm. This light fixture *must* have the words “max. 15 watt” written in large letters on the outside. The switches for the filtered lights should be located inside the darkroom at the normal distance above the floor for light switches in the department.

The correct safelight filters *must* be used: amber if blue-sensitive film is being used, and ruby red if green-sensitive film is being used.

If blue-sensitive film is used, the ceiling and walls should be painted with a semi-gloss, washable, chrome-yellow paint with no white pigment added. A pure chrome-yellow paint does not reflect any blue light, which might expose the X-ray film. If green-sensitive film is used, the ceiling and walls could be painted white, yellow, or another light colour.

Electricity supply

If the generator is to be connected to the mains, check the characteristics of the available power supply. Confirm with the expected supplier that the equipment is compatible with your power supply before ordering. 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). Sometimes a 50 A slow fuse will then suffice. Generators using batteries or large capacitors may operate from a standard grounded 220 V or 110 V outlet, and do not require more than 3 A or 6 A during operation. If batteries are used, sealed lead-acid batteries are preferred, because they do not require maintenance.

If an automatic processor is used, the power consumption may be as much as 5 kW for short periods. Running water will also be necessary.

The electricity supply for room lighting and viewing boxes can be an ordinary earthed (grounded) wall outlet of 220 V, 10 A, or 110 V, 20 A.

Earthing

Earthing is absolutely necessary.

- Connect the generator to the main earth, if agreed by the electricity authorities; follow local regulations exactly.
- If not specified by local regulations, connect to an independent earth electrode close to the X-ray department.
- **Never** connect the X-ray generator to the water-piping system.

Installation

All X-ray equipment must be installed by the manufacturer or the local agent for warranty and safety reasons. It must be checked before acceptance. When equipment is being relocated, workers experienced in X-ray installation are essential. Incorrect installation may be both dangerous and expensive.

Operation

Personnel

The following personnel are needed: radiographer, assistant radiographer, or specially trained BRS operator.

The following special training manuals have been published by WHO:¹

- *Manual of radiographic technique*
- *Manual of darkroom technique*
- *Manual of radiographic interpretation for general practitioners.*

Consumables

The following supplies are needed:

- X-ray cassettes and screens (all of the same speed and characteristics);
- films (all of the same speed and characteristics);
- chemicals for film processing;
- envelopes for films;
- record books for examinations.

Hazards

The operator and maintenance staff must be aware of the risks associated with the use of X-rays, and operate the X-ray equipment accordingly. This requires the operator:

- to use the correct X-ray exposure technique (kV and mAs);
- to adjust the collimator to the size of the film;
- to use protective devices for the patient when appropriate;
- to protect himself or herself behind the protective screen;
- to allow no one other than the patient in the X-ray room during the exposure (if the patient must be held or supported, a lead apron and gloves must be worn by all who do this);

¹ *Manual of radiographic technique*. Geneva, World Health Organization, 1986;
Manual of darkroom technique. Geneva, World Health Organization, 1985;
Manual of radiographic interpretation for general practitioners. Geneva, World Health Organization, 1985.

- to use the patient’s family or friends when possible, rather than hospital staff, for holding the patient during exposure;
- to process the film according to the WHO-BRS *Manual of darkroom technique*, following especially the time and temperature guidelines.

Maintenance

Installation, service, and repair of X-ray equipment should only be carried out by specially trained and experienced service technicians or engineers. Nevertheless, some minor mechanical and electrical repairs, such as replacement of fuses or bulbs and cleaning and repair of brakes, may be undertaken by the hospital maintenance staff, provided they have received instruction from the supplier.

Spare parts

Do not purchase or store a spare X-ray tube. Tubes deteriorate in storage. As spare parts for equipment may be very expensive, they must be ordered only after careful consideration, and parts that may not be needed should not be purchased for storage. Because the supplier will be responsible for the major servicing, only those parts that can be replaced by the hospital staff—usually only fuses—should be stored in the hospital.

Special care

- Do not service the equipment unless the main electricity supply is turned off.
- Do not open the generator control console to attempt to make repairs.
- Never use a fuse of a different rating, or type, from that recommended by the manufacturer.
- If a fuse blows regularly, inform the service department or the manufacturer’s representative.

Service contract

The original contract for the supply of WHO-BRS equipment should include the following:

- There should be an instruction book indicating which parts of the equipment require regular routine maintenance by the operator. This must be written in such a way that the reader does not need to be a skilled engineer to follow the instructions. Training for this routine maintenance should be given at the time of installation and during the period of instruction of all operators.
- There should be an instruction book indicating how to use the various controls, such as brake handles, etc., required for normal operation of the equipment. This may be part of the routine maintenance manual described above. All of these instructions must be compatible with the WHO-BRS *Manual of radiographic technique*.
- Copies of the WHO-BRS *Manual of radiographic technique*, *Manual of darkroom technique*, and *Manual of radiographic interpretation for general practitioners* should be provided by the supplier of the WHO-BRS equipment.
- Each item of electrical equipment must have a set of easily located test points so that the maintenance engineer can locate faults in the electrical circuits, on site.

Battery-powered X-ray generators

A battery pack may store enough power to give a life-threatening electric shock. Keep all metal tools away. Do not wear metal watches, watch-straps, bracelets, or necklaces.

Special advice for users of a battery-operated X-ray machine

If the quality of the X-ray films is not as high as expected, or the exposure has to be changed significantly to obtain good quality radiographs, it is often suggested that the batteries should be checked. However, this is seldom the cause of poor films because when the batteries are low the X-ray unit will not work. The commonest cause of a change in exposure and quality is failure of the processing chemicals. Before checking the batteries, make fresh chemicals, check the temperature of the solutions, and process a film for the correct time (see WHO's *Manual of darkroom technique*).

Read the manufacturer's instructions for battery maintenance.

In addition to the above, the following special instructions apply to WHO-BRS machines with battery power sources.

- If *unsealed* lead–acid batteries are used, the level of the water in the battery must be checked every month, and when necessary topped up to the proper level with distilled water. If distilled water is not available, the supplier should be consulted when the equipment is installed and the instructions followed; for example, freshly collected rainwater, without particulates or sediments, is similar to distilled water and can be used in most circumstances. A record should be kept of the performance of each battery, especially noting each time a battery requires water. The maintenance engineer should be informed if one battery requires more water replacement than others. Every three months, the acidity should be checked. Complete discharge of the battery may damage the cells, and such batteries will no longer be useful.
- If *sealed* lead–acid batteries are used, the BRS operator should check the indicator on the top of each battery at monthly intervals. If there is any evidence of failure, the maintenance engineer should be called. Sealed batteries should last for 5 years, provided they are properly recharged.
- If *nickel–cadmium* batteries are used, they must be fully discharged every 8–12 months, depending on the number of X-rays taken, so that they may be fully recharged. This is called recycling, and is a complex process. The supplier should be consulted when the unit is first installed to agree on the required recycling interval. Recycling cannot be carried out by the operators as special equipment and training are required, and it is usually better to replace the batteries with a spare set and send them to a central location for recycling. If properly maintained, nickel–cadmium batteries should have a working life of 5 years. It must be emphasized that recycling is a potentially dangerous procedure, because the batteries contain sufficient electrical power to cause second- and third-degree burns if not properly handled, and in some cases the electric shock could be fatal.

For all maintenance procedures, it is essential that the operators and the maintenance engineers are trained on the same type of equipment as they will encounter in the field. It is useless to train them on equipment from a different manufacturer, as there are so many variations. For example, some manufacturers provide an indicator to show whether the battery is high or low and in need of recharging. If this is part of the equipment, all operators should be taught to observe this regularly, and ensure that the batteries are recharged when necessary. However, other manufacturers provide automatic recharging, which occurs whenever the batteries are low, provided the X-ray machine is connected to the electricity supply. These batteries are therefore maintained at full charge, and will only fall to a low level if the X-ray unit is used many times when the main supply of electricity is cut off. These units also have a “state of the battery” indicator.