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Technical Specifications for the X-ray Apparatus to be used in a basic Radiological System

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TECHNICAL SPECIFICATIONS FOR THE X-RAY APPARATUS TO BE USED IN A BASIC RADIOLOGICAL SYSTEM

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 radiodiagnostic 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 fault finding 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.

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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 out-patients; 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, bone and joint diseases
Head	:	trauma and infections
Chest	:	tuberculosis, pneumonia and other respiratory infections, heart enlargement, tumours, trauma
Abdomen	:	intestinal obstruction, calcifications, trauma and possibly intravenous urography, cholecystography, and problems in pregnancy
Soft tissue	:	Foreign bodies, calcifications

Contrast media 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 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 1 second or less. The exposure conditions include the employment of a focussed lead/aluminium grid with 40-50 lines per centimeter and a ratio of 10:1 and an irradiated field at the position of the cassette collimated to 400 square centimeters. 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 development indicates that in the future most x-ray generators will 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 mains 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 preset 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 can 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 mAs in 25 steps for a 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 centimeter 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 30x30 cm, placed in a convenient position to give a good view of the patient.

4.4 X-ray tube 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 10°.

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

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 18x24cm. 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, focussed lead/aluminium grid having 40-50 lines per centimeter and a ratio 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 mm Pb. This requirement may obviate the need of further radiation protection of the walls of the examination room if the floor dimensions are 3x4.5 m or larger and no more than 2,000 x-ray examinations are made per year.

The design of the examination stand must permit:

a) the use of the 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 ±30° 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 load of at least 15 kg without disalignment of the focussed 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 beam 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 4 film sizes are recommended. The cassette holder must accept at least the following formats; 35.5x43 cm, 18x43 cm and 24x30 cm.

4.6 Patient support

The patient support should be rigid, with an x-ray permeable top, approximately 2.0x0.65 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 a way that when the vertical beam is used the distance between table top 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 bean is angulated ±30° from the vertical direction, the distance between the table top 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 a 110 kg patient, and the locking mechanism should preferably be central and immobilize at least one wheel at either end.

4.7 Darkroom equipment

A restricted range of standardized darkroom equipment should be offered with the x-ray equipment, including at least 2 cassettes each of the formats matching the fixed collimator formats. All cassettes must include a backing of 0.1 mm Pb equivalent.

It is anticipated that the processing will be manual, using strict time/temperature control. In certain conditions there may be a case for the use of appropriate high temperature processing or a small automatic processor.

4.8 Protective devices

Unless there is an adequate protective cubicle at the installation site, a protective lead screen (minimum 0.5 mm Pb), with a lead glass window for the operator, must be provided as an integral part of the x-ray generator control. The back wall of the cassette holder contains a protective lead screen of 0.5 mm Pb and all cassettes have a backing of 0.1 mm Pb equivalent.

At least two full length (shoulder to knee) protective aprons and two pairs of lead gloves with 0.25 mm Pb equivalent minimum, together with a range of standard devices for patient protection, should be provided with the machine, unless already available in good condition.

4.9 Operational accessories

a) Two lead rubber/plastic strips (0.5 mm Pb equivalent) of 24x15 cm should be provided to cover cassettes when in table top use in order to allow 2 exposures on the same film when required or to serve as gonad protection.

b) A measuring caliper, sliding parallel, to determine body part thickness, graduated in centimeters and with blunt tips, should be provided to assist exposure calculations.

c) A set of foam-plastic wedges and sandbags should be provided.

5. Manuals

BRS manuals on radiographic technique, film processing, and film interpretation are available in English, French, and Spanish.

Manufacturers of BRS equipment are required to supply adequate manuals for the installation, use, maintenance and repair of their equipment.

6. Testing and field trials of BRS equipment

WHO is prepared to carry out an assessment of any equipment submitted.

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NOTE: Nothing in these specifications shall imply that the unit shall not comply with IEC/ICRP recommendations.

Further technical information may be obtained by direct contact with:
Dr Thure Holm, St Lars Roentgen, Lund University Clinics, 22006, Lund, Sweden; telephone: 046-164509 (Member of the WHO BRS Advisory Group)

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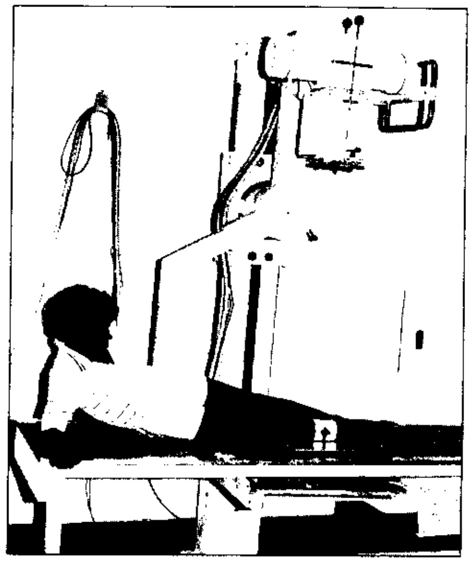
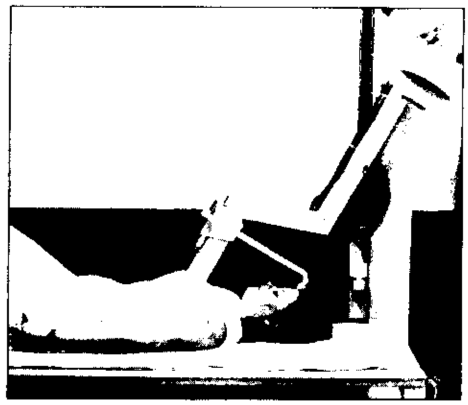
Simply perfect.





THE WHO-BRS X-RAY UNIT

Hailed as a revolution in imaging technology[1], the WHO Basic Radiological System (BRS) has perfected high-performance technology to the point of simplicity.

Built into the design of this sleek, smart machine are a number of high-tech extras that make the BRS extremely easy to operate and just as easy to maintain. The design is so foolproof[2], in fact, that it virtually forces you to take good x-rays[3]. And most safely so: radiation dose to patients is substantially reduced[4].

It's versatile, too. From head to toe, from infants through the elderly, the WHO-BRS unit can handle all the x-ray work at a district hospital, 90% at a primary care clinic, and 80% at a large university hospital[5] – anywhere in the world.

But the nicest surprise is the price. For once, the best that money can buy is also your best buy[6]. Independent tests have shown that image quality using the BRS excels that produced by conventional equipment costing several times as much[7, 8].

So what's the catch? None. And for a perfectly good reason: the BRS is produced in keeping with guidance and specifications developed by the World Health Organization with humanity's needs at heart, the best expertise in hand, and hospital budgets in mind.

Which all adds up to make the BRS the simply perfect choice for a small hospital – and a very smart add-on for any large radiography department that wants superb quality at a sensible price.

THE WHO-BRS X-RAY UNIT

High-tech sophistication in a marvel of simplicity

A WHO-BRS unit is one of the most sophisticated yet operatively simple x-ray sets ever manufactured.

The unit combines the functions of a bucky table and a vertical bucky. The apparatus consists of a high quality x-ray generator with x-ray tube, together with a high quality focused grid, and a unique tube-stand – all linked together in a sophisticated manner to produce an optimum, and deceptively simple, x-ray unit.

Snap-shot simplicity

In many ways, the WHO unit can be likened to a small modern camera: you point towards the subject, select the exposure factors according to a simplified method, and press the button.

The machine is so simple to use that operators can be trained in a matter of months, using the three WHO manuals[10–12] which are part of the system. These manuals make it easy to do over 100 different radiographic projections, including cholecystography or intravenous urography for imaging the kidney and bladder.

Specialist radiographers obtain even better results, fully comparable to the results they get with the most expensive equipment. They also like the ease of operation — and radiologists give the radiographs a high quality rating.

Designed for extra safety

The BRS is an exceptionally safe machine for patients and operators alike. The advanced design of the generator makes it possible to x-ray patients with about half the radiation dose received using common single-phase x-ray generators[4]. Other features that make for greater safety include a long focus-film distance and the high quality focused grid with exact centering.

Care-free maintenance

The unique, rugged design of the BRS has simply eliminated many of the components which are hard to maintain. Apart from the x-ray tube and generator, all moving parts are non-electrical and thus easily maintained.

Versatile

The BRS unit has been designed to meet the needs of small hospitals and clinics — anywhere.

Of course, it can also work equally well doing the routine x-ray examinations in big hospitals — anywhere.

In small hospitals, almost 100% of the required x-ray examinations are easily handled by the BRS.

In a large hospital, the BRS is excellent for routine radiography of the chest, legs and arms, abdomen, spine, and skull. By investing in the BRS for routine work, hospitals can liberate precious funds for the purchase of more complex equipment for highly specialized examinations.

Superior results

The image quality of the BRS is usually superior to the quality achieved using conventional x-ray installations. Tested in university-affiliated outpatient clinics in Sweden and in a large hospital in London, the WHO unit competes — and excels — in the same class as much more expensive and complex equipment.

At three out-patient clinics affiliated with the Lund University Hospital, Sweden, more than 300,000 clinical exposures have been made in about 80,000 examinations, using 4 BRS units from different manufacturers. The image quality is as good, and often better, than that achieved at the main university x-ray department[9].

In another recent assessment made by the U.K. National Health Services, a WHO-BRS type x-ray machine was compared with the conventional x-ray equipment in an 800 bed hospital. The images produced by the BRS were judged "excellent" in 20% of the cases versus only 6% for the conventional x-ray equipment[7].

Listen to what the critics say:

"The WHO-BRS is simply too good. It has been suggested that this unique system inhibits vigorous marketing because it might appear to threaten the established patterns of equipment selection...Would a salesman attempt to sell a Volkswagen if he can sell a Rolls Royce? Further it might also be wise for him to keep quiet about the virtues of the Volkswagen."
— The Lancet[1]

"The design is foolproof, simple to operate, and able to provide consistently high quality radiographs."
— British Medical Journal[2]

"One is almost forced to make a good quality radiograph!"
— Joel E. Gray, Ph.D.
Professor of Radiologic Physics
Mayo Clinic, Rochester, Minnesota

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