Electronics in Medicine

Part VIII—A radio technician can repair and maintain almost any X-ray installation

By EUGENE THOMPSON

X-RAYS are an invisible form of radiant energy of extremely short wavelength (0.125×10^{-8} to 0.5×10^{-8} cm). They have the ability to penetrate many opaque materials. They are produced in an evacuated glass envelope by bombarding a positively charged, tungsten-plated, copper anode with a high-velocity stream of electrons emitted from a heated filament and negatively charged cathode (Fig. 1).

As the potential between cathode and anode increases, the X-rays become shorter in wavelength and more penetrating. Commercial X-ray tubes are operated at voltages ranging from 50 kv to several million volts, depending on the design of the tube. The current consumption runs from about 15 to several hundred ma. Higher-current tubes produce better contrast in X-ray pictures.

Most of the energy produced by the electronic bombardment of the anode is liberated in the form of heat. Only a small proportion is emitted as X-rays. This heat may be dissipated by radiation fins attached to the anode, by circulating water, or by immersing the tube in oil.

Tubes may have either stationary or rotating anodes; Fig. 2 illustrates the latter. Its chief advantage is that it permits the X-rays to be concentrated into a much smaller area because of the more efficient heat dissipation of the rotating anode. A rotary anode is cool under conditions that would generate enough heat to destroy a stationary anode.

Control panel for an X-ray-fluoroscope unit.

Radio technicians are occasionally called upon for emergency servicing of X-ray apparatus belonging to local hospitals or physicians. Although many repairs can be made only by specially trained personnel with the proper replacement parts, the most commonly encountered difficulties are relatively simple to remedy. Therefore, the remainder of this article deals with some of the basic components of all X-ray equipment, with which some familiarity is required for servicing profitably such machines.

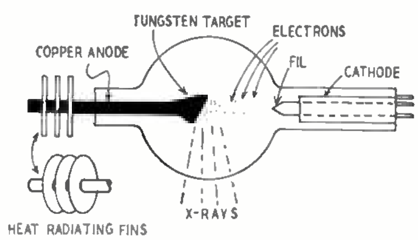

Fig. 1—High-velocity electrons strike anode.

A word of caution at the outset. X-ray equipment is dangerous! Carelessness may lead to serious injury or loss of life. *Never* violate the following rules:

1. *Never handle the free end of any cable without first carefully grounding it to discharge any high voltage.* This is doubly important in machines which employ capacitors in the power supply. Also, the negative leg of the high voltage is common with one of the filament leads.

2. *Never take measurements with the power on. Make certain that the equipment is turned off, and use a continuity meter.*

3. *Never observe an uncovered X-ray tube unless protected by the lead and glass shield provided with the equipment.* Excessive exposure to X-rays may cause severe burns. Carelessness may lead to the loss of a hand or of eyesight.

Although these warnings make X-ray servicing appear exceedingly dangerous, actually it is no more so than television work. The fact that many thousand physicians and X-ray servicemen work with such equipment daily with safety proves that it is harmless when correct and careful precautions are taken.

Typical generators

Figs. 3, 4, and 5 are schematic diagrams of relatively simple X-ray machines. Although more complicated instruments are sometimes encountered, they all boil down to the basic essentials illustrated here. The servicing of all X-ray apparatus, no matter how complex, may be greatly simplified

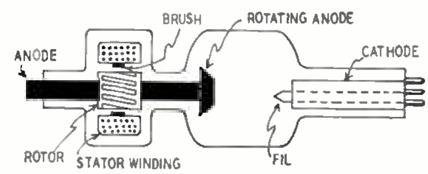

Fig. 2—The anode rotates to dissipate heat.

when it is remembered that they must all contain an X-ray tube, a high-voltage power supply, and a source of filament voltage. The remaining components found in more complicated machines are usually incorporated in the control unit to make the equipment more convenient for non-technicians to operate.

No attempt will be made to enumerate all the possible defects which may be encountered. The reader can obtain this information by inspecting the diagrams. The X-ray trouble-shooting chart enumerates those common difficulties which can be remedied by the average radio repairman. The following discussion is limited to basic principles.

The machine in Fig. 3 is a small, 15-ma portable unit of the type commonly used in many doctors' offices and for bedside work in hospitals. The schematic is more or less self-explanatory. The X-ray tube is self-rectifying because of the comparatively low potential and current at which it is operated. For higher-voltage tubes, external rectification is necessary because the operating potential is so much higher than the peak inverse voltage of the tube. Note that one side of the high voltage is common with one leg of the filament: that is why the filament's cable must be grounded when removed from the tube for inspection before being handled.

Fig. 4 is a schematic of a typical high-voltage X-ray unit. The amplitude of the high voltage is controlled by the autotransformer voltage-selector setting. A four-tube bridge-type, full-wave rectifier is used. Some units employ only one or two rectifier tubes. X-ray rectifiers are of the heavy-duty type and are commonly immersed in oil to dissipate heat. Note that again the negative side of the high voltage is tied to one side of the X-ray tube filament circuit.

As a safety measure, the filaments of the X-ray tube and rectifier tubes can be lighted independently of the high-voltage circuit. This makes possible safe inspection for servicing purposes. It also permits the X-ray operator to keep the machine warmed up for instant use.

The X-ray tube filaments can be inspected by looking through the window in the tube in some cases. In other tubes, the filament cannot be seen and continuity testing is the answer. When testing for gassy tubes with the high voltage on, always stay behind a protective shield.

An additional feature of X-ray equipment illustrated in Fig. 4 is the dead contacts or buttons between the tap contacts on the autotransformer. This prevents shorting of the high voltages developed across the autotransformer windings when switching from one contact to another. The importance of these dead buttons from the servicing standpoint is that the voltage selector may sometimes be unintentionally left on a dead button; and when the operator attempts to use the equipment, it appears to be out of order.

A two-tube unit

The circuit in Fig. 5 is similar to that in Fig. 4. However, two tubes are used instead of one. One tube is used for taking X-ray photographs, and the other is used for fluoroscopy. In this respect it is similar to the table unit illustrated in the photograph. The fluoroscopic tube is concealed under the table. The radiographic tube is mounted on the moving carriage above the table. On occasion the cables or switches to the tubes of some X-ray machines may get transposed and cause some difficulty.

The four large circles in Fig. 5 represent the X-ray tube connections. The two black circles are anode contacts. The other terminals are the filament and cathode connections. The large and small filaments are used to vary the area covered by the X-rays. The rays from the small filament are used to take pictures or fluoroscope small areas of the body, such as a finger or hand. The large filament is employed for such jobs as chest X-ray work. The cathode terminal is common to one leg of both filaments and the negative side of the high voltage.

The solenoid-actuated contactors are oil-immersed steel contacts for closing the various circuits. One of the commonly encountered difficulties in X-ray equipment servicing is a defective or dirty contact.

Many X-ray installations are pro-

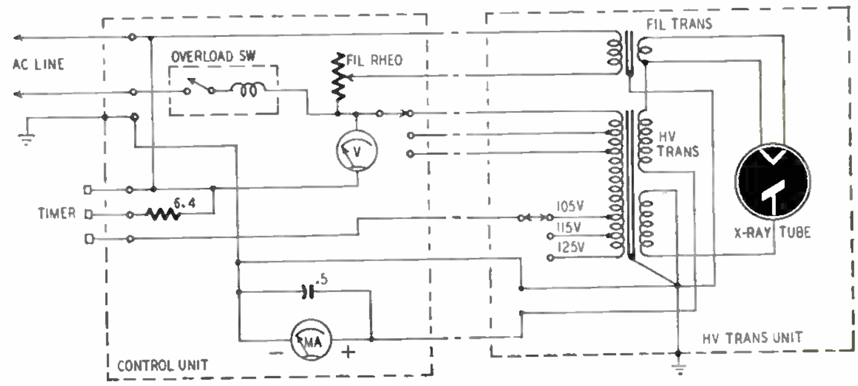

Fig. 3—Portable X-ray units like this are often found in doctors' and dentists' offices.

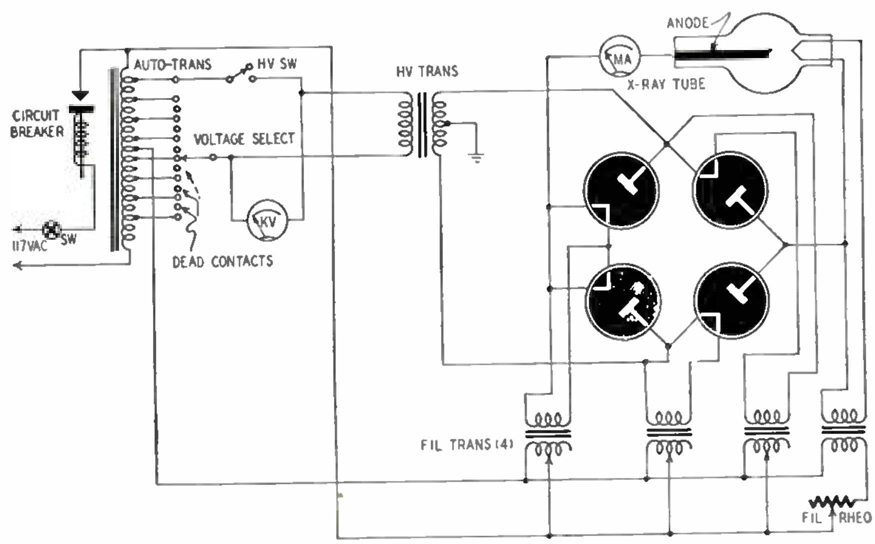

Fig. 4—A hospital X-ray machine is likely to be a high-voltage unit much like this one.

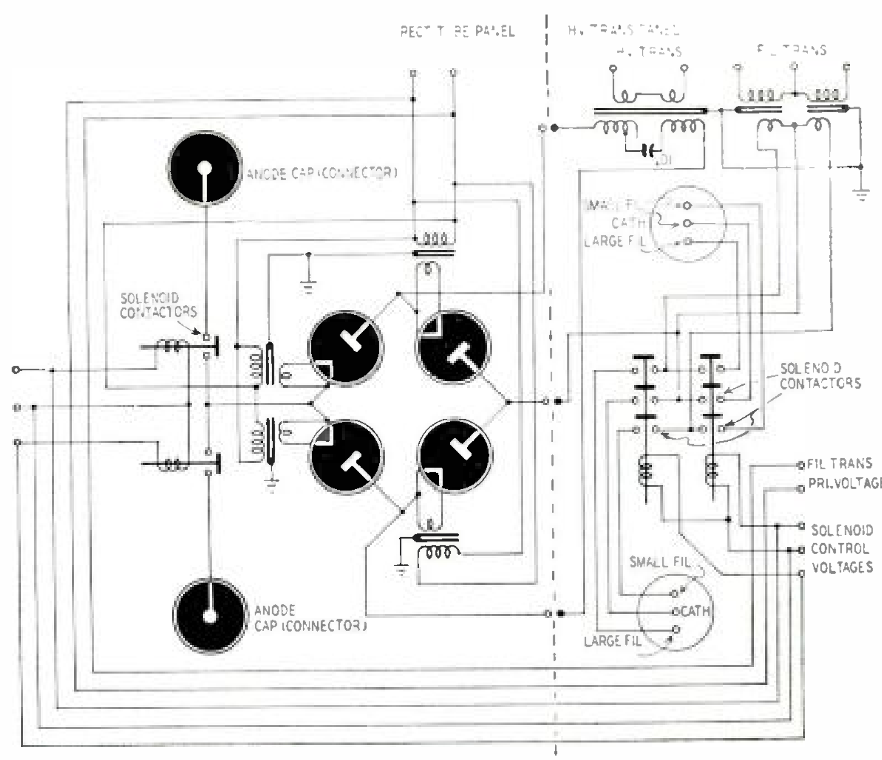

Fig. 5—To provide for both radiography and fluoroscopy, this circuit includes two tubes.

X-RAY EQUIPMENT TROUBLE-SHOOTING CHART

FAULTS \ CAUSES	H.v. switch to wrong tube	Burned out X-ray tube fil. or open fil. circuit	Shorted X-ray tube fil. circuit	No a.c. supply	Power switch open	Line fuses removed or defective	Open control unit circuit	Intermittent or loose connections in X-ray tube fil. circuit	Faulty meter	Line-voltage fluctuations	Burned-out rect. fils.	Open rect. fil. circuit	Timer defective	Inadequate rect. fil. current	Gassy X-ray tube	Partial h.v. insulation break-down	Overloaded X-ray tube	Autotransformer selector on dead contact	Complete h.v. insulation breakdown	Main exposure switch open	H.v. capacitor breakdown	Solenoid contactor not closing	Wrong meter scale	Arc-over in h.v. circuit
X-ray tube fil. not lighted	1	2	3	x	x	x	x	x																
No reading on X-ray tube fil. meter		1		x	x	x	x		x															
Fluctuations in X-ray tube fil. meter								1		2														
Off-scale X-ray tube fil. meter reading			1						2															
Rect. fils. not lighted				x	x	x	x				1	2												
No reading on rect. fil. meter				x	x	x	x		x		1	2												
No current through autotransformer				2	1	3																		
Erratic radiographic results								1		2	x		3	x	x	x								
Rect. anodes excessively hot											1						2							
No reading on h.v. prim. voltmeter				x	2	3	x		x									1						
H.v. prim. meter reads too low									4						1	2			3					
H.v. prim. meter fluctuates										1														
No reading on ma or ma-second meter		2	3	x	x	x	x	x	x		x*	x*						x	x	1	x	x		
Reading of ma or ma-second meter low									4		3†	3†				2							1	
Ma or ma-second meter fluctuates								1		3				x	2	x								
Ma or ma-second meter off scale									x						1	3			x				2	
No high voltage				x	x	x	x											x	3	1		2		
Overload switch opens															1	2	x		x		x			3

Causes for each fault are listed in order, the most usual being numbered 1. Causes found only occasionally are marked with X.

* Found only in units with one or two rectifiers.
† Found only in bridge rectifiers.

Photos Courtesy Westinghouse Electric Corp.
X-ray-fluoroscope table is tilted by a motor.

vided with an operating and servicing manual which aids greatly in servicing the equipment. However, some manufacturers sell their machines installed and provide a course of instruction for the physician or X-ray technician operating it. Under these circumstances, no diagrams of the machine may be available and servicing is somewhat more difficult. Often the physician or technician may be of great assistance if he explains the operation and purpose of the various controls to the repairman.

The chart shown above should be helpful in servicing X-ray machines. While it will not help in fixing specific faults, it will aid diagnosis by substituting for trial the experience of many technicians in associating a certain symptom with a certain cause or bad effect.

In any event, equipped with a knowledge of the basic principles and circuits of X-ray equipment, a continuity tester, and a little common sense, the average technician can trouble-shoot and repair upward of 70 per cent of the common defects in X-ray machines and add a lucrative source of income to his business.

In a previous article of this series, Part III, dealing with phototubes and pressure measurements in medical work, a photograph captioned as a photoelectric blood-pressure measuring device was actually the resistance-wire strain gauge manufactured by Statham Laboratories.

X-RAYS SEE THROUGH STEEL

New X-ray machine that "looks" through 16 inches of solid steel to find otherwise undetectable flaws was exhibited last month at the Navy's new $35 million White Oak Ordnance Laboratory in Maryland. Developed by the General Electric Consulting and Engineering Laboratory, the machine cost $95,000 and is part of the Navy's new X-ray plant. At the demonstration, pictures were taken through a 17,000-lb. cruiser anchor.

HOSPITAL USES TV THERAPY

Television therapy will be tried out in the Loudon-Knickerbocker Hall psychiatric sanatorium, Amityville, N. Y., according to a report last month. The TV setup will be similar to that used in some New York hotels, but individual receivers will have no tuning controls. All tuning will be done at the central control unit, with the psychiatrist choosing the programs he believes to have the best therapeutic value.

Other features of the special sets will be shatter-proof Plexiglas windows over the C-R tubes, steel cabinets, and provision for turning off each picture unit from the central office.