Chapter 6

X-ray Circuit and Tube Heat Management

Learning Objectives

- Given an unlabeled x-ray circuit diagram, label the principle parts and state the function of each
- Explain what is meant by rectification and compare the basic types
- Describe the voltage waveform for each of the following types: unrectified, half-wave rectified, full-wave rectified

Learning Objectives

- List the primary features of all x-ray control panels and discuss the principal differences between conventional and computerized control consoles
- Describe the components of the automatic exposure control system
- List five possible causes of x-ray tube failure and describe methods to prevent each

X-ray Circuit Sections

- Low Voltage
  - Supplies low voltage for operation of control console and for kVp selection
- Filament
  - Supplies and controls heat needed for x-ray tube filament thermionic emission
- High Voltage
  - Supplies high voltage to accelerate electrons for x-ray production

Low-Voltage Circuit Portion

1 = AC power source - provides electrical power

2 = Main switch – controls the power to the control console

3 = Autotransformer – primary purpose is to vary the voltage to the primary side of step up transformer

4 = kVp selector

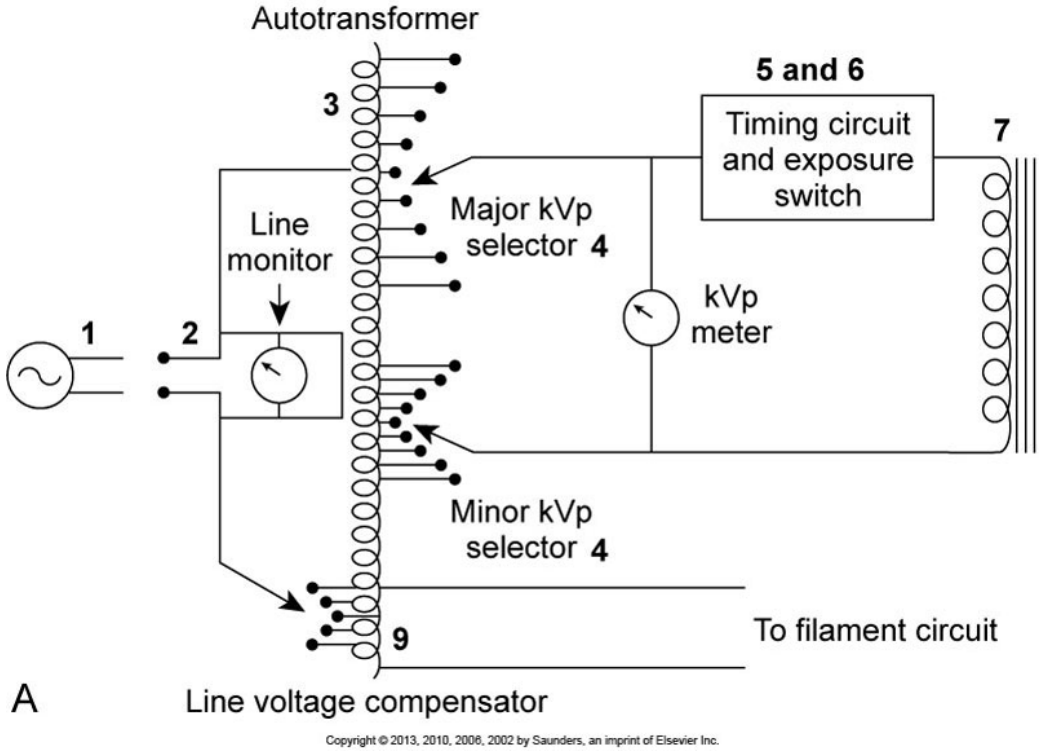
5 = Exposure switch – closes the circuit allowing current to flow through the primary side of step-up transformer

6 = Exposure timer – terminates the exposure

7 = Primary side of step-up transformer

9 = Contacts for autotransformer

kVp meter – measures the voltage output from the autotransformer



Filament Circuit

The purpose of the filament circuit is to supply a low current and control the heat required by the x-ray tube filament for thermionic emission of electrons

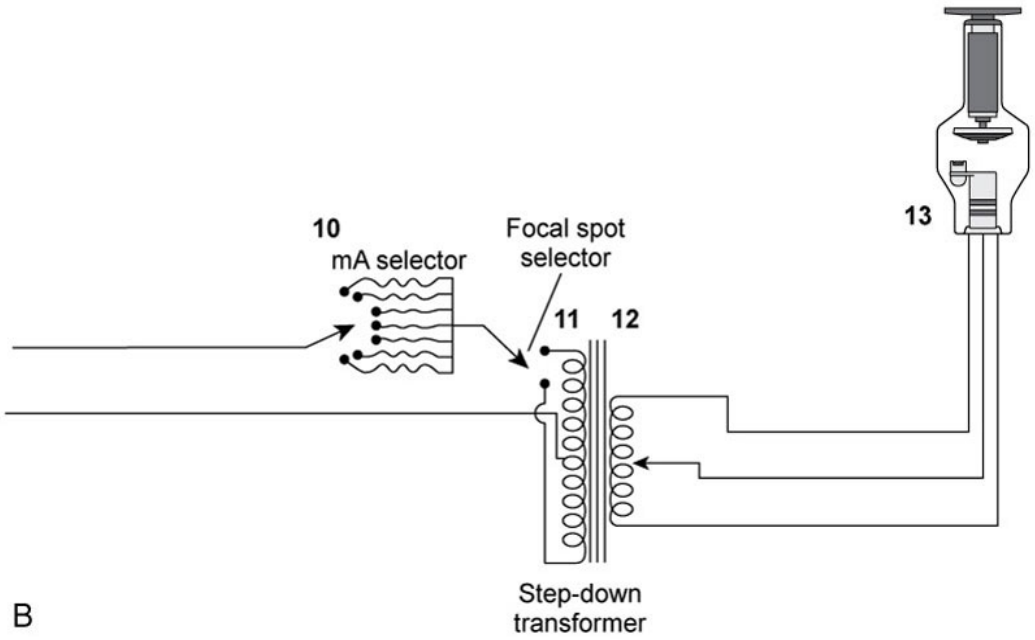
10 = mA selector – also called a rheostat; controls the amperage

11 = Primary side of step-down transformer

12 = Secondary side of step-down transfor

13 = X-ray tube filament

*Step-down transformer = decreases Voltage, increases amperage



High-Voltage Circuit

8 = Secondary side of step-up transformer

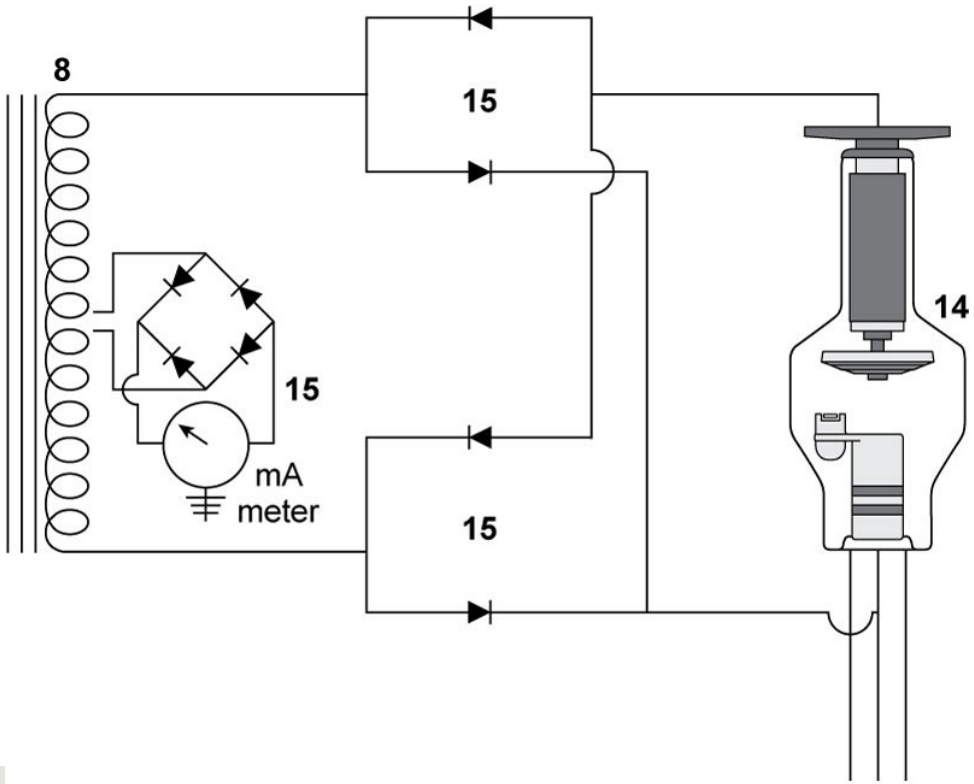
14 = X-ray tube

15 = Rectifier – changes AC (alternating current) into DC (direct current)

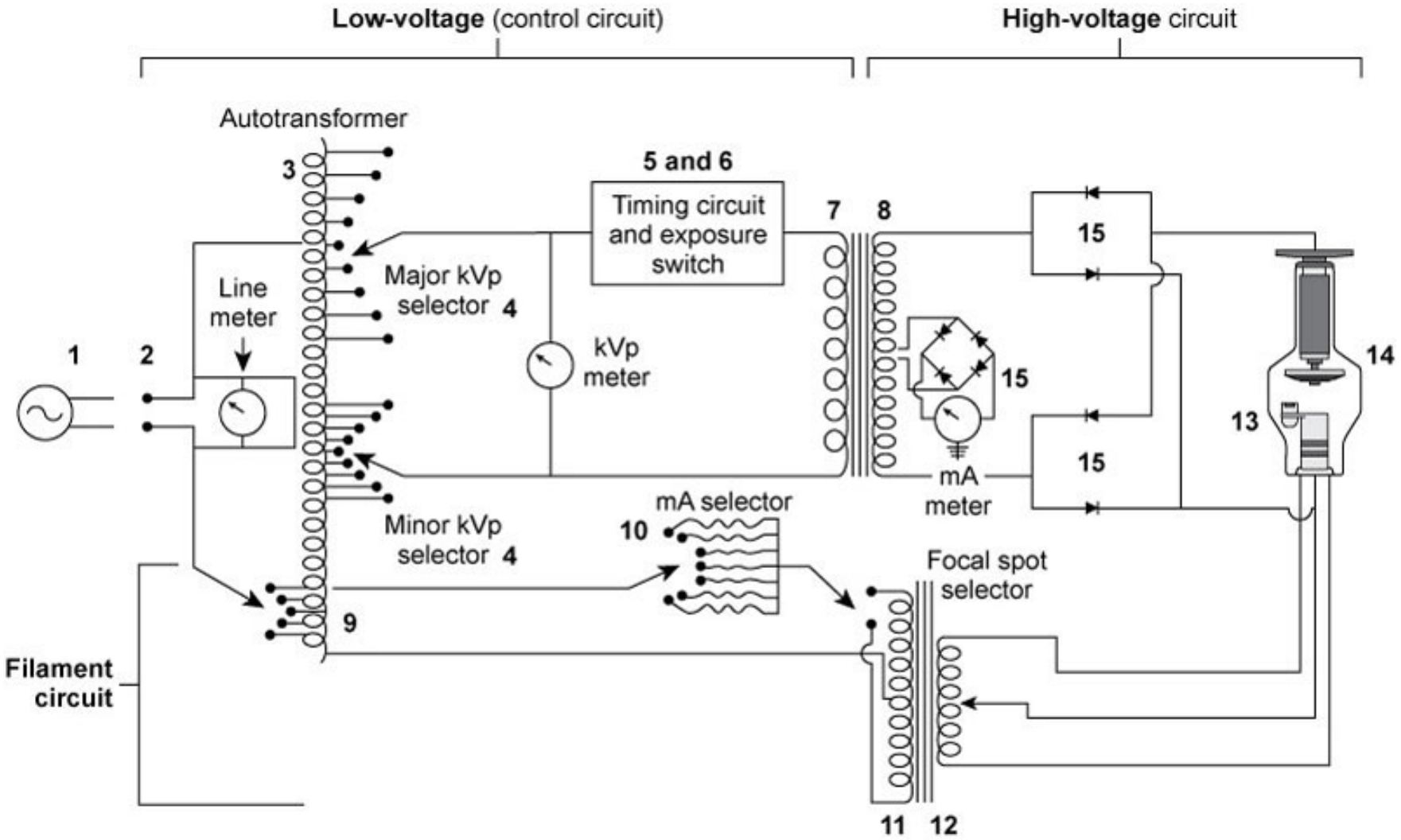
mA meter = Milliammeter – measures the current flowing in the high-voltage circuit during an exposure

*Current flows in this circuit only during an exposure

*Step-up transformer = increases voltage



Complete X-ray Circuit



Transformers in an X-ray Circuit

3 Transformers in an x-ray circuit

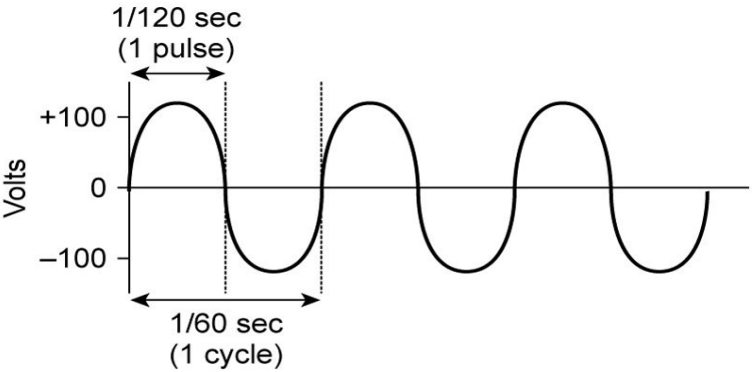
•Autotransformer – varies the voltage to the primary side of the step-up transformer

•Step-down transformer – decreases voltage

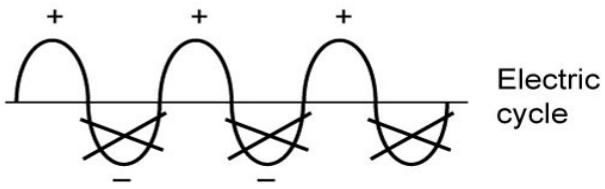
•Step-up transformer –increases the incoming voltage

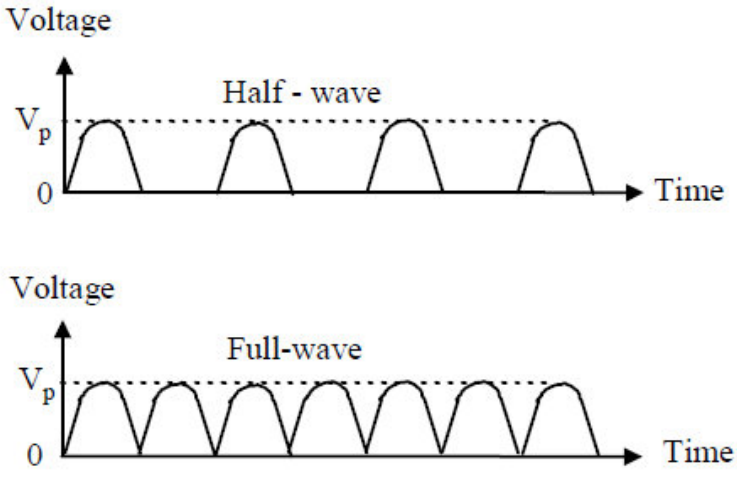
Rectification

- Changes AC to DC so that current can flow through the x-ray tube's vacuum
- Types
  - Half-wave rectification – uses two diodes
  - Full-wave rectification – employs four diodes; utilizes entire electric cycle



AC in U.S. and Canada: 60 cycles/sec (60 Hz)





Comparison of half- and full-wave rectification

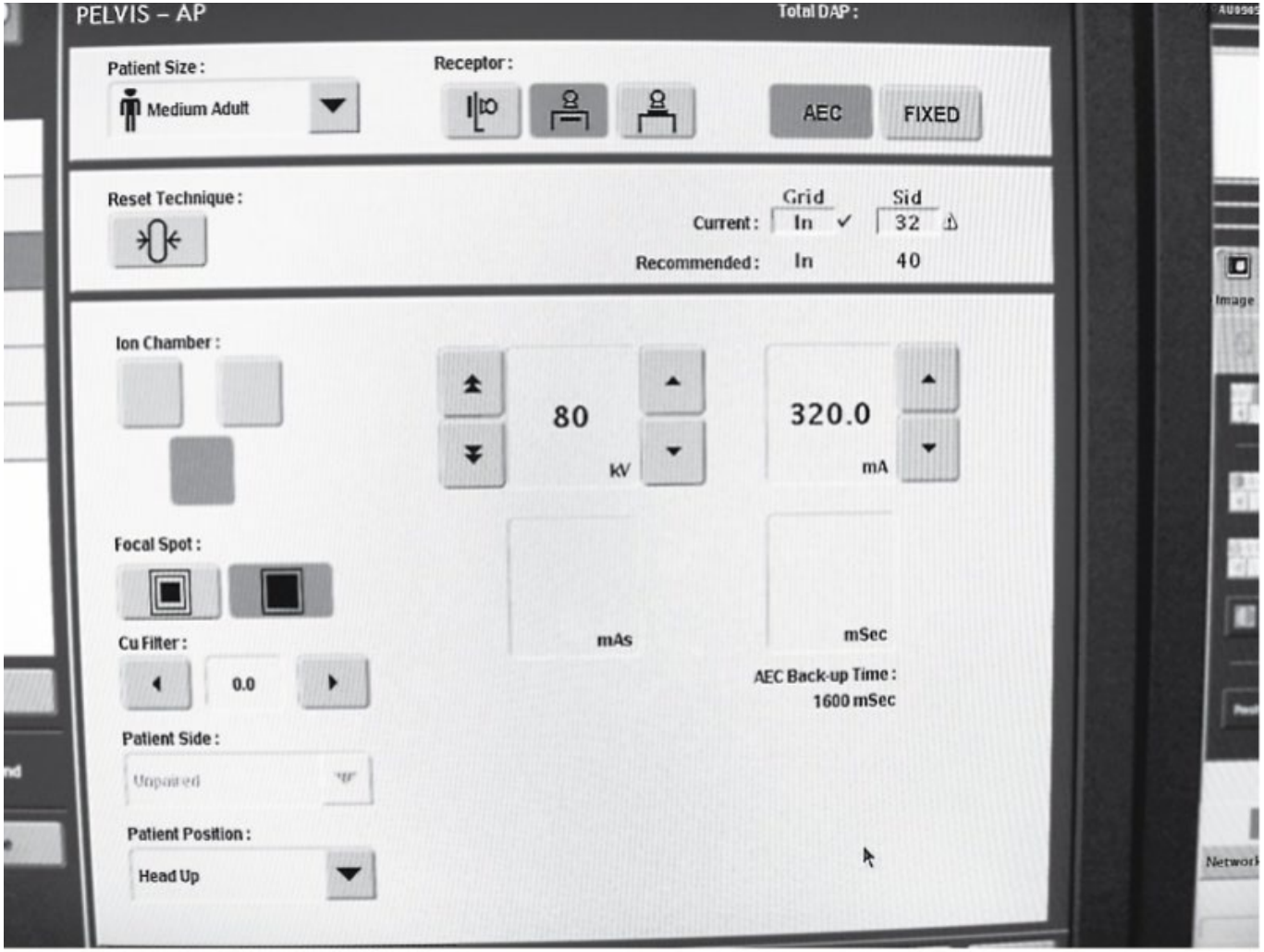
X-ray Generators

- Single-phase
  - Results in a pulsating x-ray beam
- Three-phase
  - Major advantage is that it is more efficient and produces approximately 40% more x-rays than single-phase
- High-frequency (HF)
  - 60 Hz transformed to 6,000 Hz
  - Most efficient at producing x-rays

Control Panel

- Used to select mA, kVp, exposure time, and focal spot size
- Conventional
  - Knobs and switches used to set exposure factors
  - Dials and meters indicate settings
- Computerized
  - Buttons used to set exposure factors
  - Digital readouts indicate settings
  - May be APR or anatomically programmed

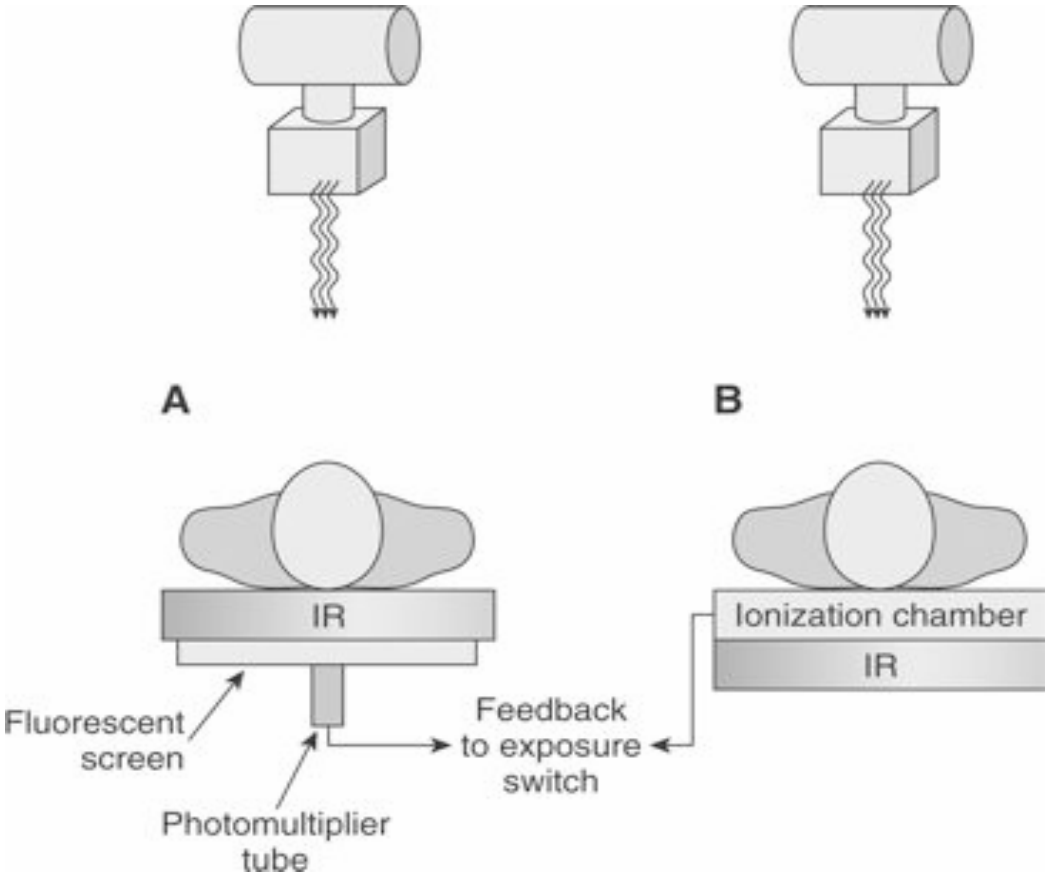
Computerized Control Panel



Ballinger PW, Frank ED: *Merrill's atlas of radiographic positions and radiologic procedures*, ed 10, St Louis, 2003, Mosby.

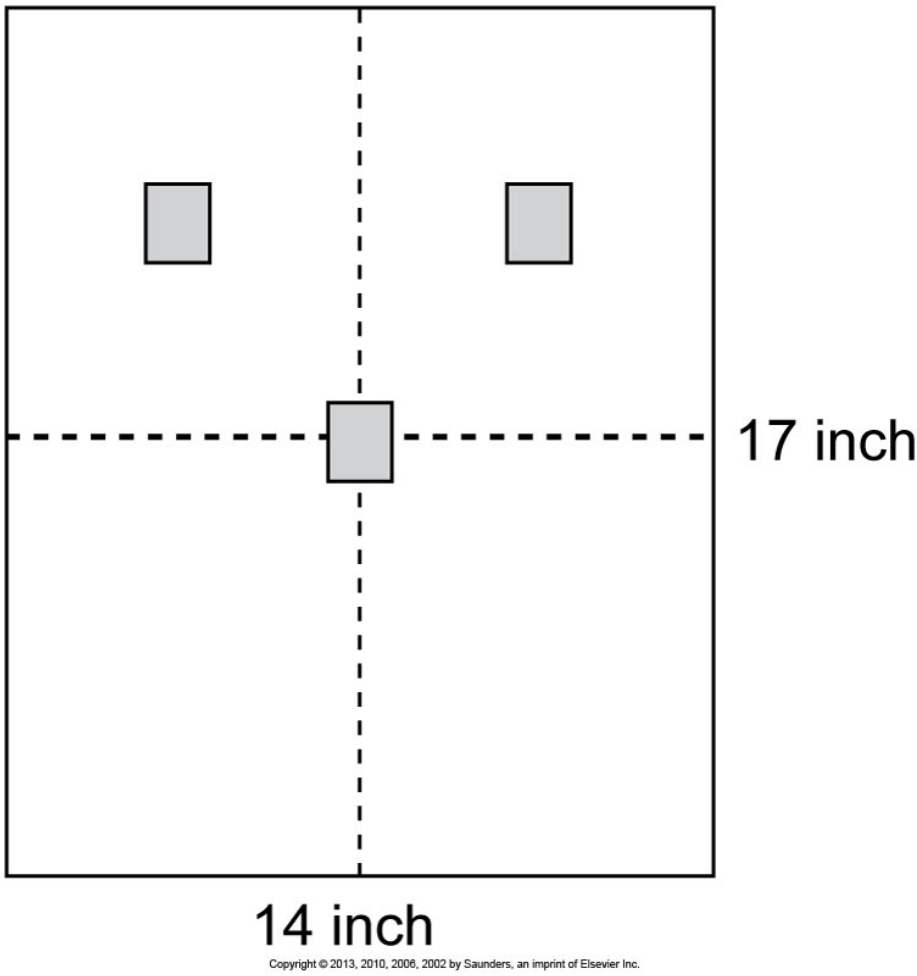
Automatic Exposure Control

- AEC automatically terminates the exposure time when the appropriate amount of radiation has been detected at the IR
- Types
  - Phototimers
  - Ionization chambers



Automatic Exposure Control

- AEC detectors
  - Selection corresponds to body part and IR size
  - Examples: use center detector for knee and the two upper detectors for chest and/or lungs



Automatic Exposure Control

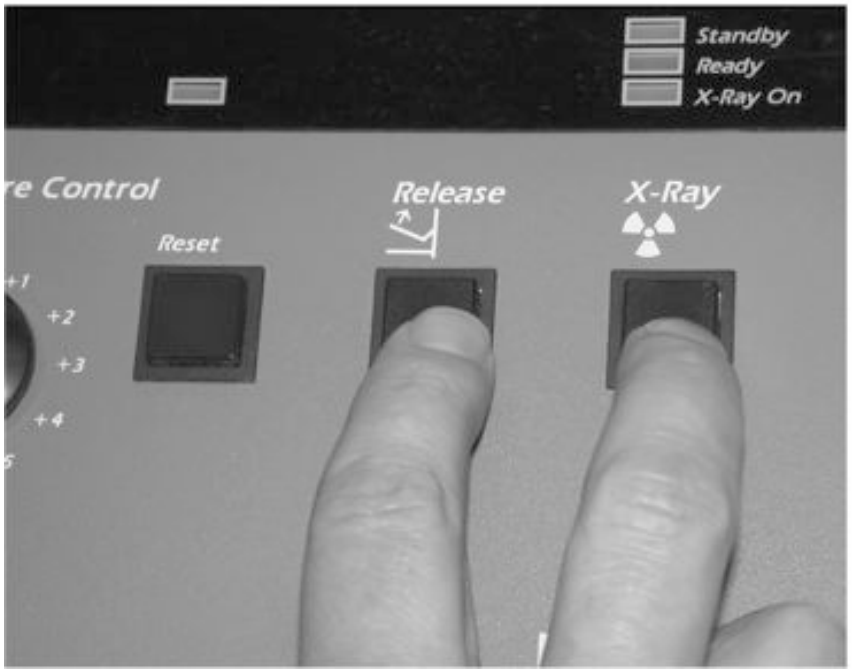
- Backup Time
  - Prevents overexposure by setting a maximum exposure time should the AEC fail to terminate the exposure
  - Is set manually by operator
  - Set backup time at 150% of anticipated exposure time

Anatomically Programmed Radiography Control (APR)

- APR
  - Most widely used electronic technique for exposure control
  - Microprocessor controls the exposure technical factors
  - The exposure technique chart is stored in the computer memory
    - By selecting one or two controls the remaining controls will be selected automatically

Making an Exposure

- Types of Switches
  - Hand held
  - Button or toggle
- Activating Switches
  - Rotor
  - Exposure

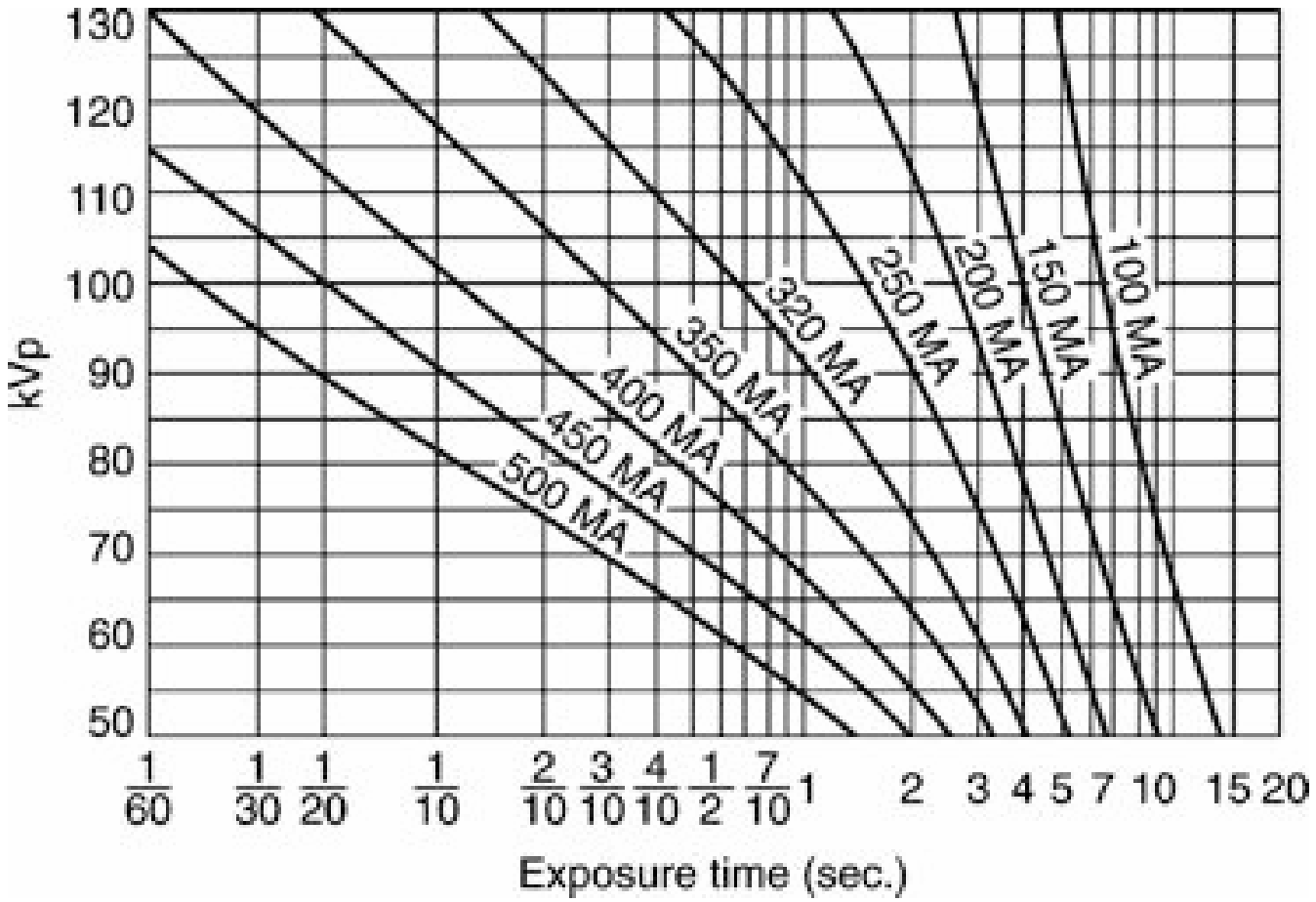


Prolonging X-ray Tube Life

- Warm up cold x-ray tubes according to manufacturer instructions before use
- Do not prolong rotor time
- Avoid making a rapid series of exposures
- Consult the manufacturer's tube rating chart before making an exposure that might exceed the tube's heat loading

Tube Rating Charts

- Indicate maximum exposure values that can be used safely



Heat Unit (HU) Formulas

The maximum heat capacity of the anode is rated in heat units (HU):

- Single-phase: HU = mA x Time x kVp
- Three-phase: HU= mA x Time x kVp x 1.35
- High-frequency: HU = mA x Time x kVp x 1.40

Summary

- The three sections of the x-ray circuit are low-voltage, filament, and high-voltage
- Rectifiers change AC to DC
- Types of rectifiers include half-wave, full-wave, three-phase, and high-frequency

Summary

- Control panels may be conventional or computerized and are used to select mA, kVp, exposure time, and focal spot size
- AEC automatically terminates the exposure when the appropriate amount of radiation has been detected at the IR
- Many causes of tube failure such as excessive and rapid exposures and prolonged rotoring can be controlled by the limited operator