

# William D. Coolidge, and the Modern X-ray Tube

David J. Allard, MS, CHP

August 3, 2016

**AAPM Annual Meeting**  
Washington, DC




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*The author has no conflicts of interest.*




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## Objective of this Presentation

- Honor Dr. Coolidge for his x-ray tube invention
- Give an overview of related x-ray history
- Brief historical review of Coolidge's life
- Note and discuss his major inventions
- Review the various technical aspects with the innovation of the 'hot cathode' x-ray tube
- Illustrate the wide uses x-ray equipment

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## Acknowledgement – Dr. Lawrence Coolidge



1995

He provided a great deal of reference materials on his father.

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## He brought good things to 'light!'



William D. Coolidge

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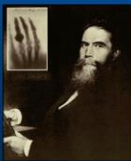
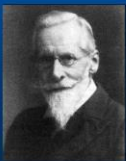
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## History of X-rays & Radioactivity

- Late 1800s Crookes discharge tube, cathode rays
- 1895 Roentgen discovers x-rays
- 1896 Becquerel discovers radioactivity
- c1898 Curies discover Po and Ra




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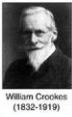
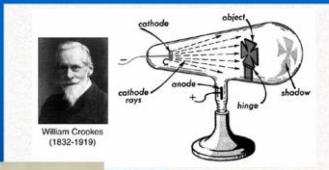
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## Crookes Tube – c1880



William Crookes  
(1832-1919)




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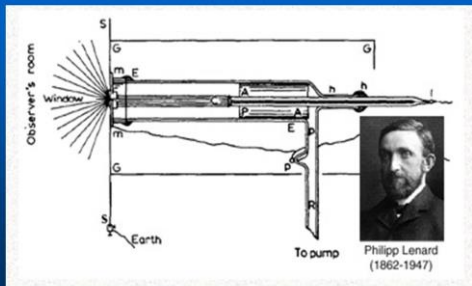
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## Lenard - early 1890s



Philip Lenard  
(1862-1947)

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## Wilhelm Conrad Roentgen Discovered X Rays 1895




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## X ray Discovery November 1895

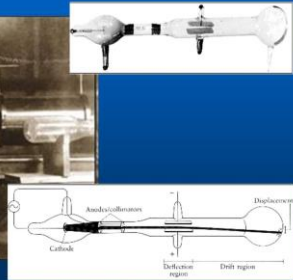
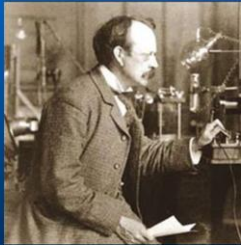


**E**lectric Photography.—It has lately been announced that Professor Hertz, of Würzburg University, has succeeded in taking photographs of objects in darkness, or through opaque screens with the aid of a new or recently invented method. In a word, the new method is as follows:—The object to be photographed is placed in the focus of a very powerful electric spark, and the light which is emitted from the spark is used to illuminate the object. The light which is emitted from the spark is of a very peculiar character, and is called "Hertzian light." It is of a very high frequency, and is capable of passing through opaque screens. The light which is emitted from the spark is used to illuminate the object, and the light which is emitted from the object is used to form the photograph. The photograph is then developed in a special solution, and the result is a photograph of the object in darkness, or through opaque screens.

**T**he New Photography.—On the fourth of January, Professor Roentgen, of the University of Würzburg, announced his discovery of a new kind of ray, differing from any previously known to science. These rays are invisible, they pass with varying degrees of readiness through wood, cardboard, rubber, flesh, glass, and metal, and they produce fluorescence upon striking certain substances and set upon the photographic plate. It is this last fact which is mentioned with the power of the rays to permeate opaque bodies that has created the great popular interest in the discovery.

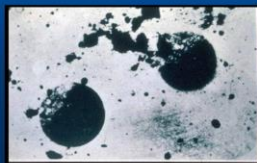
Nearly every one has seen the beautiful light effects produced by sparking electrically through glass tubes from which a portion of the air has been removed. In such a tube the discharge seems to pass mainly from one of the wires leading into the tube to the other leading out; the terminals of the wire in the tube being called the one the anode, the other the cathode. If the vacuum is sufficiently high we have a Crookes tube. In such a tube the discharge does not appear to be straight from the cathode across the tube to a glass at the opposite side. The direction of these rays in a Crookes tube are entirely independent of the position of the anode. These cathode rays have been recognized for a long time, they are visible, but do not pass through many transparent substances and do not pass through some opaque bodies, or screens. The cathode rays are deflected by a magnet, which is not the case with Roentgen's rays. It has not been found possible either

## J.J. Thomson – “Cathode Rays” / Electrons 1897



## PA History of X rays

- Radiograph image of tokens made by A.W. Goodspeed (1860- 1943) and William Jennings (1860-1945). They had made the image by accident in during a Crookes tube demonstration in Philadelphia on February 22, 1890.



## Cold Cathode X-ray Tube (c1896)

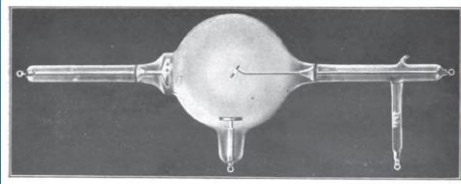


Fig. 9.  
A modern Crookes tube for X-ray work. It is provided with a small side tube which contains a substance which absorbs or gives up sufficient gas to produce most penetrative effects.

r. Compt. Rend 122, 384, (1896).

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Drs. Edwin and Gilman Frost perform the first American medical X-ray in Reed Hall, Dartmouth College on February 3, 1896

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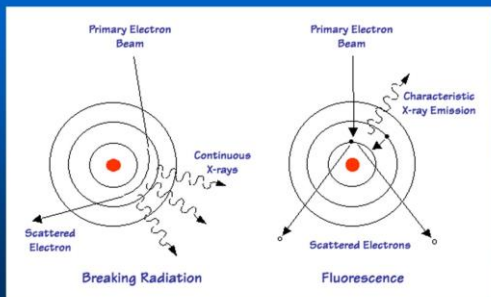
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## X-ray Production




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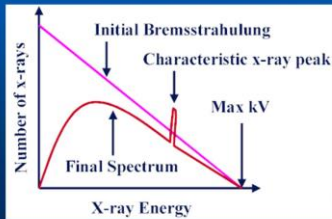
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## X Rays, what are they?

### X-rays

- > Bremsstrahlung, or 'braking' radiation
- > Characteristic




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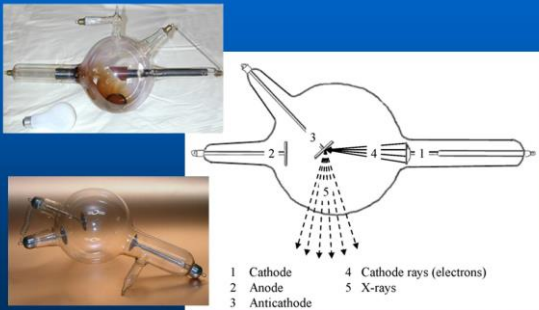
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## X-ray Technology c1900




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## Edison's X-ray Lamp!

### UNITED STATES PATENT OFFICE.

THOMAS A. EDISON, OF LLEWELLYN PARK, NEW JERSEY.

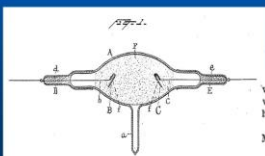
#### FLUORESCENT ELECTRIC LAMP.

No. 865,807.

Specification of Letters Patent.

Patented Sept. 10, 1907.

Application filed May 19, 1896, Serial No. 592,115. Renewed April 29, 1902. Serial No. 105,223.



#### What I claim is:

1. A fluorescent screen or surface composed of tungstate of calcium, substantially as set forth.
2. A fluorescent screen composed of glass with a fluorescent crystalline powder fused thereto, substantially as set forth.

3. A fluorescent electric lamp having in combination a vacuum tube, chemicals placed therein which fluoresce when subjected to the X ray of Röntgen, and electrodes having their centers cut away, substantially as set forth.
- This specification signed and witnessed this 16 day of May 1896.

THOMAS A. EDISON.

Witnesses:  
W. T. MALLORY,  
J. F. RANDOLPH.

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## X-ray Fluoro c1897-1903




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## PA History of X rays

Philadelphia c1900



George Phaler, MD



Figure 6. "Diagraph of a head by Arthur Goodspeed. Nasal bones appear like eyelashes. The cervical vertebrae are distinguishable in the original, but barely so in the halftone. Fillings are located." [28] [7, 8]

work and is a valuable reference source. It contained the X-ray image of a head in Figure 6 by Arthur Goodspeed (1860-1943) of Philadelphia [8].

Arthur Goodspeed, PhD

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## Skin Burns from X rays

### THE AMERICAN X-RAY JOURNAL.

Devoted to Practical X Ray Work and Allied Arts and Sciences.

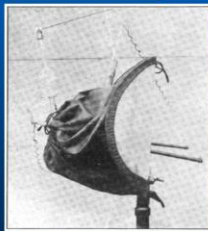
VOL. 8. ST. LOUIS, JUNE, 1901. NO. 6.

#### SHIELD FOR THE PREVENTION OF X-RAY BURNS,

and a  
Dark Chamber for the Tube, Combined.  
BY G. E. FAHLER, M. D.,  
Assistant Chief Resident Physician and Radiographer  
to the Philadelphia Hospital.

The frequency of x-ray burns has been lessened in proportion to our knowledge of the causes producing them. Their insidious onset and obstinate recovery, however, should induce the use of every possible means for their prevention.

For some time past the interposition of an aluminum shield, grounded by a wire to the steam pipe, has been recommended. In this paper I wish only to present briefly a simple and convenient method of applying this principle, which




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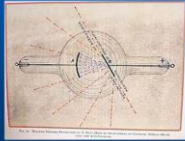
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## PA History of X rays

Patterson fluoroscopes >  
Towanda, PA. c1920



^ "Queen City X-ray"  
Philadelphia, PA c1900




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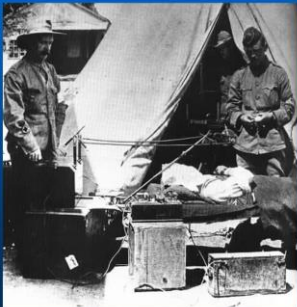
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## X-rays in the Second Boer War S. Africa c1900




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## PA History of X rays

Philadelphia



Dr. Kassabian's x-ray and fluoro lab

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## X-ray Fluoroscopy c1900




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## Coolidge - Early Years & Education



Born in Hudson, MA

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## Baby "Willie" Coolidge - 1874



[Allard Collection - stereo card by RB Lewis]

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## Early Years & Education



Studies Chemistry  
and Physics at  
Boston Tech [MIT]




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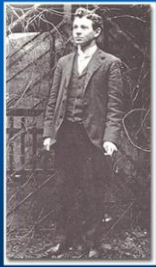
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## Coolidge in Germany



Studies Physics  
PhD in Germany



Universität Leipzig  
founded  
December 1409



Paul Drude

Returns to teach physics at  
Boston Tech [MIT]

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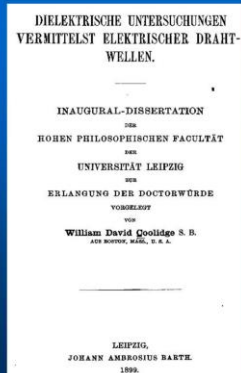
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## Coolidge's PhD Dissertation




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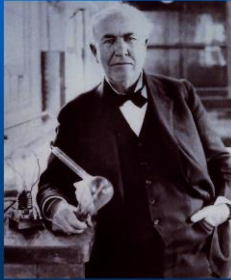
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## Edison – Light Bulb & Fluoroscope




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## GE R&D Lab Early 1900s




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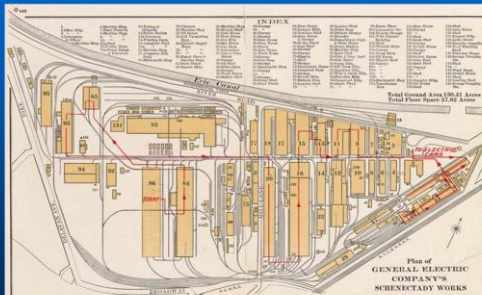
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## GE Company (c1905)




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## Coolidge in Early GE Research Lab



Scanned at the American  
Institute of Physics

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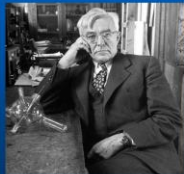
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## J.J. Thomson, I. Langmuir and W.D. Coolidge at GE



Scanned at the American  
Institute of Physics




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## Irving Langmuir



Langmuir and electron tube



Langmuir, Bernard Vonnegut  
and Vincent Schaefer

[Harvard Collection - GE Press photo.]

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## Coolidge, Lawrence and Others at Cyclotron Construction Site



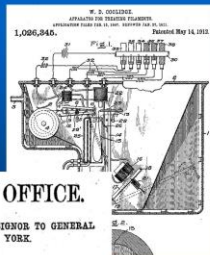
Scanned at the American  
Institute of Physics

## Coolidge's Research & Patents

In the main areas of -

- Tungsten metal processing
- X-ray Tubes
- Electrical applications

## Ductile Tungsten at GE



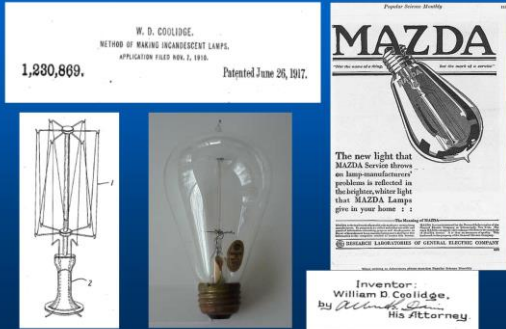
### UNITED STATES PATENT OFFICE.

WILLIAM D. COOLIDGE, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL  
ELECTRIC COMPANY, A CORPORATION OF NEW YORK

#### TUNGSTEN PURIFICATION.

1,026,428. Specification of Letters Patent. Patented May 14, 1912.  
No Drawing. Application filed September 23, 1908. Serial No. 454,450.

## GE - Metal Filament Lights




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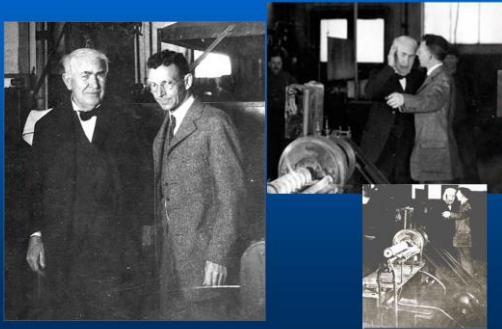
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## Edison & Coolidge c1920




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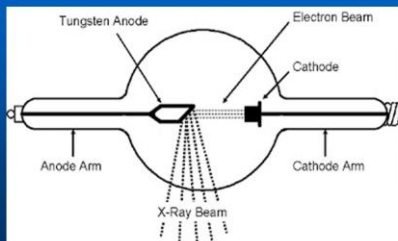
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## Cold vs. Hot Filament X-ray Tubes




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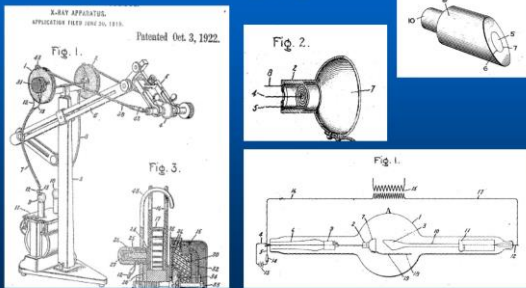
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## Improved X-ray Tube

"Coolidge X-ray Tube" circa 1913




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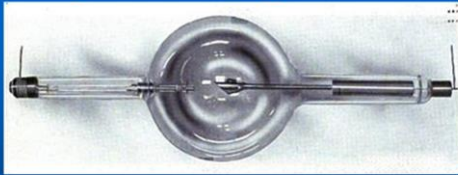
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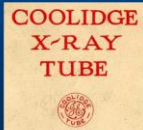
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## Improved X-ray Tube



"Coolidge X-ray Tube" c1915




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## Coolidge X-ray Tube - Major Technological Innovation




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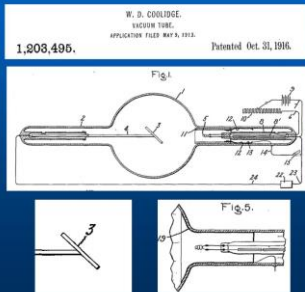
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## "Coolidge" X-ray Tube

Patent issued 10-31-1916



*To all whom it may concern:*  
 Be it known that I, WILLIAM D. COOLIDGE, a citizen of the United States, residing at Schenectady, in the county of Schenectady and State of New York, have invented certain new and useful Improvements in Vacuum-Tubes, of which the following is a specification.

My invention relates to vacuum tubes and more especially to tubes operated for the purpose of producing Röntgen or X-rays. The tube which I have produced differs so radically from the tubes of the prior art used for producing Röntgen or X-rays as to amount not so much to an improvement on prior tubes as to an entirely new variety of tube differing both in its principles of operation and in its operating characteristics.

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## Marie Curie & X rays - WWI




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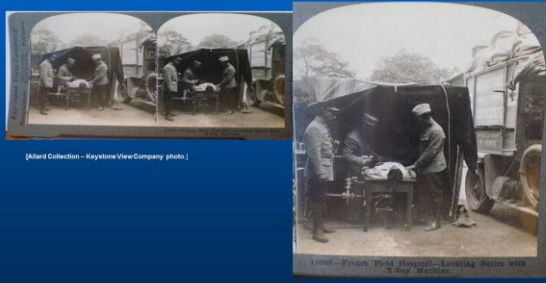
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## WW I French Field Hospital X-ray Set-up




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## X-ray Technology - 1913



W.D. Coolidge c1915  
(Maret Collection - GE Press photo.)

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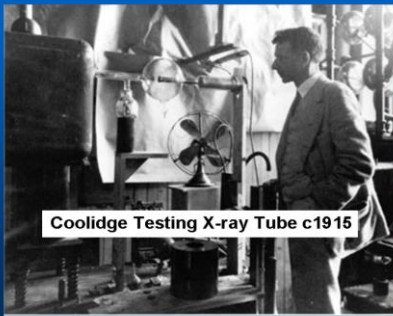
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## GE X-ray Tube Development



Coolidge Testing X-ray Tube c1915

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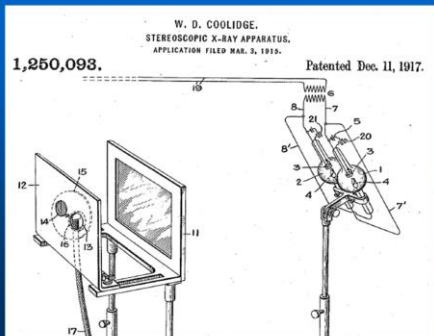
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## Stereo X-ray Apparatus




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## GE X-ray Tube Development



Coolidge with  
circa 1920 Portable  
X-ray Unit

[Allard Collection - GE Press photo and X-ray Unit.]

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## Portable GE "Coolidge X-ray Outfit" c1920



[Allard Collection - GE Press photo.]

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## Portable Coolidge Unit (1935)



AP  
Photo

A committee of doctors examines Max Baer's hands as the result of a New York state athletic commission ruling that he prove them in good shape before his match with Joe Louis on Aug. 22, 1935 is sanctioned in New York. Results of X-ray pictures were not known immediately but doctors said the former champion's fists looked "normal for a fighter." (AP Photo/Murray Becker)

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## 1921 Coolidge Dental Tube



[Harvard Collection - Press photo]

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## Tube in Lead Glass Shield w Window



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## X-ray Tube Manufacture c1925



[Harvard Collection - GE Press photo]

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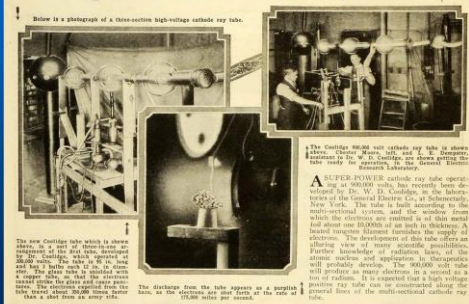
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## GE X-ray Lab (c1930)

### Super-Power Cathode Ray Tube




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## 900 keV X-ray Tube - 1931



[Harvard Collection - GE Press photo.]

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## Coolidge & New 800 keV X-ray Facility in Chicago - 1933



[Harvard Collection - GE Press photo.]

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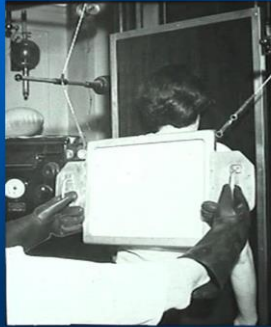
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### X-ray Fluoroscope c1930



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### Chest X-ray Exam c1940



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### Coolidge & New High Voltage X-ray Tube - 1938



[Harvard Collection - GE Press photo.]

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## GE X-ray Tube Development



Coolidge with 1 MeV X-ray Tube

c1935

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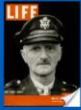
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## Life Magazine 1944



Nearly twenty years ago Dr. **William D. Coolidge**, now G-E vice-president and Director of the Research Laboratory, developed the Coolidge X-ray tube—one of the most important developments of all time in science and medicine. In the years that followed, he and other scientists and engineers worked steadily to improve this almost magical tool of research and healing.



The G-E million-volt X ray cuts from hours to minutes the time required to examine metal parts—from airplane crankshafts to turbine shells.

When you think of it as given by the discovery of X-rays, it is not surprising that the first X-ray tube was made of glass and was operated at low voltages.

But in 1904, when Dr. Coolidge was only 27, he began to think of a way to make an X-ray tube that would be more reliable and longer lasting.

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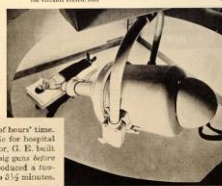
He began to think of a way to make an X-ray tube that would be more reliable and longer lasting.

GENERAL ELECTRIC



## GE Ad c1945

You  
wanted  
weapons  
fast



**Can you name this machine?** By hurrying up war work, it saves millions of hours' time. It's a million-volt X-ray machine originally developed by General Electric for hospital use. This same machine can also "see through" steel. So, since Pearl Harbor, G. E. built 47 more of them to look out possible threats in castings for battleships and big guns before thousands of hours of labor are spent machining them. G. E. has since produced a five-million-volt unit which cuts the X-raying of 8-inch steel from 4½ hours to 4½ minutes.



GENERAL ELECTRIC

FOR VICTORY—BEYOND AND BEYOND

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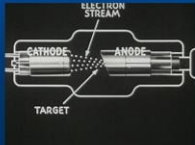
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## X rays in Film c1940

<http://www.youtube.com/watch?v=I3s5HFQ2YME>



On YouTube




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## Coolidge in Lab 1941



[Murd Collection - GE Press photo.]

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## Shoe Fitting Fluoroscope



**CERTIFICATE**

SHOE FITTING TEST DATA FOR

1. ANKLE ROLL GOOD ☐ FAIR ☐ POOR ☐

2. WEIGHT DISTRIBUTION

LEFT RIGHT

RIGHT WAY LEFT WAY

3. X-RAY FITTING TEST

LEFT RIGHT

GOOD FAIR POOR

RIGHT WAY LEFT WAY

This scientific way of approaching the problem of poorly-fitted shoes eliminates guesswork. Now you can see for yourself!

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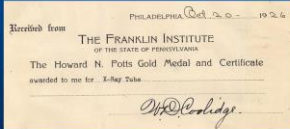
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## Awards, Medals & Honors




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## Coolidge & GM's Kettering, TV Broadcast 1-23-1940



[Alford Collection - GE Press photo.]

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## Coolidge's GE Radio Talk - 50<sup>th</sup> Anniversary of X Rays



< c1930 radio station



[Have a 78 rpm recording made by Coolidge March 1945.]

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## Coolidge, Whitney & Suits c1945



[Altair Collection - GE Press photo.]

THE DEVELOPMENT OF INDUSTRIAL RESEARCH was inspired by policies and traditions established in the General Electric Research Laboratory under a remarkable continuity of leadership. The late Dr. Willis R. Whitney (right) founded the laboratory in 1900. He was succeeded in 1932 by Dr. William D. Coolidge (left). Dr. Guy Suits (center) became director in 1945.



Painting by Normal Rockwell (c1955)

## 50<sup>th</sup> Anniversary of Modern X-ray Tube



1963



## In Retirement

c1950



c1970 &gt;

&lt; c1960




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## AAPM Coolidge Award



*American Association of Physicists in Medicine*

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## AAPM's 1<sup>st</sup> Coolidge Award

1276 J. S. Loughlin and P. N. Goodwin: History of the AAPM: 1956-1988



Fig. 17. In July 1972 the Coolidge Award was formally presented to Dr. William D. Coolidge at Schenectady, NY. The presentation, which formalized the award made by the AAPM, is being made by Mr. Vincent D. Masti of the General Electric Research and Development Center.

Fig. 18. William D. Coolidge on the cover of September 1973 issue of the AAPM Quarterly Bulletin.

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## Coolidge at 100!



[Allard Collection - GE Press photo.]

GE R&D  
Center

A.M. Bueche

C.G. Suits

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## Coolidge at 100!

From: Public Information  
GENERAL ELECTRIC RESEARCH AND DEVELOPMENT CENTER  
Schenectady, New York

Photo No. RDC 19,463

October 23, 1973

CENTENARY CELEBRATION. Dr. William D. Coolidge, famed inventor of the ductile tungsten used for filaments in virtually all electric lamps and of the Coolidge X-ray tube which made possible modern medical and industrial X-ray technology, observed his 100th birthday in Schenectady, N.Y., on October 23. Dr. Coolidge joined the staff of the General Electric Research Laboratory in 1905, and was its director from 1932 to 1945. He was succeeded by Dr. C. Guy Suits (right), director until 1965, and by Dr. Arthur M. Bueche (left) who became General Electric's vice president for research and development when Dr. Suits retired. The birthday cake was lighted with 100 ductile-tungsten lamps and topped by the target from an early Coolidge tube encrusted with 100 tiny diamonds surrounding one of GE's large laboratory-made gem diamonds.

[Allard Collection - GE Press photo.]

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## 1975 Obit



[Allard Collection - AP Press photo.]

(AP 23) SCHENECTADY, N.Y., Feb. 4--SCIENTIST DIES--Dr. William D. Coolidge, credited with developing the X-ray tube and the ductile tungsten filament used in modern incandescent electric lamps died Monday night at his home in Schenectady. He was 101. Coolidge was director of the General Electric Co. research laboratory from 1932 to 1945. (AP Wirephoto) (a/s/mh/25/0000) 1975 end: a 1971 photo.

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## R.I.P. Dr. Coolidge!



1975

You were a "super man" with an x-ray vision!

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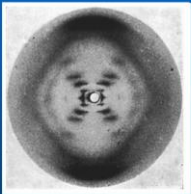
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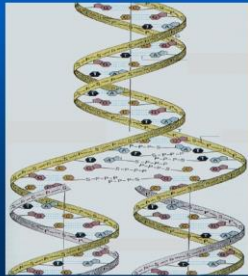
## X-ray Diffraction



Rosalind Franklin

James Watson and  
Francis Crick< Photo  
No. 51

Used to discover structure  
of deoxyribonucleic  
acid (DNA)




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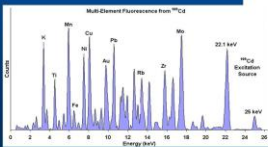
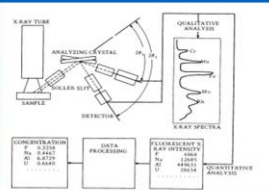
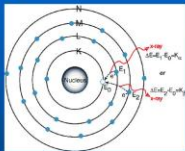
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## X-ray Fluorescence Spectrometry




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## X-ray Industrial Radiography



Vincent Roding  
(1976)  
NDT of  
Liberty  
Bell >



**GLOBAL**  
X-RAY & TESTING CORP.




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## Industrial X-ray Radiography c1960




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## Airport Security X-ray Baggage Scanners c2002




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## Backscatter X-ray Security System c2012




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## Dental X-ray Equipment




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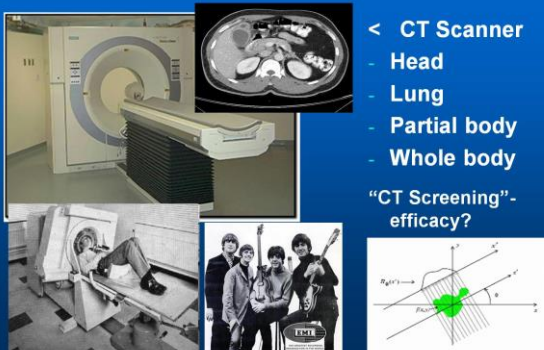
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## Medical Uses of Radiation



### < CT Scanner

- Head
- Lung
- Partial body
- Whole body

"CT Screening"-  
efficacy?

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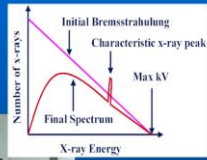
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## Medical Uses of Radiation

### Diagnostic X-rays

- > Radiography
- > Fluoroscopy




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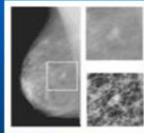
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## Medical Uses of Radiation

### Mammography




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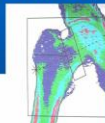
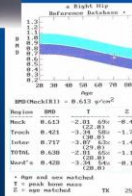
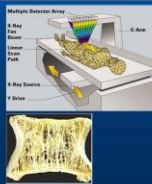
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## Medical Uses of Radiation

### Dual Energy X-ray Bone Densitometry




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## Medical Uses of Radiation

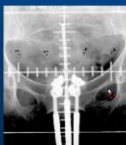
### Radiation Therapy



< Photon  
< Electron  
Proton >



eBrachytherapy >




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## Contact info -

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PA DEP, Bureau of Radiation Protection  
PO Box 8469  
Harrisburg, PA 17105-8469

Tel: 717-787-2480

E-mail: [djallard@pa.gov](mailto:djallard@pa.gov)

Web: [www.dep.state.pa.us](http://www.dep.state.pa.us)

key word "radiation"




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**Thank you!**

**Questions?**



**"Smile and say – X ray!"**

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