High Voltage X-rays

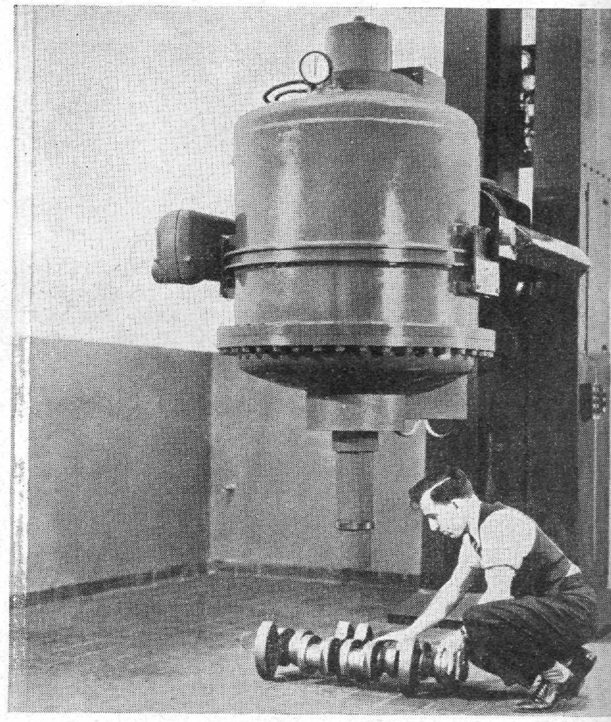
By WILLIAM HORTON, Eng. I

Pictures by courtesy of General Electric Co.

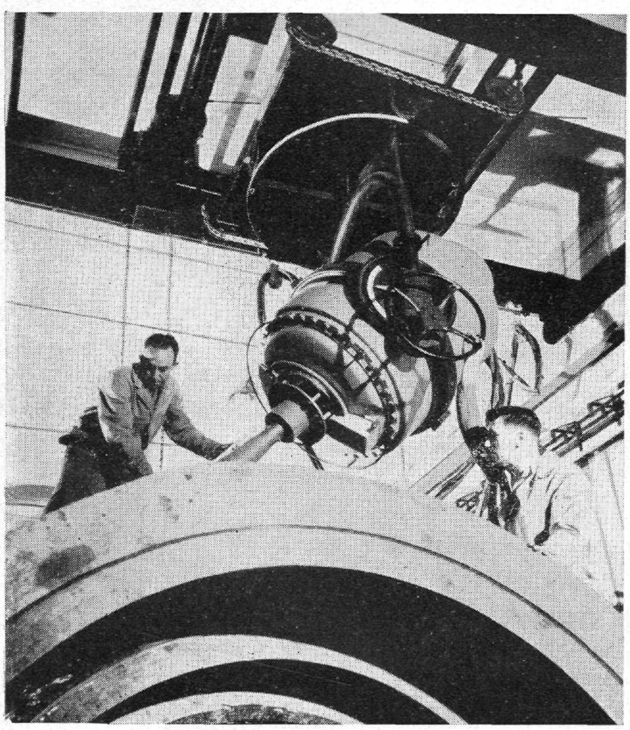
Hidden back in one corner of the basement of Mendenhall Laboratory of Physics is one of the most interesting sights on the Ohio State University campus. It is the high-voltage X-ray machine, used for experimental purposes by the Department of Physics.

Upon entering the little room in which the X-ray equipment is enclosed, one has the impression of being crowded out by a mass of electric equipment. On the left are tables strewn with graphs, notes, X-ray pictures, samples to be photographed, and stray pieces of machinery. On the right is a maze of machinery, instruments, dials, wire. The ceiling is practically covered with lines of red rubber hose and more wire. Where, you wonder, is the X-ray tube? Well, the fact is that the tube itself is only one small part of the elaborate machinery necessary in the complicated process of X-raying a substance.

Professor F. C. Blake of the Department of Physics is in charge of the X-ray equipment and of all experiments conducted with it. He is ably assisted by L. D. Ellsworth, Ph.D., Dean Rogers, A.B., M.S., and Jesse Green, a government employee who is electrician for the X-ray department.



Positioning crankshaft for picture with same equipment as in first picture

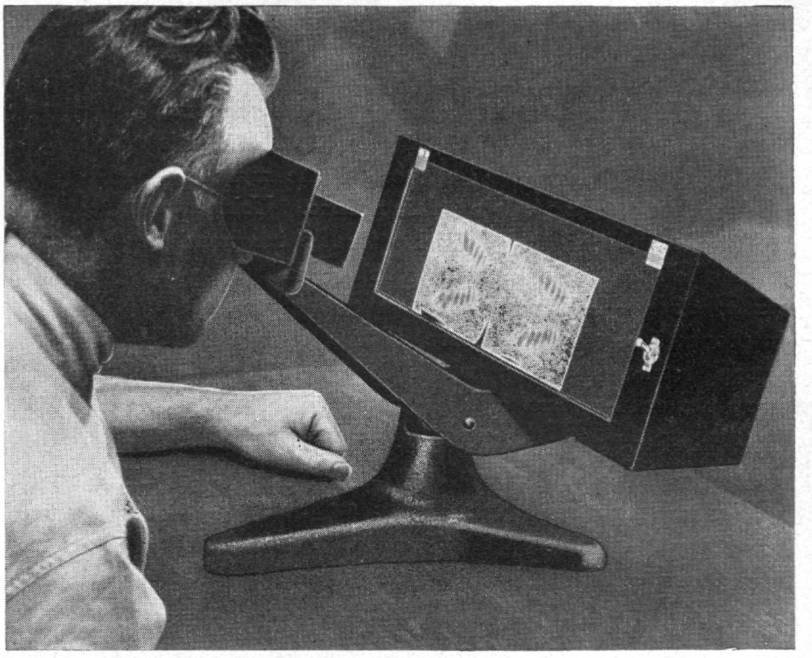


Preparing for an inspection of a casting using 1,000,000-volt G. E. X-ray tube at a 45 degree angle

The X-ray equipment includes a motor-generator set run by a DC dynamo, the generator developing a 500 cycle AC current. This current passes to several transformers hooked in series, which convert the power at 500 cycles to power at higher voltage (up to a maximum of 200,000 volts). Since a very smooth current with few irregularities is required in the operation of an X-ray tube, the current passes into the Kenetrons, and thence to the condenser, both of which instruments serve to rectify the current. It is still further smoothed out by passing through a choke, an inductance coil connected in series.

When the current leaves the choke it is smooth enough to operate the tube, and the low voltage end is connected directly to the cathode of the tube. The high voltage end of the choke is connected to a 110 volt stabilizer, which is, in turn, joined to a filament control and filament transformer. From this transformer the current travels through the X-ray tube and then through a milliammeter between it and the ground.

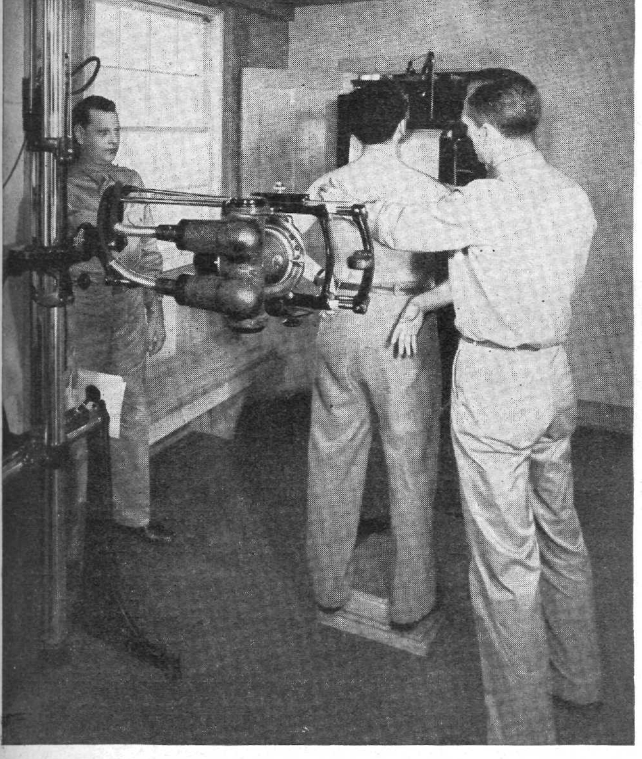
The X-ray tube (sometimes called the Coolidge tube for William D. Coolidge, the inventor of the



THREE-DIMENSIONAL X-RAY IMAGES

Greater accuracy in tuberculosis case finding is now provided by new accessories permitting stereoscopic photo-roentgenography. Two 4-by-5-inch photo-roentgenograms can be taken of the same chest on a single 4-by-10-inch film. They are then viewed with a special orthostereoscope which brings the chest pattern into perspective as a three-dimensional image.

most efficient types) used by the Department of Physics is a highly evacuated glass bulb about 22 inches in length, with electric contacts on each end. The cathode is a fine, coiled filament of tungsten or molybdenum, and the anode is a truncated cylinder of solid metal. In use, the filament is heated to such an extent that the metal actually vaporizes and electrons are emitted. These electrons are attracted to the anode, due to the great difference in potential, and strike it with great force, thus generating X-rays.



X-ray in use at Ft. Jay

Considerable heat is also created, due to the velocity with which the electrons strike the block of metal; this naturally is one of the problems to be overcome in experimenting with X-rays. Today the effects of the heat are reduced by evacuating the tube very highly (the principle utilized in electric light bulbs), or cooling the anode with water supplied by great lengths of grounded rubber tubing. (Three hundred feet of hose is needed to cool this tube.) This removes the heat, but the fact still remains that much of the energy of the electrons is being wasted generating this heat.

Since lead is impervious to X-rays, the Coolidge tube is enclosed entirely in a lead box with only one outlet, a small slit.

Through this small opening the rays are directed through two more slits mounted on a Bragg spectrometer. A lead plate is placed in such a position that it intercepts any stray rays which might prove injurious to an observer.

In line with the three slits, a briquette of extremely fine particles of the substance to be X-rayed is placed. It is inclined at an angle (called the "glancing angle") to the path of the rays, in such a way that the rays are deflected into an ionization chamber. This ionization chamber is filled with air and a dense gas, usually ethyl bromide. Here the ionization takes place and the electrons flow into an F. P. 54 tube, striking a grid and upsetting an electrical balance which existed there (similar to the Wheatstone bridge) thus creating a current which is proportional to the ionization current, but greatly magnified. This current is then conducted to a very sensitive galvanometer, in which is mounted a mirror. As the current varies, the mirror is turned at different angles, thus reflecting onto a meter stick a beam of light which is focussed on the mirror. A reading may then be taken where the light makes a fine line on the meter stick. This reading is then substituted in Bragg's Law: n y = 2d sin f, where "n" is the order of the spectrum, "y" is the wave length of the X-ray, "d" is the distance between the rows of an atom in the crystal lattice, and "f" is the angle of incidence. Using the information thus derived, much valuable information about the X-rayed material may be accrued. The intensity of the X-rays, as read on the galvanometer, is proportional to the square of the so-called "reduced" structure-factor, which is itself dependent upon the arrangement of the atoms in the crystal.

If an X-ray picture of a substance is desired, the procedure is altered somewhat. The Bragg spectrometer, including the two slits, the mounting for the briquette, the ionization chamber, and F. P. 54 tube, is removed, and in its place is put a small cylindrical camera, about one inch high and three and a half inches in diameter. In the center of the camera stands a very fine wire coated with minute particles of the substance to be X-rayed. The X-rays from the slit of the lead box enclosing the tube enter the camera through a small pin-hole and strike the particles on the wire. They are reflected from these particles onto a film which is bent in a semi-circle around the inside of the camera in back of the wire. The X-rays affect the film in the same way that visible light rays would, and information regarding the tensile strength and other factors may be judged from the appearance of the lines of light on the film. This is called the Laue process and the pictures Laue diagrams.

If a picture is to be taken of a casting, weld, or sheet of metal in order to detect flaws, the metal is simply placed in the path of the rays and a camera behind the metal, also in line with the rays, and the picture taken. With this machine a picture may be taken through 6 inches of steel.

The X-ray is still in its infancy. Every day steps are being made forward in improving the present machines. Until recently, million-volt X-rays were obtainable only with the most elaborate equipment, and were used in a few hospitals for cancer treatment. Extensive industrial use of such high-power X-rays has become possible with the development of equipment which is, relatively, as compact as a dentist's X-ray apparatus. The newest type million-volt X-ray unit weighs 1500 pounds and is easily handled in plants where large castings are swung around on cranes without difficulty.

The X-ray is already an indispensible part of our civilization and its possibilities are unlimited. Realizing this, the Department of Physics looks forward to building an even more powerful and modern machine than the present one as soon as funds are available.