calculated to have a threshold of about 3·8 MeV. No search has yet been made for α-particle emission, but a preliminary search for neutron emission, using a boron trifluoride counter with paraffin wax moderator, has failed to detect the presence of neutrons, and no activity of long life corresponding to the formation of arsenic-74 has yet been observed on the irradiated targets.

D. R. Chick
S. E. Hunt

Research Laboratory,
Associated Electrical Industries, Ltd.,
Aldermaston, Berkshire.
March 21.

[1] Chick, D. R., and Petrie, D. P. R., *J. Inst. Elect. Eng.*, B, **103**, 8, 132 (1955).
[2] Hunt, S. E., Petrie, D. P. R., Firth, K., and Trott, A. J., *J. Inst. Elect. Eng.*, B, **103**, 146 (1955).
[3] Hunt, S. E. *Proc. Phys. Soc.*, **65**, 982 (1952).
[4] Tangen, R. K., *Norske Vidensk Selsk.*, Skr. No. 1 (1946).
[5] Wapstra, A. H., *Physica*, **21**, 5, 385 (1955).

## X-Ray Radiation Hazard using Vacuum Deposition Plant

It has been shown in a recent report by Strachan and Harris[1] that a sputtering plant operated at voltages as low as 8–10 kV. can give rise to X-radiation which can be dangerous to the operator. This observation was made with an apparatus different from the two-electrode system used for the deposition of thin films. Their apparatus consisted of a glass vessel in which positive ions formed in a discharge between an oxide-coated cathode and iron anode were accelerated to a target used for sputtering. It was shown that the X-rays arose from secondary electrons emitted from the target bombarding the walls of the glass envelope. It was possible to operate the main sputtering chamber at a lower gas pressure than normal because the ions were formed in an auxiliary discharge. Thus, the secondary electrons were able to reach voltages comparable to that of the ion-accelerating potential because of their long mean free-path. In a glow discharge the secondary electrons are required for ionizing the gas molecules and their final voltage is not that of the applied potential. Thus it is uncertain whether the results of Strachan and Harris would be directly applicable to a normal two-electrode system with a cold cathode operated at 8–10 kV.

Since the above report was published, I have received several queries as to whether X-radiation is emitted from normal vacuum deposition plant, and after discussion with workers at the Research Laboratories, General Electric Co., Ltd., it was decided to make radiation tests to ensure that such apparatus was safe. Radiation tests were made with Ilford *PMI* film in standard monitor holders using different types of deposition apparatus as described below.

It should be noted that the voltages given below for both the a.c. and d.c. high-tension supplies are root-mean-square values and the peak voltage encountered will be about 1·4 times the quoted values.

Initial tests were made with a cathodic sputtering apparatus and an electron-bombarded vapour source operating at voltages up to 4 kV. inside metal vessels with observation ports of plate-glass 9 mm. thick. In neither case did the monitor film show X-ray exposure after ten hours operation.

Work was then extended to apparatus operating at higher voltages inside glass vessels, such as that used for ionic-bombardment cleaning of glass before evaporation of thin films. At one time it was customary to use for this purpose high-reactance transformers giving some 10 kV., and as the discharge approached the 'blackout' condition the applied voltage rose to nearly the open-circuit value. In the vacuum apparatus at present designed by this Company, the maximum voltage used is 5·5 kV. and this is within the safe limit found by Strachan and Harris. However, it was of interest to know whether early vacuum plants were free from hazard.

A high-tension transformer giving 10 kV. open-circuit voltage was connected to two vertical electrodes insulated from earth and made from aluminium strip inside a 'Pyrex' bell-jar 18 in. diameter by 24 in. high. The wall thickness of the vessel was about 8 mm. Two test films were placed on the side of the vessel and one at a distance of 6 in. from the vertical side. The glow discharge was operated at 7 kV. and 8 m.amp. for 11½ hr. without X-ray exposure being observed. Two 10-kV. transformers were then connected with their output terminals in series and the apparatus again run for 8 hr. at 18–20 kV. and 20 m.amp. Again no X-ray hazard was observed.

Mr. Ball (G.E.C.), who kindly examined the monitoring film used in these tests, considers that if X-radiation was being generated then the energy was insufficient to penetrate the chamber walls. He states that a voltage of about 16 kV. is necessary for X-rays to penetrate 8-mm. thick 'Pyrex' glass in measurable quantities. This voltage would, of course, refer to electrons which struck the target, etc., with an energy equal to the applied potential, as must have occurred in the apparatus of Strachan and Harris, or could occur in thermionic devices operated at low gas pressures (for example, an electron-bombarded vapour source).

Acknowledgments are made to the Research Laboratories, General Electric Co., Ltd., for the help given in the tests and to Mr. A. S. D. Barrett, technical director of Edwards High Vacuum, Ltd., for permission to publish this communication.

L. Holland

Research Laboratory,
Edwards High Vacuum, Ltd.,
Crawley, Sussex.
May 10.

[1] Strachan, J. F., and Harris, N. L., *Nature*, **178**, 588 (1956).

## Thallium-activated Sodium Chloride Recrystallization Phosphors

Investigations have been carried out with sodium chloride disks prepared in a pressure-range of 1,000–20,000 kgm./cm.². A few drops of an aqueous solution of thallium chloride were mixed with the sodium chloride powder before pressing. After ultra-violet excitation, the disks showed a good phosphorescence with a decay time of several minutes. The measurements were carried out with an *RCA* multiplier-tube type 931*A* and galvanometer.

Earlier optical and conductivity measurements showed that recovery takes place after the disks had been prepared. This recovery process can also be observed with the luminescent disks: the total light radiated gradually decreases with time.

After heat treatment of the luminescent disks, the total light radiated decreases with increasing tem-