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THE USE OF THE 20,000-VOLT BETATRON IN INDUSTRIAL RADIOGRAPHY

by

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The Allis-Chalmers Manufacturing Company has been fortunate in having the association of Dr. Don W. Kerst, Dr. G. M. Almy and Dr. Gale D. Adams of the Physics Department of the University of llinois, because it is through the efforts of these men and their aff that the Betatron has been brought to its present stage of de lopment. The electron accelerator offered so many advantages in inc trial radiography that it drew the attention of all persons who were aced with inspection problems which could be solved by super-volta X-ray examination. It became necessary to build a series of these chines to serve in research laboratories and also ordinance inspectin units and the experience and engineering technique which has been developed by the Transformer Manufacturing Division of our company, mate possible the production of these units which could be used in the armaments program which took place during the last few years. The electronic circuits of the Betatron and the specifications for the design are products of the Physics Department of the University of Illinois, and no industry can claim the major contributions which have made possible the development of this device.

As we approach a peacetime program of manufacture, we see the need of using this instrument for inspection purposes and also for medical research and medical therapy.

The development of such a tool for industrial applications required an engineering program which would simplify the instrument and make possible its operation by an industrial radiographer who would not necessarily have a background of experience and training in the physics research laboratory. Fortunately, it has proved possible to do this and the instrument in its present stage of development may be operated by one person who will require only the assistance of others in handling the material which is to be inspected and placing it in the Betatron beam.

It is out of place at this time to review the preliminary biological evaluation of this device, but it may be said that it will give to the medical therapist a source of X-rays which produce their greatest ionization intensity and their greatest destructive effect in living tissue at depths below skin surface which are far greater than has been observed with low voltage radiation. We are certain that techniques will be developed using this instrument which will have many advantages when placed in the hands of the cancer therapist.

The accelerated program of armaments manufacture made necessary y the recent war has forced us to take the time to study the applications of the Betatron to industrial radiography.

A series of experimental models which have been used for investigations of absorption coefficients and experimental radiography has yielded data which makes possible a true evaluation of the Betatron when compared to other types of X-ray sources. We may take the absorption curve for iron for purposes of illustration and show that the maximum absorption of X-ray radiation occurs when the electron energy producing the radiation lie in a range between four and six million electron volts. As the energy of the electron stream increases, there is a gradual rise in the absorption value which seems to be continuous throughout ranges of energy which have been explored. To the industrial radiographer, this means that a maximum of energy in the X-ray distributed in the ranges of 4 to 6 million electron volts will be most efficient and time saving in the radiography of thick specimen of iron, steel and various alloys.

An extended program of investigation has shown that a maximum distribution of energy within the desired range can be best obtained by employing a betatron designed for maximum energies of 18 to 22 million volts. Such instruments radiate energy in accordance with an intensity distribution curve which is high at the useful ranges of 4 to 6 million electron volts.

When the intensity curve of the 20 million volt electron accelerator is compared with similar curves obtained from machines of lower and higher energy, we conclude that the 20 million volt machine combines the advantages of being practical and economical in its construction with a high yield of energy in the most useful range. An accelerator which is constructed for a maximum of 4 million volt electrons yields an intensity curve which shows a small amount of radiation in the desirable range with a rapid rise in intensity in the ranges which are more practically covered by standard X-ray radiators which are now used for radiography. The intensity curve of accelerators operating in ranges extending to 50 million electron volts show no significant gain in intensity within the critical range and the cost of construction such machines make impractical their use for industrial inspection purposes.

The high energy X-radiation emerging from the vacuum tube of a betatron is confined to a cone shaped beam. The electron energy determines the width of the cone and as the energy of the electron is raised, the cone of the useful radiation becomes more narrow and is limited to a smaller area. The useful radiation from the 20 million volt electron accelerators covers a circular area having a diameter that is approximately one-fifth the distance from the X-ray target to the specimen. Machines having lower energy characteristics will produce a wider area of useful radiation but they show the great disadvantage of producing the maximum portion of their energy within the ranges of the absorption curve in which there is a great amount of energy absorption and, as a result, very little energy reaches the X-ray film to produce the latent image.

This means that with low energy machines, we may expect longer exposure requirements and a limitation is placed on the thickness of the specimen which may be radiographed.

Industrial radiographers are familiar with the advantages of radiators which have small focal spots. A small point source of x-radiation will yield an image on the film which is sharply defined and distortions in the image of sections which are remote from the film are reduced to a minimum. It has proved practical to employ a target which has a width of less than .010 of an inch in the 20 million volt electron accelerator and the length of an effective target may be estimated to be less than .008 of an inch. This is certainly the smallest focal spot which has been employed in industrial practice.

Conclusion

1. It has proved practical to employ the 20 million volt electron accelerator for the inspection of specimens of various alloys with a range in thickness between 4 inches and 18 inches. Copper alloys may also be successfully inspected.

2. Employing the most conservative techniques, exposure time requirements of 18 inches of steel will be less than 20 minutes and laboratory experiments have shown excellent results with high speed technique which yield satisfactory film in 6 minutes. The exposure time requirements for specimens ranging in total thickness from 6 to 14 inches is less than 15 minutes.

The smaller focal spot of the Betatron makes possible a high order of definition of the radiograph. A sharp shadow is reproduced of those elements of the subject which are remote from the film and the interpretation of the radiograph is made very easy.

4. The 20 million volt Betatron has almost absolute sensitivity in that it will reveal the same sized flaw in a specimen regardless of the thickness of the specimen within the limits of the capacity of this machine. This means that a .030 of an inch crack or cavity may be detected through five inches of steel or through eighteen inches of steel.

5. The major portion of the energy of radiation is confined to the cone shaped beam, and this fact simplifies the problem of protecting the personnel in the vicinity of the device. Adequate insulation may be provided by solid block concrete walls erected around the three sides of the machine and special heavy insulation is required only in the direct beam path.