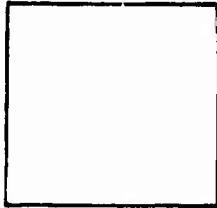


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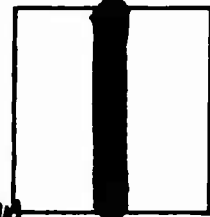
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WATERTOWN ARSENAL
WATERTOWN, MASS
LABORATORY

143/27

ULTRASONIC FLAW-PLOTTING EQUIPMENT

A NEW DEVELOPMENT FOR
ORDNANCE CORPS TESTING

8 June 1954

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INTRODUCTION

Intensive investigations of ultrasonic testing techniques and principles have been under way at Watertown Arsenal Laboratory for approximately ten years since the introduction of the pulsed echo technique by Dr. F. A. Firestone. The studies involved have been focused on potential Ordnance applicability of these techniques as a means for solving inspection problems and as a means for providing more reliable, rapid and economical techniques and equipment for the evaluation of Ordnance materiel. As a result of these investigations, it was concluded that ultrasonic testing as practiced during the last 10-year period was severely limited for Ordnance application for two important reasons:- First, ultrasonic energy was introduced into metals to be examined by placing a quartz crystal transducer directly in contact with the metal surface, employing as an acoustic coupling a film of oil or other surface-wetting material. Because of the intimate contact required between the crystal transducer and the surface of the material, only reasonably smooth surfaces could be tested and, hence, a large proportion of Ordnance inspection could not be performed. This may be referred to as the "rough surface problem". Secondly, the results of ultrasonic tests were presented on a cathode-ray oscilloscope screen in such a form that extensive training and experience on the part of the test equipment operator were required for intelligent interpretation of test results. Actually, it was felt that, for proper

utilization of existing ultrasonic equipment on Ordnance problems, the inspector or test equipment operator must have considerable knowledge of electronics, acoustics, and metallurgy. Since this situation appeared to be associated primarily with the interpretation of the cathode-ray presentation of ultrasonic echoes, it was referred to as the "data presentation problem".

In spite of the above limitations of ultrasonic techniques, it was felt that they offered potent advantages which might be realizable for Ordnance testing problems through developmental work devoted to overcoming or minimizing the limitations. The advantages might be enumerated briefly as (1) relatively inexpensive equipment cost; (2) virtually no installation expense; (3) test data obtained extremely rapidly; (4) little, if any, limitations on thickness of material which can be examined, (5) adjustable sensitivity or test severity; and (6) extremely high flaw sensitivity available when required. A comparison of the above advantages with other methods for testing Ordnance materials strongly emphasizes the advisability of developmental work to make this test available for Ordnance use, for example, magnetic tests are severely limited in their ability to detect deep-seated flaws. Radiography, the only other reliable method for subsurface flaw detection, is severely limited in its depth of penetration, requiring extremely expensive equipment and installation to penetrate steel thicknesses greater than 3 or 4 inches. Even when such radiographic equipment is available, the severity of

test cannot be readily adjusted; the test is time consuming and maximum sensitivity attainable is low compared with ultrasonic techniques. While there is no thought involved here that ultrasonic testing can or will make radiography obsolete for Ordnance testing and inspection, it has been felt for some time that there is a sufficient number of Ordnance testing problems which can be better solved by ultrasonics than by radiography to warrant a considerable expenditure of effort in this direction. It is the purpose of the following discussion to indicate the progress which has been made as a result of such effort.

ULTRASONIC FLAW-PLOTTING EQUIPMENT

In February 1951, Electro Circuits, Inc., Pasadena, California, proposed means for overcoming the two limitations cited above, namely: the "rough surface problem" and the "data presentation problem". Watertown Arsenal Laboratory accepted the Electro Circuits proposal, which resulted in the delivery of an ultrasonic flaw-plotting equipment, the breadboard model which is now undergoing extensive evaluation study to determine its applicability to Ordnance inspection problems. Initial attention is being devoted to the applicability of such apparatus to the examination of thick armor castings, for which testing problem this equipment is felt to be uniquely advantageous.

It should be repeated that metal thickness is basically no problem for ultrasonic testing. The flaw-plotting equipment is designed to function on thicknesses from 1/2" to 6". The upper

thickness limit can readily be increased by slight design modification. The problem of examining materials having rough and as-cast surfaces has been overcome by mounting the crystal in a nozzle 1 1/2 inches from the material being inspected and coupling the crystal acoustically to the specimen with a water stream. Actually, this water stream permits the realization of the advantages of immersed ultrasonic testing without the attendant awkwardness associated with the immersion of extremely large castings. The data presentation problem has been solved by employing two pictorial or flaw-image displays. In the past, ultrasonic information has been presented on an "A-Scope" (Figure 1a). The Watertown equipment is capable of a much cleaner A-Scope presentation than prior equipment, as is shown in Figure 1b, due to advanced design of the electronic receiver and advanced concepts of crystal transducer operation. These improvements permit the detection of flaws much closer to the front surface of a casting than previously possible and also the individual detection of multiple flaws lying close together in the thickness of the specimen. These, in themselves, represent major improvements over previous equipment and techniques.

In addition, the Watertown equipment provides a cross-section view of the interior of castings being examined (Figure 2), which permits the location of a flaw in the depth dimension relative to the front surface of the test specimen, and a plan view (Figure 3), which provides information regarding the area and shape of the flaw

in a plane parallel to the inspection surface. The sketches referred to above simulate actual photographs taken of the image display tubes during the testing of a specimen.

It has been felt that the ability of the radiographic method to present flaw images by which the size and shape of flaw can be employed as a means for distinguishing between one type of flaw and another is of tremendous advantage for the examination and acceptance testing of cast armor. Based on this thinking, the advantage of ultrasonic flaw images can be readily appreciated both from a point of view of flaw recognition and ease of inspector training. Of course, the additional information regarding depth of flaw below surface is readily obtainable from the ultrasonic equipment.

While the ultrasonic apparatus presently being studied is a breadboard model of the ultrasonic flaw-plotting equipment, the advantages originally sought in connection with its development have been dramatically illustrated through its early use. It is anticipated that a continuation of this evaluation will result in the specification and procurement of a production prototype equipment for the examination of thick armor castings.

WATERTOWN ARSENAL LABORATORY NON-DESTRUCTIVE TEST SECTION

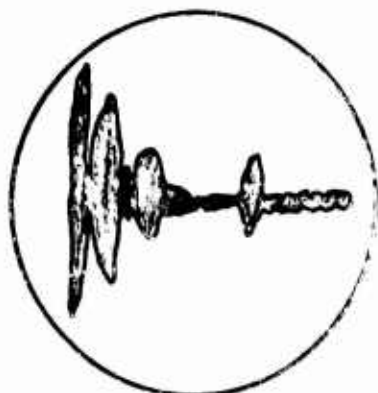


FIG. 1A - CONVENTIONAL (REFLECTOR) PRESENTATION OF ULTRASONIC ECHOES.



FIG. 1B* - IMPROVED A-SCOPE PRESENTATION OF ULTRASONIC ECHOES.

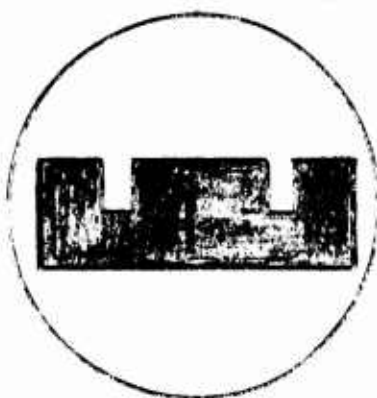


FIG. 2* - CROSS SECTION REPRESENTATION OF FLAW.

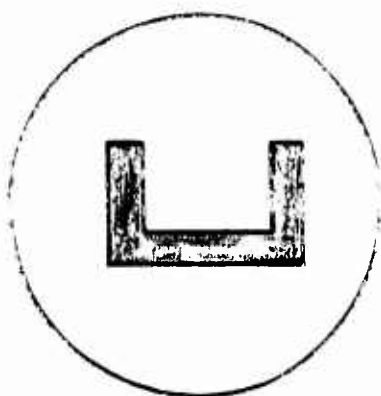


FIG. 3* - PLAN VIEW REPRESENTATION OF FLAW.

* WATERTOWN ARSENAL LABORATORY FLAW PLOTTING EQUIPMENT