

RECEIVED BY DTIE DEC 2.2 1969

AN ELECTRO-THERMAL NONDESTRUCTIVE TESTING METHOD

December 1969

AEC RESEARCH & DEVELOPMENT REPORT

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or Implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

PACIFIC NORTHWEST LABORATORY RICHLAND, WASHINGTON operated by BATTELLE MEMORIAL INSTITUTE for the UNITED STATES ATOMIC ENERGY COMMISSION UNDER CONTRACT AT(45-1)-1830

AEC-RL RICHLAND, WASH.

BNWL-1273 UC-37, Instruments

AN ELECTRO-THERMAL NONDESTRUCTIVE **TESTING METHOD**

By

D. R. Green and L. D. McCullough Nondestructive Testing Department Systems and Electronics Division

December 1969

FIRST UNRESTRICTED DISTRIBUTION MADE

DEC 2 '69

BATTELLE MEMORIAL INSTITUTE PACIFIC NORTHWEST LABORATORIES RICHLAND, WASHINGTON 99352

NOTICE LEGAL

account of Government sponsored work. Neither the United my person acting on bahalf of the Commission: presentation, expressed or implied, with respect to the secu-s of the information contained in this report, or that the use oceas disclosed in this report, or that the use upect to the use of, or for damages resulting from the

cess disclosed in this report. hobalf of the Commission" - ----

aiosion" includes any omployee or con prepares, actor such employee or c dissem nates, or prov ess to, any ini with such co with the Cos niesion, or his mployr

DISTRIBUTION OF THIS DOCUMENT IS UNL

4

Printed in the United States of America Available from Clearinghouse for Federal Scientific and Technical Information National Bureau of Standards, U.S. Department of Commerce Springfield, Virginia 22151 Price: Printed Copy \$3.00; Microfiche \$0.65

1.

BNWL-1273

AN ELECTRO-THERMAL NONDESTRUCTIVE TESTING METHOD

D. R. Green and L. D. McCullough

ABSTRACT

A nondestructive testing technique capable of detecting flaws in metals has been developed. This technique uses electrical heating in conjunction with infrared mapping of surface temperatures. It has been demonstrated on steel bars having 1/16 in. diameter holes drilled at a depth of approximately 0.146 in. under the surface.

🤉 iii

WAS INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

ABS	STRAC	r.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•				•	iii
SUM	IMARY	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	1
DIS	CUSS	ION	۱.	•	•	•	•	•	٠	•	•	•	•	•,	•	•	•	•	•	•	•.	•	•	•	•	•	•	•	• •	•	•	2
	Expe	rin	ner	Ita	1	De	emo	ons	sti	ra	ti	on	•	•	•	•	•	•	•	٠	•	•	•	•	•	•	•	•	•	•	•	2
	Basi	c F	ri	nc	;ip	ole	₽.	•		•	•	•	•	•	•	•	•	•	•	•	•	•		•		•	•	•	•	•	•	4
CON	ICLUS	[0]	IS	•	•	•	•	•	•	•			•	é	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		6
АСК	NOWL	EDG	GME	INT	S	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•	•				6
DIS	TRIBL	ILI	ON	۱.	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•		•	•	•	•				•	7

ŝ

AN ELECTRO-THERMAL NONDESTRUCTIVE TESTING METHOD

D. R. Green and L. D. McCullough

SUMMARY

*

The purpose of this report is to provide an early announcement of a newly developed thermal technique for nondestructively testing metal parts. Welds and metal parts that have rough and uneven surfaces are often difficult to test using customary nondestructive testing methods. We have developed an electro-thermal technique which images defects such as welding flaws, cracks and voids in metal. An electrical current is used to produce heat in a test object and thermal imaging is used for readout of the resulting surface temperatures. This electro-thermal technique has been experimentally demonstrated by detecting small drill holes under the surface of carbon steel and stainless steel specimens. The technique is faster than most nondestructive testing methods since only a fraction of a second is required to image flaws in test specimens. Specimens of complex shape can be tested with this method; however, the depth at which defects can be detected is limited. A high electrical current is required for testing massive parts. This technique should be useful for testing welds in heavy pressure vessels and pipes, and testing complex parts such as valves.

-1-

4

DISCUSSION

EXPERIMENTAL DEMONSTRATION

A test bar configuration which demonstrates the electro-thermal technique is shown in Figure 1. One surface of the bar is painted black to equalize the emittance. Bars of this configuration, containing 1/4, 1/8, and 1/16 in. holes drilled parallel to the surface, were made from 1020 carbon steel and 304L stainless steel. During a typical test, the density of electrical heating in the bars is about 400 watts per surface square inch. A 60 Hz alternating current was used which restricted the heating within a depth of about 0.040 in. from the surface in the 1020 carbon steel, and would allow a penetration depth of 2 in. from the surface in nonmagnetic stainless steel.



FIGURE 1. Test Bar Configuration Used to Demonstrate the Electro-Thermal Technique

Figure 2 shows the results of electro-thermal tests performed on the two test bars. The greater sensitivity of the test in the 304L steel bar was the result of its lower thermal diffusivity and a greater depth of electrical current penetration. Thermal images of the defects were obtained with an AGA Thermovision infrared scanning camera.



FIGURE 2. Electro-Thermal Test Results for Steel Bars of 1020 Carbon Steel and 304L Stainless Steel Having Holes Drilled Under Surface as Shown in Figure 1.

BASIC PRINCIPLE

The basic principle of the electro-thermal test can best be understood by inspecting Figure 3 which illustrates the electrical current flow through the test specimen.

An electrical current, passed through the specimen in a direction parallel to the top surface, must flow around nonconducting defects such as voids and cracks. This causes an increase in the electrical current density at the surface as indicated by crowding of the current stream lines shown in Figure 3. In each volume element of the specimen through which the current passes, heat is generated in an amount that depends upon the resistivity and the square of the current density. The initial rate of temperature increase within each volume element depends upon its heat capacity and the power generated within it. With a large enough power generation, the time required for build-up of appreciable temperature differences is only a fraction of a second. Rapid temperature build-up is desirable to give maximum differences between the temperatures over flaws and the temperatures over other regions in the test specimen.



FIGURE 3. Electrical Current Flow Through a Metal Test Specimen During Electro-Thermal Testing Although the stream lines shown in Figure 3 are for a direct current (as indicated by their uniformity throughout a uniform section of the specimen) the concept of stream line crowding in the surface of a specimen near a discontinuity is also applicable to alternating current (where current density drops off rapidly with depth). This assumes, of course, that the discontinuity is near enough to the surface that it interferes appreciably with the current flow. A lower frequency than 60 Hz would probably have given increased sensitivity in the 1020 steel sample, but was too expensive to obtain for the initial demonstration.

In addition to the effect on electrical current flow, discontinuities can interfere with the flow of heat into the specimen. This is why the defects can be seen in the 1020 steel bar even though the current is primarily concentrated in the material above the defects.

Limited electrical penetration depth would be advantageous when testing massive parts for near-surface defects, since not as much metal must be heated when the heat is restricted to a thin layer near the surface during the test. Hence, less power is required to produce the heat flux needed to generate detectable temperature gradients <u>along the</u> <u>surface</u> in the vicinity of defects. (This heat flux must, of course, be parallel to the surface.) Another advantage of limited penetration depth is that the effect of thickness changes in the part can be eliminated, leaving only the temperature variations caused by defects. On the other hand, penetration great enough that current flows around defects gives greater sensitivity, as seen in the stainless bar in Figure 2.

Another property of the electro-thermal technique allows it to be used on specimens having moderately wavy or bumpy surfaces. A low frequency electrical current will quite closely follow the surface contour without penetrating the entire thickness of the test specimen. Hence, under this condition heating is dependent only upon the sub-surface condition of the specimen, and not upon the moderate irregularity of the surface.

CONCLUSIONS

The electro-thermal technique appears to be a useful tool for imaging defects in metal parts. It is capable of higher speed than most other nondestructive testing techniques. It can be augmented with the emittanceindependent infrared method to eliminate the necessity for an emittance equalizing coating. This technique promises to be applicable to detection of welding flaws, cracks in large valve seats, and flaws in other complex test specimens not adequately tested by existing nondestructive testing methods.

ACKNOWLEDGEMENTS

-6-

We wish to acknowledge H. A. Clark and L. H. Fischer for their excellent assistance in performing the experiments used in this study.

This research was supported by the United States Atomic Energy Commission, Contract AT(45-1)-1830.

BNWL-1273

DISTRIBUTION

No. of <u>Copies</u>	
OFFSITE	
1	AEC Chicago Patent Group
	G. H. Lee
2	<u>AEC Division of Reactor Development and Technology</u> Fuels and Materials Branch
	J. M. Simmons T. C. Reuther
2	AEC Division of Technical Information Extension
3	Battelle Memorial Institute
ONSITE	
1	AEC Chicago Patent Group
	R. K. Sharp (Richland)
2	AEC, RDT Site Representative
	P. G. Holsted
1	AEC Richland Operations Office
	C. L. Robinson
88	Battelle-Northwest
	G. J. Dau D. R. Green (extra) L. D. McCullough H. N. Pedersen D. C. Worlton Technical Information Files (5)

21