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A REPORT GUIDE TO THERMAL TESTING LITERATURE, VOLUME II

CHARLES P. MERHIB and LEON TAYLOR
MATERIALS AND PRODUCT ASSURANCE DIVISION

April 1972

ARMY MATERIALS AND MECHANICS RESEARCH CENTER
Watertown, Massachusetts 02172

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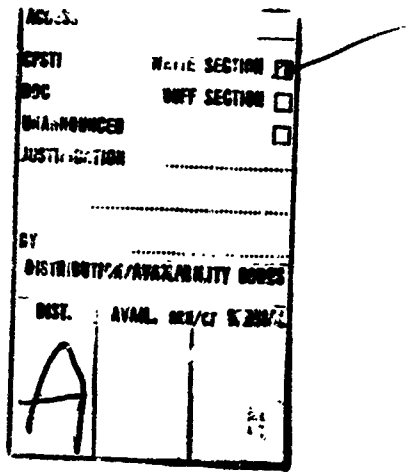

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PREFACE

The literature survey contained herein has been prepared by the Army Materials and Mechanics Research Center (AMMRC) and is the second volume on thermal testing. All items included in this volume have been taken from the holdings of the Department of Defense Nondestructive Testing Information Analysis Center (NTIAC) which is housed, staffed, and maintained at AMMRC.

The publications and articles documented herein are in some way related to thermal testing, hence the use of certain seemingly unrelated descriptors. For the sake of completeness, each item is described by a profusion of descriptors to insure complete and accurate coverage of the subject matter.

The intent of this publication is to make available, under one cover, an exhaustive literature survey of the subject matter. By means of these report guides, items of interest may be rapidly and easily retrieved by industrial and scientific users.

Input to the NTIAC is accomplished by obtaining information from all leading and recognized sources such as the Defense Documentation Center (DDC); NASA; Engineering Index; foreign translations; numerous books, technical journals, etc. Many of the items listed have been taken from reports currently on file at AMMRC, while others may have been taken directly from abstract cards on the subject matter supplied by DDC, World Information Files, etc.

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American Society of Mechanical Engineering
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Brutcher, Henry
Engineering Index
Iron Age
Journal of Applied Physics
Materials Evaluation
Materials Research and Standards
Metal Treating
Modern Castings
Nuclear Science and Engineering
Oil and Gas Journal

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A REPORT GUIDE TO THERMAL TESTING LITERATURE, VOLUME II

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13 ABSTRACT This report guide covers a portion of the abstracts on thermal testing included in the holdings of the Nondestructive Testing Information Analysis Center. (Author)

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14 KEY WORDS	LINK A		LINK B		LINK C	
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Nondestructive tests						
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Reviews						

CONTENTS

INTRODUCTION

Where available, each item in this Journal consists of the following information: (1) item, report, or article title, (2) author or authors, (3) source or facility, (4) report number or identification, (5) date, and (6) abstract.

Word descriptors pertinent to each item are listed in alphabetical order and are cross-referenced by the AMMRC identification number. Also provided is an author index or, if no author is available, then the issuing organization is listed.

OBJECTIVE

The main objective of this compilation is to provide a simple and fast access to information on the subject of thermal testing and also to provide sufficient information in the form of abstracts and word descriptors to make the listing useful.

SCOPE

This guide is the second volume of a report guide consisting of the complete coverage of items in the AMMRC Nondestructive Testing Information Analysis Center covering the subject of thermal testing. Subsequent volumes will be published as the work load permits.

The following is a list of report guides previously published by the Nondestructive Testing Information Analysis Center. The report guides are all available from the National Technical Information Service, Springfield, Virginia 22151. They may be purchased at the cost of $6.00 each for hard copy or 95¢ each for microfiche. However, report guides whose date of publication is removed two years or less from the date of intended purchase require payment of only $3.00 for hard copy.

AMRA MS 64-10 *A Report Guide to Autoradiographic and Microradiographic Literature*, August 1964, AD-612 047

AMRA MS 64-11 *A Report Guide to Gamma Radiographic Literature*, August 1964, AD-612 042

AMRA MS 64-12 *A Report Guide to Liquid Penetrant Literature*, August 1964, AD-612 044

AMRA MS 64-13 *A Report Guide to Literature in the Fields of Fluoroscopy and Remote Viewing Techniques*, August 1964, AD-612 045

AMRA MS 64-14 *A Report Guide to Thermal Testing Literature* August 1964 AD-612 043

AMRA MS 65-03 *A Report Guide to Literature in the Field of Electromagnetic Testing*, April 1965, AD-615 046

AMRA MS 65-04 *A Report Guide to Magnetic Particle Testing Literature*, June 1965, AD-617 758

AMRA MS 65-09	*A Report Guide to Ultrasonic Attenuation Literature*, December 1965, AD-627 565
AMRA MS 66-02	*A Report Guide to Ultrasonic Testing Literature*, Vol. I, March 1966, AD-630 652
AMRA MS 66-05	*A Report Guide to Ultrasonic Testing Literature*, Vol. II, June 1966, AD-638 749
AMRA MS 66-11	*A Report Guide to Ultrasonic Testing Literature*, Vol. III, December 1966, AD-648 905
AMRA MS 67-03	*A Report Guide to Ultrasonic Testing Literature*, Vol. IV, April 1967, AD-650 279
AMRA MS 67-05	*A Report Guide to Fatigue Testing Literature*, May 1967, AD-652 881
AMRA MS 67-06	*A Report Guide to Ultrasonic Testing Literature*, Vol. V, June 1967, AD-647 245
AMMRC MS 67-03	*A Report Guide to Radiographic Testing Literature*, Vol. I, December 1967, AD-664 780
AMMRC MS 68-02	*A Report Guide to Radiographic Testing Literature*, Vol. II, February 1968, AD-667 400
AMMRC MS 68-08	*A Report Guide to Radiographic Testing Literature*, Vol. III, September 1968, AD-676 835
AMMRC MS 69-03	*A Report Guide to Ultrasonic Testing Literature*, Vol. VI, April 1969, AD-689 455

SOURCES

The information contained herein and in the AMMRC Nondestructive Testing Information Retrieval System has been gathered from many sources such as: Defense Documentation Center; foreign translations; numerous books; technical journals; and reports from DOD installations.

USAGE

All word descriptors included in this guide are listed in alphabetical order and are cross-referenced to the AMMRC report identification number. Also listed is an author index, or, if no author name is available, then the issuing organization is listed. Users have only to refer to those descriptors that they are concerned with at the time and read only those abstracts which the descriptors cross-reference.

The abstracts normally refer the reader to the source where the complete report may be obtained if the reviewer desires it.

ABSTRACTS

AMMRC IDENTIFICATION NUMBER

2913 **INFRARED DEFECT DETECTION SYSTEM**

O.R. Gericke, P.E.J. Vogel
Army Materials and Mechanics Research Center, Watertown, Mass.
Tech. Rpt. AMRA TR 63-14, September 1963. 12 p.
AD-421 817

This report describes an experimental investigation of a one-sided infrared method of inspecting bond integrity in laminates of dissimilar materials such as the case, liner, and propellant of missiles. It includes a description of the instrumentation, method of low-level heat injection, method of detecting and displaying or recording the infrared radiation which varies in magnitude as a function of the bond integrity.

3052 **ELEMENTS OF INSTRUMENTATION. III MAGNETIC TRANSDUCERS**

K.S. Lion, D.A. Berkowitz
Massachusetts Institute of Technology, March 1956
AD-100 918

This report deals with magnetic field transducers or magnetic field sensing elements. Induction systems, instruments based upon magnetic effects on moving charges, transducers based on permeability variations, nuclear magnetic resonance systems and indirect systems such as mechanical methods, thermal methods and optical methods are discussed.

3116 **EVALUATION OF BRAZED HONEYCOMB STRUCTURES**

R.C. McMaster, A.T. D'Annessa, H.W. Babel
Ohio State Univ, Columbus Engineering Experiment Sta, Columbus
Rpt on the Chemistry and Physics of Materials, January 1959 - May 1960. September 1960.
AD-251 915

Nondestructive test methods and equipment were evaluated for quality control of brazed and welded joints in honeycomb structures. Test methods included (1) penetrating radiation, (2) ultrasonic, and (3) thermal tests, by which surface-layer defects are reliably detected. Internal defects are detectable only by penetrating radiation associated with (1) X-ray film radiography, zeroradiography, (2) direct fluoroscopy, (3) television fluoroscopic systems, and (4) electrostatic and photoconductive-screen X-ray image amplifiers. Ultrasonic methods included immersion tests with focused transducers, contact tests with resonance transducers and with pulse-reflection systems. Thermal methods included thermal-flash proof tests, heat-repelled fluid coatings, color changing paints, and remote IR sensing systems.

3295 **A CALORIMETER FOR MEASURING THE POWER IN A HIGH-ENERGY X-RAY BEAM**
J. McElhinney et al.
National Bureau of Standards, 1 June 1955, 8 p.
AD-116 371

The design and calibration of a calorimeter to measure the power in X-ray beams having peak energies between 1 and 180 million electron volts are described. The calorimeter included two thermally balanced lead cylinders, 4 centimeters in diameter by 7.5 centimeters long, one irradiated by an X-ray beam. The lead cylinder was large enough to absorb almost completely the X-ray beam. The absorbed energy resulted in an unbalance of temperature of the two cylinders, which was measured by the change in resistance of embedded thermistors. Calibration of the calorimeter consisted in observing the temperature rise due to a measured quantity of electric energy dissipated in the same cylinder. The results are given for five calibration runs, each using about 70 microwatts of power for approximately 20 minutes. The probable error of the mean was about ± 1 per cent. Separate reports of measurements of X-ray-beam powers at 1.4 and 36 million electron volts are in preparation.

3314 **EMISSIVITY INDEPENDENT INFRARED THERMAL TESTING METHOD**
D. R. Green
General Electric Co., Hanford Laboratories, Richland, Wash.
Materials Evaluation, February 1965, p. 79-85
AD-121 425

A new emissivity independent infrared thermal method of nondestructive testing was developed. The outer surfaces of test pieces were scanned with a heat source and two infrared radiometers. Heat transfer flaws, produced by 0.003 inch thick mica discs 1/2 and 3/8 inch diameter in aluminum to uranium bonds, were detected in the test pieces regardless of surface conditions. Theoretical and experimental results show that this new method can be applied to test pieces having rough surfaces.

3330 **VELOCITY AND ABSORPTION OF ULTRASONIC WAVES IN SEVERAL NONASSOCIATED LIQUIDS UNDER HIGH PRESSURE**
J.F. Mifsud, A.W. Nolle
Univ. of Texas, Austin, Texas, 23 September 1955, 9 p.
AD-104 458

The ultrasonic wave velocity and absorption for carbon tetrachloride, benzene, and carbon disulfide are measured by a pulse-reflection method, at several temperatures, in the pressure range of 1 to 1360 atmospheres. Generally similar pressure effects are found in the three liquids. The velocity increases with pressure to about 1.4 times the atmospheric pressure value, while the relative absorption decreases to about 0.4. The tetrachloride predicts approximately the pressure effect on the absorption at constant temperature, but gives erroneous predictions of the magnitude of the absorption, and of the effects of pressure on the absorption temperature coefficient and on the relaxation frequency.

3364 **BIBLIOGRAPHY OF INFRARED LITERATURE**
U.S. Tank-Automotive Center, Physical Sciences Laboratory, Center Line, Mich.
Rpt. RR-37, (1964)
AD-480 090

This bibliography is a list of titles and abstracts regarding infrared and thermal test methods.

3379 **A SURVEY OF TRANSDUCER RESEARCH AT DOFL**

V.A. Johnson
Diamond Ordnance Fuze Labs, Washington, DC 20025
Rpt TR-1036, 30 July 1963, 14 p.

A survey was made of transducer research at the Diamond Ordnance Fuze Laboratories. Research and development work was reported on measurement devices for acceleration, coherent light, color, electron density, electrostatic fields, gas chromatography, magnetic fields, nuclear radiation, pressure, temperature, and velocity. The need, method of attack, and the state of progress have been indicated.

3400 **PRELIMINARY REPORT ON THE DEVELOPMENT OF A NONDESTRUCTIVE TEST FOR BRIDGEWIRES**

L.J. Klamerus, J.D. Stewart
Sandia Laboratory, Alburquerque, N.M.
Rpt. SC-DR 251-63, November 1963

Tests have been performed in an effort to develop techniques for testing the integrity of bridgewire welds. The test methods employed in this project were RF fault detection, thermal fatigue, and infrared sensing. Infrared sensing has shown the most encouraging results.

3485 **APPLIED RESEARCH TO ESTABLISH INFRARED DETECTION METHODS FOR NON-DESTRUCTIVE ANALYSIS OF METALLIC AND CERAMIC STRUCTURES**

Aeronautical Systems Div., Metals & Ceramics Lab., Wright-Patterson AFB, Ohio
Rpt ASD-TDR-62-385, January 1963

This program was a study to determine the feasibility of thermal NDT evaluation of materials. A thermal testing system was conceived and developed with which certain fabricated material inconsistencies have been detected in standard test samples. The system operation is basically a programmed heating and subsequent temperature measurement over one surface of the test sample. Heat flow from the heated surface into the material is examined through the surface temperature measurement. A display of the temperature pattern over the surface is then interpreted with respect to internal material inconsistencies.

3488 **THERMAL BIBLIOGRAPHY, 1960-1963**

(Collection of unidentified mimeographed sheets available in the NTIAC only)

A literature survey covering symposiums or society presentations, technical reports and magazine articles on the subject of thermal and infrared testing. Lists titles, authors and dates of publication, as well as source. No abstracts.

3522 **THE APPLICATION OF PIEZOMAGNETIC ALLOYS TO ULTRASONIC VISCOMETERS OPERATING AT HIGH TEMPERATURES AND PRESSURES**

G. Bradfield

Proc. I.E.E.E., Monograph 521M (May 1962)

Development work at the National Physical Laboratory on torsional ultrasonic viscometers for temperatures up to 250°C, with the possibility of extension to 650°C, and for pressures up to 12,500 atm is described. The frequency range 10-250 kc/s is used with possible extension to 700 kc/s. These instruments are expected to provide useful information about the behavior of multiple component Maxwellian liquids in high pressure vessels at high temperatures.

3532 **INSPECTING METHOD AND APPARATUS**

J.T. Landin

U.S. Patent No, 3,356, 212

Commissioner of Patents, Washington, D.C.

An infrared system for inspecting hot, hollow glass articles for wall thickness distribution. The containers to be inspected are removed from a conveyor line and rotated while being scanned by an infrared detector. A rotating light chopper is used to give an ac signal from the IR detector. This signal is amplified, detected, and displayed on an oscilloscope. Container rejection is effected by a solenoid energized from a Schmitt trigger level detector.

3607 **NONDESTRUCTIVE TESTING**

W. McGonnagle, F. Park

Southwest Research Institute, San Antonio, Texas

International Science and Technology Journal, July 1964;

Also: Materials Evaluation, December 1964, p. 516-574

This paper is of a general, yet wide, coverage of the field of nondestructive testing and covers such topics as radiography, neutrons, thermal testing, liquid penetrant, magnetic techniques, Ultrasonics, etc. Some ideas for further advancing the state of the art are also included.

3705 **FUNDAMENTALS OF INFRARED RADIATION**

R. Vanzetti

Raytheon Co., Norwood, Mass.

Materials Evaluation, January 1965, p. 48-54

A discussion of the historical background and theoretical concepts of infrared radiation. Electrical performance can now be evaluated and failure-predicting anomalies can be identified with the use of infrared sensing and measuring techniques.

3831 **DIRECT ENERGY CONVERSION IN THE NAVY**

J.A. Satkowski
Office of Naval Research
Proceedings, Symposium on Physics and Nondestructive Testing, Southwest Research Institute, San Antonio, Texas, October 1962, p. 345-371

Improved power source and energy conversion systems represent one of the most important long range scientific problems facing the Nation. Five energy conversion processes are receiving most of the attention, and they are: photovoltaic cells, thermoelectricity, thermionic emission, fuel cells, and magnetohydrodynamics. This paper discusses only thermoelectric, thermionic, and magneto-hydrodynamic systems.

3856 **RADIOGRAPHIC PENETRAMETERS – AN INFRARED STANDARD**

D. Wilburn
U.S. Army Tank-Automotive Center, Warren, Michigan
Materials Evaluation, October 1964, p. 471-472, 478

Radiographic penetrameters are adapted to infrared nondestructive testing as standards of performance and technique. In laboratory tests, an industrial radiometer achieved a 2% penetrameter outline sensitivity for steel plates up to 1/4 inch in thickness. Optimum sensitivity is achieved by controlling the exposure time, or delay between the instant of heat injection and the moment of observation. Induction heating is employed to generate a temperature gradient in the sample plates. Operating parameters for the high resolution radiometer are discussed, and typical thermal profiles illustrating penetrameter outlines are presented.

3919 **DETECTING SERVICE FAILURES IN POWER PLANTS**

H. Thielsch
Nondestructive Testing, v. 19, July-August 1961, p. 252-259

Radiographic, ultrasonic, dye penetrant and magnetic particle inspection of boilers, turbines, piping, pipe supports and hangers, valves, fittings and shafts to prevent failures caused by thermal or mechanical shock or fatigue, corrosion, erosion, creep, cracking or rupture. 5 ref.

3[illegible] **AN INFRARED NONDESTRUCTIVE TESTING SYSTEM FOR ROCKET MOTORS**

F.E. Alzofon
Lockheed Missiles and Space Company, Sunnyvale, California
Materials Evaluation, November 1965

The Lockheed Missiles and Space Company has designed, fabricated, and delivered to the U.S. Navy, an infrared nondestructive testing system to be applied to inspection of Polaris A3 motors. The system is intended to be used for usability analysis of the infrared nondestructive testing technique in production line inspection. Research conducted along with the design and fabrication program, indicates the feasibility and value of infrared testing relative to other NDT techniques. A description of the system is presented, along with some of the results of the experimental program.

3985 **INFRARED EVALUATION OF MICROWELD QUALITY**
F.E. Alzofon, A.D. McDonald
Lockheed Missiles and Space Co., Sunnyvale, California
Unnumbered company rpt, 1964

Author examines the feasibility of using infrared nondestructive testing to determine the type of weld between two lead wires, each 0.020 inches in diameter. Results indicate further study should be advantageous to determine the character of weld types and flaw .

4002 **PIEZOELECTRIC IMPULSE MEASUREMENTS DURING PHASE REACTIONS IN UNALLOYED SPECIMENS OF THE BINARY ALLOYS LEAD-TIN, LEAD-ANTIMONY, AND CADMIUM-ZINC (German)**
H. Borchers, H.M. Tensi
Metall, v. 17, August 1963, p. 784-788

Thermal anslysis and piezoelectric impulse measurements are carried out during cooling and heating operations at 20 to 450 C. Analysis of volume contraction and of liquid-solid reactions for all compositions of the three binary systems is given.

4009 **PROCESS FOR GAGING DIMENSIONS BY MEANS OF RADIATION**
M. Weiss
U.S. Patent No. 3,131, 306
Materials Evaluation, October 1964, p. 454

This patent describes an improved infrared gage for measuring rod diameters continuously while the rod is moving at high speed. A previous gage utilized an infrared radiometer which scanned rapidly and repetitiously across the rod at a distance from it. If the rod had a different temperature than its environment or background, then a trapezoidal-shaped current wave was generated by its associated electronics circuits. The width of this trapezoid is a function of the width or diameter of the rod being measured. Thus, an averaging type indicator can be used for continuously indicating rod diameter. In order to obtain greater precision, the inventor suggests that an accurately dimensioned reference rod should be maintained at the same temperature as the material being measured. The reference standard is placed in the scanning position and used for calibration of the equipment.

4038 **THERMAL IMAGING TECHNIQUES**
*P.E. Glass and **R.F. Walker
*Arthur D. Little; **National Bureau of Standards
Proceedings, First Conference on Thermal Imaging Techniques, October 1962

Detailed discussions are presented on: the performance of thermal imaging devices using a wide variety of radiation sources including carbon arcs; resistance heated surfaces; zenon lamps and solar radiation and experimental procedures useful for thermal property determinations; crystal growth and materials research at high temperatures. These reports will be particularly useful to experimentalists in the physical sciences who are seeking a better understanding of the behavior of materials at high temperatures.

4050 **EVALUATION AND TESTING OF HIGH TEMPERATURE OXIDATION RESISTANT COATINGS ON REFRACTORY METAL SUBSTRATES**

W.L. Aves, Jr.

Proceedings, Second Annual Symposium on Nondestructive Testing of Aircraft and Missile Components, Southwest Research Institute, San Antonio, Texas, 1961

This article discusses Nondestructive tests to determine the integrity of high temperature coatings on molybdenum, tantalum, columbium, tungsten, and their basic alloys. The various test techniques their advantages and limitations are described and supplemented by use of representative slides. Also discussed is determining coating discontinuities using such nondestructive procedures as thermal oxidation, infrared emission, fluorescent penetrants and electromagnetic inspection.

4063 **A THERMAL SCANNING TECHNIQUE FOR NONDESTRUCTIVE TESTING**

D.R. Maley, G.I. Posakony

Automation Industries, Incorporated.

Proceedings, Fourth Annual Symposium on Nondestructive Testing of Aircraft and Missile Components, San Antonio, Texas, 1963

In this paper, a feasibility study is discussed in which nondestructive thermal methods are utilized in the investigation of certain characteristic properties of materials. For this purpose, material properties include intrinsic physical, mechanical, and chemical properties, and also such conditions as the presence of voids, porosity, corrosion, etc.

4064 **ELEVATED TEMPERATURE TESTING TECHNIQUES PROVIDE PROOF OF HIGH TEMPERATURE COATING INTEGRITY**

W.L. Aves, Jr.

Chance Vought Corporation

Proceedings, Fourth Annual Symposium on Nondestructive Testing of Aircraft and Missile Components, San Antonio, Texas, 1963, p. 53-65

Thermal testing techniques are so modified as to verify the applicability of a material system for use in fabricating a component or structure to serve a specific high temperature function described. The tests discussed in this paper are employed to aid in establishing material system (coated substitute) reliability, as well as to provide information on the effect of the coating and processing technique on the mechanical and metallurgical properties of the substrate. High temperature tests are described. Supplementary inspection techniques used in the evaluation and development of oxidation resistant coating systems on the refractory metal (Mo, Cb, Ta, W) base alloy and superalloy (Ni and Co base) materials employing metallographic and X-ray diffraction analysis are also reviewed.

4065 **INFRARED INSTRUMENT FOR NONDESTRUCTIVE HEAT TRANSFER TESTING**
D.R. Green
General Electric Co; Hanford Atomic Products Operation
Proceedings, Fourth Annual Symposium on Nondestructive Testing of Aircraft and Missile Components, San Antonio, Texas, 1963, p. 79-97

The instrument described in this paper uses an infrared radiometer to detect transient surface temperatures of test pieces during and after application of heat. Detected surface temperatures which are higher in the vicinity of defects are quantitatively mapped using either a helical area map, or a newly developed method which represents the temperature as lengths of line segments printed on a two dimensional field. A reflective technique was used to minimize the effect of emissivity differences on the test results. Although the Hanford heat transfer test was developed for application to cylindrical nuclear fuel elements, the techniques and concepts presented should be applicable to testing aircraft and missile components.

4066 **A THERMAL INFRARED INSPECTION PROCEDURE FOR DETECTION AND LOCATION OF FLAWS IN SOLID PROPELLANT ROCKET CASES**
H.L. Sachs
Perkin-Elmer Corp.
Proceedings, Fourth Annual Symposium on Nondestructive Testing of Aircraft and Missile Components, San Antonio, Texas, 1963, p. 99-114

Work is described and continuing, with the end goal of establishing detailed operation parameters for thermal IR inspection of large diameter rocket engines at field installations. The technique appears as a promising adjunct to ultrasonic and radiographic procedures presently employed for rocket engine inspection.

4067 **NONDESTRUCTIVE TEST DEVELOPMENT FOR POLARIS WOUND CHAMBERS**
A.M. Granat, P.A. Sreinkritz
Lockheed Missiles and Space Co.
Proceedings, Fourth Annual Symposium on Nondestructive Testing of Aircraft and Missile Components, San Antonio, Texas, 1963, p. 115-119

A general discussion of the objectives to follow for testing filament wound chambers. Discussion of feasibility of infrared testing.

4087 **NONDESTRUCTIVE TESTING FOR MICROELECTRONICS: AN APPRAISAL**
H.S. Kleiman
Arinc Research Corp, Washington, D.C
Twenty-fourth National Convention of the Society for Nondestructive Testing, Philadelphia, October 1964, Publication 234-02-10-466

An extensive review of the problems associated with inspection of microelectronic components and a review of techniques used and to be used. Covers X-ray, scanning electron beam microscope, and the thermal or infrared technique.

4143 **NONDESTRUCTIVE METHODS OF EVALUATING COATING-METAL BONDS**

A.M. Baumanis, W.E. Lawrie
Armour Research Foundation, Chicago, Ill.
Rpt ARF 1213-5, July-September 1962
AD-296 977

The objective of the program was the development of ultrasonic methods to examine the strength and continuity of ceramic-metal bonds. The investigations continued along two main paths. Further work was done on the measurement of Rayleigh wave attenuation and several limitations and effects not previously noted, were discovered. Further investigations were also made of the interferometric method of determining the properties of a coated specimen. A small proportion of the total effort was expended in investigating non-ultrasonic methods of inspecting ceramic metal bonds. In particular, thermal, electrical and nuclear methods were selected as possible appropriate techniques.

4197 **A HIGH SPEED INFRARED MAPPING SYSTEM FOR RELIABILITY ASSESSMENT OF MINIATURE ELECTRONIC CIRCUITS**

H.F. Dean, R.M. Fraser
U.S. Navy Electronics Laboratory, San Diego, California
Rpt NEL 1272, 15 March 1965
AD-615 018

A system consisting of a cryogenically cooled IR detector, a scanning mechanism, electronic circuitry, and a modified facsimile machine was developed and is described. Thermal maps of a 1 inch square circuit surface can be made in a 30 minute period. Mapping resolution is sufficient to display large IR energy level changes occurring in a 0.001 inch square circuit area. Present circuitry permits mapping of specimens at environmental temperatures of 60 to 70 degrees C.

4237 **INFRARED/THERMAL NONDESTRUCTIVE TESTING ABSTRACTS**

D.K. Wilburn
U.S. Army Tank-Automotive Center, Warren, Michigan, 1963-1964

A compilation of abstracts and bibliography of reports covering infrared/thermal activities.

4249 **NONDESTRUCTIVE TESTING OF ISOTOPE HEAT SOURCES (INTERIM REPORT)**

R.W. Steffens, D.R. Green, G.F. Garlick
Battelle Memorial Institute, Pacific Northwest Laboratory, Richland, Washington
Rpt BNWL-51, April 1965, (AEC Contract AT(45-1)-1830), 29 p.

Because of the high concentration of radioactive material contained in isotope heat sources, it is imperative that the container integrity be established so the sources can be safely used. In addition, information about various source properties, such as uniformity and cracking of the core material, the presence of molten material within the core, and any thermal unbond between the core and cladding material, would assist in predicting the operating characteristics of each heat source. Nondestructive techniques are being developed at Battelle and Northwest to meet these testing needs. This report describes the tests that are being developed and presents data taken using prototype test equipment on simulated (nonradioactive) heat sources. Ultrasonic and thermal transient tests are included.

4259 **INFRARED SCANS FOR INNER DEFECTS**
T.H. Malim
Iron Age, May 27, 1965, p. 140-142

This article discusses the use of the infrared technique for inspection of discontinuities in materials. Welding defects, lack of bond or poor plate adhesion and voids and inclusions are covered. Another application mentioned for thermal detection techniques is that of crack detection in metal sheet and in oxide coatings on refractory metal.

4275 **INFRARED FINDS THE HOT SPOTS**
Barnes Engineering Co., Stamford, Conn.
Iron Age, April 8, 1965, p. 146-147

Using infrared, it is now possible to tell the temperature of industrial equipment simply by looking at a photograph. A new camera is described which converts infrared energy to black and white.

4326 **DEVELOPMENT OF NONDESTRUCTIVE TESTING INSTRUMENTATION FOR REACTOR PRESSURE VESSELS** (Quarterly rpt no. 2, 1 April to 1 July 1963)
W.J. McGonnagle
Southwest Research Institute, San Antonio, Texas
Rpt SWRI-1296-6-2, 15 July 1963, 62 p.

An investigation is being conducted to develop a nondestructive testing technique for measuring the shift in the nil ductility transition temperature of A-212 Grade B steel. A correlation was found between the amount of cold working and magnetoabsorption, thermal conductivity, and ultrasonic attenuation. Magnetoabsorption measurements as a function of cold work in A-212 Grade B steel appear to be very promising. The measurement of the ultrasonic attenuation coefficient in cold work material by a through transmission technique showed a relationship between cold work and the attenuation coefficient. The thermal comparator shows applicability to measuring the level of cold work in A-212 Grade B steel. It appears that all three of the techniques evaluated have potential for determining the level of cold work in A-212 Grade B steel.

4486 **ULTRASONIC AND THERMAL BEHAVIOR OF NB-25% ZR IN STRONG MAGNETIC FIELDS**
L.J. Neuringer, Y. Shapira
National Magnet Lab, Mass. Institute of Technology, October 1964, 4 p.
AD-614 851

An absorption edge for ultrasonic shear waves was observed at the upper critical field of NB-25% ZR. The temperature variation of the field at which this edge occurs was compared with several theoretical models.

4575 **INVESTIGATION OF NONDESTRUCTIVE METHOD FOR THE EVALUATION OF GRAPHITE MATERIALS**

G.E. Lockyer
Avco Corp., Rsch and Advanced Devt Div, Wilmington, Mass.
Tech Rpt AFML-TR-65-113. (Wright-Patterson AFB) June 1965
AD-465 715

Prime accomplishments noted in this report are the accurate determination of properties of graphite by correlations with sonic and penetrating radiation measurements. Measurement of ultrasonic longitudinal-wave velocity by a through transmission technique is described, and the observed correlations with such properties as modulus of elasticity, ultimate tensile strength, and total strain to failure are related to specific grades, both with and against the grain. Determination of bulk density within $\pm 1\%$ by a radiation transmission technique is discussed. Combined use of longitudinal-wave velocity and radiation bulk density measurements in the same discrete region in bulk graphite is discussed and correlated to elastic modulus.

4595 **DETECTION OF SOLDER JOINT IMPERFECTIONS**

Autonetics, Anaheim, California
Rpt C5-19/33. January 1965. 15 p.
AD-455 842

The work accomplished in Producibility Study 9326 involved the evaluation of various nondestructive test methods and devices for possible utilization in increasing solder joint reliability and reduced rework. A method was not found that assured inherent reliability and applicability to Autonetics solder joints on multilayer boards.

4607 **JOINING OF REFRACTORY METAL FOILS**

J.W. Welty, P.J. Valdez, C.E. Smeltzer, Jr., C.P. Davis
Solar, San Diego, Calif.
Rpt ASD-TDR-63-799, pt. 2, November 1964
AD-451 649

Additional joining evaluation work carried out on refractory alloys is reported. The resistance welding characteristics of foils and foil joints were rated by penetrant, radiographic, metallographic, and mechanical tests. Low-temperature behavior was established both in parent material and welded joints by a series of bend ductility tests using liquid nitrogen as a cooling medium. High-temperature behavior was characterized by tensile, creep, and fatigue evaluations. A total of 18 brazing alloys were screened to meet the several program objectives. The most promising of these alloys were further evaluated by honeycomb block shear tests.

4614 **THERMOGRAPHIC PROFILES OF MATERIAL DISCONTINUITIES**

D.K. Wilburn
U.S. Army Tank-Automotive Command, 1501 Beard, Detroit 9, Michigan
Report No. RR-37, 1 March 1961

An infrared line scan radiometer was utilized to obtain thermal patterns of interior discontinuities in solids of low heat conductivity. Temperature differences as low as 0.6^{0} Centigrade could be detected with a theoretical resolution of 0.031 inches. Non-metals with thermal conductivity "k", below 0.01 can be examined by this method. Metals and non-metals with "k" values above 0.1 dissipate surface thermal gradients too rapidly to produce a sufficient temperature difference for detection. The radiometer system is evaluated with respect to parameters of frame time, bandwidth and sample distance. Typical thermograms are presented for a variety of low "k" value materials.

4615 **IR TECHNIQUES FOR ELECTRONICS: LATEST PROGRESS IN R&D AND APPLICATIONS**

R. Vanzetti
Raytheon Company, Norwood, Mass.
Proceedings, 3rd Annual Meeting of the Infrared Techniques for Electronics Committee, February 19-21, 1964. Evanston, Illinois: Society for Nondestructive Testing, October 1964

A review of the overall progress made to date in the field of infrared techniques for electronics. Application of IR techniques as being used at Raytheon. Problems of general interest in the field.

4616 **INFRARED TECHNIQUE FOR ELECTRONIC TESTING AND A PLAN FOR ITS IMPLEMENTATION**

R. Judd, J.F. Pina
The Boeing Company, Huntsville, Alabama
Proceedings, 3rd Annual Meeting of the Infrared Techniques for Electronics Committee, February 19-21, 1964. Evanston, Illinois: Society for Nondestructive Testing, October 1964

Present testing techniques are not sufficiently adequate for detection of faulty components before higher assembly. New techniques are needed to more fully determine functional integrity of items under test. Plans are under way at Boeing to scan from one part to another with radiation measurements with meter indications and chart recording readout.

4621 **THE THERMAL PLOTTER AND ITS USES IN MICROCIRCUIT ANALYSIS AND TESTING**

B.G. Marks, G. Revesz, M. Walker
Philco Corporation, Lansdale Division, Lansdale, Pa.
Proceedings, 3rd Annual Meeting of the Infrared Techniques for Electronics Committee, February 19-21, 1964. Evanston, Illinois: Society for Nondestructive Testing, October 1964

This article describes and analyzes an instrument capable of measuring the radiated energy of small structures. Various methods are investigated and their relative merits for using the instrument in conjunction with systems to display information. Results of investigations involving a variety of structures using the instrument described are given.

4622 **RECENT DEVELOPMENT IN INFRARED THERMOGRAPHY**

R. Yoder
Barnes Engineering Company, Stamford, Connecticut
Proceedings, 3rd Annual Meeting of the Infrared Techniques for Electronics Committee, February 19-21. Evanston, Illinois. Society for Nondestructive Testing, October 1964

This paper presents a brief description of the instruments used by the Barnes Engineering Company in their work with various modification for specific applications. Illustrative photographs are included, showing the various capability of imaging and line scan techniques, as well as illustrations of infrared thermography to mechanical, military, and medical problems.

4623 **CRYOGENIC METHODS APPLICABLE TO THE USE OF LONG WAVELENGTH PHOTOCONDUCTIVE INFRARED DETECTORS**

G. Giggey
Raytheon Company, Infrared and Optical Research Lab, Burlington, Mass.
Proceedings, 3rd Annual Meeting of the Infrared Techniques for Electronics Committee, February 19-21, 1964. Evanston, Illinois: Society for Nondestructive Testing, October 1964

This paper discusses the application of cooled long wavelength photoconductive detectors to the infrared scanning, plotting, or mapping of electronic equipment. The first section investigates why one might want to use this type of detector and the second portion relates to why these detectors must be cooled, along with some methods to achieve the required cooling.

4662 **A REVIEW OF NONDESTRUCTIVE TESTING FOR PLASTICS: METHODS AND APPLICATIONS**

N.T. Baldanza
Plastics Technical Evaluation Center (PLASTEC) Picatinny Arsenal, Dover, N.J.
Plastec Report 22, August 1965, 182 p., References and bibliography

A review of nondestructive test methods and applications for plastics is presented. Included are the activities of both industrial and governmental establishments within this area, with special reference to specifications, significant defects, and test methods. Recent techniques for certain missile and aircraft components are discussed.

The information presented is particularly applicable to those readers desiring a general review of the science of nondestructive testing and a better understanding of its scope for plastics. Included are the tests which were felt to be applicable. These are defined, discussed, and frequently illustrated. Included are listings of 146 references used, and a bibliography of 254 items.

4676 **INFRARED TESTING OF MICROCIRCUITS**

B.G. Marks, G. Revesz, M. Walker
Philco Corporation, Willow Grove, Pennsylvania
Electro-Technology, October 1965, p. 112

A thermal microplotter has been developed and is described. It is used for sensing infrared emission from temperature distribution in small structures. Displays may be presented or plotted on a cathode ray tube and viewed readily or photographed for permanent record.

4709 **SYMPOSIUM ON NONDESTRUCTIVE TESTING TRENDS IN THE AEC REACTOR PROGRAM,**
Germantown, Maryland, May 1960
AEC publication TID-7600, March 1961

The purpose of this symposium was to acquaint industry representatives with the equipment and techniques used in nondestructive testing as performed by the commission. Presentations covered testing specifications, radiation techniques, ultrasonic techniques, leak, thermal and surface test methods, and electromagnetic testing of reactor components.

4780 **A THERMAL IMAGING TECHNIQUE OF NONDESTRUCTIVE TESTING**
D.K. Wilburn
U S. Army Tank-Automotive Center, Warren, Michigan 48090
TR No. 8883, June 1965

A passive infrared thermal imaging technique is used to study material integrity by observing the radiation transfer patterns generated in a material under test. The observed images are representative of the thermal homogeniety of the material and can be diagnosed in terms of structural integrity. Methods of producing an optimum thermal contrast or "exposure" in the test specimen are discussed as well as observation and imaging techniques. The dynamic effects of the "exposure" are characterized by cine-type imaging methods. Advantages of the thermal imaging method of IR-NDT are discussed with respect to other methods in common use.

4823 **THE FEASIBILITY OF UTILIZING THERMAL DETECTING DEVICES TO DETERMINE FATIGUE DAMAGE IN METALS**
G.S. Tint, M. Herman
Franklin Institute, Laboratories for Research and Development, Philadelphia, Pa.
Rpt No. NAVAIRENGCEN-ASL-1064, December 1962
AD-406 200

An estimate of the possibility of detecting fatigue damage by infrared methods is made by: (1) determining what damage does occur in fatigue; (2) estimating the resulting temperature changes that occur at the damage sites; (3) relating the magnitude of these temperature changes to the characteristics of available infrared detecting devices. The section concerning fatigue damage is essentially a short review of the known data. That division dealing with possible thermal effects is primarily of a speculative nature and the portion dealing with infrared equipment is concerned primarily with imaging devices.

4836 **AN INVESTIGATION TO DETERMINE THE CAUSE OF INTERNAL CRACKS IN THE MAIN STEAM AND CATAPULT PIPING IN THE USS SARATOGA (CVA-60)**
G. Sandoz
U.S. Naval Research Laboratory, Washington, D.C. March 1965
NRL Memorandum Rpt 1601, March 1965
AD-463 432

It was found that the cracks occur only in the vicinity of the spray nozzle of the auxiliary desuperheater. The cracks are of the corrosion-thermal fatigue type. Metallurgical effects were observed near the inner surface of the pipes which had cracked in service but these were not observed in pipes which were free of cracks. It was established that the Zn-pigmented enamel used in the reserve feed tanks can produce similar metallurgical effects if contacted with the pipe steel at 950°F.

4840 **TWO THERMAL NONDESTRUCTIVE TESTING TECHNIQUES**

D.R. Maley
Automation Industries, Inc., Boulder, Colorado
TR 65-25, February 1965 (Presented at the Spring 1965 National Convention, Society for Nondestructive Testing, Los Angeles, California)

Properties and discontinuities in solids are investigated by the analysis of heat flow patterns. These patterns are evaluated by infrared measurement of surface temperature. Two techniques are discussed. The first is a scan heat technique which utilizes a small moving heat spot as the probing energy source. The second, the static heat technique, makes use of a fixed large area radiant source of heat energy. These techniques are used in the examination of bond quality, plating adhesion, cracks, thickness of thin sheet, spot weld quality, and ceramic coating thickness.

4859 **A STATE-OF-THE-ART EVALUATION OF INFRARED IN HEAT TRANSFER ENGINEERING**

G.W. Carter
IBM, Federal Systems Division, Owego, New York
IBM No. 65-825-1434, April 1965

A report on the temperature measurements of microelectronics by infrared techniques. Limiting parameters and applications of two basic types of systems are discussed. Basic advantages and disadvantages are outlined. Typical examples of infrared techniques used on electronic equipment are outlined.

4860 **TESTING BLOSSOMS OUT INTO COLOR**

T.H. Malim
Iron Age, January 27, 1966, p. 69-74

Describes the potentials of liquid crystals, laser holograms, laminographs, and thermal images on color television. Liquid crystals consist of a colorless coating which undergoes vivid color changes as changes of temperature or stress appear. Laser Holograms show objects or scenes in three dimensions. Infrared imaging presents thermal information in visual form. Color X-ray provides an extension of conventional radiography to promote resolution and fast reading. Laminography permits radiography of very thin layers of a structure.

4886 **SURVEY OF INFRARED TECHNIQUES FOR NONDESTRUCTIVE EVALUATION**

B. Bernard, H.E. Williams
Infrared Industries Inc., Santa Barbara, Calif.
Proceedings, Fifth Annual Symposium on Nondestructive Evaluation of Aerospace and Weapons Systems, Components, and Materials, San Antonio, Texas, April 1965, p. 65-78

This article describes, in brief, what infrared is, what it presently can do, and predicts future uses for it. Some of the applications include electronic component inspection such as semiconductors, circuitry, and solder joints; detecting voids in cast metal, indicate cracks in welds, detect stresses in glass materials, etc.

4887 **THERMAL IMAGING FOR MATERIAL INTEGRITY**

D.K. Wilburn
U.S. Army Tank Automotive Center, Warren, Michigan
Proceedings, Fifth Annual Symposium on Nondestructive Evaluation of Aerospace and Weapons Systems, Components, and Materials, San Antonio, Texas, April 1965, p. 79-94

Thermal images of radiation transfer patterns are observed directly with a high resolution mechanical-scan infrared camera. The observed radiation patterns are diagnosed in terms of structure integrity. The "heat-exposure" to produce optimum thermal contrast in the test specimen is generated by the through-transmission method of heating. Thermal images are displayed at sufficiently fast frame rates to allow the dynamic effects of exposure rate and range to be observed. An infrared imaging program for the evaluation of resin-impregnated fiberglass structures is outlined and documented with radiation transfer patterns of typical defects. Application is made to the inspection of fiberglass reinforced polyester resin tanks which are component parts of U.S. Army M-149 Cross Country Liquid Transport Trailer.

4888 **THERMAL EVALUATION OF BOND INTEGRITY IN WELDED, BRAZED AND ADHESIVE JOINTS**

W.R. Apple, D.R. Maley
Automation Industries, Inc., Boulder, Colo.
Proceedings, Fifth Annual Symposium on Nondestructive Evaluation of Aerospace and Weapons Systems, Components, and Materials, San Antonio, Texas, April 1965, p. 95-121

This paper concerns thermal nondestructive evaluation of bond quality in welded, brazed, soldered, and adhesive joints. Included are definitions, theory, methods, systems, and test results for the thermal evaluation of bonded joints in metals and nonmetals.

4893 **AN INFRARED NONDESTRUCTIVE TESTING SYSTEM**

G.L. Schmitz
General American Transportation Corporation, Niles, Illinois
Proceedings, Fifth Annual Symposium on Nondestructive Evaluation of Aerospace and Weapons Systems, Components, and Materials, San Antonio, Texas, April 1965, p. 239-251

This paper describes an infrared inspection system that was investigated for detecting fatigue cracks and flaws in aircraft and missile structures undergoing testing in an intense sonic environment. This system was successful in locating fatigue cracks. A change in temperature resulted in a signal from the detector and electronic equipment. This change of temperature was caused by the thermal discontinuity represented by the flaws. Smallest cracks detected were visible to the eye.

4909 **TANTALUM ALLOY TUBING DEVELOPMENT PROGRAM**

F.S. Turner
Allegheny Ludlam Steel Corporation Research Center, Brackenridge, Penn.
Contract AF 33 (357) 11261, Seventh interim rpt.
RTD tech rpt 8-109 (VII), January 1966
AD-476 663

The efforts during this report period were concerned with the vacuum annealing and inspection of the tube hollows prior to tube reducing. Results of the metallographic examination vidigage, ultrasonic and dye penetrant tests are given. The T-222 alloy appears to be extremely sensitive to thermal stress cracking and extreme care must be taken in cutting or conditioning operations.

4936 **INSTRUMENTATION AND NONDESTRUCTIVE TESTING**

General Electric Co., Richland, Wash. Hanford Atomic Products Operation
In: Rpt HW-84384 (Rsch. and devt. programs executed for the Division of Reactor Development. Quarterly report, July-September 1964), December 1964, p. 7.1-27

Research is reported on fuel rupture monitoring systems, gamma scanning fuel burnup measurements, regenerating neutron flux detectors, microwave neutron flux monitors, and boron-11 neutron detectors. Development of electromagnetic and thermal nondestructive test methods is described along with ultrasonic transducer research, ultrasonic imaging studies, and development of fatigue detection methods.

4955 **CHARACTERISTICS OF AN INFRARED VIDICON TELEVISION SYSTEM**

H. Berger, I.R. Kraska
Argonne National Laboratory, Argonne, Illinois
Materials Evaluation, April 1966, p 197-200

An infrared sensitive television system is described. The system employs a relatively inexpensive vidicon camera, which shows a nominal useful response from 0.8 to 2.3μ with some response to wavelengths as long as 2.7μ. Data include response characteristics, speed, and temperature differentials which can be detected at various temperatures. The observed lower temperature threshold response of the system was 170C; temperature variations as small as 3C were detected for surface temperatures of 350C or higher. The low cost, ease of operation, and speed of response of the system make it attractive for preliminary infrared nondestructive testing applications, and for testing applications in which the temperature differential capability of the system can be utilized.

4963 **THERMAL SURFACE IMPEDANCE FOR PLANE HEAT WAVES IN LAYERED MATERIALS**

D.R. Green
Battelle-Northwest Laboratory, Richland, Washington. Rpt BNWL-SA-433
Journal of Applied Physics, v. 37. July 1966, p. 3095-3099

Thermal surface impedance is defined as the ratio of temperature to heat flow for plane steady state sinusoidal heat waves at the surface of a sample. The general analytical expression relating thermal surface impedance of a two layer material to the thermal properties of the layers and the conductance of the joint between them is given. Computed values, for the special cases of two layers in perfect contact and of a single layer are graphically presented. Experimental data supporting the graphic presentation were obtained with a novel thermal transducer method. The close theoretical relationship between the sinusoidal steady state impedance and transient behavior is also briefly discussed.

4974 **AN INSTRUMENT FOR NONDESTRUCTIVELY TESTING FUEL CORE TO CLADDING HEAT TRANSFER**

D.R. Green
General Electric Co., Hanford Atomic Products Operation, Richland, Wash.
Nuclear Science and Engineering, v. 12 (February 1962), p. 271-275

This paper describes equipment developed which is capable of nondestructively plotting core-to-cladding heat transfer quality. Surface temperature variations were detected by an infrared radiometer during induction heating. Defects as small as 1/8 in. diameter in zercoloy-2 clad and down to 3/8 in. diameter in aluminum alloy clad fuel elements are detectable.

4994 **THE SURFACE-TENSION METHOD OF VISUALLY INSPECTING HONEYCOMB-CORE SANDWICH PLATES**

S. Katzoff
National Aeronautics & Space Adm., Langley Field, Virginia
Nondestructive Testing, March-April 1960

When one face of a metal-honeycomb-core sandwich plate is heated or cooled relative to the other, heat transfer through the core causes the temperature on each face at the lines of contact with the core to be slightly different from that on the rest of the face. If a thin liquid film is applied to the face, the variation of surface tension with temperature causes the liquid to move from warmer to cooler areas and thus to develop a pattern corresponding to the temperature pattern on the face. Irregularities in the pattern identify the locations where the core is not adequately bonded to the face sheet. The pattern is easily observed when a fluorescent liquid is used and illumination is by means of ultraviolet light.

4995 **QUALITATIVE ANALYSIS OF BRAZED SANDWICH**

F.J. Filippi
Solar Aircraft Co., San Diego California
Nondestructive Testing, January-February 1959

A discussion of the various methods utilized for the inspection of brazed honeycomb sandwich materials. Methods include radiography, fluoroscopy, ultrasonics, thermal gradient, heat sensitive paint, fluid repulsion, and infrared.

5012 **APPLIED RESEARCH TO ESTABLISH INFRARED DETECTION METHODS FOR NON-DESTRUCTIVE ANALYSIS OF METALLIC AND CERAMIC STRUCTURES (Part II)**

D.R. Maley, H.T. Pinnick, R.J. Barton
Automation Industries, Inc., Boulder, Colorado
Rpt ASD-TDR-62-385, part II, August 1963
AD-605 511

Emphasis has been on metals. A thermal testing system developed previously was utilized to study material properties through the inspection of heat-transfer rate that is monitored by infrared radiometric surface-temperature measurements. These temperature measurements are used to indicate certain material properties that have an effect on heat transfer. Properties detected to date are voids, inclusions, unbonding, porosity, coating thickness, alloy percentage, grain size, and lattice deformation by cold working. (For Part I, see AD-299 230).

5013 **APPLIED RESEARCH TO ESTABLISH INFRARED DETECTION METHODS FOR NON-DESTRUCTIVE ANALYSIS OF METALLIC AND CERAMIC STRUCTURES (Part III)**

D.R. Maley, S.W. Maley
Automation Industries, Inc. Boulder, Colorado
Rpt ASD-TDR-62-385, part III, March 1964
AD-605 510

Various material properties or defects in samples have been evaluated by one or both of two basic testing methods, known as the scan heat technique and the heat support technique. Both methods operate on the principle that heat-transfer rates through a material are dependent on the properties of the material and the presence of internal defects. Heat is introduced at the surface of a sample. Its transfer away from the surface into the sample is gaged by continuous monitoring of surface temperature with an infrared radiometer. The scan heat technique utilizes a moving spot heat source, while the heat support technique relies on large area heating. Material parameters studied have included voids and unbonds, adhesion of plating, cracks in coatings, bulk and surface deformation, grain size, and analysis of alloys.

5079 **DEVELOPMENT OF KRYPTON-85 AS A UNIVERSAL TRACER**

O. Cucciara, P. Goodman
Panametrics, Inc., 221 Crescent St., Waltham, Mass.
Contract AT(30-1)-2757. Final rpt, 1 December 1964-30 November 1966
Rpt NYO-2757-6, May 1967

Discusses the application of kryptonates to the detection of wear and to the study of wear parameters, and the feasibility of preparing phosphor kryptonates for luminescent panels, signs, and signal lights. Comparison of the accuracy for the kryptonates technique for the measurement of surface temperatures of various steel alloys with the accuracy obtained by thermocouples, optical pyrometers, photographic techniques and temperature sensitive paints is described. Additional areas outlined: application of kryptonates to the detection of hazardous vapors and an investigation of the kryptonate technique for the assessment and study of ultraviolet induced degradation in thermal control coatings.

5116 **UNUSUAL NONDESTRUCTIVE TESTING TECHNIQUE--EQUIPMENT, APPLICATIONS, AND INTERPRETATIONS**

B. Ostrofsky
ASM Tech Rep no. D5-10.5. American Society for Metals, Metals Park, Ohio, October 1965.

Several new nondestructive techniques are presented for materials evaluations. These include color radiography, ultrasonic imaging, ultrasonic attenuation, acoustoelastic measurements, correlation of heat transfer with ultrasonic transmission and measurements of residual stress. Examples of color radiographs include welds of aluminum plate showing lack of penetration and four enriched foils showing differences in thickness. The use of ultrasonic imaging in inspecting an Al-alloy fuel cladding material reveals defects not detected by other types of inspection. A block diagram is shown of an ultrasonic pulse system for attenuation measurements and a commercial ultrasonic attenuation comparator. Relationship between thermal conductivity and ultrasonic amplitude is shown for Cu braze-bonded specimens.

5135 **AN INFRARED RADIOMETRIC MICROSCOPE FOR NONDESTRUCTIVE TESTING OF INTEGRATED CIRCUITS (English)**
R.B. McIntosh, Jr.
Chemische Rundschau, no. 23, November 11, 1965, p. 725-727

The problem associated with electrical testing of thin films and integrated electronic circuits and comprehension of related thermal problems have been resolved in recent times by employing non-destructive infrared techniques. Recent advances in infrared radiometry for precision temperature measurements are discussed. The apparatus consists of two sections–a microscope to make thermal measurement of small regions and an electronic control unit to coordinate the data. Direct temperature measurements can be made from 15 to 165 C. A reflecting microscope objective collects visible and infrared energy from target and transmits to a detector. An automatic scanning device provides thermal patterns of selected areas. The detector is a thermistor bolometer which provides wide spectral response by employing a technique called hyperimmersion, which allows a small differential region to have a large effective collecting area. Mathematical equations for sensitivity and system performance are obtained. The wide temperature range, high resolution, and simplicity of use make this a versatile instrument. Improper bonding and adhesion of circuit elements may be detected from thermal patterns.

5140 **DEVELOPMENT OF NONDESTRUCTIVE METHODS**
In: Metallurgy Division Annual Progress Report for 1964, Rpt ANL-7000,
Argonne National Laboratory, Illinois, p. 146-152

Progress in the development of nondestructive methods of materials testing is reported. Effort was directed in the areas of: correlation of the sound transmission properties, heat transfer properties, and strength of a bond; ultrasonic instrument and transducer development; ultrasonic imaging; determination of elastic moduli of high-temperature materials by ultrasonics; development of a neutron image intensification system; development of infrared systems; and investigation of the quality of brazed joints.

5150 **THIN FILM MICROCIRCUIT INTERCONNECTIONS**
H.M. Greenhouse et al.
The Bendix Corporation, Bendix Radio Division, Baltimore, Maryland
Tech rpt. ECOM-01482-2, March 1966
AD-631 412

Infrared photography has been evaluated as a nondestructive test for the quality of thin film interconnections; and it was found not to be very useful. A new interfacial interconnection pattern is proposed which will make possible precise quantitative values for the interfacial resistance. No correlation between capacitance and breakdown voltage has been found. An automatic tester for breakdown voltage determinations is being designed.

5162 **CHOLESTERIC LIQUID CRYSTALS AND THEIR APPLICATION TO THERMAL NON-DESTRUCTIVE TESTING**

W.E. Woodmansee
The Boeing Company, Seattle, Washington
Materials Evaluation, October 1966, p. 564-566, 571-572

The unique properties of cholestric liquid crystals are described, and a number of applications involving the use of these materials to visualize small thermal gradients are shown. The paper also discusses mixtures of liquid crystals which respond rapidly to temperature changes of 1 C or less by reflecting visible light of different colors. Examples are shown of the detection of surface and subsurface flaws in metals and nonmetals, measurement of the surface temperature of electronic components, identification of circuit board interconnections having excessive resistance, and inspection of adhesively bonded honeycomb sandwich materials with liquid crystals.

5165 **CHARACTERISTICS OF A THERMAL NEUTRON TELEVISION IMAGING SYSTEM**

H. Berger
Argonne National Laboratory, Argonne, Illinois
Materials Evaluation, September 1966, p. 475-481

This article describes a thermal neutron sensitive image-intensifier tube said to be capable of presenting a demagnified, bright-visible image of a thermal neutron beam. The system is capable of following fast moving objects without objectionable blurring, and displays a contrast sensitivity of 4 percent in a narrow thickness range for steel and uranium. Resolution and contrast sensitivities are analyzed and application areas are indicated.

5172 **AN INFRARED METHOD OF ROCKET MOTOR INSPECTION**

J.C. St. Clair
Thiokol Chemical Corporation, Huntsville, Alabama
Materials Evaluation, August 1966, p. 425-430

A sensitive method was developed to determine band integrity in solid propellant rocket motors. The method uses a near-surface direct-current thermal detector that is not significantly affected by emissivity variations. Temperature differences as small as 0.1F have been detected, and a capability demonstrated to distinguish between case-lines and liner-propellant separations. The equipment is small, portable, and inexpensive. Accepted methods of infrared or thermal inspections are described.

5216 **RELATIONSHIP BETWEEN THE EFFECTIVE THERMAL CONDUCTIVITY AND ULTRASONIC TRANSMISSION FOR COPPER BRAZE BONDS**

R.A. Di Novi
Applied Materials Research, v. 5, n. 3, July 1966, p. 162-167

The heat transfer and ultrasonic transmission properties of Cu braze bonds were investigated and a correlation between these properties established, thereby insuring that the ultrasonic nondestructive tests employed to assess bond quality of nuclear fuel elements do bear a relation to the serviceability of the element. A decrease in the amplitude of the ultrasonic transmitted pulse signifies a loss of effective thermal conductivity, but the relationship is strongly frequency-dependent. Methods of measuring the effective thermal conductivity and ultrasonic transmission are described, and a discussion of the results is presented.

5256 **AUTOMOBILE TIRE HOT-SPOT DETECTION**
Theory, Application and Instrumentation for Infrared Nondestructive Testing
Barnes Engineering Co., 30 Commerce Rd., Stamford, Conn.

The Barnes Models R-4D1 and R-4C1 Industrial Radiometers were successfully used in rubber tire experiments conducted by two different tire manufacturers. Tests were performed to check the uniformity of manufacture by monitoring the temperature of the rubber materials with the tires placed on conventional tire test stands and the tires rapidly rotated. Any hot spots or widely varying temperature gradients were determined using the Barnes Industrial Radiometer and on an electronic monitoring network.

5260 **INFRARED TESTING OF ELECTRONIC COMPONENTS**
W.R. Randle et al.
Martin Marietta Corp., Orlando, Florida
Rpt OR 8347, June 1966
N66-29973

A 14-month study program was conducted to explore the feasibility of developing infrared radiation NDT techniques for electrical/electronic devices. The completed study included 3 distinct phases: (1) state-of-the-art survey, (2) testing conformal coating materials to standardize surface emissivity, (3) determining the feasibility of using infrared in various actual applications. The overall objective of the program was to detect incipient failures not revealed by present electrical testing methods.

5262 **THERMAL (INFRARED) RADIOMETERS AS INSTRUMENTS FOR NONDESTRUCTIVE RELIABILITY TESTING**
R.M. Fraser
U.S. Navy Electronics Laboratory, San Diego, Calif.
NEL Rpt 1377, May 1966
AD-635 607

Exploitation of radiometers for the reliability testing of monolithic integrated circuits requires a knowledge of the capabilities and limitations of these instruments. As a basis for the design, development, and evaluation of radiometer systems, graphs have been worked out which illustrate the interaction of the major design parameters and the system requirements. The graphs were obtained by an analysis of the thermal detection and display problems from an engineering viewpoint.

5281 **NDT ON ADHESIVE JOINTS MAY OPEN UP NEW JOBS**
Steel, 27 March 1967, p. 59-62

This is a general article that discusses the various ways in which NDT is applied to adhesive bonded joints. The methods discussed are: acoustic emission, infrared testing, eddy-sonic testing, Fokker Bond Tester, and liquid crystals. While not a technical article, there are several good leads to individuals and companies involved or using NDT on adhesives.

5338 **FAST SCAN INFRARED MICROSCOPE FOR IMPROVING MICROELECTRONIC DEVICE RELIABILITY**

L.C. Hamiter, Jr.
NASA, Marshall Space Ctr., Huntsville, Ala.
Its Research Achievements Review, v. II (1966), rpt no. 5, p. 1-7
Also in: Rpt NASA-SP-5082, p. 99-111
N67-27751

The emission of infrared radiation by semiconductor chips led to a method for testing microminiature circuits with an infrared microscope. A description of infrared radiation is presented and is related to the electrical power dissipation of an electronic part. A description of the composition and operation of the infrared microscope is presented. The feasibility of inspection of the elements and circuit junctions of microelectronic chips is demonstrated. Thermal maps of circuits are examined for defects and design problems. The possibility of using the infrared microscope for testing transistors is discussed.

5388 **THERMAL SURFACE IMPEDANCE FOR PLANE HEAT WAVES IN LAYERED MATERIALS**

D.R. Green
Journal of Applied Physics, v. 37, July 1966, p. 3095-3099
Also in: Current Infrared Papers, October 1966 (Available from NST, Chicago, Ill.)

Thermal surface impedance, Z_S, is defined as the ratio of steady state sinusoidal temperature to heat flow at the surface of a sample. Measurement of Z_S can be used to nondestructively evaluate materials in a manner similar to that in which electromagnetic impedance is used in eddy current testing of conductors. Dependence of the thermal surface impedance on sample properties is discussed theoretically and is graphically illustrated in this paper. A thermal transducer method developed for experimentally measuring Z_S and some of the experimental results obtained are described. This method can be applied to measure thermal properties in one or two layers of solid materials, the thickness of a layer, or the thermal bond resistance between two layers.

5395 **THERMOELECTRIC METAL COMPARATOR DETERMINES COMPOSITION OF ALLOYS AND METALS**

AEC-NASA Tech Brief 67-10035, February 1967, CFSTI, Springfield, Virginia

A device was developed which measures the difference in emf produced by the junction of a hot probe and the junction of a cold contact on the surface of an unknown metal. The instrument utilizes the "Seebeck" effect, where a hot junction between two dissimilar metals produces a characteristic emf, the magnitude of which is dependent on the temperature of the junction and the composition of the metals.

5466 **RESOLUTION OF FLAWS IN INFRARED NDT**

F. Alzofon
American Rocket Society Solid Propellant Conference, Baylor Univ., Waco, Texas, January 24-26, 1962

A survey of factors influencing recent effort to extend the thermal NDT method is presented, as to affect the resolution of flaws. One of these factors is the method of heating selected. Various methods of heating are described and some of the advantages and disadvantages of each are analyzed.

5480 **EDDY CURRENT AND INFRARED INSPECTION OF GRAPHITE**

C.V. Dodd
Oak Ridge National Laboratory, Oak Ridge, Tenn.
Paper no. 61 (advance copy), ASTM 70th Annual Meeting, Boston, June 25-30, 1967

Eddy Current and Infrared techniques are applied successfully to the inspection of graphite. A phase-sensitive eddy current instrument has been used in a through transmission mode to measure the thickness of thin graphite plates and to detect cracks in a variety of different graphite components such as spheres, tubes and cylinders. An infrared heat transfer technique was also applied to the spheres to detect near-surface laminations. Sample laminations with a diameter four times their depth beneath the surface were easily detected.

5482 **ULTRASONIC MEASUREMENT APPARATUS EMPLOYING A COOLED CYLINDRICAL TRANSDUCER**

E.H. Carnevale et al.
Patent No. 3,354,699
Commissioner of Patents, Washington, D.C.

A measurement system for determining the ultrasonic transmission characteristics of a material which employs a cylindrical ultrasonic transducer. A belt is passed around the cylindrical transducer and around an idler roller which serves both to couple ultrasonic energy between the material and the roller and to transfer heat away from the roller. A cooling element displaced from the cylindrical transducer cools the belt.

5500 **ON THE SINGULAR CHARACTER OF THERMAL STRESSES NEAR A CRACK TIP**

G.C. Sih
Journal of Applied Mechanics, September 1962, p. 587-88

A mathematical analysis of crack-tip stress singularities in isothermal elastic bodies utilizing Irwin-Griffith fracture concepts.

5547 **THERMAL SURFACE IMPEDANCE METHOD FOR NONDESTRUCTIVE TESTING**

D.R. Green
Battelle Memorial Institute, Richland, Washington
Materials Evaluation, v. 25, (October 1967), p. 231-236

Thermal surface impedance, Z_S, is defined as the ratio of steady state sinusoidal temperature to heat flow at the surface of a sample. Measurement of Z_S can be used to evaluate materials nondestructively in a manner similar to that in which electromagnetic impedance is used in eddy current testing of conductors. Dependence of the thermal surface impedance on sample properties is discussed theoretically and is graphically illustrated in this paper. A thermal transducer method developed for experimentally measuring Z_S and some of the experimental results obtained are described. This method can be applied to measure thermal properties in one or two layers of solid materials, the thickness of a layer, or the thermal bond resistance between two layers.

5607 **RELIABILITY SCREENING USING INFRARED RADIATION**

B. Selikson, J. DiMauro
Sylvania Electric Products, Woburn, Mass.
Tech Rpt no. RADC-TR-66-360, October 1966
AD-642 112

This paper describes the development of a process of screening transistors with a high probability of failure from similar but reliable transistors on a basis of the infrared output under operating conditions. The Evaporograph is compared with a bolometer and an indium antimonide-type microscope. A screening efficiency index is calculated.

5624 **SOUND VELOCITIES IN ROCKS AND MINERALS**

O.L. Anderson, R.C. Liebermann
Columbia Univ, Lamont Geological Observatory, Palisades, N.Y.
Publisher: University of Michigan, Geophysics Lab (VESIAC) of the Willow Run Labs,
Willow Run, Mich. Rpt no. 7885-4-A, November 1966
AD-804 865

This state-of-the-art report summarizes experiments and data on sound velocities in rocks and minerals and projects useful lines of research. The report discusses in detail the three common measuring techniques now employed. Promising techniques, both direct and indirect, are described. Methods of estimating elastic constants at high pressure and high temperature are indicated. The data extent on the sound velocities of rocks are considerable and are tabulated in several appendixes. A method of estimating unmeasured properties in a class of rocks, using data already reported for that class, is reviewed.

5700 **ULTRASONIC TEMPERATURE DETERMINATIONS IN A PLASMA**

E.H. Carnevale et al
In: Temperature--Its Measurement and Control in Science and Industry,
v. 3, part 2 (NY: Reinhold, 1962), p. 959-967

Temperatures in the range 4000 to 8000°K have been measured in an air plasma jet using an ultrasonic pulse technique. The results are estimated to be accurate to within 10 or 20%. Ultrasonic pulse techniques offer a relatively simple practical method for measuring spatially averaged temperatures in a plasma over a wide range of conditions provided that the gas composition is known and that high accuracy (better than a few percent) is not required.

5701 **STUDY OF THE BORDONI PEAK IN A SILVER SINGLE CRYSTAL**

M. Mongy, et al.
Nuovo Cimento, series X, v. 36 (1 March 1965), p. 10-17

The Bordoni peak has been investigated in the (100), (111), and (110) orientations of a silver single crystal. The measurements have been made at frequencies 10, 20 and 50 MHz in the temperature range 80° to 300°K. The activation energies and the relaxation frequencies are found to be different from one orientation to the other; the minimum values are obtained when the ultrasonic waves are applied parallel to the (100) direction.

5702 **ULTRASONIC AND THERMAL EFFECTS IN SUPERCONDUCTORS**
R.S. Kagiwada
University of California at Los Angeles, Physics Dept., December 1966
AD-644 182

Some of the properties of three transition metals, niobium, vanadium and tantalum have been investigated using the ultrasonic technique. The normal attenuation in niobium possessed a typical electron-photon behavior with a temperature dependence of $T^{-3.2}$. In the superconducting state attenuation was measured in both the absence of a magnetic field and at various values of the external magnetic field. The energy gap temperature dependence was investigated over a wide temperature and close to the transition temperature. For niobium in the mixed state, the propagation of both transverse and longitudinal waves was studied. In tantalum, the usual hysteresis of the ultrasonic attenuation was found. In the course of the ultrasonic studies, some rather unusual behavior in the mixed state of niobium was observed. The cause of these temperature and ultrasonic attenuation spikes is attributed to the jumping of flux bundles.

5723 **THE CHAMELEON CHEMICAL**
Life, January 12, 1968, p. 40-4[illegible]

This article is an excellent, full-color introduction to liquid crystals and their potential application to medicine, metal analysis, circuit testing, xerographic printing, and gas leak detection. While this is not a scientific paper, per se, the color pictures are quite good as a primer in the field.

5736 **SURVEY OF THE STATE-OF-THE-ART OF THERMAL-TYPE INFRARED DETECTORS**
E.M. Wormser
Barnes Engineering Co., 30 Commerce Rd., Stamford, Conn. (Company publication)

This report reviews the need for infrared detectors responding to different wavelengths which are a function of target temperature, and reviews the type and sensitivity of available detectors including photodetectors, thermal detectors as such, and thermocouples, bolometers, thermopiles, immersed thermistor bolometers and others.

5766 **KRYPTON OBSERVES WEAR IN ACTION**
Iron Age, 14 April 1966

General discussion of the use of kryptonates to solve a variety of practical problems. Rapid screening of lubricants, checking interfacial temperatures for materials compatibility and determining corrosion in various environments are suggested applications. Example given on peak temperature determination at different sections on a kryptonated turbine blade after use. The formation of surface oxides or other corrosion products on rubbing surfaces are measurable because kryptonates lose activity from the surface if a chemical reaction destroys the lattice structure of the solid. Unlike temperature, oxide formation can be measured in kryptonated solids as it occurs. Can detect wearing irregularities or the sudden onset of severe wear caused by lubricant breakdown or sudden load increases.

5767 **SURVEY OF TRACING AND SENSING SYSTEMS FOR THE DETAILED STUDY OF FIBROUS MATERIALS UNDER TENSILE-IMPACT LOADING**

B. Rosen, R.H. Supnik
Plas-Tech Equipment Corporation, Natick, Mass.
Army Natick Labs. Report 68-28-CM, November 1967
AD-664 781

Some of the systems surveyed include optical trackers, magnetic tapes, multiple flash photography capacitance transducers, and magnetic proximity devices. Under a section entitled, supplementary aids for dynamic-photography recordings, there are included grid photographs, moire fringe pattern photographs, liquid crystal photographs, thermal image photographs, and photographs of radiation images. Conclusions are drawn and recommendations for follow-up on the various methods are given.

5770 **DEVELOPMENT OF LABORATORY MODEL FATIGUE CRACK DETECTION DEVICE BASED ON INFRARED TECHNIQUES**

E.J. Kubiak, L.M. Frank
General American Transportation Corp., General American Research Div, Niles, Ill.
Tech rpt AFFDL-TR-67-39, October 1967
AD-824 656

A laboratory model fatigue crack detection system based on infrared techniques was developed for use in the A.F. Sonic Test Facility, Wright-Patterson AFB. The system operates at a maximum working distance of 6 feet and scans a 12 x 12 inch square area in three minutes or less. Cracks open to the surface and subsurface cracks close to the surface can be detected. A dynamic IR method is used which injects energy into the structure with a sharply focused radiative heat source and which measures the resulting local temperature rise with an infrared detector. Location and size of cracks can be determined from a 2 dimensional "thermal gradient map". (Abstract distribution - unlimited)

5802 **A NOVEL INFRARED NONDESTRUCTIVE TESTING TECHNIQUE FOR DETERMINING THE THERMAL CONDUCTIVITY OF GRAPHITE**

A.W. Schultz
Avco Corp, Avco Space Systems Div., Lowell, Mass.
In: Nondestructive Testing of Nuclear Graphite. ASTM STP 439. ASTM, 1968. P. 70-86

A unique method has been developed for rapidly determining, nondestructively, the localized thermal conductivity, and thermal diffusivity of graphites near room temperature. The method employs transient heating and requires access to only one surface of a solid. Application of this technique to coated ATJ graphite indicates that it is capable of discerning inertia differences equal to 15 percent, conductivity differences of 15 percent, and diffusivity differences of 10 percent. Noteworthy features of this method include: (1) point-to-point conductivity/diffusivity/inertia determinations, which afford an additional tool for nondestructively evaluating material variability; (2) extension of its application to poor thermal conductors, which will increase the method's precision; and (3) probable application to materials in elevated temperature environments.

5818 **THERMAL AND INFRARED METHODS FOR NONDESTRUCTIVE TESTING OF ADHESIVE-BONDED STRUCTURES**

E.W. Kutzcher, K.H. Zimmerman, J.L. Botkin
Lockheed-Calif. Co., Burbank, Calif.
Materials Evaluation, July 1968, p. 143-148

Thermal and infrared NDT methods of adhesive-bonded aerospace structures are discussed. The design of an active rapid-scanning infrared inspection system for large, panel-shaped components is described. Examples of measuring results are presented.

5821 **STUDY ON DEVELOPMENT OF TECHNIQUES FOR RESISTANCE WELDING**

W.R. Hutchinson, et al.
Martin Marietta Corp., Orlando, Fla.
NASA Contract NAS 8-20339, February 1967
N67-40315

Report verifies the correlation between infrared heat radiation and the quality of the weld joint. 7000 welds, including four wire combinations most commonly used in industry, provide evidence that the IR technique can guarantee high quality welds, mass produced. Statistical experiments varied the welding parameters including watt-second energy, weld pulse rise time, and electrode pressure, for different wire combinations, and simultaneously recorded the voltage, current, and infrared radiation. A Go, No Go visual indicator was designed and breadboarded to implement the technique. Initial work on developing the in-process, pre-weld inspection technique utilizing the pseudoweld concept was accomplished.

5886 **DETECTION OF MATERIAL DISCONTINUITIES WITH LIQUID CRYSTALS**

W.E. Woodmansee, H.L. Southworth
The Boeing Co.
Materials Evaluation, August 1968, p. 149-154

The inspection capabilities and limitations of liquid crystals applied after various joining methods have been used are discussed, and a comparison is made between these materials and conventional techniques. In addition, a brief description is given of the properties of liquid crystals from the standpoint of their applicability to nondestructive testing.

5904 **KRYPTONATES: KR^{85} BECOMES A UNIVERSAL TRACER**

D. Chleck, et al
Nucleonics, v. 21, n. 7 (July 1963), p. 53-55

Discusses the preparation, properties, stability, safety, and applications for kryptonates. Feasibility for applications to radiochemical analysis and corrosion, friction, and wear studies shown. Improves existing radioisotope techniques. Temperature-dependent leakage coupled to the fact that KR^{85} is located at or near the surface permits measurement of surface and interfacial temperatures. Other applications include detection and measurement of reactive gases, detection and analysis of species in solution such as acids in aqueous solution, and chemical kinetics studies.

5908 **PROGRESS REPORT OF INFRARED NDT OF SOLID PROPELLANT MOTORS WITH LMSC MOD VI AND BARNES T-4 IR CAMERA SYSTEMS**

E.M. Bergh, T.F. Jennings

In: Nondestructive Test Procedures, Part 2. U.S. Naval Weapons Station, Quality Evaluation Lab, Concord, California, 1966. Part 15

A checkout of the LMSC Mod VI IR system modifying it as required to make it suitable for IR scans of Polaris Second Stage A-3 motors is described. Similar independent IR scans using the Barnes T-4 IR camera for evaluation and correlation of both systems were made. In addition, data processing systems using the Alden "C" scan recorder and Tektronic Storage Scope are used. The results of both systems were to be further correlated with X-rays of the motors tested. Two motors which had been radiographed several times in a previous project were scanned with the two types of IR equipment.

5911 **A METHOD FOR PHOTOGRAPHIC MICROWAVE WITH A POLAROID FILM**

K. Iizuka

Division of Engineering and Applied Physics, Harvard University

Tech Rpt no. 558, March 1968. (Office of Naval Rsch Contract N00014-67-A-0298-0005; NASA grant NGR-22-007-056)

AD-667 729

A regular Polaroid film has proved to be applicable to a quick and easy direct mapping of an electromagnetic field. The method utilizes the selective development of the film in accordance with the thermal image produced by the electromagnetic field. The power required for the creation of a clear image is about 0.06 watts per square inch. The time of exposure to the microwave is about 15 to 60 seconds. The method would be useful for preparing microwave holograms. It can also be applied to the mapping of the temperature distribution in space.

5958 **RELIABILITY SCREENING AND STEP-STRESS TESTING OF DIGITAL-TYPE MICROCIRCUITS**

H.F. Dean, K.F. Harper

Naval Electronics Laboratory Center for Command Control and Communications, San Diego, Calif.

NELC/Rpt 1512, 1 September 1967

AD-662 197

The effectiveness of thermal infrared mapping and nondestructive electrical tests for reliability screening was tested on 100 specimens of an industrial grade digital-type microcircuit. It was shown that more effective screening tests are needed, as a number of early failures were not predictable by the test methods employed. It was also shown that microcircuit containers may be opened for inspection and testing without degrading their reliability.

5969 **TEMPERATURE MEASUREMENT SYSTEM UTILIZING INFRARED RADIATION SENSING TECHNIQUES**

Infrared Industries, Inc., Santa Barbara, Calif.
Goddard Space Flight Center, Greenbelt, Md. Final Proj. Rpt. 14 August 1967
N68-10001

Final report of a design study of a temperature measurement system utilizing infrared radiation sensing techniques. Measures the temperature profile of a low-level, hot gas thruster during operation in a vacuum chamber. Signal-to-noise ratio and the minimum detectable temperature is adequate with ample safety margin to measure temperatures at 80°F to 800°F with an accuracy of five degrees. Designed to scan a 4-inch diameter cylinder, 7 inches long, while located at center of a 4-foot diameter environmental vacuum chamber. Spatial resolution at focal plane: Two sizes 0.930 inches square and 0.0600 inches square.

5987 **INFRARED TESTING OF BONDS BETWEEN GRAPHITE AND PROTECTIVE COATINGS**

D.R. Green, C.K. Day
In: Nondestructive Testing of Nuclear Graphite. ASTM Special Technical Publication no. 439
ASTM, 1968, p. 4-17

A nondestructive infrared method has been developed for testing bonds between coatings and graphite. Application of a special digital dual-scan technique makes the test independent of the specimen surface emittance (often called emissivity). In addition, this method does not require contact with the specimen, and can be automated for production testing. Heat was applied during tests by projecting a hot jet of helium onto the specimen surface. A commercial infrared radiometer was used to sense the resulting surface temperatures. This paper describes the theory and equipment, and some of the experimental results from tests on bonds between graphite and thin columbium carbide coatings.

6001 **THERMAL EVALUATION OF DIFFUSED-JUNCTION SEMICONDUCTORS**

R.A. Delaney
IBM Components Div., East Fishkill, N.Y.
Rpt TR 22.706, 4 October 1968
Presented at the 6th Reliability Physics Symposium in Los Angeles, Calif, 6-8 November 1967

A printed thick-film cobalt oxide thermistor is interposed in parallel with the transistor chip, between the land and substrate, to monitor temperature. This sensor, along with the "diode equation" (which describes the relationship between current, temperature, and voltage for a diffused junction), gives temperature readings at points previously more difficult to obtain. Each substrate interface can be sensed individually by the thermistor. Using input/output pins with heat sinks as thermal reference points, one can approximate actual circuit conditions, minus cooling perturbations. Other advantages are that thermal evaluation of module packaging can compare heat transfer rates through covers or electrical attachments, and that thermal resistance can be evaluated at specific points without making special test modules for selectively measuring various component parts.

6078 **NONDESTRUCTIVE TEST METHODS FOR REINFORCED PLASTIC/COMPOSITE MATERIALS**

G. Epstein
Aerospace Corp., El Segundo, Cal.
Aerospace Rept. No. TR-0200(4250-20)-4
Air Force Rept. No. SAMSO- TR-69-78, 3 February 1969
AD-686 466

A review is presented of various methods for nondestructive testing (NDT) of reinforced plastic/composite materials and structures. Visual inspections, ultrasonic methods, sonic methods, radiography, electrical properties, microwave techniques, thermal techniques, and other NDT methods are examined with regard to their characteristics, instrumentation, utility, and limitations. Recent developments are also discussed.

6079 **NONDESTRUCTIVE INSPECTION OF AN ADVANCED GEOMETRY COMPOSITE BLADE**

R.D. Whealy, A. Intrieri
Boeing Co., Vertol Div., P.O. Box 16858, Philadelphia, Pa. 191..
Presented at Conference on NDT of Plastic and Composite Structures, Dayton, Ohio, March 1969

This paper presents Boeing's approach to provide an integrated QA plan for an Advanced Geometry Composite Rotor/Propeller Blade program which includes specific applications that will be used to control quality throughout the fabrication process. Included are: Inspection of Rotor Blade Honeycomb Box assemblies for voids using infrared; Inspection of rotor blades using a semiautomatic X-ray sensitive vidicon/image intensifier system; Inspection of rotor blades for bond quality using a semiautomatic ultrasonic system; and inspection of steel spars using a magnetic perturbation technique.

6080 **INFRARED TO VISIBLE IMAGE TRANSLATION DEVICES**

R.W. Astheimer
Photographic Science & Engineering, v. 13, n. 3 (May-June 1969), p. 127

Infrared to visible image translation systems have been constructed where each infrared wavelength band is made to correspond to a visible color. The results of this translation have been disappointing when displaying objects near ambient temperature by their self-emitted or thermal radiation because the spectral contrast of such images is usually poor. An alternate approach is to translate successive temperature intervals into visible tonal or color bands. This results in a great enhancement of contrast and permits quantitative thermal data to be stored and presented conveniently on film. Two scanning devices operating on this principle are described and examples of the image translations shown.

6097 **A SURVEY OF LEAK DETECTION FOR AEROSPACE HARDWARE**

F.E. Wells
Marshall Space Flight Center, Huntsville, Ala.
Materials Evaluation, May 1969, p. 97-101

This paper is a survey of leak-detection equipment, practice, and philosophy applicable to external leak testing of aerospace hardware, based on experimentation and evaluation work performed at the Marshall Space Flight Center, engineering analysis of work by others, and experiences gained at MSFC during extensive checkout work on three major vehicle programs, presented in an endeavor to alleviate some of the confusion in this field. The three principle areas covered are: setting acceptance limits, techniques currently available, and selecting a technique for a particular job.

6100 **MEASUREMENT OF ANODIC COATING ON ALUMINUM BY EMISSIVITY**

A.E. Lawler, H. Pirzadeh
Quality Assurance Engineering, The Boeing Co., Seattle, Wash.
Materials Evaluation, May 1969, p. 118-120

The quality of anodizing on aluminum aircraft parts can now be measured nondestructively by emissivity. The method requires that standards relating the amount of aluminum oxide and percent hydration be determined gravimetrically on a series of panels of the several alloys, then correlated against the emissivity value for each respective oxide and hydration value. As a result of the developed data, the Emissometer has been adapted to examine production parts as they emerge from the anodizing tanks and rapidly determine the quality of the oxide layer and degree of hydration.

6101 **NONDESTRUCTIVE TESTING BY HIGH-SPEED THERMOGRAPHY**

L. Bergstrom, D. Baeu
Materials Evaluation, May 1969, p. 25A-28A

AGA Thermovision, an infrared scanner with real time picture presentation is described. The scanning optical system produces 16 frames/second, each frame containing 100 lines with 100 elements per line. The thermal image is presented on a cathode ray tube coated with the fast P4 phosphor. Accurate evaluation of the thermal picture is done by means of isotherms, which are superimposed on the normal picture. The temperature resolution is 0.2 C. AGA Thermovision is used in medicine, in research, and for nondestructive testing. Some of the most interesting and promising applications are described.

6107 **SURFACE TEMPERATURE MAPPING WITH INFRARED PHOTOGRAPHIC PYROMETRY**

NASA Tech Brief 69-10113, June 1969
Available: NTIS, Springfield, Va.

Describes a method for using infrared photographic pyrometry to measure and map the temperature distribution on a heated surface with a high degree of accuracy and precision. The method involves the collection, detection, and measurement of a narrow bandwidth of emitted infrared radiation using commercially available equipment together with systematic procedures. These procedures, compared to conventional methods, can produce higher accuracy, extend the range of temperatures measured, and simplify data handling.

6125 **COATING THICKNESS DETERMINATION BY MEANS OF MEASURING BLACK-BODY RADIATION RESULTANT FROM INFRARED IRRADIATION**
Patent No. 3,413,474
Commissioner of Patents, Washington, D.C. 20231

A measurement of coating thickness such as the thickness of the plastic film applied to paper cartons. The coated material is heated for a predetermined time by infrared radiation and then placed under an infrared detector which measures the black-body radiation of the material. Measurements on previously evaluated samples are used for correlation and coating thickness determination.

6134 **LEAK TESTING WELDED VESSELS**
R.J. Roehrs
Materials Evaluation, October 1969, p. 205

In the leak testing field, numerous methods are at the disposal of the NDT engineer, such as the bubble testing, halogen testing, mass spectrometer testing, etc., and it is his responsibility to determine the best method to be used for detecting, locating, and/or measuring leakage. Even though this paper is slanted toward the leak testing of welded vessels, the basic principles covered apply to many items. As an example, the specific methods described can often be used in determining leakage into, or out of, numerous objects, such as electronic components, aerospace hardware, piping, and pressure and vacuum systems.

6164 **INFRARED EVALUATION OF MULTILAYER BOARDS**
R.W. Jones, L.M. White
Autonetics Div., North American Rockwell Corp., Anaheim, Cal.
Materials Evaluation, February 1969, p. 37

An infrared tester has the unique ability to measure the distributive properties of circuits. This feature is put to good use in testing multilayer etched circuit boards (MLB's). Many of the etched lines in a multilayer board are connected in parallel until the final process steps are completed. This prevents the use of conventional continuity and leakage tests of the individual layer before lamination. Infrared testers can be used to screen out defective layers before lamination, thereby saving the processing of multilayer boards that have defective layers. The equipment and procedures are described in the paper.

6176 **CONTACT THERMOGRAPHIC MATERIALS APPLIED TO NONDESTRUCTIVE TESTING**

W.E. Woodmansee
The Boeing Company, Seattle, Washington

In: Proceedings, 7th Symposium on NDE of Components and Materials in Aerospace Weapons Systems, and Nuclear Applications, San Antonio, Texas, 23-25 April, p. 67-78

When employing thermography for a problem, one must consider the approximate surface temperature at which measurements must be made, spatial and temperature resolution requirements of the test, the stability of the temperature gradients to be sensed, and the rate at which extended areas may be examined. For contact thermographic material, one must also consider the heat capacity of the temperature-sensing medium relative to the test surface, material cost, the time to apply and remove thermally sensitive coatings, equipment requirements, and the skill and training of personnel. These factors are considered in evaluating the following: Cholesteric liquid crystals, thermally quenched phosphors, ionic compounds which exhibit order-disorder transitions, organic compounds which are absorbed by porous papers upon melting, thermally softenable plastics containing a dispersion of minute air bubbles, and dye precursors which combine upon heating. The advantages and disadvantages of performing thermography with each of these media are discussed, and typical applications described.

6219 **STUDY AND DEVELOPMENT OF NONDESTRUCTIVE WELD INSPECTION TECHNIQUES – PHASE II**

W.V. Sterling, Inc., Los Altos, Cal.

NASA-CR-73385, October 1969
N70-10858

The design of prototype nondestructive weld testers (NDT) and the preliminary results of an evaluation program are presented. The NDT system measures the peak values of weld pulse, infrared and dynamic setdown and compares them to acceptance limits. Production welds in a manufacturing environment were processed, and included a large number of material combinations and weld energies from 2.8 to 44 watt-seconds. Welds made with 50 percent dynamic setdown, reverse polarity, deviations in welding process, or operator errors were rejected consistently. The major design criteria were noninterference with the operator, no effect on welding characteristics, minimum complexity, measurement integrity and visual results presented to the operator. Details are given on the general design and the electrical components, and on the evaluation test plan.

6255 **AN INFRARED SCANNING SYSTEM FOR INSPECTION OF PRINTED CIRCUITS**

T.R. Bazemore, Jr.
Western Electric Company, Burlington, North Carolina

In: Proceedings, 7th Symposium on NDE of Components and Materials in Aerospace Weapons Systems and Nuclear Applications, San Antonio, Texas, 23-25 April 1969, p. 388-394

Increased reliability and decreased inspection time are two objectives of an infrared printed circuit scanning system being developed. These objectives will be accomplished by measuring the temperature of every component on a printed circuit, under power, in less than 30 sec. Deviations in temperature from previously established forms will be used to indicate trouble areas. The scanning portion of the system will consist of an infrared microscope and a pair of digitally programmed and positioned mirrors. The infrared microscope will measure the temperature of a 0.040-in.-diameter spot, with a resolution of 0.2°C in approximately 16 ms. The electrical output of the microscope is digitized and compared with programmed values on a Hi, Lo, Pass basis. This information is stored on magnetic tape for digital processing or reference.

6269 **BIBLIOGRAPHY OF INFRARED AND THERMAL TECHNIQUES FOR NONDESTRUCTIVE TESTING**

A.J. Intrieri
The Boeing Company, Vertol Div., Phila. Pa., March 1970
(Distributed by the Infrared & Thermal Committee of ASNT)

The bibliography contains the abstracts of 364 papers and reports which discuss the theory and applications of infrared and thermal methods as applied to NDT. Papers which do not have a direct bearing on NDT (such as infrared tracking systems) have been excluded. The 364 abstracts have been grouped into 4 basic categories as follows: 1. Infrared Techniques for Electronic Circuits and Components (85), 2. Infrared Techniques for Materials and Structures (160), 3. Thermal (Non-Infrared) Techniques (47), 4. Infrared Test Equipment (72). The sources used to compile these abstracts are: 1) previous IR bibliographies, 2) technical journals such as Materials Evaluation, Scientific Instruments, etc., 3) symposia and conferences sponsored by technical societies such as ASNT and IEEE, and 4) technical reports from various government agencies on in-house and contracted research. All ASNT sponsored conferences up to and including the 1970 Spring Conference Los Angeles March 9-13 are covered by this bibliography.

6281 **HIGH SPEED THERMAL TRANSDUCER FOR PRACTICAL NDT APPLICATION**

D.R. Green
Battelle Memorial Institute, Richland, Washington
Presented at the 1970 Spring Conference ASNT, Los Angeles, Cal.
Materials Evaluation, May 1970, p. 97-102

The author describes a new type of thermal transducer capable of imaging bond defects and thermal property differences within test specimens. Images of defects in specimens comprising stainless steel bonded to glass, carbon-carbon composites, aluminum honeycomb with aluminum skin, titanium honeycomb with titanium skin and titanium honeycomb with fiberglass skin are presented. A testing time of 3 sec for a specimen of any size is typical.

6282 **INFRARED EVALUATION OF RUBBER TIRES**

P.E.J. Vogel
Army Materials & Mechanics Research Center, Watertown, Mass.
Presented at the 1970 Spring Conference ASNT, Los Angeles, Cal.

The safety of pneumatic tires depends greatly upon the bonding of the plies and the bonding of the tread to the carcass-inspection problems that do not lend themselves to earlier NDT methods. This paper describes some infrared techniques developed by USAMMRC and reviews some other infrared approaches that have been successful in locating these types of flaws in tires.

6283 **ECONOMIC EFFECTIVENESS OF IR-NDT**

H.M. Hedgpeth
Vanzetti Infrared & Computer Systems, Inc., Dedham, Mass.
Presented at the 1970 Spring Conference ASNT, Los Angeles, Cal.

This paper describes an approach to the quantized measurement of NDT economics and provides trial formulae for evaluation of 1) NDT costs, 2) cost of failure, 3) cost of IR-NDT versus conventional methods, and 4) value added by IR-NDT. Examples in electronics and materials are shown, verifying the economic advantages, of IR-NDT in design evaluation, production process control, testing, maintenance, and warranty.

6284 **NDT APPLICATIONS OF IR FAST SCANNING**

F.J. Stoddard, F.A. Orabona, R. Dorval
Dynarad, Inc. Norwood, Mass.
Presented at the 1970 Spring Conference ASNT, Los Angeles, Cal.

This paper will emphasize applications of fast-scanning infrared cameras and microscopes. Particular emphasis will be placed on thermal analysis of printed circuit boards and microcircuits. Data obtained from Recombination Radiation Studies will be discussed with emphasis on current crowding within device junctions of diode transistor logic.

6292 **NONDESTRUCTIVE TESTING TECHNIQUES FOR FIBER GLASS, GRAPHITE FIBER AND BORON**

D.J. Hagemaier, H.J. McFaul, J.T. Parks
Douglas Aircraft Co., Long Beach, Calif.
Presented at the 1970 Spring Conference ASNT, Los Angeles, Calif.

Various nondestructive test (NDT) methods were evaluated for inspection and evaluation of boron, graphite, and glass-fiber composites for aircraft structures. Typical specimens were evaluated using microscopic, fluorescent penetrant, radiographic. ultrasonic, and thermochromic test methods. Optical microscopic examination is useful for determination of fiber pattern from the edge of a panel. It was concluded that fluorescent penetrant combined with microscopic examination is a useful tool to determine surface defects; radiography combined with magnified photography is an excellent method to determine fiber pattern, fiber gaps, broken fibers, crushed core, and resin-rich areas, and ultrasonic and thermal methods have merit for determining unbonded areas. The results of a literature survey concerning NDT of composites are presented in abstracted form and indicate significant applications and limitations of various test methods.

6294 **THERMAL INSULATION MOISTURE DETECTION**

D.J. Hagemaier
Douglas Aircraft Co., Long Beach, Cal.
Materials Evaluation, March 1970, p. 55-60

This report describes the development of a moisture detector used for evaluating the effect of entrapped water in thermal insulation. Basically, the test method consists of heating a specified area of an insulation panel using a quartz-iodide lamp, then measuring the rise in surface temperature above ambient with thermocouple and pyrometer. When the insulation is dry, the temperature change above ambient exceeds a value of 140 deg F. When moisture is present inside the panel, the temperature change can be related to moisture content in lb/sq ft. Establishment of the heat-sink principle test method is described. Test results for changes in temperature versus moisture content are presented. Finally, test method applications and results of tests on actual thermal insulation panels are described.

6300 **AN ELECTRO-THERMAL NONDESTRUCTIVE TESTING METHOD**
D.R. Green, L.D. McCullough
Battelle Memorial Institute, Pacific Northwest Laboratories, Richland, Wash.
Rpt. BNWL-1273, December 1969

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.

6303 **INFRARED TIRE STATE-OF-THE-ART MEETING (Minutes of)**
G.J. Sperry
Wright-Patterson AFB, Ohio, 8 April 1970

These are the minutes of a state-of-the-art meeting held at Wright-Patterson AFB on 8 April 1970. Representatives of several manufacturers were there and numerous IR systems for tire testing were demonstrated or explained, in addition to the presentation of technical papers and a final discussion period. The meeting concluded that IR Technology finds itself at the start of a very promising road which shows potential for achievements of significant advancement in tire technology.

6316 **INFRARED ANALYSIS OF TELEMETRY AMPLIFIERS AND DISCRIMINATORS**
J.F. Pina, J.W. Opperheim
The Boeing Company, New Orleans, La.
Materials Evaluation, April 1970, p. 88

Infrared profiles of telemetry amplifiers designed for space vehicle use and discriminators utilized for detection of multiplexed signals were analyzed to evaluate design and reliability. Hot spots were detected in both types of units. A defective capacitor that would otherwise be undetected was revealed by infrared testing. Reliability improvements are proposed.

6334 **INVESTIGATION OF NONDESTRUCTIVE TEST METHODS FOR METALLIZED TANK ENGINE CYLINDERS**
I.R. Kraska, E.J. Kubiak
General American Transportation Corp., Niles, Ill.
Contract DAAE07-67-c-1990, May 1968. ATAC, Warren, Mich.
AD-686 344

In reconditioning tank engines, worn cylinders are flame sprayed with 0.010 in. thick molybdenum to bring the cylinder back to its original dimensions to permit use of pistons and rings of the original size. This reconditioning method generally works quite well but occasionally reconditioned cylinders have failed in operation. This program was initiated to (1) study in detail the flame spraying process to determine the nature of the steel-to-molybdenum bond and the molybdenum itself, (2) determine, if possible, the actual flaw producing mechanism, (3) investigate various NDT methods with the purpose of developing a method of detecting flaws and determining the integrity of the flame-sprayed coating.

6337 **HIGH TEMPERATURE EDDY CURRENT CRACK DETECTION**

N.B. Edenborough
Los Alamos Scientific Laboratory, Los Alamos, N.M.
Materials Evaluation, December 1968, p. 251-253

A technique was developed to detect the time of cracking of samples representing atomic reactor components under high thermal gradients. An eddy current coil of tungsten-rhenium wire (W-26%Re) was wound on a specially machined boron nitride coil form. This coil has been shown to operate at temperatures up to approximately 3200 F. This temperature was reached, from ambient, in 22 seconds. Special electronic circuitry was also developed to detect the small signal change caused by the cracking but ignoring the large changes caused by the quick heating.

6339 **MEASURING MICROBOND INTEGRITY WITH AN INFRARED MICRORADIOMETER**

D.H. Schumacher
Martin Marietta Corp., Orlando, Fla.
Materials Evaluation, December 1968, p. 257-260

This paper reports the preliminary results of n investigation into the feasibility of using an infrared microradiometer to determine the quality of microbonds after the bonding process. Tests were conducted on 0.002-in. diameter, gold-plated copper wire thermo-compression bonded to gold-plated, thin-film ceramic substrates. The technique is also applicable to integrated circuits. The test procedure requires the measurement of small temperature changes (approximately one degree Fahrenheit) over short periods of time (1 to 3 seconds). It is based on the premise that the time required for heat to propagate across a bond is a function of the effective area of the bond which also determines the strength of the bond. It follows that good and bad bonds will produce different changes. Data presented on infrared response, bond area, and bond strength show good correlation.

6366 **AN ELECTRO-THERMAL NONDESTRUCTIVE TESTING METHOD**

D.R. Green, L.D. McCullough
Battelle Memorial Institute, Pacific Northwest Labs. Richland, Wash. 99352
BNWL-1273, December 1969

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.

6440 **INFRARED RADIATION AS A TOOL IN NONDESTRUCTIVE EVALUATION OF WELDING AND BONDING**

S.N. Bobo
Consultant at Beach Island, Cohasset, Mass. 02025
Nondestructive Testing, v. 3, n. 5, (October 1970), p. 345-350

The use of infrared in the nondestructive evaluation of welding has evolved into a technique worthy of consideration. This paper presents a brief summary of infrared techniques available to the user.

6479 **INFRARED TEMPERATURE-MAPPING OF HIGH-PERFORMANCE WEAPONS**

G.E. Van Dame, et al.
U.S. Army Weapons Command, Rock Island Arsenal, Rock Island, Ill.
Proceedings of 18th Defense Conference on NDT, 29-31 October 1969 p. 195-205

In this paper, a unique, high-speed, scanning infrared radiometer system is described which has been successfully used to map the longitudinal temperature distribution of the rotating barrels of a 7.62 mm machine gun (minigun) mock-up. The high-speed radiometer, in which a PbSe detector, cassegrain focusing optics, and a rotating mirror scanner were developed to perform elevated temperature measurements on high-performance weapons.

6480 **ANALYSIS OF POLYIMIDE DIELECTRIC COATING USING ATTENUATED TOTAL REFLECTANCE**

R.J. McGowan
DCASR - Los Angeles, Van Nuys, California
Proceedings of the 18th Defense Conference on NDT, 29-31 October 1969, p. 207-218

A method for rapid and accurate determinations of the degree of cure of a polyimide dielectric coating on wire utilized in spacecrafts. Technique is based on infrared absorbance measurements using Attenuated Total Reflectance. The ATR technique is based on the change of absorption peak during the curing process with an intensity that is directly proportional to the curing time.

6486 **NONDESTRUCTIVE METHODS OF MATERIAL IDENTIFICATION**

R.E. Birley
Rolls Royce Ltd, P.O. Box 31, Derby DE2 8Bj, United Kingdom
Nondestructive Testing, v. 3, n. 3 (June 1970), p. 177-180 (Originally published by IPC Science and Technology Press, IPC House, 32 High Street, Guilford, Surrey, England)

Current nondestructive methods of material identification and typical applications are briefly surveyed. The general approach and factors to be considered when establishing a suitable test method are discussed with particular reference to the compilation and evaluation of test data.

6491 **INFRARED NONDESTRUCTIVE INSPECTION – A STATUS REPORT**

W.R. Apple
Automation Industries, Boulder, Colo.
Materials Research and Standards, v. 9, n. 5 (May 1969), p. 10-14

Infrared nondestructive inspection is applied to that type of testing involving the measurement of heat flow through any given medium. Two types of testing are described, passive and active testing. Passive testing involves monitoring the natural temperature variations of a functioning unit. Active testing includes those tests where the operator applies or removes heat from an object. Equipment and actual results are presented. Typical applications are illustrated.

6516 **INFRARED NONDESTRUCTIVE INSPECTION – A STATUS REPORT**
W.R. Apple
Automation Industries, Boulder, Colo.
Reprint No. 87-803, Materials Research and Standards, November 1969

Two thermal NDT methods (passive and active) are presented with typical equipment as well as actual test results for various samples. Successful tests have been performed on aircraft parts such as wing sections and helicopter blades. Advantages of thermal NDT such as rapid inspection, non-contact with part; and insensitivity to minor alignment variations easily offset the limitations.

6531 **NONDESTRUCTIVE TESTING FOR VOID CONTENT IN GLASS FILAMENT-WOUND COMPOSITES**
B.E. Walker, Jr. et al.
Naval Research Laboratory, Washington, D.C.
NRL Report 6775, October 1968
AD-679 573

Precise nondestructive methods for void determinations on glass-filament-wound composites in the form of rings and ring segments were tested for feasibility. Experimental data related to void content are presented for several possibilities, infrared transmission, backscatter from laser transmission, density measurements, and corona discharge inception. Feasibility of a nondestructive test method for void determinations on rings is demonstrated.

6559 **ASPECTS OF USING INFRARED FOR ELECTRONIC CIRCUIT DIAGNOSIS**
R.A. Herman
Air Force Aero Propulsion Lab., Wright-Patterson Air Force Base, Ohio
Materials Evaluation, September 1967, p. 201-205

The validity of infrared radiation as a checkout parameter for the diagnosis of electronic equipment is verified by laboratory research. A discussion follows on the implementation of the infrared-radiation technique. The location of faulty electronic components on printed-circuit boards is stressed.

6592 **SIXTH TRANSDUCER WORKSHOP**
NASA Langley Research Center, Hampton, Va.
Document 112-70, White Sands Missile Range, October 1969
AD-712 467

To examine critically practices and problems in the calibration, evaluation, and application of transducers to physical measurement. A two day seminar covering the subject matter. A series of papers presented covering thermal measurements, measurement of pressure and flow, measurement of force and acceleration, and general measurement problem areas.

6601 **LASTING THERMAL PAINTS**

G. Lewis
Engineering, v. 20, n. 5459 (January 1971), p. 676

A range of multi-colour change temperature indicating paints has been developed which change color at calibrated temperatures and, it is claimed, can withstand 50 hours of gas turbine blade conditions without damage. Moreover, a 2-year minimum paint life at temperatures up to 400°C is claimed. Temperature of the paints available range from 60°C to 1070°C. The use of such paints permits a rapid and comprehensive thermal survey of surface conditions without the need for instrumentation or testing equipment.

6602 **NONDESTRUCTIVE TESTING OF INTERCONNECTIONS AND MICROJOINTS**

W.V. Sterling, Inc.
135 South Spring St., Claremont, Cal.
Rpt. WVS-170-2467-06, March 1970
N71-11529

This report discusses the successful development of nondestructive weld evaluation techniques and instrumentation for ultimate application in the field of high reliability electronic circuit and component welding. Also, consideration was given to the possibility of applying these techniques to the evaluation of microjoints in integrated circuits. The results are given of a prototype instrumentation program and a feasibility study to utilize in other programs cross-wire NDT test concepts and methods already developed. The specific system described measures setdown, infrared, and weld pulse during time the weld is being made, compares these measurements to previously established criteria for good welds between a given pair of materials, and accepts or rejects the weld accordingly.

6609 **INVESTIGATION OF A LASER ILLUMINATOR – THERMAL IMAGING SYSTEM FOR THE DETECTION OF VOIDS AND DISBONDS**

O. Renius
U.S. Army Tank Automotive Command, Warren, Mich.
Technical Report No. 11169, January 1971
AD-719 241

An infrared nondestructive testing technique employing laser heating of the specimen was developed and evaluated on several bonded materials. Thermal images were obtained using a two-dimensional reflective scanner coupled to a 30-watt CO_2 laser to irradiate the specimen and a thermal imaging camera to view the specimens irradiated surface. The technique is capable of providing a versatile, high-resolution, real-time nondestructive test for subsurface defects in large specimens.

6612 **AN INFRARED DIAGNOSTIC TECHNIQUE FOR EVALUATION OF AUTOMOTIVE TIRES**
D.K. Wilburn
U.S. Army Tank Automotive Command, Warren, Mich.
Tech. Rept. No. 11154, December 1970
AD-719 692

A real time infrared tire diagnostic procedure is described which utilizes a method of pattern recognition to predict and classify real and developing failures in pneumatic automotive tires. The instrumentation developed for this inspection method comprises a dual mode AC-DC high speed indium antimonide detector radiometer capable of measuring both absolute high resolution tire temperature in the AC mode and thermal profile in the DC condition. Tire defects as small as 0.5-inch square can be discriminated at speeds of 60 MPH. Pattern recognition of standard tire defects was "learned" by examination of specially prepared tires having built-in or known type defects. The report classifies ten types of defects and describes the instrumentation and diagnostic techniques developed during the course of the program.

6630 **HIGH-SPEED INFRARED TEMPERATURE-MAPPING OF HIGH-PERFORMANCE WEAPON COMPONENTS**
G.E. Van Dame et al.
U.S. Army Weapons Command, Science & Technology Laboratory, Rock Island, Ill.
Report RE 70-158, June 1970,
AD-710 229

High-speed infrared instrumentation (having a response time of 10 microseconds) and techniques developed at the USAWECOM Science and Technology Laboratory, for the remote, noncontact, temperature measurement of high-performance weapon components are described. The instrumentation and the techniques developed were subsequently utilized to temperature-map the six rotating barrels of the M134 7.62mm Minigun, firing at 4000 rounds per minute, and to temperature-map the barrel of the AM140 30mm Automatic Gun in actual firing tests. The instrumentation and the techniques described have direct application to many other areas of weapons research and development being conducted at the U.S. Army Weapons Command (See also*6479)

6638 **DEVELOPMENT, FABRICATION, TESTING, AND DELIVERY OF ADVANCED FILAMENTARY COMPOSITE NONDESTRUCTIVE TEST STANDARDS**
W.M. Pless, et al.
Lockheed-Georgia Company, Marietta, Georgia
NASA Contractor Report CR-61340, November 1970

Detailed designs of the test standards, including configuration, placement of defects/variations, and fabrication methods are presented together with the NDT development and results. Destructive tests were conducted on additional test panels, where necessary, to verify the defective condition of the standards. A single nondestructive test method did not reveal all possible defects in a composite structure. Two or more methods were used in a complementary fashion to characterize these materials adequately. Generally, radiography and ultrasonic C-scan techniques reveal most defects that may be present in a single structure.

6695 **INFRARED TESTING OF ELECTPONIC COMPONENTS**
E.G. Osburn
Marshall Space Flight Center, Alabama, 9 September 1969
N70-36000

This report presents the results of a task to develop nondestructive, infrared test techniques for detection of incipient failures not revealed by present electrical test methods. High emissivity standardization was achieved using commercially available compounds as conformal coatings. Thermal profile techniques proved useful for defect isolation on printed circuit cards, design verification of thermal derating calculations, and evaluation of different heat sink configurat s. Infrared radiation from power transistors could not be correlated with transistor life expectan during accelerated life tests. Also, thermal runaway of power transistors could not be predicted using infrared techniques.

6701 **THERMAL DETECTION OF SIMULATED PIPELINE LEAKS**
Bendix Aerospace Systems, Ann Arbor, Michigan
Technical Report BSR 2852, January 1970

Gas leaking from a pressurized pipeline produces a sharp drop in temperature at the point of the leak. Tests conducted by Bendix have demonstrated that this temperature drop changes the temperature of the soil over the leak sufficiently to be detected by the Bendix Thermal Mapper.

6714 **INFRARED NONDESTRUCTIVE TESTING TECHNIQUES IN WHICH A SCANNING CO_2 LASER HEAT SOURCE IS USED**
M.J. Amoruso, et al.
U.S. Army Weapons Command, Rock Island, Ill.
Technical Report RE 70-159, June 1970

Active infrared nondestructive testing instrumentation and techniques developed in the USAWECOM Science and Technology Laboratory have been used to detect programmed defects in metallic materials. A CO_2 laser was employed to inject relatively large amounts of thermal energy into a sample, and a sensitive infrared radiometer was utilized to detect the resulting surface temperature perturbations. The unique method described in this report is anticipated to have wide application to many USAWECOM problems associated with the detection of fatigue cracks, voids, and inclusions in military items such as gun tubes, artillery recoil mechanisms, and aircraft components.

6749 **THERMAL INTROSCOPE FOR RESISTOR QUALITY CONTROL**
NA. Bekeshko, P.K. Oschepkov, A.B. Upadyshev
Soviet Jl. of NDT, May-June 1968, p. 178-180

The operating principle, circuit, and design of equipment for resistor quality control in accordance with surface temperature distribution are described. Some results are given for the revelation of resistor defects.

6752 **HIGH-TEMPERATURE EDDY-CURRENT SENSORS**
V.E. Staternikov, V.A. Denisov
Soviet Jl. of NDT, May-June 1968, p. 189-191

The article reports the results of research and development work on high-temperature eddy-current devices for work at variable temperatures up to 500°C. Design and fabrication technology of the devices are described, and hints on proper use are given.

6758 **APPLICATION OF PHOTOCHROMIC COATINGS FOR NONDESTRUCTIVE INSPECTION**
S. Allinikov
Air Force Matls. Lab. Wright-Patterson AFB, Ohio
Rpt AFML-TR-70-246, December 1970
AD-720 239

The application of a photochromic compound to provide a nondestructive inspection (NDI) technique for aerospace materials and structures is discussed. The photochromic compounds, incorporated into a paint formulation, is converted from a white to a bright violet color upon a brief irradiation from an ultraviolet source. The colored paint surface is then heated by any suitable means, such as a hot air blower. Heat serves to bleach the paint to the original white color. Defects are disclosed because heat conductivity at the defect site is different from that of the rest of the area under inspection. The defect thus appears as a colored or white area dependent upon the nature of the defect and originating direction of the heat source. Some of the types of defects and kinds of structures to which the NDI paint has been applied are discussed. Along with advantages and limitations of the paint.

6761 **THE USE OF AN INFRARED RADIOMETRIC MICROSCOPE IN THE NONDESTRUCTIVE DETERMINATION OF FLEXIBLE PACKAGE SEAL DEFECTS**
R.A. Lampi, F. Fiori
U.S. Army Natick Labs., Natick, Mass.
Technical Report 68-60-GP May 1968

Infrared radiometry, whereby changes in heat conduction through the seal thickness and the resulting effect on the thermal radiation characteristics of the opposing seal surface are measured by an infrared radiometric microscope, has been used to detect significant defects in flexible package seals. Sample manipulation techniques and measurement parameters have been established to the extent that occluded matter such as single sugar crystals, 0.5-milligram amounts of meat fibers, single fruit and vegetable fibers and traces of moisture, as well as significant seal wrinkles, and the presence of small voids (90 to 100 microns in diameter) can be positively detected.

6786 **THE DESIGN AND APPLICATION OF THE TRAVERSING INFRARED INSPECTION SYSTEM (TIRIS)**

S.E. Cohen
Lockheed-Georgia Co., Marietta, Ga.
Presented at the 1971 Design Eng. Conf. 22 April 1971, Americana Hotel, N.Y.

A Traversing Infrared Inspection System (TIRIS) was designed primarily for high volume production inspection of C-5 aircraft fail-safe strap panels. These panels are bonded laminates of 0.020 inch thick titanium and 0.125 inch thick aluminum. The system is flexible enough to be used for the development of special techniques such as the detection of entrapped water in aluminum honeycomb and the inspection of advanced structural composites. The system injects heat into the panels by means of hot air guns. Imperfections as small as 0.30 inches in diameter are displayed on an 8x10 inch cathode ray tube in real time. The inspection scanning rate is 4.3 square feet per minute. A Polaroid camera is used to produce thermograms which define the size and shape of voids, disbonds, and delaminations which are located directly on the panels with a unique marking device.

6825 **THE IDENTIFICATION OF FABRICS USING ATTENUATED TOTAL REFLECTANCE**

R.J. McGowan
DCASR, Van Nuys, Cal. 91402
Proceedings, 19th Defense Conference on NDT, 4-6 November 1970

A method is described for rapid and accurate nondestructive identification of all types of fabrics, such as: wool, cotton, silk, nylon, etc., and mixtures of these fabrics. This technique is based on infrared absorbance measurements using Attenuated Total Reflectance. It will enable an activity to identify these fabrics nondestructively in 15 minutes or less.

6828 **APPLICATIONS OF EXO-ELECTRON EMISSION TO NONDESTRUCTIVE TESTING**

J.W. Bohlen
AFML, Wright-Patterson AFB, Ohio
Proceedings, 19th Defense Conference on Nondestructive Testing, 4-6 November 1970

A simplified explanation of exo-electron emission (referred to as EEE) introduces experimental results from 1100-0 and 7075-T6 aluminum indicating that heat and UV light stimulated EEE are related to residual stress and fatigue damage. Other experiments helping to explain EEE phenomena are discussed. A placket detector for field detection of EEE is described. Additional studies of grinding and the Shenstone Effect are revealed.

6840 **INFRARED NONDESTRUCTIVE TESTING – PAST, PRESENT AND FUTURE**

R. Vanzetti
Raytheon Company
Proceedings, 5th International Conference on NDT, Montreal, 1967

The physical principles upon which infrared techniques are resting, and the two basic application approaches are discussed: heat injection from without, and heat generation from within. Performance capabilities of the IR test equipment available today is added, with special mention of the fast scan microscope for evaluation of microelectronics. The concept of infrared-to-visible conversion is presented as well as cost comparisons of IR versus conventional techniques.

6841 **DYNAMIC INFRARED DETECTION OF FATIGUE CRACKS**

E.J. Kubiak, et al.
General American Transportation Corp.
Proceedings, 5th International Conference on NDT, Montreal, 1967

A non-contacting nondestructive inspection system is described that can rapidly locate, in real time, the position and extent of fatigue cracks in aircraft and missile structures. The automated infrared system was developed for the USAF for use in their Sonic Test Facility at Wright-Patterson Air Force Base. In addition to presenting the basic concepts of the method, this article describes briefly the design of the system, discusses test results, and presents conclusions and indicates future applications of the technique.

6842 **THERMAL NONDESTRUCTIVE TESTING WITH CHOLESTERIC LIQUID CRYSTALS**

W.E. Woodmansee, H.L. Southworth
The Boeing Co.
Proceedings, 5th International Conference on NDT, Montreal, 1967

The properties of a family of liquid crystals which scatter light over small temperature intervals near room temperature are described. Simplified methods of applying cholesteric films to test surfaces for thermal mapping are discussed. A technique for obtaining permanent flaw patterns is discussed. The application of liquid crystalline materials to evaluation of aerospace cooling panels and flaw detection in adhesively bonded titanium components is described.

6846 **TELEVISION SYSTEMS FOR NONDESTRUCTIVE TESTING**

H. Berger
Argonne National Laboratory
Proceedings, 5th International Conference on NDT, Montreal, 1967

The methods of operation of a number of unusual television techniques are discussed, as are the capabilities of each system in regard to sensitivity, resolution, contrast, and speed of response. Emphasis is placed on those television techniques which respond to X-radiation, infrared, ultrasound, and neutrons. The general areas of application of television systems for nondestructive testing are outlined. Several methods for recording and using test data from such systems are given.

6872 **THERMAL AND INFRARED NONDESTRUCTIVE TESTING OF COMPOSITES AND CERAMICS**

D.R. Green
Wadco Corp., Richland, Washington. Presented at 30th Fall Natl. Conf., Am. Soc. for NDT, Cleveland, October 1970, 33 p.
N71-25215

The application of high-speed thermal and infrared methods to the detection of density differences, cracks, voids, and other defects in ceramics and composites is described. A single-pass induction heating method, made possible with a full-width paint brush heating coil, was used in infrared tests on carbon-carbon composites. Unique characteristics of the induction heating make it possible to detect cracks that are perpendicular as well as parallel to the surface of the test specimen. All of the materials were also tested using the new low-cost thermal image transducer, and the resolution and sensitivity to defects were determined. Both the infrared method and the thermal transducer method are capable of completing a test on a large area in a few seconds (not including specimen handling time).

6884 **CRITICAL THOUGHTS ON STRUCTURAL MECHANICS AND NDE**

M.B. Zisfein, W.B. Tarpley
Franklin Institute Research Laboratories, Philadelphia, Pa.

Rpt. AFOSR-70-2870TR, 9 September 1970, 36 p.
AD-720 899

A critical review NDE is given in general terms and specific examples of NDE techniques are given. The state-of-the-art is presently technique-oriented, rather than problem oriented due, in part, to ineffective communication links between designer, NDE researcher and user. Problem areas are identified which include better data handling and interpretive techniques for the user as well as detectability and resolution criteria; and certain materials problems (e.g., limited ductility materials); and an especially urgent need is expressed for control indices for surface contamination by NDE. Methods are suggested for improving the communications link and the idea of "analogue" acceptability or evaluation is stressed in favor of "binary" go-no-go type decisions.

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All descriptors listed in alphabetical order pertain to the information contained in the report or item that is identified by the AMMRC number following descriptor. This journal is concerned with radiographic testing literature and every item in the journal contains some aspect of radiographic testing. A complete breakdown of each subject item by descriptors was deemed necessary in order to make the journal useful.

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