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76

INFRARED TESTING OF ELECTRONIC COMPONENTS

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E. G. Osburn

ABSTRACT

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 commerically 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 configurations. Infrared radiation from power transistors could not be correlated with transistor life expectancy during accelerated life tests. Also, thermal runaway of power transistors could not be predicted using infrared techniques.

ELECTRICAL TEST SECTION
ELECTRICAL TEST AND ANALYSIS BRANCH
ANALYTICAL OPERATIONS DIVISION

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SUMMARY

This program was pursued to determine the feasibility of applying infrared techniques to the testing of electrical/electronic components, systems, and subsystems. Special emphasis was placed on determining if infrared techniques could be developed for detecting incipient failures.

The study consisted of three phases:

(1) Investigation of the state-of-the-art of infrared technology.

(2) Surface emissivity standardization by means of conformal coating.

(3) Feasibility of using infrared techniques in specific applications.

Investigation of infrared technology has, in recent years, attracted considerable attention from both governmental agencies and industries concerned with the production and utilization of solid-state devices and other electrical and electronic devices. Research efforts are independent and there is duplication in most areas.

Major efforts performed to date on Infrared Technology consist of feasibility studies in which the primary industrial interest was towards packaging design of circuit boards and micro-miniature circuits while the primary government interest was in failure analysis and diagnostic measurements. Other areas of interest were Process Control, Screening, Fault Detection, Electronic Component Design, and Instrumentation Improvements.

In the conformal coating investigation, effort was expended to find one or more compounds which exhibited high surface emissivity, was transparent to facilitate identification of components, and otherwise fulfilled all electrical, mechanical, and environmental requirements for a conformal coating. Ten commercially available conformal coatings performed satisfactorily and their superiority depended on the environmental application. It is recommended that future studies should include investigation of comparable emissivities of different lots of the same material and the effect of aging in various environments on emissivity.

In the specific applications phase of the program, effort was directed toward:

(1) Determining if a relationship existed between infrared radiation from,and the life expectancy of,electrical/electronic components such as diodes, transistors, resistors, etc.

(2) Thermal profiling or "fingerprinting" of printed circuit boards, thin film assemblies, etc.

(3) Evaluation of transistor heat sinks and mounting techniques.

There appears to be some relationship between infrared radiation and life expectancy of transistors, but random failures prevent any definite predictions based on infrared radiation. Using thermal profiles of printed circuit boards obtained through infrared techniques, the designer can locate and eliminate "hot spots" and verify thermal derating calculations. Thermal profiles can also be used for failure analysis of defective printed circuit boards. Infrared measurements of transistor heat sink techniques indicated that prediction of thermal runaway in power transistors was not feasible.

The conclusion drawn from this study is that infrared testing of electrical/electronic equipment is feasible for design evaluation and for failure analysis of circuit boards, components, and heat sinks. Using these techniques, design configuration of electronic equipment can be improved to obtain better quality and reliability. Their application as a predictive technique for quality control will require further investigations into failure mechanisms as related to thermal conditions. Further study in the area of specific applications, development of detailed methodology and techniques, and development of equipment for specific applications is needed.

SECTION I. INTRODUCTION

The purpose of the infrared testing contract was to determine the feasibility of developing a nondestructive testing technique, using infrared radiation measurement, for detecting incipient failures that are not detected by present electrical testing methods. This contract, NAS8-20131, was performed by the Orlando Division of the Martin-Marietta Corporation during the period between April 5, 1965 and June 5, 1966 and was divided into three phases. Copies of the phase reports issued by Martin-Marietta may be obtained from the Scientific and Technical Information Branch (MS-I), MSFC.

Phase I consisted of a survey of literature, industry, government agencies, and educational institutions to determine the state-of-the-art in:

(1) Infrared radiation sensing and measuring instrumentation.

(2) Nondestructive testing of electrical and electronic components and subsystems by infrared techniques.

(3) Areas in fabrication and testing presently being investigated for possible application of infrared techniques.

Detailed results are documented in the Martin-Marietta Phase I Report OR6610, dated June 196[illegible].

Phase II consisted of developing one or more conformal coating materials for standardizing the surface emissivity of electrical and electronic components to a high constant value while meeting specified mechanical, electrical, and environmental requirements. The results were documented in the Martin-Marietta Phase II Report OR8031, dated January 1966.

Phase III was to determine the feasibility of further development in and applications of the use of infrared technology as a nondestructive testing technique for electrical/electronic components and subassemblies. This phase consisted of:

(1) Establishing a correlation between infrared emission and transistor life expectancy.

(2) "Fingerprinting" analysis of circuit designs.

(3) Investigating the use of infrared techniques for thermally evaluating packaging techniques.

(4) Preparation of specifications for radiometers and associated equipment.

Phase III results were documented in the Martin-Marietta Phase III Report OR8347, dated June 1966.

SECTION II. PHASE I, INDUSTRY/GOVERNMENT SURVEY AND LITERATURE SEARCH

A. GENERAL

A survey of industry and government and a literature search were conducted to ascertain the level of interest and state-of-the-art in:

(1) Infrared technology as applied to nondestructive testing of electrical/electronic components and subsystems.

(2) Infrared radiation measuring instrumentation applicable to the task.

(3) Areas of testing and fabrication under investigation for possible application of infrared techniques.

Mailed questionnaires and personal interviews were utilized in gathering information.

The industry, government, and technical report surveys revealed strong and active interests in developing infrared test techniques for use in the electronics field. Most of the work has been in the area of feasibility studies relative to screening applications with emphasis toward design evaluations and new design techniques. The survey indicates 32 industrial organizations and 11 government agencies investigating and/or applying infrared technology to electronic components and subsystems. The area of largest interest of infrared technology by industry was packaging design of circuit boards and microminiature circuits while government agencies' interests were failure analysis and diagnostic measurements. Table 1 indicates areas and levels of interest.

Table 1. Areas and Levels of Interest

AREA	GOV. PERCENT	INDUST. PERCENT
Failure Analysis and Diagnostic Measurements	55	34
Process Control of Circuit Boards and Microminiature Circuitry	36	13
Design and Packaging of Circuitry Boards and Microminiature Circuitry	27	44
Fault Detection	27	--
Electronic Component Screening	27	28
Electronic Component Design	18	19

The surveys indicated that 25 percent of the industrial companies were investigating normal and accelerated life testing techniques to correlate infrared radiation with component life. However there was lack of detail on how the investigations and studies were being conducted. There was also repetition of infrared technology and lack of scientific data to substantiate conclusions. In areas of repetition several different approaches may have been used.

It is expected applications of design analysis and improvement of design techniques will be used along with later development of routine inspection. The eventual use of these applications will require equipment improvement and the acquiring of data.

B. QUESTIONNAIRE SURVEY

Questionnaires were mailed to 149 organizations known to be either interested or engaged in investigations of infrared testing techniques. The questions were designed to require minimum effort on the part of the respondent and still provide maximum information. Forty-nine percent of the 66 organizations responding indicated investigation or application of infrared technology to the testing of electrical/ electronic components, parts, packaging, etc.

C. PERSONAL INTERVIEW SURVEY

Eight companies, all active in infrared investigations, were contacted through personal interviews with project task leaders, and four government installations were visited. Information relating to areas of application and instrumentation employed was obtained.

Aside from the normal technical obstacles to be overcome in the development of any technique, several problems have been encountered for which no solutions are presently apparent. Among these are:

(1) Adequate instrumentation with the degree of accuracy necessary for obtaining useful data.

(2) Higher speeds and spatial resolution of scanning devices.

(3) The need of a coating material that would provide a uniformly high surface emissivity.

(4) Most contactees believed their programs had been adversely affected by purported oversimplification which had been attached to the development of infrared techniques in various talks and articles.

D. TECHNICAL REPORT SURVEY

The technical report survey included reports, magazine articles, and technical papers covering a period from December 1962 to March 1965. The review of 24 reports indicates a gradual transition from peripheral probing to more specific applications of infrared testing. Some specific applications under current investigation were:

(1) Selective screening of transistors and resistors.

(2) Development of new design criteria for thin film circuits.

(3) Development of high speed thermal mapping techniques for microelectronics.

(4) Investigation of materials to equalize emissivity.

Some shortcomings indicated as a result of newness of infrared technology were redundancy in most areas of investigations and lack of detail on study methods and data.

SECTION III. PHASE II, HIGH EMISSIVITY CONFORMAL COATING TEST PROGRAM

A. BACKGROUND

Any object, with temperature above absolute zero, radiates infrared energy. The amount radiated depends upon the absolute temperature and the surface emissivity of the object radiating the energy. Since emissivity is a function of surface material and finish, it may be possible to standardize the emissivity of all surfaces by coating with a film of a suitable substance.

The development of one or more suitable coatings was the objective of Phase II. These coatings must be capable of standardizing the emissivity of electronic components to a high constant value under specified electrical, mechanical, and environmental requirements.

B. TECHNICAL APPROACH

According to Kirchoff's law, absorptivity is directly proportional to emissivity; therefore, a satisfactory absorber is a desirable emitter. It was this relationship that was used to determine the relative emissivities of the compounds being evaluated, since the absolute measurement of emissivity would be time consuming and unnecessary.

In organic compounds, each generic type of chemical bonding has characteristic absorption frequencies (bands). The number of these bands increases directly with molecular complexity. The intensity of the band is determined by the dipole moment (the difference in the electronegativity between two atoms).

Two types of plastic materials having properties meeting the optical, chemical, and physical requirements for emissivity coatings were chosen for investigation. These were thermosetting plastics, such as the polyurethanes, silicones, and epoxys; and thermoplastic materials, such as the acrylics and polycarbonates.

C. TESTS

Relative emissivity measurements were made of 25 commercial compounds used as conformal coatings. Compounds having the highest emissivity characteristics and fulfilling transparency requirements were subjected to further tests. Of the 25 compounds given screening tests, 10 were selected for extensive mechanical, electrical, and environmental testing.

All of the compounds subjected to extensive tests were found to be acceptable in a variety of applications, depending upon the characteristics which were felt to be of most importance in each particular application. No one compound was determined to be best during all tests. Three of the polyurethane compounds receiving extensive tests are approved MSFC conformal coatings for printed circuit boards.

Because of the large number of available materials in the above categories, those materials that were readily available were given screening tests before being subjected to further extensive testing. Table 2 is a list of screening tests performed. The ten coatings selected as having the most desirable qualities from results of the screening tests are given in table 3. In table 4, the three highest ranking of the ten coatings in each of the extended tests performed are given.

Some of the materials that performed above average are:

(1) Dow Corning Q92-009, recommended for elevated temperature and high humidity environments.

(2) Hysol PC16, recommended for general environmental usage where high emissivity is required in standardizing thermal measurements.

(3) General Electric SS4090, recommended for high temperature and humidity environments requiring only fair emissivity and limited resistance to outgassing.

Final selection, however, should be made from a more detailed tabulation since, in many instances, the variations between the first and tenth rated compound are very slight.

An extensive tabulation of data is included in Report No. OR8347 of Martin-Marietta titled "Infrared Testing of Electronic Components", dated June 1966.

Table 2. Tests Performed

CATEGORY	TEST
SCREENING TESTS	
Liquid Properties	Viscosity, drying time, curing cycle, pot life, and infrared absorption
Cured Properties	Transparency, emissivity factor, maximum use temperature, flexibility, and color compatibility
EXTENDED TESTS	
Cured Proper	Adhesion, water absorption, thermal expansion coefficient, solderability, and chemical resistance
Electrical Properties	Dielectric strength, dissipation factor, dielectric constant, surface resistivity, volume resistivity, and outpassing
Environmental Tests	Vibration, high temperature, low temperature, temperature shock, humidity, fungus.

Table 3. Ten Selected Coatings

COMPOUND	TYPE
Hysol PC16	Epoxy
Hysol PC22	Polyurethane
Magnolia Plastics M-29	Epoxy-Polysulfide
Products Research PR 1538	Polyurethane
Uraline 5712	Polyurethane
Dow Corning Q92-009	Silicone
General Electric SSR090	Silicone
Martin Emissivity Coating (MEC)	Acrylic
Minnesota Mining 3M 280	Epoxy
Humiseal 1A27	Polyurethane

Table 4. Three Highest Ranked Coatings (Sheet 1 of 2)

TEST	ORDER OF PERFORMANCE		
	1	2	3
Emissivity	PC16	1A27	M-39
Curing Cycle	MEC	1A27	Q92-009
Flexibility	Q92-009	SS4090	PC22
Adhesion	PC-16	PC22	M-39
Water Absorption	SS4090	3M280	Q92-009
Thermal Expansion	PC16	3M280	UR5712
Solderability	SS4090	Q92-009	PC16
Chemical Resistance	M-39	Q92-009	PC22

Table 4. Three Highest Ranked Coatings (Sheet 2 of 2)

TEST	ORDER OF PERFORMANCE		
	1	2	3
Dielectric Constant (Room Temp)	MEC	SS4090	1A27
Dissipation Factor (200° F)	SS4090	Q92-009	3M280
(Room Temp)	SS4090	Q92-009	1A27
Surface Resistivity (200° F)	Q92-009	SS4090	3M280
(Room Temp)	M-39	3M280	UR5712
Volume Resistivity (200° F)	SS4090	3M280	Q92-009
(Room Temp)	Q92-009	1A27	3M280
Outgassing (200° F)	Q92-009	SS4090	3M280
	PC16	3M280	PC22
High Temp Resistance	SS4090	MEC	3M280
Low Temp Resistance	PC16	Q92-009	M-39
Temperature Shock	SS4090	PC16	M-39
Humidity Resistance	1A27	M-39	SS4090

SECTION IV. PHASE III, FEASIBILITY OF INFRARED AS A NONDESTRUCTIVE TESTING TECHNIQUE

A. GENERAL

During this phase of the project, several promising areas of application of infrared techniques investigated were:

(1) Attempt to correlate life expectancy of electrical/electronic devices and infrared radiation from these devices.

(2) "Fingerprinting" (measuring the thermal profile of) circuit assemblies for purposes of determining temperature tolerances, thermal derating analysis, and troubleshooting.

(3) "Fingerprinting" circuit assemblies to determine the feasibility of utilizing infrared testing in evaluating thermal design in packaging techniques. Three elements of packaging investigated were:

- Heat sink designs
- Component mounting on heat sinks
- Component density on circuit boards

(4) Preparing specifications adequate for the procurement of infrared testing equipment such as radiometers, etc.

B. SUBTASK 1, INFRARED RADIATION/LIFE EXPECTANCY CORRELATION

It is a known fact that increasing the operating temperature or power dissipation of a transistor decreases its life expectancy. The purpose of this subtask was to determine if infrared techniques could be utilized in establishing the temperature/life relationship of transistors and the effects of large and small increases of operating temperature on the life expectancy of the transistor.

Due to case size, power rating, breakdown voltage, internal configuration, and cost, the 2N717 transistor was selected as the test article for this subtask. Two hundred and forty transistors were divided into four groups and operated at 100, 117, 134, and 150 percent of maximum rated power dissipation in free air. The number of transistors in each group was 96, 72, 48, and 24 respectively. ON time was recorded by an elapsed time meter and the total ON-OFF cycle was set at 15 minutes, as previous stabilization after application or removal of power. Power supplies were regulated, and fail-safe circuits were employed to guard against catastrophic results in case of power supply failure.

All transistors were identified, tested, and their characteristics recorded before the life test was started. Characteristic deviations could then be detected during tests at the end of each 100 hours of ON time. Any deviation of any characteristic beyond the limits of published specifications for the transistor was considered a failure.

Only six transistors had failed when tests were terminated after 1650 hours of ON-OFF testing; all failures occurred at dissipation levels greater than 100 percent of rated electrical load. Two of seventy-two transistors failed at the 117 percent dissipation and one was shorted after 600 hours of operation. One of forty-eight transistors had excessive current leakage after 300 hours of operation at the 134 percent dissipation level. Three of twenty-four transistors failed at the 150 percent dissipation level; one was shorted after 300 hours of operation and two had excessive current leakage after 500 hours of operation.

Since the accelerated life test resulted in failures of the transistors as noted in the paragraph above, it must be concluded that excessive operating temperature and/or power dissipation has a detrimental effect on the life expectancy of the transistors. The erratic nature of failures as illustrated also indicates that the manufacturer's process control may have as much, if not greater bearing on the life expectancy than does the amount of controlled operating temperature, even where the temperature becomes excessive.

C. SUBTASK 2, THERMAL DERATING ANALYSIS AND TROUBLESHOOTING

In this subtask, thermal profiles of operating circuit boards were recorded to determine the feasibility of evaluating a design for thermal derating and to determine whether this technique would be of value in troubleshooting defective production units.

Six identical Apollo control signal processor rate switch boards were used for these tests. These boards were selected for test specimens due to the relatively high component density so that a large number of components were available on a few boards and also due to the ease of measuring the infrared radiation from each component.

1. Component Derating Evaluation - Infrared Radiation Levels. To evaluate the thermal derating of components, a case temperature measurement was made for each component with the component dissipating rated power. The hottest spot on the component under test was located and measured. Several components of each type were tested in order to establish limits of variation in temperature for each type of component. This range of variation was found to be very narrow,

After establishing these limits, infrared "fingerprints" were made of six normally operating circuit boards containing these same component types in 18 identical circuits. Testing was accomplished at an ambient room temperature after circuit temperature had stabilized. Using data obtained from these tests, a standard thermal profile for a good circuit board was constructed.

Maximum allowable case temperature rise was determined by subtracting the case temperature of a normally operating component from the case temperature of the same component when operating at maximum rated power. Thermal derating is adequate if maximum allowable case temperature rise is greater than anticipated ambient temperature rise which results when circuit operation is in an elevated temperature environment.

There are many situations where circuit fluctuations will result in increased power dissipation. Under these conditions, circuit operation should be evaluated for the greatest dissipation expected during operation. Also, using the methods previously described for thermal derating determination introduces an error which will restrict its application if the circuit is operating at much less than maximum rated power.

Ideally, the semiconductor junction temperature would be measured and used for transistor thermal derating calculations. However, this temperature cannot be measured due to component configuration and must be given an implied value. When assuming the same case to junction temperature gradient in determining maximum allowable case temperature rise, the error introduced is equal to the difference between the actual temperature gradients. This error is of the "safe" type since it will cause more derating than is actually necessary. Use of this derating technique should be limited to operating dissipations which are near the maximum rated dissipation.

Thermal derating techniques described here for transistors are applicable to other parts which have a thermal gradient from the central, heat producing area to the outer surface.

2. Component Derating Evaluation - Infrared Levels and Free Air Dissipation Curves. For practical purposes, thermal derating errors, caused by using fixed case to junction temperature differentials established at maximum rated power for all computations and by ignoring case temperature increased due to heat radiated from adjacent "hot" components may be too great. However, these errors

can be reduced significantly by using data extrapolated from plotted case and junction temperature/power dissipation curves to correct thermal derating calculations.

Required correction curves will be plotted using the manufacturer's specified maximum operating junction temperature and the free air case temperature measured at maximum rated power during previous tests. The junction temperature/power dissipation curve is a straight line from ambient room temperature/zero power to maximum operating junction temperature/maximum rated power. A straight line drawn from ambient room temperature/zero power to measured case temperature/maximum rated power will provide the case temperature/power dissipation curve. Temperature gradient is determined by subtracting the case temperature from the junction temperature with both temperatures being read at the same dissipation level.

The case to junction temperature differential error is eliminated by using a revised maximum allowable case temperature rise for thermal derating determination. This revised figure is obtained when the temperature difference between thermal gradients for normal operation and for maximum rated dissipation is added to the maximum allowable case temperature rise ascertained in the previous section.

If heating from adjacent components is suspected, this effect can be eliminated by using the temperature/power dissipation curves and a computed maximum power dissipation, obtained from the circuit schematics, to determine the thermal gradient for normal operation.

3. Troubleshooting Defective Boards Using Infrared "Fingerprints". Thermal patterns of defective printed circuit boards were studied to determine if infrared techniques could be used to detect abnormal operation. Defects were introduced on the six Apollo Control signal processor rate switch boards used for derating analysis to facilitate this study.

Comparison of infrared "fingerprints" obtained after defects were added and of those made during derating analysis revealed that small defects could be indistinguishable. This problem was easily overcome by increasing the detector sensitivity and repeating tests for both the "good" and the "bad" boards. Lower sensitivity was necessary during derating analysis due to excessive derating of the components; in other words, the tests run at rated power provided a very high infrared signal which required reduced detector sensitivity for an on scale reading.

Also, during this investigation two abnormal infrared patterns were detected for which there was no known cause. Conventional circuit analysis including electrical testing was required to isolate the cause for the defect patterns as being open transistors. While removing the board from the connector with power applied, the transistor collector was accidentally shorted to 28 vdc. Evaluation of the procedure required to determine specific component failures indicates that "defect location" is a more appropriate term for describing the use of thermal profiles for failure analysis than is "troubleshooting".

In concluding, it is readily apparent that infrared is in fact a useful tool for derating analysis and for troubleshooting defective boards. However, use of component thermal analysis for derating purposes may be economically applied to large or small quantities while troubleshooting would be practical only for volume production quantities.

D. SUBTASK 3, THERMAL DESIGN IN PACKAGING.

The purpose of this task was to evaluate thermal radiation effects due to component relocation, to demonstrate that infrared radiation tests may be used as a tool when selecting the proper heat sink, and to determine if infrared radiation levels from power transistors can be used to predict thermal runaway.

1. Heating Effects of Adjacent Components. Tests were conducted to determine the heating effects due to thermal radiation from adjacent components. Infrared profiles obtained in subtask 2 of the six operating circuit boards were evaluated to select components whose temperature rise was largely due to adjacent sources. Selected components were relocated by evaluating them well above the surface of the board and infrared profiles were made of the modified boards. These new profiles, when compared with the normal profiles, showed a reduced temperature for the relocated components. It is apparent that use of infrared techniques readily permits isolation of hot components and aids when relocating these components.

2. Component Mounting on Heat Sinks. A temperature/power dissipation analysis was made using six different widths of a basic heat sink configuration. For this experiment, a free-air suspended power transistor operating at up to maximum power dissipation was the standard. Temperature/power dissipation measurements were obtained with discrete power inputs to power transistors mounted on the heat sinks. Data obtained showed a linear temperature/power dissipation relationship for all heat sinks investigated.

3. Thermal Runaway. Tests were conducted to determine whether infrared techniques could be used to detect impending thermal runaway in power transistors and whether this runaway always occurs at the same temperature. Test results obtained rule out the use of infrared measurements as a means of detecting thermal runaway; thermal runaway is ultimately influenced by the collector load and not the parameters of the transistor.

E. SUBTASK 4, EQUIPMENT SPECIFICATIONS

The purpose of this subtask was to provide guidelines for the prospective purchaser or designer of infrared instrumentation for specific applications. A single specification is not sufficient or appropriate for all possible applications.

Such characteristics as field of view, focusing, ambient temperature, operating range, noise level, etc., are very important and definitely must be taken into consideration. The following equipment requirements are performance characteristics that are generally considered when developing a specification.

(1) Field of View - The diameter of field view should not exceed one half of the minimum dimension of the component whose temperature is to be measured.

(2) Focusing - The light spot should accurately indicate the location and size of the field of view. The light should be detectable under normal ambient lighting and should not cause temperature measurement error.

(3) Electronic Offset - Provides for expanded scale operation. Stability, resolution, and linearity of the setting should be a maximum and the noise should be a minimum.

(4) Ambient Operation Temperature - Since Laboratory ambient temperature variations are small, it is only necessary to assure temperature fluctuations do not produce measurement errors.

(5) Measurement Parameters - Considering accuracy, resolution and stability, temperature tolerances of

± 2° C, ± 0.5° C, and 0.25° C, respectively, would suffice for most programs. A temperature range of 10° to 200° C is adequate for most measurements.

(6) Amplifier - Depends on type of recorder.

An arrangement for automatic scanning of circuit boards will be desirable in some applications and has been used. Single line scanning in synchronism with an X-Y plotter was used with satisfactory results. However, production requirements would be different. There were no satisfactory area scanning techniques that could accurately present data.

SECTION V. CONCLUSIONS

There definitely is a highly active interest in developing infrared techniques for electronics. This was shown by the 32 active programs of infrared investigation in the industry/government survey. Many companies are working independently and there is duplication of effort, but this may be beneficial since the same problem is being attacked from different directions.

Emissivity standardization, considered a problem by the industry/government organizations surveyed, was achieved at a high constant value with 10 conformal coatings. These 10 coatings were transparent and, with few exceptions, performed satisfactorily during electrical, mechanical, and environmental tests. Areas of appreciable weaknesses were in adhesion (two coatings), water absorption (one coating), electrical properties at elevated temperature (two coatings), and outgassing (one coating).

A virtually unlimited number of applications for infrared techniques in electronics seems possible. The main problem appears to be distinguishing between the potentially successful and the many possible applications. Infrared techniques used as a design evaluation tool appear to be the most promising application. Infrared was quite successfully employed in locating the hot components on a circuit board, evaluating a variety of heat sinks with speed and accuracy, and evaluating component mounting techniques.

Infrared use for routine inspection will probably be among the last areas of development. High initial equipment costs and high skill levels required to operate the equipment and evaluate test results will make these inspection techniques too expensive.

A marked amount of criticism of instrumentation was noted during the industry/government survey with respect to its lack of adaptability to different types of investigations. Some of the complaints were probably due to the lack of familiarity with infrared technology and techniques. Any recommendation for further study should include instrumentation improvement with special emphasis on faster scanning, improved response time, and better spatial resolutions. Also, recording and analysis equipment should be improved.

The application of infrared to integrated circuits was not discussed. Integrated circuits are at the embryo stage of application in electronics and will decrease the use of discrete printed circuit board components. Integrated circuits will not replace printed circuit boards with their discrete components completely; however, the application of infrared would be toward a proportionally decreasing market. Infrared testing of integrated circuits, because of the spatial resolution required, requires very complex equipment. Development of a high-scan-rate, high resolution radiometer test system will allow accurate determination of the power handling capabilities of micro-circuits. When used for reliability testing, life testing, or failure analysis, this system will be able to rapidly evaluate large numbers of integrated circuits and other small structures.

The use of infrared radiation to determine life expectancy of transistors yielded too few failures to permit other than preliminary conclusions. It appears that the manufacturer's production methods have as much or more effect on life expectancy than operating temperature. The detection of short term failures at a receiving inspection level based on small temperature differentials also appears to be unlikely.

The use of infrared fingerprinting of printed circuits for thermal derating analysis and troubleshooting proved to be feasible. Component derating evaluation with minimum safety error was made by infrared measurements and free air dissipation curves. Thermal derating analysis was simple, rapid, and could be applied to any quantity produced; troubleshooting techniques were slowed initially as a result of circuit analysis and defect cataloging and could be applied only to volume production operations.

Use of infrared measurements to predict thermal runaway was not possible. Other variables in the transistor circuit such as an external emitter resistance changed the case temperature at which thermal runaway would start.

Future infrared tasks should include preparation of a guidebook which specifies standardized measurement techniques, calibration procedures, and data evaluation methods. Areas of future study should include determining the variance in emissivity between different conformal coating lots, determining the effect of aging in various environments on conformal coating emissivity, and furthering infrared use with microelectronic devices.

March 15, 1967 IN-R-QUAL-67-2

APPROVAL

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By

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The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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