RECEIVED BY DTIC 17 1971

3 up

MASTER

BDX-613-527

RAPID VISUAL SCANNING SYSTEMS
FOR PCB's, FY71-2

PDO 6984522, Quarterly Report

R. D. Taylor, Project Leader

Prepared September, 1971

Prepared for the
United States Atomic Energy Commission
Under Contract Number AT(29-1)-613 USAEC

**Kansas City
Division**

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

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

DISCLAIMER

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

RAPID VISUAL
SCANNING SYSTEMS
FOR PCB's, FY71-2

BDX-613-527

Published
September, 1971

Project Leader:
R. D. Taylor
Department 445

PDO 6984522
Quarterly Report

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Technical Communications

**Kansas City
Division**

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

199

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

This report was

Prepared by:

R. D. Taylor
D/445

Approved by:

J. S. Carson
D/445

THE BENDIX CORPORATION
KANSAS CITY DIVISION
KANSAS CITY, MISSOURI

A prime contractor for the Atomic Energy Commission
Contract Number AT(29-1)-613 USAEC

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

ABSTRACT

An analysis of X-ray techniques used to detect metallic foreign material on printed wiring assemblies is given. The use of a long-working-distance Olympus microscope is also described. The microscope is an MTX model with a complete set of lenses.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

CONTENTS

Section	Page
SUMMARY	9
DISCUSSION	11
SCOPE AND PURPOSE	11
ACTIVITY	11
<u>X-Ray Technique</u>	11
<u>Microscope Evaluation</u>	12
RESULTS AND CONCLUSIONS	17

TABLES

Number		Page
1	X-Ray Versus Visually Located Defects for a 15-Board Sample	12
2	Defects Found During Final Inspection of Sample Boards	13
3	Olympus MTX Operation Microscope Evaluation.	15
4	Bausch and Lomb Stereo Microscope Evaluation.	16

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

SUMMARY

X-ray inspection techniques have been tried in an effort to detect metallic foreign material on printed wiring boards. Two representative boards were carefully prepared to contain solder splatters. These solder targets were placed under components, on circuit paths, and on the epoxy portion of the board. The boards were then radiographed to give an indication of the effectiveness of this technique. The test was successful, indicating that resolution is good enough to pick up metallic foreign material as small as 0.0015 inch in all locations except relatively high density areas. The next test phase was radiographing 29 product-quality PWA2 boards. Examination of radiographs revealed 3 to 12 apparent defects per board. Following a final cleaning process, the radiographs were compared to the boards. Sixty-six percent of the 84 incidences of metallic foreign material found on the boards were marked on the X-ray film and an additional 15 percent not marked were visible on the film upon closer examination. Nineteen percent of the metallic foreign material found on the boards was not identifiable on the X-ray film. Fifty-five percent of the apparent defects marked on the radiographs were found on the boards even though the boards had been through a final cleaning process after the film was taken.

A search for improved microscopes has been conducted. The manufacturers contacted were Olympus, Zeiss, Bausch & Lomb, and Americal Optical. Each manufacturer was asked about a microscope with a large depth of field and a fairly long working distance. Olympus and Zeiss were the only makers of a long-working-distance microscope. The Olympus was chosen for evaluation because it was about one-third the cost of the Zeiss. The working distances of the Olympus MTX are 5, 8, and 19 inches depending upon the objective lens used. Depth of field measured about one-half inch at 5 power and about one-third inch at 10 power. A standard Bausch & Lomb stereo microscope has less than one-fifth inch depth of field at 10 power. An on-the-floor evaluation by an inspector in D/54 indicated that the best liked features other than depth of field were the internal lighting, the built-in color filters, and the ease of operation.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

DISCUSSION

SCOPE AND PURPOSE

The objective of this project is to develop new and improved methods for inspection of printed circuit boards (PCB's) and printed wiring assemblies (PWA's). Development is progressing on automatic pattern recognition, directed attention, and various forms of inspection aids. Another important aspect of the project has been evaluation of new equipment and techniques for their potential application as inspection equipment for PCB's and PWA's.

ACTIVITY

X-Ray Technique

The feasibility of using X-ray techniques for inspection for metallic foreign material on PCB's and PWA's was investigated. The first step was a determination of whether the radiograph would have sufficient resolution. Two printed wiring boards with components were carefully prepared to contain solder splatters of 0.002- to 0.015-inch diameters. These solder targets were placed on circuit paths, components, the epoxy portion of the board, component leads, and under a transistor can. The radiographs of these boards indicated that the solder targets could be observed clearly in most area. Solder splatters as small as to 0.0015 inch could be seen on the film. The only problem is when a lead or high density component obscures the solder splatter.

The next step was to have two product-quality boards X-rayed after the final cleaning process. PWA2 and PWA3 boards were selected. No defects were found except a small piece of solder embedded in a resistor. Still it was evident that if metallic foreign material had been on the board it would have been visible on the X-ray.

In order to get a better idea of the cost per board and to examine the full capabilities of this process one final experiment was run. Twenty-nine product-quality PWA2 boards were sent to the X-ray Laboratory after the final cleaning process and before the final inspection. The film was taken so that the part number of the board appears on the film. The film was carefully inspected by X-Ray Laboratory personnel and all apparent defects on the film were marked with a yellow oil pencil. Three to twelve defects were found on each board. The radiographs were then sent to the Inspection Department to be compared with the boards. The boards were sent through an unscheduled final cleaning before a comparison could be made. Every yellow circle on the film was carefully checked against the board and the results were recorded to determine the presence, type, size, and location of the foreign material. The results are shown in Tables 1 and 2.

Table 1. X-Ray Versus Visually Located Defects for a 15-Board Sample

Defects Detected by X-Ray	Additional Defects Detected Visually	Total Defects on Board	Number of Apparent Defects Marked on X-Ray	Number of Defects Visible on X-Ray, But Unmarked	Part No.
1	1	2	3		2054
7	1	8	13	1	1947
0	2	2	3		1745
3	3	6	4	1	2057
4	3	7	4		2070
8	3	11	10	1	2039
6	2	8	8	1	2091
6	2	8	6	1	2085
1	1	2	3		2008
6	1	7	9		1922
4	0	4	7	1	2006
5	3	8	7	1	2005
5	3	8	8	2	1991
3	1	4	4	1	2049
1	0	1	5		2020
Total	Total	Total	Total	Total	
60	26	86	94	10	

The boards were final inspected using the normal inspection method (an eight power microscope). A total of 85 incidences of foreign material, ranging in size from 0.002 to 0.015 inch, were found on the 29 boards. Sixty of the defects were found by X-ray film comparison. The other 25 were found during the final visual inspection. Upon re-examination, 10 of the 25 additional defects were visible on the X-ray film; the other 15 were not. The largest piece of foreign material found in the group of 25 was 0.004 inch in diameter.

Microscope Evaluation

A search for better microscopes is being conducted. After evaluating input from the General Foreman, talking with inspection foremen from several departments, and talking and working with a few inspectors from D/54, a need for improved microscopes was apparent. Improvements needed are larger depth of field, better field of view, improved illumination, and a more universal base to allow more freedom of movement of the microscope head. Several microscope manufacturers have been contacted. Only two manufacturers, Olympus and Zeiss, offered microscopes meeting our specifications for depth of field of 0.5 inch at 5X power magnification, working distance of at least

Table 2. Defects Found During Final Inspection
of Sample Boards

Sizes of Defects Found (in. $\times 10^{-3}$)	Part Number
3, 2	2054
13, 9, 6, 3	1947
2, 4, 4, 3	
4, 2	1745
2, 3, 3, 2	2057
1, 3	
4, 2, 2, 3	2070
1, 2, 2	
8, 4, 3, 8, 3, 8	2039
2, 2, 3, 6, 1	
3, 9, 2, 12	2091
2, 3, 2, 2	
2, 3, 5, 2	2085
4, 3, 2, 2	
2, 3	2098
3, 3, 8, 4	1922
2, 3, 3	
3, 2, 3, 4	2006
7, 7, 6, 3	2005
4, 3, 3, 2	
2, 3, 5, 9	1991
2, 4, 3, 4	
3, 9, 3, 4	2049
3	2020

9 inches, and internal illumination. An arrangement was made with Olympus to obtain their MTX Model Operation Microscope (used by doctors during surgery) on loan for evaluation. Some outstanding advertised features of this model are:

- Working distance from 4 to 19 inches;
- Internal lighting;
- Built-in green and blue color filters;
- Magnification capability of 1.3 to 69.5 power; and
- Depth of field of over 0.5 inch at 5 power and about 0.35 inch at 10 power.

The microscope Model MTX was received in our lab complete with a small swivel stand and a set of lenses. The lenses included two sets of eyepieces, 10 and 20 power, and three objectives, F125, F200, and F500. The field of view, depth of field, and working distance were measured with each lens combination. Results are shown in Table 3. A standard Bausch and Lomb stereo microscope was measured using the same techniques and serves as a comparison. An auxiliary lens attachment, used to increase the working distance of a standard Bausch and Lomb microscope, was tested. The results are shown in Table 4.

Several Quality Process Engineers, department supervisors, and members of Quality management were invited to see a demonstration of the MTX. The MTX and a standard Bausch and Lomb stereo microscope were set side by side at the same magnification for comparison. The unanimous opinion was that the MTX is a superior instrument. One of the engineers in D/445, after inspecting a printed wiring board using the MTX, commented that it felt like he was walking around on the printed wiring board.

Upon completion of the lab evaluation, the microscope was sent to D/54 for an on-the-floor evaluation. It was used by one inspector for two weeks. The inspector's complete list of advantages and disadvantages of the MTX compared to the Bausch and Lomb microscope follow.

Advantages

- Ease of operation--the MTX is easier to use and simpler to focus.
- Color filters--the MTX has both green and blue filters. The blue daylight filter is the favorite; however, green is used occasionally. The scope is seldom used without any filter.
- Long working distance--the 8-inch working distance gives more room to manipulate the boards.
- Depth of field--because of the 30-percent better depth of field, location and inspection of points on the boards is easier.

Disadvantages

- Height of eyepiece above the table top--the microscope was equipped with a 45° head for the eyepiece. This head, coupled with the long working distance, required an inspector seated at a bench to stretch uncomfortably in order to see into the eyepieces. A 90° head could cure this problem; however, none is available.

Table 3. Olympus MTX Operation Microscope Evaluation

Working Distance (in.)	Lens	Eyepiece (Power)	Magnification (Power)	Depth of Field (in.)	Field of View (in. diam)
5	F125 Objective	10	5	0.445	1.4
			8	0.229	0.85
			12.6	0.153	0.56
			20	0.135	0.35
			32	0.103	0.22
		20	10	0.317	0.81
			16	0.153	0.49
			25.3	0.074	0.35
			40	0.066	0.19
			64	0.060	0.11
8	F200 Objective	10	3.1	1.39	2.13
			5	0.521	1.40
			8	0.264	0.89
			12.6	0.159	0.61
			20	0.157	0.32
		20	6.3	0.556	1.24
			10	0.262	0.79
			15.8	0.156	0.49
			25	0.163	0.31
			40	0.156	0.19
19	F500 Objective	10	1.3	2.91	6.13
			2.1	2.43	2.71
			3.3	0.715	2.11
			5.3	0.495	1.38
			8.4	0.481	0.81
		20	2.7	1.91	2.93
			4.2	1.25	1.89
			7	0.612	1.21
			10.6	0.368	0.79
			16.9	0.421	0.41

Table 4. Bausch and Lomb Stereo Microscope Evaluation

Working Distance (in.)	Magnification (Power)	Depth of Field (in.)	Field of View (in. diam.)
4	7	0.325	1.1
	8	0.309	0.94
	9	0.25	0.81
	10	0.19	0.75
	15	0.13	0.44
	20	0.11	0.38
	30	0.09	0.28
8*	3.5	0.75	2.37
	4	0.67	1.92
	4.5	0.57	1.62
	5	0.48	1.48
	7.5	0.39	1.00
	10	0.24	0.67
	15	0.18	0.49
*Auxiliary Lens			

- The stand--the stand was very awkward to use. During use, if the microscope had to be adjusted more than 2 inches vertically (more than the fine adjust), the stand had to be manipulated. The only means for adjusting the stand was a ring clamp which totally released the heavy microscope, requiring difficult two-handed adjustment. Also, the stand required a 3-foot-deep by 2-foot-wide bench space.

RESULTS AND CONCLUSIONS

The evaluation of X-ray inspection of PCB's for foreign material showed that radiographs could show metallic particles as small as 0.0015 inch. However, on areas of the board with high density or opacity to X-rays, other inspection techniques must be used.

Evaluation of the Olympus MTX Operation Microscope for inspection purposes showed that it was preferred by the inspectors over standard stereo microscopes now in use.