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**OMNI-DIRECTIONAL ILLUMINATION FOR
PRINTED CIRCUIT BOARD INSPECTION**

Technological Spinoff Report

August 1973

Bendix Corporation
Kansas City, Missouri

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OMNI-DIRECTIONAL ILLUMINATION
FOR PRINTED CIRCUIT BOARD
INSPECTION

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THE BENDIX CORPORATION

KANSAS CITY DIVISION

KANSAS CITY, MISSOURI

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August 1973

Prepared by R. D. Taylor

Omni-directional, shadow-free illumination for the visual inspection of printed wiring boards and assemblies has been achieved by using an integrated sphere to internally reflect light upon the inspection part. The result is totally indirect lighting.

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SUMMARY

The need to improve illumination for the visual inspection of printed circuit boards and other assemblies produced at Bendix Kansas City prompted the development of omni-directional illumination. The improved lighting technique employs an integrated sphere which reflects light from all points on its internal, magnesium-oxide-coated surface onto the object under inspection. Totally indirect lighting results, and the object viewed is without shadow or glare. Spheres of 3, 8, and 30 inches (7.5, 20, and 76 cm) in diameter were developed in addition to a hemisphere or dome illuminator.

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DISCUSSION

SCOPE AND PURPOSE

This project is part of an overall investigation to improve illumination for the visual inspection of printed circuit boards and other assemblies produced at Bendix Kansas City. As a result of this study, a lighting technique which reduces glare and shadowing to an extremely low level has been developed. The improved lighting technique, called omni-directional illumination, employs an integrated sphere as an internally reflecting surface to produce totally indirect lighting.

PRIOR WORK

Bendix has studied ways to improve techniques of illumination for 2 years under Process Development Order 6984522 titled Rapid Visual Scanning. In 1971, the first omni-directional prototype was assembled, and since that time, four additional models have been built and tested.

ACTIVITY

Principle of Operation

By the omni-directional method of illumination, light reflects off the total spherical inner surface of the illuminator ball and hits the inspection object from all directions (Figure 1). The result is a totally indirect, soft lighting, which does not evolve from a point source and is characterized by the absence of glare and shadowing (Figure 2). The omni-directional view of the printed wiring assembly shown in this figure was made through a 30-inch (76 cm) sphere. Both views were made at the same light level. The omni-directional technique allows higher levels of illumination without increased eye fatigue.

The 8-Inch (20 cm) Sphere

The first omni-sphere was 8 inches (20 cm) in diameter, and its spherical inside surface was coated with a magnesium oxide powder for optimum reflection. The light source was a 180-watt focused unit which beamed light into the ball at 90 degrees from vertical. The operator views the object through the center of the ball by means of viewing holes in the top and bottom (Figure 3).

Text continued on page 15.

Figure 1. Diffuse Light Reflection Within Omni-Sphere

Figure 2. Printed Wiring Assembly Seen Under Standard Illumination (Above) and Omni-Directional Illumination (Below)

Figure 3. Eight-Inch (20 cm) Omni-Directional Lighting Sphere

The 8-inch (20 cm) sphere has been used with long-working-distance microscopes and also in unaided visual inspection. Printed wiring assembly inspection was an initial application of this sphere. The reduced shadowing and absence of glare made component number verification easier and improved solder inspection. The 8-inch (76 cm) sphere also enabled automation of pattern recognition techniques by eliminating glare and shadowing. The absence of false information caused by uneven lighting makes possible a vidicon camera scan of the actual object, instead of a backlighted picture scan.

The 30-Inch (76 cm) Sphere

After the 8-inch (20 cm) sphere proved successful, a 30-inch (76 cm) sphere was developed to test the lighting technique on a larger scale and to establish the capability of inspecting entire assemblies and other large foam and metal parts (Figure 4). The 30-inch (76 cm) sphere functioned as well as the smaller version. An experiment was then devised to measure intensity and direction of light for each square inch of a 15- by 15-inch (38- by 38-cm) work surface. A highly unidirectional photocell arrangement was used in the test. The results showed a 3 to 4 percent variation in light intensity over the total area and about the same percentage in directionality. By comparison, a typical incandescent lighting arrangement with the coordinate system on the work bench showed 40 to 60 percent variation in light intensity and 150 to 200 percent variation in directionality. Directionality was measured by sweeping 90 degrees in two opposite directions from vertical then rotating the sensor 90 degrees and repeating the sweep. This measurement was made at 15 sample points on the coordinate system.

The 30-inch (76 cm) sphere was designed primarily for direct visual inspection of the surface quality of large foam or metal parts. Of particular interest is the application of the sphere to photoresist exposure. The photoresist process is extremely critical and requires uniform exposure to ultraviolet light. The ability of the sphere to diffuse ultraviolet light to ensure uniform exposure over curved surfaces is currently being tested.

The 30-Inch (76 cm) Cylinder

As an alternate design, a 30-inch (76 cm) cylinder was also built and subjected to the same tests as those for the 30-inch sphere. The cylindrical design provided easier access for large part insertion and cooler operating temperatures, an important factor when an incandescent light source is used. The unit did not function quite as well as the sphere but was still superior to normal lighting. Although the quantitative data of the cylinder proved as favorable as that of the sphere, the cylinder was more awkward to use and required more light to achieve the same illuminative intensity. Several

Figure 4. Thirty-Inch (76 cm) Omni-Directional Lighting Sphere

alternative coatings for the inside surfaces of the cylinder were tried, but the result was variation only in light efficiency and not in light quality.

For the 30-inch (76 cm) sphere neon, fluorescent, and incandescent illumination were tried. No significant difference was noted in performance. Only the color and temperature of the light varied. However, incandescent illumination is recommended because of its lower cost.

The 3-Inch (7.5 cm) Sphere

The need for a high performance illuminator for microscopic inspection prompted the development of a 3-inch (7.5 cm) diameter sphere. The smaller sphere was machined from aluminum and coated with flat white magnesium oxide paint. The source of illumination was a 160-watt unit and a 1/2-inch (0.6 cm) diameter fiber bundle which produced abundant light for this unit. The light can be mounted on any microscope which has at least a 100 mm objective (Figure 5).

Tests similar to those performed on the larger models were made on the 3-inch sphere. A miniature photocell was constructed and the test results were almost identical to those of the larger model. Light varied about 2 percent in intensity and directionality, mainly because of the smaller sample area (about 1-3/4 inch or 4.3 cm in diameter).

The need for a unit requiring less working distance prompted a special setup using a hemisphere or upper dome of the 3-inch (7.5 cm) sphere (Figure 6). This unit was backlighted and required less than 1-1/2 inches (3.7 cm) working distance. At higher magnification, the dome provided still better viewing because the lower sphere surface reflections, which produce a thin haze at low power and degrade the image above 60X, were eliminated. Bendix now has a microscope that magnifies to 200X and still maintains the working distance required by the dome. The dome design is especially well suited for hybrid microcircuit and beam lead inspection. Figure 7 shows the high reflectivity of the gold plating on the microcircuit under standard illumination and its reduction under omni-directional dome illumination. Improved definition of path edges and clarity of numbers on the chip are also evident in the omni-directional views in Figure 7.

ACCOMPLISHMENTS

All three spheres, in addition to the dome illuminator, significantly improve the intensity and directionality of illumination for visual and microcircuit inspection (Figures 7 and 8). Universal mounting fixtures for the dome and the sphere, which allow use of the illuminator without direct attachment to

Figure 5. Three-Inch (7.5 cm) Omni-Directional Lighting Sphere Unmounted (Above) and Mounted (Below) to Microscope

Figure 6. Omni-Directional Lighting Dome

a microscope, have been built. It is, therefore, recommended that the standard lighting technique be replaced with omni-directional incandescent illumination.

STANDARD ILLUMINATION

OMNI-DIRECTIONAL
ILLUMINATION: SPHERE

OMNI-DIRECTIONAL
ILLUMINATION: DOME

Figure 7. Hybrid Microcircuit Illuminated by Standard Lighting and by Omni-Directional Lighting: 45X

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Figure 8. Integrated Circuit Chip Seen Under Standard Illumination (Left) and Omni-Directional Illumination (Right): 60X