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SOLDER LEVELING APPLIED
TO MANUFACTURING

EP 41172-00, Final Report

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**Kansas City
Division**

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**EP 41172-00
Final Report**

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ABSTRACT

Incorporation of solder leveling in the manufacture of an electronic device resulted in reduction of metallic foreign material and improvement in the ease of assembly and inspection. Program controls were established to warn of changes in solderability and to provide engineering data.

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SUMMARY

Electronic assemblies in which high reliability is required are often plagued by metallic foreign material that may ultimately cause an electrical short. This is especially true if the assemblies contain printed circuit boards with small holes and close spacing between paths. It is difficult to remove solder from small holes by the solder-slinging process commonly used in the manufacture of printed circuit boards. Removal of the solder from the holes during assembly manufacturing too-often generates solder particles. It is difficult to remove small, partially clinging solder particles remaining on the board after solder slinging, and, if these particles loosen, they may cause electrical shorts. Solder slinging occasionally results also in solder bridging between adjacent, closely-spaced circuit paths and lands. It appears feasible to eliminate these conditions by use of solder leveling, a relatively new process in the printed circuit board industry. However, additional evaluation of the solderability of solder-leveled boards was required before incorporating the process into manufacturing procedures.

By experiment and by acquisition of information from several companies involved with solder leveling, solderability was found to remain satisfactory for at least five months. Therefore, incorporation of the solder leveling process into the fabrication of printed circuit boards for a complex electronic device manufactured by Bendix is warranted.

Controls were established to give early indications of any decrease in board solderability, and to provide long-term engineering data related to solder leveling and solderability of solder-leveled boards.

The findings thus far indicate that:

- Solder leveling eliminates practically all solder splatter on the boards and removes excess solder from the holes;
- Solderability remains more than adequate for at least five months after solder leveling;
- Ease of visual inspection is enhanced; and
- The time required to manufacture the assembly is reduced.

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DISCUSSION

SCOPE AND PURPOSE

Complex high-component-density electronic assemblies in which high reliability is required emphasize the need to clean printed circuit boards for complete removal of all loose and clinging solder that might cause electrical short circuits between component terminations and solder paths. Particles of solder that tend to cling to the board surfaces and hole walls and excess solder buildup in the holes of tin/lead-coated boards that are processed by the conventional "solder-slinging" method of removing superfluous solder dictate the need for a more-effective process. "Solder leveling" is such a process.

The principal objection to solder leveling as a manufacturing process is the purported problem of poor solderability on boards that are stored for extended periods after solder leveling.

Because of a need for an improved method of removing metallic particles from complex pc-board assemblies, supported by previous Bendix work which revealed that solderability of solder-leveled boards is controllable within satisfactory limits, solder leveling was incorporated into the manufacturing processes for production of a particularly complex electronic timing and programming assembly in which high reliability was a prime requirement.

The standard Pessel spread-factor test was adopted to monitor solderability, and procedures were established to maintain solderability and to provide engineering production-support data on solderability.

PRIOR WORK

Previous Bendix investigation of the solder-leveling process included work reported by W. A. Mulholland, "Solder Leveling of Printed Wiring Boards," BDX-613-443, available from NTIS. The findings from that work included the following.

- The thickness of the solder-leveled coating is nominally 55 microinches for a fairly-wide range of leveling fluid temperatures and pressure. A temperature of 430°F and a spray pressure of 60 psig produce the least thickness variation.

- The solderability of a solder-leveled surface decreases with time. Printed circuit boards that were stored as long as five months had been tested at the time of that report, and tests were continuing. Solderability decreased quite rapidly during the first two to three months of storage, then tended to level off within a range of good solderability.

The solderability factors stated in Mr. Mulholland's report were determined by standard Pessel spread-factor tests in the Bendix Test Laboratory. The Pessel factors were not correlated with actual manufacturing conditions, in which the soldering iron, the flux, and the operator technique might influence solderability. However, the results reported were considered sufficiently encouraging to warrant further investigation and consideration of solder leveling as a manufacturing process, particularly for those assemblies in which metallic particles might create a reliability problem.

ACTIVITY

During the initial period of Bendix production of an electronic device by methods that did not include solder leveling, it was found that a significant number of units contained excessive metallic foreign material after assembly was completed. A substantial amount of processing and manufacturing effort was being expended to correct these problems. A portion of the problem was caused by printed circuit boards that were sometimes received with excessive solder splatter on the surfaces and holes filled with solder. Removal of solder from the holes only aggravated the situation in that it generated additional metallic foreign material. Faced with this situation, an investigation of the printed circuit board fabrication processes was initiated. The solder-slinging process was the major source of difficulty. Solder slinging for removal of excess solder is a process in which the board is sharply rapped on a solid object immediately upon removal from the fuzing tank. After solder slinging, some boards contained generous amounts of splatter and numerous holes remained filled with solder (Figure 1). Improvement of the solder-slinging process was needed, or a completely new process that would yield a clean board had to be found.

Solder leveling, a relatively new process previously investigated by Bendix, provided answers to the foregoing problems; however, it was found that some other companies were reporting difficulties with the solderability of solder-leveled boards.

A. Bridging Between Paths

B. Partial Bridging

C. Solder-Filled Holes

D. Solder Particles

Figure 1. Printed-Circuit-Board Defects

Solderability Study

A report by The Institute of Printed Circuits, "Solderability of Printed Circuit Thin Fuzed Coatings," described evaluations of two groups of solder-leveled boards. The first group was leveled with normal processing, while the second group was leveled with concerted effort to remove all excess solder from the printed circuit board conductors. The IPC found that the boards retained solderability for one year after solder leveling. Furthermore, the test results did not indicate any noticeable difference in the solderability of the two groups.

Of several companies from which the IPC solicited comments on the report, fourteen concurred with IPC findings, whereas six dissented. Those companies that did not concur were contacted by Bendix to determine the reasons for disagreement. The replies were categorized as follows:

- Favoring solder leveling one company;
- Processing not comparable to that of Bendix two companies; and
- Information insufficient to support a conclusion. . . three companies.

Based on these findings, there appeared little evidence that solderability would decrease to unacceptable levels during the manufacture of printed circuit boards and electronic assemblies at Bendix.

Solder-Leveled Board Samples

As a further means of increasing confidence in the solderability of solder-leveled boards, components were assembled on several solder-leveled boards by means of a common Bendix soldering process: diluted nonactivated flux, solid solder, and small soldering irons. Some of the boards had been solder-leveled as long as two years before use, and had been exposed to normal factory atmospheric conditions during that period. No difficulty was encountered during assembly of components onto the boards. In fact, those who assembled the units felt that the ease of installing components on solder-leveled boards was equal to that on other types of boards.

Initial Production

Since the solderability investigations failed to reveal anything that justified concern related to deterioration of solderability, solder leveling was used in production of 27 complex electronic timers (Figure 2). Each timer required three major boards on which 354 components were installed.

A. Three Major Subassemblies and Assembly Stack

B. Close-Up Edge View of Completed Assembly

Figure 2. The Programming and Timing Unit

Previously solder-slung, unleveled boards were solder leveled before assembly by use of a Hydro Squeegee Model 600D machine (Figure 3). Hydro Squeegee leveling compound was used at a temperature of 430°F and a pressure of 60 psig. The boards were mounted on fixtures designed to allow free impingement of the spray upon all circuit paths. They were then immersed in the leveling compound spray for approximately 30 seconds, followed by a 1-minute 150°F water spray to remove the residual leveling compound. The boards were then blown dry with filtered air and cleaned in a trichloroethylene vapor degreaser.

After solder leveling the boards were given a normal visual inspection in which particular attention was given to the following requirements:

- No solder bridging between circuit features;
- Holes free of all except a minimal coating of solder;
- No solder balls, humps, splatter, or partially-adhered particles;
- No dewetted areas, excessive pin holes, or voids in the solder coating that exceeded the requirements of unleveled boards;
- No evidence of slivers, spurs, or cracked overhang along the edges of the conductive pattern;
- No delaminations that exceeded the requirements of unleveled boards; and
- No measling that exceeded the requirements of unleveled boards.

All of the solder-leveled printed circuit boards met the above requirements, as well as additional ones applicable to unleveled boards.

Following completion of solder leveling activities, the boards were sent to the electronic assembly area for fabrication of 27 timers. Those units were fabricated with processes and personnel normally used in the manufacture of units with solder-slung, unleveled boards. Approximately 370 components were installed and 1,000 solder joints were made on each unit. Twenty-watt, chisel-tip soldering irons were used in conjunction with solid-wire solder and Alpha 611 flux diluted with Isopropyl alcohol to a 50/50 solution. Solid-solder preforms were used on approximately 700 of the 1,000 connections on each unit.

Figure 3. Hydro Squeegee Model 600D in Operation

The variety of solder joints made during assembly of three relays, fifteen integrated circuits, a shift register, and assorted semiconductors, capacitors, resistors, and inductors were evaluated by engineering personnel, and workers were questioned as to the relative merits of leveled and unleveled boards. Since the boards were free of excess solder at the start of fabrication, time spent in removing solder particles and opening solder-filled holes was reduced. With the exception of slightly larger amounts of solder being required to make connections, the solderability characteristics of leveled boards appeared to be the same as that of those which had not been leveled. This was true even on those units which, because of unrelated delays, required five months for completion.

As the 27 units were manufactured each assembly was submitted to the Bendix inspection department for normal inspection. Inspection procedures require that each solder joint be checked visually under magnification. There were no rejections caused by solder-leveled boards. Inspection for loose and partially adhered metallic particles also is required. Since the boards originally were free of excess solder, this inspection time was reduced. All units were accepted by the Inspection Department, without rejections attributable to solder leveling.

Controls for Large Production Quantities

In view of the success obtained with the initial 27 units, the solder-leveling process was incorporated into the manufacture of all printed circuit boards used in the program. Controls were established to assure the solderability of boards supplied to the production line and to provide long-term engineering data related to solder leveling and solderability. These controls require that Pessel spread-factor tests be run on solder-leveled samples (Figure 4).

The trim material will be salvaged during contouring operations, from each lot of boards processed during the first six months of manufacture. Each lot consists of 16 to 80 pieces, with each board within a given lot subjected as nearly as possible to identical processing. Lot identity of the boards is maintained at all times, including during assembly of the units. Trim material from each lot is identified, sectioned into a large number of samples (Figure 5), and stored in an atmosphere approximating that of the storerooms and the electronic-assembly areas. After each storage period listed below, three samples from each lot are tested in accordance with standard Pessel spread-factor test procedures.

Figure 4. Pessel Spread-Factor Solderability Testing

A

E

C

- A. PC-Board Panel After Contouring
- B. Trim Material to be Sectioned
- C. Sample Sections for Pessel Testing

Figure 5. Pessel Spread-Factor Solderability Test Sampling

Pessel Spread Factor Test Schedule

Test No.	Storage Period
1	Upon receipt
2	1/2 month
3	1 month
4	1 1/2 months
5	2 months
6	2 1/2 months
7	3 months
8	4 months
9	5 months
10	6 months
11	7 months
12	8 months
13	9 months
14	10 months
15	11 months
16	12 months
17	14 months
18	16 months
19	18 months

Graphs of solderability versus storage time (Figure 6) are maintained for each lot of material. Formal distribution of the results is made periodically. Spread-factor measurement less than 75 percent are reported by lot number to Quality and Products Engineering, so that solderability characteristics of that lot can be determined. If the lot is still in the storeroom, samples are sent to the production area for checks of solderability under normal assembly conditions. If the lot is already being used in the assembly of units, checks are made to determine if the assemblers are experiencing difficulty in making solder joints. Microscopic examinations are conducted, particularly for characteristics indicative of sub-standard solder joints. Corrective action is taken as required.

The Pessel spread-factor test provides stringent indications of changes in solderability. Past experience has shown that the factory worker also provides notification of soldering problems that may develop on the assembly line. However, the success of the solder-leveling process thus far indicates that soldering problems traceable to solder leveling will not occur.

Figure 6. Solderability Versus Storage Time

ACCOMPLISHMENTS

Results obtained during this work show that the solder leveling process can be used successfully in the manufacture of printed circuit boards. Limited production quantities of boards free of metallic particles and undesirable quantities of solder in the holes were produced. Solderability of solder-leveled boards under factory conditions is essentially equal to that of solder-slung boards for at least five months.

Sufficient confidence was established to warrant use of solder leveling in relatively-large production quantities of printed wiring boards. Success in a larger production run, combined with confidence supplied by the long-term Pessel test program, may lead to more-extensive use of the solder-leveling process at Bendix.

FUTURE WORK

Future work will include maintaining cognizance of the following activities:

- Solder-leveling processing (to assure boards free of metallic particles and solder filled holes);
- Assembly of components onto solder-leveled boards (to determine the degree of solderability over extended time periods); and
- Pessel solderability tests (to check for trends indicating an unacceptable decrease in solderability).

The solder-pot dip process of applying a tin/lead coating to the boards will be investigated. This method has two distinct advantages over the present plating process. First, the tin/lead ratio can be better controlled. Since this ratio influences solderability, the solderability of solder-dipped boards will be better. Second, the processing steps are reduced, resulting in a cost saving.

Preliminary experiments with solder-pot dipping produced boards with excess solder that bridged circuit paths and filled holes. These problems were eliminated by subsequent solder leveling, which removed all excess solder. Thirty boards are now being fabricated by these two processes. After evaluating these boards, solder-pot dipping, rather than tin/lead plating, will be incorporated in the processing of printed circuit boards for the timer assembly.