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FLATPACK
REFLOW
SOLDERING

August, 1970

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ABSTRACT

Parallel-gap reflow soldering techniques in use at the outset of this program resulted in degradation of printed wiring board assemblies containing IC flatpacks and necessitated excessive rework. A single-probe method was found superior and was adopted for production use. As a result, the present production rate is higher than was possible with the parallel-gap process, board quality is improved, and rework is reduced. The work required to establish the improved soldering method and refine the supporting processes and procedures is described in this report. Continued investigation, including evaluation of another single-probe reflow soldering system which is expected to yield even further improvements, will be described in a final report upon completion of the project.

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Section 1

SUMMARY

Problems encountered in the use of parallel-probe resistance-soldering to install IC flatpacks on printed wiring boards led to a search for a more suitable reflow soldering method. The principal goals were: increased production rates, more uniform solder fillets, reduced rework, and greater process versatility.

Soldering processes investigated included a multilead heated probe, for soldering several leads simultaneously; infrared heating, also permitting simultaneous lead soldering; and a single heated probe, whereby leads are soldered individually. Neither the multilead probe nor the infrared method provided any appreciable advantage, and both methods were less satisfactory than the previously used parallel probes. The single-probe method, however, used with Development Associates control equipment, provided most of the improvements sought. Production rates were increased significantly, solder fillet uniformity was improved, and rework was sharply reduced. Therefore, the Development Associates Controls (DAC) single-probe system was adopted for use in current scheduled production of printed wiring board assemblies which contain flatpacks.

Since lead forming and pretinning are important aspects in reflow soldering installation of flatpacks, these, too, were investigated. Leads were successfully formed at angles of 60, 65, and 80 degrees, with both bend-angle and lead-length within requirements. Leads formed after tinning were not satisfactory.

The tinning experiments employed a special fixture to hold the flatpacks while the leads were dipped in molten solder. After trying aluminum and steel fixtures with Teflon coatings over the head portion without success, a holding fixture was machined from solid Teflon. The Teflon was heat-stressed before machining to prevent distortion caused by the heat transfer encountered in normal use. The Teflon reduces heat transfer to the circuitry within the flatpack and lessens the tendency of solder to bridge between the leads when dipped. The redesigned holding fixture proved satisfactory, and is in present scheduled production use.

A review of the previous board cleaning procedure resulted in adoption of a simplified interim method for current production use. Tests revealed that solderability was poor after boards cleaned with Surf-Prep (a product of Claude Michael, Inc.) had been exposed to high humidity. For that reason Surf-Prep was tentatively removed from the cleaning procedure. Continued investigation, however, is expected to yield some method whereby the virtues of Surf-Prep can again be utilized.

Because of the DAC single-probe soldering method, use of diluted flux, adoption of an interim cleaning process, and other processing improvements resulting from this project, production of reflow soldered flatpack printed wiring board assemblies is much improved over that obtainable with the parallel probe soldering method. The production rate is increased, solder fillets are more uniform, the appearance of the boards is better, and much less rework is required.

Evaluation of an alternate single-probe system, the Browne timed-pulse heating method, is now being conducted. Initial trials indicate that further improvements may be made possible by use of that equipment. The Browne probe is smaller than that used with the DAC equipment; therefore, the Browne system is more versatile for both initial installation and rework on crowded boards. In addition, the timed-pulse heating principle provides more uniform probe temperature during the soldering operation.

The outcome of the Browne system evaluation and other work in progress will be reported upon completion of the project.

Section 2

BACKGROUND

Since flatpack leads are small and closely spaced, the amount of solder applied is very critical and must be limited to the amount necessary to produce strong connections and satisfactory fillets, without sufficient flow to short-circuit to adjacent leads. Conventional soldering by application of solder to the probe and the joint surfaces does not provide sufficient control. Therefore, the proper amount of solder is applied by pretinning the flatpack leads, and the joint areas are heated after the flatpacks are placed in proper position, thus causing the solder to flow. Such a process is called reflow soldering.

PARALLEL-PROBE SOLDERING PROBLEMS

Because of nonuniform soldering of flatpacks to printed wiring boards and the subsequent necessity of reworking an excessively large number of such boards, an investigation is in progress to find an effective means of alleviating that condition. The principal problems encountered with the parallel-probe resistance-soldering process in use at the outset of this program were as follows.

- Cleaning the probes was necessary after approximately seven operations, thus slowing the rate of production.
- The space required for the parallel probes made it difficult to solder multilead flatpacks with 80-degree preformed leads.
- Small discrepancies in lead-forming made it difficult to attain the precise alignment required to solder the leads in correct positions, thereby making it necessary to reheat the solder to align individual leads.
- Nonuniform solder fillets made it difficult to evaluate the strength and condition of the soldered connections by visual inspection methods.
- Occasional arcing because of excessive contact resistance at one or more of the lead, land, or probe contact points due to highly-resistive flux buildup sometimes created pits in the contact surfaces.

The Development Associates Controls soldering control equipment, as used with the parallel-probe soldering method in use at the outset of this investigation, is shown in Figure 1. The difficulty of soldering 80-degree formed flatpack leads is illustrated in Figure 2. The other reflow soldering methods investigated were compared to the parallel-probe method.

Figure 1. The Development Associates Controls Soldering Control System as Used With Parallel Probes

Figure 2. Detail of Parallel Probes in Contact With a Flatpack Lead
(This photograph illustrates the limitations encountered in soldering 80-degree formed flatpack leads with the parallel probes.)

OBJECTIVES

The major purpose of this project was to evaluate the merits of the parallel-probe flatpack reflow soldering process as compared to those of alternate methods and to select the method which would best fulfill the following objectives:

- To increase production rates in flatpack reflow soldering operations;
- To obtain uniform solder fillets, as required, to sustain visual inspection reliability and to produce acceptable board appearance;
- To improve repeatability and uniformity of the soldering process, thereby reducing the necessity for reworking the boards; and
- To establish the greatest possible process versatility, thereby enabling sharp-angle preformed flatpack leads to be soldered on boards that provide little space for soldering probes.

APPROACH

Because of the critical nature of flatpack soldering, it was apparent that the capability of the operator and the versatility of the process were equally important. Therefore, operator skills were considered in the evaluation of each of the several processes investigated. Alignment of all leads of multilead flatpacks is difficult and time consuming. If not properly aligned, leads that are not in proper position during the initial soldering operation must be reheated and moved. Such rework procedures are highly critical; therefore, the utmost in both operator skill and process versatility is required to produce proper alignment and uniform solder fillets. Rework operations are commonly complicated by space limitations and the close proximity of the other leads of the flatpack and other components, including the solid state components of the flatpack itself, which may be damaged by excessive heat.

Because of the critical functional and appearance requirements, the plan for the investigation was designed to include the following considerations:

- Evaluation of several reflow soldering methods;
- Single probe soldering techniques;
- Operator qualification;
- In-process tests; and
- Cleaning methods.

REPORTING

Although progress on the project has been reported in previous departmental quarterly reports, the work has progressed to selection and use of a single-probe reflow soldering method which produces satisfactory results in production of flatpack printed wiring board assemblies. The work required to establish that process is discussed in this interim report.

For ease in reading and convenience in indexing, a subject heading system of organization is used in this report. Therefore, the events reported may not be in chronological order. Evaluation of a time-pulse method of controlling probe temperature and refinement of some other aspects of the project will be reported upon completion of the work. To avoid unnecessary duplication of effort, much of the content of this publication will be referenced in the final report. Therefore, those who are interested in the outcome of this project are urged to retain this report for future reference.

Section 3

METHODS INVESTIGATED

Each of the following methods of reflow soldering was investigated, and the results obtained with each were compared to those obtained with the parallel-gap method which was in use at the outset of the development program.

INFRARED HEATING

Infrared heating was generally unsatisfactory because it was not possible to confine the heat to the desired areas. Consequently, heat-sensitive components were subjected to excessive heat. The method was not suitable for rework applications because the heat could not be restricted to individual leads. Simultaneous alignment and soldering of leads was extremely difficult, and the leads could not be held in position until the solder cooled.

Less cleaning was required, as compared to the parallel-gap method, and flatpack installation required less time; however, the necessary additional rework resulted in an overall decrease in the production rate, and the solder fillets were irregular.

HEATED MULTILEAD PROBE

Results obtained with the multilead probe were similar to those experienced with the infrared heating method. It was difficult to align and hold the leads; therefore, much rework was required after the initial flatpack installation.

Since heat could not be restricted to a single flatpack lead, the multilead probe was not suitable for use in reworking the boards. The initial installation was faster with the multilead probe than with the parallel-probe method, and 80-degree formed leads could be soldered; however, additional rework resulted in an overall decrease in the production rate.

HEATED SINGLE PROBE

Single-tip soldering probes were used in conjunction with the existing Development Associates (DAC) soldering control equipment to evaluate the single-probe reflow soldering process. A thermocouple mounted in the probe provided the temperature-sensing function necessary to monitor and control the process. (See Figures 3 and 4.)

Comparisons of the results of the single-probe soldering process to those obtained by the other methods investigated proved the single-probe method superior in the following respects.

(Text continued on page 11)

Figure 3. DAC Single-Probe Reflow Soldering Station

Figure 4. Detail of the Single Probe in Soldering Position on a Flatpack Lead

- Reduced Probe Cleaning

The necessity for cleaning the probe was reduced by a factor of nearly ten, as compared to the parallel-probe resistance-soldering method. Single-probe cleaning was required after 50 to 75 joints, whereas the parallel probes required cleaning after approximately seven operations.

- Improved Heating Uniformity

Heating was more uniform and predictable, thereby enabling the process to be controlled more closely. Reliance on the contact resistance of the parallel probes was eliminated; therefore, the heat applied to the joints was dependent only upon the constant resistance of the single probe and the controlled current applied thereto.

- Less Damage to Lead and Board Surfaces

Elimination of the flux buildup problem, which caused arcing, occasional circuit board damage, and pitted surfaces on the parallel probes, resulted in less need for redressing the board lands and flat-pack leads. Consequently, the single-probe method was more reliable and repeatability was improved.

- Improved Fillet Uniformity

More uniform solder fillets were produced by use of the single probe, thus reducing the necessity for reheating connections after initial soldering, improving the appearance and dependability of the board assemblies, and avoiding damage to components and boards which sometimes results from repeated heating.

- Reduced Rework

Improvements resulting from use of the single probe allowed easier alignment in initial soldering. Consequently, less rework was necessary.

- Suitability for Use in Rework

Because of the small access space required and the ability of the single probe to concentrate heat on small areas, the single-probe soldering method is ideally suited for rework operations. Therefore, use of the single probe for initial soldering eliminates the need for an alternate reworking process.

- Reduced Heat Conduction

Concentration of heat upon one connection at a time reduces the transfer of heat to adjacent connections and components. Therefore, adjacent soldered joints exhibit less tendency to loosen and heat-sensitive components are less likely to be damaged by excessive heat.

- Greater Versatility

Because of the small size of the single probe, as compared to the dimensions of the probes used with the parallel-gap and multilead-probe methods, the single probe is more adaptable to dense packaging applications which provide very little space for probe access.

- Increased Production Rates and Improved Quality

Because of the superiority of the single-probe reflow soldering technique over the other methods investigated (as enumerated above), production rates have been increased significantly and the quality of etched wiring board subassemblies that contain multilead flat-packs is superior to those produced by previous methods.

- Operating Simplicity

After initial adjustment of the temperature, current, rise-time, and fall-time controls for a specific board, no further adjustment of the single-probe DAC system is normally required. When changing to a different type of board, only the temperature control need be re-adjusted. Since the parallel-probe method required frequent readjustment of both current and temperature, and because much reheating was necessary to redress the flatpack leads and fillets, the operating simplicity of the DAC single-probe system is a decided advantage.

- Simplified Calibration

Initial calibration of the DAC single-probe system is performed with the probe thermocouple attached, rather than by use of a resistance standard, as in most other systems. Therefore, calibration can be performed at the production station, thus eliminating the need to transport the equipment to a maintenance station. Subsequent recalibrations require only a verification of settings, rather than a complete realignment. The DAC power supply need not be turned off between periods of use, thereby eliminating the 4-hour warmup period required to stabilize the control limiters contained in the power supply.

- Improved Appearance

The appearance of boards soldered by the single-probe method was much improved over that of boards soldered by the parallel-probe, infrared-heating, and multilead-probe methods--as evidenced by the shiny surfaces of the solder connections, more uniform solder fillets, proper lead dress, and absence of blistering or measling on the board surfaces. For that reason, and because of favorable results of investigative procedures reported in the following section, the single-probe method was adopted for use in current production of etched wiring board subassemblies that contain multilead flatpacks.

Solder fillet uniformity was further improved by use of a diluted liquid flux which was dried before soldering. The dry flux does not conduct heat away from the solder area as readily as the wet flux used with the parallel probes, the dry flux coating is more uniform, and the dry boards can be handled more conveniently.

Since the single probe can be used in any position, fixed board positioning fixtures are not required and precise adjustment of height, angle, and rotation required with the parallel-probe method is not necessary with the single probe. Therefore, the resultant time saving is a definite aid to production.

Section 4

INVESTIGATION PROCEDURES

The results of tests and studies conducted to determine the relative merits of single-probe soldering method as compared to the parallel-probe method are given in this section. Experiments and tests, such as forming flatpack leads, tinning the leads prior to soldering, cleaning techniques, and other considerations that influence the quality of the finished product are also discussed.

PULL STRENGTH TESTS

The comparative pull strengths of leads soldered by the single-probe and parallel-probe methods were determined by testing fifty 60-degree formed specimens prepared by each method.

Of the 50 leads soldered by the single-probe method, 40 leads failed before reaching the ultimate pull strength of the joint. Of the remaining 10 leads that pulled loose, the lowest pull strength was five pounds eight ounces.

Of the 50 leads soldered by the parallel-probe method, only 23 failed before reaching the joint pull strength, and the remaining 27 pulled loose. The pull strength of the weakest of the parallel-probe soldered joints was only two pounds three ounces--less than half that of the weakest of the joints soldered by the single probe.

Plots of the data from the pull strength tests are shown in Figures 5 and 6. Those graphs show the pull strengths of the leads that failed before reaching the ultimate pull strengths of the joints as being equal to the break strength of the leads. Therefore, there was no way of measuring the joint strength of the broken leads.

The results of the pull strength tests were programmed for an IBM 360 computer, which performed process capability studies of the two soldering methods. The computer printouts from those programs are shown in Figures 7 and 8. The programs substantiate the superiority of the single-probe soldering technique.

LEAD FORMING

Uniformity of length and bending angle of the leads is highly important when flatpacks are to be soldered to wiring boards. The leads must be of proper length after bending and the lower surfaces of the terminal ends of the leads must rest flatly upon the land surfaces. Therefore, it is necessary to consider the spring-back of the leads when calculating the desired length and clearance between the bottom of the flatpack and the board.

(Text continued on page 18)

Figure 5. Pull Strengths of Parallel-Probe Soldered Samples

Figure 6. Pull Strengths of Single-Probe Soldered Samples

Parallel-Gap Process Capability Study

(Weights are stated in ounces)

Lower Specification Limit: 35.00000 Upper Specification Limit: 105.00000

Part Number: Parallel Characteristic Number: Gap

Date: 4300

Sample Size: 50 Mean: 89.16000 Standard Deviation: 14.8535156 Range: 69.00000

Percent Defective Statements:

Number of standard deviations between the mean and the upper specification limit	1.066	QU
Number of standard deviations between the mean and the lower specification limit	3.646	QL
Estimate of the percent defective above the upper specification limit	14.335	PU
Estimate of the percent defective below the lower specification limit	0.025	PL
Estimate of the total percent defective (PU + PL)	14.360	

Normality Statement:

The process is significantly non-normal because the distribution is skewed to the smaller values.
The distribution is peaked. Skewness -1.49 Kurtosis 2.72

Tolerance Limit Statement:

With 95 percent confidence 99 percent of the population is between 42.72558 and 135.59442

Control Statement:

The process is assumed to be in control.

95 percent Confidence Statements:

The true population mean is between 84.93989 and 93.38001

The true population standard deviation is between 12.4026852 and 18.5074615

The true population percent defective is between 7.89 and 23.69

Figure 7. Computer Printout From Parallel-Gap Process Capability Study Program

Single-Probe Process Capability Study

(Weights are stated in ounces)

Lower Specification Limit: 85.00000 Upper Specification Limit: 120.00000

Part Number: Single Characteristic Number: Probe

Date: 4300

Sample Size: 50 Mean: 101.06000 Standard Deviation: 6.3129597 Range: 29.00000

Percent Defective Statements:

Number of standard deviations between the mean and the upper specification limit	3.000	QU
Number of standard deviations between the mean and the lower specification limit	2.544	QL
Estimate of the percent defective above the upper specification limit	0.158	PU
Estimate of the percent defective below the lower specification limit	0.563	PL
Estimate of the total percent defective (PU + PL)	0.721	

Normality Statement:

The process is normal.

Skewness -0.38 Kurtosis -0.03

Tolerance Limit Statement:

With 95 percent confidence 99 percent of the population is between 81.32470 and 120.79530

Control Statement:

The process is assumed to be in control.

95 percent Confidence Statements:

The true population mean is between 99.26639 and 120.85361

The true population standard deviation is between 5.2713203 and 7.8659430

The true population percent defective is between 0.16 and 2.92

Figure 8. Computer Printout From Single-Probe Process Capability Study Program

Lead samples were formed at angles of 60, 65, and 80 degrees by use of two different bending tools (FA228124-400 and K2604) with appropriate dies. Five samples from each of the three groups were encapsulated as shown in Figure 9 and sectioned as shown in Figure 10. The lines superimposed on the photograph in Figure 10 define the angle of measurement. The length and the bending-angle measurements of the 15 samples are shown in Table 1.

Although results with both bending tools and all three bending angles were within requirements, those with the FA228124-400 adjustable tool with the 65-degree and 80-degree dies were somewhat better than those with the K2604 tool and 60-degree die. Therefore, the former tool is preferred.

Regardless of the tooling used, it is important that the ends of the leads be sheared upward, thereby ensuring flat contact with the board and avoiding contact of sharp edges upon the land surfaces.

Tinning the leads before forming was tried however, bending could not be accomplished satisfactorily after an adequate amount of solder had been deposited on the leads, and solder flow over the sheared lead ends during reflow soldering was not adequate. Therefore, the final process requires that the leads be formed before tinning.

FLATPACK LEAD TINNING

Application of solder to flatpack leads for reflow soldering is accomplished by dipping the lead ends in liquidus solder. Solder temperature, dipping time and depth, and the number of dips must be controlled for the required amount of solder deposited on the leads.

A flatpack holding tool is used to control the depth of the dip and to prevent excessive transfer of heat to temperature-sensitive elements in the flatpack. The original flatpack holding tool was made of aluminum, with a Teflon coated head where the tool comes into contact with the melted solder. That tool was initially satisfactory; however, the Teflon coating deteriorated after approximately a week of continued production use. The result was an increased tendency for the solder to bridge between the leads. A similar tool made of steel with a high-temperature Teflon-S coating over the head area lasted about two weeks. A third tool made of solid Teflon lasted about two months. The Teflon used to make the solid Teflon tinning tool was heat stressed before machining to reduce the tendency of the Teflon to lose shape and rigidity during use. The latest tinning tool, shown in Figure 11, is in current production use.

Tempilac, a temperature-indicating paint, was used during the tinning experiments to determine the amount of heat conducted to the flatpack seals. Tempilac melts at a point within plus or minus one percent of the temperature at which it is rated, thereby providing a comparatively accurate method of measuring the temperature rise at a given point on a surface.

(Text continued on page 22)

Figure 9. Encapsulation for Sectioning

Figure 10. Encapsulated Flatpack Sectioned for Lead-Forming Check

Table 1. Flatpack Lead-Forming Test Measurements

FA228124-400 Tool - 65° Die (A, C, and S Adjustable)					
Specimen	θ_L (°-')	θ_R (°-')	F_L (in.)	F_R (in.)	C (in.)
1	66° 25'	64° 36'	0.0529	0.0519	0.4599
2	68° 28'	64° 56'	0.0521	0.0608	0.4573
3	68° 10'	68° 15'	0.0516	0.0490	0.4567
4	65° 0'	65° 10'	0.0511	0.0512	0.4613
5	66° 30'	5° 56'	0.0029	0.0118	0.0046
Deviation	3° 10'	5° 56'	0.0029	0.0118	0.0046
FA228124-400 Tool - 80° Die (A, C, and S Adjustable)					
Specimen	θ_L (°-')	θ_R (°-')	F_L (in.)	F_R (in.)	C (in.)
1	78° 38'	79° 0'	0.0580	0.0685	0.4288
2	83° 11'	78° 42'	0.0589	0.0630	0.4355
3	76° 45'	76° 44'	0.0593	0.0633	0.4408
4	76° 51'	79° 9'	0.0602	0.0585	0.4394
5	78° 5'	78° 57'	0.0592	0.0702	0.4339
Deviation	6° 26'	2° 25'	0.0022	0.0117	0.0120
K2604 Tool - K2708 60° Die					
Specimen	θ_L (°-')	θ_R (°-')	F_L (in.)	F_R (in.)	C (in.)
1	56° 2'	54° 58'	0.0538	0.0525	0.4888
2	57° 12'	52° 54'	0.0529	0.0521	0.4889
3	53° 21'	56° 59'	0.0611	0.0534	0.4963
4	60° 15'	57° 41'	0.0502	0.0519	0.4848
5	62° 9'	59° 12'	0.0515	0.0495	0.4832
Deviation	8° 48'	6° 18'	0.0109	0.0039	0.0131

Figure 11. The Teflon Flatpack Lead-Tinning Holder

As measured by the Tempilac method, the temperature at the flatpack seals was well below 300°F when the leads were tinned in the Teflon holder. After dipping the leads three times in molten solder, 250°F Tempilac melted on the leads, but little melting was apparent at the seals. (Almost identical conditions were later encountered when the flatpack was reflow soldered to the board.) After the first dip, the 250°F Tempilac melted to the top edge of the Teflon jaws of the holder, and 200°F Tempilac melted to the seals.

The aluminum and steel holders required longer dipping times to acquire smooth, shiny surfaces; therefore, the temperature at the flatpack seals often exceeded 300°F.

Because of lower seal temperatures, increased tool life, and more convenient operation, the Teflon holder offered distinct advantages over those of aluminum and steel, while maintaining equal or better tinning quality.

Single dipping proved insufficient to remove the gold plating and to deposit an adequate amount of solder for reflow soldering. The coating deposit was dull, as shown in Figure 12. A sweeping lateral movement is to be avoided in dipping the leads because the forward edges of the leads tend to pick up oxidation from the molten solder, even when the solder has been skimmed a short time before dipping. The result is a rough surface and spurs on the leads, as shown in Figure 13.

Experiments with various numbers of dips, dipping and cooling times, fluxing and cleaning procedures, and related process variations, resulted in adoption of the following procedure.

Tinning Procedure

- Form and cut leads.
- Spray clean with solvent (as specified on Production Traveler).
- Apply diluted flux (50/50 ratio, MS4705011 flux/MS4601030 alcohol) with small camel-hair brush to one-half to three-quarters of the lead length.
- Dip three times, vertically, in molten solder, using the Teflon holder and submerging the leads to the holder. (Each dip can vary between one and three seconds in duration, with an equal cooling time between dips.)

Application of flux before each dip produced no improvement in tinning quality; therefore, flux is applied only once -- before the first dip.

(Text continued on page 24)

Figure 12. Single Dipping Produces Dull Finish on Leads and Insufficient Solder Deposit

Figure 13. Lateral Movement in Dipping Produces Spurs on Leads

The solder buildup ranged from 0.004 to 0.012 inch thick on each side of the flat portion of the flatpack leads, and the desired uniformity and shiny surface finish were obtained. An example is shown in Figure 14. The angle formed between the foot and the slope of the leads contained an additional solder buildup which assisted in forming satisfactory fillets when the leads were reflow soldered to the board. That additional buildup is shown in the magnified view of a cross-sectioned encapsulated joint in Figure 15.

SURFACE PREPARATION

Adequate cleaning of printed wiring board surfaces is always a vital consideration in preparing the boards for soldering. Principally because of the use of reflow soldering methods, board cleaning requirements are even more stringent for installation of flatpacks by soldering. Both the leads and the board lands are very small, and the close spacing of adjacent leads requires precise flatpack alignment, critical lead dress, and close control of solder fillets. To ensure free solder flow it is necessary to remove all oil and chemical residue from the board surface. Cleaning operations should be performed immediately before soldering to prevent further collection of foreign matter.

Two different methods of cleaning the boards were compared: the first using Surf-Prep, a product of Claude Michael, Inc. as the cleaning agent; the second a simplified procedure using trichloroethylene. Both cleaning procedures follow.

Surf-Prep Cleaning Procedure

- Solvent clean or vapor degrease in trichloroethylene or perchloroethylene for one to two minutes to remove grease and soil-type contaminants.
- Dry with nitrogen or clean air.
- Immerse in Surf-Prep solder cleaner for one to three minutes at approximately 70°F to remove oxides.
- Water rinse.
- Ultrasonic clean in distilled water for one to two minutes to ensure complete removal of Surf-Prep.
- Rinse in warm distilled water to hasten drying.
- Oven dry for ten minutes at 125°F.
- Package individually in clean plastic bags.

(Text continued on page 27)

Figure 14. Deposit Uniformity and Good Surface Finish Obtained by Multiple Dipping

Figure 15. Magnified Cross-Section of Soldered Flatpack Lead,
Showing Details of Acceptable Solder Fillets

Trichloroethylene Cleaning Procedure

- Spray both sides of the boards thoroughly with trichloroethylene, using a pressure of 45 to 50 psig.
- Dry with nitrogen.
- Package individually in clean plastic bags.

Evaluation Procedures

Sixteen printed wiring boards were selected from various types produced at Bendix during the preceding two years. Because of oxidation, surface contamination, etc, the finish on most of the boards was dull, thus providing very poor surfaces for reflow soldering. Each board was halved and labeled, one half to be cleaned by the Surf-Prep method, the other by the trichloroethylene procedure. There was no visible difference in the appearance of the boards when soldered immediately after cleaning. (Compare Figures 16 and 17.)

Solderability tests were conducted on the boards immediately after cleaning, and again after exposure to humidity and high-temperature storage conditions. Initial solderability was equally good on boards cleaned by either of the two methods. The DAC single-probe reflow soldering process was used in the tests, with the same control settings and the same type of flatpack used in all tests.

After the initial solderability tests, ten of the worst-appearing boards were placed in a controlled humidity chamber at 90 percent rh, and cycled from 77°F to 149°F twice during each 24-hour period for 15 days. A similar dull appearance was evident on all of the boards at the end of that time; however, the boards cleaned with Surf-Prep had a residue buildup around the paths and lands, and green or blue streaks were visible on the metal surfaces. Laboratory tests revealed that the residue buildup was due to incomplete removal of the Surf-Prep during the cleaning process, and that the discoloration was caused by penetration of the Surf-Prep into the metallic paths, thus resulting in a molecular interchange between the Surf-Prep and the metal. The two boards shown in Figure 18 are typical of monochromatic differences in appearance between boards cleaned by the two different methods after exposure to humidity.

Solderability tests on the boards that had been subjected to humidity revealed that the Surf-Prep cleaned boards could not be soldered satisfactorily, whereas those cleaned with trichloroethylene were unaffected by humidity. For that reason, use of Surf-Prep was deleted from the current cleaning procedure.

(Text continued on page 31)

Figure 16. Appearance of Flatpack Leads on Boards Cleaned With Surf-Prep and Soldered Before Storage

Figure 17. Appearance of Flatpack Leads on Boards Cleaned With Trichloroethylene and Soldered Before Storage

Cleaned With
Surf-Prep

Cleaned With
Trichloroethylene

Figure 18. Appearance of Boards After Exposure to Humidity

FLUX APPLICATION

Usual production procedures require that MS4705011 flux be applied to the board lands and flatpack leads with a small camel-hair or sable brush immediately before soldering. Soldering normally follows before the flux dries on the surfaces; hence, the term wet-flux soldering. MS4705011 flux is relatively heavy-bodied and rather tacky; therefore, it is difficult to maintain uniform application--frequently resulting in deposition of a greater amount of flux than is necessary to perform the required function. When heated, the excess flux flows, leaving an unnecessarily large amount of flux residue on the board surface. The excess flux conducts heat away from the joint, thus requiring use of higher probe temperature to obtain satisfactory solder fillets. The additional heat transfer tends to produce delaminations, blisters, or measling on the board surfaces.

A series of single-probe reflow soldering tests was conducted to compare the relative merits of the conventional wet flux to those of the same flux diluted 50/50 with alcohol and allowed to dry before soldering. For convenience, the diluted flux is called 50/50 flux to distinguish it from the undiluted tacky flux.

Typical flatpack connections soldered with each of the flux systems are shown in Figure 19. Although detail in the photographs is somewhat limited, it was easily apparent by visual observation that the boards soldered with 50/50 diluted flux were less measled than those upon which undiluted flux was used. Because of the more uniform application of 50/50 flux, excess flux was avoided; therefore, less cleaning was required after soldering.

DAC CONTROL CALIBRATION

The soldering experiments revealed that the most uniform solder fillets and best joint strengths were obtained with probe temperatures ranging between 600°F and 650°F. Therefore, all of the DAC Limitecs were calibrated for a probe temperature of 625°F with the control set at Position 1. Heat sinks were not used in the initial calibration. Average printed wiring board paths (acting as heat sinks) drop the probe tip temperature about 100°F at the end of a normal soldering operation; however, the tip returns to the calibration temperature very quickly when removed from contact with the joint.

Although a second calibration point at about midscale on the Limitec control would have provided more convenient control of varied soldering operations, such calibration was not possible because of variations of the controls at the many soldering stations. The simple single-point calibration, however, provides a uniform starting point from which settings for a specific soldering operation can be readily determined.

(Text continued on page 33).

Soldered With 50/50 Diluted Flux
(Clean, bright joints, and no measling)

Soldered With Undiluted Flux
(Measling apparent)

Figure 19. Soldering Quality With Diluted Flux Compared to That With Undiluted Flux

FLATPACK SOLDERING PROCEDURE

The experimental work produced a single-probe reflow soldering technique which improved the quality and appearance of flatpack printed wiring boards to a significant degree, and is capable of yielding repeatable results in production soldering operations. However, there are several areas in which continued investigation is expected to produce further improvements.

The Browne Auto Pulse, Model 950 Soldering System, which employs a timed (0.20 to 3.5 sec) pulse method of probe heating (rather than the cut-off principle of the DAC system) is being evaluated. The Browne equipment (shown in Figure 20) does not require a thermocouple in the probe. That equipment permits application of heat to be programmed for a specific soldering requirement, thereby eliminating the need for a temperature-sensing device. When properly programmed, the probe temperature remains essentially the same throughout the soldering operation.

Initial experiments with the Browne system indicated that use of that equipment will increase production, maintain equal or better joint strength and fillet uniformity, reduce rework, and less maintenance will be required. The probe used with the Browne equipment is smaller than that used with the DAC system; therefore, it should be more suitable for use on closely spaced flatpack leads and dense boards.

The DAC soldering procedure which was developed during this investigation is controlled by Flatpack Soldering Specification 9913008 and has been adopted for current production use pending the outcome of the Browne system evaluation.

The current DAC soldering procedure is listed below.

- Form flatpack leads on forming fixture.
- Clean flatpack leads with solvent spray.
- Tin flatpack leads, using a Teflon holder.
- Clean leads and boards with solvent spray.
- Apply diluted flux to leads and board lands.
- Solder the flatpack to the printed wiring board.
- Clean the entire assembly with solvent spray.

Figure 20. The Browne Auto Pulse Soldering System

The DAC soldering system is now producing high quality flatpack printed wiring board assemblies at production rates appreciably higher than was previously possible, and rework has been substantially reduced. An example of the quality of soldering obtained by the present DAC single probe system is shown in Figure 21.

Figure 21. Example of Present Soldering Quality

OTHER PLANNED WORK

Continued investigation will include evaluation of solder preforms and other flux formulations, with special interest in establishment of more uniform soldering schedules.

The initial work indicated that a fixed control setting can be established for flatpack soldering; however, schedules for soldering discrete components may require considerable alteration, depending upon the nature of the components and the boards.

Other printed wiring board cleaning methods will be evaluated, with emphasis upon cleaning the boards in the flatpack reflow soldering area immediately before installing the flatpacks. One prospective method is a scrubber-dryer machine which is to be evaluated.

Although use of Surf-Prep was discontinued on the current cleaning procedure because of discoloration resulting from storage under high relative humidity conditions, it has not been eliminated from consideration for future use. Because of the desirable attributes of the cleaner, research is continuing. It appears possible that more complete removal of the Surf-Prep during the cleaning process may eliminate the residue and discoloration problems, and that good solderability may be assured.

Section 5

OPERATOR QUALIFICATION

Audio-visual aids were designed and a training program was initiated to ensure a sufficient number of qualified operators to man the flatpack reflow soldering stations. During the initial phases of training, the prospective operators are taught the fundamentals of flatpack reflow soldering: precautions necessary to avoid heat damage to heat-sensitive components and boards during tinning and soldering; handling to avoid surface contamination; equipment adjustment and use; and correct reflow soldering techniques. Later phases of the training program include lead forming; tinning; flatpack lead and printed wiring board cleaning; and correct procedures for initial flatpack installation, reheating, and replacement. The training in equipment operation includes control settings, probe maintenance, and verification of joint quality.

Satisfactory completion of the training program requires that each operator demonstrate proficiency in all phases of flatpack reflow soldering and reworking procedures to the requirements of Flatpack Soldering Specification 9913008 and Visual Aid to Inspection SS230039.

After completion of the training program, operator skills are maintained by supervisory surveillance and access to an audio-visual station in the production area. Audio-visual programs are promptly up-dated to reflect any change in the reflow soldering process.

Section 6

DESTRUCTIVE TESTING

Flatpack lead forming and soldering are the two principal functions that must be monitored for repeatable results. Neither can be checked satisfactorily by nondestructive methods. The forming fixtures and dies must be monitored at intervals to ensure that proper lead dimensions and configuration are obtained without damage to the flatpack cases, leads, or seals. Results from each soldering station must be checked to ensure required joint pull strength (four pounds or greater) and uniformity of soldering at the various stations.

Destructive tests are normally conducted at three-month intervals to verify the performance of the lead forming tools and dies used in continuous production. Such tests are also required on new fixtures and dies, and each time lead length or bending angle is changed.

Lead forming destructive tests require two representative flatpacks formed with each fixture. Each flatpack is encapsulated and sectioned, as previously shown in Figures 9 and 10. A photomicrograph at 20-times magnification of a lead on each side of the flatpack is carefully examined for lead dimensions, bend angle, and strain marks in the leads, case, and seals.

Tests to determine soldering uniformity at the various stations require inspection of ten 60-degree formed leads soldered at each station. Each lead is photographed at 20-times magnification and examined for desired solder fillets, surface smoothness, and freedom from visible flaws. After visual inspection, each lead is pull tested at 60 degrees for a minimum pull strength of four pounds. Routine tests are performed at intervals of approximately three months during continuous production. Additional tests are required each time the soldering equipment is altered, and when the probe and thermocouple are replaced.

Section 7

CONCLUSIONS

Since some phases of the work have not been completed, factors which are contingent upon further work are not known. However, the work that has been performed and the present status of the DAC reflow soldering procedure, which is now in production use, substantiate the following conclusions.

- The DAC single probe soldering process is superior to the previous parallel probe method in these respects:

Production rates are increased;

Solder fillets are more uniform;

Cleaning is reduced;

Flatpacks and boards are less subject to heat damage; and

Rework is significantly reduced.

- Diluted flux (MS4705011 flux, diluted 50/50 with alcohol, and allowed to dry before soldering) is superior to the same flux in undiluted form.
- Success attained in the operator qualification program resulted in increased production rates, improved product quality, reduced rework, and availability of a sufficient number of qualified operators to man the reflow soldering stations.
- Results of initial experiments with the Browne timed-pulse heating system were encouraging, though not conclusive, thus indicating that further reflow soldering improvements may be attained by use of that equipment.
- Although use of Surf-Prep was discontinued in the present cleaning procedure because of surface discoloration and poor solderability resulting from extended exposure to high relative humidity, new cleaning methods that are being considered may again enable Surf-Prep to be used.

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