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Electronic Manufacturing Process Improvement (EMPI) For Printed Wiring Assemblies

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For Period August 1990 - December 1991

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13. ABSTRACT

This Final Technical Report is comprised of six basic sections. The first section is an overall description of the objectives and goals of the Electronic Manufacturing Process Improvement (EMPI) for Printed Wiring Assemblies (PWAs) Program. Included is a description of the PWA design, continuous process improvement, and the basic seven experiment approach. The second section is a summary of the results achieved during the performance of the contract.

Section 3 presents the activities performed and the results obtained during the interval between Technical Report Task No. 3 and the end of the program. Section 4 identifies the priorities of the tasks TRW will perform as indicated by the results achieved during this program. These tasks will be run by reentering the continuous process improvement cycle. Section 5 presents a list of lessons learned as a result of experience gained while performing the experiments designed for this program.

Appendix A, B, C, and D to this report contain the detailed experimental plans for two single point experiments (solder paste placement and component placement), a final, full factorial experiment, and a final confirmation run.

14. SUBJECT TERMS

Printed Wiring Assemblies (PWAs), Electronic Manufacturing Process Improvement (EMPI), Fine Pitch Device (FPD), Lean Tinning, Lead Forming, Design of Experiments (DOE), Continuous Process Improvement (CPI), LCC.

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1. SUMMARY

As reported in Technical Report Task No. 1 to this program, yield and process capability indices were reported for seven basic processes used in the assembly of surface mount printed wiring designs. These results were developed as a result of intrastation experiments that were run prior to the award of this EMPI program. The seven processes are LCC component standoff, solder paste deposit, FPD lead forming, FPD lead tinning, component placement, infrared reflow, and PWA cleaning. First, pass yield was calculated by taking the product of infrared reflow yield and the PWA cleaning yield. The response variables of these two processes are those used in the final PWA inspection process and include:

- Visual cleanliness
- Ionic cleanliness
- Solder joint appearance (shiny/dull/dewet)
- Solder joint quantity (excessive/insufficient)
- Component registration (component lead to footprint pad alignment).

Five of the seven EMPI experiments comprised the initial run of this program. These experiments are:

- Solder paste placement
- Component placement
- LCC component standoff
- FPD lead tinning
- FPD lead forming.

Where possible, process variable factor levels that optimized response variable centering and reduced response variable variability were incorporated in the experiments run in the "First Improvement" cycle. Using the infrared reflow and PWA yields at this "first improvement" cycle, the estimate first pass yield is shown to be zero. This zero yield was found to be due to solder paste placement problems and FPD component placement problems that manifested themselves in the initial run and were not improved in the infrared reflow experiment of the "first improvement" column.

As a result of non-contract studies, the component placement problems were found to be due to the illumination characteristics of the robotic placement cell and the vision recognition algorithm used by the robotic placement cell. The solder paste placement problems were found to be due to a lead-screw backlash condition found on the stencil printer and to oversize apertures on the stencil itself. Identification of the component and solder placement problems was achieved by performing two single-point experiments. Yields for these two experiments were found to be essentially 100 percent.

Incorporation of these improvements into the "Final PWA Run" experiment resulted in a first pass yield of 73 percent.

A confirmation run was designed to determine what the first pass yield would be on a set of eight PWAs using the seven assembly processes incorporating the optimum process variable levels identified to that point. First pass yield achieved 95 percent.

2. INTRODUCTION

Our final technical operating report is comprised of 7 sections and Appendices A, B, C, and D.

- Section 1: Provides a summary of the results achieved during the performance of the contract.
- Section 2: Introduction to the volume and our approach to the Electronic Manufacturing Process Improvement (EMPI) for printed wiring assemblies (PWAs) program. Figure 1 provides a flow of the continuous process improvement cycle involved.
- Section 3: Printed wiring board design.
- Section 4: A five-step approach that describes five subtasks involving seven total experiments requiring the application of the DOE methodology.
- Section 5: Experimental details are provided showing process variables, location effects, probability plots, single-point FPD placement, solder paste placement, and confirmation run.
- Section 6: Identifies potential process variables to explore and additional experiments to increase process capability of FPD registration.
- Section 7: Presents a list of lessons learned as a result of experience gained in performing the experiments designed for this program.
- Appendices A, B, C, D: Details experimental plans for two single-point experiments (solder paste placement and component placement), a final factional experiment, and a final confirmation run.

TRW's goal in performing the Electronic Manufacturing Process Improvement (EMPI) project is to identify, quantify (through process capability indices), and optimize significant process variables used in the surface mount printed wiring assembly of military avionics hardware. The resulting improvements in the processes, and the methodologies used to achieve these improvements, will directly benefit TRW MEAD. In addition, through an Industry Days presentation, the methodologies and improvements realized through the application of DOE and continuous process improvement (CPI) will be offered to industry in general.

Covered by this study are five subtasks: (1) infrared reflow of printed wiring assemblies (PWAs); (2) fine pitch device (FPD) lead tinning; (3) cleaning (which includes a component standoff experiment and a solvent cleaning experiment); (4) FPD lead forming; and (5) placement (which includes a solder paste placement experiment and a component placement experiment).

Figure 2 presents a roadmap – yield summary of the initial run, first and second improvements cycles, and the final results for the seven basic assembly processes; the first pass yield achieved 95 percent.

Table 1 (Program Goals/Results/First Pass Yield) breaks the yield data away from the testing roadmap and introduces the goals that were established at the beginning of the program. Table 2 (Yield/Cpk Improvement) associates process capability indices (Cpk) with the yield data for the seven processes used in the second improvement run and the overall actual first pass yield in the confirmation run.

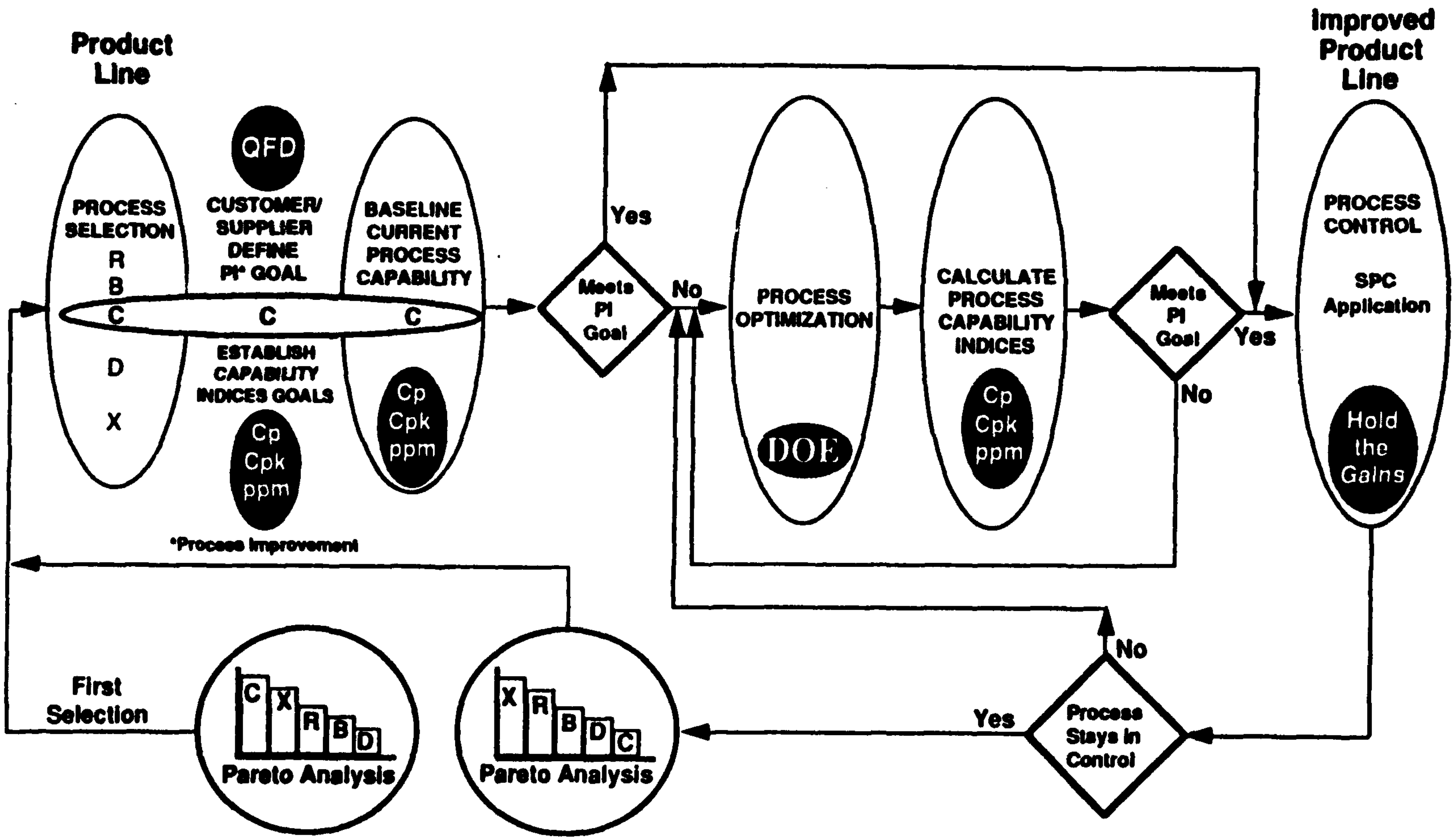


Figure 1. Continuous Process Improvement Cycle

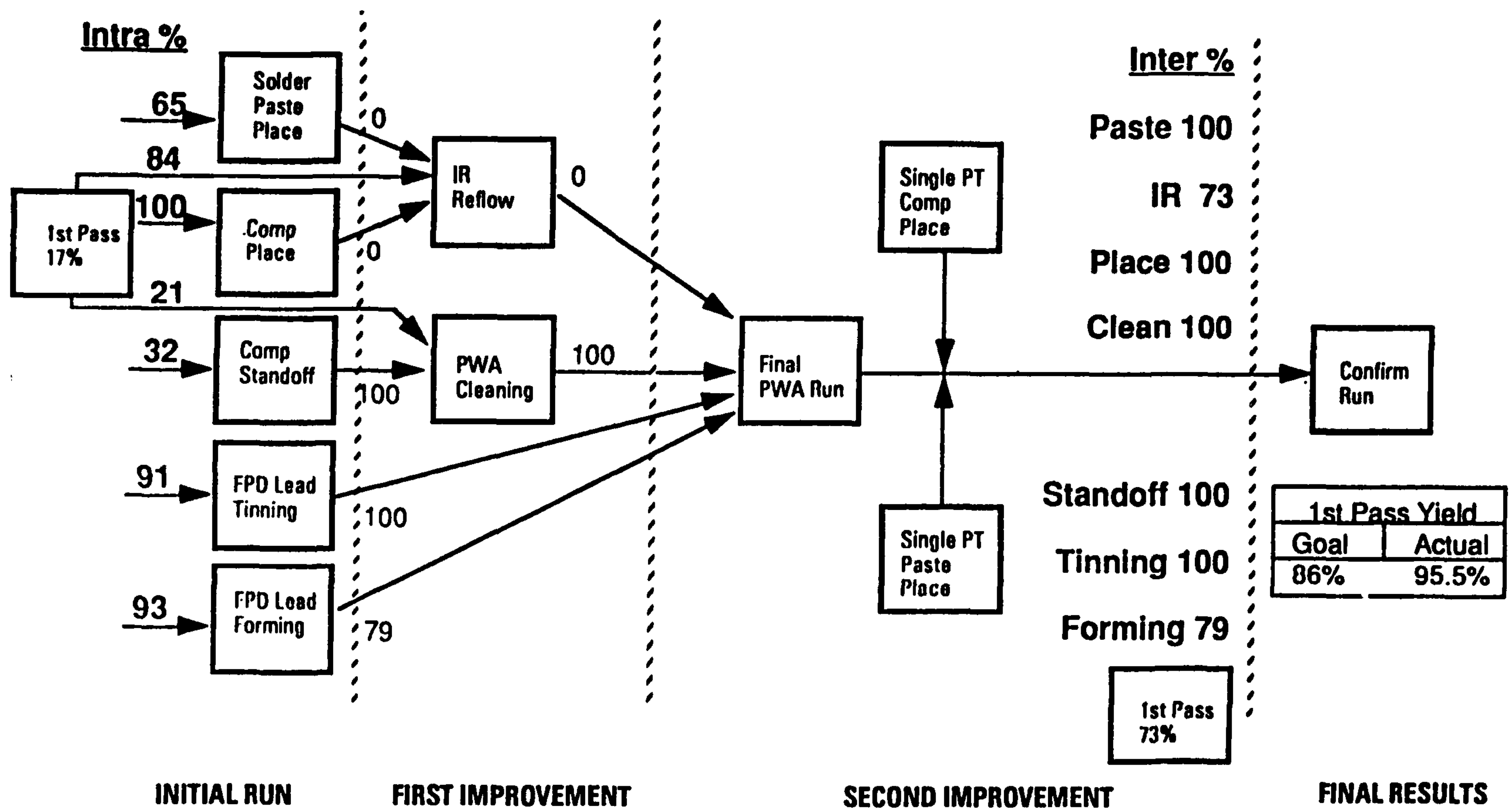


Figure 2. Roadmap – Yield Summary

Table 1. Program Goals/Results (First Pass Yield)

Workcells	Intra Baseline (%)	Inter Goal (%)	2nd Improvement Results (%)	Inter Results
Dry film standoff application	32	98	100	
Solder paste, registration	65	85	100	
Leaded component forming	93	95	79	Confirmation Run
Leaded component tinning	91	98	100	
Component placement	100	90	100	
Reflow	84	90	73	
Cleaning	21	95	100	
Overall first pass yield	**17**	**86**	**73**	**95.5**

Table 2. Yield/Cpk Improvement

Workcells	Intra Baseline Yield %	Intra Baseline Cpk	Inter 2nd Improvement Results Yield %	Inter 2nd Improvement Results Cpk	Inter Confirmation Results Yield %	Inter Confirmation Results Cpk
Dry film standoff application	32	-0.15	100	1.62		
Solder paste	65	0.31	100	0.9		
Leaded component forming	93	0.60	79	0.42		
Leaded component tinning	91	0.57	100	4.6		
Component placement	100	3.07	100	1.34		
Reflow	84	0.48	73	0.37		
Cleaning	21	-0.27	100	2.38		
Overall Results	**17.6**	**0.07**	**73.0**	**0.37**	**95.5**	**0.67**

Processing improvements as a function of time are presented in Table 3 (Cycle Time Goals/Results BD (100 Bd Lot). These cycle time improvements are based on the reduction in rework due to the increase in first time process yield.

Finally, cost improvements achieved as a result of implementing optimized process variable factor levels are presented in Table 4 (Summary Cost Improvements - 100 Bd Lot). The cost improvement of 27 percent is based on labor sa· ings due to reduction in rework time and scrapped parts cost.

This project has included all of the potentially significant process variables that are controlled and determined outside of the workstation in which the specific experiment is being run (interstation variables). These include significant process and equipment variables that are not monitored or controlled at the workstation being used in the specific experiment. These variables may still contribute directly to that workstation's yield. An example of an interstation variable would be the PWB thickness which is controlled by the PWB fabricator, according to TRW MEAD engineering drawing requirements. This variable influences the reflow process yield by introducing variations in the heat required to reflow the PWA due to variation in the mass of the PWB.

The value of the EMPI for the PWA program cannot be reported without a cost-benefits analysis. The model for this analysis was developed as well as a goal for the cost benefit for the program and presented in the Task 3 Report. The final results are summarized in Section 1.

Table 3. Cycle Time Goals/Results/BD (100 Bd Lot)

Workcells	Intra Yield %	Baseline/mins	Goal/mins	Inter Yield%	Results/mins
Standoffs	32	29.0	0	100	0
Solder paste	65	11.5	5.2	100	1.1
FDP lead forming	93	19.3	19.0	79	23
FDP lead tinning	91	9.8	9.3	100	9.1
Component placement	100	13.1	15.3	100	13.1
Reflow	84	39.2	36.5	73	44.5
Cleaning	21	22.8	12.0	100	7.0
Total		**144.7**	**97.3**		**97.8**
Overall cycle time improvements			33%		32%

Table 4. Summary Cost Improvements (100 Bd Lot)

Process	Intra Yield %	Intra Cost ($)	Inter Yield%	Inter Cost ($)
Standoff	32	2387	100	300
Solder	65	439	100	439
Forming	93	1264	79	1412
Tinning	91	6 38	100	591
Placement	100	852	100	852
Reflow	84	2978	73	3299
Clean	21	1482	100	455
		10,040		**7351**

Cost Improvement 27%

3. PRINTED WIRING ASSEMBLY DESIGN

3.1 PRINTED WIRING BOARD DESIGN

A Standard Electronic Module (SEM), Format E size was selected for this EMPI study. This format, approximately 5.6 inch by 5.2 inch, has become a standard for electronic modules currently being developed for Air Force integrated avionics applications. Polyimide glass with 1/2-oz/ft^2 copper foil outer layers and two inner layers of 2-oz/ft^2 copper foil were used in the construction of the PWB. The mass of copper selected simulates the thermal characteristics of copper-Invar-copper, constraining layers, without imposing the cost penalty associated with it.

The footprint patterns used for several components associated with this design were taken from TRW MEAD's design standards. Vias, power and ground connections, and power/ground layer clearances were provided for component pins; however, no circuit interconnections were provided. These interconnections are not considered to be relevant to any of the studies being performed. The power and ground pin connections are significant because of the different thermal affect they have on solder joint formation compared to the affect of component pads that are not heat-sinked to internal power/ground planes.

Different PWB styles were fabricated in order to determine the affects these styles would have on the PWA assembly process. These styles are discussed in some detail in the second technical report for this program. Essentially these different styles were associated with the thickness, plated finish, component standoff, and "stretch" of the PWB. The complete documentation package for several PWBs were presented in the second technical report for the program.

3.2 COMPONENT SELECTION

The selection and placement of components on the PWB was made after first considering the different types of components that would be expected on a "typical" TRW MEAD avionics SEM-E design. Their locations on the PWB were chosen to provide the most beneficial experimental data for this EMPI program. Figure 3, EMPI PWA Layout, depicts these locations. A parts list was presented in the second technical report for this program.

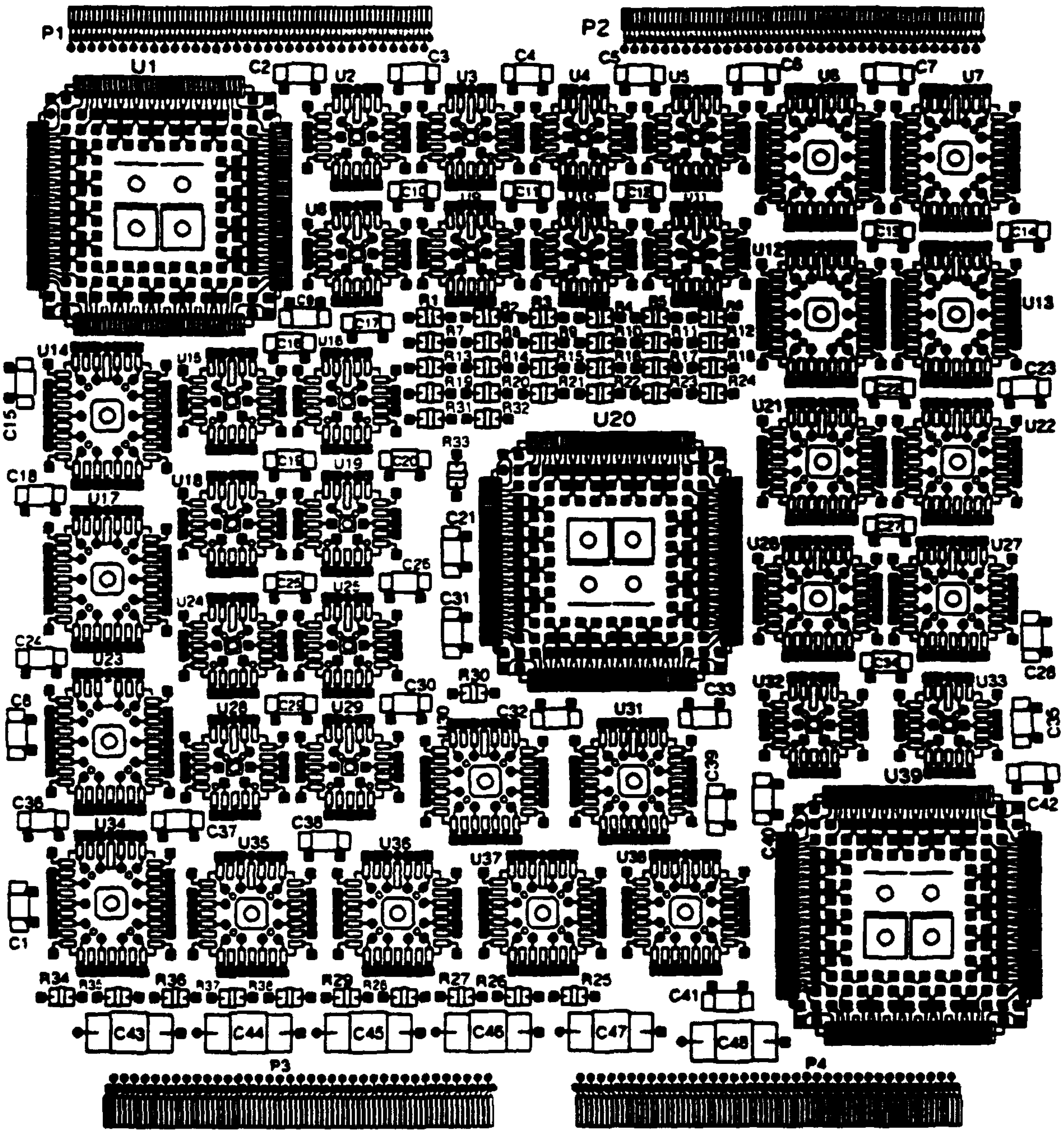


Figure 3. EMPI PWA Layout

4. CONTINUOUS PROCESS IMPROVEMENT

The goal of this EMPI for Printed Wiring Assemblies program is to understand and quantify the process variables that have significant affects on process responses that are critical to the manufacture of military avionics printed wiring assemblies. The measures of this are the process capability indices known as Cp and Cpk. Cp is an index that measures the variation in a process. Cpk is an index that measures how well a process fits within a required process "window." Experiments are designed around the PWB assembly processes in order to arrive at values for these process capability indices. For this program there are five subtasks that involve a total of seven experiments. Each of the experiments requires the application of the DOE methodology. This experimental design process methodology consists of five basic steps that are described as follows:

4.1 STEP 1

The first step is to identify the process flow to be studied. This was done as a part of the Task 1 baseline phase of the program and is presented here as Figure 4, EMPI Process Flow Diagram. The identified workcells are the "core" of the PWB assembly process at TRW MEAD. The subtasks outlined by the heavier weighted lines are those intercell processes being investigated by this program.

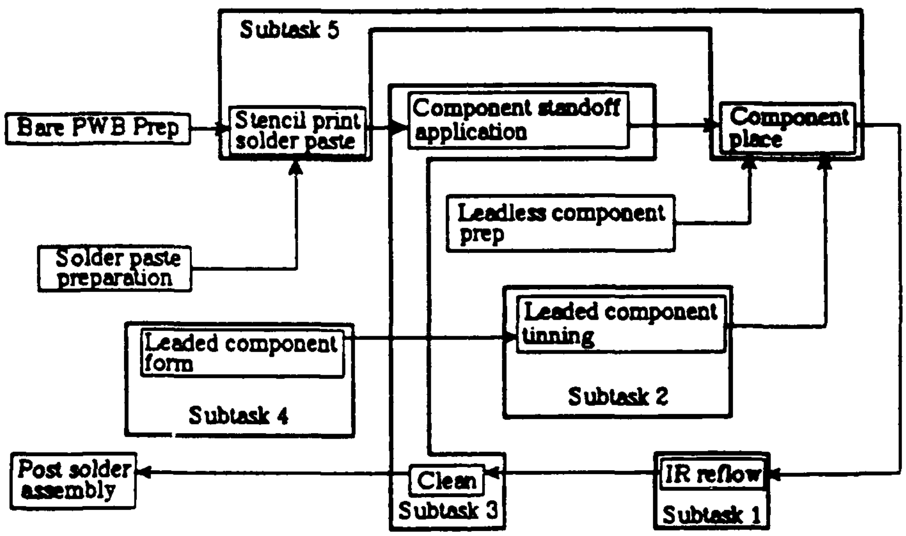


Figure 4. EMPI Process Flow Diagram

4.2 STEP 2

The second step in the process identifies critical process responses or outputs, and all suspected process variables or inputs that influence the responses. This was accomplished at a brainstorming session attended by process and manufacturing engineers and technicians that were familiar with the assembly process and equipment. The output of this step was a "cause and effect" diagram for each of the seven experiments and were the foundations of the designs for those experiments. These "cause and effect" diagrams are presented in each of the detailed experimental plans which can be found in Appendix C to this report.

4.3 STEP 3

The third step in the process quantifies the process and response variable requirements and establishes the measurement method used to collect the data for the experiments. The requirements for the process and response variables have been taken, for the most part, from the frequently imposed contractual requirement, MIL-STD-2000. Since this EMPI program was begun in August of 1990, this standard has been revised to level "A," and many of the original requirements have been deleted. Where MIL-STD-2000 had no applicability to the manufacturing process, internal process specifications and workmanship standards were used.

During this step of the DOE process, measurement techniques used to collect the data are developed and identified. The goal is to maintain an order of magnitude margin between the data and the measurement precision. For example, if a response is expected to have a measured value of 4 mils, the precision of the measurement needs to be 0.4 mils, minimum. This goal may not be achievable in all instances. An example is where a property, such as roughness, is compared against a visual standard and ranked from 1 to 5. Special care in interpreting the results under these circumstances is advised.

It is important that a consensus is reached regarding the details of each experiment because, once an experiment has been finalized and started, no changes should be incorporated.

4.4 STEP 4

The fourth step in the process establishes the relationships between the process variables and responses for each experiment to be performed. This is an important step in the DOE process. It identifies the recipe" for each run of each experiment. This relationship is determined by establishing a process and response variable matrix. It is at this point that selection of the type of experimental design is determined. Where three or fewer process variables are being examined, the selection of a full factorial design is warranted, because the number of experimental runs is not prohibitive. Where more than three, but less than eight, process variables are chosen, a fractional factorial experimental design is considered.

The assumptions that are made for the fractional design are that there are no interaction effects among the process variables and that the effects of the process variables on the response are linear. These assumptions must and can be tested for the fractional factorial designs by running a reflected (or folded design which identifies interactions if they exist. Since the goal of the experiment is to detect linear changes in a response due to changes in a particular process variable, the experimental designs are based on a two-level process variable scheme. The detailed experimental matrix can be represented by a classic "1-2" matrix with the response to be observed and the process variables to be exercised heading the columns with the experiment run numbers leading the rows. This matrix gives the exact recipe for each experimental run. An excellent reference for this experimental design methodology may be found in "Designing for Quality" by Robert Lochner and Joseph Matar, ASQC Quality Press. See Figure 5 for an example of an eight run experimental matrix.

Full factorial designs should be replicate at least once to enable the variability of the response variables and the experimental error to be established. It is this response variable variability that is issued to determine the process capability index for the process being measured.

Fractional factorial designs require that a reflected experiment be run in additional to a replicated run. This is due to the fact that process variables are assigned to columns in the matrix that would normally be assigned to collect interaction effects. Any significant effects associated with these columns must be identified as due to interactions or due to the interloping process variable. If neither direct or interactive effects are noted, the data in these columns may be used to measure experimental error. This error will give an experimenter an indication whether or not a significant process variable has been overlooked.

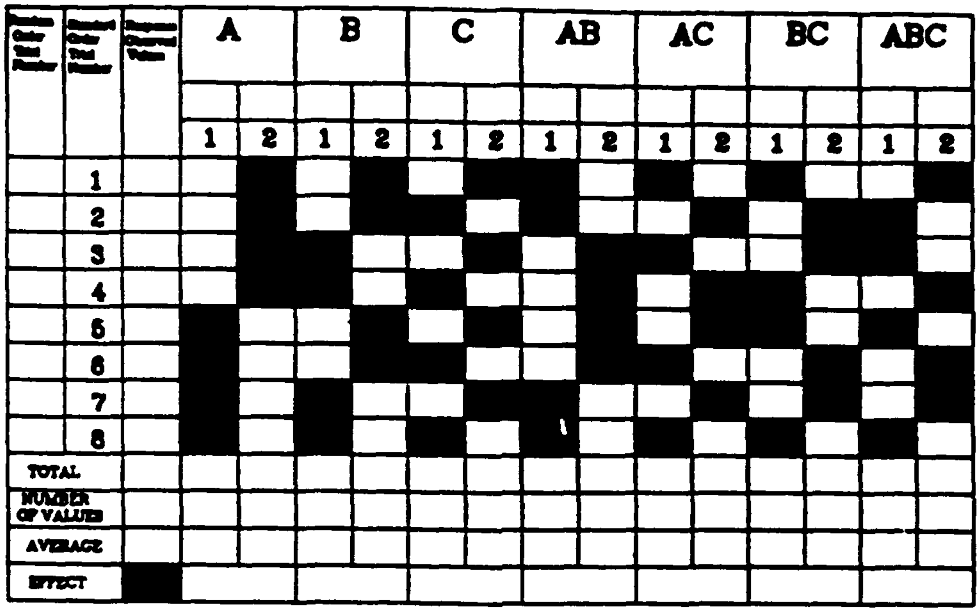


Figure 5. Eight Run, Two-Level Experimental Matrix Response

The data which is gathered from the experiment is subjected to an analysis of variance (ANOVA) which is described in Task 3 Report, Section 2.

4.5 STEP 5

The fifth and final step in this process implements the results obtained. Process variables that need to be improved, as determined by the analysis of the experimental data, will be implemented, as indicated, and verified by additional experimentation. The process variables that are identified as being required to be brought under control will be brought under control. The limits of that control will also come from the analysis of the experimental data.

Many of the process variable limits that are equipment related are monitored in a closed loop fashion by the equipment. This lends itself to automated tracking and reporting since the process variable data can be systematically processed by an automated shop floor management system. Other process variables need to be manually tracked and entered into the shop floor management system.

The Total Quality Management (TQM) methodology implemented by this EMPI program implies that there is a never ending process improvement cycle in place. Data is provided by the implementation of DOE to indicate where improvement can best be made, and advantage must be taken of that information constantly if TQM is to be meaningful.

5. DESCRIPTION OF EXPERIMENTS

The finalized versions of the original seven experiments are presented in Appendices B through F to Technical Report Task No. 3. These experiments are Subtask 1, Infrared Reflow; Subtask 2, Fine Pitch Device Lead Tinning; Subtask 3, Experiment 1, Component Standoff; Subtask 3, Experiment 2, Printed Wiring Assembly Cleaning; Subtask 4, Fine Pitch Device Lead Forming; Subtask 5, Experiment 1, Solder Paste Deposit Placement; and Subtask 5, Experiment 2, Component Placement.

As previously mentioned, two single-point experiments (solder paste and component placement), one full factorial experiment (final run), and a confirmation experiment were run.

5.1 EXPERIMENTAL DETAILS

Subsequent to the release of Technical Report Task No. 3 for this program, one full factorial and two single-point experiments were run. These were followed by a confirmation run that was designed to give an indication of the first pass yield that would be achieved by incorporating those levels of process variable factors that optimized response variable centering and reduced response variable variability. (See Tables 23a through 23g.) The selection of these process variable factor levels often required an engineering tradeoff. The selection of a solder paste to be used required a selection between a product whose material gave better appearing solder joints, yet was very difficult to apply and a product that was very easy to apply, yet gave slightly poorer appearing solder joints.

Similarly, a selection had to be made between two dry film solder mask materials, each of which performed well but were not available in comparable thicknesses. One solder mask came in a 4.5–mil thickness, while another came in a 4.0-mil thickness. In this case, the material selection was purely arbitrary.

In some instances, the selection of factor levels were intuitively obvious, but the experiments verified this intuition and assigned a number to the improvement. The process variables that fall into this category are solder aging, lead aging, paste powder aging, lag time between soldering and cleaning, and lead skew. In this case, it seems obvious that no aging or lead skew is desirable; however, no aging or lead skew is impossible to achieve.

5.1.1 Final Experiment

The final experiment was intended to determine the process capability for many response variables where process variable factor levels were optimized. Only three process variables were tested. These variables were PWB plating style (fused and hot air leveled), LCC standoff height (4 and 6 mils), and solder paste vendor (Metech and Multicore).

Figure 6 presents the cause and effect diagram for this experiment. Tables 5 and 6 present the process variables and their levels and the response variables and their specification limits, respectively. The detailed experimental plan for this full-factorial experiment is presented in Appendix A to this Final Report. This experimental matrix for this design is presented in Figure 7.

The magnitude of the effect that each process variable has an applicable response variables in presented in Table 7. Associated normal probability plots are presented in Figures 8 through 13. The variability effects were determined by an analysis of variance of data obtained from two replicate runs. The results are presented in Tables 8 through 13.

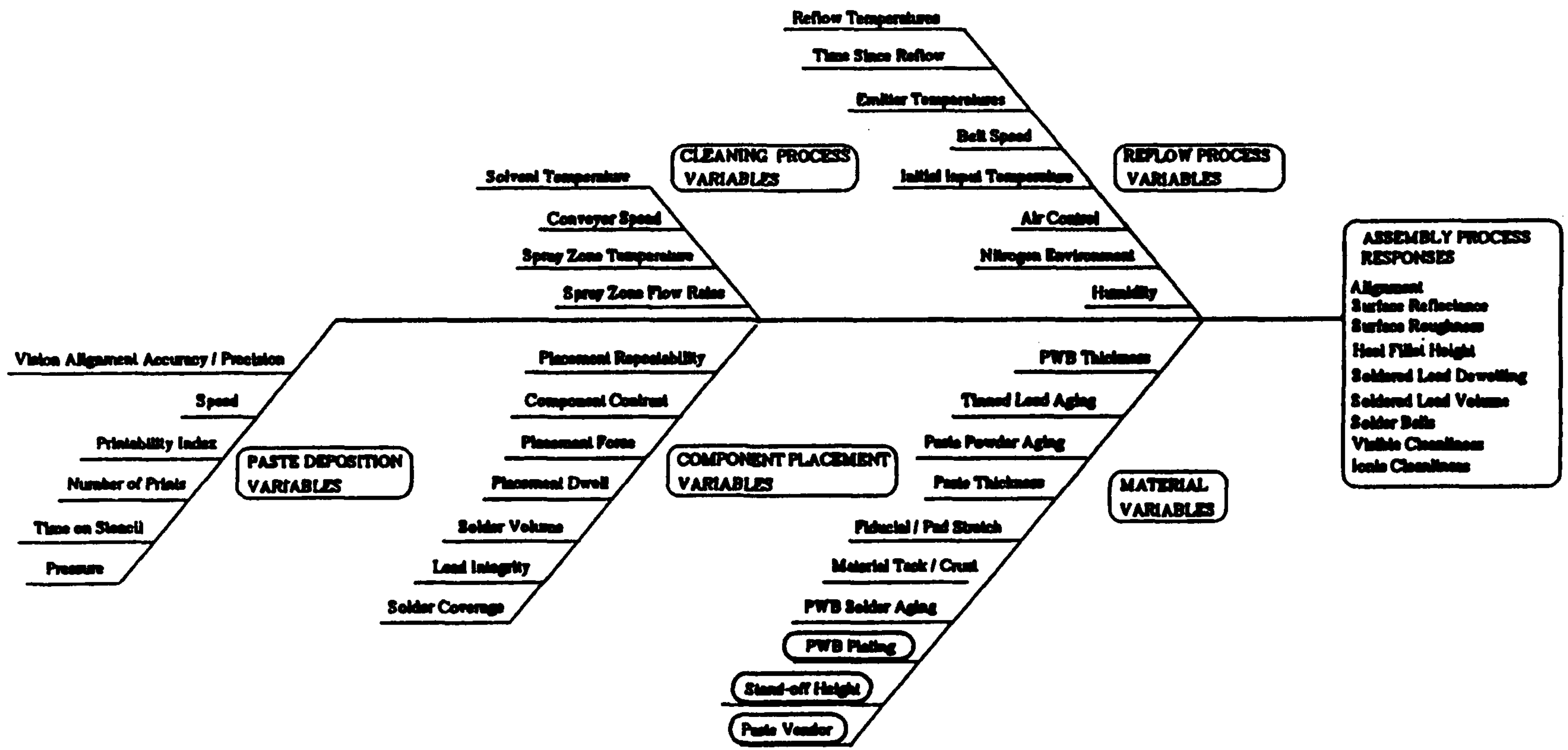


Figure 6. Final Experiment - Cause and Effect Diagram

Table 5. Final Experiment Process Variables

Process Variable	Variable Level
Standoff height	4 to 6 mils
PWB style	Hot air leveled to tin-lead plate and fuse
Solder paste vendor	Metech to Multicore

Table 6. Final Experimental Response Variables

Response Variable	Specification Limit
Visual cleanliness	1 to 5 units
Ionic cleanliness	0 to 10 μgm of Na Cl/sq.in.
Solder joint roughness	1 to 5 units (visual comparison)
Solder joint reflectance	1 to 5 units (visual comparison)
Heel fillet height	0 to 100% of calf
Soldered lead dewetting	0 to 5% of soldered area

Random Order Trial Number	Standard Order Trial Number	PWB Serial Number	A: Standoff Height mils		B: PWB Style		C: Solder Paste Vendor		AB: INTERACTION AND ERROR TERMS		AC		BC		ABC		RESPONSE
			1	2	1	2	1	2	1	2	1	2	1	2	1	2	
16	1	3001	4		air		Metech										
7	2	3002	4		air			Multi									
15	3	3006	4			fused	Metech										
13	4	3007	4			fused		Multi									
12	5	3011		6	air		Metech										
14	6	3012		6	air			Multi									
6	7	3016		6		fused	Metech										
2	8	3017		6		fused		Multi									

Figure 7. Final Experiment – Experimental Matrix

Table 7. Final Experiment - Location Effects

	Process Variables						
	A	B	C				
	Standoff Height	PWB Style	Solder Paste Vendor	AB	AC	BC	ABC
Response Variables	4 to 6	Hal-Fuse	Met-Multi	Interaction and Error			
LCC lead-to-pad registration	1.24	-0.71	0.31	-0.26	0.51	0.76	0.11
LCC solder joint reflectance	-0.05	-0.29	1.252	-0.04	0.05	-0.12	-0.14
FPD solder joint reflectance	0.32	-0.01	0.49	0.21	0.21	0.04	-0.24
LCC solder joint roughness	0.01	-0.18	1.53	-0.13	-0.13	-0.18	-0.11
FPD solder joint roughness	0.06	0.26	0.15	-0.02	-0.06	0.24	0.02
PWA visual cleanliness	-0.75	0.00	1.75	0.00	-1.25	-0.5	-0.5

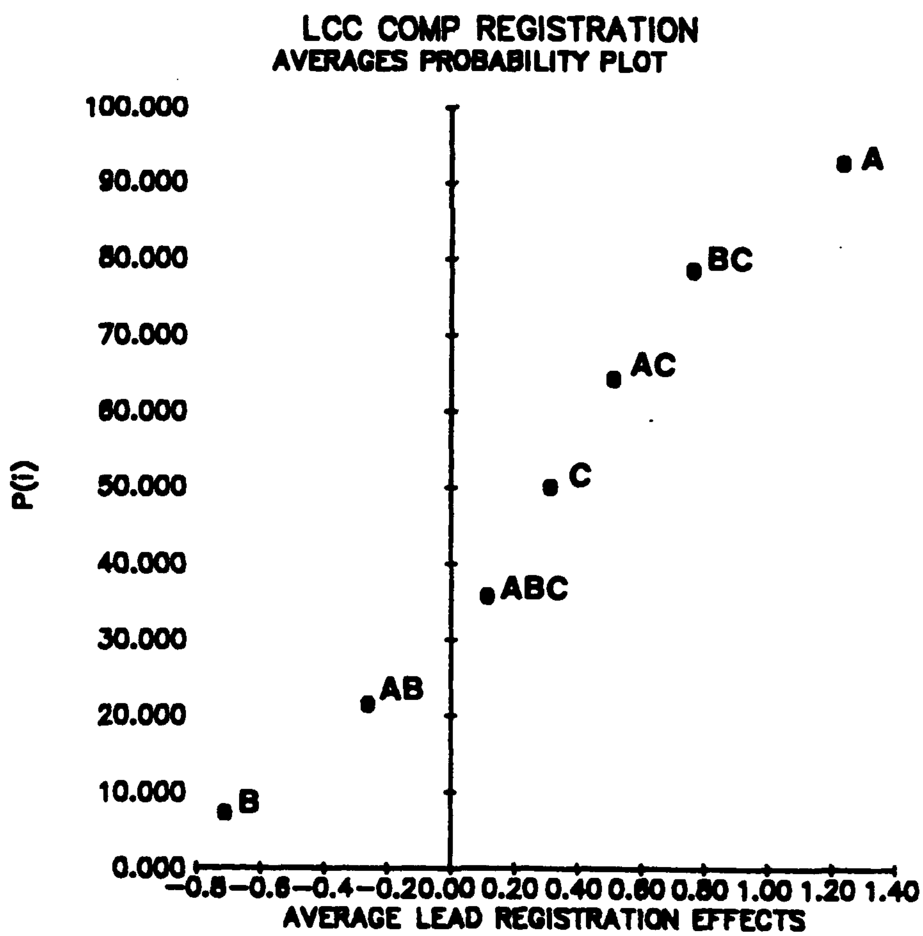


Figure 8. Final Experiment – Normal Probability Plot (LCC Comp Registration)

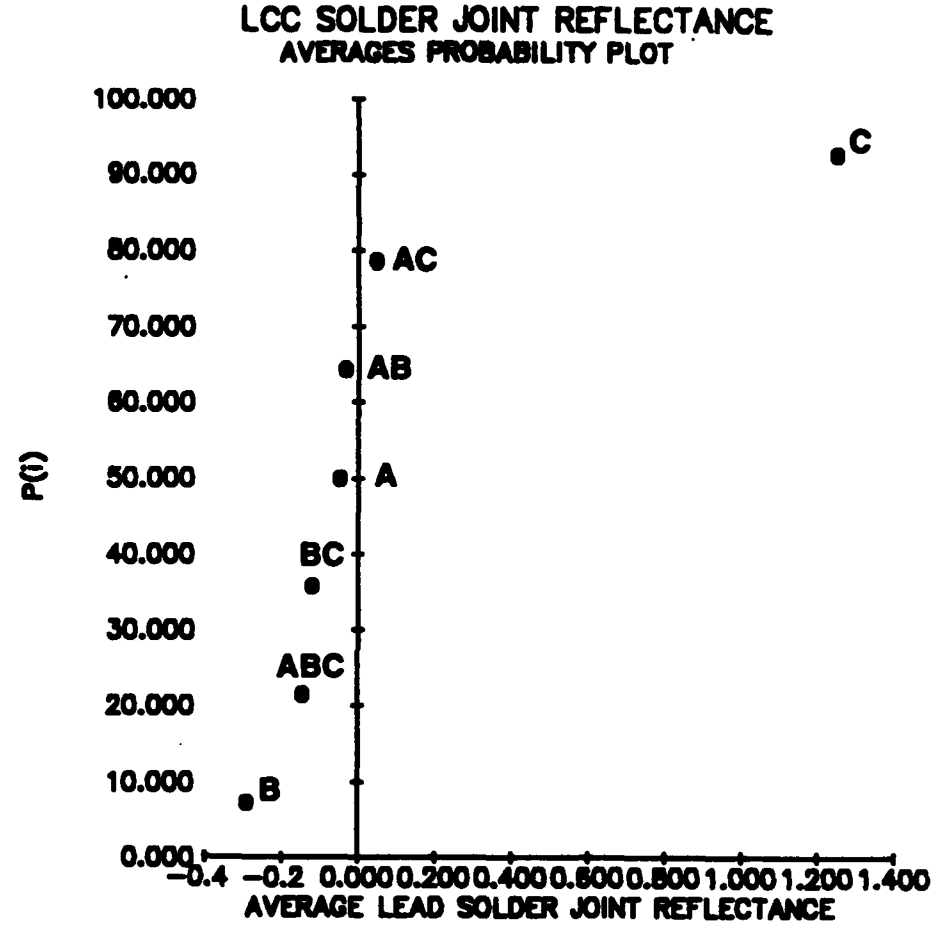


Figure 9. Final Experiment - Normal Probability Plot (LCC Solder Joint Reflectance)

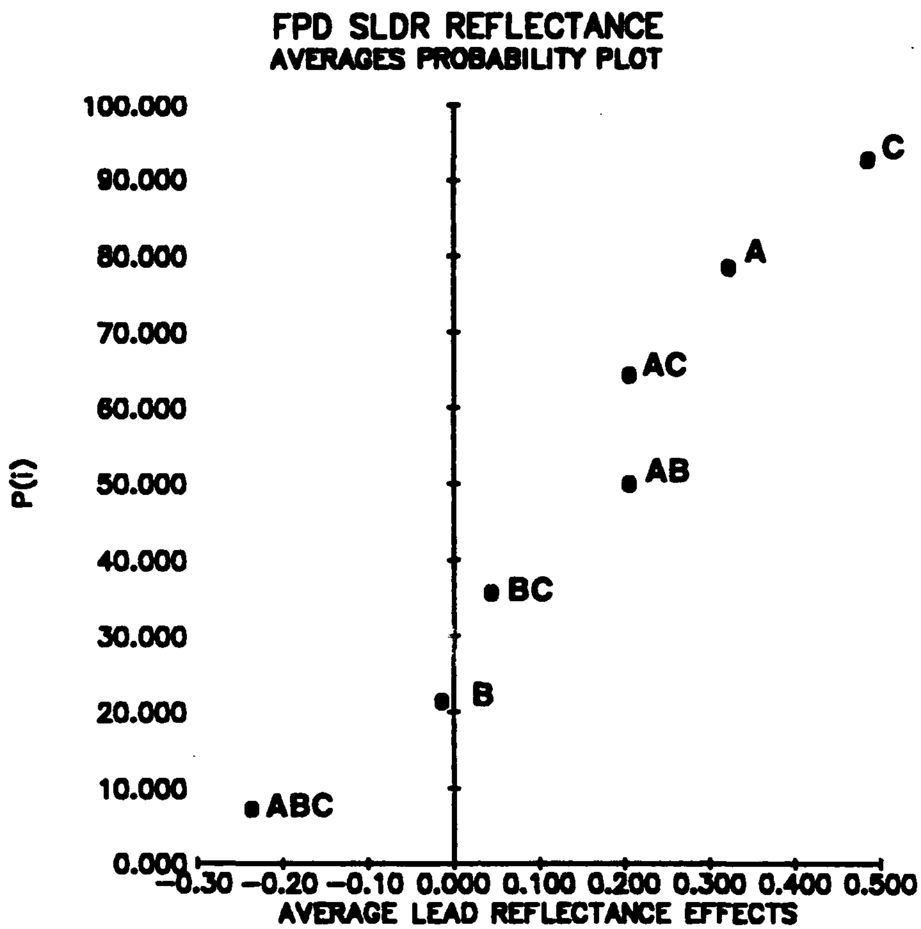


Figure 10. Final Experiment – Normal Probability Plot (FPD SLDR Reflectance)

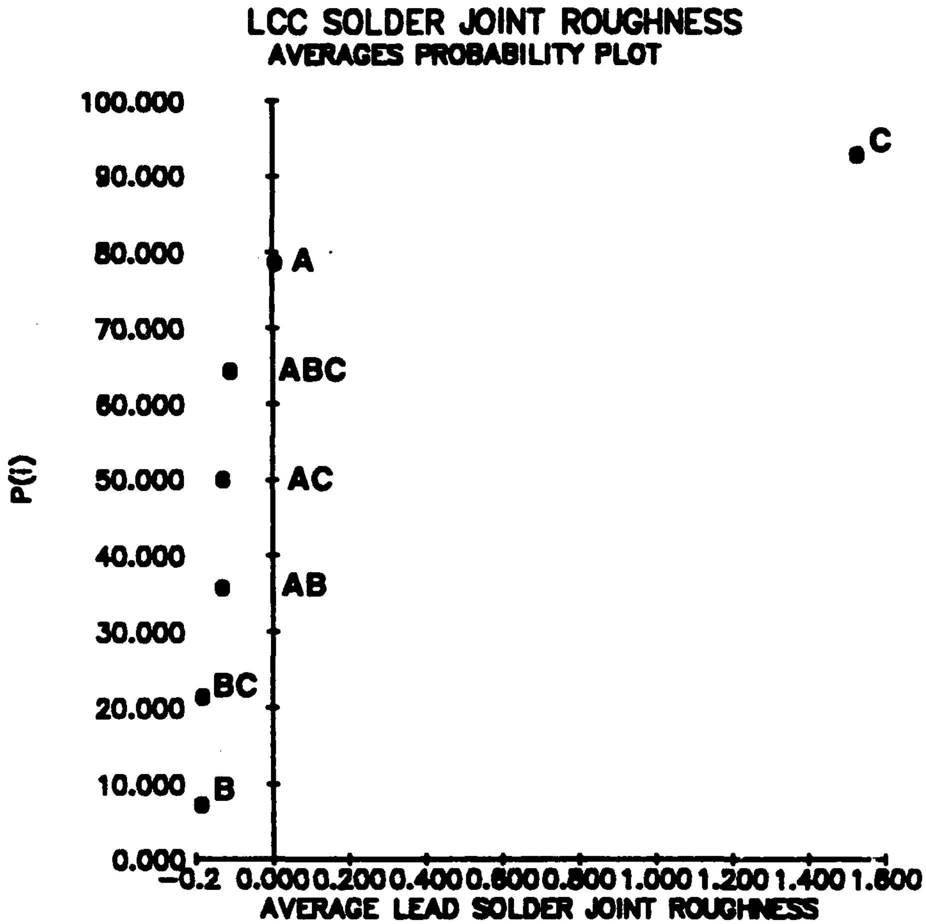


Figure 11. Final Experiment – Normal Probability Plot (LCC Solder Joint Roughness)

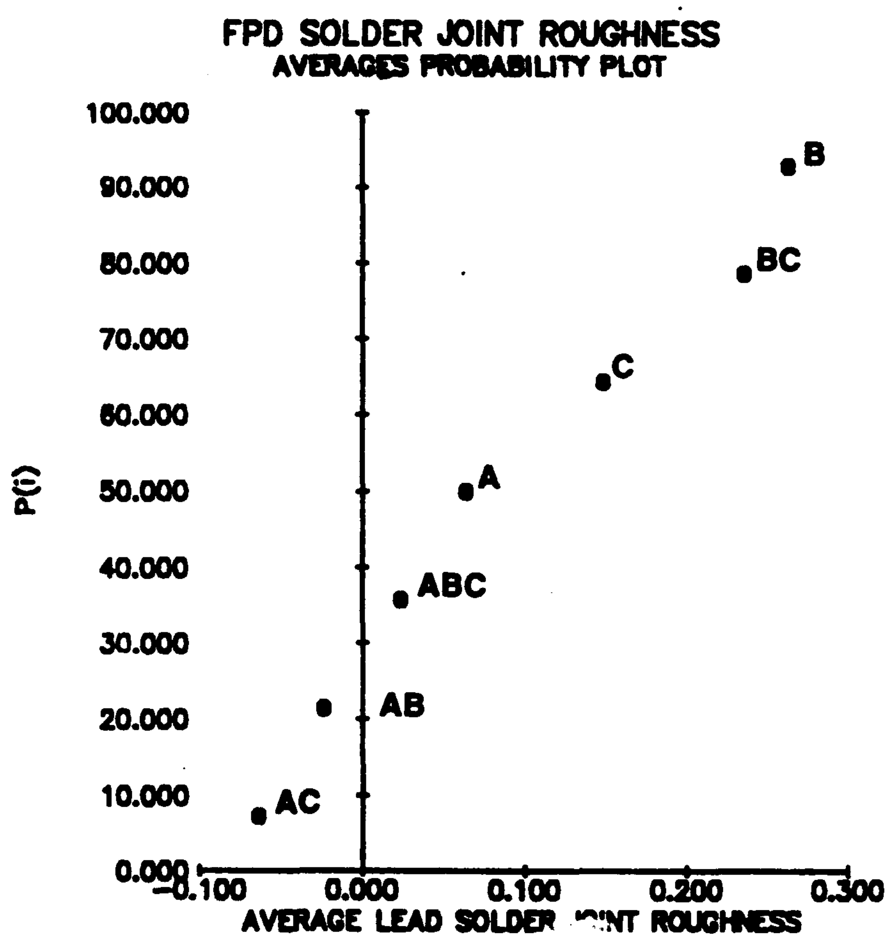


Figure 12. Final Experiment – Normal Probability Plot (FPD Solder Joint Roughness)

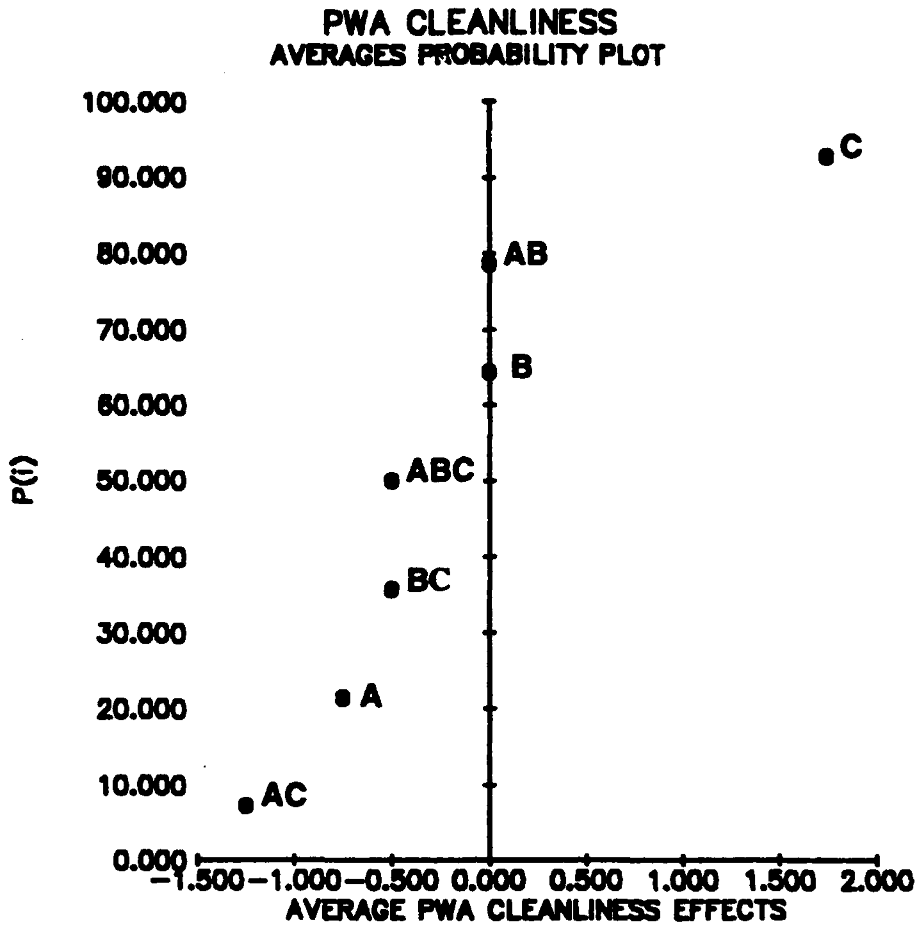


Figure 13. Final Experiment – Normal Probability Plot (PWA Cleanliness)

Table 8. Final Experiment

ANOVA Table
LCC Lead-to-Pad Registration

|----ANOVA FOR MEAN(n=1) , POOLED ERROR USED FOR F TESTS--------|

FACTOR	CD	PL	NAME	SS	DF	MS	F	PROB	%
1			STD HT	3.062812	1	3.062812	6.617	0.06	42.5%
2			PWB TYPE	1.015312	1	1.015312	2.193	0.21	9.0%
3			PASTE VEN	0.195312	1	0.195312	0.422	0.55	0.0%
4		P	ERROR	0.137812	1	0.137812	NA	NA	0.0%
5		P	ERROR	0.525312	1	0.525312	NA	NA	0.0%
6		P	ERROR	1.162812	1	1.162812	NA	NA	0.0%
7		P	ERROR	0.025312	1	0.025312	NA	NA	0.0%
POOLED ERROR:				1.85125	4	0.462812			48.5%
TOTAL(CORRECTED):				6.124687	7				

Table 9. Final Experiment

ANOVA Table
LCC Solder Joint Reflectance

|----ANOVA FOR MEAN(n=1) , POOLED ERROR USED FOR F TESTS--------|

FACTOR	CD	PL	NAME	SS	DF	MS	F	PROB	%
1			STD HT	0.004512	1	0.004512	0.231	0.66	0.0%
2			PWB TYPE	0.1682	1	0.1682	8.646	0.04	4.4%
3			PASTE VEN	3.137512	1	3.137512	161.2	0.00	92.0%
4		P	ERROR	0.00245	1	0.00245	NA	NA	0.0%
5		P	ERROR	0.004512	1	0.004512	NA	NA	0.0%
6		P	ERROR	0.0288	1	0.0288	NA	NA	0.0%
7		P	ERROR	0.04205	1	0.04205	NA	NA	0.0%
POOLED ERROR:				0.077812	4	0.019453			3.6%
TOTAL(CORRECTED):				3.388037	7				

Table 10. Final Experiment

ANOVA Table
FPD Solder Joint Reflectance

:----ANOVA FOR MEAN(n=1) , POOLED ERROR USED FOR F TESTS--------:

FACTOR	CD	PL	NAME	SS	DF	MS	F	PROB	%
1			STD HT	0.209628	1	0.209628	2.935	0.16	14.3%
2			PWB TYPE	0.000378	1	0.000378	0.005	0.90	0.0%
3			PASTE VEN	0.472878	1	0.472878	6.622	0.06	41.5%
4		P	ERROR	0.085078	1	0.085078	NA	NA	0.0%
5		P	ERROR	0.085078	1	0.085078	NA	NA	0.0%
6		P	ERROR	0.003828	1	0.003828	NA	NA	0.0%
7		P	ERROR	0.111628	1	0.111628	NA	NA	0.0%
POOLED ERROR:				0.285612	4	0.071403			44.3%
TOTAL(CORRECTED):				0.968496	7				

Table 11. Final Experiment

ANOVA Table
LCC Solder Joint Roughness

:----ANOVA FOR MEAN(n=1) , POOLED ERROR USED FOR F TESTS--------:

FACTOR	CD	PL	NAME	SS	DF	MS	F	PROB	%
1			STD HT	0.000112	1	0.000112	0.002	0.91	0.0%
2			PWB TYPE	0.06845	1	0.06845	1.762	0.25	0.6%
3			PASTE VEN	4.697112	1	4.697112	120.9	0.00	94.7%
4		P	ERROR	0.0338	1	0.0338	NA	NA	0.0%
5		P	ERROR	0.032512	1	0.032512	NA	NA	0.0%
6		P	ERROR	0.0648	1	0.0648	NA	NA	0.0%
7		P	ERROR	0.0242	1	0.0242	NA	NA	0.0%
POOLED ERROR:				0.155312	4	0.038828			4.7%
TOTAL(CORRECTED):				4.920987	7				

Table 12. Final Experiment

ANOVA Table
FPD Solder Joint Roughness

----ANOVA FOR MEAN(n=1) , POOLED ERROR USED FOR F TESTS--------

FACTOR	CD	PL	NAME	SS	DF	MS	F	PROB	%
1			STD HT	0.007812	1	0.007812	0.253	0.64	0.0%
2			PWB TYPE	0.137812	1	0.137812	4.477	0.10	34.1%
3			PASTE VEN	0.045	1	0.045	1.461	0.29	4.5%
4		P	ERROR	0.00125	1	0.00125	NA	NA	0.0%
5		P	ERROR	0.007812	1	0.007812	NA	NA	0.0%
6		P	ERROR	0.112812	1	0.112812	NA	NA	0.0%
7		P	ERROR	0.00125	1	0.00125	NA	NA	0.0%
POOLED ERROR:				0.123125	4	0.030781			61.4%
TOTAL(CORRECTED):				0.31375	7				

Table 13. Final Experiment

ANOVA Table
PWA Visual Cleanliness

----ANOVA FOR MEAN(n=1) , POOLED ERROR USED FOR F TESTS--------

FACTOR	CD	PL	NAME	SS	DF	MS	F	PROB	%
1			STD HT	0.5	1	0.5	0.340	0.59	0.0%
2			PWB TYPE	0.125	1	0.125	0.085	0.77	0.0%
3			PASTE VEN	8	1	8	5.446	0.08	45.0%
4		P	ERROR	0.125	1	0.125	NA	NA	0.0%
5		P	ERROR	4.5	1	4.5	NA	NA	0.0%
6		P	ERROR	1.125	1	1.125	NA	NA	0.0%
7		P	ERROR	0.125	1	0.125	NA	NA	0.0%
POOLED ERROR:				5.875	4	1.46875			55.0%
TOTAL(CORRECTED):				14.5	7				

Process variables that have significant centering and variability effects are presented in Table 14.

Table 14. Final Experiment/Significant Location and Variability Effects

	Significant Variables	
Response Variable	Location Effects	Variability Effects
LCC lead-to-pad registration	Standoff height	Standoff height
LCC solder joint reflectance	Solder paste vendor	Solder paste vendor PWB type
FPD solder joint reflectance	Solder paste vendor	Solder paste vendor
LCC solder joint roughness	Solder paste vendor	Solder paste vendor
FPD solder joint roughness	Inconclusive	PWB type
PWA visual cleanliness	Solder paste vendor	Solder paste vendor

FPD placement data not reported due to robot problems

The associated process capability indices (Cpks) and actions to be taken are presented in Table 15.

FPD lead to pad registration continued to be a problem. Placement of these parts were manually tweaked after placement in order to gather data regarding solder joint appearance and PWA cleanliness.

A decision was made to halt all further EMPI evaluations until the cause of FPD component placement misregistration problems were identified and fixed. In addition, no further EMPI tests would be run until the solder paste deposit problems were fixed.

5.2 Single-Point FPD Placement

The vendor of the robotic placement workcell was brought in to assist TRW MEAD in identifying the cause of poor FPD placement. The root cause was attributed to the illumination system on the placement arm of the robot. The robot was designed with a ring of "grain-of-wheat" incandescent lamps surrounding the lens of the system's vision camera. This system created a great deal of variability of the fiducial image of the PWB fiducials as presented to the vision system's camera. This light was replaced with a ring fluorescent lamp and this lamp was placed closer to the work surface than the incandescent lamps were placed. Performance improvement was immediately noted.

The single point FPD placement experiment is described in detail in Appendix B to this Final Report. The results are presented in Table 16. The Cpk values clearly show that the process is significantly improved.

Table 15. Cpks and Actions

Response Variable	Cpk	Actions to Improve
LCC lead-to-pad registration	8.39	Nothing at this time, although standoff height has influence
LCC solder joint reflectance	2.38	Use paste vendor 1
FPD solder joint reflectance	6.93	Nothing at this time, although paste vendor 1 is preferred
LCC solder joint roughness	5.20	Nothing at this time, although paste vendor 1 is preferred
FPD solder joint roughness	9.95	Nothing at this time
PWA visual cleanliness	2.38	If excessive squeegee pressure can be overcome; paste vendor 1 might be preferred

FPD registration data not reported due to robot problems.

Table 16. DOE Results - Single Point Component Placement

Response Variable	Cpk	Yield, Approximate	
	FPD	1.34	1
	LCC	1.75	1

5.3 Single Point Solder Paste Placement

The vendor of the stencil printing machine was contacted and they were provided with a description of the machine's problems related to consistent placement of the solder paste deposit. As a result of this contact, it was learned that the most probable cause of the registration problem was due to a backslash in a lead screw. A lock ring was adjusted and set and it became apparent that the registration variability became greatly reduced.

Paste smear problems were attributed to stencil aperture openings that were the same size as the PWB features they were associated with. Any misregistration between the stencil and the PWB resulted in a gap that allowed squeegeed paste to extrude and smear between pads in the PWB. Consequently, a new stencil was ordered in which a 2-mil reduction of the stencil aperture, compared to the associated PWB feature, was developed. Initial applications using this stencil and the "fixed" printer clearly demonstrated that the solder paste problems had been greatly reduced. A single point solder paste placement experiment was designed and it is described in Appendix A to this report. Table 17 presents the results of this single point experiment. There is a clear improvement in the process capability of the solder paste deposit process.

Table 17. DOE Results - Single-Point Solder Paste Placement

Response Variable	Cpk	Yield
Paste registration		
FPD pattern	1.37	1
LCC pattern	7.34	1
Paste smear		
FPD pattern	1.02	0.997
LCC pattern	0.96	0.996

5.4 Confirmation Run

The success achieved with FPD and solder paste placement processes justified a resumption of the EMPI activities. A confirmation run was designed in which the process variable levels were optimized for response variable centering and variability. (See Tables 23a through g.) Appendix D to this final report presents the detailed experimental plan for this confirmation run.

Table 18 gives a description of the PWA and components used for the confirmation run. Table 19 gives a description of the conditions used to accomplish the confirmation run. The eight PWBs had a total of 10,336 solder joints associated with FPD and LCC components. Of these 3168 were FPD solder joints and 7168 were LCC solder joints.

Table 20 presents the defect rate when both LCC and FPD solder joints are included. Table 21 presents the defect rate if just LCC joints are considered. Table 22 presents defect rates associated with FPDs, only. Clearly, the data indicate that further process improvement can be achieved by focusing on component and solder placement issues associated with FPDs.

Table 18. DOE Results - Confirmation Run

Test Vehicle Description

EMPI PWA

- Quantity of eight
- Nominal thickness
- Normal "stretch"
- Fused tin lead
- No steam aging
- Annular ring for local fiducial

Components

- Full set of FPDs
  - Single vendor
  - No steam aging
  - 10-mil belly-to-toe dimension

- Full set of LCCs
  - No steam aging
  - 6-mil, single vendor, dry film solder mask standoff

- Solder paste
  - Single vendor
  - Unaged powder

Table 19. DOE Results - Confirmation Run

General Process Description

Solder paste placement workcell

- Set up stencil snap-off parameters
- Set up squeegee pressure and stroke parameters
- Set up the vision PWB-to-stencil alignment parameters
- Set up offsets and printed a first article PWB
- Printed 8 PWBs in succession and submitted to robotic workcell for placement

Robotic workcell

- Set up component preparation side
  - Belly-to-toe on form die
  - Solder pot temperature and height
  - Component immersion depth
  - Flux station
  - Cleaner
  - Nitrogen flow

- Set up component placement side
  - Adjusted parameters for LCC and FPD recognition
  - Adjusted parameters for PWB fiducial recognition

- Trimmed, formed, and tinned all FPD components while simultaneously placing them and all LCC components onto 8 PWBs

- Submitted the placed PWB to the IR reflow station

Infrared reflow workcell

- Set up nitrogen flow rates
- Set up the EMPI 210 profile
- Verified the temperature profile with an instrumented PWA
- Input the 8 placed PWBs as they were submitted by the robotic workstation
- Submitted the reflowed PWAs to the cleaner workstation as soon as they cooled to ambient conditions (~10 minutes)

Solvent cleaning workcell

- Set up EMPI PWA cleaning profile
- Verified settings for profile
- Entered PWAs into cleaner as they were received from the IR workcell

Table 19. DOE Results - Confirmation Run (Continued)

General Process Description

Inspection process

- Submitted the 8 PWAs to inspection
- Parameters inspected
  - Visual cleanliness
  - Lead alignment
  - Solder bridges
  - Insufficient solder
  - Excess solder
  - Solder joint appearance

- Criteria for inspection
  - MIL-STD-2000
  - WS-6536
  - Martin Marietta Workmanship Standards

Table 20. DOE Results - Confirmation Run

Defect Rates - Overall

LCC solder joints	7168
FPD solder joints	3168
Total	10336

Defect	Rank	Quantity	Rate (%)
Lead alignment	1	427	4.13
Solder bridges	2	30	0.29
Solder, insufficient	3	6	0.06
Solder, excess	4	0	0
Solder, appearance	5	0	0
Cleanliness, visual	6	0	0

Overall Yield 95.5%

Table 21. DOE Results - Confirmation Run

Defect Rates - LCC

LCC solder joints 7168

Defect	Rank	Quantity	Rate (%)
Lead alignment	-	0	0
Solder bridges	-	0	0
Solder, insufficient	-	0	0
Solder, excess	-	0	0
Solder, appearance	-	0	0
Cleanliness, visual	-	0	0

Overall Yield 100%

Table 22. DOE Results - Confirmation Run

Defect Rates - FPD

FPD solder joints 3168

Defect	Rank	Quantity	Rate (%)
Lead alignment	1	427	13.48
Solder bridges	2	30	0.95
Solder, insufficient	3	6	0.06
Solder, excess	4	0	0
Solder, appearance	5	0	0
Cleanliness, visual	6	0	0

Overall Yield 85.5%

Table 23a. IR Reflow
Process Variable Ranges

Variable	Range	Comments
PWB thickness	Nominal ± 3 mils	Maintains ± 3°C, run-to-run solder joint temperature
Tinned lead aging	0 to 6 months	Reduces variability of solder joint appearance
PWB solder aging	0 to 6 months	Reduces variability of solder joint appearance
Nitrogen environment	>98.5%	Enhances solder joint appearance and improves cleanability
Solder particle aging	<30 days	Reduces variability of solder joint appearance
Component placement	Nominal ± 2.5 mils	No adverse effects noted
Solder paste placement	Nominal ± 3.5 mils	No adverse effects noted
Solder paste thickness	4/10 mils	6/12 caused excessive smear and bridging
PWB solder finish	Fused tin-lead	Hot air leveled PWBs not as solderable

Table 23b. FPD Lead Tinning
Process Variable Ranges

Variable	Range	Comments
Tinned lead aging	0 to 6 months	One year accelerated aging adversely affects solder coverage
Belly-to-toe dimension	4 to 12 mils	No adverse affects noted
Lead cleanliness	Solvent clean	Good engineering practice even though shop oil contamination had no adverse affect
Nitrogen flow	≥100 scfh	Eliminates solder bridges

Table 23c. Component Standoff
Process Variable Ranges

Variable	Range	Comments
Vendor	Single vendor	Reduces variability in standoff heights
Developer temperature	90 to 105°F	No adverse affect
Exposure intensity	2500 to 5000 watts	No adverse affect
PWB plating style	Fused to hot air leveled	No adverse affect
Lamination temperature	Nominal ± 5°C	No adverse affect
Lag time to processing	0 to 24 hours	No adverse affect
Style of process film	Diazo	Silver halide is difficult to manually align to PWB

Table 23d. **PWB Cleaning**
Process Variable Ranges

Variable	Range	Comments
Time since reflow	0 to 30 minutes	No adverse affect
Standoff height	6 mils, minimum	Reduces variability of ionic cleanliness measurement
Reflow temperature	210 to 220°C	No adverse affect
Nitrogen environment	98.5%, minimum	Reduces variability of visual cleanliness response
Solder paste vendor	Single vendor	Reduces variability of ionic cleanliness response

Table 23e. Solder Paste Deposit
Process Variable Ranges

Variable	Range	Comments
PWB solder finish	Hot air leveled	Combining fused and hot air leveled PWBs adversely affects variability for registration, thickness and smear
Solder pulse vendor	Single vendor (2)	Minimizes spikes
Fiducial pad stretch	Nominal $\pm$2 mils	Greater range adversely affects smear

Table 23f. FPD Lead Forming
Process Variable Ranges

Variable	Range	Comments
Package geometry	Single geometry	Different package styles adversely affect forming process
Lead material	Single material	Different spring rates, etc., adversely affect formed lead geometry
Lead thickness	5 to 8 mils	No adverse affect on formed leads
Lead skew	Nominal ±1 mil	Skewed leads are not straightened by forming die

Table 23g. Component Placement
Process Variable Ranges

Variable	Range	Comments
Illumination	Fluorescent	Incandescent illumination adversely affected placement of fine pitch devices
Solder paste open time	0 to 3 hours	No adverse affect
PWB solder finish	Fused on hot air leveled	Combining fused and hot air leveled finishes adversely affects registration of LCCs
Tinned lead aging	0 to 6 months	Accelerated aging adversely affected registration of LCC components
Fiducial pad stretch	Nominal ± 3 mils	No adverse affect
PWB thickness	Nominal ± 5 mils	No adverse affect

6. FOLLOW-ON TASKS

The confirmation run clearly indicates defects due to misregistration of fine pitch device components (13.48 percent) is the leading cause of defects on the EMPI printed wiring assemblies. (See Table 24, DOE Results - Confirmation Run, Defect Rates.) Additional experiments will be designed to increase the process capability of FPD registration. Potential process variables to explore are infrared illumination for the robotic placement vision system, and the elimination of stray (environmental) light entering the robotic workcell.

Table 24. DOE Results - Confirmation Run

Defect Rates - FPD

FPD solder joints 3168

Defect	Rank	Quantity	Rate (%)
Lead alignment	1	427	13.48
Solder bridges	2	30	0.95
Solder, insufficient	3	6	0.06
Solder, excess	4	0	0
Solder, appearance	5	0	0
Cleanliness, visual	6	0	0

Overall Yield 85.5%

The second leading cause of defects as identified in Table 24 is associated with solder paste (bridges [0.95 percent] and insufficient [0.06 percent]). Potential process variables to explore here are: 1) additional solder paste formulations; 2) 100 percent inert atmosphere in the IR reflow oven; and 3) thicker stencils. Low priority for improvement is indicated for the FPD lead tinning, PWA cleaning, and LCC standoff processes. FPD lead forming process improvement will most assuredly improve by controlling the FPD package to a single lead material.

7. LESSONS LEARNED

TRW MEAD does not have a staff statistician to support the continuous process improvement activities in the area of the statistical design of experiments and the interpretation of data that is gathered from these experiments. As a result, a statistician was brought under contract to support these activities. It turned out that the services of a statistician were indispensable. There are many errors that can be made by not setting an experiment up properly. A statistician will prevent that from happening. In regard to the analysis of data the statistician is also indispensable. There are so many data points generated and so many ways to look at that data that without a statistician one can never be sure that proper analyses are made and conclusions derived. Process/manufacturing engineers have enough to do developing the detailed experimental plans and running the experiments without having to be burdened with the task of analyzing the data gathered.

Product assurance must be included in the data collection scheme. It needs to be their responsibility to determine just how the response variables are to be measured. In addition, they need to be given the responsibility to make those measurements. Having a third party make these measurements eliminates any tendency of the manufacturing/process engineer from influencing the data measurements as a result of preconceived ideas about what the measurement should be.

Do not take on more experiments than your group can reasonably handle. Do a Pareto analysis on the processes involved and work on the worst process until it comes under control and then move on to the next worst process.

Make sure production operators participate in the brainstorming sessions for the cause and effect diagrams. These operators will have an intimate understanding of process idiosyncrasies that the process/manufacturing engineers may not be aware of.

Keep the designed experiment as simple as possible by being clever in the selection of process variables. Overly complex experiments will often yield confusing results. An exception to this advice may be appropriate if it is the intention of an experimental run to get a "big picture" of what might be influencing response variables. If data seems to be confusing or if data yields meaningless results, do not despair. Redesign the experiment and continue on.

Appendix A

Detailed Experimental Plan
Single Point Solder Paste Deposit

Interoffice Correspondence
TRW Avionics & Surveillance Group

91.Q602.PCC.SPPASTE

Subject	Date	From
Detailed Experimental Plan Single Point Solder Paste Deposit	7 October 1991	J. MURRAY
To	**cc**	**Location/Phone**
P. Glaser	P. Crepeau P. Finkenbinder	RC4/1073/3182

This IOC presents the detailed experimental plan and procedures for a single point solder paste deposit procedure. This experiment is designed to verify that a redesign to the solder paste stencil corrected an excessive solder paste smear problem encountered when running the subtask 5, experiment 1 procedure. The problem was attributed to the aperture opening in the stencil being the same size and slightly larger than the size of the corresponding pads on the PWB that had paste deposited on them.

Table 1. Process variable details.

Process Variable	Measuring Device/ Precision	Variable Range	Specification
Squeegee speed	Printer readout/ +/- 0.01-in/min	x.xx - y.yy sec/stroke	TRW study
Squeegee pressure	Dial indicator/ +/- 2 psi	x.x - y.y psi	TRW study
Fiducial pad stretch	Coordinatograph +/- 0.1 mil	nominal	PWB fabrication drawing
Alignment accuracy/ precision	24-ASP machine tolerance	nominal	Baseline document
Time on stencil	Timer/ +/- 1-min	nominal	Baseline document
Printability index	Visual comparison of standard	nominal	Baseline document
PWB plating	Visual inspection/ certification	Reflowed tin-lead	MEAD Design options
Solder paste vendor	Visual inspection/ certification	Multicore Sn62-RM92A90	MEAD solder paste study

Table 2. Response variable details.

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Registration	Coordinatograph, scope with filar/ +/- 0.1-mil	deposit overhang </=25% of pad axis in direction measured	MM para. 2-1
Smear	coordinatograph, scope with filar/ +/- 0.1-mil	print separation >25% of design spacing	MM para. 2.3
Thickness	Microscan/ +/- 0.1-mil	+/- 20% of stencil thick. at location measured.	MM para. 2.5
Slumping	coordinatograph, scope with filar/ +/1 0.1-mil	print separation >25% of design spacing.	MM para. 2.7
Spikes	Microscan +/- 0.1-mil	<1 times 't' of stencil thick at location measured.	MM para. 2.7

II. MATERIALS AND SUPPLIES

PWB

Qty	P/N	Description
3	786582C Rev A SN 5101-5103	Tin-lead plated and fused, no fiducial stretch, normal thickness

Solder paste

Multicore SN62RM92A90	Multicore Solders Cantiague Rock Road Westbury, NY 11590

Stencil

T-786582-6/1 T-786582-6/2	6/12 mil thickness

Miscellaneous

Palette knife, plastic	Holbein
Bristle brush	
Shamis 99-150 cleaning cloth	Affiliated Manufacturers, Inc.
96244 Protective gloves	Jones Associates

Solvents

Isopropyl alcohol	TT-I-335
1,1,1-Trichloroethane	MIL-T-81533

III. TOOLS AND EQUIPMENT

General purpose stereo microscope, 0.7x-3x zoom with an American Optical No. 424, 10x-filar eyepiece.

Screen Printer No. 24-ASP	MPM Corp. 10 Forge Park Franklin, MA 02038

Malcom Viscometer	Austin America Technology 12201 Technology Blvd Austin, TX 78727
Vapor degreaser, CBL-18	Baron-Blakeslee, Inc. 2001 N. Janice Ave. Melrose Park, IL 60160
Vapo-Kleen Stencil Cleaner Model No. LP-1824	Unique Industries, Inc. Sun Valley, CA
Microscan	CyberOptics Corp. 2331 University Ave. SE Minneapolis, MN 55414
Coordinatograph Video CMM	microVu 7750 Bell Rd. Windsor, CA 95492

IV. PROCEDURE

A.

1. Select one 786582C, Rev A PWB and use it as a stencil set-up PWB.

2. Clean the serialized PWBs in an in-line solvent cleaner or batch vapor degreaser.

3. Set up the ASP-24 stencil printer with the reference PWB.

4. Print the first serialized PWB (5101) and set it aside for data collection.

5. Break down the screen, reteach the fiducial locations using the setup PWB, print the second serialized PWB (5102), and set it aside for data collection.

6. Repeat 9., above, for the final PWB (SN 5103).

V. RESPONSE DATA

A. Registration

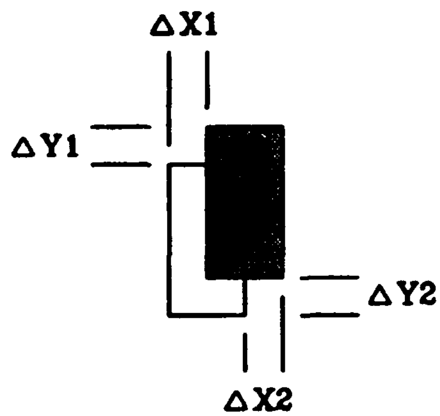
1. Measure the solder paste deposit delta x(1), delta x(2), delta y(1), and delta y(2) misregistration for each of the 3 runs at the locations listed in Table 4. Use the CMM coordinate measuring machine or a filar eyepiece on a microscope with a precision of at least +/- 0.1-mil.

Table 4.

Solder paste misregistration.

RUN NO. ________ DATE ________

COMPONENT	PAD	ΔX1	ΔX2	ΔY1	ΔY2
U7	29				
U7	28				
U7	28				
U2	04				
U2	05				
U2	06				
U30	25				
U30	24				
U30	23				
U34	11				
U34	12				
U34	13				
U33	14				
U33	15				
U33	16				



B. Smears

1. Visually scan the fine pitch device footprints (U1. 20. and 39) that are parallel to the squeegee blade (x-direction). Measure and record a paste smear condition, on a worksheet similar to that shown by Table 5, that represents 80 percent of the pads and one that represents a worst case condition. Use a coordinate measuring machine or a microscope with a filar eyepiece with a minimum precision of +/- 0.1 mils.

2. Repeat B.1, above, for paste deposits that are perpendicular to the squeegee blade (y-direction).

3. Visually scan the 50-mil pitch LCC device footprints that are parallel to the squeegee blade (x-direction). Measure and record a paste smear condition, on a worksheet similar to that shown by Table 5, that represents 80 percent of the pads and one that represents a worst case condition. Use a coordinate measuring machine or a microscope with a filar eyepiece with a minimum precision of +/- 0.1 mils.

4. Repeat B.3, above, for paste deposits that are perpendicular to the squeegee blade (y-direction).

C. Thickness

1. Measure and record, on a worksheet similar to that shown by Table 6, the solder paste thickness for each of the 16 runs at the FPD locations listed in Table 6. Use a Microscan with a precision of 0.1-mil max.

2. Measure and record, on a worksheet similar to that shown by Table 7, the solder paste thickness for each of the 3 runs at the LCC locations listed in Table 7. Use a Microscan with a precision of 0.1-mil max.

Table 5

Smear on Component Pads

INITIAL RUN: ____
REPLICATE RUN: ____

DATE ________

	X 50-MIL PITCH		Y 50-MIL PITCH		X FINE PITCH		Y FINE PITCH	
RUN	80%	MAX	80%	MAX	80%	MAX	80%	MAX
1								
2								
3								
4								
5								
6								
7								
8								

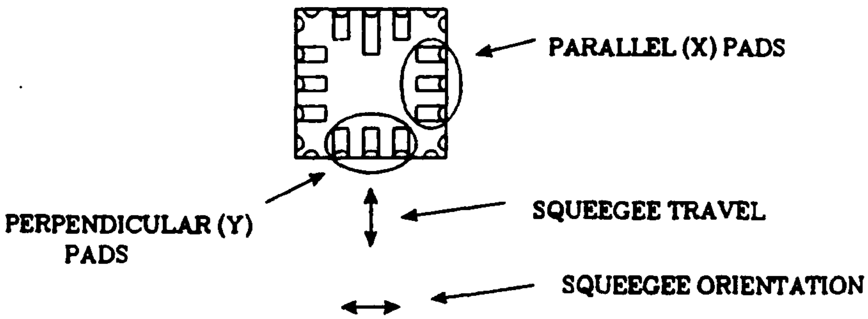


Table 6

Solder paste deposit thickness, FPDs

PWB SN: ____________________

REF DES	PAD PARALLEL TO SQUEEGEE	PAD PERPENDICULAR TO SQUEEGEE
U01	132	001
	131	002
	130	003
	129	004
	128	005
AVG.		
U20	132	001
	131	002
	130	003
	129	004
	128	005
AVG.		
U39	100	099
	101	098
	102	097
	103	096
	104	095
AVG.		

Table 7

Solder paste deposit thickness, LCCs

PWB SN: ____________________

REF DES	PAD PARALLEL TO SQUEEGEE	PAD PERPENDICULAR TO SQUEEGEE
U02	03	04
	02	05
	01	06
AVG.		
U07	30	29
	31	28
	32	27
AVG.		
U38	26	25
	27	24
	28	23
AVG.		
U34	30	29
	31	28
	32	27
AVG.		
U19	19	18
	20	17
	01	16
AVG.		

D. Slumping

1. Visually scan the fine pitch device footprints (U1, 20, and 39) that are parallel to the squeegee blade (x-direction). Measure and record, on a worksheet similar to that shown in Table 9, a paste slump condition that represents 80 percent of the pads and one that represents a worst case condition. Use a coordinate measuring machine or a microscope with a filar eyepiece with a minimum precision of +/- 0.1 mils.

2. Repeat B.1, above, for paste deposits that are perpendicular to the squeegee blade (y-direction).

3. Visually scan the 50-mil pitch LCC device footprints that are parallel to the squeegee blade (x-direction). Measure and record, on a worksheet similar to that shown in Table 9, a paste slump condition that represents 80 percent of the pads and one that represents a worst case condition. Use a coordinate measuring machine or a microscope with a filar eyepiece with a minimum precision of +/- 0.1 mils.

4. Repeat B.3, above, for paste deposits that are perpendicular to the squeegee blade (y-direction).

E. Spikes

1. Visually scan the fine pitch device footprints (U1, 20, and 39) that are parallel to the squeegee blade (x-direction). Measure and record, on a worksheet similar to that shown in Table 10, a paste spike condition that represents 80 percent of the pads and one that represents a worst case condition. Use the Microscan with a minimum precision of +/- 0.1 mils.

2. Repeat B.1, above, for paste deposits that are perpendicular to the squeegee blade (y-direction).

3. Visually scan the 50-mil pitch LCC device footprints that are parallel to the squeegee blade (x-direction). Measure and record, on a worksheet similar to that shown in Table 10, a paste spike condition that represents 80 percent of the pads and one that represents a worst case condition. Use the Microscan with a minimum precision of +/- 0.1 mils.

4. Repeat B.3, above, for paste deposits that are perpendicular to the squeegee blade (y-direction).

VI. DATA REDUCTION

Using the data gathered by this experiment, determine the average value and the dispersion for each response and estimate the Cpk and yield for the procedure

Table 9

Slump on Component Pads

INITIAL RUN: ____
REPLICATE RUN: ____

DATE ________

	X 50-MIL PITCH		Y 50-MIL PITCH		X FINE PITCH		Y FINE PITCH	
RUN	80%	MAX	80%	MAX	80%	MAX	80%	MAX
1								
2								
3								
4								
5								
6								
7								
8								

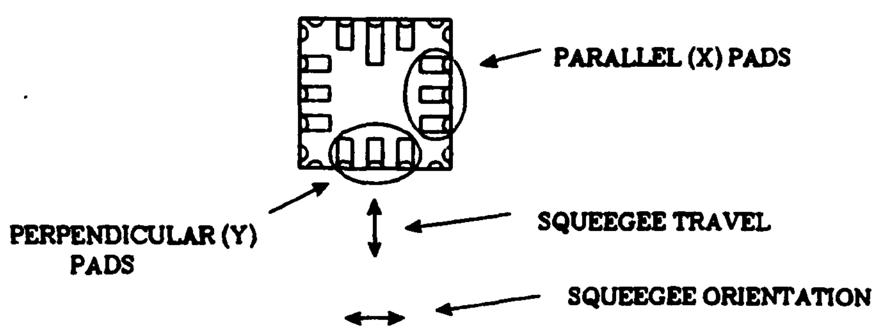
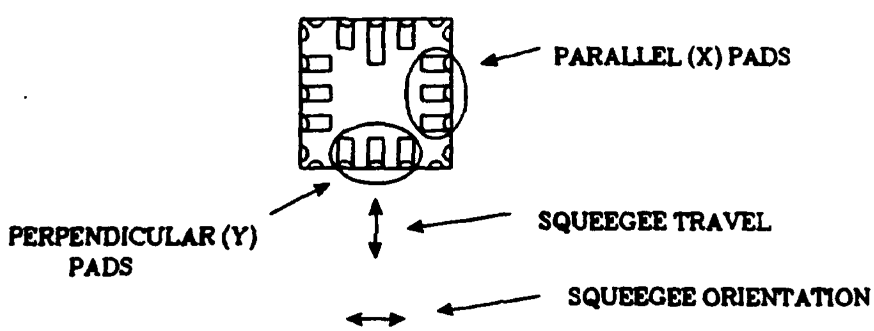


Table 10

Spikes on Component Pads

INITIAL RUN: ____
REPLICATE RUN: ____ DATE ________

	X 50-MIL PITCH		Y 50-MIL PITCH		X FINE PITCH		Y FINE PITCH	
RUN	80%	MAX	80%	MAX	80%	MAX	80%	MAX
1								
2								
3								
4								
5								
6								
7								
8								



Appendix B

Single Point Experiment
FPD Placement
(Annular Ring Fiducial)

SINGLE POINT EXPERIMENT
FPD PLACEMENT
(ANNULAR RING FIDUCIAL)

I. INTRODUCTION

This document presents the detailed experimental plan and procedures for performing the single point FPD placement experiment. This experiment is being run, because of the serious problems encountered placing FPDs during both the execution of the Subtask 5, Experiment No. 2, component placement experiment and a subsequent single point FPD placement experiment.

The conclusions reached from the ST5E2 experiment were that the Gelzer robot could neither accurately nor precisely locate the local fiducials associated with the FPD pad patterns on the PWB. The difficulty was thought to be due to the fact that pad pattern pads with attached traces and plated through holes (see Figure 1a) were selected to double as local fiducial patterns.

Modifications were made to the basic EMPI PWB design to provide dedicated local fiducials for the three FPD pad patterns. See Figure 1 for the before and after conditions. Figure 1b shows the dedicated local fiducial design. Sixteen PWBs with this design were ordered and run. The same problem was encountered as before. The robot was neither accurately nor precisely recognizing and placing the FPD devices.

After conversations with Gelzer Inc., it was decided to take the following approach. Glezer Inc. would provide technical support at the robot and, working with TRW MEAD personnel, solve the FPD component placement inaccuracy and variability problem. In addition, in accordance with Gelzer Inc.'s (and others') recommendations, an annular ring pattern was selected for the local fiducial. Eight PWBs with the annular ring pattern, local fiducials were ordered.

This experiment, then, is designed to determine if the annular ring local fiducials and the Gelzer Inc. maintenance fix the FPD placement problems. If this effort is successful, the

SINGLE POINT EXPERIMENT

FPD PLACEMENT

I. INTRODUCTION

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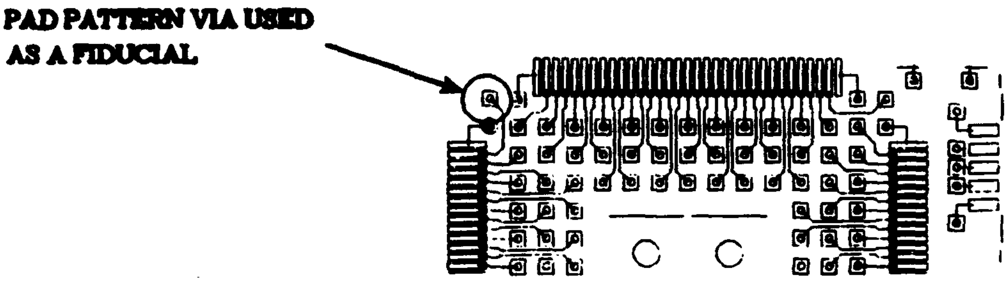
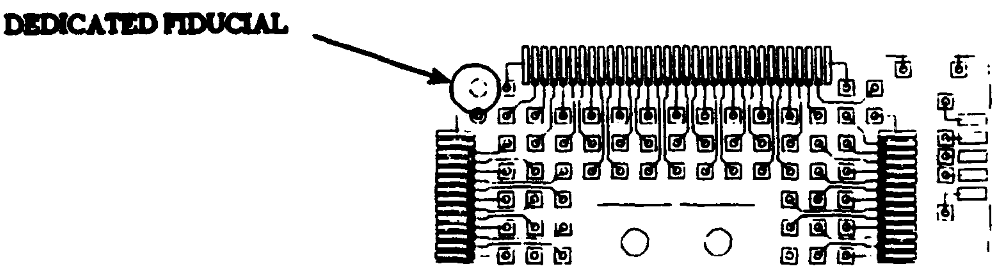
This experiment, then, is designed to determine if the annular ring local fiducials and the Gelzer Inc. maintenance fix the FPD placement problems. If this effort is successful, the accuracy and precision of this process will be quantified and used for establishing a Cpk index and yield.

Figure 1

EMPI FPD Pad Pattern Local Fiducials



(a)



(b)

Table 1. Response variable details.

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
FPD lead and toe overhang	microscope with filar eyepiece, +/- 0.2 mils	25% of lead width, max or 20 mils, max; whichever is less. (+/- 5 mils center-to-center misregistration	MIL-STD-2000
LCC overhang	same	25% of castell~~ion~~ation width, max. +/- 8.8 mils center-to-center mis-registration, max.	

II. MATERIALS AND SUPPLIES

P/N	S/N	Description
786582/C Rev. B	4101, 4102, 4103	Tin-lead plate and fused

Component

Qty	P/N	Description
9	IMKX3F1-4546AA	NTK 132-pin FPD
9	PB-44823	28-pin LCC

Supplies

Unsupported adhesive film	3M

Solvents

Isopropyl alcohol	TT-I-335
1,1,1-trichlorethane	MIL-T-81533

III. TOOLS AND EQUIPMENT

General purpose stereo microscope, 0.7x-3x zoom with an American Optical No. 424, 10x-filar eyepiece and a Trimos vertical digital readout.

Batch & In-Line Vapor Degreaser Models MLR-120 & CBL-18 (as noted or equiv.)	Baron-Blakeslee, Inc. 2001 N. Janice Ave. Melrose Park, IL 60160
Microscope with filar eyepiece	
Robotic Preparation and Placement Workcell Model 1312	Gelzer Systems 425 Enterprise Drive Westerville, OH 43081

IV. ROBOTIC PLACEMENT PROCESS OVERVIEW

During the course of a printed wiring assembly build cycle, several functions are performed by the workcell in a logical sequence. The following are brief explanations of those functions, offered in the same order in which the workcell performs them.

A. BOARD BUILD FILE DOWNLOAD

1. Board build files are comprised of the PWB CAD data which specifies component and fiducial locations, component part numbers and component orientation. Also included in the file are certain PWB attributes such as PWB thickness and presentation orientation. The required board build file is, on demand, loaded to active memory from either the main storage disk (hard drive) or the VAX host.

2. The loaded file is then reviewed in the controller to verify that component feeders have been designated and that component description files are in place for all part numbers existing in the file.

B. BOARD BUILD SEQUENCE

1. The PWB is loaded onto the workholder, the cycle is initiated and the PWB is shuttled into the workcell so that it may be accessed by the robotic arm.

2. A downward looking camera locates the global fiducials and generates the pattern offset for the PWB.

3. The required nozzle is obtained by the robotic arm and the build sequence begins as delineated in the board build file.

4. Each component is picked up, in the designated sequence, vision inspected (see description below) for orientation and geometry and then placed on its respective pad pattern with offset compensation applied.

5. This process continues until all parts have been placed at which time the completed assembly is shuttled back out of the workcell where it is once again accessable to the operator.

C. VISION INSPECTION

LEADED COMPONENTS

The vision algorithm for the 132-pin ceramic quad flatpacks (CQFP's) is designed to create a silhouette of the components leads. The silhouette is created by backlighting the component via an ultra-violet illuminator and a luminescent surface situated directly behind the component and attached to nozzle. Six leads to either side of a component body corner are viewed and utilized to locate that corner with respect to the lead outline. This process is repeated for the remaining three corners (the component is rotated three times) and the derived corner locations are used to derive the centroid of the lead outline and its orientation (offset).

V. PROCEDURE

A. Preliminary

1. Clean the serialized PWBs in the in-line vapor degreaser.

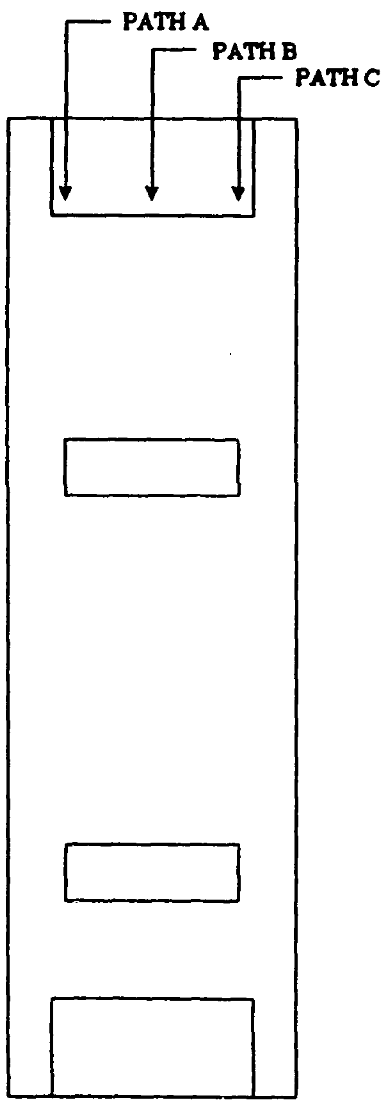
2. Clean all of the components in a vapor degreaser.

3. Place a piece of unsupported adhesive film on the middle five pads of each side of the three FPD pad patterns and in the center of the 28LCC pad patterns at U22, U31, and U35 on the three PWBs (SNs 4101, 4102, and 4103).

NOTE: Gloves or finger cots must be worn for all PWB and component handling from this step on and continued until all components have been placed.

Figure 2

Oxygen Sampling Locations



L, ft	PATH A	PATH B	PATH C
0.0			
0.5			
1.0			
1.5			
2.0			
2.5			
3.0			
3.5			
4.0			
4.5			
5.0			
5.5			
6.0			
6.5			
7.0			
7.5			
8.0			
8.5			
9.0			
9.5			
10.0			
10.5			
11.0			
11.5			
12.0			
12.5			
13.0			
13.5			

Figure 2

FPD Package Measurement Locations

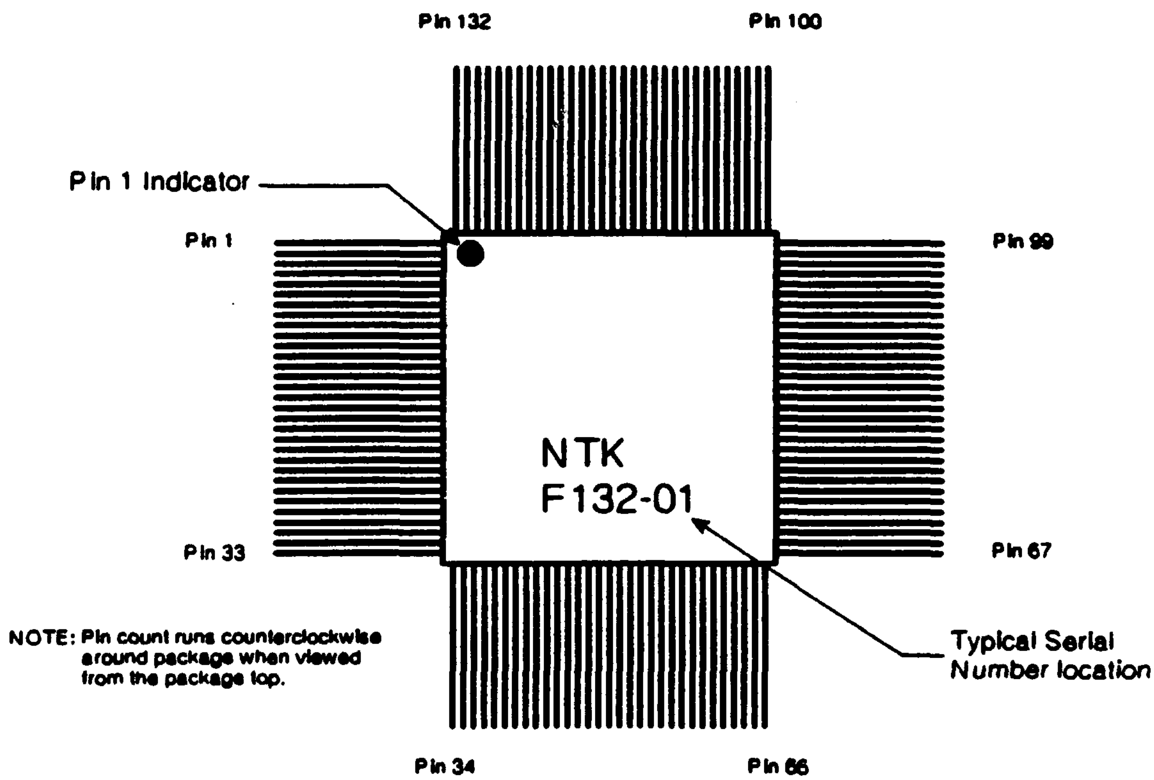


Table 2

NTK Package Body Thickness

Serial No.	Pin 1	Pin 34	Pin 67	Pin 100	Body Center

Table 3

NTK Package Body Height After Forming

Serial No.	Pin 1	Pin 34	Pin 67	Pin 100	Body Center

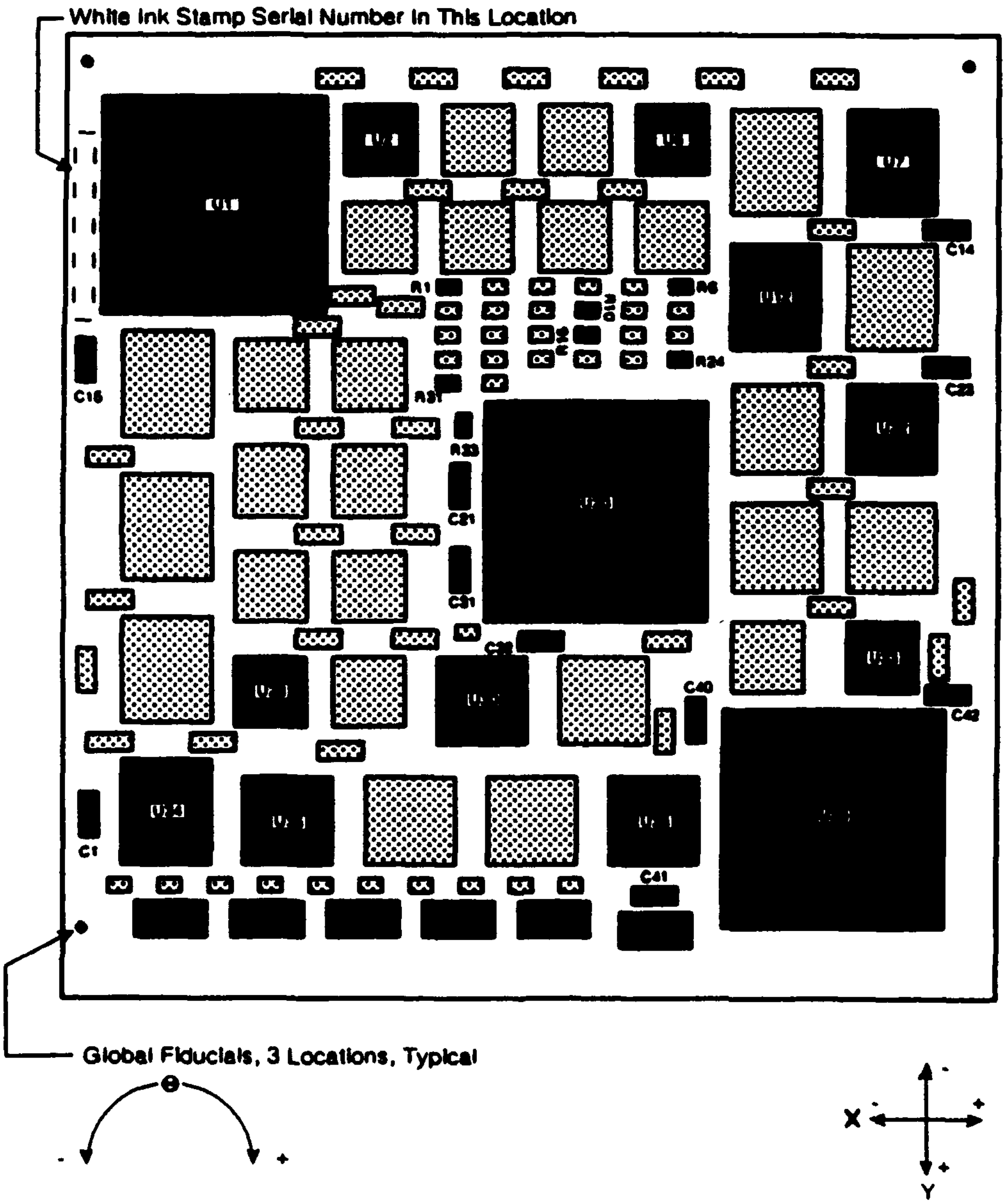
Table 4

NTK Package Belly-to-Toe Dimension

Serial No.	Pin 1	Pin 34	Pin 67	Pin 100	Body Center	Avg

Figure 3

PWB Measurement Orientation



1. Energize the Gelzer Model 1312 robotic workcell as per EOP10160.

2. Turn on the solder pot.

3. When the solder pot comes up to temperature, turn on its pump and adjust the height of the fountain using the fountain height gauge.

4. Turn on the nitrogen supply to the solder pot.

5. Reset the L132 compont description file at the preparation side controller to trim, form, and inspect only.

6. Adjust the preparation side trim die to accept the NTK 132-pin FPDs.

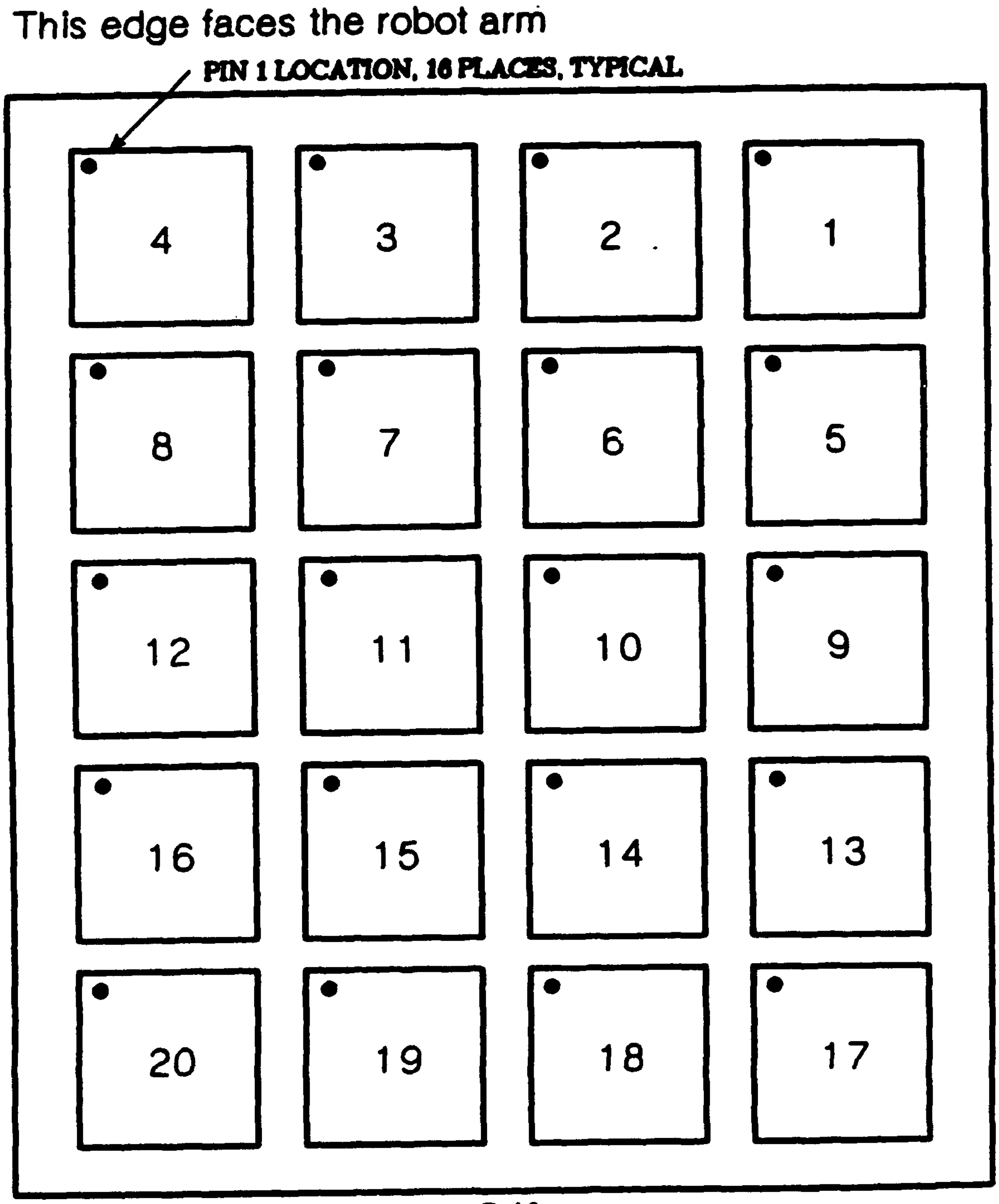
7. At the placement side controller, load a program that will place the three FPD packages (U01, U20, U39) and the three 28LCC packages (U22, U30, U35).

8. Load the 9 NTK packages into tray #1 of the preparation side parts elevator with pin #1 of each component in the upper right hand corner of its respective pocket (see Figure 4). Load the 9 28LCC packages into their tray.

9. Start the board build cycle and form, tin, and place these eighteen (18) devices, 6 each, on SNs 4101, 4102, and 4103.

Figure 4

Prep Side Elevator Tray and Component Orientation



VI. RESPONSE DATA

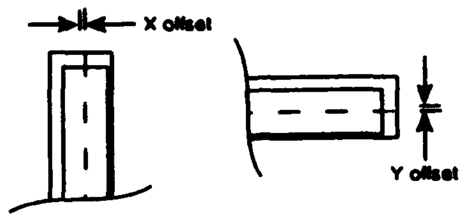
1. All measurements for X and Y are stated relative to the board orientation as shown in Figure 3.

2. The actual offset measurement conventions are delineated in Figure 5 for the FPDs and Figure 6 for the 28LCC.

3. Measure and record the lead placement misregistration for each of the 3 experimental runs at the locations listed in Table 5 for the FPDs and Table 6 for the 28LCCs. Use a filar eyepiece on a microscope with a precision of at least 0.2-mil.

Figure 5

FPD Offset Measurement



FPD Offset Measurement

Table 5

FPD Placement Misregistration Data

PWB S/N________________________

U 1

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
1			
2			
3			
34			
35			
36			
67			
68			
69			
100			
101			
102			

U 20

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
1			
2			
3			
34			
35			
36			
67			
68			
69			
100			
101			
102			

U 39

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
1			
2			
3			
34			
35			
36			
67			
68			
69			
100			
101			
102			

Figure 6

LCC Offset Measurement

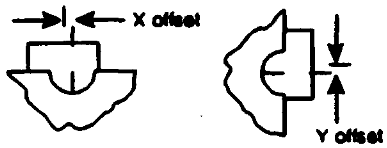


Table 6

LCC Placement Misregistration Data

PWB S/N________________

U 22

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
11			
18			
25			

U 30

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
11			
18			
25			

U 35

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
11			
18			
25			

VII. DATA REDUCTION

1. Using analysis of variance (ANOVA) techniques determine the mean, standard deviation, variability, Cpk, and yield for this process.

Appendix C

Detailed Experimental Plan
Final Run

Interoffice Correspondence
TRW Avionics & Surveillance Group

TRW

91.Q602.PCC.FNL.RUN

Subject	Date	From
Detailed Experimental Plan Final Run	15 August 1991	P. CREPEAU
To	**cc**	**Location/Phone**
P. Glaser	P. Finkenbinder J. Murray	RC4/1073/3182

I. INTRODUCTION

This IOC presents the detailed experimental plans and procedures for performing the experimental procedure for the final EMPI PWA process. This experiment is designed to identify significant inter-workstation process variables that effect several responses for the PWA Assembly process. It incorporates information from runs on seven previous experiments.

The significant process variables were identified in a 'brain storming' session among several manufacturing and process engineers. Figure 1 presents the cause and effect diagram that resulted from that 'brain storming' session and identifies the process variables and responses for this final PWA process run. The encircled process variables are those being evaluated in this experiment. The other process variables were previously evaluated.

Ranges (or levels) for the process variables were selected based on tolerances that were expected to be encountered on the factory floor. These ranges, the instruments used to measure the variables, and the reference to the source for the ranges are presented in Table 1. An asterisk identifies those process variables being evaluated by this experiment. Responses to be analyzed for this final run, the instruments used to measure the responses, the specification limits for the responses, and the source for the specification limits are presented in Table 2. This experimental design is a full factorial with three process variables. Columns AB, AC, BC, and ABC are be used for interaction and experimental error measurements. One replicate will be run so that the process variability can be determined along with the process capability index, Cpk, and the process yield. Table 3 presents the form that will be used for each response evaluated by this experimental design.

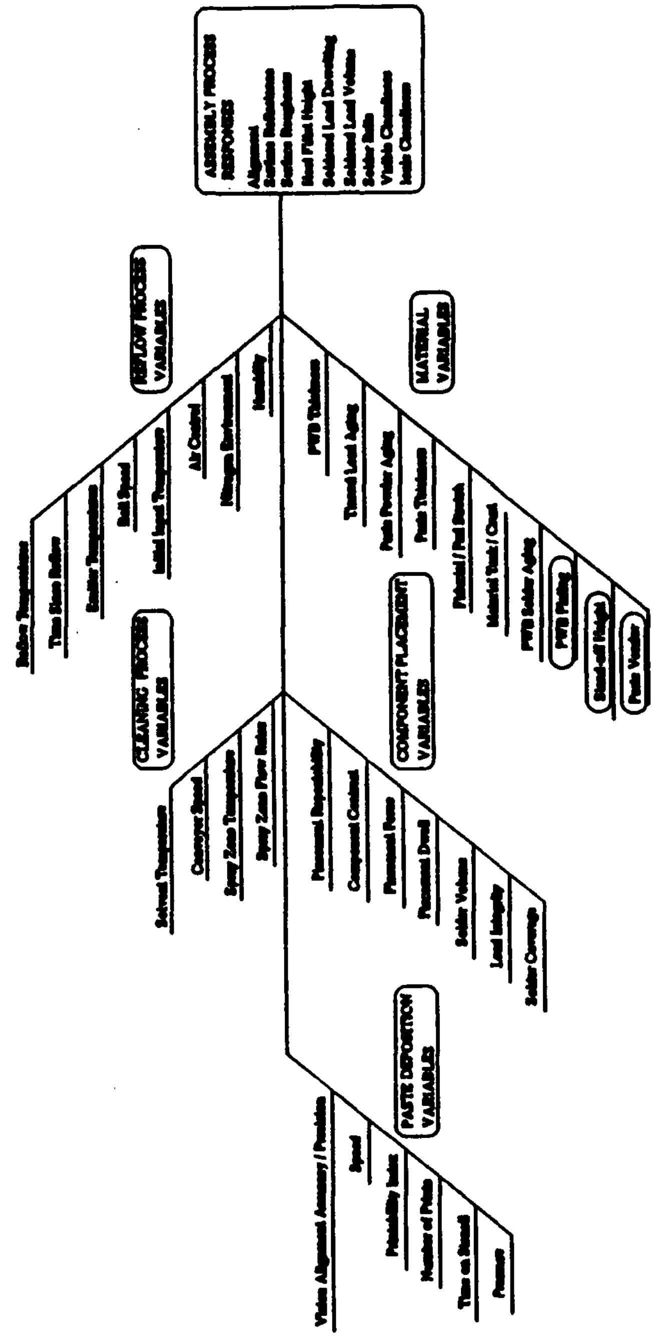


Figure 1

Final EMPI Printed Wiring Assembly Run
Cause And Effect Diagram

Table 1

Process Variable Details

	Process Variable	Measuring Device/ Precision	Variable Range	Specification
	Time since reflow	Timer/ +/- 1 min	0 to 30 mins	ST3E2 experiment
	Reflow temperature	Thermocouple/ +/- 1 deg C	208 to 212 deg C	ST1E0 experiment
	Nitrogen environment	Oxygen analyzer/ +/- 2 percent	70 to 98 percent	ST3E2 experiment
*	Component stand-off height	Light section microscope +/- 0.2 mils	4 to 6 mils	ST3E2 experiment
*	Solder paste vendor	not applicable	Metech and Multicore	ST5E1 experiment
	Solvent temperature	Thermocouple/ +/- 1 deg C	140 to 160 deg F	Baseline document
	Conveyor speed	Common operator interface/+/- 0.1 fpm	1 to 3 fpm	Baseline document
	Spray zone temperatures	Common operator interface/+/- 1 psi	40 to 50 psi and 170 to 190 psi **	Baseline document
*	PWB plating style	N/A	solder dipped and hot air leveled and Sn/Pb plate and fused	ST1E0
	FPD lead skew	+/- 1 mil	as received	Engineering drawing
	FPD lead aging	N/A	less than 1 yr	ST2E0 experiment

Table 1. concluded

Process Variable Details

PWB aging	N/A	less than 1 yr	ST1E0 experiment
Package type	N/A	Kyocera	ST4E0 experiment
Solder paste aging	N/A	as received	ST1E0 experiment
Belly-to-toe dimension	surface gauge +/- 0.2 mils	11 +/- 1 mil	ST2E0 experiment
Flux density	Sensby system +/- 0.001	0.885 to 0.895	Baseline document
Tinning solder temperature	Robot cntrlr +/- 1 deg F	490 to 510 F	MIL-STD-2000
Wave smoothness	Visual	0 to minor turbulence	Baseline document
Nitrogen flow	Flow meter +/- 1 scfh	40 and 100 scfh	ST1E0 experiment
Coplanarity	Microscan +/- 0.1 mil	+/- 4 mils	ST4E0 experiment
Toe-to-toe	as formed	1.225 +/- 0.005 in	ST4E0 experiment
Toe angle	as formed	0 +/-15 deg	ST4E0 experiment
Toe burrs	as formed	1x lead thick (5 mils)	ST4E0 experiment
Solder paste open time	timer +/- 1 sec	0.5 to 3 hrs	ST5E2 experiment
Fiducial pad stretch	+/- 0.1 mils	+/- 3 mils from A/W dim	ST5E2 experiment
Placement force	force gauge +/- 1 gm	5 to 50 gm per lead	ST5E2 experiment
PWB thickness	dial microm. +/- 0.1-mil	58 to 68 mils	ST5E2

* Process variable being studied by this experiment

Table 2

Response Variable Details

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Visual cleanliness	Comparison to visual standards/ +/- 1 unit	1 to 5 units	MIL-P-28809
Ionic cleanliness	Ionic contamination tester/+/- 1 ugm NaCl/sq in	0 to 10 ugm NaCl/sq in	MIL-C-28809
Solder joint roughness	Comparison to visual standards/ +/- 1 unit	1 to 5 units	MIL-P-28809
Solder joint reflectance	Comparison to visual standards +/- 1 unit	1 to 5 units	MIL-P-28809
Heel fillet height	Microscope with filar +/- 0.1-mil	0 to 100% of calf length	MM 3-23
Soldered lead dewetting	Microscope with particle counting grid	0 to 5 % of soldered area	MM 3-22

Table 2

Response Variable Details

Soldered lead soldered fillet volume	visual comparison	No lead-to-pad fillet extending over top of lead foot and beyond edge	MM 3-21 and MM 3-22
Solder balls	Microscope with filar +/- 0.1-mil	5 mils, max	MM 5-6
Lead-to-pad alignment	Microscope with filar +/- 0.1-mil	+/- 25% of lead width (+/- 2.75 mils)	MIL-STD-2000

Table 3

Response Table With Interaction Effects

Random Order Trial Number	Standard Order Trial Number	Response Observed Values	A		B		C		AB		AC		BC		ABC	
			1	2	1	2	1	2	1	2	1	2	1	2	1	2
	1															
	2															
	3															
	4															
	5															
	6															
	7															
	8															
TOTAL																
NUMBER OF VALUES																
AVERAGE																
EFFECT																

II. MATERIALS AND SUPPLIES

PWB.-

Qty	PIN	Description
8	786582/A	Solder dipped and hot air leveled
8	786582/C	Sn/Pb plate and fused

Components.-

Qty	PIN	Description
48	PB-F86259	132-pin. Kyocera. FPD package
288	PB-C85124	20-pin. LCC
160	PB-44823	28-pin. LCC
128	IRK32F1-200B	32-pin. RLCC
608	M55342K06B-110BR	M55342/6. chip resistor
672	CDR02BX103-BKURT/BKUS	CDR02. chip capacitor
96	49BCP	CWR06. chip capacitor

Solder Paste.-

Metech RHF63	Metech. Inc Route 401 Halverson. PA 19520
Multicore SN62RM92A90	Multicore Solders Cantiague Rock Road Westbury. NY 11590

Stencil.-

T786582-6/1	6/12 thickness

Dry Film Solder Mask.-

Vacrel 8100	E.I. DuPont de Nemours Wilmington. DE

<u>Solder Mask Artwork</u>.-

T786582-5/1	0.020-in diameter standoff pattern

<u>Miscellaneous</u>.-

Palette knife, plastic	Holbein
Bristle brush	
Shamis 99-150 cleaning cloth	Affiliated Manufacturers, Inc.
96244 Protective gloves	Jones Associates

[illegible]

<u>Solvents</u>.-

Isopropyl alcohol	TT-I-335
1,1,1-Trichloroethane	MIL-T-81533

III TOOLS AND EQUIPMENT

General purpose stereoscope, 0.7X to 3X zoom with an American Optical No. 424, 10X, filar eyepiece

Screen Printer No. 24-ASP	MPM Corporation 10 Forge Park Franklin, MA 02038
Malcom Viscometer	Austin American Technology 12201 Technology Blvd. Austin, TX 78727
Gelzer Robot	Gelzer Systems Westerville, OH
In-Line Cleaner, CBL-18	Baron Blakeslee 2001 N. Janice Ave. Melrose Park, IL 60160
Vapo-Kleen Stencil Cleaner, Model No. 1110187	Universal Electronics, Inc.
Microscan	CyberOptics Corp. 2331 University Ave. S.E.

	Minneapolis, MN 55414
IR Reflow Oven, Model SMD 722	Vitronics Corp 40 Forge Haymarket, NH
Ionic Contamination Tester Model ICOM 4000	Westek, Inc. 400 Rolyn Place Arcadia, CA 91006

IV PROCEDURE

A. Eight Run Full Factorial Design with One Replicate

Note: Select 8 786582/A PWBs and serialize them as 3001 through 3004 and 3011 through 3014. Select 8 786582/C PWBs and serialize them as 3006 through 3009 and 3016 through 3019. Set aside for the experiment and its replicate.

1. Initial 'normal' experiment

   a. Create one worksheet similar to the one shown in Table 3, for each of the responses listed in Table 2, that are to be monitored. Column A is assigned to 'Standoff Height'; sub-column 1 is for '4 mils'; sub-column 2 is for '6 mils'. Column B is assigned to the 'PWB Plating Type'; sub-column 1 is for 'hot air leveled'; sub-column 2 is for 'fused'. Column C is assigned to the 'Solder Paste Vendor'; sub-column 1 is for 'Metech'; subcolumn 2 is for 'Multicore'. Columns AB, AC, BC, and ABC are reserved for interaction and experimental error determinations. See Tables 15 and 16.

   b. Run the experimental trials for this initial experiment using the random number sequence listed in the "Random Order Trial Number" column of Table 15.

   c. Clean the appropriate, serialized PWBs in the in-line solvent cleaner.

   d. Set up the 24-ASP stencil printer with an appropriate reference PWB. Keep in mind that different solder paste vendors are being applied to different boards depending on the run number.

   e. Set up the component preparation and placement sides of the Gelzer robot.

   f. Set up the CBL-18 in-line cleaner with the appropriate PWA cleaning process profile (Profile No.1).

   g. Select the PWB, solder paste, and standoff parameters required for the run identified as random number 1 in Table 15.

   h. Stencil print the PWB forcing the desired material vendor as required by the test matrix.

   i. Place the printed PWB in the Gelzer robot load station and form, trim, tin, and place the selected FPD and all other components using the nominal placement values for all components. Other than the CWR06 parts, chip components need not be placed.

   j. Reflow the PWA subassembly in the IR reflow oven using nitrogen and the 210 EMPI profile (No. 34).

k. Clean the PWA in the CBL-18 in-line cleaner using the PWA cleaning profile no. 1.

l. Repeat steps IV.A.1.c through IV.A.1.k, inclusive, until all 8 experimental runs have been completed for this initial experiment.

3. Second Replication Experiment

a. Using the test parameters and the random order sequence specified by the Table 16 matrix for a second replicated run, repeat steps IV.A.1.b - IV.A.1.l.

V. RESPONSE DATA

A. Visual Cleanliness

1. Scan the entire PWA and compare and rank the cleanliness against the visual standards presented in Figure 2. Record the data in Table 4.

B. Ionic Contamination

1. Measure the cleanliness of the PWA using the Westek ICOM 4000. Record the data in Table 4.

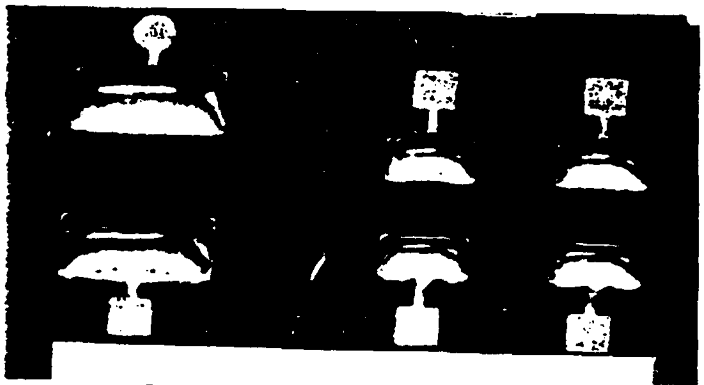
Figure 2

Visual PWA Cleanliness Standards

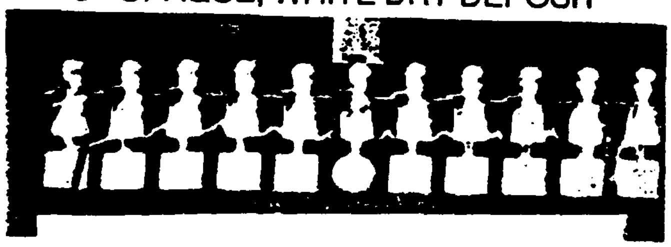
0 NO CONTAMINATION VISIBLE REGARDLESS OF LIGHT OR MAGNIFICATION (MAX 30X)

1 EDGE OF VISIBILITY, TRANSPARENT DRY RESIDUE

2 EASILY VISIBLE, TRANSPARENT DRY RESIDUE



3 OPAQUE, WHITE DRY DEPOSIT



4 LIGHT DEPOSIT OF WET FLUX

5 HEAVY DEPOSIT OF WET FLUX

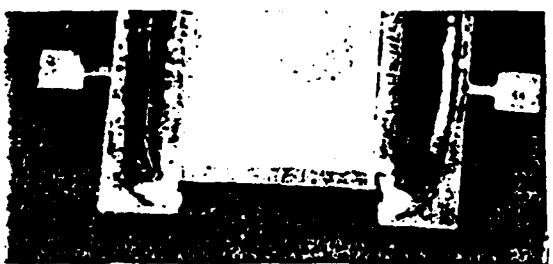


Table 4

Data Collection Table for PWA Cleanliness

PWB SN	CLEANLINESS		COMMENTS
	VISUAL, 0-5	IONIC, Mg NaCl/in2	
3001			
3002			
3006			
3007			
3011			
3012			
3016			
3017			
3003			
3004			
3008			
3009			
3013			
3014			
3018			
3019			

C. FPD Lead-to-Pad Alignment

1. Measure the lead-to-pad alignment as shown in Figure 3 and record the data in Table 5.

D. LCC Termination-to-Pad Alignment

1. Measure the termination-to-pad alignment for the 20-, 28-, and 32-pin LCC packages as shown in Figure 4. Record the data for the packages shown in the applicable Tables 6 through 8.

E. Solder Joint Reflectance

1. FPDs

a. Measure the solder joint reflectance of the U01 and U20 FPD package pins and record the results in Table 9. Use the visual standards as presented in Figure 5.

2. LCCs

20-Pin LCCs

a. Measure the solder joint reflectance of the U04, U19, and U33 LCC package terminations and record the results in Table 10. Use the visual standards as presented in Figure 5.

28-Pin LCCs

a. Measure the solder joint reflectance of the U22, U30, and U32 LCC package terminations and record the results in Table 11. Use the visual standards as presented in Figure 5.

32-Pin LCCs

a. Measure the solder joint reflectance of the U07, U17, and U34 LCC package terminations and record the results in Table 12. Use the visual standards as presented in Figure 5.

F. Solder Joint Roughness

1. FPDs

a. Measure the solder joint roughness of the U01 and U20 FPD package pins and record the results in Table 9. Use the visual standards as presented in Figure 6.

2. LCCs

20-Pin LCCs

a. Measure the solder joint roughness of the U04, U19, and U33 20-pin LCC package terminations and record the results in Table 10. Use the visual standards as presented in Figure 6.

28-Pin LCCs

a. Measure the solder joint roughness of the U22, U30, and U32 28-pin LCC package terminations and record the results in Table 11. Use the visual standards as presented in Figure 6.

32-Pin LCCs

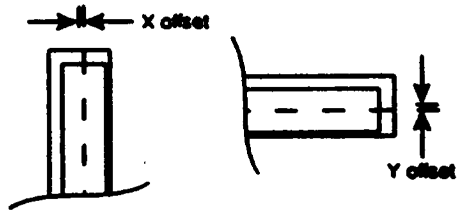
a. Measure the solder joint roughness of the U07, U17, and U34 32-pin LCC package terminations and record the results in Table 12. Use the visual standards as presented in Figure 6.

G. FPD Solder Joint Heel Fillet Height

1. Measure the solder joint heel fillet height as shown in Figure 7 for the U01 and U20 FPD component leads. Record the data in Table 9. Data is reported as a percent of the total 'calf' length.

Figure 3

FPD Lead-to-Pad Offset Depiction



FPD Offset Measurement

Table 5

Fine Pitch Device Placement Misregistration

PWB S/N________________________

U 01

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
2			
35			
68			
101			

U 20

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
2			
35			
68			
101			

Figure 4

LCC Castellation-to-Pad Offset Depiction

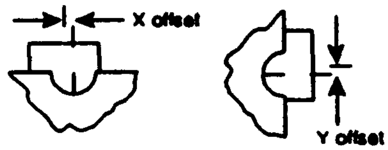


Table 6

20-Pin LCC Placement Misregistration

PWB S/N________________

U 04

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
3			
8			
13			
18			

U 19

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
3			
8			
13			
18			

U 33

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
3			
8			
13			
18			

Table 7

28-Pin LCC Placement Misregistration

PWB S/N________________

U 22

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
11			
18			
25			

U 30

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
11			
18			
25			

U 35

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
11			
18			
25			

Table 8

32-Pin LCC Misregistration

PWB S/N______________

U 07

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
13			
20			
29			

U 17

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
13			
20			
29			

U 34

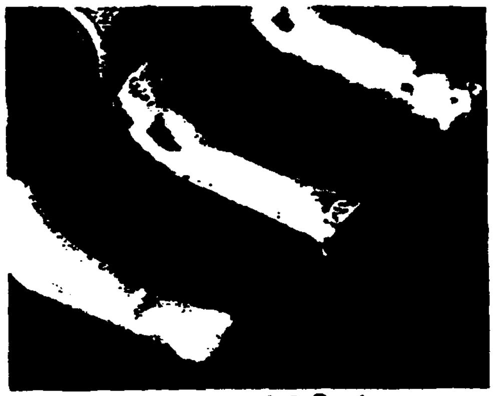
Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
13			
20			
29			

Figure 5

Reflowed Solder Joint Reflectance

MAGNIFICATION 30X

a. (MM 3-4, top) Rank = 1



b. (MM 1-8, middle) Rank = 2

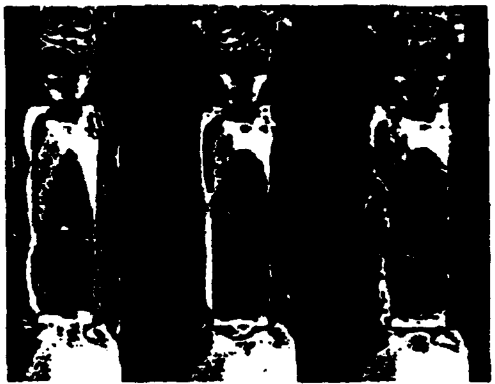
c. (MM 1-6, top) Rank = 3

d. (MM 3-22, top) Rank = 4

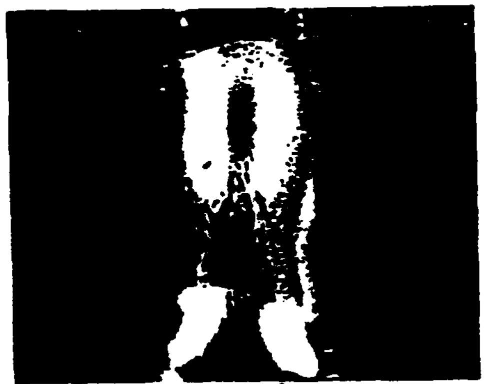
e. (MM 1-11, bottom) Rank = 5

Figure 6

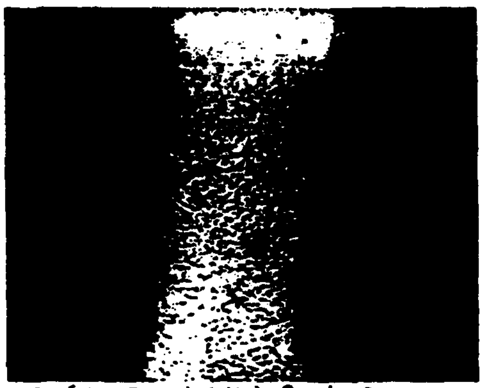
Reflowed Solder Joint Roughness



a. (MM 3-42, mid-left) Rank=1



b. (MM 3-41, bot-rt) Rank=2



c. (MM 3-41, bot lt) Rank=3

d. (MM 3-41, top rt) Rank=4

e (MM 3-41, mid rt) Rank=5

Figure 7

FPD Solder Joint Lead Heel Fillet

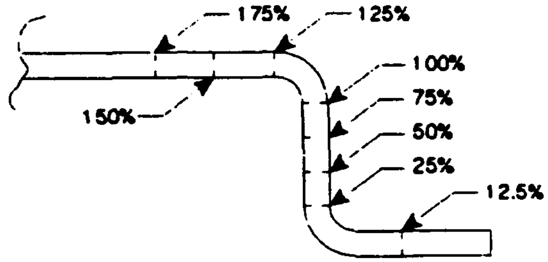


Table 9

FPD Solder Joint Appearance

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
01	130				
	131				
	132				
	001				
	002				
	003				
	007				
	064				
	065				
	066				
	067				
	068				
	069				
20	130				
	131				
	132				
	001				
	002				
	003				
	007				
	064				
	065				
	066				
	067				
	068				
	069				

Table 10

20-Pin LCC Solder Joint Appearance

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
04	001				
	002				
	003				
	004				
	005				
	006				
	007				
	011				
	012				
	013				
	014				
	015				
	016				
19	001				
	002				
	003				
	004				
	005				
	006				
	007				
	011				
	012				
	013				
	014				
	015				
	016				

Table 10, concluded

20-Pin LCC Solder Joint Appearance

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
01	001				
	002				
	003				
	004				
	005				
	006				
	007				
	011				
	012				
	013				
	014				
	015				
	016				

Table 11

28-Pin LCC Solder Joint Appearance

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
	002				
	003				
	004				
	005				
22	006				
	007				
	016				
	017				
	018				
	019				
	020				
	021				
	002				
	003				
	004				
	005				
30	006				
	007				
	016				
	017				
	018				
	019				
	020				
	021				

Table 11, concluded

28-Pin LCC Solder Joint Appearance

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
35					
	002				
	003				
	004				
	005				
	006				
	007				
	016				
	017				
	018				
	019				
	020				
	021				

Table 12

32-Pin LCC Solder Joint Appearance

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
07					
	002				
	003				
	004				
	005				
	006				
	007				
	018				
	019				
	020				
	021				
	022				
	023				
17					
	002				
	003				
	004				
	005				
	006				
	007				
	018				
	019				
	020				
	021				
	022				
	023				

Table 12. concluded

32-Pin LCC Solder Joint Appearance

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
	002				
	003				
	004				
	005				
	006				
34	007				
	018				
	019				
	020				
	021				
	022				
	023				

H. FPD Lead Dewetting

1. Examine the leads of the U01 and U20 FPD packages at 10x and map the dewet areas onto a grid. Record the percent dewet in Table 13. See Figure 8 for an example of a mapping grid.

I. FPD Solder Joint Volume

1. Examine the solder joints of the U01 and U20 FPD packages at 10x and rate the volume of the solder in the solder joints by comparing them against the standards shown in Figure 9. Record the results in Table 13.

J. Solder Balls

1. Transmission X-ray examine the assembled PWB after the in-line cleaning process, and locate the largest solder ball. Measure the diameter of the solder ball using a microscope with a filar eyepiece. Record the results in Table 14.

Table 13

FPD Solder Joint Volume and Dewetting

PWB SN:

REF DES	LEAD NO.	SOLDER VOLUME	SOLDER DE-WETTING	COMMENTS
01	130			
	131			
	132			
	001			
	002			
	003			
	007			
	064			
	065			
	066			
	067			
	068			
	069			
20	130			
	131			
	132			
	001			
	002			
	003			
	007			
	064			
	065			
	066			
	067			
	068			
	069			

Figure 8

FPD Soldered Lead Dewetting

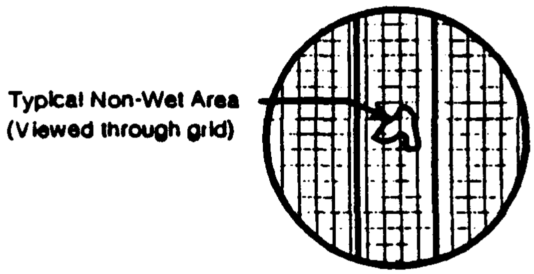
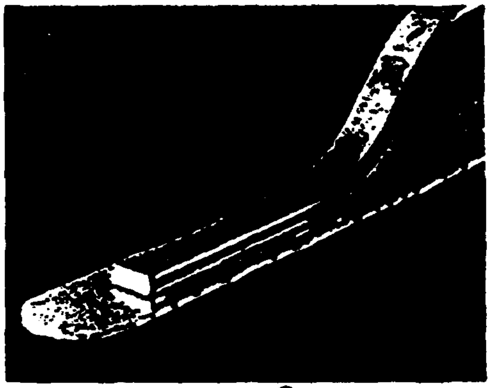
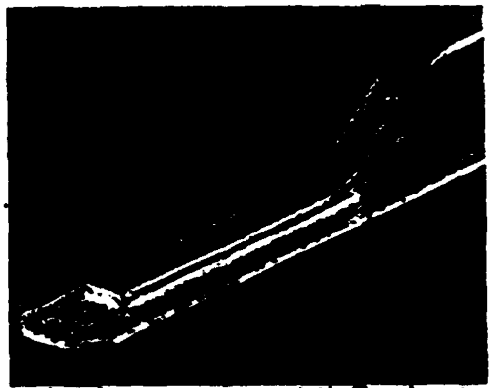


Figure 9

Reflowed Solder Joint Volume

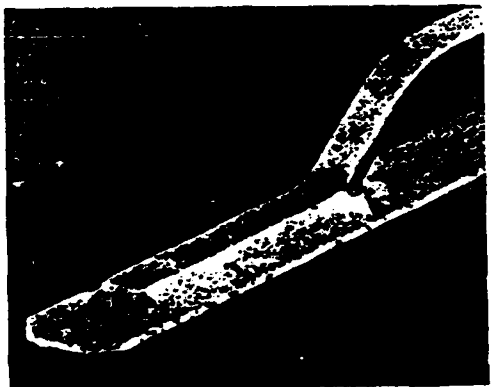


a.(MM3-21, bot Rank=1

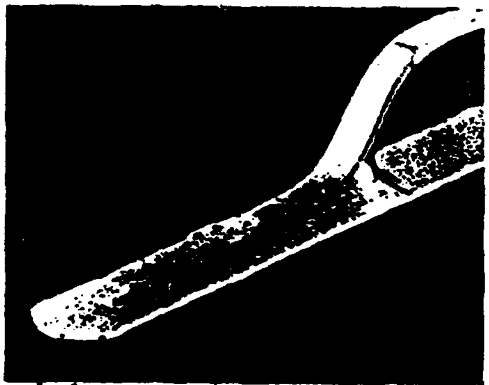


b. (MM 3-21, bot mid) Rank= 2

MAGNIFICATION 8X



c. (MM 3-21, top) Rank=3



d. (MM 3-22, bot mid) Rank=4

e. (MM 3-22, bot) Rank = 5

Table 14

Solder Ball Data

PWB SN	Diameter of largest solder ball

VI. DATA REDUCTION

1. Using the data gathered by this experiment, the response sheets typified by Table 3 will be completed for the responses; and significant interstation process variables will be identified.

2. Additional analyses of the data using analysis of variance (ANOVA) techniques will yield variability, experimental error, process capability indices, and process yield data.

Table 15
Replicate No.1 Experiment Recipe

PWB Serial Number	Random Sequence Number	Run Number	Proposed/Actual Variable States: Standoff Height Prop.	Standoff Height Act.	PWB Type Prop.	PWB Type Act.	Solder Paste Vendor Prop.	Solder Paste Vendor Act.	Interaction and Error	Forced Sub-response
3001	16	1	4 mils		Solder Dipped Hot Air Leveled		[illegible]			
3002	7	2	4 mils		Solder Dipped Hot Air Leveled		Multi-core			
3006	15	3	4 mils		Sn/Pb Fused		[illegible]			
3007	13	4	4 mils		Sn/Pb Fused		Multi-core			
3011	12	5	6 mils		Solder Dipped Hot Air Leveled		[illegible]			
3012	14	6	6 mils		Solder Dipped Hot Air Leveled		Multi-core			
3016	6	7	6 mils		Sn/Pb Fused		[illegible]			
3017	2	8	6 mils		Sn/Pb Fused		Multi-core			

Table 16
Replicate No.2 Experiment Recipe

PWB Serial Number	Random Sequence Number	Run Number	Proposed/Actual Variable States						Interaction and Error	Forced Sub-response
			Standoff Height		PWB Type		Solder Paste Vendor			
			Prop.	Act.	Prop.	Act.	Prop.	Act.		
3003	11	1	4 mils		Solder Dipped Hot Air Leveled		[illegible]			
3004	9	2	4 mils		Solder Dipped Hot Air Leveled		Multi-core			
3008	1	3	4 mils		Sn/Pb Fused		[illegible]			
3009	4	4	4 mils		Sn/Pb Fused		Multi-core			
3013	5	5	6 mils		Solder Dipped Hot Air Leveled		[illegible]			
3014	10	6	6 mils		Solder Dipped Hot Air Leveled		Multi-core			
3018	8	7	6 mils		Sn/Pb Fused		[illegible]			
3019	3	8	6 mils		Sn/Pb Fused		Multi-core			

Appendix D

Detailed Experimental Plan
Confirmation Run

Interoffice Correspondence
TRW Avionics & Surveillance Group

TRW

91.Q602.PCC:[redacted].RUN

Subject	Date	From
Detailed Experimental Plan Confirmation Run	7 October 1991	P. CREPEAU

To	cc	Location/Phone
P. Glaser	P. Finkenbinder J. Murray	RC4/1073/3182

I. INTRODUCTION

This IOC presents the detailed experimental plans and procedures for performing the confirmation run of the EMPI PWA process. This experiment is designed to get a measure of the variability of the process that is run using the process variable levels indicated by previous experiments as providing the optimum response yields.

Table 1

Process Variable Details

Process Variable	Measuring Device/ Precision	Variable Range	Specification
Time since reflow	Timer/ +/- 1 min	0 to 30 mins	ST3E2 experiment
Reflow temperature	Thermocouple/ +/- 1 deg C	208 to 212 deg C	ST1E0 experiment
Nitrogen environment	Oxygen analyzer/ +/- 2 percent	70 to 98 percent	ST3E2 experiment
Component stand-off height	Light section microscope +/- 0.2 mils	6 mils	ST3E2 experiment and final run
Solder paste vendor	not applicable	Multicore	ST5E1 experiment and final run
Solvent temperature	Thermocouple/ +/- 1 deg C	140 to 160 deg F	Baseline document
Conveyor speed	Common operator interface/+/- 0.1 fpm	1 to 3 fpm	Baseline document
Spray zone temperatures	Common operator interface/+/- 1 psi	40 to 50 psi and 170 to 190 psi **	Baseline document
PWB plating style	N/A	Sn/Pb plate and fused	ST1E0 experiment and final run
FPD lead skew	+/- 1 mil	as received	Engineering drawing
FPD lead aging	N/A	less than 1 yr	ST2E0 experiment

Table 1. concluded

Process Variable Details

PWB aging	N/A	less than 1 yr	ST1E0 experiment
Package type	N/A	NTK	ST4E0 experiment
Solder paste aging	N/A	less than 6 months	ST1E0 experiment
Belly-to-toe dimension	surface gauge +/- 0.2 mils	11 +/- 1 mil	ST2E0 experiment
Flux density	Sensby system +/- 0.001	0.885 to 0.895	Baseline document
Tinning solder temperature	Robot cntrlr +/- 1 deg F	490 to 510 F	MIL-STD-2000
Wave smoothness	Visual	0 to minor turbulence	Baseline document
Nitrogen flow	Flow meter +/- 1 scfh	40 and 100 scfh	ST1E0 experiment
Coplanarity	Microscan +/- 0.1 mil	+/- 4 mils	ST4E0 experiment
Toe-to-toe	as formed	1.225 +/- 0.005 in	ST4E0 experiment
Toe angle	as formed	0 +/-15 deg	ST4E0 experiment
Toe burrs	as formed	1x lead thick (5 mils)	ST4E0 experiment
Solder paste open time	timer +/- 1 sec	less than 3 hours	ST5E2 experiment
Fiducial pad stretch	+/- 0.1 mils	+/- 3 mils from A/W dim	ST5E2 experiment
Placement force	force gauge +/- 1 gm	5 to 50 gm per lead	ST5E2 experiment
PWB thickness	dial microm. +/- 0.1-mil	58 to 68 mils	ST5E2

Table 2

Response Variable Details

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Visual cleanliness	Comparison to visual standards/ +/- 1 unit	1 to 5 units	MIL-P-28809
Ionic cleanliness	Ionic contamination tester/+/- 1 ugm NaCl/sq in	0 to 10 ugm NaCl/sq in	MIL-C-28809
Solder joint roughness	Comparison to visual standards/ +/- 1 unit	1 to 5 units	MIL-P-28809
Solder joint reflectance	Comparison to visual standards +/- 1 unit	1 to 5 units	MIL-P-28809
Heel fillet height	Microscope with filar +/- 0.1-mil	0 to 100% of calf length	MM 3-23
Soldered lead dewetting	Microscope with particle counting grid	0 to 5 % of soldered area	MM 3-22

Table 2

Response Variable Details

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Solder balls	Microscope with filar +/- 0.1-mil	5 mils, max	MM 5-6
FPD lead-to-pad alignment	coordinate measuring, scope with filar/ +/- 0.1-mil	+/- 25% of lead width (+/- 5 mils) center-to-center misregistration, max.	MIL-STD-2000
LCC overhang	same	+/- 25% of castellation width (+/- 8.8 mils center-to-center misregistration, max.	

II. MATERIALS AND SUPPLIES

PWB.-

Qty	PIN	Description
8	786582/C, Rev B	Sn/Pb plate and fused

Components.-

Qty	PIN	Description
24	IMKX3F1-4546AA	132-pin, NTK, FPD package
144	PB-C85124	20-pin, LCC
80	PB-44823	28-pin, LCC
64	IRK32F1-200B	32-pin, RLCC
48	49BCP	CWR06, chip capacitor

Solder Paste.-

Multicore SN62RM92A90 — Multicore Solders
Cantiague Rock Road
Westbury, NY 11590

Stencil.-

T786582-6/1 — 6/12 thickness

Dry Film Solder Mask.-

Vacrel 8100, for 6-mil build — E.I. DuPont de Nemours
Wilmington, DE

Solder Mask Artwork.-

T786582-5/1 — 0.020-in diameter standoff pattern

Miscellaneous.-

Palette knife, plastic — Holbein

Bristle brush

Shamis 99-150 cleaning cloth	Affiliated Manufacturers, Inc.
96244 Protective gloves	Jones Associates

Solvents.-

Isopropyl alcohol	TT-I-335
1,1,1-Trichloroethane	MIL-T-81533

III TOOLS AND EQUIPMENT

General purpose stereoscope, 0.7X to 3X zoom with an American Optical No. 424, 10X, filar eyepiece

Screen Printer No. 24-ASP	MPM Corporation 10 Forge Park Franklin, MA 02038
Malcom Viscometer	Austin American Technology 12201 Technology Blvd. Austin, TX 78727
Gelzer Robot	Gelzer Systems Westerville, OH
In-Line Cleaner, CBL-18	Baron Blakeslee 2001 N. Janice Ave. Melrose Park, IL 60160
Vapo-Kleen Stencil Cleaner, Model No. 1110187	Universal Electronics, Inc.
Microscan	CyberOptics Corp. 2331 University Ave. S.E. Minneapolis, MN 55414
IR Reflow Oven, Model SMD 722	Vitronics Corp 40 Forge Haymarket, NH
Ionic Contamination Tester Model ICOM 4000	Westek, Inc. 400 Rolyn Place Arcadia, CA 91006
Coordinate Measuring Machine CMM	microVu 7750 Bell Rd Windsor, CA 95492

IV PROCEDURE

A. Eight Piece Confirmation Run

Note: Select 8 786582/C, Rev B PWBs and serialize them as 6101 through 6108.

1. Clean the eight, serialized PWBs in the in-line solvent cleaner.

2. Clean all components in the Vapo-Kleen stencil cleaner

3. Set up the 24-ASP stencil printer with an appropriate reference PWB.

4. Set up the component preparation and placement sides of the Gelzer robot.

5. Set up the Vitronics SMD 722 IR reflow machine with nitrogen 'on' and the '210 EMPI' profile (No. 34).

6. Set up the CBL-18 in-line cleaner with the appropriate PWA cleaning process profile (Profile No.1).

   Assure this setup by profiling the oven and comparing the profile to that accepted for the ST1E0 experiment.

7. Stencil print PWB SN 6101 using the Multicore solder paste.

8. Place the printed PWB in the Gelzer robot load station and form, trim, tin, and place the selected FPD and all other components using the nominal placement values for all components. Other than the CWR06 parts, chip components need not be placed.

9. Reflow the PWA subassembly in the IR reflow oven using nitrogen and the 210 EMPI profile (No. 34).

10. Clean the PWA in the CBL-18 in-line cleaner using the PWA cleaning profile no. 1.

11. Repeat steps 3. through 10., inclusive, until all 8 PWBAs have been completed for this confirmation run experiment.

V. RESPONSE DATA

A. Visual Cleanliness

1. Scan the entire PWA and compare and rank the cleanliness against the visual standards presented in Figure 2. Record the data in Table 4.

B. Ionic Contamination

1. Measure the cleanliness of the PWA using the Westek ICOM 4000. Record the data in Table 4.

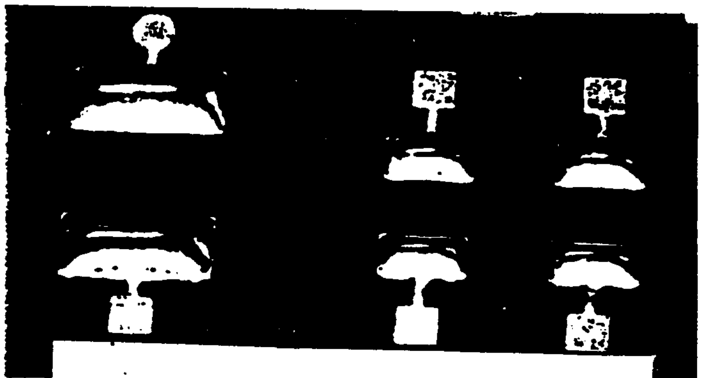
Figure 2

Visual PWA Cleanliness Standards

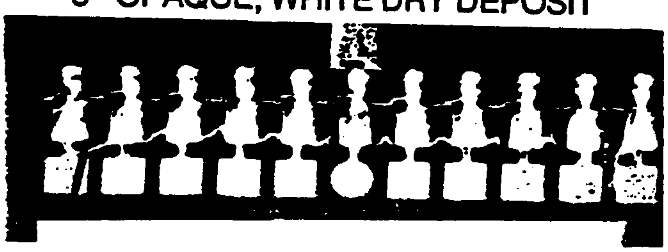
0 NO CONTAMINATION VISIBLE REGARDLESS OF LIGHT OR MAGNIFICATION (MAX 30X)

1 EDGE OF VISIBILITY, TRANSPARENT DRY RESIDUE

2 EASILY VISIBLE, TRANSPARENT DRY RESIDUE



3 OPAQUE, WHITE DRY DEPOSIT



4 LIGHT DEPOSIT OF WET FLUX

5 HEAVY DEPOSIT OF WET FLUX

Table 4

Data Collection Table for PWA Cleanliness

PWB SN	CLEANLINESS		COMMENTS
	VISUAL, 0-5	IONIC, Mg NaCl/in2	
3001			
3002			
3006			
3007			
3011			
3012			
3016			
3017			
3003			
3004			
3008			
3009			
3013			
3014			
3018			
3019			

C. FPD Lead-to-Pad Alignment

1. Measure the lead-to-pad alignment as shown in Figure 3 and record the data in Table 5.

D. LCC Termination-to-Pad Alignment

1. Measure the termination-to-pad alignment for the 20-, 28-, and 32-pin LCC packages as shown in Figure 4. Record the data for the packages shown in the applicable Tables 6 through 8.

E. Solder Joint Reflectance

1. FPDs

a. Measure the solder joint reflectance of the U01 and U20 FPD package pins and record the results in Table 9. Use the visual standards as presented in Figure 5.

2. LCCs

20-Pin LCCs

a. Measure the solder joint reflectance of the U04, U19, and U33 LCC package terminations and record the results in Table 10. Use the visual standards as presented in Figure 5.

28-Pin LCCs

a. Measure the solder joint reflectance of the U22, U30, and U32 LCC package terminations and record the results in Table 11. Use the visual standards as presented in Figure 5.

32-Pin LCCs

a. Measure the solder joint reflectance of the U07, U17, and U34 LCC package terminations and record the results in Table 12. Use the visual standards as presented in Figure 5.

F. Solder Joint Roughness

1. FPDs

a. Measure the solder joint roughness of the U01 and U20 FPD package pins and record the results in Table 9. Use the visual standards as presented in Figure 6.

2. LCCs

20-Pin LCCs

a. Measure the solder joint roughness of the U04, U19, and U33 20-pin LCC package terminations and record the results in Table 10. Use the visual standards as presented in Figure 6.

28-Pin LCCs

a. Measure the solder joint roughness of the U22, U30, and U32 28-pin LCC package terminations and record the results in Table 11. Use the visual standards as presented in Figure 6.

32-Pin LCCs

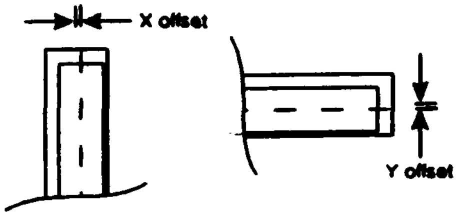
a. Measure the solder joint roughness of the U07, U17, and U34 32-pin LCC package terminations and record the results in Table 12. Use the visual standards as presented in Figure 6.

G. FPD Solder Joint Heel Fillet Height

1. Measure the solder joint heel fillet height as shown in Figure 7 for the U01 and U20 FPD component leads. Record the data in Table 9. Data is reported as a percent of the total 'calf' length.

Figure 3

FPD Lead-to-Pad Offset Depiction



FPD Offset Measurement

Table 5

Fine Pitch Device Placement Misregistration

PWB S/N________________________

U 01

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
2			
35			
68			
101			

U 20

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
2			
35			
68			
101			

Figure 4

LCC Castellation-to-Pad Offset Depiction

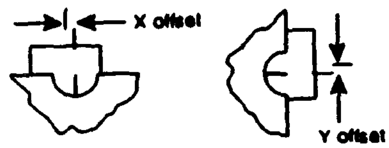


Table 6

20-Pin LCC Placement Misregistration

PWB S/N________________

U 04

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
3			
8			
13			
18			

U 19

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
3			
8			
13			
18			

U 33

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
3			
8			
13			
18			

Table 7

28-Pin LCC Placement Misregistration

PWB S/N________________

U 22

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
11			
18			
25			

U 30

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
11			
18			
25			

U 35

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
11			
18			
25			

Table 8

32-Pin LCC Misregistration

PWB S/N____________

U 07

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
13			
20			
29			

U 17

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
13			
20			
29			

U 34

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
13			
20			
29			

Figure 5

Reflowed Solder Joint Reflectance

MAGNIFICATION 30X

a. (MM 3-4, top) Rank=1

b. (MM 1-8, middle) Rank = 2

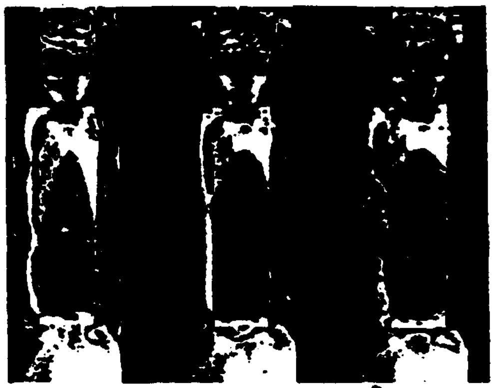
c. (MM 1-6, top) Rank=3

d. (MM 3-22, top) Rank = 4

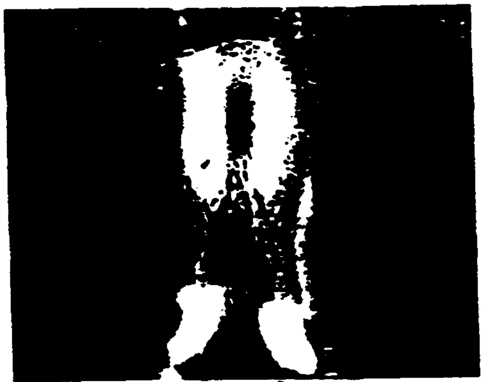
e. (MM 1-11, bottom) Rank = 5

Figure 6

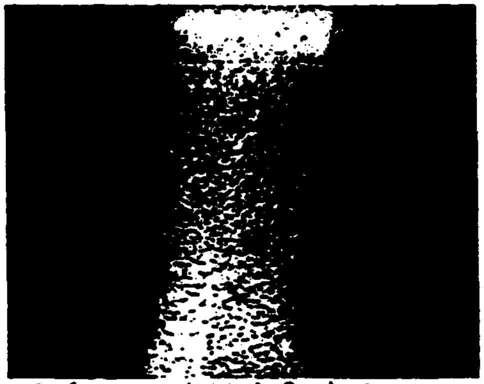
Reflowed Solder Joint Roughness



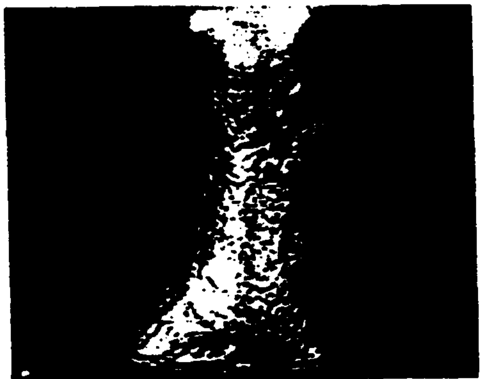
a. (MM 3-42, mid-left) Rank=1



b. (MM 3-41, bt-rt) Rank=2



c. (MM 3-41, bt lt) Rank=3



d (MM 3-41, top rt) Rank=4

e (MM 3-41, md rt) Rank=5

Figure 7

FPD Solder Joint Lead Heel Fillet

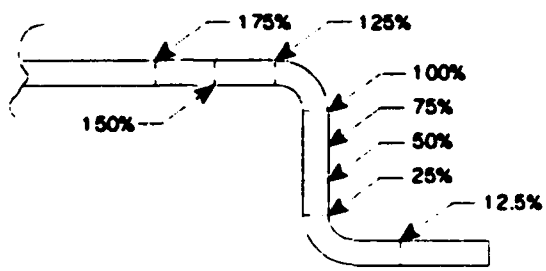


Table 9

FPD Solder Joint Appearance

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
01	130				
	131				
	132				
	001				
	002				
	003				
	007				
	064				
	065				
	066				
	067				
	068				
	069				
20	130				
	131				
	132				
	001				
	002				
	003				
	007				
	064				
	065				
	066				
	067				
	068				
	069				

Table 10

20-Pin LCC Solder Joint Appearance

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
04	001				
	002				
	003				
	004				
	005				
	006				
	007				
	011				
	012				
	013				
	014				
	015				
	016				
19	001				
	002				
	003				
	004				
	005				
	006				
	007				
	011				
	012				
	013				
	014				
	015				
	016				

Table 10. concluded

20-Pin LCC Solder Joint Appearance

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
01	001				
	002				
	003				
	004				
	005				
	006				
	007				
	011				
	012				
	013				
	014				
	015				
	016				

Table 11

28-Pin LCC Solder Joint Appearance

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
22					
	002				
	003				
	004				
	005				
	006				
	007				
	016				
	017				
	018				
	019				
	020				
	021				
30					
	002				
	003				
	004				
	005				
	006				
	007				
	016				
	017				
	018				
	019				
	020				
	021				

Table 11. concluded

28-Pin LCC Solder Joint Appearance

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
	002				
	003				
	004				
	005				
35	006				
	007				
	016				
	017				
	018				
	019				
	020				
	021				

Table 12

32-Pin LCC Solder Joint Appearance

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
07					
	002				
	003				
	004				
	005				
	006				
	007				
	018				
	019				
	020				
	021				
	022				
	023				
17					
	002				
	003				
	004				
	005				
	006				
	007				
	018				
	019				
	020				
	021				
	022				
	023				

Table 12, concluded

32-Pin LCC Solder Joint Appearance

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
	002				
	003				
	004				
	005				
34	006				
	007				
	018				
	019				
	020				
	021				
	022				
	023				

H. FPD Lead Dewetting

1. Examine the leads of the U01 and U20 FPD packages at 10x and map the dewet areas onto a grid. Record the percent dewet in Table 13. See Figure 8 for an example of a mapping grid.

I. FPD Solder Joint Volume

1. Examine the solder joints of the U01 and U20 FPD packages at 10x and rate the volume of the solder in the solder joints by comparing them against the standards shown in Figure 9. Record the results in Table 13.

J. Solder Balls

1. Transmission X-ray examine the assembled PWB after the in-line cleaning process. and locate the largest solder ball. Measure the diameter of the solder ball using a microscope with a filar eyepiece. Record the results in Table 14.

Table 13

FPD Solder Joint Volume and Dewetting

PWB SN:

REF DES	LEAD NO.	SOLDER		COMMENTS
		VOLUME	DE-WETTING	
01	130			
	131			
	132			
	001			
	002			
	003			
	007			
	064			
	065			
	066			
	067			
	068			
	069			
20	130			
	131			
	132			
	001			
	002			
	003			
	007			
	064			
	065			
	066			
	067			
	068			
	069			

Figure 8

FPD Soldered Lead Dewetting

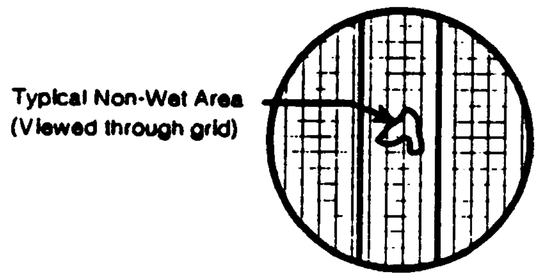
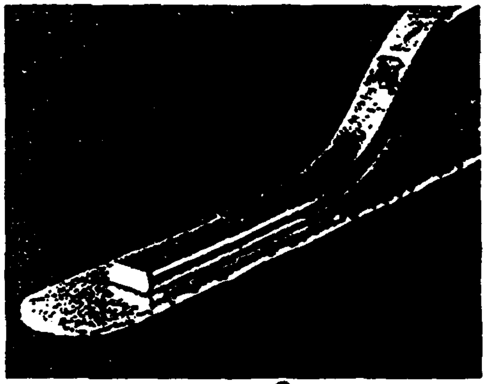
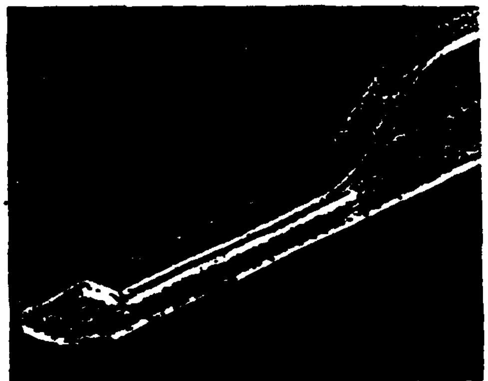


Figure 9

Reflowed Solder Joint Volume

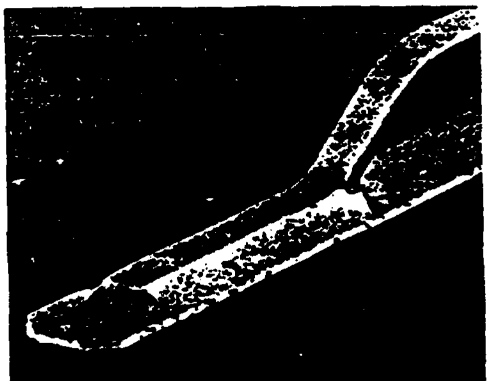


a.(MM3-21, bot Rank=1

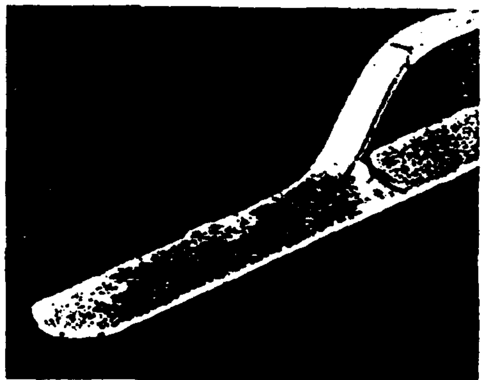


b. (MM3-21, bot mid) Rank=2

MAGNIFICATION 8X



c. (MM3-21, top) Rank=3



d. (MM3-22, bot mid) Rank=4

e. (MM3-22, bot) Rank=5

Table 14

Solder Ball Data

PWB SN	Diameter of largest solder ball

VI. DATA REDUCTION

1. Using the data gathered by this experiment, determine the variability for each of the responses measured.

2. This variability will be used to derive Cpk and yield data.

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