RECEIVED BY RTIE SEP 2 1974

**Kansas City
Division**

RESERVATION OF TITLE IS UNLIMITED

DISCLAIMER

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

DISCLAIMER

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

UC-38

RECEIVED BY DTIC SEP 1 1971

MASTER

VISUAL AND
ELECTRICAL
INSPECTION OF
MINIATURE RADARS

BDX-613-451

July, 1971

Project Leader:
W. P. Beck
Department 842

Project Team:
J. W. Davis
C. W. McTyer
R. J. Blazek

PDO 6984713
Final Report

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

Technical Communications

**Kansas City
Division**

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

This report was

Prepared by:

Walter P. Beck

W. P. Beck
D/842

Reviewed by:

J. A. Peters

J. A. Peters
D/842

Approved by:

T. A. Wiley

T. A. Wiley
D/842

THE BENDIX CORPORATION
KANSAS CITY DIVISION
KANSAS CITY, MISSOURI

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

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

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

ABSTRACT

Development of inspection techniques for miniature electronic assemblies included consideration of a scanning electron microscope for in-process inspection, determination of accuracies that can be maintained in drilling pc boards, establishment of component identification methods which are less dependent upon markings, consideration of visual-defect histories as guides for electronic packaging, setting guidelines for mechanical piecepart tolerances, and definition of inspection requirements for microcircuit assemblies. A piecepart tolerance guide and a preliminary inspection outline were developed. The inspection outline will provide a checklist for Bendix microcircuits as that technology advances.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

CONTENTS

Section	Page
SUMMARY	13
DISCUSSION	15
SCOPE AND PURPOSE	15
ACTIVITIES	16
<u>Scanning Electron-Beam Microscope</u>	16
<u>Tape Controlled Drilling Accuracy</u>	16
<u>Visual Defect Analysis</u>	18
<u>Component Verification</u>	49
<u>Machining Tolerances</u>	52
<u>Microcircuit Inspection Guidelines</u>	53
ACCOMPLISHMENTS	54
APPENDICES	
A. COMPONENT PROCESSING REQUIREMENTS FOR COMPONENT KITS	A-1
B. PIECEPART TOLERANCE GUIDE	B-1
C. MICROCIRCUIT INSPECTION OUTLINE	C-1
DISTRIBUTION	C-11

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

ILLUSTRATIONS

Figure		Page
1	Group 1 Defects Per Solder Joint Versus Mounting Area . . .	22
2	Group 1 Defects Per Component Versus Number of Components Per Assembly	23
3	Group 1 Defects Per Component Versus Components Per Square Inch	24
4	Group 1 Soldering Reject Rate Versus Joints Per Square Inch	25
5	Group 1 Component Reject Rate Versus Components Per Square Inch	26
6	Group 2 Defects Per Solder Joint Versus Mounting Area . . .	27
7	Group 2 Defects Per Component Versus Number of Components Per Assembly	28
8	Group 2 Defects Per Component Versus Components Per Square Inch	29
9	Group 2 Soldering Reject Rate Versus Joints Per Square Inch	30
10	Group 2 Component Reject Rate Versus Components Per Square Inch	31
11	Group 3 Defects Per Solder Joint Versus Mounting Area . . .	32
12	Group 3 Defects Per Component Versus Number of Components Per Assembly	33
13	Group 3 Defects Per Component Versus Components Per Square Inch	34
14	Group 3 Soldering Reject Rate Versus Joints Per Square Inch	35
15	Group 3 Component Reject Rate Versus Components Per Square Inch	36

ILLUSTRATIONS

Continued

Figure		Page
16	Group 4 Defects Per Solder Joint Versus Mounting Area . . .	37
17	Group 4 Defects Per Component Versus Number of Components Per Assembly	38
18	Group 4 Defects Per Component Versus Components Per Square Inch	39
19	Group 4 Soldering Reject Rate Versus Joints Per Square Inch	40
20	Group 4 Component Reject Rate Versus Components Per Square Inch	41
21	Group 5 Defects Per Solder Joint Versus Mounting Area . . .	42
22	Group 5 Defects Per Component Versus Number of Components Per Assembly	43
23	Group 5 Defects Per Component Versus Components Per Square Inch	44
24	Group 5 Soldering Reject Rate Versus Joints Per Square Inch	45
25	Group 5 Component Reject Rate Versus Components Per Square Inch	46

TABLES

Number		Page
1	Visual Defect Summary, Products A and B, January 5, 1970 to July 5, 1970	19
2	Visual Defect Summary, Products C and D, January 1, 1969 to August 29, 1970	20
3	Significance Tests of Confidence Curves	47
4	Sets of Variables in Regression Analysis	48
5	Significant Correlation Percentages	49
B-1	Machining Operations	B-5
B-2	Results of Mechanical Inspection	B-9
C-1	Microcircuit Substrate Receiving Inspection	C-5
C-2	Microcircuit Substrate Metallization Inspection	C-7
C-3	Microcircuit Substrate Machining Inspection	C-9

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

SUMMARY

The project was conducted to develop and define inspection criteria for application to present and future electronic assemblies and to establish quality guidelines for production designs of similar assemblies. Project work completed includes:

- Evaluation of the scanning electron-beam microscope for feasibility as a production-inspection method;
- Determination of hole-location precision in printed circuit boards drilled with numerical tape controlled grid drills;
- Studies of production visual-defect histories;
- Determination of new methods of component verification that are less dependent upon component markings;
- Establishment of good, but not necessarily the best obtainable, production tolerance levels and expected yields for the more common machining operations; and
- Preparation of a preliminary inspection outline for a microelectronic assembly.

A long-range endeavor to evolve a plan for computerized automatic testing of electronic subassemblies was not completed. A literature search was conducted, and the information gathered is being retained for possible future use.

Sample preparation and setup time for the scanning electron-beam microscope (SEM) are not long, but mechanical alteration of the sample is required. At minimum magnification (20X), approximately a five-centimeter-square area is projected on a four-inch-square screen. By use of X and Y transversals up to 10 and 25 millimeters, respectively, large areas may be scanning. Visual reading is time consuming and requires extensive training. A permanent photographic record is easily obtained after a problem has been localized. The SEM was not considered suitable for in-process inspection because it requires that the part be altered; however, it might be a valuable aid for failure analysis and process prove-in.

Hole positions on printed circuit boards drilled on tape-controlled machines can be held within a positional tolerance of 0.0045 inch. If the holes are modified by tin/lead plating and hot-fat fusing, a relaxed positional tolerance of 0.0128 inch is required.

A review of visual defects of electronic packages of various complexities and different packaging methods was made to determine guides to package size, style, and complexity for future product applications. Clear-cut design-center values did not evolve from the production defect histories; however, plots of product features do reflect trends that may be useful in packaging future products. Computer-plotted graphs show these plots outlined by their respective confidence envelopes.

Exploration of the history of component-identification problems shows that production inspection has always relied upon visual techniques to identify components in assemblies. Although steps have been taken to improve the overall quality of component markings, legibility and permanence still varies from one component family to another. The conclusions were that color-band marking provides more-permanent and more-positive visual identification than the alphanumeric marking methods now commonly used; that component kitting will provide for inspection of components before the markings can be obliterated by cleaning or other processing operations; that special assembly areas for installation of frequently-used components will lessen the burden of tedious visual inspection; and that use of automatic insertion and verification machines (when applicable) would essentially eliminate the necessity for visual inspection for component identification and verification.

Average production dimensional tolerancing for the more-common machining operations was studied to evolve a tolerancing guide which is primarily intended as an aid to the electrical-product engineer in determining drawing callouts. The guide was constructed from electronic-package piecepart-inspection data. Concentrated processing effort and the use of higher-precision machines can yield tighter tolerance control when necessary.

The microelectronic inspection outline that was developed includes a checklist of new inspection activities that are likely to be required with increased use of microcircuit assemblies. The principal uses of the inspection outline are for receiving inspection of alumina substrates, in-process inspection of thin-film metallized substrates, receiving inspection of beam-lead devices, and microelectronic-assembly operations.

The equipment capabilities given in this report were not determined during the course of this project, nor were any test data generated. The data used for this work were derived from other investigations and/or from scheduled production operations. The data analyses were made to assist in determining yields that can be expected when specific tolerances are required, and to establish criteria that is pertinent to the inspection of specific types of parts and products. While some of the information presented might be useful to engineers who are responsible for initial product designs, it is specifically intended as an aid in determining the manufacturability of products assigned to Bendix manufacturing facilities and in manufacturing those products to previously established requirements. The component-kitting procedure that is presented is not complete and has not been released for production.

DISCUSSION

SCOPE AND PURPOSE

This project was guided by the problems common to past and present electronic assembly operations and those expected in future electronic assemblies, especially those associated with microcircuit components and thin-film technology.

The project deals with ways to decrease inspection problems by providing quality guidelines for design and manufacture of electronic assemblies such as radars, analyzers, and timers. Initially, the work was to involve both visual and electrical inspection problems; however, the work was terminated at about the halfway point, leaving electrical inspection problems unsolved. Better ways of confirming the integrity of electronic assembly were sought, particularly, methods that minimize the need for part markings. The scanning electron microscope (SEM) was employed on assembly samples of beam-lead devices to determine the feasibility of the SEM as an in-process inspection tool for thermal-compression lead bonds. A study was made of hole-location precision on printed circuit boards drilled on numerically-controlled grid drills. Hole locations were analyzed after drilling and after subsequent plating operations. Methods of dealing with the conflict between marking legibility and assembly cleaning procedures were proposed, and a processing specification was developed for use with a component kitting technique.

Visual-reject histories of current production items were statistically analyzed to evolve packaging guidelines to minimize visual rejects. Machined parts inspection data and processing inputs were used to develop a tolerance guide for the more-common machining operations. This guide is primarily intended for use by electronic engineers for determining mechanical drawing callouts. Because microcircuit fabrication is relatively new at Bendix, a preliminary inspection outline was developed to provide a checklist for both present and future inspection needs.

The capabilities and the data given in this report were derived from other development efforts and/or scheduled production operations. Only the analytical aspects that are pertinent to the establishment of manufacturing and inspection criteria were derived from this project. While it is possible that some of the information presented might be useful to engineers who are responsible for new-product designs, it is specifically intended as an aid in determining the manufacturability of products assigned to Bendix manufacturing facilities and in manufacturing those products to previously established requirements. An incomplete procedure (in standard Bendix procedure format) was prepared to illustrate some of the information that will be required when using a component-kitting technique to facilitate component identification and verification.

ACTIVITY

Scanning Electron-beam Microscope

Three samples were viewed on the Bendix SEM at a magnification of 500 times. The samples were approximately one-inch-square thin-film substrates with three beam-lead devices thermocompression bonded on one side of each substrate. The samples were SEM inspected for characteristics of the beam-lead bonds and after removal of the beam leads for determination of the most-probable mode of structural failures at the bonds. The 143,000 times magnification capability of the SEM is seldom used. A 10,000 times enlargement is the normal maximum, and less than 3,000 times is the typical usage. The SEM has potential for failure analysis and process prove-in to determine the location and nature of contaminants, weak structures, flaws in thin-film patterns, and poor bonds. However, the SEM is not suitable as an in-process inspection tool, since removal of a metallic film applied to the sample to allow electron beam scanning alters the part.

The sample preparation and machine setup times for the SEM are not long, but visual reading is time consuming and requires extensive training. At minimum magnification (X20), approximately a five-centimeter-square area is projected on a four-inch-square viewing screen. By manual X and Y traversing up to 10 and 25 millimeters respectively, larger areas may be scanned. Once a problem area is pinpointed, a permanent photographic record is easily obtained.

Tape-Controlled Drilling Accuracy

Certification data for the machining tape of a printed circuit board was studied. The board chosen was 1/32-inch-thick laminated plastic, with two-ounce copper cladding on both sides of the board. The board was processed in the normal Bendix manner, on a standard panel having two tooling holes spaced away from the printed pattern. For the case studied, eight circuit boards were obtained from each panel.

Tape certification at Bendix consists of coordinate inspection of hole locations on all parts of five panels in accordance with the drawing requirements. It is performed on pc boards prior to plating and etching. Approval for the tape master, based on the part inspection results, is granted by the quality process engineer, and the tape is serialized and identified as approved. Approval is granted for a period of 6 months, not to exceed 1000 drilling cycles on the tape.

The machine used at BKC for pc-board tape-controlled hole drilling is the Gardner-Denver grid drill. The capabilities of the machine and fixturing allow two panels to be drilled on each setup and uses four spindles (four different hole sizes) for hole sizes of 1/8-inch diameter and smaller. Typical drilling time, after setup, is one minute for 400 holes.

A newer Gardner-Denver grid drill which allows for setup of four panels is now available. The new machine has nine drilling spindles, and will drill holes of 1/4-inch diameter and smaller. This machine, when fully utilized, will require fewer tapes to complete board drilling, will in many instances eliminate the need for subsequent drilling operations for holes (e. g. mounting holes) larger than 1/8-inch in diameter, and will protect against schedule failures when the other Gardner-Denver is out of service for maintenance or repair. The drilling accuracy specified for both machines by the Gardner-Denver Company is ± 0.005 inch of the taped input value.

Layout inspection is performed for tape certification. The Cord-ax coordinate measuring machine is most often used (as was the case for the subject board). The vendor-specified accuracy for the Cord-ax is ± 0.0003 inch. The measured coordinates of the holes are computer compared (manual coordinate readout also available) to the nominal drawing coordinates for the holes. The drawing coordinates are provided via a tape input to the computer and deviations of measured locations from drawing locations are obtained. Improved measurement accuracy can be obtained on the Boise coordinate measuring machine, primarily because of its air-bearing, probe carriage design. The Boise, however, is slower in operation, since the settling time of the electronic coordinate indicators is significantly longer than on the Cord-ax machine and positional deviation must be calculated manually.

The tape certification data from 40 pc boards was reviewed. Tape certification hole data are generated from drilled, but unetched and unplated panels; therefore, these data do not indicate the hole-location accuracy of finished parts. The hole center misplacement of the hole with the greatest deviation from true position was 0.0011 inch, and standard deviation (sigma) was 0.0005. The average mislocation of all hole centers was 0.000005 inch on the positive X axis and 0.000012 inch on the positive Y axis. The true position deviation for all holes (corresponding to a diameter position tolerance) averaged 0.0018 inch, with a sigma of 0.0009 inch.

A data analysis was made of another NC-drilled pc board, but was inspected after completion of all processing steps, including through-hole plating. Twenty-five of these boards were analyzed. The average misplacement of the hole with the greatest deviation from true position was 0.0029 inch, and the standard deviation was 0.0021. The average misplacement of all hole centers was 0.0008 inch on the positive X axis and 0.00014 on the positive Y axis. The true-position deviation of all holes (corresponding to a diameter positional tolerance) averaged 0.0044 inch, with a sigma of 0.0028.

Visual Defect Analysis

The visual defect histories of two electronic timers and two electronic altimeters were reviewed to determine desirable packaging parameters. The subassemblies selected for comparison are summarized in Tables 1 and 2 for characteristics of solder joint density and component density.

Comparison studies were made via statistical computer programs to evolve smoothed curves with curve-confidence envelopes. A computer regression analysis was employed for the most significant relationships to establish order-of-concern for design layouts. The assemblies were group analyzed as follows:

- Group 1: Eleven subassemblies of an electronic timer, covering twenty month's production;
- Group 2: Subgroup of 1, consisting of six subassemblies;
- Group 3: Four subassemblies of an electronic altimeter, covering twenty month's production;
- Group 4: Seven subassemblies of an electronic altimeter, covering six month's production; and
- Group 5: Nineteen subassemblies including those of groups 2, 3, 4 and two subassemblies of an electronic timer covering six month's production.

The analysis made the following comparisons:

- Defects per solder joint versus mounting area;
- Defects per component versus number of components per assembly;
- Defects per component versus components per square inch;
- Solder reject rate versus joints per square inch; and
- Component reject rate versus components per square inch.

The values compared in the analysis were obtained from Tables 1 and 2. Defects-per-solder-joint is the total defects charged to soldering operations divided by the total number of solder joints examined by inspection. Similarly, defects-per-component only relates the ratio of total component installation errors to the total components inspected. The mounting area is the printed circuit board area used for mounting components. In a few instances it is the area of both sides of the printed circuit board.

Table 1. Visual Defect Summary, Products A and B, January 5, 1970 to July 5, 1970

Solder Information						Component Information						Misc. Information	
Joints Insp.	Total Def.	Joints Per Def.	Joints Per Assy.	Joints Per In ²	% of Def. Via Sold.	Comps. Insp.	Total Def.	Comps. Per Def.	Comps. Per Assy	Comps. Per In ²	% of Def. Via Comps.	Mounting Area (In ²)	Total Vis. Def.
6,864	0	∞	12	7.56	----	3,432	0	∞	6	3.78	----	1.586	2
9,270	13	713	15	8.79	40.6	4,326	8	541	7	4.10	25.0	1.706	32
10,470	22	476	10	10.29	41.5	4,188	6	698	4	4.11	11.3	0.971	53
28,246	26	1086	58	21.03	35.6	12,662	5	2532	26	9.43	6.8	2.757	73
38,482	16	2405	71	12.71	16.5	17,344	14	1239	32	5.72	14.4	5.586	97
21,650	7	3093	50	15.41	14.3	9,093	13	699	21	6.47	26.5	3.244	49
3,906	36	109	14	10.44	76.6	1,953	1	1953	7	5.22	2.1	1.340	47
224,580	142	1582	380	26.24	31.6	86,877	54	1609	147	10.15	12.0	14.478	449
172,216	344	500	418	35.03	24.6	75,396	74	1019	183	15.33	1.8	11.932	768
97,728	92	1062	192	9.55	46.0	7,126	10	713	14	2.57	5.0	5.436	200
25,670	35	733	34	-----	27.3	3,775	2	1887	5	10.00	1.5	0.500	128
62,780	125	502	86	102.25	57.6	4,380	6	730	6	7.13	2.7	0.841	217
29,264	189	155	118	-----	41.4	1,488	14	106	6	-----	3.1	-----	456
43,011	15	2867	81	-----	8.0	26,736	25	285	56	3.60	13.3	15.553	188
33,201	70	474	93	-----	26.3	23,562	26	906	66	4.14	9.8	15.904	266
19,440	60	320	80	-----	17.4	12,879	40	322	53	1.62	11.6	32.520	344
1,554	8	194	6	-----	53.3	1,295	0	∞	5	1.69	-----	2.946	15
9,024	12	752	16	-----	16.9	11,280	6	1880	20	7.35	8.4	2.720	71
8,416	14	601	16	4.83	18.4	526	0	∞	1	0.30	-----	3.306	76
11,925	12	160	25	7.56	30.7	3,816	5	763	8	2.41	12.8	3.306	39
9,641	6	1607	31	6.38	24.0	933	1	933	3	0.61	4.0	4.857	25

Table 2. Visual Defect Summary, Products C and D, January 1, 1969 to August 29, 1970

Solder Information						Component Information						Misc. Information	
Joints Insp.	Total Def.	Joints Per Def	Joints Per Assy	Joints Per In ²	% of Def. Via Sold.	Comps. Insp.	Total Def.	Comps. Per Def.	Comps. Per Assy	Comps. Per In ²	% of Def. Via Comps.	Mounting Area In ²	Total Vis. Def.
328,700	250	1,315	173	5.6	44.9	131,100	10	13,100	69	2.5	1.8	30.70	556
227,312	128	2,166	224	5.6	33.4	110,182	12	9,181	89	2.2	3.3	39.95	361
80,920	75	1,079	68	4.0	31.3	27,370	36	788	23	1.4	15.0	17.00	240
286,342	271	1,056	226	8.3	38.2	117,831	30	3,927	93	3.4	4.2	27.20	709
80,882	4	20,220	74	37.4	12.5	32,790	5	6,558	30	15.2	15.6	1.98	32
87,375	1	87,375	75	34.7	10.0	34,950	3	11,650	30	13.9	30.0	2.16	10
42,106	0	∞	37	24.7	----	17,070	0	∞	15	10.0	----	1.50	6
81,092	0	∞	76	26.2	----	34,144	2	17,072	32	11.0	50.0	2.90	4
73,360	2	36,680	70	40.9	10.5	30,392	5	6,078	29	16.9	26.3	1.71	19
61,974	6	10,329	66	34.5	9.8	24,414	0	∞	26	13.6	----	1.91	61
53,568	0	∞	27	11.4	----	15,872	0	∞	8	3.4	----	2.36	28
60,435	1	60,434	51	31.7	20.0	26,070	1	26,070	22	13.7	20.0	1.61	5
291,522	5	58,304	66	34.2	10.0	97,188	5	19,473	22	11.4	10.0	1.93	50
75,855	7	10,836	65	33.7	28.0	25,674	3	8,588	22	11.4	12.0	1.93	25
138,408	0	∞	158	34.7	----	54,312	4	13,578	62	13.6	25.0	4.55	16

Components-per-square-inch is the number of components for an assembly divided by the component mounting area. Similarly, joints-per-square-inch relates the number of solder joints for an assembly to the mounting area. Solder-reject-rate and component-reject-rate are the percentages of the total defects caused by soldering operations or component installation, respectively.

That similar comparisons for the subassembly groups do not yield a consistent trend is evident from the graphs. It was expected that variations within manufacturing and inspection would affect the results of the defect study. Factors in the accuracy of the data which apply to both fabrication and inspection are: abilities of workers; physical makeup of the task and surroundings; and the organization and methods which define the job.

A controlled experiment to determine inspection accuracy was reported by Douglas H. Harris of the Autonetics Division of North American Rockwell Corporation. Mr. Harris concluded from the experiment that:

- Complexity of an inspection task negatively affects inspection performance;
- With reductions in defect rate, the inspection accuracy decreases and the false defects reported increases;
- Where repeated inspections are made, inspection accuracy increases; and
- Although vigilance is difficult to evaluate, observed trends indicate that inspection accuracy decreases with length of time at the inspection task, and less change in vigilance takes place on the more complex inspection tasks.

Figures 1 through 25 show the data points plus plots of best fit linear curves evolved by a least-square data analysis. Confidence envelopes for the fitted linear curve are shown outward for the 50-percent, 80-percent, and 95-percent confidence levels. In addition, significance tests were made for the slope of the linear curve at these confidence levels. The results of the significance tests are shown in Table 3. The significance test checks a confidence interval about the coefficient of $\bar{X}$ in the regression equation. If this interval contains the element zero, the plot at the tested confidence level is not considered significant. The significance test takes into account the sizes of the data sample; hence, closely grouped plots are not always found to be significant.

Figure 1. Group 1 Defects Per Solder Joint Versus Mounting Area

Figure 2. Group 1 Defects Per Component Versus Number of Components Per Assembly

Figure 3. Group 1 Defects Per Component Versus Components Per Square Inch

Figure 4. Group 1 Soldering Reject Rate Versus Joints Per Square Inch.

Figure 5. Group 1 Component Reject Rate Versus Components Per Square Inch

Figure 6. Group 2 Defects Per Solder Joint Versus Mounting Area

GP 2 DEFECTS/COMPONENT VS. NO. COMP./ASSY.

Figure 7. Group 2 Defects Per Component Versus Number of Components Per Assembly

Figure 8. Group 2 Defects Per Component Versus Components Per Square Inch

GP 2 SOLDER REJECTS RATE VS. JOINTS/IN.²

Figure 9. Group-2 Soldering Reject Rate Versus Joints Per Square Inch

Figure 10. Group 2 Component Reject Rate Versus Components Per Square Inch

GP 3 DEFECTS/SOLDERING JOINT VS. MOUNTING AREA

Figure 11. Group 3 Defects Per Solder Joint Versus Mounting Area

GP 3 DEFECTS/COMPONENT VS. NO. COMP./ASSY.

Figure 12. Group 3 Defects Per Component Versus Number of Components Per Assembly

Figure 13. Group 3 Defects Per Component Versus Components Per Square Inch

Figure 14. Group 3 Soldering Reject Rate Versus Joints Per Square Inch

Figure 15. Group 3 Component Reject Rate Versus Components Per Square Inch

GP 4 DEFECTS/SOLDERING JOINT VS. MOUNTING AREA

Figure 16. Group 4 Defects Per Solder Joint Versus Mounting Area

Figure 17. Group 4 Defects Per Component Versus Number of Components Per Assembly

Figure 18. Group 4 Defects Per Component Versus Components Per Square Inch

Figure 19. Group 4 Soldering Reject Rate Versus Joints Per Square Inch

Figure 20. Group 4 Component Reject Rate Versus Components Per Square Inch

Figure 21. Group 5 Defects Per Solder Joint Versus Mounting Area

Figure 22. Group 5 Defects Per Component Versus Number of Components Per Assembly

Figure 23. Group 5 Defects Per Component Versus Components Per Square Inch

Figure 24. Group 5 Soldering Reject Rate Versus Joints Per Square Inch

Figure 25. Group 5 Component Reject Rate Versus Components Per Square Inch

Table 3. Significance Tests of Confidence Curves

Items Plotted	Confidence Level (Percent)	Group 1	Group 2	Group 3	Group 4	Group 5
Defects/Solder Joint Vs Mounting Area	50	Yes	No	Yes	Yes	No
	80	No	No	Yes	No	No
	95	No	No	No	No	No
Defects/Component Vs No. of Components/Assembly	50	Yes	Yes	Yes	No	Yes
	80	Yes	No	Yes	No	No
	95	No	No	Yes	No	No
Defects/Component Vs Components/Square Inch	50	Yes	Yes	Yes	No	Yes
	80	Yes	Yes	No	No	Yes
	95	Yes	Yes	No	No	Yes
Soldering Reject Rate Vs Joints/Square Inch	50	Yes	Yes	No	No	Yes
	80	Yes	Yes	No	No	Yes
	95	No	Yes	No	No	Yes
Component Reject Rate Vs Components/Square Inch	50	Yes	No	Yes	No	Yes
	80	No	No	No	No	No
	95	No	No	No	No	No

A multiple linear-regression analysis was separately performed to examine the importance of several variables in explaining a result. The analysis included the set of variables shown in Table 4. The analysis was performed on each of the five data groups. The output of this analysis is a multiple correlation coefficient (MCC)², given as a percentage. Comparison of the correlation level to statistical tables for the sample size used indicated the significance of correlation percentages. Table 5 lists only the correlation factors where significance was determined. The correlation values shown are the coefficient for the corresponding variables and those variables preceding it in the list.

Table 4. Sets of Variables in Regression Analysis

Y_1 = Total Solder defects	Y_2 = Defects per joint
X_{11} = Joints inspected	X_{12} = Joints inspected
X_{21} = Joints per assembly	X_{22} = Joints per assembly
X_{31} = Joints per square inch	X_{32} = Joints per square inch
Y_3 = Total component defects	Y_4 = Defect per component
X_{13} = Components inspected	X_{14} = Components inspected
X_{23} = Components per assembly	X_{24} = Components per assembly
X_{33} = Components per sq in.	X_{34} = Components per square inch

Table 5. Significant Correlation Percentages

Group 1, 11 Timer Subassemblies		Group 5, 19 Conglomerate Subassemblies	
Variable	$(MCC)^2 \times 100\%$	Variable	$(MCC)^2 \times 100\%$
$Y_3 \quad X_{13}$	39.04	$Y_1 \quad X_{21}$	69.26
X_{33}	61.84	X_{11}	78.94
$Y_4 \quad X_{34}$	41.74	X_{31}	83.32
Group 3, 4 Radar Subassemblies		$Y_3 \quad X_{23}$	33.48
Variable	$(MCC)^2 \times 100\%$	X_{33}	45.82
$Y_4 \quad X_{14}$	96.39	X_{13}	46.85
		$Y_4 \quad X_{34}$	19.58*
		X_{14}	39.77
		X_{24}	47.86
*Not significant, listed for interpretation of percentages listed below it.			

Component Verification

The component verification problems that have been encountered are of four types: obliterated markings; wrong components; missing components; and components improperly oriented. Component verification problems expected in the future are unmarked components, limited component marking due to small physical size, and microcircuit components which are not easy to handle or easy to examine visually.

Obliterated marking is not a new problem. Past effort has been made to solve that problem, especially by the Components Engineering department. Variations in marking quality, even from the same vendor and within the same lot of build, have been troublesome. Component vendors have recently been given test criteria (SS282173) for adequate marking permanence. This

appears to be a major step forward, since marking flake-off and dissolved marking due to handling and assembly cleaning operations have been instrumental in marking obliteration. The marking adequacy test consists of thumb rubbing the marking before and after several cycles of simulated assembly spray cleanings with trichloroethylene solvent.

Color-Band Marking

Obliteration of markings, either by flaking or spray solvent dissolving, normally consists of letter or number characters partially missing or smeared so that the character can not be accurately deciphered by production-inspection personnel. Color banding is believed less susceptible than printed or stamped characters to marking obliteration by assembly and cleaning processes.

Partial color-band obliteration still allows components to be identified, whereas partial character obliteration may make the marking indistinguishable. It is not proposed, however, that the color banding should give the type of information given on Mil-R-11 fixed composition resistors. Minimum information should be the SA dash number and perhaps an indicator for the SA family. By using the electrical color code for numbers, a maximum of four color bands would be required for the SA family indicator and a three-digit dash number. Additional information (if the component size allows) could be permitted in alphanumeric form, but should not be required for verification by assembly inspection personnel.

Component Kits

Of 1,092,426 component installations on production assemblies, 425 defects were registered as incorrect, missing, or improperly-oriented components. More than half of the defects were noted as improperly-oriented components. A procedure was written to provide a means of dealing with component orientation and marking problems by use of a component-kitting technique. "Component Processing Requirements for Kits," Appendix A, defines a method whereby inspection can perform rigid component verification before the components are installed, thereby eliminating the loss of identification markings that sometimes results from cleaning and assembling operations. Use of component kits also enables preformed and pretinned leads to be inspected. Properly planned component kits aid production by relating component locations and polarities to the assembly configuration, and also permit verification of location and polarity before the component leads are permanently connected to the assembly.

For control of kit usage, sample-component inspection is required after component attachment. The extra time of inspection and component kitting over the time now being expended without kitting is warranted by the expected improvements. Increased inspection accuracy, improved prediction of production flow times, reduced component attachment errors, and decreased

engineering support required for component identification on the assembly line are the expected improvements. However, the benefits of kitted components can be obtained without extra time expenditures if components are captively inserted (clinched leads through pc boards) in the actual circuit configuration and submitted to visual inspection prior to attachment. Compared to kits with simulated circuit configurations, the added requirement of positioning components for purposes of marking inspection is necessary. Again, color banding of SA dash numbers will alleviate the concern for marking position.

Electrical Overtests

In the assembly area components are drawn from production stores, which is not controlled by the Quality Department. Assembly inspection, therefore, assumes that the parts used in the assemblies are of the required quality, and for that reason, inspects for identifying markings against the assembly list of material and for proper insertion against the graphic assembly drawing. Electrical testing is generally performed before component verification. For electrically acceptable units, this gives a measure of confidence that the proper components were installed. However, electrical test requirements are not normally adequate for component verification.

An attempt was made to determine the feasibility of verifying incorrect and improperly-oriented components of a subassembly by applying a voltage overload at designated test points and observing the ac or dc voltage or current output characteristics.

Circuit modules for this investigation were selected from the present Bendix product line on the basis of component type: passive, transistor, or transformer type circuits. Since the passive circuit is the most straight forward design to analyze, it was selected for the initial investigation.

A test box that accommodates modules with as many as ten pins and allows inputs and outputs to be monitored at any circuit module interface pin was designed. Power supplies and frequency generators were used to simulate operating conditions, and outputs were monitored with voltmeters and an oscilloscope. A 15-percent overvoltage was set up as the test condition.

The initial investigation of the passive-circuit module revealed that the module pins do not provide a sufficient number of test points to enable all individual components to be verified by the overtest method. Components functioned or failed as expected of properly selected, correctly oriented components. Because two or more components are connected between the same two module pins in many instances, individual components often could not be verified. For that reason, this portion of the investigation was discontinued after looking at the passive-circuit module.

While feasibility was not proven for component identification by overvoltage application, it is deemed worthy of further investigation with circuit configurations designed for this approach. It is recommended that future module designs allow for auxiliary test points which bridge any two components. Careful design layout would make this a relatively simple requirement to meet.

Infrared Scanning and Thermal Mapping

Heat contours generated by infrared scanning were considered as a possible means of component verification. Information on available equipment was obtained from Barnes Engineering and Philco-Ford. Two pieces of infrared (IR) equipment are now in use at Bendix. They are the Barnes Infrared Camera and the Barnes Infrared Radiometric Microscope, and are located in the Test Laboratory.

Test Laboratory personnel were consulted about the use of this and similar equipment for component verification with respect to microcircuits. It was not feasible to use the Barnes equipment for such an application because of small circuit-size considerations. Resolution of the IR camera is not compatible with the size of microcircuits, and the IR radiometric microscope does not have a read-out system which is adaptable to scanning a small surface.

Equipment is available, however, which is applicable to small-surface scanning. Since considerable cost is involved in such equipment, a careful and thorough investigation of Bendix needs and applications should be made before purchasing.

With the proper equipment, thermal scanning appears to have merit as a possible method of component verification, especially in conjunction with the electrical overtest approach. It is recommended that efforts be made to obtain (by rent or loan) such equipment for an application investigation here at Bendix.

Machining Tolerances

Production drawings of sundry mechanical parts for electronic assemblies were reviewed, and from these pieceparts were selected for use in a tolerance study which was based on the types of machining operations required to produce the part. In general, parts were selected to give at least three different part samples for each type of machining operation. This objective, however, was compromised somewhat because inspection results for some of the parts used in the study could not be obtained.

Statistical Quality Control processed the data to give $\bar{x}$ and sigma values for each dimension. A dimensional sample of thirty of each part was chosen for the evaluation. See Appendix B for the data tabulation.

Review of the data showed that the dimensional control was extremely good, but in contradiction to the known guidelines (i. e. ; ± 0.005 inch for traversing machine operations and ± 0.015 for sheet metal work). This contradiction is apparently due to the complex tooling, production check fixtures, and re-work. In other words, the inspection acceptance record is not indicative of true production yield. To provide a practical tolerancing guide and to ensure that engineers are not lead to believe that low-cost functional pieceparts can be produced, even when ultra-close tolerances are required, actual process yields were used to supplement the inspection data.

The tolerancing guide was developed by use of the processed inspection data and the process-yield information. The guide was prepared in chart form and lists the machining operation, a simple part sketch to indicate the type of feature formed during the operation together with the typical drawing callout, the applied dimensioning system, the tolerance callout versus expected yields of 70, 95, and 99.9 percent, and a comments column. The tolerancing guide and the inspection data are shown in Appendix B.

While most tolerance versus yield values given in Table B-1 are practical values, it is recommended that more relaxed tolerances be used when a dimension is not critical. The yields indicated are for individual machined features. Since most pieceparts have multiple machined features, the part yield is an aggregate of yields for the different machining operations. Another argument for relaxing machining tolerances as much as possible is reduced tooling cost, which is made possible by simplified tool design and by greater allowable tool wear. Time is also an important consideration, since closer tolerances often require repeated machining operations.

Special attention should be given to plating-thickness callouts. These should indicate part areas where the plating thickness is important and should require only minimal plating coverage in all other areas.

Microcircuit Inspection Guidelines

An inspection outline for microelectronic assemblies was developed, as shown in Appendix C. The outline covers new inspection activities required for procurement, part fabrication, and assembly of microminiature circuitry. The purpose of the outline is to maintain an up-to-date checklist of all probable inspection responsibilities as the SC Bendix microelectronic technology is advanced. Some inspection redundancies are included for completeness, because the best characteristics to monitor have not yet been designated. Although it is not complete, the outline includes entries to list applicable inspection specifications, recommended inspection equipment, and define measurement ranges. The inspection outline is a composite of the other information presented in Appendix C.

ACCOMPLISHMENTS

The results obtained from this work provide detailing and processing guidelines that are useful in supporting present Bendix product-quality levels, and which are considered particularly essential to projected future microcircuit fabrication. These guidelines include:

- Determination of hole-location accuracies that can be maintained on printed wiring boards;
- Tolerance requirements for common metal-machining operations; and
- A checklist for areas of inspection that will likely be required in future microcircuit fabrication.

Procedures resulting from re-examination of the continuous problem of component verification provide several potential means of reducing that problem. Although no single method of solving all component-marking obliteration problems was found, each of the following methods appears to be suitable for specific types of products, components, or assemblies:

- Color banding;
- Use of kitted components;
- Voltage overtests;
- Infrared scanning;
- Controlled, single-component assembly areas; and
- Machine component insertion and verification.

Of the methods investigated, color banding to identify components and assemblies offers the greatest promise. Although considerable effort would be required to phase in that method, the expected increases in production rates and yields and the anticipated decrease in product flow time would warrant that effort.

Microcircuit components--whereon identification markings may not be possible because of limited space--can be verified by use of single-component assembly areas or by certified-component machine-controlled insertion.

Other related work that is in progress at Bendix includes evaluation of a tubular-component insertion machine and a study of handling and probing techniques for beam-lead microcircuit components.

Appendix A

COMPONENT PROCESSING REQUIREMENTS
FOR COMPONENT KITS

Prepared by W. P. Beck

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

	DWG CLASSIFICATION LEVEL					
<p>1. <u>GENERAL.</u></p> <p>1.1 <u>Scope.</u> Defined herein are the minimum production and inspection requirements for component installations when the components are prepared in assembly kits prior to insertion in a circuit configuration. The required processing is designed to facilitate verification of component marking.</p> <p>1.2 <u>Terms and Definitions.</u></p> <p>1.2.1 Component. An electrical circuit element defined by its own electrical and physical characteristics.</p> <p>1.2.2 Component Assembly Kit. A set of components prepared and oriented for direct and position related insertion into a defined circuit configuration.</p> <p>1.2.3 Circuit Configuration. A defined pattern for interconnection of components.</p> <p>1.2.4 Applicable Specification. An assembly drawing callout defining the particulars of a processing operation (i. e. ; pretinning and soldering, preforming, bonding, welding etc.).</p> <p>2. <u>DOCUMENTS</u> (Incomplete)</p> <p>2.1 <u>Required.</u></p> <table style="width: 100%; border: none;"> <tr> <td style="width: 30%; text-align: center;"><u>Number</u></td> <td style="text-align: center;"><u>Title</u></td> </tr> </table> <p>2.2 <u>Reference.</u></p> <table style="width: 100%; border: none;"> <tr> <td style="width: 30%; text-align: center;"><u>Number</u></td> <td style="text-align: center;"><u>Title</u></td> </tr> </table> <p>3. <u>REQUIREMENTS</u></p> <p>3.1 <u>Production Requirements</u></p> <p>3.1.1 Prepare component kits. The order of component pretinning, preforming and loading is optional.</p> <p>3.1.1.1 Pretin leads of components to be soldered per applicable specification.</p> <p>3.1.1.2 Preform component leads per applicable specification.</p> <p>3.1.1.3 Load component kits with prepared components.</p>			<u>Number</u>	<u>Title</u>	<u>Number</u>	<u>Title</u>
<u>Number</u>	<u>Title</u>					
<u>Number</u>	<u>Title</u>					
ISSUE	A	DWG CLASSIFICATION LEVEL				
UNCLASSIFIED	A	14213				
SS.	SHEET	2 OF				

	DWG CLASSIFICATION LEVEL	
<p>3.2.2 Make inspection disposition and return the noncleaned assemblies to production after examining the assemblies for:</p> <p>3.2.2.1 Correct orientation of polarized components;</p> <p>3.2.2.2 Required components in proper location;</p> <p>3.2.2.3 Component height within maximum allowed dimensions;</p> <p>3.2.2.4 Complete assembly except for electrically selected components; and</p> <p>3.2.2.5 Mechanical damage.</p> <p>3.2.3 Make inspection disposition and return material to production routing after visual evaluation of the assembly for the following:</p> <p>3.2.3.1 Completion of all component attachment;</p> <p>3.2.3.2 Cleaning adequacy per applicable specification; and</p> <p>3.2.3.3 Conformance of component attachment joints to the applicable specification.</p> <p>3.3 <u>Rework Requirements.</u></p> <p style="padding-left: 40px;">(Incomplete)</p> <p>4. <u>QUALITY PROVISIONS.</u></p> <p>4.1 <u>Inspection Equipment and Aids.</u></p> <p style="padding-left: 40px;">Inspection aids shall be provided to expedite the inspection task and to provide firm guidelines of acceptance by providing standards for product comparison. Suggested aids are:</p> <p>4.1.1 Image magnifiers;</p> <p>4.1.2 Up-to-date product standards for comparisons of proper component identification and component location; and</p> <p>4.1.3 Component identification guides.</p> <p>5. <u>PACKAGING AND HANDLING.</u></p>		
ISSUE	A	
UNCLASSIFIED	A	14213
DWG CLASSIFICATION LEVEL		DWG NUMBER
UNCLASSIFIED		SS
SHEET		4 OF

	DWG CLASSIFICATION LEVEL	
--	--------------------------	--

5.1 Component Kits.

The design intents of the component kits shall be:

- 5.1.1 Low cost and ease of procurement;
- 5.1.2 Reusability;
- 5.1.3 Protective against spillage and mechanical damage;
- 5.1.4 Materials noncorrosive to component leads;
- 5.1.5 Scaled to be an integral multiple of the assembly drawing scale; and
- 5.1.6 Compatible with regard to tooling features for interfacing to possible machine insertion aids.

6. NOTES.

6.1 The following sequence is provided for expedient and thorough, repeated application of this specification by personnel familiar with the specification intent.

<u>Responsibility</u>	<u>Task Description</u>
6.1.1 Production	Pretin component leads. Preform component leads. Insert components in kits and check polarities. Submit kits to inspection.
6.1.2 Inspection	Visually inspect for Component identification;* Locations of components;* Orientation of polarized components;* Preforming of components; Completeness of the kit; and Functional damage. Make inspection disposition. Return kits to production.
6.1.3 Production	Insert components from kits into corresponding positions in circuit configuration. Caution: Observe component polarities. Attach components per applicable specification. <u>Do Not Solvent Clean After Attachment.</u> Submit assembly to inspection.

ISSUE	A																					
										DWG CLASSIFICATION LEVEL										SIZE	CODE IDENT	DWG NUMBER
										UNCLASSIFIED										A	14213	SS
																				SHEET	5	OF

	DWG CLASSIFICATION LEVEL	
<p>6.1.4 Inspection</p>	<p>Visually inspect for Component identification; Location of components; Orientation of polarized components;* Maximum component height; and Functional damage.* Make inspection disposition. Return assemblies to production.</p>	
<p>6.1.5 Production</p>	<p>Clean assembly. Add electrically selected components. Clean assembly locally. Submit assembly to inspection.</p>	
<p>6.1.6 Inspection</p>	<p>Visually inspect for Component attachments per applicable specification;* Foreign material (cleaning)*; and Workmanship (damage). Make inspection disposition. Return assembly to routing.</p>	
<p>* 100-Percent inspection sample is recommended.</p>		
ISSUE	A	
DWG CLASSIFICATION LEVEL		
UNCLASSIFIED		
SIZE	A	
CODE IDENT	14213	
DWG NUMBER		SS
SHEET		6 OF

Appendix B

PIECEPART TOLERANCE GUIDE

Prepared by J. W. Davis

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Appendix B

PIECEPART TOLERANCE GUIDE

The following tables were prepared for use as aids for product engineers and designers who are often responsible for establishing tolerances and design details that are not stipulated in the product specifications.

Table B-1 describes typical design features and drawing callouts and indicates percent yields that can be expected from typical machining operations at specific tolerances. This table illustrates the economic advantage that can be gained from relaxed tolerances. For example: a typical boring operation produces a yield of only 70 percent when a tolerance of ± 0.001 inch is necessary, whereas a 99.9-percent yield can be expected when a tolerance of ± 0.005 is sufficient--resulting in a cost saving of approximately 30 percent.

Table B-2 lists the inspection results from representative Bendix machining operations.

Although these tables show the tolerances that can be maintained, economic reasons dictate that tolerances be as broad as the product specifications will allow. This may not increase piecepart yields in some instances, but will always reduce the cost of tooling required to process and inspect the part.

The best machines that are available are necessary to maintain the tolerances required on many Bendix products, and machine maintenance is an important factor in maintaining the highest possible yields. Comparatively-new numerically-controlled machines have made closer tolerances possible and have increased production yields.

Closer tolerances usually require more expensive tools and fixtures, more exact in-process, and more complex final inspection facilities, whereas broader tolerances can reduce costs and product flow time in all of those areas

The notes A through D in Table B-1 are described as follows.

- A: The hole size should be defined around standard drill sizes, and the tolerance should allow for the type of hole that can be obtained in the material used. The process engineer can assist the product engineer by supplying that information.
- B: Such callouts as "Plate per specification AAAAAA, 0.0001 to 0.0003-inch thick" on complex shapes can significantly increase the cost of producing the part because of special tooling requirements and reduced yields. If the design requires this type of callout, apply it only to those areas where plating thickness is critical, and specify only complete coverage on all less-critical areas.
- C: Such callouts as "Plate to specification AAAAAA, .XXX-inch minimum" or "Plate to specification AAAAAA, .XXX-inch maximum" should be stipulated only on those areas where plating thickness is critical. Specify only complete coverage, not less than the specified minimum, or not more than the specified maximum (as applicable) on noncritical areas.
- D: The callout "Plate to specification AAAAAA, complete coverage only" indicates a noncritical requirement.

Table B-1. Machining Operations and Tolerances for Expected Yields

Standard Operations Equipment	Typical Drawing Callouts and Dimensions	Bilateral or True Position Callout	Expected Percent Yield			Comments
			70%	95%	99.9%	
<u>Drilling</u> Drill Press Lathe Auto-Screw		BIL	0.001 ¹	0.002 ²	A	¹ Requires reaming ² May require reaming A See Notes
<u>Boring</u> Lathe Borematic		BIL	0.001	0.003	0.005	
<u>Depth</u> Blind Holes Counterbore Drill Press Lathe Auto-Screw Borematic End Mill		BIL	0.002	0.004	0.005	Where design allows use minimum depth required or maximum remaining material callout
	BIL	0.001	0.003	0.005	

Table B-1 (Continued). Machining Operations and Tolerances for Expected Yields

Standard Operations Equipment	Typical Drawing Callouts and Dimensions	Bilateral or True Position Callout	Expected Percent Yield			Comments
			70%	95%	99.9%	
<u>Plains</u> Mill Grinder		BIL	0.001	0.0025	0.005	
<u>Facing</u> Lathe Auto-Screw		BIL	0.001	0.003	0.005	
<u>Parting</u> Lathe Auto-Screw		BIL	0.003 ³	0.006	0.009	³ May require facing
<u>Turning</u> Lathe Auto-Screw		BIL	0.002	0.004	0.008	

Table B-1 (Continued). Machining Operations and Tolerances for Expected Yields

Standard Operations Equipment	Typical Drawing Callouts and Dimensions	Bilateral or True Position Callout	Expected Percent Yield			Comments
			70%	95%	99.5%	
<u>Grooves</u> ⁴ Lathe Auto-Screw		TP	0.004 ⁴	0.008	0.016	⁴ Special cutting tools are required
<u>Forming</u> Press Hydroform		BIL	0.004	0.007	0.010	Reduction of material thickness will be effected by complexity of the form and depth of the draw
	BIL	0.001	0.002	0.003
	TP	0.005	0.010	0.015	

Table B-1 (Continued). Machining Operations and Tolerances for Expected Yields

Standard Equipment Operations	Typical Drawing Callouts and Dimensions	Bilateral or True Position Callout	Expected Percent Yield			Comments
			70%	95%	99.9%	
<u>Slots</u> Width and Depth End Mill EDM		BIL	0.001	0.002	0.003
	BIL	0.002	0.004	0.005	
<u>Stamping</u> Press		TP	0.002	0.005	0.010	Tolerances also apply to contours
<u>Plating</u>			B	C	D	BCD See Notes

Table B-2. Results of Mechanical Inspection

Operation	Drawing Callout	$\bar{X}$	Sigma
<u>Slots</u>			
Width	0.013 ± 0.002	0.01315	0.00033
	0.016 ± 0.002	0.0162	0.0009
Depth	0.020/0.027 R Material	0.02347	0.00155
<u>Drilling</u>			
	0.072 ± 0.001 Dia	0.0714	0.0006
	0.260/0.261 Dia	0.26011	0.00011
	0.754 ± 0.002 Dia	0.75391	0.00032
	0.626 ± 0.001 - 0.000 Dia	0.62655	0.00035
<u>Parting</u>			
	0.565 ± 0.005	0.56514	0.00257
<u>Facing</u>			
	0.010 ± 0.002	0.01045	0.00074
	0.176 ± 0.001	0.17592	0.00078
	0.010/0.013	0.01164	0.00027
	0.102 ± 0.002	0.10148	0.00055
	0.X935 +0.0018 -0.0007	0.X9382	0.00042
<u>Boring</u>			
	X.X017 ± 0.0007	X.X0213	0.00015
	X.X115 ± 0.0007	X.X1145	0.00014
	X.X075 ± 0.0007	X.X0791	0.0002
<u>Depth of C'Bore</u>			
	0.036 +0.002 -0.000	0.03681	0.00054
	X.X95 ± 0.002	X.X9493	0.00045
<u>Thickness</u>			
	0.080 ± 0.002	0.0795	0.0006
	0.109 ± 0.002	0.10978	0.00062
	0.124 ± 0.003	0.125	0.001
	0.217 ± 0.003	0.217	0.0004
	0.018/0.021	0.1951	0.00062
	0.036/0.041	0.03963	0.00053
<u>Turning</u>			
	0.033/0.034 Dia	0.03335	0.00009
	1.044 ± 0.0002 Dia	1.04394	0.00006
	1.044/1.045 Dia	1.04312	0.00025
	1.297 +0.000 -0.004 Dia	1.29438	0.00016
	5.040 ± 0.002 Dia	5.040	0.0004
	5.123 ± 0.002 Dia	5.1227	0.0004
<u>Grooves</u>			
	2.200 Rad 0.003 MMC	2.19812	0.00186

Table B-2 (Continued). Results of Mechanical Inspection

Operation	Drawing Callout	$\bar{X}$	Sigma
<u>Forming</u>	1.290 $\pm$ 0.001 Dia	1.29138	0.00068
	0.450 $\pm$ 0.005 Rad	0.4502	0.00170
	0.030/0.035 Rad	0.0331	0.00090
	0.075/0.080	0.07372	0.00340
	3.384 +0.000 -0.006 Dia	3.3810	0.00120
	0.030 +0.006 -0.002	0.03538	0.00070
	Mat'l Reduce		
<u>Stamped Hole Locations</u>			
	X 1.120	1.12009	0.00032
	Y 0.000	0.0002	0.00008
	X 0.210	0.21004	0.00047
	Y 0.489	0.48898	0.00024
	X 1.144	1.14399	0.00024
	Y 0.570	0.570	0.00027
	X 1.313	1.31306	0.00041
	Y 0.473	0.47303	0.00023
	X 1.313	1.31314	0.00038
	Y 0.277	0.27697	0.00021
	X 0.871	0.87119	0.00032
	Y 0.010	0.0101	0.00021
	X 0.221	0.22113	0.00034
	Y 0.010	0.00995	0.00053
	X 0.000	0.0004	0.00014
	Y 1.100	1.11273	0.03408
	X 0.357	0.35704	0.00014
	Y 0.360	0.35997	0.00017
	X 0.524	0.52381	0.00019
	Y 0.338	0.33767	0.00017
	X 0.657	0.65691	0.00013
	Y 0.440	0.43980	0.00015
	X 0.679	0.67867	0.00037
	Y 0.607	0.60664	0.00024
	X 0.577	0.57694	0.00015
	Y 0.740	0.73981	0.00013
	X 0.410	0.41031	0.00009
	Y 0.762	0.76191	0.00029

Appendix C

MICROCIRCUIT INSPECTION OUTLINE

Prepared by R. J. Blazek and W.P. Beck

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Appendix C

MICROCIRCUIT INSPECTION OUTLINE

SUBSTRATES

Receiving Inspection

Physical Properties

- Cleanliness
- Composition
- Panel Dimensions
- Surface Finish
- Camber (Warp)
- Waviness
- Grain Size
- Flexural Strength
- Density
- Hardness
- Appearance
 - Pits
 - Cracks
 - Excess Material
 - Scratches

Metallization Inspection

Appearance

- Indentations
- Voids
- Cracks
- Scratches
- Pin Holes
- Bumps (Blisters)
- Evaporation Comets

Adhesion

Thickness

Thermal Stability

Machining Inspection

Hole Location

Hole Size

Contour

Electrical Properties

- Dielectric Constant
- Dielectric Strength
- Dissipation Factor

Thermal Properties

- Thermal Conductivity
- Thermal Expansion

Vendor Certification

Circuit Pattern

- Completeness
- Corrosion
- Bridges
- Path Size
- Resistor Alignment
- Clearance From Substrate Edge
- Foreign Material

Resistor Values

Damage

- Cracks
- Scratches
- Chips

MICROCIRCUIT COMPONENTS (RECEIVING)

Visual

Package

Apparent Mechanical Damage

Component Identification

Review of Vendor Certifications

Repackaging for Storage

Dimensional

Lead Size

Contour

Height

Matrix Locations

Electrical

Per Specification

Environmental

Per Specification

Analytical

Lead Composition

ASSEMBLY INSPECTION

Visual

Markings

Component Placement

Component Values

Bonds

Interconnect Routing

Component Height

Solder Wetting

Cleanliness

Conformal Coating

Electrical

Room Temperature

High Temperature

Low Temperature

Environmental

Gaging

Size

Shape

Table C-1. Microcircuit Substrate Receiving Inspection

Features Inspected	Inspection Method	Equipment Required	Sample Rate (%)	Measurement Range
<u>Physical Properties</u>				
Cleanliness	Contact-Angle Water-Drop	Microscope	100	Angle <10 degrees
Composition	Spectrographic Analysis	Mass Spectrometer	33	99.5% Al ₂ O ₃ 99.0% minimum
Panel Dimensions		Micrometer	33	Specified thickness $\pm 10\%$ length and width $\pm 1.0\%$
Surface Finish		Surf Analyzer	100	<10 microinches CLA
Camber (Warpage)		Parallel-Plates	100	0.004 in./in. maximum
Waviness				
Grain Size	At 500 X with reflected light	Microscope	33	1 micron maximum
Flexural Strength	ASTM D116-65		25	40,000 to 70,000 psi
Density	Wt/Vol Data		25	3.8 to 4.0 g/cc
Hardness	ASTM E18-67		25	78 to 90 Rockwell 45N
Appearance				
Pits		Microscope	100	0.005 in. maximum
Cracks		Microscope	100	Reject all cracks
Excess Material		Microscope	100	0.001 inch height max
Scratches		Microscope	100	0.0005 inch depth max

Table C-1 (Continued). Microcircuit Substrate Receiving Inspection

Features Inspected	Inspection Method	Equipment Required	Sample Rate (%)	Measurement Range
<u>Electrical Properties</u>				
Dielectric Constant	ASTM D150-65T		25	9.0 to 10.1 at 75°F and 1 MHz to 10GHz
Dielectric Strength	ASTM D116-65		25	180 to 260 rmsV/mil
Dissipation Factor	ASTM D150-65T		25	0.0001 to 0.0004 at 75°F and 1 MHz
<u>Thermal Properties</u>				
Thermal Conductivity	ASTM D116-65		25	0.05 to 0.08 cal-cm/cm ² -sec-°C at 25°C
Thermal Expansion	ASTM D116-65		25	(5.3 to 6.8) x 10 ⁶ /°C at 25 to 200°C
<u>Vendor Certification</u>	Visual		100	As required

Table C-2. Microcircuit Substrate Metallization Inspection

Features Inspected	Inspection Method	Equipment Required	Sample Rate (%)	Measurement Range
<u>Appearance</u>				
Indentations		Microscope	100	0.007 inch maximum
Voids		Microscope	100	0.002 inch maximum
Cracks		Microscope	100	Reject all cracks
Scratches		Microscope	100	Length 0.010 inch max Depth 0.0005 inch max
Pin Holes		Microscope	100	200 per square inch max
Bumps (Blisters)		Microscope	100	0.002 inch max height
Evaporation Comets		Microscope	100	0.002 in. max diameter 0.002 in. max height
<u>Adhesion</u>	Scotch-Tape Test	Microscope	100	Reject all lifted metallization
<u>Thickness</u>		Surf Analyzer	20	
<u>Thermal Stability</u>				
<u>Circuit Pattern</u>				
Completeness	Comparison		100	
Corrosion		Microscope	100	Reject if any corrosion
Bridges		Microscope	100	Reject for paths reduced to 1/4 or less of specified spacing

Table C-2 (Continued). Microcircuit Substrate Metallization Inspection

Features Inspected	Inspection Method	Equipment Required	Sample Rate (%)	Measurement Range
Path Size		Microscope	100	Reject for resistor and path-width deviations of more than ± 5 percent
Resistor Alignment		Microscope	100	Conductor metallization must cover entire width of resistors
Clearance From Substrate Edge		Microscope	100	0.020 inch minimum clearance
Foreign Material		Microscope	100	None visible on substrate or in package
<u>Resistor Values</u>			100	Within specified limits

Table C-3. Microcircuit Substrate Machining Inspection

Features Inspected	Inspection Method	Equipment Required	Sample Rate (%)	Measurement Range
<u>Hole Location</u>				
<u>Hole Size</u>				
<u>Contour</u>				
<u>Damage</u>				
Cracks		Microscope	100	Reject all cracks greater than 1 mil that are pointed toward active area
Scratches		Microscope	100	Reject all scratches in resistor paths that are greater than 10 percent of resistor width or 33 percent of conductor width
Chips		Microscope	100	Reject all chips within the active circuit area

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

DISTRIBUTION

	Copy
B. W. Colston, AEC-KCAO	1
V. C. Vespe, AEC-ALO	2
R. A. Wilson, SLA	3
L. E. Borgman, D/113	4
Q. S. Bastin, D/200	5
C. Latimer, D/416	6
R. D. Taylor, D/445	7
H. T. Barnes, D/534	8
L. Stratton, D/535	9-11
R. P. Frohmberg, D/800	12
F. A. Spies, D/800	13
W. P. Beck, D/842	14-16
J. A. Peters, D/842	17
T. A. Wiley, D/842	18
J. H. Swafford, D/863	19