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CD725 TRANSFORMER LEAD SOLDER
JOINT EVALUATION

PDC 6989163 Final Report

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CDA725 TRANSFORMER LEAD SOLDER JOINT EVALUATION

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Prepared by P. F. Burk, D/846, under PDO 6989163

This work was conducted because of nickel transformer-lead solder joint fatigue in printed circuit board eyelets on transformers encapsulated in a polyurethane potting material. Good nickel lead solderability is difficult to attain. The large thermal expansion of polyurethane potting material accelerates solder joint fatigue. A CDA725 copper alloy with improved solderability and different properties was found a superior substitute for nickel in this application.

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SUMMARY

Cracked nickel transformer-lead solder joints detected in printed circuit board eyelets on transformers encapsulated in a polyurethane potting material prompted this investigation. Transformer lead materials were evaluated in relation to ease of assembly, solderability, electrical resistance, and number of temperature cycles before solder joint failure. Any crack visible at 30X magnification was considered a solder-joint failure. Three types of transformer lead material were evaluated: CDA725 copper alloy, ETP copper, and nickel. ETP copper transformer leads were included as a control sample. The ETP copper is known to have good solderability, but it is undesirable for transformer leads because it will work harden and break fairly easy.

The assembly procedure for the standard stud-type solder joint was similar for each type of lead. No difficulty was encountered during assembly. Solderability was about the same on each type of pretinned lead. All pretinned transformer pins were bright, shiny, and continuous. There was no detectable difference in the pretinned layers of the different lead materials.

There is considerable variation in the electrical resistance of these three pin materials. This is not a concern because of the short lead length and the limited effects of milliohm variations on the functions of the transformers examined. However, resistive effects should be considered for each specific application.

Regardless of lead material, stud-type solder joints on encapsulated transformers on printed circuit boards will crack after a few temperature cycles. In these experiments, electrical continuity at the solder terminal was maintained during 53 temperature cycles even though the terminals were cracked.

When cracking was observed on the standard stud solder joints, two methods of stress relieving the leads were examined, both of which prevented cracking. One method provides stress relief on the component side of the printed circuit board (spider-joint relief), and the other provides relief on the noncomponent side (lap-joint relief). Both methods require transformers with low-modulus lead material such as soft copper; otherwise, soft-copper leads must be spliced to the nickel or copper-alloy leads. When lead bending is used for stress relieving, copper is the most workable material, followed by CDA725 and nickel, in that order.

DISCUSSION

SCOPE AND PURPOSE

The purpose of this work was to determine the acceptability of CDA725 copper-alloy transformer lead material as a replacement for nickel. The work required identification of the process variables associated with CDA725.

Solder joint cracking was observed in component leads potted in EN-4* polyurethane. This cracking was caused by cyclic stresses resulting from differences in the thermal coefficients of expansion of the components, component leads, potting material, and the printed circuit board laminate, lands, and eyelets.

Dummy transformers and special printed circuit boards were fabricated to compare ETP copper (control samples), CDA725 alloy, and nickel transformer-lead materials. The transformers were soldered to the test boards, potted in EN-4 polyurethane, and temperature cycled. Several methods of providing stress relief were examined.

ACTIVITY

Test Panel and Transformer Fabrication

Printed circuit boards were fabricated in accordance with DLPS 02354-20, *XT0001 Transformer Basic Test Board*. Dummy transformers were fabricated with internal jumpers to permit the series resistance of the leads and transformer solder terminals to be measured. Jumpers were installed from Pin 1 to Pin 2 and from Pin 3 to Pin 4 of the XT0003 transformers, and from Pin 1 to Pin 2, Pin 3 to Pin 4, and Pin 5 to Pin 6 of the XT0002 transformer. Sample quantities consisted of 30 XT0002 and 30 XT0003 transformers, 10 of each type with ETP copper, CDA725 alloy, and nickel leads. The copper-lead transformers were numbered 1 to 20, the nickel-lead transformers were numbered 21 to 40, and the CDA725-lead transformers were numbered 41 to 60. Foam pads were installed under the transformers and the four sides were coated with polysulfide, in accordance with Bendix drawings AY296091 and AY293663. The urethane foam pads were not bonded to the printed circuit boards (PCB). The transformer pins were pretinned.

*EN-4 is a two-component polyurethane encapsulating compound made by Conap, Incorporated, Allegheny, New York.

The leads were soldered with SN63 Kester 0.032-inch-diameter (0.81 mm) P-3 flux-core solder. An external, mildly active liquid soldering flux (Alpha 611, Bendix MS4705010) was used. The joints were soldered with a 20-watt chisel point iron on a laminar-flow clean bench. The operator exercised care to ensure that the top of the transformer was reasonably parallel to the surface of the PCB. The laminate was 0.062-inch-thick (1.57 mm) Type GH. The leads were inserted in the plated-through holes, the leads and pads were coated with liquid flux, pressure was applied to the top of the transformer, and two leads were tack soldered (corner to corner) to hold the transformer to the pads. The leads were soldered by placing the soldering iron tip in contact with the pad and the lead, applying the solder, and leaving the tip on the joint for an additional 3 seconds after the solder melted. One nickel-lead transformer (Sample 32) was removed from the PCB when one hole pad did not wet well with solder on the transformer side. Several attempts had been made to solder from the noncomponent side of the board. The problem hole was coated with activated flux and tinned with Kester 281 flux-core solder. This resulted in a satisfactory joint. Another nickel-lead transformer (Sample 20) had a similar problem, with the hole pad failing to wet well on the component side of the board. Resoldering on the component side produced an acceptable joint.

A slight nonuniformity observed in solder terminal height may have been caused by differences in solderability, by different heat capacities (specific heat) of the leads, or, more likely, by the addition of different amounts of solder by the operator. The poor wetting ability of two PCB pads was not attributed to transformer pin solderability.

The transformers with CDA alloy and nickel leads were mounted on 10 sample boards. On each of these was mounted one XT0002 with CDA725 leads, one XT0002 with nickel leads, one XT0003 with CDA725 leads, and one XT0003 with nickel leads. The 20 transformers with copper leads were installed on five other boards.

Potting forms 0.5-inch (12.7 mm) high were installed on the transformer side of the test panels. The transformers and potting forms were arranged in a symmetrical array to minimize or relate any geometric effects in the encapsulant. The potting forms were attached to the PCB with polysulfide. The panels were cleaned in accordance with Bendix process cleaning and handling specification SS295101, Procedure C. The panels were sprayed with trichloroethylene, slosh rinsed in isopropyl alcohol, sprayed with Freon, blown dry with nitrogen, and vacuum baked at 50 torr (6.7 kPa) and 71°C. The potting form areas were encapsulated with EN-4 polyurethane in accordance with Bendix process specification 9927083.

Transformer Thermal Testing

The transformer panels were temperature cycled on edge in the temperature chamber with the air flow parallel to the sides. The chamber was cycled from 21.1°C to -40°C, to 71.1°C, and back to 21.1°C. The complete cycle consisted of 30 minutes maximum between temperature levels, 4 hours minimum at each temperature extreme, and one hour minimum at 21.1°C. After 20 cycles, the time at each temperature extreme was reduced to 2 hours. The solder terminals were examined for fatigue and cracks and the series resistance was measured at intervals during the temperature exposure. Table 1 and Figure 1 show the results of inspection for terminal degradation. Selected panels were removed after the second, third, fourth, fifth, and fifty-third cycles; the panels were sectioned and metallographically examined for fatigue and internal cracks in the solder terminals.

Resistance (dc) measurements were made at room ambient conditions after the test panels were potted in EN-4, after each of the first nine temperature cycles, and at selected intervals thereafter. Tables A-1, A-2, and A-3 list the copper, nickel, and CDA725 test results. The location of the nickel and CDA725 transformers is shown on Figure 2. Transformer internal jumpers and paths on the PCB were arranged so that the terminals were in series. Series resistance measurements of transformers (T1) were read between board terminals 64 and 65. T2 measurements were taken between terminals 66 and 67, T3 between terminals 78 and 79, and T4 between terminals 80 and 81. The dc measurements were made with a Cimron Ohmmeter composed of a Model 6869B Ohms-Preamplifier and a Model P9400B Voltmeter.

Variations in the readings were typically ± 2.0 milliohms after each of the first four temperature cycles. The ohmmeter sensitivity was increased for the remaining readings, and the variation was typically ± 1.0 milliohm. The variations resulted from meter tolerance, test-probe contact resistance, and changes in ambient temperature.

Cracked Solder Joints

With the stud type of solder joint on transformers with leads of either ETP copper, CDA725 copper-alloy, or nickel, the solder terminals cracked after four temperature cycles (Appendix B, Figures B-1 through B-5). Examination revealed that the cracks resulted from displacement or strain between the solder and transformer-lead interface. After each of the first nine cycles, each solder joint was visually inspected at 30 times magnification to determine if the joint was crazed, cracked, or displaced. Crazed joints are defined as those which have a rough or dull appearance caused by slip movements within the solder along regions of strain. Cracked joints are those which exhibit cracks

Table 1. Evaluation of Lead Joints on XT0002 and XT0003 Transformers

Number of Cycles*	Lead Material	Number of Terminals	Crazed (Percent)	Cracked (Percent)	Displaced (Percent)
1	Ni	100	61	0	0
	CDA725	100	47	0	0
	Cu	100	2	0	0
2	Ni	100	72	0	0
	CDA725	100	60	0	0
	Cu	100	4	0	0
3	Ni	90	90	5	10
	CDA725	90	70	0	5
	Cu	80	60	0	5
4	Ni	80	100	22	35
	CDA725	80	80	10	10
	Cu	60	70	10	40
5	Ni	70	100	35	35
	CDA725	70	90	20	15
	Cu	40	95	20	75
9	Ni	60	100	80	38
	CDA725	60	100	72	15
	Cu	40	97.5	75**	67.5
12	Ni	60	100	88	38
	CDA725	60	100	78	15
	Cu	40	100	82.5	67.5

*Temperature Cycles = 4 hr at -40°C; 1 hr at 21.1°C;
4 hr at 71.1°C; 1 hr at 21.1°C

****Sunken terminals are difficult to judge**

Figure 1. Temperature Cycles Versus Percent of Crazed and Cracked Terminals

Figure 2. XT0001 Transformer Test Board for XT0002 and XT0003 Transformers

or fissures visible at 30X. Displaced leads are those extruded from or recessed into the solder fillet. Nickel leads were typically extruded from the fillet, ETP copper leads were typically recessed into the fillet, and CDA725 leads were typically not affected, with 15 percent exhibiting extrusion or recession. These inspection data are listed in Table 1 and Figure 1. Appendix B Figures B-6 through B-16 are photographs of these failures.

When cracked solder terminals were observed, strip-chart recorders were used to monitor resistance continuously throughout the tests. To monitor more transformers with the recorders available, transformers on any one type PCB (each lead material) were wired in series (Figure 3). Two Hewlett-Packard Model 7100B and four Simpson two-channel recorders were used. Some noise was detected on the Simpson recorders when they were first set up. This noise was caused by vibration from the temperature-chamber fans; therefore, the recorders were placed on foam pads for isolation. It is possible that the series resistance variations were a result of the temperature coefficients of resistivity of the PCB lands, transformer leads, and internal jumpers. The power sources maintained a constant current of 100 mA and the voltage produced across the transformer series resistance was recorded. The data indicate that the solder terminals maintained electrical continuity, even though the terminals were cracked. Resistors of 4 and 100 ohms provided isolation between recorders and limited the maximum voltage across the series resistance applied to each recorder.

Series resistance was continuously monitored on HP Model 7100B strip-chart recorders with a sensitivity of 20 milliohms/inch ($0.787 \text{ m}\Omega/\text{mm}$) and Simpson 2750 recorders with a sensitivity of 200 milliohms/inch ($7.87 \text{ m}\Omega/\text{mm}$).

Stress Relief Methods and Thermal Testing Results

When the solder joints cracked on the original panels, several methods of stress relief were examined. Two types, lap-joint and spider-joint prevented the cracking.

Lap-Joint Stress Relief

Transformers were mounted on PCB with the leads looped on the noncomponent side and soldered in the plated hole and at the end of the lead to the board lands. Figure 4 shows the lap-joint type of terminal. These transformers were modified by soldering soft copper leads to the nickel leads to provide flexibility for lead dressing and to allow the lead to flex during thermal cycling. The lap-joints require PCB with paths leading to the plated holes on the noncomponent side.

Figure 3. Strip-Chart Recorder Setup for DC Resistance Test

Figure 4. Spider-Joint (Upper) and Lap-Joint (Lower) Type Stress-Relief Solder Terminals

Spider-Joint Stress Relief

Two XT0002 and two XT0003 transformers were modified by attaching soft copper leads to the nickel leads. These were mounted on a PCB with stress relief on the component side of the board. The leads were stress relieved before entering the plated holes. Figure 5 shows typical spider-joint stress relief.

Stress Relief Testing Methods

The test panels were prepared in the same manner as the 15 previous panels. The sides of the transformers were coated with polysulfide, 0.500-inch-high (12.7 mm) potting forms were installed, the potting forms were filled with EN-4 polyurethane, and the solder terminals were visually inspected. These test panels with stress relief in the transformer leads were subjected to 25 temperature cycles. No cracks were detected on the stud solder joints at the spider-joint terminals. The lap-joint solder terminals were not cracked at the board-path terminations. As expected, the stud-type solder terminals of the lap joints were cracked. The stud-type joints were used only to maintain component spacing from the PCB.

Either of these two stress relief methods defined can be employed to minimize low-cycle fatigued solder joints. Both methods require transformers with low modulus leads such as soft copper, or low modulus leads must be spliced to the nickel or copper-alloy leads. One method provides stress relief on the component side of the PCB, and the other provides relief on the noncomponent side. Both methods have limitations that may require PCB or packaging changes. For stress relief on the noncomponent side of the board, paths must exist to the eyelets in such a configuration that lap joints can be made. The solder-joint height is increased by the stress relief loop, requiring added packaging space. For spider-joint stress relief on the component side of the PCB, added space on the sides of the transformers is required for the stress relief loop.

ACCOMPLISHMENTS

CDA725, ETP copper, and nickel transformer lead materials were evaluated in relation to ease of assembly, solderability, electrical resistance, and number of temperature cycles before solder terminal failure. All three lead materials exhibited severe fatigue and cracking after four temperature cycles. However, the solder terminals maintained electrical continuity during 53 temperature cycles. Both the spider-joint and lap-joint effectively eliminated the effects of thermal stresses.

Figure 5. Cross Section of Spider-Joint

CDA725 copper-alloy transformer lead material was found superior to nickel. The copper alloy was more solderable, more flexible, and less deformed from temperature cycling than the other materials. Regardless of lead material, stress relief must be provided to prevent solder joint fatigue and cracking when transformers are encapsulated in a polyurethane or in any other material with a large coefficient of expansion and low modulus.

With the standard stud solder joint, the ease of assembly was similar for each type of pretinned lead, and no assembly difficulty was encountered. However, when the leads required bending to provide stress relief, copper was the most workable, followed by CDA725 and then nickel. Nickel is difficult to work because of its relative stiffness. Stiff, high modulus lead material transmits stress to the solder joint. For both types of stress relief, the leads were trimmed and more flexible leads were soldered to the trimmed leads before bending.

Solderability was essentially the same on all three lead materials. All pretinned transformer pins were bright, shiny, and continuous. There was no detectable difference in the pretinned layer of the different lead materials; however, there was considerable variation in the electrical resistances of the three pin materials. This is not a concern of these transformers because of short lead lengths and the small effect of milliohm variations of the transformer functions. However, effects of resistance in each specific application should be considered.

Appendix A

RESISTANCE MEASUREMENTS

Table A-1. Resistance Measurements on Copper-Lead Transformers

Unit Number	Reference/ Panel Number	Unit Type	Resistance (mΩ)									
			Before Potting in EN-4	After Potting in EN-4	Temperature Cycles*							
					1	2	3	4	5	6	7	8
1	T2/13	XT0003 (4 Pin)	44	44	44	44	43	45	41.2	41.8	42.2	42.6
2	T2/15		43	43	44	44	--	--	--	--	--	--
3	T1/12		53	55	55	54	55	56	53.1	53.1	54.1	54.4
4	T1/15		43	42	43	42	--	--	--	--	--	--
5	T2/14		48	48	47	49	49	--	--	--	--	--
6	T2/12		41	39	40	38	40	41	37.8	38.1	38.7	39.0
7	T1/14		48	48	48	49	48	--	--	--	--	--
8	T2/11		46	46	46	44	47	46	--	--	--	--
9	T1/11		47	46	46	45	47	47	--	--	--	--
10	T1/13		43	45	44	43	45	45	41.3	41.7	42.1	42.5
11	T4/13	XT0002 (6 Pin)	42	41	42	42	42	43	39.5	39.5	40.6	40.8
12	T4/11		36	37	36	36	37	38	--	--	--	--
13	T4/14		44	44	44	45	46	--	--	--	--	--
14	T3/11		37	38	36	36	38	37	--	--	--	--
15	T3/12		37	38	38	38	39	41	36.7	37.3	38.1	38.0
16	T3/15		43	42	42	43	--	--	--	--	--	--
17	T3/14		45	45	43	44	44	--	--	--	--	--
18	T4/12		37	38	38	37	40	40	37.0	36.8	37.8	37.6
19	T3/13		41	42	42	43	42	41	39.8	39.9	40.5	40.7
20	T4/15		44	43	44	44	--	--	--	--	--	--
*Temperature Cycle = 4 hr at -40°C; 1 hour at 21.1°C; 4 hr at 71.1°C; 1 hr at 21.1°C												

Table A-1 Continued. Resistance Measurements on Copper-Lead Transformers

Unit Number	Reference/ Panel Number	Unit Type	Resistance (mΩ)							
			Temperature Cycles							
			9	12	15	18	21	37	53	76
1	T2/13	XT0003 (4 Pin)	42.5	41.2	42.2	43.9	41.4	41.2	42.3	44.9
2	T2/15		--	--	--	--	--	--	--	--
3	T1/12		54.5	53.4	53.8	54.8	53.7	53.8	55.3	--
4	T1/15		--	--	--	--	--	--	--	--
5	T2/14		--	--	--	--	--	--	--	--
6	T2/12		39.3	37.9	38.6	38.8	37.7	37.8	38.9	--
7	T1/14		--	--	--	--	--	--	--	--
8	T2/11		--	--	--	--	--	--	--	--
9	T1/11		--	--	--	--	--	--	--	--
10	T1/13	XT0002 (6 Pin)	42.7	41.2	42.1	43.0	41.8	40.4	42.3	42.7
11	T4/13		40.7	39.6	40.4	40.9	39.5	38.9	40.2	44.4
12	T4/11		--	--	--	--	--	--	--	--
13	T4/14		--	--	--	--	--	--	--	--
14	T3/11		--	--	--	--	--	--	--	--
15	T3/12		38.4	36.9	38.0	37.7	36.8	36.3	38.6	--
16	T3/15		--	--	--	--	--	--	--	--
17	T3/14		--	--	--	--	--	--	--	--
18	T4/12		37.7	36.6	37.7	37.4	36.7	36.2	38.0	--
19	T3/13		41.1	39.6	40.3	41.1	40.4	39.6	40.3	40.9
20	T4/15		--	--	--	--	--	--	--	--

Table A-2. Resistance Measurements on Nickel-Lead Transformers

Unit Number	Reference/ Panel Number	Unit Type	Resistance (mΩ)									
			Before Potting in EN-4	After Potting in EN-4	Temperature Cycles*							
					1	2	3	4	5	6	7	8
21	T1/9	XT0003 (4 Pin)	49	50	50	50	50	--	--	--	--	--
22	2		53	53	54	49	54	54	--	--	--	--
23	1		53	56	53	53	55	56	--	53.1	54.4	54.3
24	14		54	56	54	55	54	57	53.0	52.8	54.0	53.8
25	5		54	56	55	51	55	56	52.4	52.8	53.8	53.6
26	3		47	47	47	45	48	49	45.8	46.2	47.2	46.8
27	6		56	56	57	55	56	57	55.1	54.3	55.3	55.4
28	10		54	54	54	51	--	--	--	--	--	--
29	7		49	50	48	50	51	50	47.1	47.6	48.8	48.6
30	8		53	52	52	52	54	53	--	--	--	--
31	T3/1	XT0002 (6 Pin)	54	57	56	57	58	58	55.5	55.8	56.6	56.5
32	6		56	57	57	55	58	58	55.6	55.9	56.8	56.9
33	10		54	57	57	60	--	--	--	--	--	--
34	4		54	57	56	57	57	58	55.0	55.4	56.2	56.3
35	3		47	55	55	55	55	55	53.0	53.4	54.2	53.7
36	7		49	53	53	53	53	54	51.1	51.1	52.1	52.3
37	9		49	55	55	55	55	--	--	--	--	--
38	8		53	55	55	55	55	57	--	--	--	--
39	5		54	58	60	59	58	60	57.0	57.5	58.1	--
40	2		53	61	61	61	61	62	59.0	--	--	--
*Temperature Cycle = 4 hr at -40°C; 1 hr at 21.1°C; 4 hr at 71.1°C; 1 hr at 21.1°C												

Table A-2 Continued. Resistance Measurements on Nickel-Lead Transformers

Unit Number	Reference/ Panel Number	Unit Type	Resistance (mΩ)							
			Temperature Cycles							
			9	12	15	18	21	37	53	76
21	T1/9	XT0003 (4 Pin)	--	--	--	--	--	--	--	--
22	2		--	--	--	--	--	--	--	--
23	1		54.3	53.4	53.7	54.0	53.6	54.0	55.3	56.8
24	4		53.8	52.8	53.3	53.7	52.1	53.0	53.7	55.8
25	5		54.2	52.6	53.3	54.1	52.7	53.4	54.7	59.4
26	3		46.9	45.6	46.3	46.6	45.8	45.8	47.3	--
27	6		56.1	54.4	55.2	56.8	54.0	53.8	55.7	58.8
28	10		--	--	--	--	--	--	--	--
29	7		49.0	47.3	48.2	48.5	47.7	47.7	48.8	49.6
30	8		--	--	--	--	--	--	--	--
31	T3/1	XT0002 (6 Pin)	56.6	55.5	56.2	56.4	55.8	55.3	57.7	80.5
32	6		57.6	55.9	56.1	58.9	55.8	54.9	57.4	60.9
33	10		--	--	--	--	--	--	--	--
34	4		56.6	55.2	56.1	56.1	54.2	54.2	56.2	58.7
35	3		53.6	53.0	53.4	53.4	52.6	53.1	54.2	--
36	7		52.3	51.1	52.2	51.6	51.1	50.8	52.6	53.1
37	9		--	--	--	--	--	--	--	--
38	8		--	--	--	--	--	--	--	--
39	5		59.1	57.2	57.8	59.0	56.2	56.1	58.1	59.4
40	2		--	--	--	--	--	--	--	--

Table A-3. Resistance Measurements on CDA725 Copper Alloy-Lead Transformers

Unit Number	Reference/ Panel Number	Unit Type	Resistance (mΩ)									
			Before Potting in EN-4	After Potting in EN-4	Temperature Cycles*							
					1	2	3	4	5	6	7	8
41	T2/5	XT0003 (4 Pin)	60	60	61	61	61	61	58.6	58.8	59.8	59.5
42	1		62	62	63	63	63	64	60.1	60.3	61.1	61.0
43	6		62	62	63	63	64	63	60.1	60.5	61.1	61.2
44	9		57	56	53	55	56	--	--	--	--	--
45	7		54	56	55	54	56	55	53.0	53.3	54.4	54.3
46	2		60	60	60	61	60	60	58.1	--	--	--
47	8		60	58	60	58	58	60	--	--	--	--
48	3		55	57	55	51	55	57	53.3	53.1	54.2	53.9
49	10		59	59	60	55	--	--	--	--	--	--
50	4		61	62	62	61	62	64	60.0	60.3	61.1	61.4
51	T4/1	XT0002 (4 Pin)	68	68	67	66	68	70	67.0	66.7	67.4	67.6
52	7		63	63	62	63	63	63	60.9	61.7	61.8	62.1
53	8		65	64	64	64	65	65	--	--	--	--
54	10		65	66	64	63	--	--	--	--	--	--
55	9		65	65	64	65	65	--	--	--	--	--
56	6		68	68	67	68	69	69	66.2	66.7	67.2	67.4
57	3		68	66	67	70	67	69	65.2	65.3	66.6	66.2
58	5		70	69	70	70	70	70	68.0	67.3	68.6	68.6
59	2		69	69	70	70	70	70	67.4	--	--	--
60	4		69	68	67	65	68	68	66.6	66.6	67.1	67.6
*Temperature Cycle = 4 hr at -40°C; 1 hr at 21.1°C; 4 hr at 71.1°C; 1 hr at 21.1°C												

Table A-3 Continued. Resistance Measurements on CDA725 Copper Alloy-Lead Transformers

Unit Number	Reference/ Panel Number	Unit Type	Resistance (mΩ)							
			Temperature Cycles							
			9	12	15	18	21	37	53	76
41	T2/5	XT0003 (4 Pin)	60.1	58.6	59.4	60.3	58.9	58.7	60.5	61.3
42	1		61.1	60.4	61.0	61.0	60.3	60.8	61.9	64.3
43	6		61.8	60.2	61.1	61.6	60.2	60.3	62.2	64.0
44	9		--	--	--	--	--	--	--	--
45	7		54.7	53.4	54.3	54.2	53.7	54.0	55.3	56.4
46	2		--	--	--	--	--	--	--	--
47	8		--	--	--	--	--	--	--	--
48	3		53.8	53.0	53.6	54.3	53.2	53.6	55.3	--
49	10		--	--	--	--	--	--	--	--
50	4		61.3	60.4	61.1	61.4	58.4	59.6	59.9	62.9
51	T4/1	XT0002 (6 Pin)	67.4	66.4	61.0	67.0	66.6	66.6	67.1	68.5
52	7		63.4	61.0	61.8	61.7	61.0	60.8	62.5	63.1
53	8		--	--	--	--	--	--	--	--
54	10		--	--	--	--	--	--	--	--
55	9		--	--	--	--	--	--	--	--
56	6		67.8	66.6	67.2	68.2	66.4	65.7	67.0	69.1
57	5		69.5	67.8	68.6	69.3	68.0	68.0	66.9	71.8
58	3		66.6	65.3	66.0	66.3	65.2	65.6	66.9	--
59	2		--	--	--	--	--	--	--	--
60	4		67.3	66.1	67.3	66.8	66.3	66.6	67.7	69.3

Appendix B

**TEMPERATURE CYCLE EFFECTS ON
NICKEL, CDA725, AND COPPER
TRANSFORMER-LEAD/SOLDER
INTERFACE**

40X

400X

Figure B-1. CDA725 Copper Alloy Lead and Solder Interface After Two Temperature Cycles, Transformer 49

40X

400X

Figure B-2. Nickel Lead and Solder Interface
After Two Temperature Cycles,
Transformer 10

40X

400X

Figure B-3. Copper Lead and Solder Interface
After Two Temperature Cycles,
Transformer 15

30X

30X

Figure B-4. Solder Fillets Showing a Crack at Solder and Lead Interface (Upper Photo) and Recession of Lead into the Solder (Lower Photo) After Four Temperature Cycles, XT0003

30X

30X

Figure B-5. Solder Fillets Showing Severe Crazing at CDA725 Lead (Upper Photo) and Crack at Nickel Lead and Solder Interface (Lower Photo) After Four Temperature Cycles on Panel 8, XT0003

NICKEL

30X

CDA725

30X

Figure B-6. Solder Fillets Showing Cracks at Lead and Solder Interface After Five Temperature Cycles on Test Panel 2, XT0002

40X

400X

Figure B-7. Nickel Lead and Solder Interface
After Five Temperature Cycles,
Transformer 22

40X

160X

Figure B-8. CDA725 Copper Alloy Lead and Solder Interface After Five Temperature Cycles, Transformer 46

160X

Figure B-9. Tapered Sections of CDA725 Copper Alloy Pin Solder Joint of Transformer 48 Showing Varying Degrees of Solder Working and Fatigue

600X

400X

Figure B-10. CDA725 Alloy Lead and Solder
Interface Showing Crack on Surface
and Working of Solder After 53
Temperature Cycles, Transformer 48

60X

60X

Figure B-11. Nickel Lead Fillets Showing Crack and Extrusion of Leads After 53 Temperature Cycles, Transformer 26

60X

160X

Figure B-12. Nickel Lead and Solder Interface
Showing Extrusion of Lead and
Working of Solder After 53
Temperature Cycles, Transformer 26

400X

400X

Figure B-13. Nickel Lead and Solder Interface
Showing Working of Solder After
53 Temperature Cycles, Trans-
former 26

60X

60X

Figure B-14. Copper Lead Solder Fillets Showing
Recession After 53 Temperature
Cycles, Transformer 3

60X

60X

Figure B-15. Copper Lead and Solder Terminal Showing Recession of Lead into Terminal and Deformation of Lead Causing Recession After 53 Temperature Cycles, Transformer 3

400X

Figure B-16. Copper Lead Solder Fillet Cross
Section Showing Working of Solder
After 53 Temperature Cycles,
Transformer 3

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