Pyralux® LF Flexible Circuit Materials
Excellent
Automotive Fluids Reliability

Tom R. Fisher; Product Manager Adhesiveless Products, 4/03

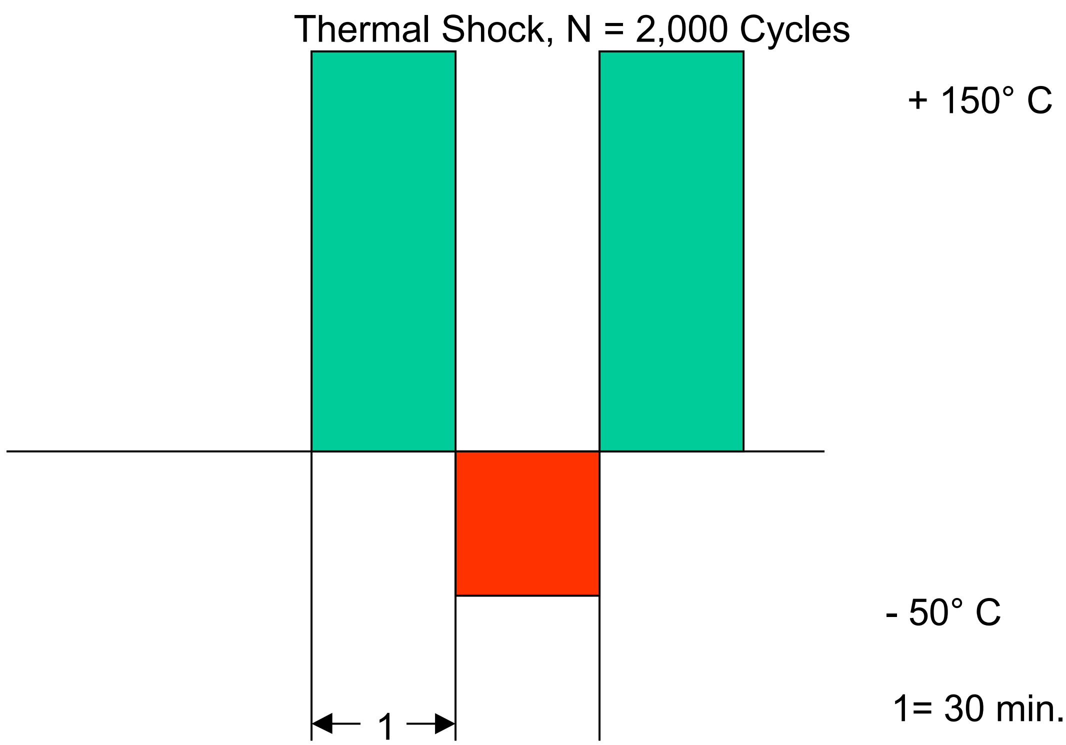
Evaluation Testing

- Thermal Cycling – Peel Strength Performance

Thermal cycling has been established as one of the standard Accelerated aging test methods to assess functional reliability throughout the industry. Bond strength retention after thermal cycling at the temperature range -50° C to +150° C was selected as realistic and representative of the under the hood environment.

The two-chamber thermal shock test was used. The test constructions were exposed to a 30 minute dwell time at each temperature extreme as per mil-std-202E method 107D. Cycling was accomplished through 2000 hours.

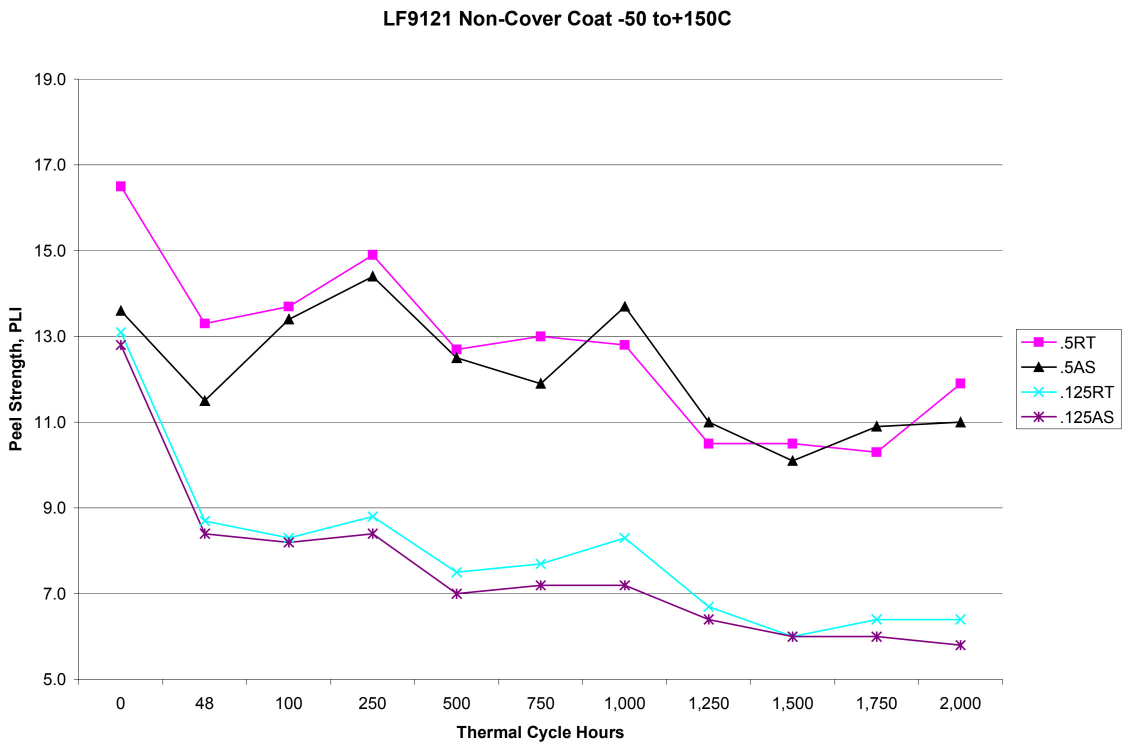
Peel strength measurements were obtained per .5” cut and .125” etched specimens as per IPC TM 650 method 2.4.9 , both initial and after thermal exposure.



<u>Bond Strength Copper – Pyralux ® LF9121</u>

The peel strength performance is adequate with good bond integrity and the composite is still very pliable.

Graph #1



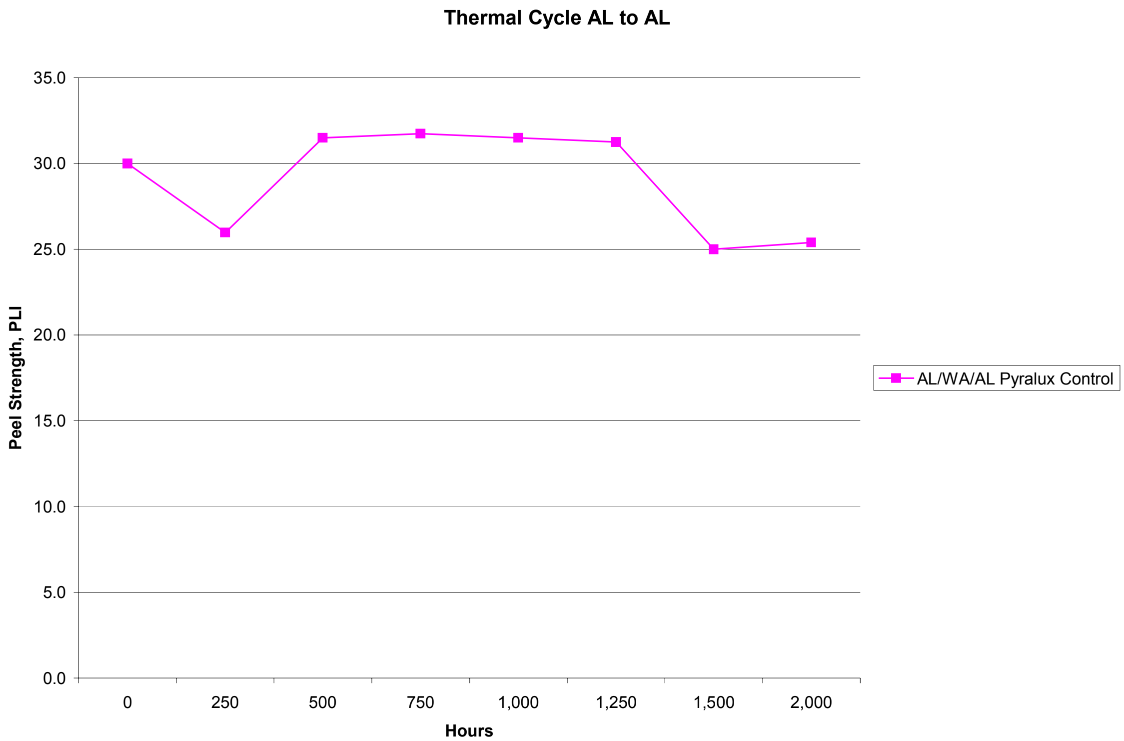
Peel results taken on Pyralux ® LF9121 after thermal cycling is shown in Graph #1. Bond strength retention is often considered correlatable to functional performance. The initial room temperature peel strength was 16.5 PLI for .5" cut method decreasing to 11.9 PLI after 2000 hrs. thermal cycle (-50º C to +150º C) for 72% bond retention. For the .125" etched method, bond retention was 49% (13.1 PLI → 6.4 PLI). Failure mode in both methods was at the copper adhesive interface.

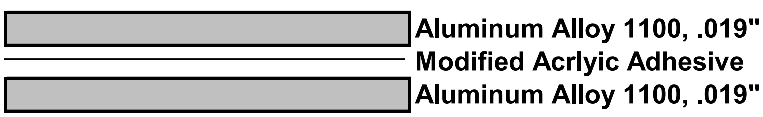
Peel strength was also tested per both peel methods after solder float exposure (30 sec//550º F) following the thermal cycling. This simulates reworking and is a severe test of the integrity of the composite. Bond retention was 80% for the .5" cut method and 45% for the .125" etched method. Again bond failure was at the copper adhesive interface. This failure mode is theorized to be caused by oxidation from the copper sheet or inward. Test specimens were not cover coated by cover sheet or conformal coating which would reduce the level of oxidation.

<u>Bond Strength Aluminum to Aluminum</u>

This demonstrated bond performance indicates the modified acrylic adhesive will perform well in this heat sink application.

Graph #2



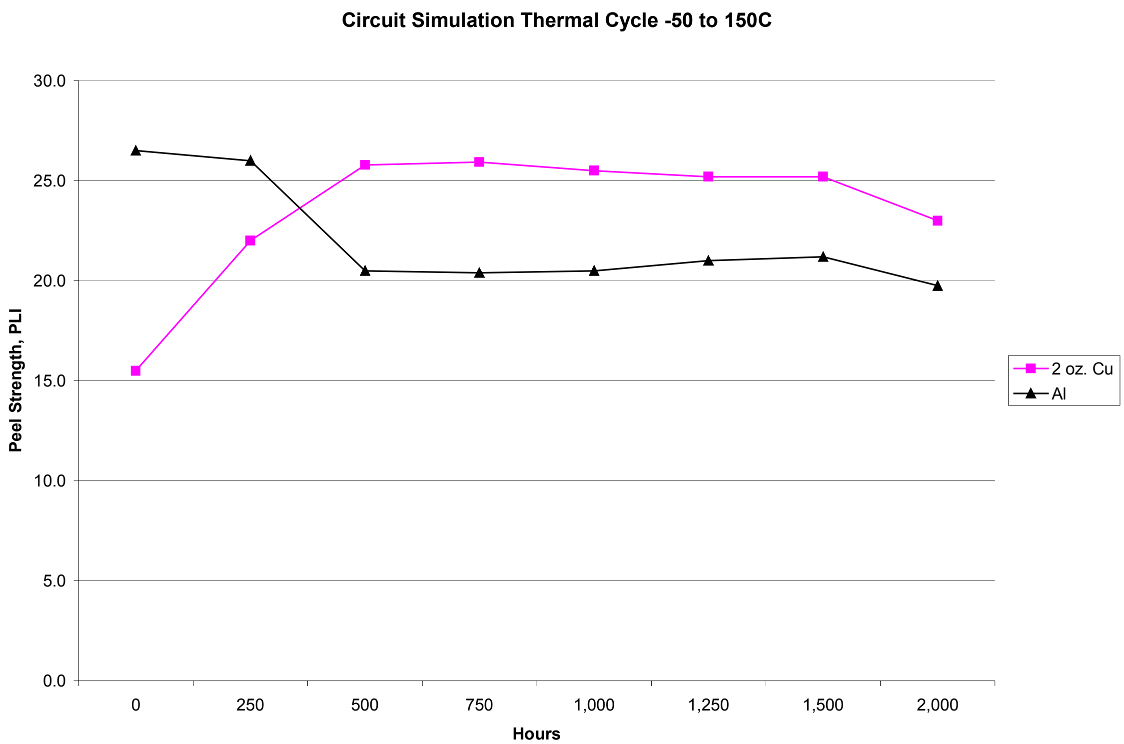


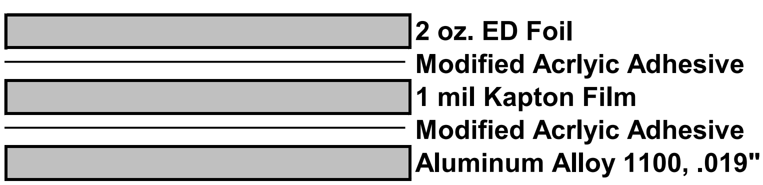
Peel strength results taken on the aluminum to aluminum composite shown in Graph #2 with the test data, indicate an initial peel strength of 30 PLI. After 2000 cycles at –50º C to +150º C, the bond is 25.3 PLI (84% bond retention). Failure mode was cohesive within the adhesive.

<u>Bond Strength Circuit Simulation</u>

Based on bond retention, functional performance of the composite materials should be no problems in the under-hood application.

Graph #3





Bond testing of circuit simulation composite illustrated with the data in Graph #3, shows an initial bond of 26.3 PLI for the copper foil. After the 2000 thermal cycle exposure the bond was 19.8 PLI (bond retention of 75%). Mode of failure was the adhesive copper interface.

The aluminum plate bond was 15.6 PLI initially and after 2000 cycle exposure was 23.2 PLI. This agrees very closely with the aluminum to aluminum performance in Graph #2. Mode of failure was cohesive in the adhesive. The increased bond performance (149%) is theorized to be the result of organo metallic bonds with thermal aging.

High Humidity Simulation

Pyralux ® composites, which include the modified acrylic adhesive and Kapton ® dielectric film, are routinely tested for insulation resistance (IR) and moisture insulation resistance (MIR) per IPC TM650 method 2.6.3.2 (SM840A).

It is common for all materials to drop 1E1→1E3 ohms in resistance when measured "wet" because of the continuous water film between the electrodes on the surface and a certain concentration of ions in the water film. It is hypothesized that increased water absorption or water retention by the base insulator causes the lower resistance.

Examination of the below table of test results demonstrates the phenomenon.

Sample ID	IR	MIR	2 HR RECOVERY
LF9111 Pyralux	E12-E13	E9	E12-E13
FR-4 Cu Control	6E14	1E11	4E13

This drop in insulation resistance under wet conditions has a minimal affect on the functional characteristics of the finished product. This is supported by the after 2 hour recovery value which shows the IR improved to the original or higher value.

Testing of Pyralux ® 8 mil lines/9 mil spaces comb patterns under the test conditions of IPC SM8404A indicate that the humidity environment should not be a problem. The test coupons were not covered or hermetically sealed.

Testing of initial IR values on comb pattern bonded to an aluminum heat sink achieved 1E12→1E13 ohms resistance. IR was measured with continuous voltage of 500 vdc for 60 seconds between tracks and heat sink. Refer to Table #2 for MIR values initially and after 3 hours total immersion at room temperature in various typical automotive fluids.

Gasoline
- unleaded — Sunoco Ultra 94 octane
- leaded — Sunoco Regular 89 octane

Diesel Fuel — Texaco

Motor Oil
- 10W30 Castrol Hydrocarbon base
- Synthetic Oil Mobile 1 15W-50

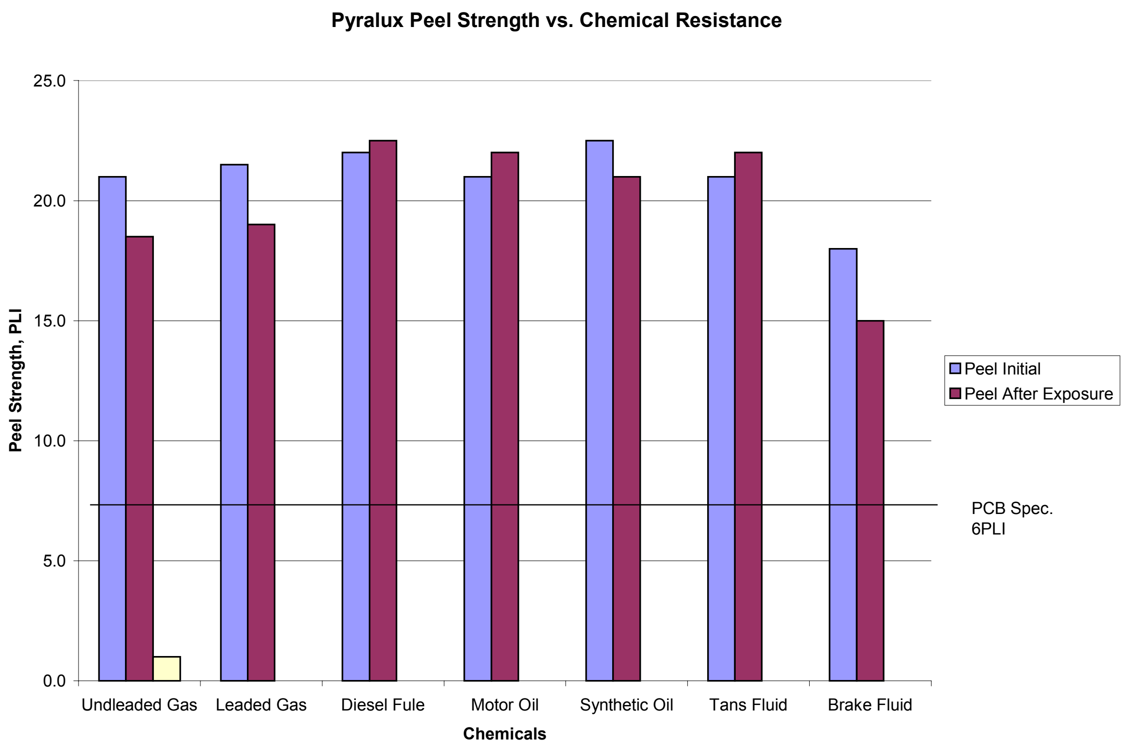
Transmission Fluid — Motorcaft — Mercon/Dextron

Functionality in high humidity conditions should not be a problem. Industry experience with Pyralux ® fabricated into complicated PWB's at high volume confirms this fact.

Chemical Resistance – Automotive Fluids

Pyralux ® will perform well in automotive fluids as shown by the bond strength retention.

Graph #4



In an effort to define the performance of Pyralux® flex circuits in the automotive environment, IPC TM650 method 2.3.2 was employed. In this method, .020" etched copper conductors were exposed to the below fluids by total immersion of the lower half of the specimen for three (3) hours at room temperature.

Gasoline	• unleaded	Sunoco Ultra 94 octane
	• leaded	Sunoco Regular 89 octane
Diesel Fuel		Texaco
Motor Oil	• 10W30 Castrol Hydrocarbon base	
	• Synthetic Oil Mobile 1 15W-50	
Transmission Fluid	Motorcraft	Mercon/Dextron
Bake Fluid	Prestone	DOT 3

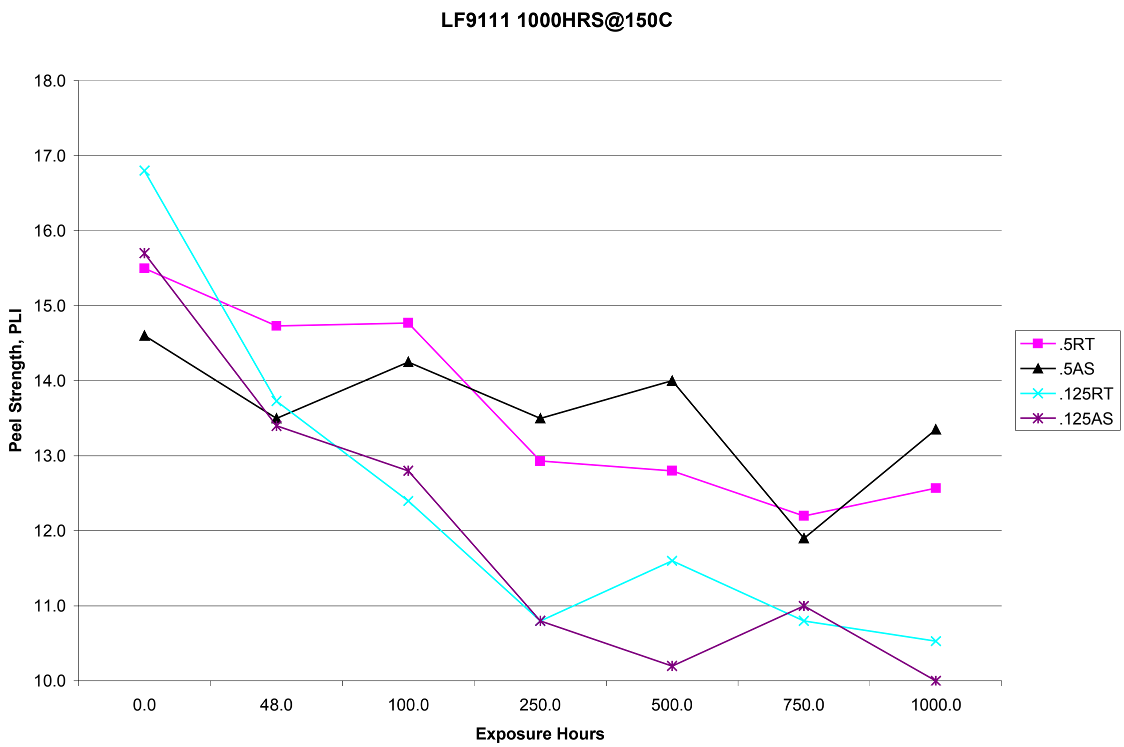
After removal from the test fluid, the specimens are allowed to air dry at standard laboratory conditions and are examined for tackiness, blistering, swelling or delamination. Observations are noted. Then peel strength of the conductor in the exposed and non-exposed areas is performed.

Actual test data is provided in Graph #4. The results indicate **Pyralux® will perform well in automotive fluids as shown by the bond strength retention.** This experiment is general, since each particular application or company has a different set of test conditions; however, the testing would show any gross non-compatibility.

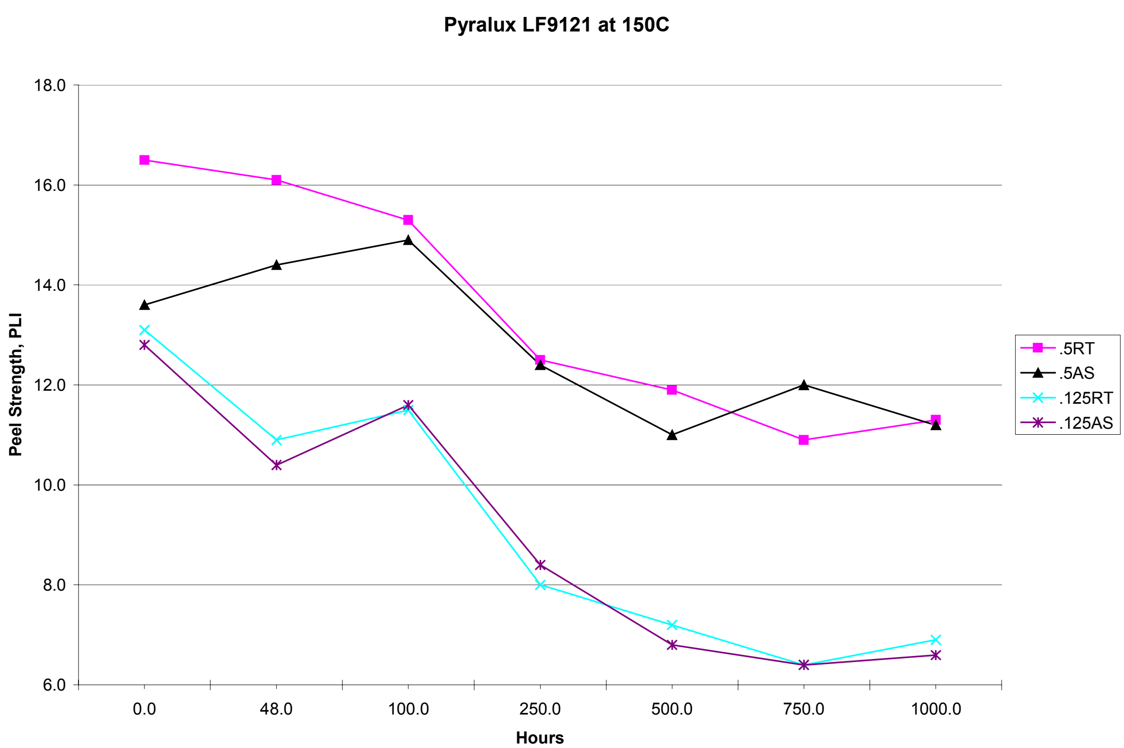
<u>Heat Aging</u>

All bond values after thermal aging and thermal aging plus solder float, which simulates any rework procedure, are of sufficiently high value (6-10 PLI) to assure composition integrity and circuitry functionality.

Graph #5



Graph #6



Concern for the high temperature environment of the underhood compartment prompted thermal aging to accumulate 1000 hours continuous exposure to 150 º C temperature. The 150 º C temperature was chosen as the upper extreme expected in the engine area, although actual temperature monitoring indicated 110-125 º C is more realistic.

Two Pyralux® products were thermally aged. These were LF9111 and LF9121. The constructions are 1 mil or 2 mil Kapton® dielectric film coated with 1 mil modified acrylic adhesive both sides and bonded to one ounce RA copper foil each side.

Peel strength was performed on .5" cut and .125" etched peel specimens per IPC TM650 method 2.4.9. Testing was conducted initially and after each day exposure on "as received" and after solder float for 30 seconds at 550º F.

Graph #5 illustrates bond performance for Pyralux ® LF9111 for 1000 hours @ 150º C. Initial RT bond was 15.5→16.8 PLI (.5" cut/.125" etched) and after 1000 hours bond was decreased to 12.6→10.5 PLI (62-81% Retention).

Bond performance after thermal exposure and solder float shows initial after solder (AS) values of 14.6→15.7 PLI and drops to 10.0→13.3 (64-91% bond retention).

Graph #6 demonstrates the same bond performance for Pyralux ® LF9121.

Packaging Density

It is difficult to generalize about packaging density due to:

- Different component sizes and shapes
- Number of component leads
- Complexity of interconnection

The number of component mounting holes per square inch of usable surface is a good general estimate of circuit density.

IPC Test Methods Used to Generate This Report

IPC TEST MEOTHODS MANUAL, NUMBER; 2.3.2
SUBJECT
Chemical Resistance of Printed Wiring Materials
Chemical Resistance Test Pattern. A9A) Overal size 0.180” by 6.500”. (B) Conductor width and length 0.0200” by 6.000”. (C) Left end conductor tab width and length 0.500” by 0.180” (IPC-A.31).

AUTOMOTIVE TESTING

Chemical Resistance

Gasoline	unleaded leaded	Sunoco Ultra 94 octane Sunoco Regular 89 octane
Diesel Fuel	Texaco	
Motor Oil	10W30 Synthetic Oil Mobile 1	Castrol Hydrocarbon base 15W-50
Transmission Fluid	Motorcraft	Mercon/Dextron
Bake Fluid	Prestone	DOT 3

All exposure total immersion 3 hours at room temperature.

IPC TEST MEOTHODS MANUAL, NUMBER; 2.6.3.2
SUBJECT
Moisture and Insulation Resistance. Flexible Printed Wiring

AUTOMOTIVE TESTING

Chemical Resistance

Expose 8/9 mil line/spaces comb pattern to M&IR conditions (25-65C/90 + %RH/7 days/100 vdc bias/500 vdc) after fluid immersion (3 hours at room temperature).

Gasoline	unleaded leaded	Sunoco Ultra 94 octane Sunoco Regular 89 octane
Diesel Fuel	Texaco	
Motor Oil	10W30 Synthetic Oil Mobile 1	Castrol Hydrocarbon base 15W-50
Transmission Fluid	Motorcraft	Mercon/Dextron
Bake Fluid	Prestone	DOT 3

TABLE #1

Material	CTE Ppm/º C	Thermal Conductivity W/in - º C	Density 1b/in ³
Aluminum	23.0	5.50	.098
Copper	17.3	10.10	.323
Copper/Invar/Copper	5.7	3.40	.296
Ni Molybdenium	5.6	3.30	.370
Alumina (96%)	7.0	.75	.137
Alumina Nitride	4.6	5.15	.118
Solder 60/40 Sn/Pb	25.1	1.60	.307
FR-4 (Reference)	14.4	.0086	.070

Table #2

MOISTURE AND INSTALLATION RESISTANCE
IPC Method SM-840A (25-65C90% RH/7 days/100 vdc bias/500 vdc for 60 sec.)

Sample ID	Description	IR	Results Ohms, Specification E12 M & IR		
			0hrs	2hrs recovery	24hrs recovery
LF9111	ED copper/Aluminum Control	E13	PASS		
LF9111	RA copper/Aluminum Control	E13			
LF9111	ED copper on Aluminum-Control	E12-E13	E8-E9	E12	-
LF9111	RA copper on Aluminum-Control	E11-E12	E8	E11-E12	-
LF9111	ED/A1 Unleaded Gas	E10-E11	E7	E11-E12	E12
LF9111	RA/A1 Unleaded Gas	E10-E11	E7	E11	E11
LF9111	ED/A1 Leaded Gas	E12	E7	E11	E11-E12
LF9111	RA/A1 Leaded Gas	E12	E7	E11	E11-E12

Exposure to other automotive fluids below illustrate the same trend of IR drop (E7 wet).

- º Exposure 8/9 mil/line/spaces comb pattern to M&IR conditions (25-65C/90 + %RH/7 days/100 vdc bias/500vdc) after fluid immersion (3 hrs at room temperature).

Diesel Fuel	Texaco	
Motor Oil	10W30 Synthetic Oil Mobile 1	Castrol Hydrocarbon base 15W-50
Transmission Fluid	Motorcraft	Mercon/Dextron

CONCLUSIONS:

Exposed 8/9 mil line/spaces comb pattern bonded to Aluminum heat sink.

- º Insulation resistance (IR) passes 1E12
- º Fluid exposure drops moisture insulation resistance (MIR) to E7 ohms. One decade below non-exposed (E8 ohms) experience.

Reference; C.E. Killian CRP-715 11/16/89