GOLD FLASH CONTACTS: SUPER SAVER OR TICKING TIME BOMB

By

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Within the last 5 years, a new philosophy has evolved as world economic conditions have changed. This philosophy embraced the concept of "global competition". As with all other industries, the connector industry was not immune from this strong influence.

The finish system used on contacts is one of the most basic and critical features of a connector. A good connector design will fail in the field if an improper or poor quality finish system is used. Up to the late 1970's, the basic gold finish employed was 50 μ inch (microinch) of gold over 50 μ inch of nickel regardless of application. As gold escalated in price (early 1980's), the gold thickness decreased to 30 μ inch and became the standard for general industry usage. During that period of time, a number of long term performance characterizations were performed by various companies and user agencies which in conjunction with increased improvement in plating processes, quality and effectiveness allowed this reduction to be incorporated except in special cases such as the military or other critical applications. Thus, the change was successful since it was based on sound technical approaches and evaluations which were shared with the industry as a whole.

As the new market philosophy took hold in the early 90's a significant "thought" process change took place. The decision making criteria shifted from technological input to a strictly sales approach. The hue and cry became "reduce costs, reduce gold - we won't have any problems. After all the Pacific rim countries are doing it and we have to be competitive." This unfortunately is only so much nonsense and to a degree, is somewhat irresponsible. The fact of the matter is that careful thought and analysis, which should have prevailed, is being ignored or not even being considered. Many generic connector families have moved towards using gold flash.

The definition of gold flash is considered anything ≤ 10 μ inch (microinch) gold. To understand whether this system is a super saver or a ticking time bomb, one has to revisit the common failure mechanisms that could exist with contact systems such as:

a) Corrosion, Edge Creep, and Pore Corrosion

b) Fretting Corrosion resulting from thermal and / or vibratory mediums

c) Diffusion, Migration

d) Wet and Dry Oxidation Mechanisms

The above are time dependent mechanisms and occur within a few weeks up to years in field applications. The failure trigger is contingent on application and environmental severity's imposed. This is further complicated by a number of interrelating connector design factors such as:

a) Normal Force

b) Durability Levels required (wear)

c) Contact pin count (is the connector 40 positions or 400 positions)

d) Electrical requirements (power, signal, high speed data, etc.)

e) Connector environmental shielding features

f) Contact geometry, redundancy and configuration

g) Wipe

h) End of life considerations

As previously indicated, environmental considerations and severity levels are interwoven with the above and involve thermal, humidity and harsh environments. Electrical requirements are also becoming more stringent as a result of the evolution of new circuits operating at lower and lower energy levels and the still exploding application arena such as high speed data transmission, networking capabilities, automotive, etc.

During the past 12 to 18 months, there has been reported an increasing number of problems involving the use of gold flash contacts. This has resulted in a number of evaluations to be initiated relative to the system. Although they are not yet being performed on a comprehensive basis, they have addressed specific issues. The following are the results of a few of these studies to illustrate the pertinent points of concern.

DURABILITY AND HUMIDITY

Durability is a measure of the number of possible mating cycles which may be typical of the wear occurring on a contact system in its application. Wear may cause one or two problems - expose the underplate/base metal or entrap wear debris between the two contact surfaces.

The study used as an example involved a number of connector configurations as indicated in the tables following. The study involved the following:

a) No. Of Mating Cycles : 1, 25, 50

b) Pltg. Thickness : 30 to 40 µ in Au/Ni

5 to 10 µ in Au/Ni

c) Connector Types : Card Edge

"Din" Type

D.Submin Type

d) Procedures : DMG (Dimethylglyoxime)- Spot Test,

Thermal Cycling with Humidity

The DMG test is simple. After durability cycling, the contacts are dipped into a solution of DMG in accordance with EIA (Electronic Industries

Association) 364,TP (Test procedure) 85 proposed. If the gold has been worn thru exposing the nickel underplate, it will have a bright red color.

The following are the results as observed:

Cycled 1X : ≤ 10 μ in Au - Minor Spots

30 μ in Au - No Spots

Cycled 25X : ≤ 10 μ in Au - Sustained wear tracks

30 μ in Au - No Spots

Cycled 50X : ≤ 10 μ in Au - Heavy wear tracks

30 μ in Au - A few Spots

Since the above was not definitive, additional connectors were exposed to a temperature cycle with humidity in accordance with EIA 364, TP 31. This involved a 10 day exposure with temperature cycling between 25° C to 65° C at a humidity level of 90-95% (cycle time 24.0 hours). LLCR (low level circuit resistance) was performed in accordance with EIA 364, TP 23 using a 100 ma test current and a 20 mv open circuit voltage so as not to disturb any surface films or oxides which had formed. The change in LLCR was monitored. The results are shown in Figure #1 and Table 1.

TABLE 1

CHANGE IN LLCR (Milliohms)

	< or = 10 microinches		30 microinches	
Durability Level (# of positions)	**Average Change**	**Maximum Change**	**Average Change**	**Maximum Change**
A)**CARD EDGE** (100)				
1X	-0.2	+2.1	-0.5	+1.5
25X	+6.6	+113.8	0.0	+1.0
50X	+50.7	+612.3	-0.2	+1.2
B) **DIN TYPE** (96)				
1X	+0.2	+0.5	0.0	+0.5
25X	+2.8	+15.8	+0.2	+0.6
50X	+4.1	+32.8	+0.1	+0.3
C) **D-SUBMIN** (25)				
1X	+0.1	+0.3	0.0	+1.1
25X	+0.3	+6.8	+0.4	+1.9
50X	+3.6	+46.7	+0.1	+1.8

The connectors used in this study were procured from distribution and involved three different manufacturers, one for each connector family indicated. The above results are obvious comparing the two thickness. Essentially the ≤ 10 μ in gold system remained stable when mated only once and increased degradation occurred as durability increased. The card edge was an

"open" (non shielded) design with the contacts exposed directly to the humid environment. The "Din" and D-Submin designs were well shrouded and protected by the design features normally employed. Although the DIN and D-Submin connectors were sheltered, they were showing signs of degradation.

Unfortunately, there's no definitive accelerator factor for this environment. It does however, crudely represents 1 to 2 years in the field typical of the Northeast part of the country. The normal force of the contact systems for all three connector families was 100-125 grams but a direct comparison between families is difficult due to contact size and configuration differences.

Examination of the connectors revealed the following:

A) Card edge connector: The mating card had a champhor in the mating pad area. However this champhor was rough with a "sandpaper" texture. This resulted abrasive wear which very quickly penetrated the gold exposing large areas of nickel underplate at both the 25 and 50 mating cycle levels. Exposing these connectors to a humidity with thermal cycling, a "breathing action", results which forces the humidity to the inner portions of the connector. Nickel exposed to normal air will oxidize. The addition of humidity accelerates this oxidation until an equilibrium thickness occurs (generally 70 to 80 angstroms). This thin film is very tenacious and resistive in nature.

B) DIN and D-Submin Types: The mating portions of these connectors were relatively smooth. The resultant wear was adhesive and thus less damaging. Although nickel was exposed, it was not as significant as with the card edge. Another factor was the connector shrouding or shielding factors which offered a form of protection. Although it was approaching unstable levels (after 50 mating cycles), they exhibited significantly lower magnitudes of change (still unacceptable but not catastrophic). The shrouding delayed penetration of the humidity into the connector interiors.

All of the connectors mated once remained stable for the exposure durations. The 30 µin gold connector for all three families remained stable. Examination revealed some wear but nickel exposure was minor to non existent.

HARSH ENVIRONMENT

Harsh environments exist in every area of the world to varying degrees. From a practical point of view, there is no such area with a benign environment. The definition of a benign environment is a positive pressure area with filtered air conditioning and humidity control (<70%). There are very few areas which fit this definition. Thus connectors will see some form of harsh environment. For many years, relatively high gas concentrations have been used for evaluation purposes. This has been felt to be unrealistic since no correlation or accelerator factors have been established. The test

environment gaining in popularity is the so called Battelle mixed flowing gas procedures which utilizes low concentration of 3 or 4 gases. It is based on

field data generated over a number of years. The procedures to perform this test is well described in EIA 364, TP65, ASTM B827 and B845 as well as IEC (International Electro-Technical Commission) 68-2-60. Table II indicates the gas concentrations commonly used.

TABLE II

MIXED FLOWING GAS

(Concentration - ppb*)

	Class II	Class III
$C1_2$	10 +/- 3	20 +/- 5
NO_2	200 +/- 50	200 +/- 50
H_2O	10 +/- 5	100 +/- 20
SO_2 (Optional)	200 +/- 20	200 +/- 20
Temperature	30 +/- 2°C	30 +/- 2°C
Humidity	70 +/- 2°C	75 +/- 2°C

* ppb = parts per billion

There is an accelerator factor for this test (2 days exposure =

1 year). The Class II is generally used for controlled conditions and Class III for uncontrolled. The SO_2, although optional, is fast becoming common for these exposures (predominately used by such organizations as Bellcore, IBM, etc.). This gas (SO_2)is particularly important for finish systems using nickel as the underplate.

Figure #2 illustrates the impact of these gas environments on a porous gold surface. The basic study involved 15 µin gold over 50 µin nickel on CA725 copper alloy coupons (SO_2 was not included in this study).

The coupons as illustrated by Figure #2 were exposed for 10 days removing a few coupons after 2, 6 and 10 days of exposure. As can be seen, after 6 days of exposure, an extremely high level of pore spots existed relative to the Class II environment. This is typical of classical pore corrosion and based on the number of spots is classified as gross porosity. Figure #2 also illustrates the same type of coupon exposed to Class III. In this instance, the test duration was aborted after 6 days, the corrosion observed was a combination of pore corrosion and edge creep with the entire surface nearly being covered by corrosion products. When the surface was probed, the LLCR observations were in the hundreds of milliohms.

In evaluating connectors, those on backplanes are normally exposed unmated for a portion of the duration and are generally header types.

This is to simulate option card applications. The contact pins in this case are not well protected or shielded from the environment. Additionally, many test schedules require 10 to 100 cycles of durability prior to the exposure. Table II is a compilation of results from various studies performed over a wide variety of connector families relative to unmated exposure durations.

TABLE II

EXPOSURE TIME (UNMATED - DAYS)

Gold Thickness (microinches)	**CLII**	**CLIII**	**CLII**	**CLIII**	**CLII**	**CLIII**	**CLII**	**CLIII**
~ 5	S-M	U	M-U	U	M-U	U	U	U
~ 10	S-M	U	S-U	U	M-U	U	U	U
15	S	U	S-M	U	S-M	U	M-U	U
30	S	S-U	S	M-U	S	U	S-M	U

Analysis of the Class II exposures indicate that the results were dependent on contact geometry's, normal force, "quality" of the plating system, surface conditions, etc. relative ≤ 10 µin of gold. The 30 µin thickness level appeared to be almost independent of these variables up to and including 6 day exposure levels. Failures involved pore corrosion and edge effects. The Class III environment is considered to severe for the plating thickness levels involved. Similar tests in the mated state only, had similar results except the acceptable % increased. This was attributed to the effectiveness of the connector shielding (shrouding, etc.).

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VIBRATION

Figure #3 indicates the results of a study involving connectors exposed to vibration environments. The connectors were square in configuration with the number of positions being in excess of 350 contacts. The application involved required that the mating device not be restrained during the test phase. Two groups representing different mating concepts were evaluated. The first group involved a zero insertion force mating concept. The second group, utilizing multiple tine contacts (six contact elements), was designed to mate in the conventional manner utilizing low insertion force design techniques. Both connector groups had two plating thickness' - ≤ 15 µin Au/Ni and 30 µin Au/Ni, with all other things being equal.

The severity level used was based on amplification factors anticipated from system level requirements and the packaging schemes employed. The severity level established was 7.3 G's rms (random). The duration of the exposure was 45 minutes/axis, 3 axis. Sine vibration was not used since it was felt to be non-realistic. The frequency ranged from 50HZ to 2000 HZ. The connectors were mounted to test boards. The vibration fixture was mounted in a manner to surround the test samples along their periphery. There was no provision to restrain the mating devices used.

Review of this data indicates that all of the manufacturers 30 µin gold product remained stable or stable with minor change. The same design's with 10 µin gold had significantly different results, ranging from stable to unstable resistance conditions.

The following are the results of the design and failure analysis (≤ 15 µin gold) performed.

1. The greatest changes were occurring in the corner positions for all versions.

2. The failure mechanism was fretting corrosion relative to manufacturer 1 and 2. Fretting motion occurred wearing through gold and exposing the nickel underplate.

3. Manufacturer 4 used a conventional geometry but had a high normal force. The magnitude apparently was great enough to overcome the dynamics of fretting motion with no motion being observed.

4. Manufacturer 3 had a significantly different contact geometry than all other manufacturers. This geometry added to stability of the contact/pin system minimizing fretting motion but allowing a lower normal force to be used.

5. Manufacturer 2 utilized conventional geometry while manufacturer 1 was more of an edge contact system which tended to "cut" through the thin plating thereby resting on the nickel underplate (an abrasive condition).

6. There was a similar difference between manufacturers 5 and 6 relative to contact geometry. Manufacturer 5 had a conventional geometry. Manufacturer 6 contact's were mating to a blanked edge at the end of the beam. Due to the low normal force, the contacts were fretting and the edge contact (manufacturer 6) resulted in abrasive wear thus penetrating through the gold faster.

In summary, this comparative evaluation indicates that the successful use of "thin" gold was contingent on designing for the proper combination of contact geometry, configuration as well as normal force for the vibratory severity level used. It also indicates the 30 µin gold system is more forgiving and allows a greater latitude in the design concept. The reader should be cautioned, however, that due to the complex interrelationships relative to vibratory application, generic use of marginal platings will pass in one application and may fail in others. This is an area which requires constant evaluation and design considerations.

Figure #4 illustrates a fretting evaluation which was performed on a dual tine convential type contact. The evaluation was a forced motion test. In other words, the test was set up to deliberately force fretting motion in a

precise manner at specific amplitudes. The contacts had two types of plating - gold flash Pd Ni (palladium nickel) and a 50 µin gold over nickel system.

The test was performed up to 10^7 fretting cycles monitoring LLCR at discrete periods of time. As can be seen , the gold flash Pd Ni degraded rapidly at 6×10^5 cycles. In this instance the gold flash had been worn through resulting in the final contact surface being Pd Ni. Pd Ni is susceptible to frictional polymer formation and was the ultimate failure mechanism. At 0.0002 inch displacement degradation was also occurring but not in the same magnitude. The 50 µin gold system remained stable at both amplitudes. The results further demonstrate the susceptibility of gold flash in fretting applications such as seen and discussed in Figure #3.

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THERMAL ENVIRONMENT

Figure #5 indicates the results of a temperature life study on standard type DIN connectors. The test environment was 500 hours at 85° C. All backplane connectors were header (plug connectors) style and the "daughter" card unit contained right angle receptacle connectors. The results indicate (except for manufacturer 4) that the contact systems remained stable in this environment for both the 10 and 30 µin gold product. Porosity testing on manufacturer 4 contacts indicated gross porosity existed on the pin and socket contacts, thus implying heavy influence of the exposed nickel underplate. Nickel oxidizes very quickly reaching an equilibrium level(approx 80-90 angstroms thick). It is very resistive in nature. The plating for manufacturer 4 was considered poor quality. The other manufacturers contacts were also tested for porosity. Although porosity did exist on the 10 µin gold product, it was not gross and ranged from 1 to 2 pores per contact within the contact area. The results shown herein is typical with other connector styles tested at 85° C. The systems remained stable as long as gross porosity was not present. There are indications, however, that there is potentially increased problems as the temperature increases. This is demonstrated in Figure #6. The data shown are the results of a basic coupon test which was being evaluated for high temperature characterization. The influence of normal force was also evaluated.

Although the 15 µin gold system met the requirements, it was approaching the failure level at 100° C. It is also interesting to note the impact of normal force. Interpretation of the data indicates that higher normal forces did decrease the resistance values to a level where adequate design margins were available.

At 150° C and 200° C, the degradation was much greater. This was anticipated for the gold and gold flash Pd Ni systems. Surface analysis indicated nickel diffusion occurring. This diffusion decreased in intensity as the gold thickness increased. The influence of normal force was also evident.

RECOMMENDED CHARACTERIZATION PROGRAM

A vehicle to evaluate gold flash performance is shown in the following minimum test schedule.

MINIMUM TEST PLAN

SAMPLE PREPARATION

LLCR LLCR LLCR LLCR REFERENCE

TESTS

T-LIFE POROSITY

VIBRATION DURABILITY (300-1000 HRS) DURABILITY NORMAL

RANDOM (PRECONDITIONING) (PRECONDITIONING) FORCE

LLCR

LLCR, X-AXIS LLCR LLCR

Y-AXIS

Z-AXIS CYCLIC MFG,UNMATED

HUMIDITY (4-5 DAYS)

(500-1000 HRS)

LLCR

LLCR

MFG,MATED

(5-6 DAYS)

LLCR

LLCR: Low Level Circuit Resistance

MFG : Mixed Flowing Gas

The above plan can be modified or expanded contingent of application specific situations or based on generic product families. Each of the above test groups addressses different basic failure mechanisms as follows:

Vibration : Fretting corrosion induced by mechanical stress.

Durability : To simulate wear normally expected in the use of the product (should not be an arbitrary number).

Cyclic Humidity : Fretting corrosion induced by thermal excursions,wet

oxidation processes.

T-Life : Dry oxidation processes, diffusion or migration mechanisms.

MFG : Corrosion, pore or edge creep.

Reference Test : Attribute determination to allow the monitored data

to be viewed in proper perspective.

Assuming the data generated is of sufficient quantity to satisfy confidence levels, then the product assessment can be properly established.

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SUMMARY

The results as discussed above are similar with other studies which have been performed. In essence, the 30 µin gold thickness products appear to have consistent performance regardless of product family or manufacturer (unless plating quality is at issue). The gold flash system appears to be to lacking this consistency. The following summarizes the results as discussed herein in combination with other data.

PLATING THICKNESS

(microinches)

		< / - 10	30
Durability	**(1X)**	**Stable**	**Stable**
	(25X)	**Stable to Unstable**	**Stable**
	(50X)	**Marginal to Unstable**	**Stable**

Note: When performed and then exposed to a humid environment.

Harsh Environment			
	Controlled	**Stable to Unstable**	**Stable to Marginal**
	Uncontrolled	**Unstable**	**Unstable**

Note: Contigent on porosity, sheltering, unmated exposure and durability preconditioning.

Vibration	**Stable to Unstable**	**Stable**
Fretting Corrosion	**Susceptible**	**Significantly Less Susceptible**
Temperature		
85 degrees C	**Stable to Unstable**	**Stable**
100 degrees C	**Stable to Unstable**	**Stable**
> / - 125 degrees C	**Marginal to Unstable**	**Stable to Marginal**
Porosity	**Moderate to Gross**	**Very Low**

As indicated above, the gold flash product performance varies from manufacturer to manufacturer as well as between product families. Putting aside basic limitations (such as durability and temperature), those products (gold flash) which appear to perform in a satisfactory manner appear to be tied to the following interrelated variables among others:

a) plating quality (process capability)

b) normal force levels

c) contact geometry and configuration

d) surface conditions

e) contact sheltering techniques

The above indicates that a gold flash product may be successfully used but in a tightly product controlled manner if the performance limitations are known. This implies that this type product may be used in application specific situations after, however, proper technical evaluations have been performed. In this instance, it can be a super saver.

The common perception of using this plating system in a generic sense without objective performance characterization, is on the other hand a "ticking time bomb". A secondary danger is to allow this system to be used in other connector families after successful use in a specific application. This is also a "ticking time bomb". This, unfortunately, is todays thinking and philosophy being employed by a large segment of industry.

One final note, recent work by Dr. Mort Antler and Bill Abbott indicates the possibility of applying contact lubricants which have the potential of enhancing the use of gold thickness < 30 µinch. The reader should be cautioned that in this situation, the cost of the additive process may negate the cost savings realized by reducing gold thickness.

CONCLUSION

Based on todays perceptions and a "sell at all cost" philosophy, a new law has evolved which answers the basic question reflected in the title of this paper.

PEEL'S LAW

Anyone who uses, buys, sells, manufactures or specifies generic socket/connector product families with gold flash, deserves all of the problems which can result.

It is hoped that over time this law will become obsolete. However, without proper data generation to address performance, it will not go away. It is important to remember that cost savings is important in a competitive market but the product still must function properly.

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