# Invotec Group

### The Drive Towards Zero Contamination Within the Delivered PCB



## **Company Overview**





- The Facility has been producing PCBs since 1974
- Largest PCB Manufacturer in UK. Top 11 in Europe.
- Sales 2013 circa £21m. 62% UK & Eire, 35% Europe, 3% ROW.
- 65% of product is for Military, Civil Aerospace or other High Reliability Applications.
- Circa 8% is for Space OEMs

#### invotec Major Customers JABIL THALES BAE SYSTEMS Aviation Northrop Grumman LITEF Gmbh Detica 1 PLEXUS ındra Ultra Alcatel-Lucent ELECTRONICS The Product Realization Company RUAG GE Energy MBDA GENERAL DYNAMICS Aero Engine RIGGILS SWETERS Controls Aerospace Defence Technology Selex ES Quantel ALSTOM Raytheon ELMATICA<sup>®</sup> A Fireneccanica Company THE IN & DESCRIPTION UTC Aerospace Systems ASTRIUM EADS DELPHI Delivering the future. **ASML** SIEMENS HALLIBURTON

## Key Markets - Aerospace & Defense





- Military & Civil Aerospace
- Naval & Land Systems
- Aero Engine Controls
- Weapon Systems & Countermeasures
- Missile & Missile Defense
- Encryption/Cyber Security/Intelligence
- Radar Detection

- Reconnaissance Systems
- UAV
- Guidance Systems
- Communications
- Head Up Displays
- Defensive Aids

## Key Markets - Space



Supply to the European space market includes payloads, ground infrastructure and space equipment for a wide range of civil and military applications.

Projects include:

- Inmarsat 4
- Glonass
- Gaia VPU
- Beacons Product Line
- Sirius (US)
- SSPA Product Line
- Skynet 5
- Alphasat Processor
- Sentinel 1 and 2
- Radarsat 2
- Yahsat



## **Quality & Environmental Approvals**



Invotec operate to the most exacting global quality standards and are accredited to:





NADCAP (Electronics) For flex-rigid multi-layers and microvia technologies



#### BACKGROUND TO INCIDENTS OF INCLUSIONS

- Cinvotec
- Highlighting the potential and risks associated with inclusions is relatively recent from the Space sector.
- Invotec have been working with our Major Civil Aerospace Customers since 2008.
- Trigger Point for Invotec was an aborted take off on a Civil Jet due to an Engine Shutdown.
- The resulting Investigation by the customer established an internal short circuit within the PCB had been the cause.
- The PCB had passed Electrical Testing at Invotec and all subsequent testing after assembly and final integration of the Equipment

#### Example of Actual Short Circuit



#### Surface Appearance

#### . Internal pathway created





#### Characteristics of the Inclusions



In Total 7 Reported Incidents within the Time Frame

Spread over 3 designs only, whilst supplying £2.5M product annually?

All Polyimide with Copper Invar Copper CTE control layers

No occurrences in Epoxy FR4

All incidents occurred after around 100 hours usage time

Every failure was located between PWR/GND layer within a laminate core

No evidence of a Metallic Inclusion, only a void created by the short circuit

Common trace elements found were Carbon (caused by the short circuit event) and Chlorine

### **Corrective Actions in Partnership with Customer**



Monthly Joint Working Parties held on site

Joint Audit carried out of the Laminate Supplier to 'spread the message' and look for possible sources of inclusions

Initial Corrective Action was to improve cleaning of inner layers at the lay up by means of brushing Good intention but subsequently PCB found containing an embedded bristle

Cleaning Technique changed to Vacuum Cleaning of inner layer

Analysis of cleaning head shown to have PVC content (heavy chlorine)

TIME FOR A MAJOR RETHINK

### Kick Starting the Change Process Jan 2010



Weekend Event involving ALL personnel to Clean Down the Entire Facility



#### BACKGROUND TO INCIDENTS OF INCLUSIONS

**Renovation and Refurbishment** 

We have repaired, refurbished and renovated throughout the facility. All areas on the shop floor have had clear out and clean down – some areas such as DES, Bonding, Lay up, ATE Inspection and Despatch have had major renovations. A programme to renovate floors throughout the manufacturing areas instigated and we have installed polycarbonate cladding on walls and replaced ceiling tiles

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## Lay Up Room Improvements



#### Before and After 5S Activity

Central Lam Bonding Room Improvements After befores After

Before







## Lay Up Room Improvements



'Easy Clean' Cladding of Room throughout

**Total Roof Refurbishment** 

Stainless Steel Food Hygiene Standard Furniture

All Lay Up Stations Grounded to minimise Static

Laminar Flow & De ioniser Lay Up Stations

Interlock Doors for Access

Clearly Visible Charts showing what Tools , Kit and accessories are allowed within the area







#### ENVIRONMENTAL IMPROVEMENTS

CLADDING, NEW ROOF, STEEL FURNITURE, AIR CON, ANTI-STATIC, INTERLOCKED DOORS, LAMINAR FLOW



### Lay Up Area Improvements



Before



Old composite Furniture removed Plastic Trays replaced

Prepreg stacked Horizontal Inner Layers stacked Vertical



## **General Improvements**



Before



After





## **General Improvements**



BEFORE

#### AFTER



### SEM Evaluation Survey within Lay Up Area



Sample pieces from circa 128 items used with Lay Up were bonded into test panels and then submitted for SEM evaluation for Chlorine content.

These included:- Pens

Plastic Grips from Mallets
Casing from Radio
Sellotape Dispenser
Plastic Wallet for Job Card / Traveller
Kapton Tape
Gloves

From this a list of permissible items was generated and displayed within the Area.

Some items essential of use even though high content. Red flagged for close scrutiny

## All Contents of Lay Up Area evaluated using SEM



			· · · · · · · · · · · · · · · · · · ·	
Itom Description		- Ber	Excision	Ci Castral, Techh 7
1	Decethane			
2	Paconad			
3	DTEE release			
4	Conformal		Teachara	<2 Aprel
5	Swiss white		Farged	C ligns
6	Route card sleeve	2	FTTE minus	d ligns
7	Polyimeide pre-pred packet Arlon		Earland Natural	16.00
8	New pre-preg backet Anon		Forde and shares	d here
9	Sealing rod for above		Televisia reverse realist Julas	Glim
10	Kraft paper	1	Mana Daulut anda	C ligns
11	Cutter handle material		Indiag not far shares	Gliges
12	Anti static han	22	Keed paper	<1 Signal
13	FR4 pre-preg packet Isola	11	Cultur baselle material	03.0X
14	FR4 pre-preg packet Venter	17	Anti-viata keg	-C Signs
15	Dacovia	10	764 per project passes taxas	C Signs
16	Pacotiana nius		Large banded Certain Annue	- C Jens
17	Polyimide pro prog packet Ventec	20	Facebook Control of Co	1.0
18	ED4 blue pre-preg packet Ventec	17	Palorinida preveny pashat Ventes	Gliges
19	Kanton tana			
20	Sallatana		FE4 blue perman pashet Ventes	C liens
21	Peditape	17	Kapian lage for undenida	42 Bigma 0.00
22	Tak rag	20	Salaringe	1.0
22	Scalpel bolder	21	Laiter	-C Signs
24	Foil packaging fibre board		Taking	1.13
25	Foil packaging melomine	24	Call radianter film based	1.0
26	Yallow Jahal	20	Tel redenire extenire	Glens
27	Scalnal blada	38	Yellew lated	-C ligns
21		27	Zanipri binin	C ligns
28	Hair	21	Hair	< Signa
00	I Linear	29	Kair nat	C ligns
29	Hair net	- 22	Firm of suff	2.04
30	Fibres off cuff	21	Carel (TA	118
JU			De pe	1.0
31	Cured FR4	24	Earth adults insulation	14.27
00	D's see	38	Classing" - marky missing"	Glipse
32	Bic pen	22	Deer out	1.13
33	Conveyor paint	37	Reer maintai	вя
33		- 11	Silama salari	5.19
34	Earth cable insulation			
35	Cladding		<2 Signs - At a balance the limit of datastics, which makes between 0.12% and 0.22% C	
36	Door seal	-		
37	Floor material		Sample 33 - the Cladding was wholeg, incring a void in the main. Some small pollow patholes around the edge	of the weld, generally elabling residues, were analyzed.
31				
30	Silicone sealant			

### All Glove Types used evaluated by SEM



Sample	Key elements detected.	Other elements detected	Comment
White finger fluff (glove)	Carbon, oxygen.	Silicon, aluminium, magnesium, calcium, sulphur.	Benign. Others: pre-preg debris.
Blue thumb rubber (glove)	Chlorine (very high).	Copper, iron, silicon, titanium, sulphur.	'Rubber' appears chlorinated. Others: debris
Finger round bobble (glove)	Chlorine (very high).	Iron, copper, silicon zinc, calcium aluminium.	Material appears chlorinated. Others: debris.
Yellow wrist fluff (glove)	Carbon, oxygen.	None	Benign.
'Rubber' hammer	Chlorine (very high).	Calcium and titanium.	PVC. Others used as fillers.
K56 B-side squiggly bit (INVt167517 2306)	Sulphur (high).	Copper from adjacent copper plane.	Origin not known.

As a part of the trials to establish the source of debris found in a small number of K56 PWBs, samples were taken from gloves used in and around the lay-up area and laminated between pre-preg sheets. The findings are summarized here.

Also investigated was a B-side from a scrap (by and at Invotec) K56 and the 'rubber' end of the hammer used in the lay-up area.

The descriptions of the glove derived items are as presented by Invotec.

## Lay Up Room Improvements



#### **Product Contamination Reduction**

We have developed improved 5S checks in areas such as Bonding Lay up to strictly control materials allowed into the area and prevent potential contaminants entering our products. Further 5S cleaning checks and instructions ensure that potential contamination in critical areas is held to an absolute minimum.

GREEN = OK

AMBER = LOW RISK

RED = RISK / CAREFUL USAGE AND REINSPECTION OF ITEM



## **Total Supply Chain Involvement**



Important to stress that Invotec view this activity as Continuous Improvement rather than an Event

Having 'Cleaned Up our Act' it was important to Roll out the Message to the Laminate Suppliers

Invotec have carried out regular Audits of the Laminate Suppliers in Europe, USA and Asia

Varying reactions to the suggestions for improvements

Space Sector is only a very small amount of the Laminate Suppliers end use

Essential that PCB Fabricators use Laminate Suppliers adopting the best manufacturing processes (filtration and enclosed Treaters, camera/AOI inspection, magnetic absorption to remove metallic inclusions etc.)

## Summary of Inclusions



As a Key Statement Invotec have had no further incidence of short circuits developing in a working unit since the internal clean up and the Continuous Improvement started in Jan 2010

By mutual agreement with the customer Invotec have changed polyimide laminate supplier

Design would appear to be a key factor. (Differential potential across Power and Ground Planes or Voltage used?)

Invotec have only experienced such incidents on polyimide material?

Is it a consequence of the increased bonding temperature or simply 'poor' laminate as supplied?

Any improvements have to be applied across the PCB Fabricator and Laminate Supply Chain

Checking for debris/inclusions is heavily reliant on visual Inspection. Therefore it can never be 100% effective

## Summary on Inclusions



Imposing a greater cleanliness requirement for the substrate will add a major cost and a two tier logistical requirement for Space product with no absolute guarantee of being inclusion free

Invotec's experience is that all incidents occurred between copper planes. No inspection will screen this out

By the very nature of the Approval Process and Change Control the Space sector is very restricted in material suppliers used across many Products

We all need to be sure we are using the most capable and evolving material suppliers to minimise risk of inclusions within the base material as supplied.



# Thank You