Qualification of PWBs Outsourced from Asia

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Abstract
The growth of portable wireless products and related consumer electronics is fueling a major outsourcing effort towards Asia. Most OEM (original equipment manufacturers) are partnering with CMs (contract manufacturers) in Asia to outsource key operations such as board design, fabrication, SMT assembly and procurement to maintain profitability and competitive edge.

Outsourcing can offer OEMs significant advantages in maintaining a healthy bottom line, reduced capital risks, increased access to current technologies and reduced time to market. Outsourcing also allows CMs and EMS (Electronic Manufacturing Services) to subcontract the work that does not fit their core competencies, so they can make diversified product.

Outsourcing with strategic partners is more important for OEMs for the lead free migration as this is bringing many challenges for the PCB and SMT industry with new high Tg (Glass transition temperature) laminates, new lead free alloys, rework processes, moisture sensitivity etc. This requires careful evaluation of new laminate materials, balancing component layout and optimization of reflow profiles to minimize damage to PWBs. This is critical for thin PWBs (less than 0.1 mm) boards used in cell phones and other portable products that use build up microvia technologies.

The handheld wireless product market place demands products that are small, thin, low-cost and lightweight and improved user interfaces. In addition, the convergence of handheld wireless phones with palmtop computers and Internet appliances is accelerating the need for functional circuits designed with miniaturized, low-cost technology.

Outsourced PWBs from Asia are becoming more and more of a reality for OEMs involved in high volume manufacturing. Proper evaluation and qualification of these facilities is critical for assembly reliability.

This paper reviews qualification efforts from HDI (High Density Interconnect)[1} and ALIVH (Any layer Inner Via Hole) PWBs [2} procured from Asian fabs in China, Taiwan, Korea and Japan. Quality systems audit, PWB evaluation, acceptance criteria, DPPM (Defective Parts Per Million) Review and reliability testing will be presented. Additionally, ways and strategies for overcoming cultural differences, communication, conflict resolution, and building supplier/ customer relationship will be reviewed.

Introduction:
High volume SMT assembly production requires careful evaluation of suppliers for critical commodities like PWBs as SMT assembly yields heavily depend on good quality PWBs, solder paste print processes and oven reflow profiles. This has become more critical in lead free reflow due to higher peak reflow temp. And narrow process windows. Proper storage, handling controls in the supply chain and process controls in production are necessary for good yields and reliability. DPPM reduction efforts have to focus on manufacturing processes and overcoming many cultural, communication and interpretation differences.

Supplier Audit and Qualification:
The qualification effort required a factory and warehouse visit and conducting a Quality systems audit of the PWB manufacturing process. Critical items such as ISO 9001-2000 certification, capabilities survey, staff training and certification, 8D Process, Design management, Process and Materials controls, etc. were reviewed. Based on this review a ranking was provided for four major categories- Customer Satisfaction, Manufacturing Process, Materials Management and Quality System. The supplier is certified for production based on a minimum score of 90% or above as shown in Figure 1.

Most suppliers in Asia have some operations outsourced from their manufacturing processes. It is important to understand the manufacturing process flow for your product or technology and also survey the subcontract operations during the audit as process controls implemented there also affect the end product. All action items generated from the audit were closed within 5 working days. It is important to follow up with annual quality systems audits.

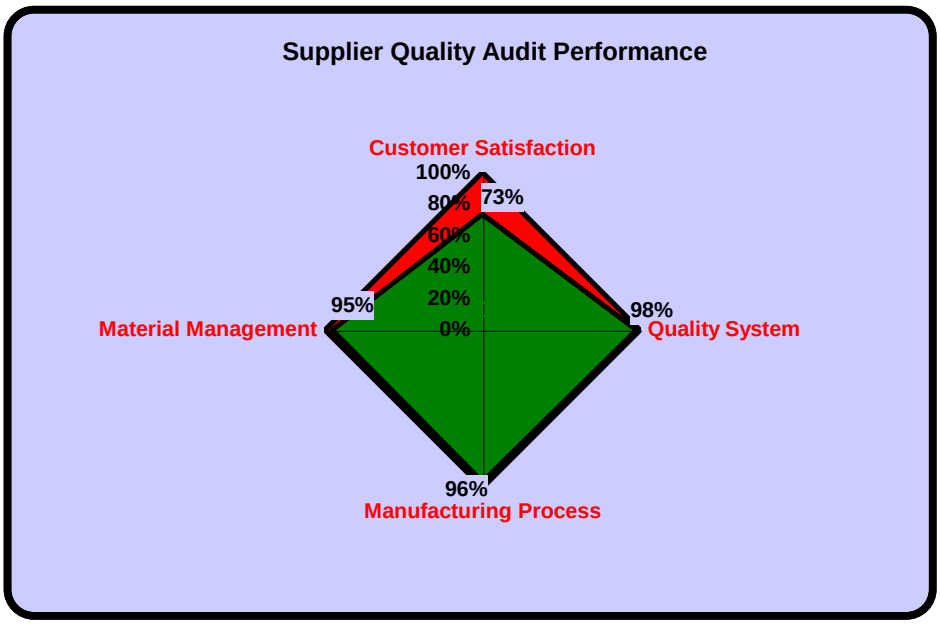

Figure 1- Supplier Score for Quality Systems Audit

Product Qualification

Board assembly process was a double-sided surface mount assembly soldering of ball grid array packages, connectors, chip resistors, capacitors, and diodes etc. The assembly was reflowed in convection air at a peak temperature of 244°C. The solder paste used for assembly was (Tin/Silver/Copper)– SAC 305 - No clean version. [3].

X-sections were performed on the BGA packages and other components to evaluate the quality of the solder joints and ensure compliance to IPC 610 – Rev D for leaded packages and IPC 7095 for BGA packages. Also microvia integrity was evaluated with X-sectional analysis. X-sections showed acceptable solder joints and no degradation of microvias. [3, 4].

The qualification process was conducted using product build for a phone program and X-sectional analysis, and reliability testing per IPC 9701[5]. Temp. Humidity test was conducted at 85°C/85% Relative Humidity for 500 hours and Thermal Shock testing was conducted from –25°C to +125 C - 20 min. dwell for 500 Cycles. Figure 2 shows X-sections for HDI board assembly post reflow and Figure 3 shows ALIVH PWB assembly post reflow.

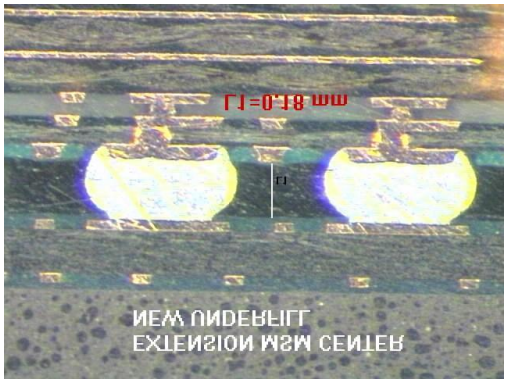

Figure 2 – HDI PWB

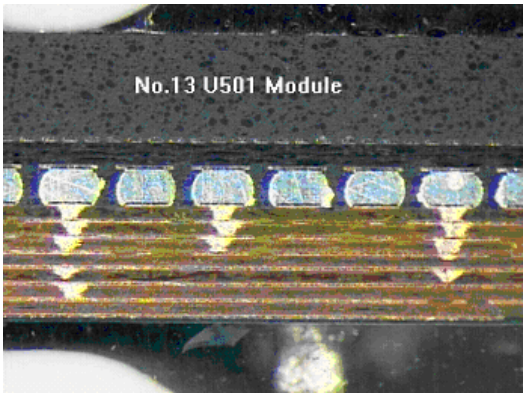

Figure 3- ALIVH PWB

Rework Process

SMT packages were reworked using hot air soldering tools and BGA packages were reworked with hot air using controlled ramp/soak profile. The main concern was damage to microvia connections and PWBs pads during component removal and reattach. Component rework was performed 2X on the leaded packages and 1X on the Ball-Grid Array packages. All packages survived rework. There was no damage to PWB pads, or blistering of solder mask during rework. No damage was

seen on microvia connections. Figure 4 and Figure 5 are X-sections of HDI and ALIVH PWB post rework and 500 thermal shock cycles.

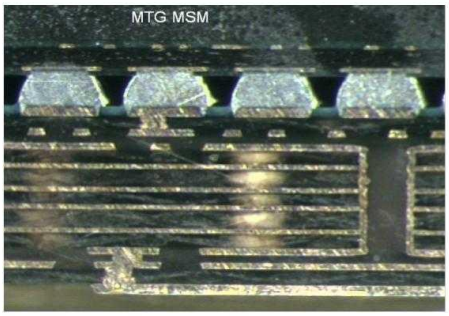

Figure 4 HDI PWB –Thermal Shock

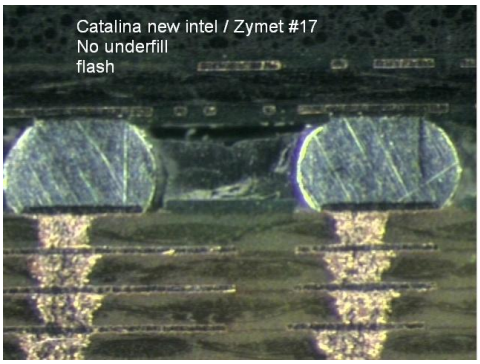

Figure 5 ALIVH PWB –Thermal Shocks

Production DPPM Issues
The production rejects were of two types. Cosmetic rejects were the lots rejected at Incoming IQC Inspection. The functional rejects were lots rejected post reflow (after SMT assembly) and during board level electrical test.

Cosmetic Rejects
There were many rejections at incoming, due to incorrect paperwork, scratches, exposed copper etc.
Incoming inspection was done using IPC 600 Rev G.

A joint meeting was held with suppliers and CM to address these issues. After the paper work trail was clarified this issues were reduced. Suppliers put a plan in place to address the scratches, exposed copper etc and reduce this escape to CM. KWC team audited them for this corrective action.

There were several process flow and material handling issues that had to be worked out to minimize PWB fallout at SMT production. Prior to assembly outsourcing, PWBs were shipped from Supplier locations to KWC – San Diego and immediately utilized for production so staging and storage was minimal. This situation changed when SMT factory operations moved to CM in China. Due to customs requirements, all incoming parts to China go through customs in Hong Kong and then they are staged in a warehouse facility until they are ready to move to CM warehouse. The staging time and handling of PWBs increased. Suppliers were required to improve the packaging from regular plastic bags to MSL bags with vacuum sealing and desiccant. This required some changes in PWB packaging, but in the long run gave better reliability. The warehouse audits were conducted to ensure that temperature was maintained at 22+/- 5C and humidity less than 60%. Particular attention was given to storage during summer months when heat and humidity is very high in this area.

Functional Rejects
The majority of the fallout after reflow was classified into 3 major defect categories - opens, delamination and shorts. This required a review of handling and test operations at CM and process controls at suppliers. The corrective action effort began with compiling defect data and having joint meetings with supplier and CM. This was followed up with storage and handling audits to ensure that controls were being executed properly.

The PWB fabs implemented controls in the PWB packaging area by switching to a bake cycle of 120°C for 4 hours prior to dry packaging. The CM implemented controls at IQC in resealing all packages opened for inspection before returning to storage. On the production floor, packages were only opened just prior to loading on the SMT line. All opened packages were stored in dry boxes. Reflow Assembly time was controlled within 48 hours. Warehouse storage controls were implemented to store PWBs in controlled temp/ humidity portion of the warehouse and first in/first out FIFO (First In, First Out) was enforced.

In order to address delamination issues, PWB suppliers conducted designed experiments (DOE) with their materials suppliers and got a better understanding of processing of high Tg laminates. Circuit trace opens issues were addressed by implementing controls in the electroless plating process and various other bath parameters and controls. Additionally, controls were implemented in the hot air rework process at the CM as some of the opens issues were occurring after rework. Proper training of rework operators, controlled distance of hot air nozzles and airflow and ongoing audits further helped in

lowering the DPPM for opens. The issue of shorts was addressed by controlling contamination in the PWB expose, develop and etch process and implementing proper sampling frequency to minimize the escape to CM.

All of these combined efforts have helped in reducing the DPPM post reflow and minimized the scrap cost.

Communication Strategies

When switching from in-house manufacturing to overseas, a lot of time, distance and interpretation get added to resolving daily line issues. As an OEM, it is very essential to keep your documentation correct and updated because any misinformation can cause yield loss, delay in shipments to customer and chargeback's to OEM.

PWB is a complex commodity. When parts are rejected, it requires a good understanding of the PWB manufacturing process, acceptance criteria, failure analysis of the defects and root cause determination.
Since CM did not have very knowledgeable team for PWBs, OEM component engineers had to mediate when rejections occurred. This helped both sides (CM and PWB Suppliers) understand the defect and work towards an improvement plan.

This first step was to have a joint meeting of suppliers and CM to understand CM's IQC spec and acceptance criteria. Simple lot rejects caused by incorrect paperwork, labeling, X-Outs etc. were eliminated after an understanding of IQC specs and lot acceptance rate at IQC improved to 100% within 6 months.

The was followed up with monthly DPPM data to suppliers and conducting a 3 way teleconference .For major fallout, upto 5 failed samples were sent to supplier for failure analysis. Additionally, each quarter we met jointly at the CM facility and reviewed DPPM and defects. This gave a chance for the suppliers to know the CM team and understand the assembly operations and parts movement procedures.
Supplier teams reviewed the failure analysis and corrective action plans were defined.

In order to assist the supplier teams in finding root cause for defect, specific information was provided, instead of DPPM bar charts. DPPM data was further broken down into top 3 defects and top 3 part numbers, to enable them to root cause the major issues first and minimize impact to production. An example is shown in Figure 6 and Figure 7

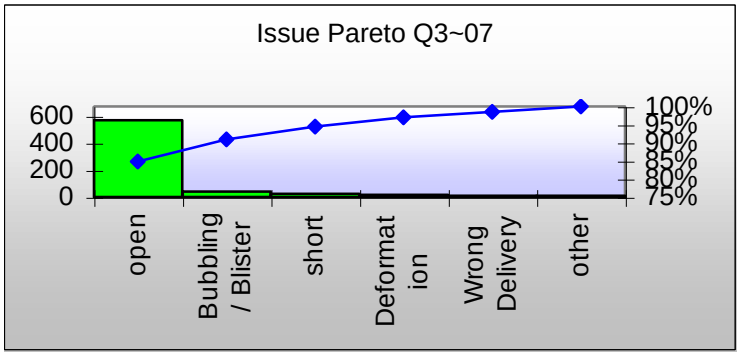

Figure 6 – Defect Pareto –Top 3 defects

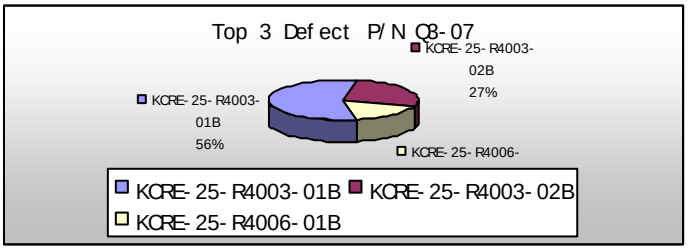

Figure 7 – Top 3 Part Numbers- Defect

Conflict Resolution

The differences in operations, parts management and chargeback system and language at CM did result in conflicts for scrap charges. In these cases, OEM had to step in and ensure that a fair resolution of the chargeback was taking place. The failure analysis was evaluated to ensure that correct root cause was determined. If it was a supplier fab issue, supplier was charged. If it was a process-induced defect such as uncontrolled rework, CM was charged. If both parties had contribution in the defect, the charge was split 50/50 between supplier and CM.

Training /Knowledge Base

The labor force in the CM factories is from a very young age group and not as well experienced and equipped with training as we are used to in the USA, so proper monitoring of their training level is important for good yields and product reliability. This is also essential due to employee turnover. Tight control should be maintained over all process changes, Engineering Change orders (ECOs), Manufacturing Change Orders (MCOs) etc. to minimize defect escape to customers. OEM led training sessions in product handling, test, storage, inspection has improved yields.

Conclusion

Outsourcing assembly operations give OEMs the advantage of high volume manufacturing capacity, massive database systems and corporate direction, but also bring many new challenges of cultural differences, communication barriers, and skill levels which we have not experienced in the US manufacturing fabs. Clear concise communication, documentation, patience and team work with suppliers and CM is one way to ensure success.

References:

1. Microvias for low cost, high density interconnect. John H. Lau, S. W. Ricky Lee
2. The Progress of the ALIVH Substrate- Daizo A., Yoshihiro T., Tadashi N., Fumio E.
3. IPC A-610 Rev D – Acceptability of Electronic Assemblies
4. IPC 7095- Design and Assembly Process Implementation for BGAs
5. IPC 9701 Performance Test Methods and Qualification Requirements of Surface Mount Solder Attachments
6. Control and stability in Lead Free Reflow R.Burke – www.smtmag.com

Qualification of Outsourced PWBs

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Agenda/Overview

- Fab Capabilities
- Quality Systems Audit
- Product Qualification
- Supply Chain Changes
- DPPM Monitoring
- Communication
- Lessons Learned
- Supplier/Customer Partnership

Fab HDI Capabilities

- Taiwan
  - 1n+1, 2n +2, 3n+3
  - Solid/Stack Vias
  - Buried Vias
  - Laser Drilling
  - Multiple Surface Finish
  - Line/Space- 3/3, 2.5/2
  - All Layer Via – Proto
  - Mid Tg, Hi Tg and Halogen Free
- China
  - 1n+1, 2n staggered
  - Solid/Stack Proto
  - Buried Vias
  - Laser Drilling
  - Multiple Surface Finish
  - Line Space 4/4 , 3/3
  - All Layer Via – Proto
  - Mid Tg, Hi Tg , Halogen Free

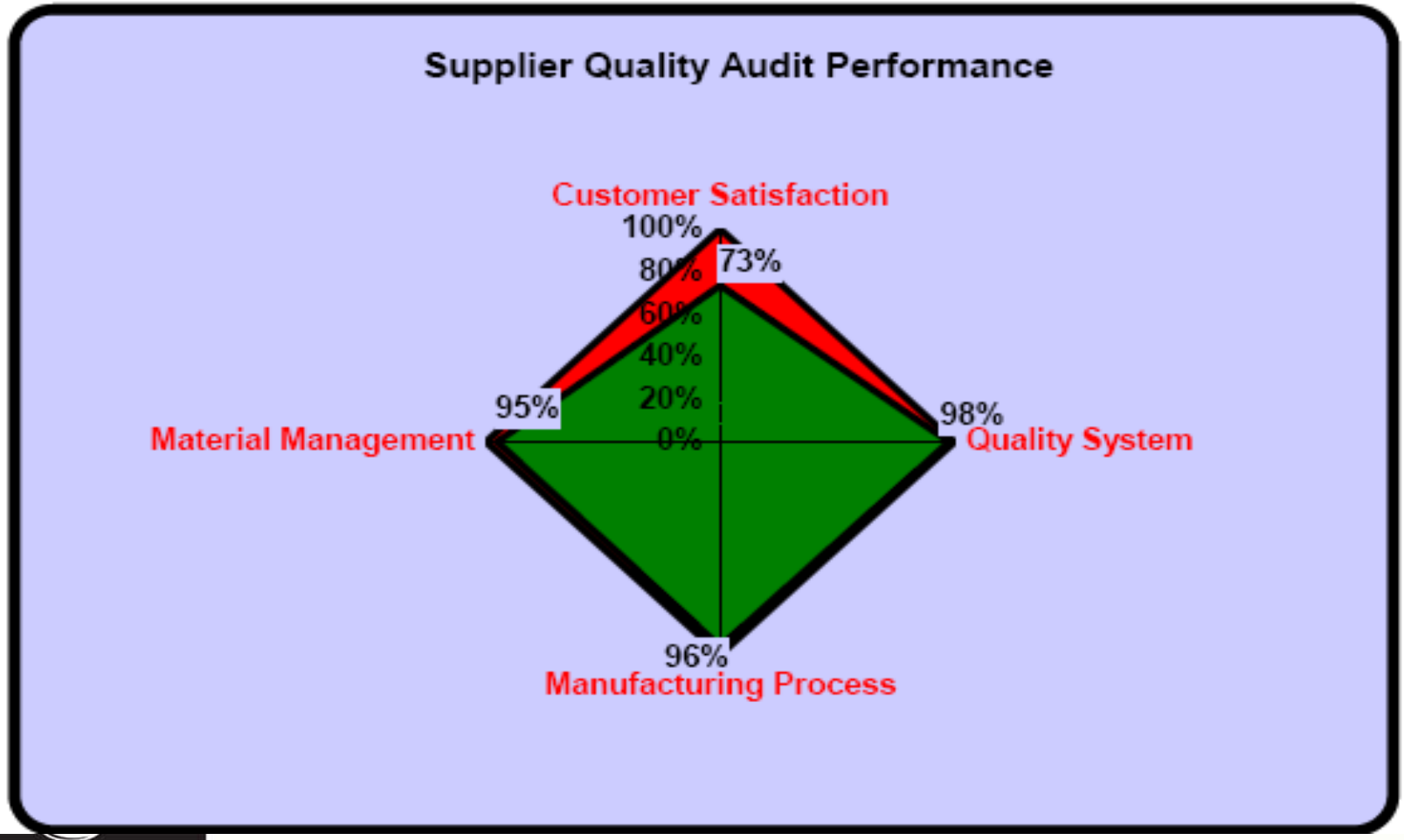
Fab HDI /ALIVH® Capabilities

- Korea
  - HDI1n+1, 2n +2, 3n+3
  - Solid/Stack Vias
  - Buried Vias
  - Laser Drilling
  - Multiple Surface Finish
  - Line/Space- 3/3, 2.5
  - B2IT All Via – Proto
  - Mid Tg, Hi Tg and Halogen Free
  - Subcontract
- Japan
  - ALIVH®
  - Thin Laminates
  - Laser Drilling
  - Multiple Surface Finish
  - Line Space 3/3, 2.5
  - Thin Copper – 12u
  - High Tg /Halogen Free
  - Subcontract

Supplier Audit and Qualification

- **2- Day Quality Systems Audit**
  - Factory/Support Labs
  - Warehouse
  - Rework Operations/ Drill Repoint
  - Subcontract Operations
- **Performance**
  - Material Management
  - Quality Systems
  - Manufacturing Process
  - Customer Satisfaction
- **Acceptance**
  - 90% score overall

Quality Audit Score



Post Audit Action Items

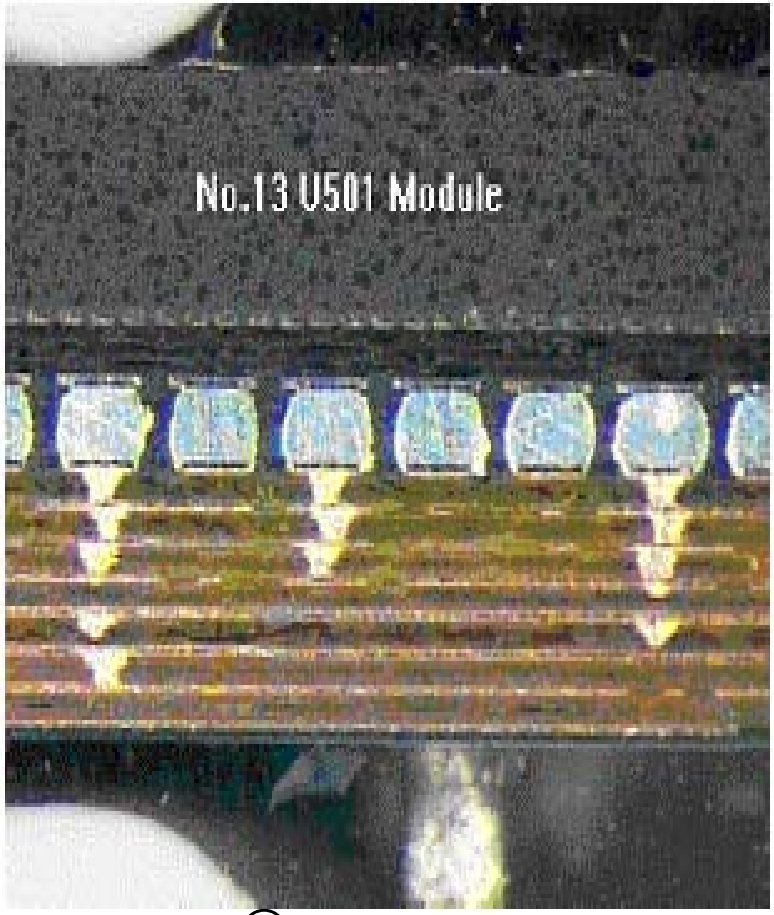
- Review findings and score with supplier
- Summarize Action Items
- Closure within 5 working days
- Conduct Annual Audits
- Have Monthly/Quarterly Telecons
- Provide Positive feedback
- Provide Guidance to monitor DPPM

Product Qualification

- Double Sided SMT Assembly
- Post – Reflow X-sectional Analysis
- 2X Rework – SMT /1X Rework – BGA
- Temp. Humidity Test 85C/85% RH
- Thermal Shock Test –25C to +125C - 500 cycles
- Board Level Electrical Test
- X-section Post Thermal Shock
- Failure Analysis

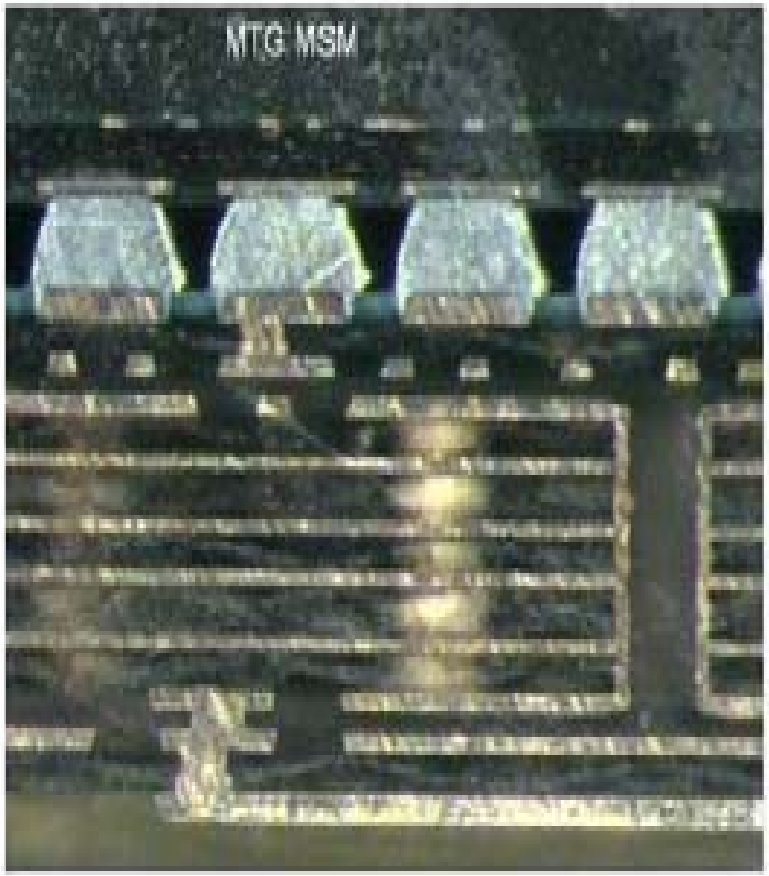
HDI/ALIVH®PWB

HDI PWB –Post Reflow



ALIVH®PWB-Post Reflow

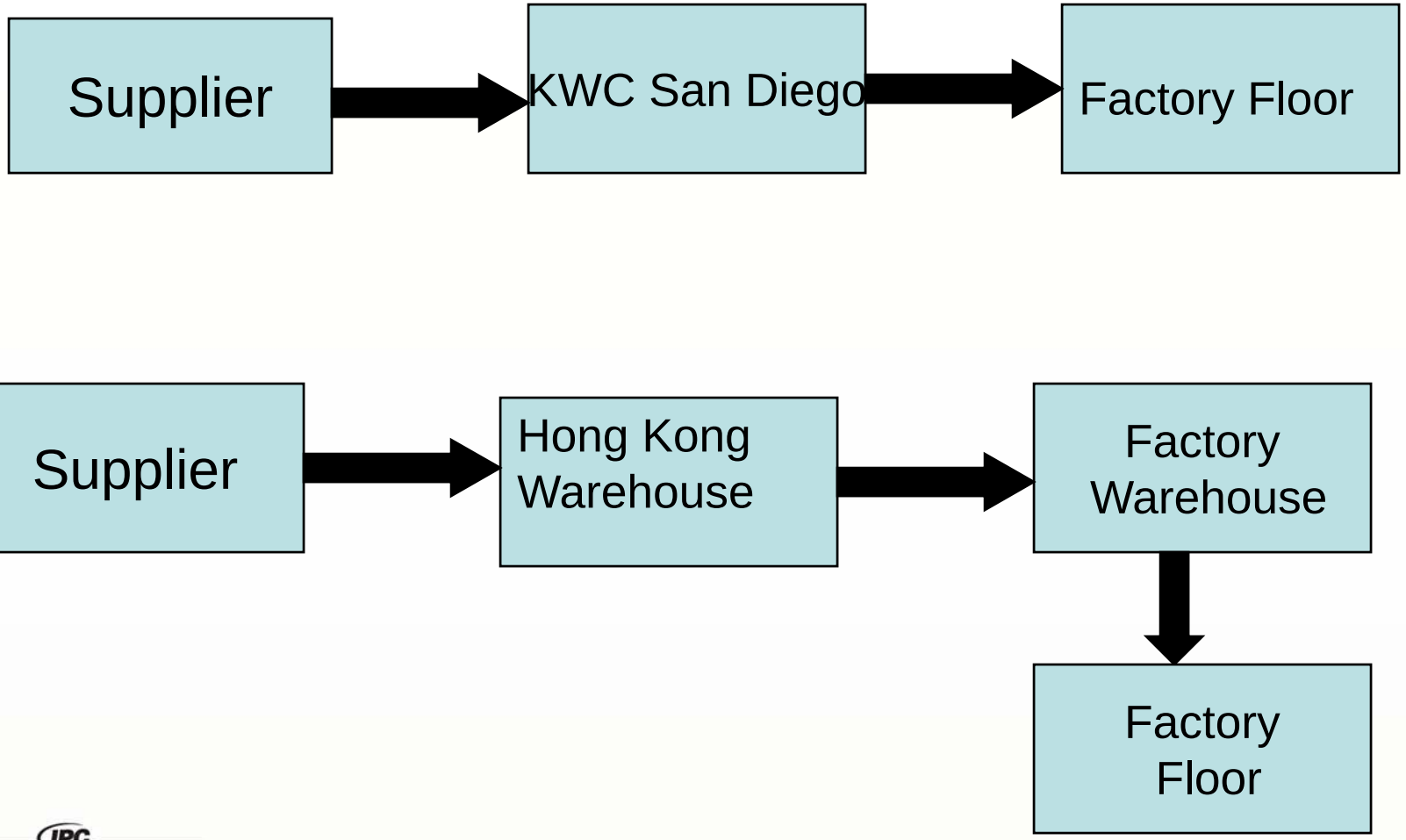
X-sections- Post Thermal Shock



HDI – Post Thermal Shock

ALIVH® Post Thermal Shock

Supply Chain Changes



Production DPPM Issues

- IQC- Incoming Quality Inspection
  - CM Internal Spec
  - IPC A 600 Rev G
- Rejects
  - Cosmetic Rejects at IQC
  - Functional Rejects at Assembly
- Type
  - Opens
  - Delamination
  - Shorts

Defect Analysis

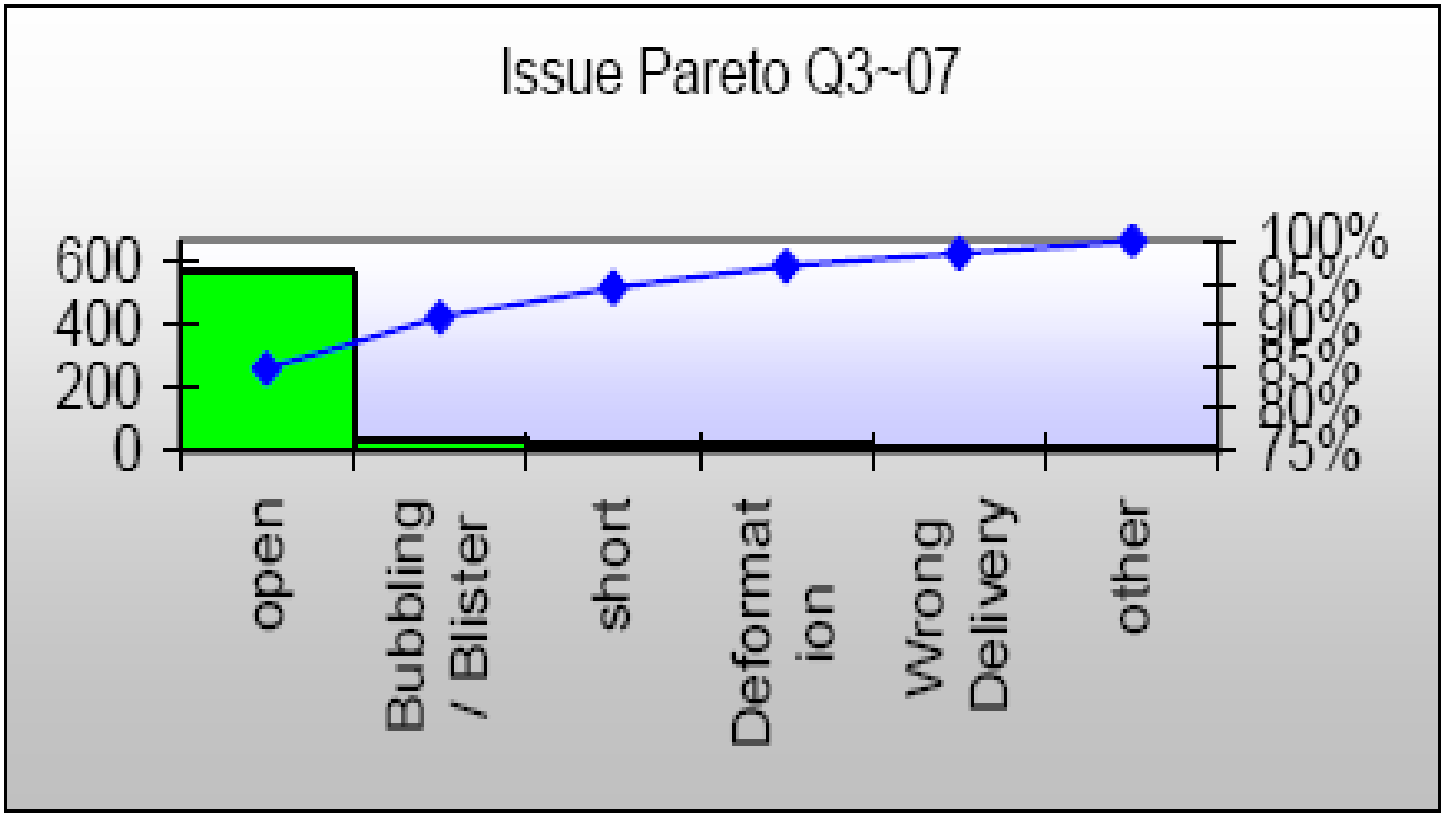
- Cosmetic Rejects
  - Labeling
  - Scratches
  - Exposed Copper
  - Plating Stains
- Corrective Action
  - MSL Packaging/Bake
  - Review CM IQC spec
  - Audit Staging Areas
  - Minimize Handling
  - Training

- Functional Rejects
  - Opens
  - Delamination
  - Shorts
- Corrective Actions
  - Monthly DPPM Data
  - Joint Supplier/CM Mtg/Qtr.
  - DOEs for Lamination
  - MSL Handling in SMT
  - FIFO Controls
  - Warehouse Audits
  - Continuous Feedback

Communication Strategies

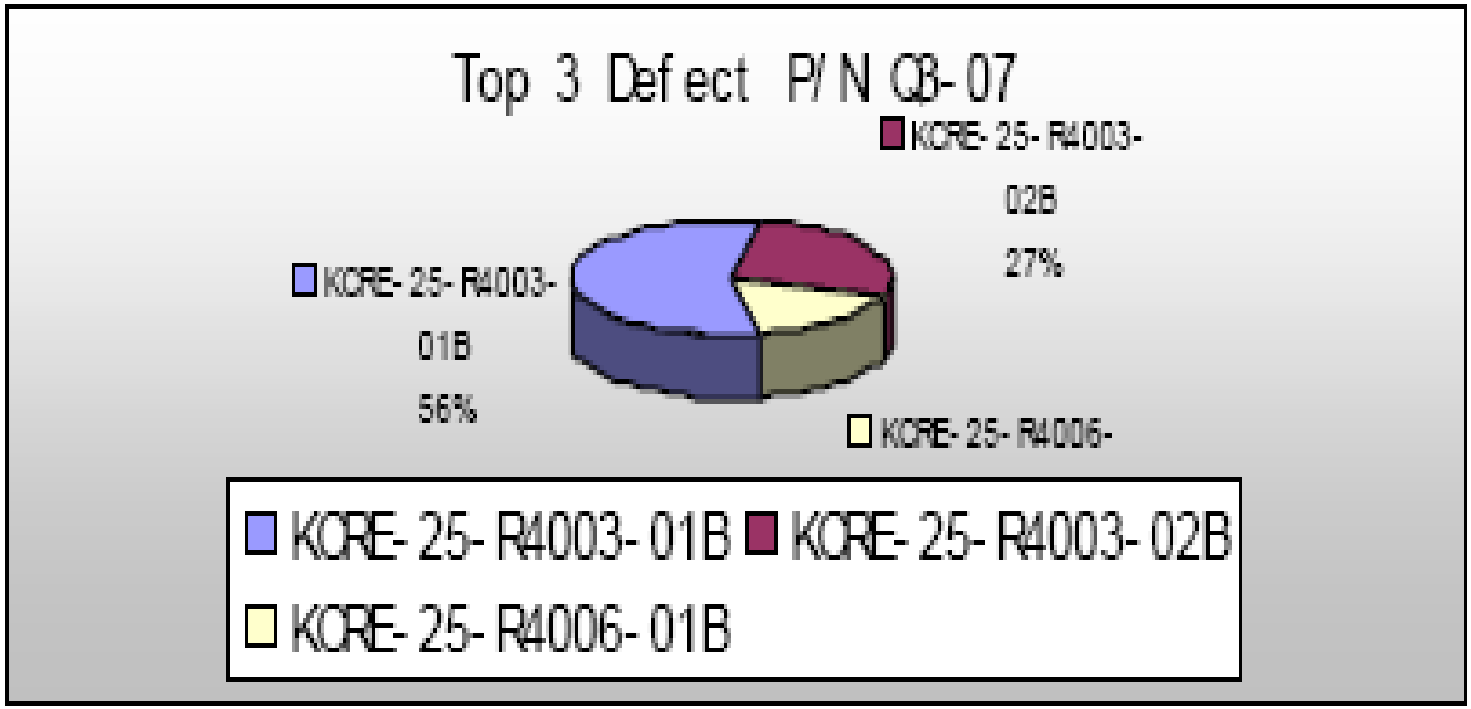
- CM - DPPM Summary(IQC/ Assembly)
- Supplier/CM Joint Meetings
- Reviewed Monthly DPPM
- Top 5 Defects
- Top 5 Part Numbers
- Customer Specific Corrective Action
- Continuous feedback
- Person/Person Interaction
- OEM – Mediator

DPPM – Defect Pareto



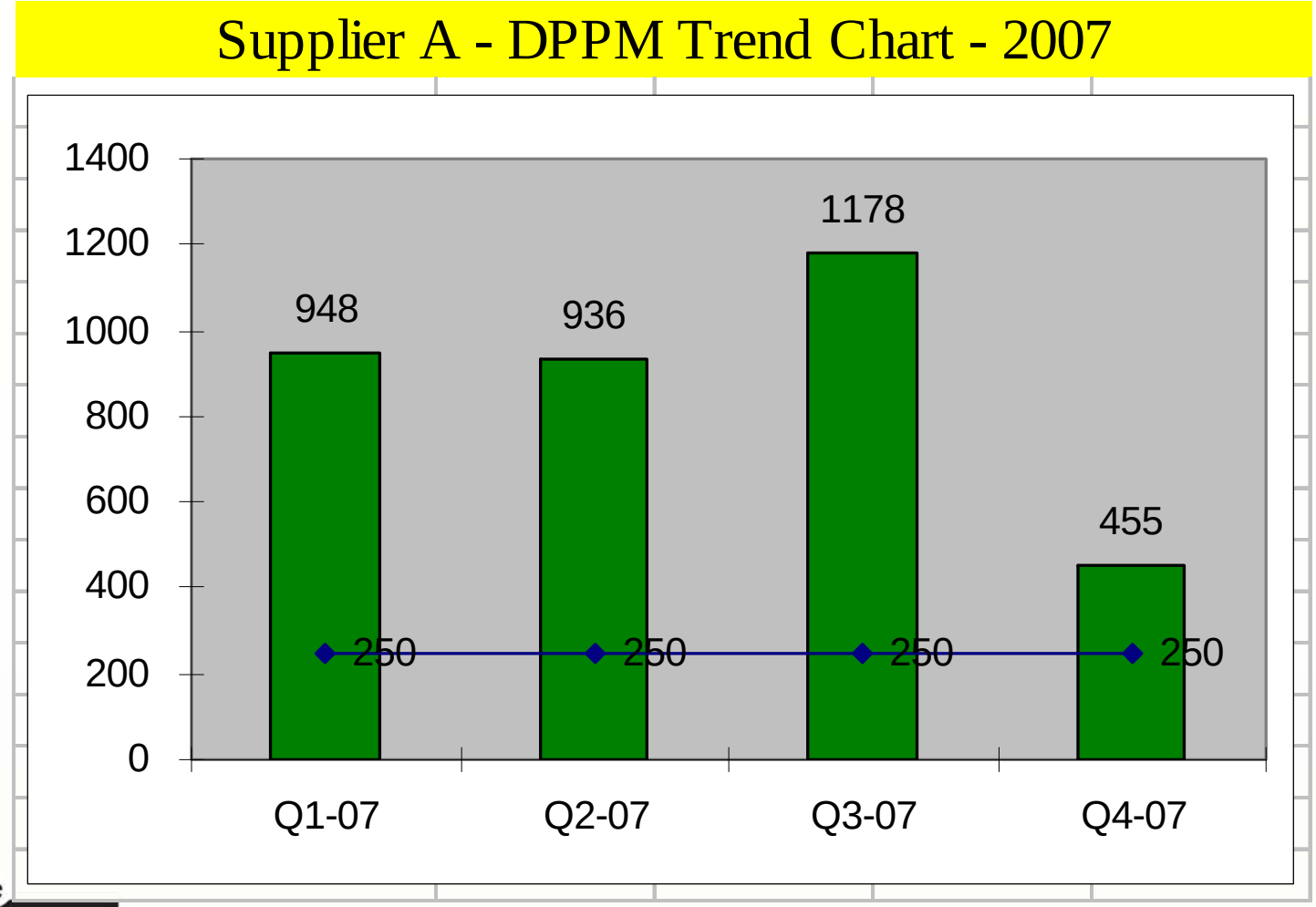
Pareto- Top 5 Defects

Pareto – By P/N

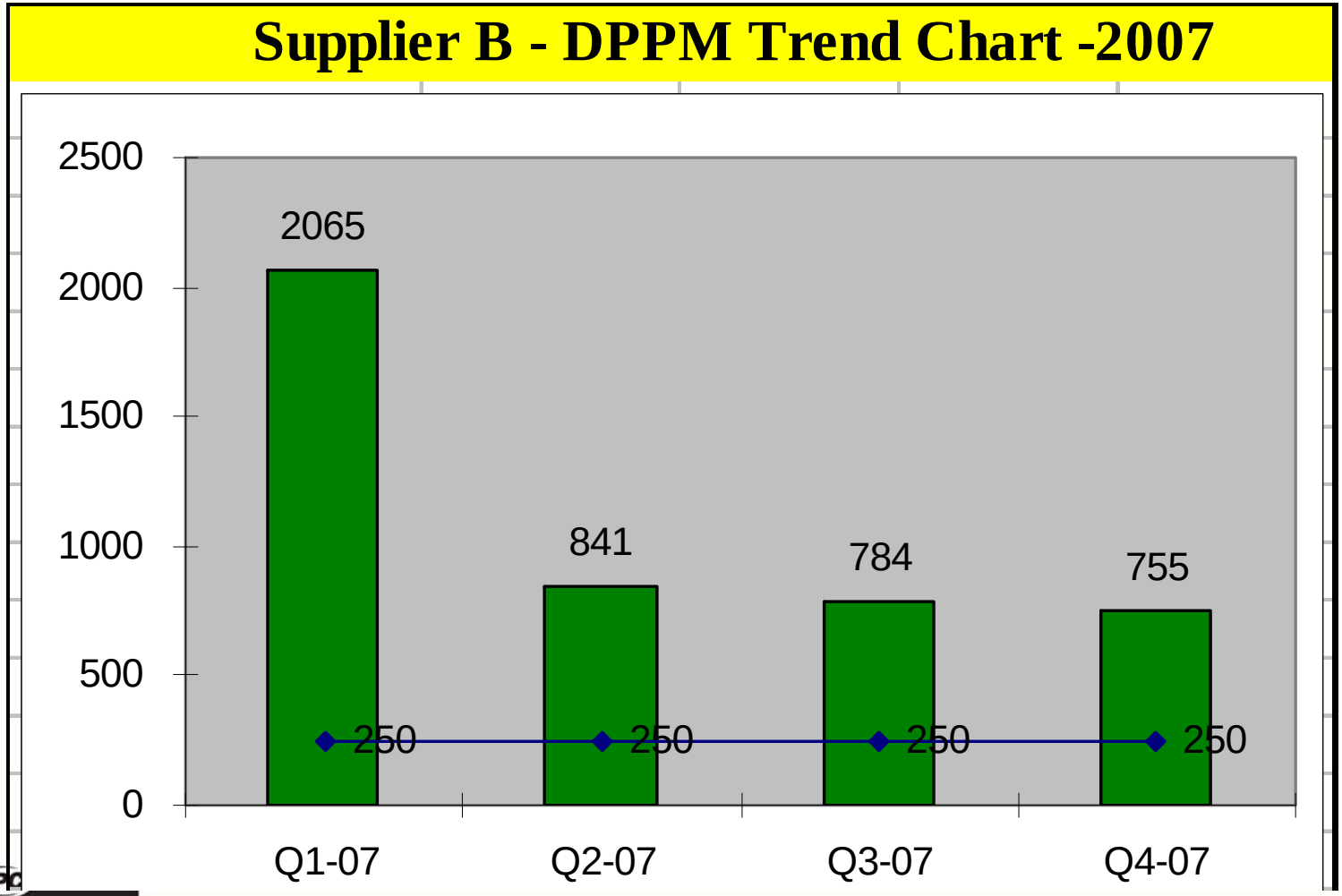


Pareto By Part Number

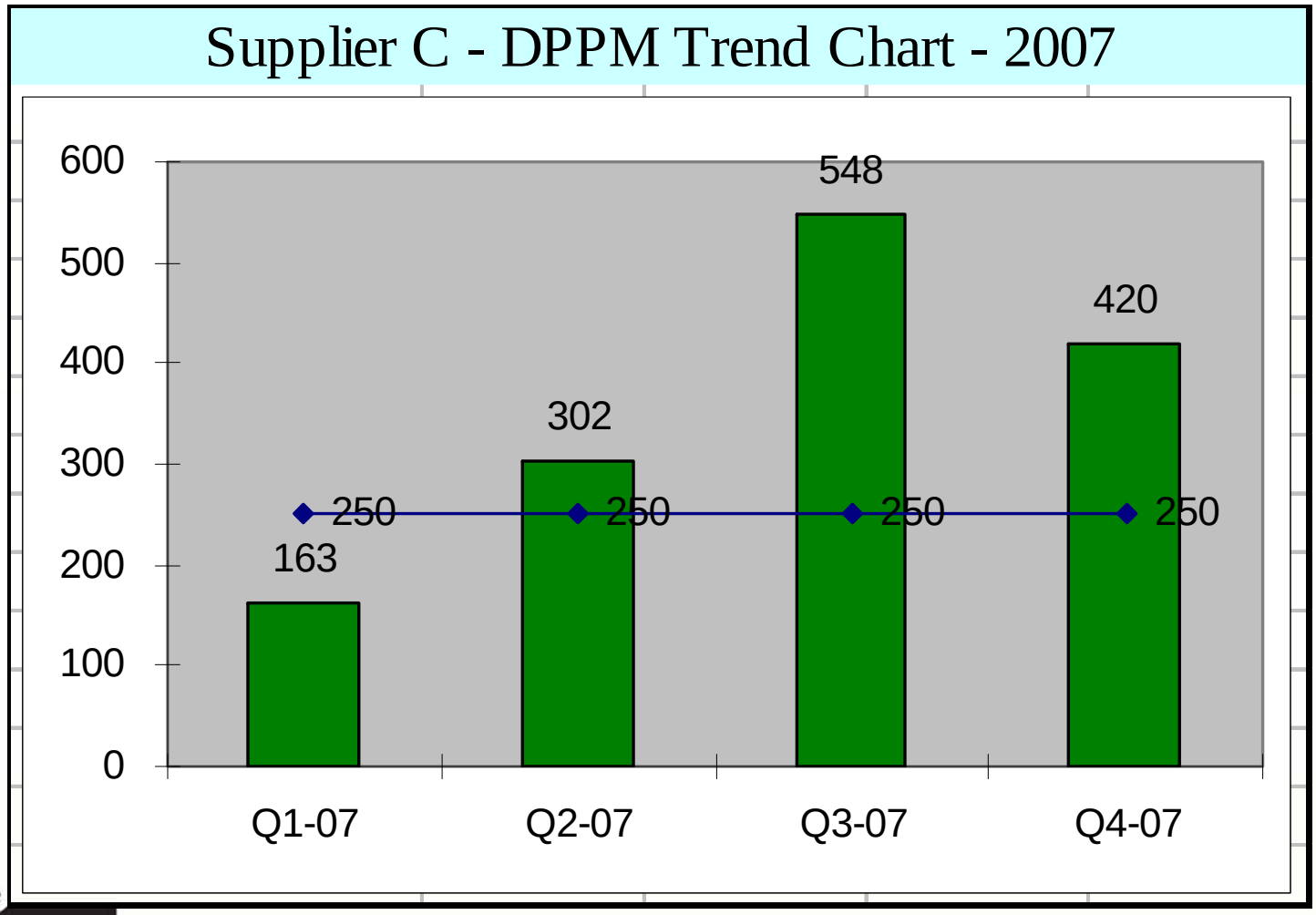
DPPM Trend Chart



DPPM Trend Chart



DPPM Trend Chart -2007



Scrap Resolution

- Biggest Challenge
- Failure Analysis is critical
- Assess Both - PWB Fab and Assembly
- Evaluate and Audit Rework Processes
- Damage in Test /Depanel Operation
- Equipment/Process Induced Damage
- Guidance for Root Cause Analysis
- Split scrap charges with CM/Supplier

Lessons Learned

- Allow time for Supply Chain Changes
- Understand Parts Movement and paperwork
- OEM - Keep Pristine Documentation
- Keep Eng. Changes to a Minimum
- CM Training/Knowledge is Critical.
- Audit Assembly Processes/Warehouses
- Clear , Concise Communication
- Team Work /Partnership
- Overcome Cultural Differences
- Overseas Travels

Conclusion

- Outsourcing is achievable with good yields
- Supplier quality targets need diligent monitoring
- Partnership with CM/Supplier
- Product reliability should not be compromised
- OEM commitment is key
- Focus on Cost /Yield Targets
- Develop joint technology roadmaps
- Teamwork for Success