Implementation of Dry Ice Blasting for Flux Cleaning on Post – Soldering PCBs

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***Abstract* — Flux residue remaining on Printed Circuit Boards (PCBs) after the soldering process can lead to surface contamination and corrosion, potentially affecting product reliability and performance. This study evaluates the implementation of dry ice blasting as an efficient and environmentally friendly cleaning method for removing flux residues from PCBs. The cleaning process was performed using the A500 Dry Ice Machine, which utilizes solid carbon dioxide (CO_2) pellets to remove contaminants without causing damage to sensitive electronic components. In addition to assessing cleaning effectiveness, the study investigates the electrostatic safety of the process through Electrostatic Discharge (ESD) measurements, including ion balance and surface resistivity tests. The results demonstrate that dry ice blasting effectively removes flux residues while maintaining ESD parameters within acceptable industry-standard limits. These findings indicate that dry ice blasting is a reliable and sustainable solution for post-soldering PCB cleaning applications in electronics manufacturing.**

Keywords: Dry Ice Blasting, Flux Cleaning, Printed Circuit Board (PCB), Electrostatic Discharge (ESD), A500 Dry Ice Machine.

I. INTRODUCTION

In the electronics manufacturing industry, the cleanliness of Printed Circuit Boards (PCBs) after the soldering process plays a crucial role in ensuring product quality and reliability. One of the most common challenges encountered during post-soldering operations is the presence of flux residue on PCB surfaces. If not adequately removed, flux residues can lead to various reliability issues, including corrosion, dendritic growth, and reduced insulation resistance, which may ultimately affect the long-term performance and functionality of electronic devices [1], [2].

To address this issue, effective cleaning methods are required to ensure that PCB assemblies meet both quality and reliability standards. As a company specializing in electronic assembly services, PT PCI Electronics International continuously seeks to improve its manufacturing processes, including post-soldering cleaning operations. Conventional cleaning methods typically involve chemical solvents or physical contact-based techniques. However, these methods may present challenges when applied to modern electronic assemblies that contain miniaturized and densely populated components.

Dry ice blasting has emerged as a promising alternative cleaning technology due to its non-abrasive, non-conductive, and chemical-free characteristics. This method utilizes solid carbon dioxide (CO_2) pellets accelerated by compressed air to remove contaminants from PCB surfaces through a combination of thermal shock, kinetic impact, and sublimation effects. As a result, flux residues can be effectively removed without causing mechanical damage to sensitive electronic components [3], [4].

Despite its advantages, the implementation of dry ice blasting in electronics manufacturing requires careful assessment of Electrostatic Discharge (ESD) safety. The interaction between compressed air, dry ice particles, and PCB surfaces has the potential to generate electrostatic charges that may adversely affect ESD-sensitive components. Therefore, it is essential to verify that the cleaning process complies with industry ESD requirements. In this study, the effectiveness of the A500 Dry Ice Machine is evaluated not only in terms of flux removal capability but also through ESD performance measurements, including ion balance and surface resistivity assessments, to ensure compliance with established industry standards [5], [6].

The objective of this research is to validate the implementation of dry ice blasting as a reliable and ESD-safe cleaning method for post-soldering PCB applications at PT PCI Electronics International. The findings are expected to support the adoption of dry ice blasting technology as an effective solution for improving cleaning quality while maintaining component integrity and product reliability in high-volume electronics manufacturing environments.

II. METHOD

This study employs a structured experimental approach to evaluate the effectiveness of the dry ice blasting method in the PCB cleaning process at PT PCI Electronics International. The research was conducted through several stages, including material preparation, implementation of the cleaning process, and evaluation of electrostatic safety parameters to assess the performance and safety of the proposed method.

2.1. Preparation of Materials and Equipment

The initial stage of this study involved preparing Printed

Circuit Board (PCB) assemblies containing flux residues generated during the soldering process. These PCB samples were used as test specimens to evaluate the effectiveness of the cleaning method.

The primary equipment used in this research was the A500 Dry Ice Machine, which served as the main cleaning system for removing flux residues from the PCB surface. In addition, several measuring instruments were utilized to assess electrostatic safety and ensure that the cleaning process did not adversely affect the integrity of electronic components.

Figure 2.1. A500 Dry Ice Cleaning System Used as the Main Equipment

2.2 Experimental Procedure

The experimental procedure began by securing the PCB assembly on a stable fixture to maintain its position during the cleaning process. The A500 Dry Ice Machine was then configured by adjusting the compressed air pressure and CO_2 pellet feed rate according to the level of flux contamination present on the sample.

Subsequently, the dry ice blasting process was performed by directing the nozzle toward the contaminated areas of the PCB surface. To ensure consistent cleaning performance and prevent potential damage to the board, the nozzle distance, spraying angle, and exposure duration were maintained at constant values throughout the experiment. These controlled parameters enabled uniform distribution of the blasting energy while preserving the physical integrity of the PCB and its electronic components.

2.3 Evaluation and Data Collection Methods

Following the completion of the cleaning process, data collection was conducted to evaluate the effectiveness and safety of the dry ice blasting method. The evaluation began with a detailed visual inspection of the PCB assemblies to verify the complete removal of flux residues from the soldering areas.

In addition to visual assessment, electrostatic safety was evaluated through ion balance and surface resistivity measurements performed on the PCB surface. These tests were conducted to determine whether the cleaning process generated electrostatic conditions that could potentially affect sensitive electronic components.

The measurement results were subsequently compared with the requirements specified in the ANSI/ESD STM11.11 standard and the internal quality protocols of PT PCI Electronics International. This comparison was performed to ensure that all measured parameters remained within acceptable limits and complied with ESD safety requirements for electronics manufacturing environments [7], [8].

III. RESULTS AND DISCUSSION

3.1 Analysis of Flux Cleaning Effectiveness

Based on the experimental results, the implementation of the A500 Dry Ice Machine demonstrated effective removal of flux residues from the surface of Printed Circuit Boards (PCBs). The cleaning mechanism combines compressed air and the thermal shock effect generated by solid carbon dioxide (CO_2) pellets, enabling the removal of contaminants from both accessible and difficult-to-reach areas of the PCB assembly.

Visual inspection conducted after the cleaning process indicated a significant reduction in flux contamination across the tested samples. No visible residues were observed on the soldering areas, suggesting that the dry ice blasting process was capable of achieving the required level of cleanliness. Furthermore, no signs of physical damage, such as scratches, cracks, or component displacement, were detected on the PCB surface or electronic components following the cleaning operation.

These findings indicate that dry ice blasting is an effective cleaning method for post-soldering PCB applications, providing efficient residue removal while preserving the physical integrity of the board and its components.

BEFORE AFTER

Figure 3.1. Visual Comparison of PCB Surfaces Before and After the Dry Ice Blasting Process

3.2 Evaluation of ESD Parameters

ESD testing was conducted to ensure that the dry ice blasting process did not generate electrostatic conditions that could potentially damage ESD-sensitive electronic components. The evaluation focused on three key parameters: surface resistivity, static charge, and ion balance. These parameters were measured to verify compliance with ESD safety requirements and to assess the electrostatic performance of the cleaning process.

A. Ion Measurement at the Nozzle

Ion balance measurements were performed at the nozzle of the A500 Dry Ice Machine to evaluate the electrostatic conditions generated during the blasting process. The measurements were conducted to determine whether the ion levels remained within acceptable limits and did not pose a risk to sensitive electronic assemblies. The results of the ion balance measurements are presented in Table 3.4.

Table 3.4. Ion Measurement Results at the Dry Ice Machine Nozzle

Trial No	Discharge time (sec)	Measurement Result (volt)	Status
1.	0.55 Sec	82 Volt	Pass
2.	0.75 Sec	90 Volt	Pass
3.	0.60 Sec	74 Volt	Pass
4.	0.50 Sec	75 Volt	Pass
5.	0.50 Sec	50 Volt	Pass

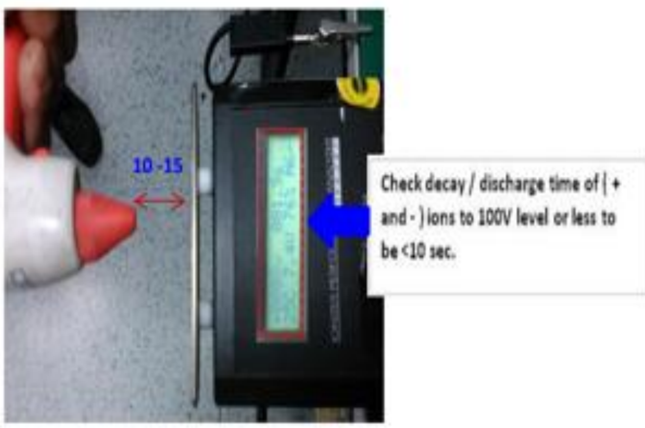

Figure 3.8. Static Charge Discharge Time Test at a Spraying Distance of 10–15 mm

Analysis:

The evaluation of the dry ice machine nozzle at a spraying distance of 10–15 mm demonstrated optimal charge neutralization performance. As presented in Table 3.4 and Figure 3.8, the shortest discharge time recorded was 0.50 seconds, with the residual voltage remaining below 90 V. These results comply with the PE45634 standard [9], which specifies a maximum allowable voltage of 100 V, and are significantly below the maximum discharge time limit of 10 seconds [10].

The consistent discharge performance indicates that the dry ice blasting process effectively dissipates electrostatic charges generated during operation. Therefore, the cleaning process can be considered safe for ESD-sensitive electronic components, minimizing the risk of static charge accumulation that could potentially affect product reliability.

B. Ion Balance Measurement on PCB

According to the PE45634 standard [11], ion balance measurements were conducted to evaluate the stability of ion levels on the PCB bar before and after the cleaning process. This assessment is essential to verify that the dry ice blasting method does not adversely affect the electrostatic environment and remains compliant with ESD protection requirements for sensitive electronic assemblies [12].

Table 3.3. Ion Balance Measurement Results on PCB

Trial No	Measurement Before Spray (Volt)	Time (Sec)	Measurement After Spray (Volt)	Time (Sec)	Status
1.	100 Volt	0.5 Sec	84 Volt	0.7 Sec	Pass
2.	115 Volt	0.5 Sec	30 Volt	0.1 Sec	Pass
3.	80 Volt	0.5 Sec	54 Volt	0.5 Sec	Pass

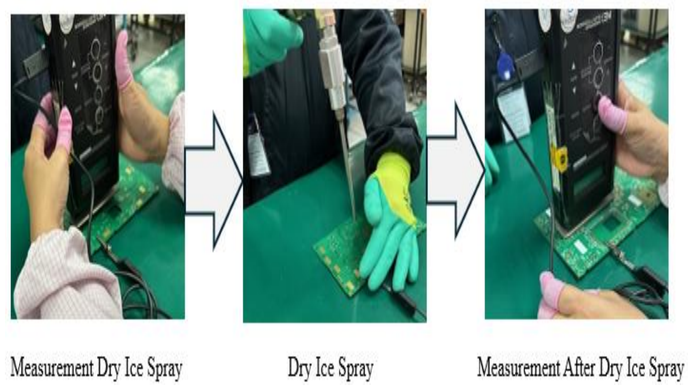

Figure 3.7. Stages of Ion Balance Measurement on the PCB Surface

Analysis:

The results presented in Table 3.3 and Figure 3.7 indicate a significant reduction in static charge following the dry ice blasting process. One notable example was observed in Trial 2, where the measured charge decreased from 115 V before cleaning to 30 V after cleaning. Similar trends were observed across the remaining test samples, demonstrating the effectiveness of the ionization system integrated into the A500 Dry Ice Machine.

The reduction in surface charge confirms that the nozzle ionization system effectively neutralizes electrostatic charges generated during the cleaning process without causing harmful charge accumulation on the PCB surface [13]. Furthermore, all measured values remained below the maximum allowable limit of 100 V specified in the PE45634 Standard [14]. Therefore, the dry ice blasting process can be considered compliant with ESD safety requirements and suitable for use with ESD-sensitive electronic components in the production environment, in accordance with IPC-A-610H guidelines [15].

C. Evaluation Resistivity Measurement

Table 3.4. Surface Resistivity Measurement Results Before and After Dry Ice Blasting

Trial No	Result Before Spray (Ohms)	Result After spray (Ohms)	Status
1.	1.0 x 10^9 Ohms	1.0 x10^9 Ohms	Pass
2.	1.0 x 10^9 Ohms	1.0 x 10^8 Ohms	Pass
3.	1.0 x 10^9 Ohms	1.0 x 10^9 Ohms	Pass

Figure 3.5. Surface Resistivity Test Results Before and After Dry Ice Cleaning

Analysis:

Based on the results presented in Table 3.1 and Figure 3.5, surface resistivity measurements were conducted to evaluate whether the dry ice blasting process affected the electrical characteristics of the PCB surface. The test results showed that the surface resistance values remained stable before and after the cleaning process, ranging from $1.0 \times 10^8\ \Omega$ to $1.0 \times 10^9\ \Omega$.

These values fall within the dissipative material range specified by the QC40230 standard [16], indicating that the dry ice blasting process did not adversely affect the surface conductivity properties of the PCB. Furthermore, the consistency of the measured resistivity values suggests that the cleaning method does not damage the protective coating or conductive traces on the PCB surface.

Therefore, the results confirm that dry ice blasting is a safe cleaning method that preserves the electrical and physical integrity of PCB assemblies while maintaining compliance with ESD control requirements during the manufacturing process.

D. Evaluation of Electrostatic Field Surface Charge

Table 3.5. Electrostatic Field Surface Charge Measurement Results

Sample No	Measurement Before Spray (KV)	Measurement After Spray (KV)	Status
1.	0.00 KV	0.00 KV	Pass
2.	0.00 KV	0.02 KV	Pass
3.	0.00 KV	0.00 KV	Pass

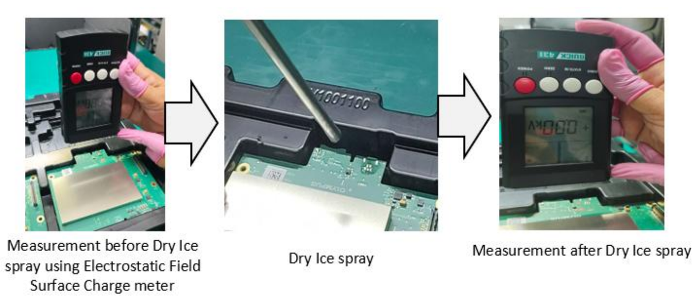

Figure 3.6. Surface charge measurement using Electrostatic Field meter.

Analysis:

Electrostatic field surface charge measurements were conducted to verify that the dry ice blasting process did not generate excessive static charge accumulation on the PCB surface. Based on the results presented in Table 3.5, the measured surface charge values after the cleaning process ranged from 0.00 kV to 0.02 kV, indicating a high level of charge stability.

These values are significantly below the maximum allowable limit of 0.12 kV (125 V/inch) specified by the QC40230 standard [17]. The low surface charge levels demonstrate that the dry ice blasting process does not introduce hazardous electrostatic conditions that could potentially affect ESD-sensitive electronic components.

Therefore, the results indicate that the dry ice blasting method is compliant with ESD control requirements and can be safely implemented in PCB cleaning applications without increasing the risk of electrostatic discharge-related damage during the manufacturing process.

3.3 Comparative Analysis: Dry Ice Blasting vs. Manual Cleaning

To validate the advantages of implementing the A500 Dry Ice Machine in the production line at PT PCI Electronics International, a comparative analysis was conducted between the dry ice blasting method and the conventional cleaning method, which utilizes isopropyl alcohol (IPA) solution and a manual brush. The comparison focused on key aspects, including cleaning effectiveness, process efficiency, ESD safety performance, and potential impact on PCB integrity.

Tabel 3.6 Comparative Analysis: Dry Ice Blasting vs. Manual Cleaning

Feature	Manual Cleaning (IPA/Brush)	Dry Ice Blasting (A500)
Residual Range	Limited (Surface only)	Height (SMT narrow gap)
ESD Safety	Uncontrolled	High (Integrated Ionizer)
Material Impact	Risk of scratches/peeling	Non-abrasive (Safe)
Dry Season	Needs drying time	Instant (Dry immediately)
Chemical Risk	Flammable (Science)	Environmentally Friendly / None

The implementation of dry ice blasting contributes to improved safety and quality standards in the PCB cleaning process. In addition to eliminating the risks associated with hazardous chemical cleaning agents, this method enhances production efficiency by reducing processing time, as PCB assemblies do not require an additional drying stage after cleaning. As a result, the overall manufacturing cycle can be completed more efficiently while maintaining product quality and reliability.

IV. CONCLUSIONS

Based on the results and analysis of the implementation of the A500 Dry Ice Blasting Machine at PT PCI Electronics International, the following conclusions can be drawn:

4.1 Conclusions

1. The dry ice blasting method effectively removed flux residues from PCB assemblies while maintaining the physical integrity of the board and its electronic components.
2. The electrostatic field surface charge measurements showed a maximum value of 0.02 kV, which is significantly lower than the company's maximum allowable limit of 0.12 kV, indicating compliance with ESD safety requirements.
3. The evaluation of critical components demonstrated that the dry ice blasting process is non-abrasive and does not adversely affect protective coatings or component integrity.
4. The implementation of dry ice blasting improved production efficiency by eliminating the need for an additional drying stage, as dry ice sublimates directly into gas during the cleaning process.

4.2 Suggestion

1. Routine cleaning of the Wave Fluxer and Soldering Jig areas is recommended to prevent excessive flux residue accumulation and to maintain the effectiveness of the cleaning process.
2. Operators should strictly follow the established Standard Operating Procedures (SOPs), particularly when setting air pressure parameters, to ensure consistent cleaning performance and maintain product safety.
3. Future studies are recommended to evaluate the performance of dry ice blasting on different PCB designs and component configurations under various production conditions.

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