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Expanded Usage Window of Molding Compound to Reduce Material Wastage in Manufacturing Line

Roland Soriano[1], Lester Joseph T. Belalo[1*] and Rey Nino C. Arnido[1]

[1]Process Engineering, STMicroelectronics, Inc. Calamba City, Laguna-4027, Philippines.

Authors' contributions

This work was carried out in collaboration among all authors. Author LJTB designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors RNCA and RS managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This paper discusses about direct material wastage brought by expiring molding compound particularly for QFN-mr Packages.
An Engineering problem solving methodology was used to identify the material, its consumption, cost, the root cause, and solution of the problem. The study aims to solve huge amount of compound material disposed in the manufacturing line.
By challenging the current 24hours suppliers thawing time, it is shown that at 16hours thawing time, molding compound already reached the required room temperature (23°C ± 3°C). To maximize the usage window of molding compound, the existing floor life of 24hrs was also reviewed and after experiment, it was found out that it can still be extended to another 24hrs or 48hrs total floor lifetime.
Combining the 2 improvements, a total of 56hrs usage window for the molding compound from 24hrs usage window.

Keywords: Molding compound; thawing; floor life; expired molding compound.

**Corresponding author: Email: lester.belalo@st.com;*

1. INTRODUCTION

Molding compound is one of the direct materials being used on our products. Normally, an average of ~60% of the tablet/pellet compound goes directly to the product, while the remaining ~40% is consumed for mold culls. Culls are normal in transfer mold process. It is covered by the computed usage rate [1,2,3].

Material wastage is our main concern and molding compound wastage is the problem we will be addressing. There is a 300kg per month average wastage of molding compound caused by floor life expiration.

Out of 300kg, we then rank each compound material code and select the highest compound wastage as vehicle for evaluation. It shows that 5ST97227 material code of Hitachi CEL9240ZHF10W is the top at an average wastage of 20kg/month [4,5].

Wastage is one of the problems we need to have special attention as it is one factor that affects the process in terms of cost.

There are various reasons why compound reaches its expiration and turn to waste like non-linear loading of the lot with a possible delay in processing at Front Line or in Molding Process due to downtimes, machine sharing allocation and also some excess withdrawals, etc. All these reasons are valid and considered as normal scenario in the manufacturing line [6,7,8]. Refer to Fig. 4

With the high wastage of molding compound, the problem statement is derived as:

High compound material wastage on 5ST97227 averaging 20kg per month.

2. REVIEW OF RELATED WORK

The study is related to moisture which is the main concern if we will widen or expand the usage window of molding compound. In relation to moisture, research was made to better understand what areas or condition is to be considered.

Compound when still cold (10°C below) and exposed suddenly to room temperature of average 23°C will absorb huge amount of moisture [9,10]. This condition is not good in terms on moldability. This condition is called "Condensation Reaction". Fig. 6.

What happen if there is high moisture on molding compound?

It is like having a water inside the molding compound which is crucial when heat is applied. Effect of Moisture (Fig. 7)

1. Blisters on package surface
2. Delamination or poor adhesion when moisture is concentrated on LF to package surface
3. Critical to wire and die component due to presence of vapor when heat is applied
4. Pop-corn effect as moisture will vaporize at high pressure

To prevent compound from absorbing moisture, temperature must be controlled. The temperature of the compound inside its box or can must be the same as the outside temperature to avoid condensation reaction.

3. METHODOLOGY

At first, molding compound is stored in cold storage under 5°C maximum temperature. When production has a requirement, a withdrawal is to be made, and thawed the compound for 24hrs in room temp. Then after 24hrs of thawing, a floor life starts until 24hrs of usage in the line, the excess compound after 24hrs floor life will go to scrap bin or simply, a wastage.

Molding Compound- A moisture sensitive material which requires environmental control in terms in storage, thawing and usable production window.

Molding Compound Thawing is a process in which compound withdrawn from cold storage must undergo a staging process of 24hours or 1 day under required environmental condition.

Room Temperature: 23°C ± 3° (Alert: 21°C to 24°C)

Relative Humidity: 40 to 55 %RH (Alert: 41% to 51%)

Molding Compound Floor life is the effective time wherein mold compound can be used for production currently set to 24hrs.

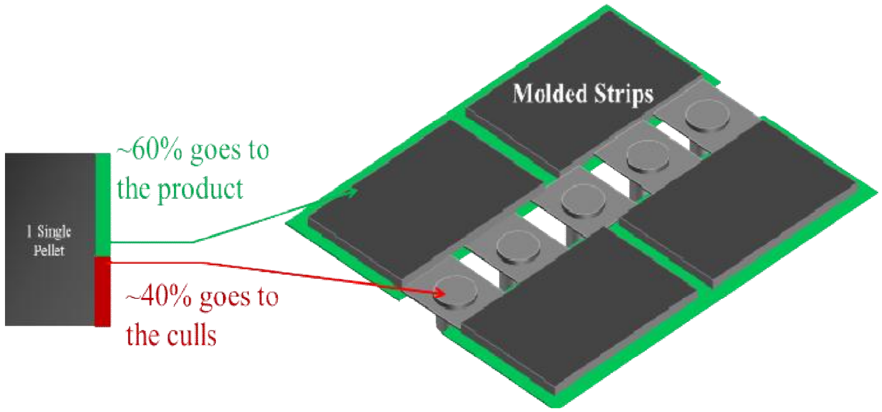


Fig. 1. Distribution of compound in 1 mold shot

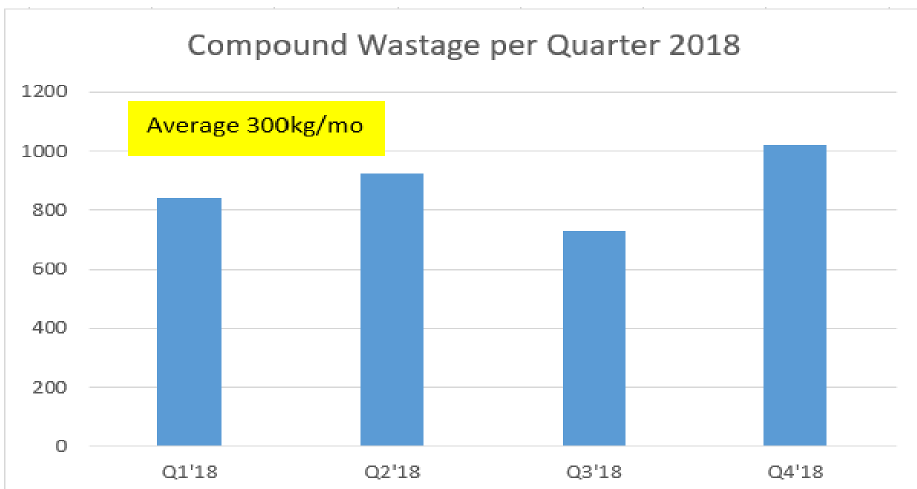


Fig. 2. Compound wastage per quarter

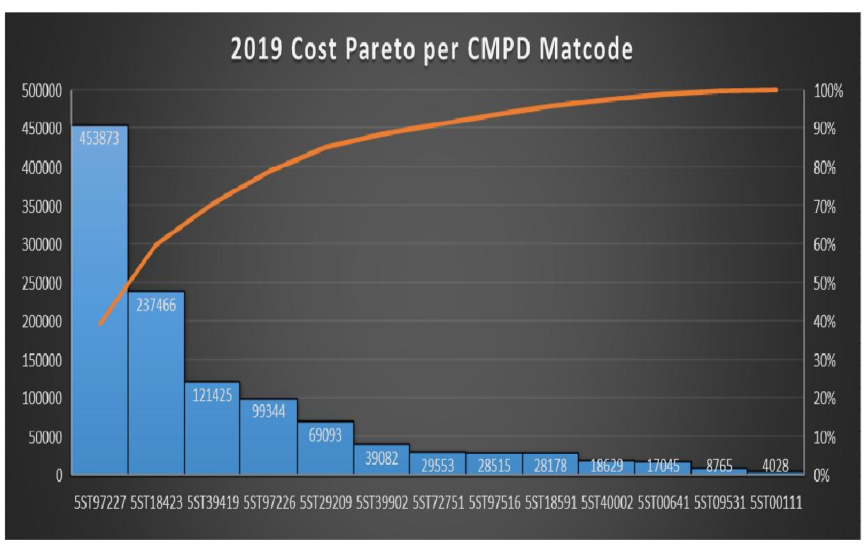


Fig. 3. Expired compound per material code

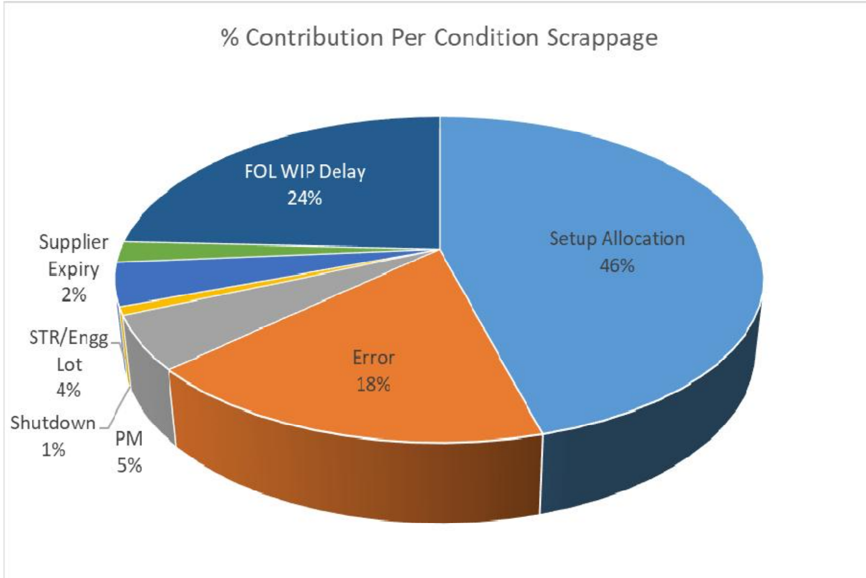


Fig. 4. Contribution of each scenario in compound expiration

Expired Molding Compound is the time after 24hrs floor life is consumed wherein mold compound is scrapped.

1st discussion is from Thawing and its main purpose is to equalize the temperature of compound to room temperature to avoid moisture absorption. To equalize is the key word, meaning it should be the same temperature of the compound inside the sealed box or can to the outside temperature which is the room temperature. This challenge the 24hrs defined thawing time if how many hours the compound will normalize of equalize its temperature from cold storage to thawing area.

The result shows a very impressive data; at 14hrs the temperature already reaches the room temperature or considered equalized. Then another run to have repeatability data and again the readings confirmed the previous data.

But 14hrs is almost the boundary of just acceptable temperature. So 16hrs is the safest and has buffer in case of any process shift.

2nd discussion is the floor life of existing 24hrs. Floor life means the compound usage time in molding process after thawing stage.

Compound even after its manufacturing already started to cross link, it means it started its reaction between the resin plus the hardener and other components inside compound but on a very slower rate of reaction as the temperature is very controlled at 5°C.

A rapid reaction rate will happen if exposed to room temperature of average 23°C as shown on Fig. 11.

So, considering the floor life, it is link to the performance of compound flowability. Referring to the list of compound characteristics, spiral flow and gelation time are the critical characteristics that need to be checked.

Supplier laboratory data on the analysis of 2 critical characteristics of molding compound, it still passed specification even when used at 24hrs floor life. Note that the existing floor life is only 24hrs. Test result is on Fig. 13.

Combining the condition, 1st the Thawing time of 16hrs and 2nd is the floor life of 48hrs, there is a total of 56hrs window usage for a molding compound as illustrated on Fig. 14.

4. RESULTS AND DISCUSSION

With the good results on initial test and data gathering, final stage of assessment is the reliability performance of the product. A reliability check was fully assessed to confirm the initial data and result.

1st test is the MSL3 for moisture impact to the product.

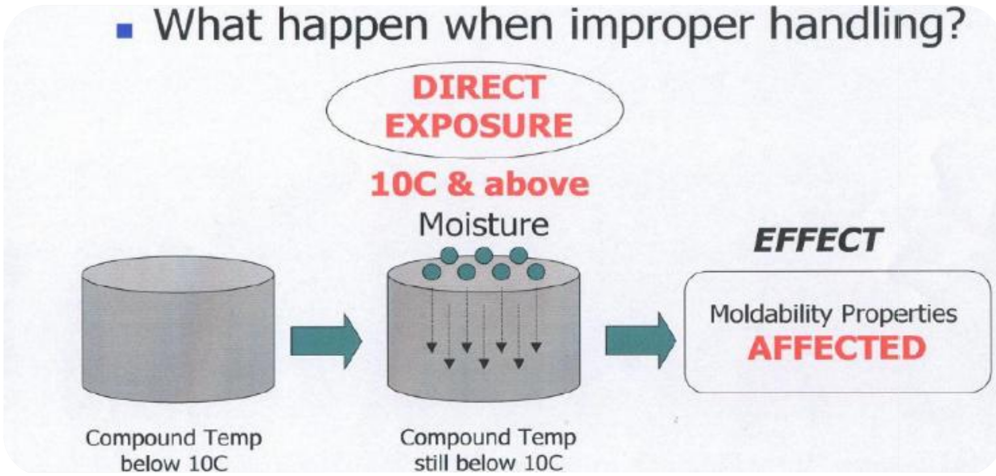


Fig. 5. Supplier data in proper handling of compound

Fig. 6. Condensation reaction

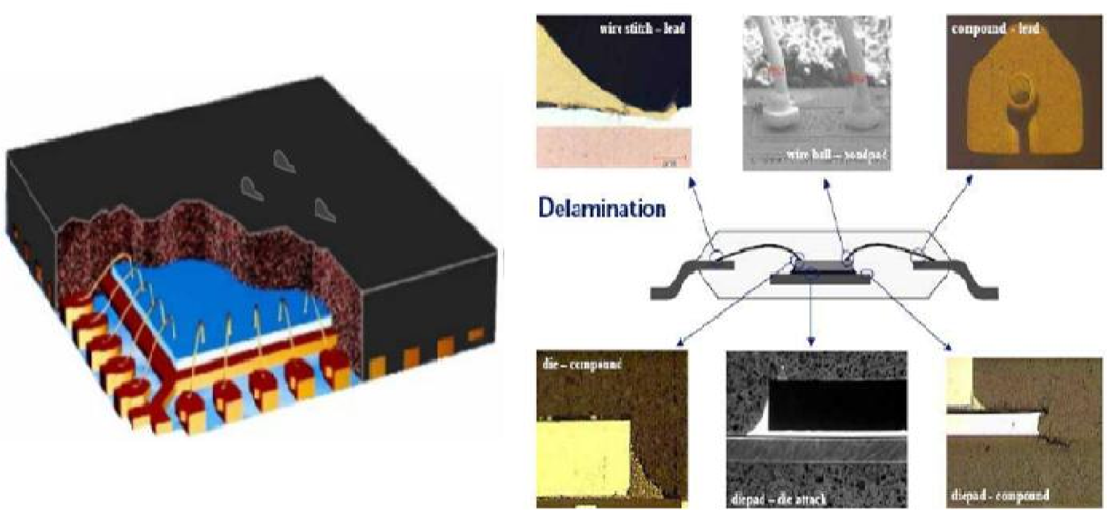


Fig. 7. Defect and reliability effect of moisture to package

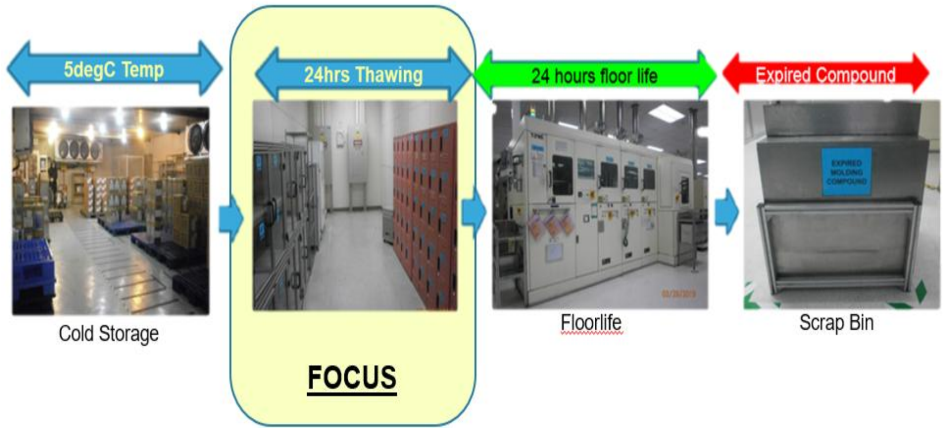


Fig. 8. Compound handling flow

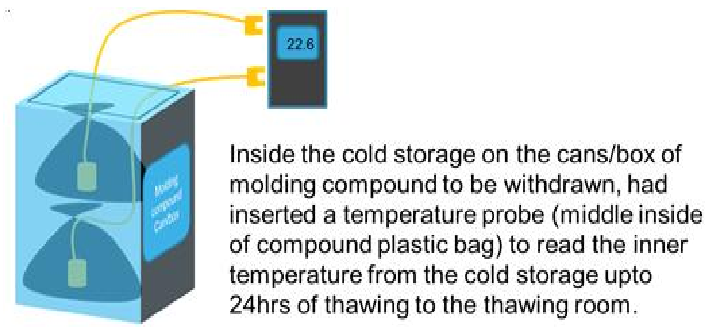
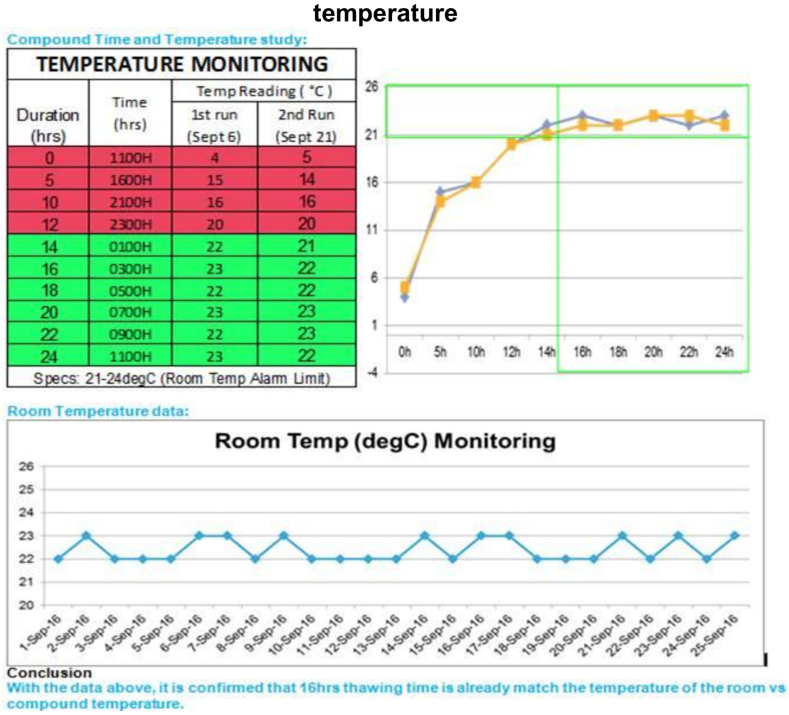


Fig. 9. Methodology on how temperature reader plant inside the compound box to read for temperature



TEMPERATURE MONITORING

Duration (hrs)	Time (hrs)	Temp Reading (°C) 1st run (Sept 6)	2nd Run (Sept 21)
0	1100H	4	5
5	1600H	15	14
10	2100H	16	16
12	2300H	20	20
14	0100H	22	21
16	0300H	23	22
18	0500H	22	22
20	0700H	23	23
22	0900H	22	23
24	1100H	23	22
Specs: 21-24degC (Room Temp Alarm Limit)			

Fig. 10. Actual temperature data inside the compound during thawing stage

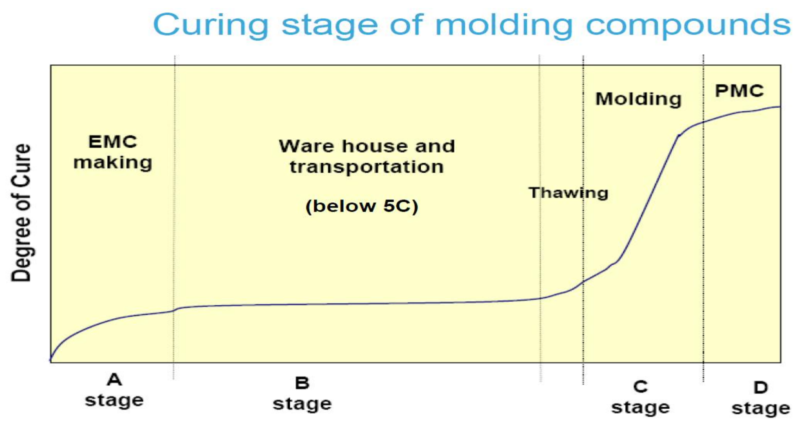


Fig. 11. Reaction rate of compound each stage

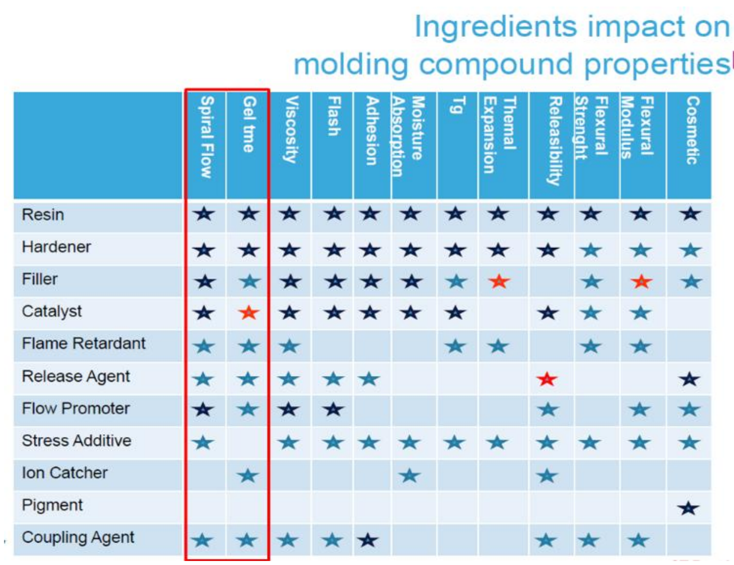


Fig. 12. Molding compound characteristics

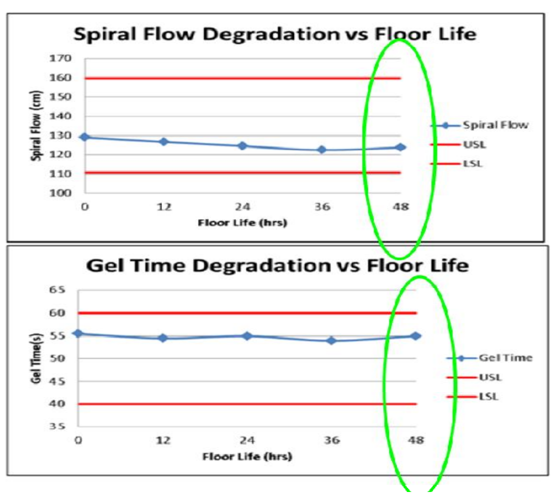


Fig. 13. Spiral flow test and gel time result

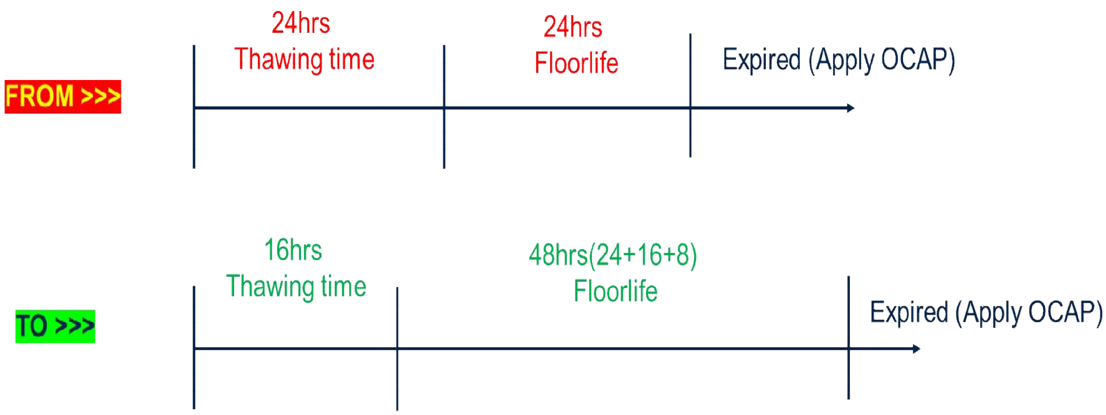


Fig. 14. Final recommended compound usage

- **Table 1. Test Precondition and Reflow**

MSL Level	Units	% Moisture Incoming	Bake	Moisture Soak	% Moisture after Soak	Solder Reflow
Eval – 16hrs thawing time			125°C 24 hrs	30°C/60%RH 192 hrs		Peak Temperature 260°C, 3X Solder Reflow performed within 4 hrs of moisture soak Board Type (Poly)
3	1-22	0.069%			0.058%	
Ctrl – 24hrs thawing time						
3	1-15	0.061%			0.053%	

Note: The % moisture data may not be very accurate due to the low weight of the test groups combined with the accuracy of the balance

MSL Level	Units- ID	Electrical Fails		Visual Inspection	
		Test Results	Moisture Related	External Cracks	Comments
Eval – 16hrs thawing time					
3	1-22	0/22	0/22	0/22	All units passed ATE at post MSL3.
Ctrl – 24hrs thawing time					
3	1-15	0/15	0/15	0/15	All units passed ATE at post MSL3. *(1 unit failed was validated marginal per TPE Tito Alangcao)*

Fig. 15. MSL3 moisture test

Purpose /Objective				Floor life extension PROJECT #3	
Reliability Trial		Test Conditions	Duration	788490BCZX *Extend Compound floor life from 24 hrs to 48 Hrs*	788490BCZW *24hrs Control*
PC + TC	Pre Conditioning: Moisture Sensitivity Jedec Level 3 **STD020/ JESD22 A113** + Thermal Cycling **JESD22 A104**	Bake (125°C / 24 hrs) Soak (30°C / 60% RH / 192 hrs) reflow +-65°C +150°C	SAM	Done (refer to slide 14)	Done (refer to slide 17)
			MSL3	Done	Done
			ATE	0/79* All passed	0/80 All passed
			SAM	Done (refer to slide 15)	Done (refer to slide 18)
			500cy	Done	Done
			ATE	0/79* All passed	0/80 All passed
			SAM	Done (refer to slide 15)	Done (refer to slide 18)
			1000cy	Done	Done
			ATE	0/79* All passed	0/80 All passed
			SAM	Done (refer to slide 16)	Done (refer to slide 19)
PC + UHAST	Pre Conditioning: Moisture Sensitivity Jedec Level 3 + UnBiased Highly Accelerated Temperature and Humidity Stress **JESD22 A118**	Bake (125°C / 24 hrs) Soak (30°C / 60% RH / 192 hrs; 3x Reflow @Tpeak 260°C + uHAST 130°C/85%Rh	MSL3	Done	Done
			ATE	0/80 All passed	0/80 All passed
			96h + LEAD CLEANING	Done	Done
			ATE	0/80 All passed	0/80 All passed
HTSL	High Temperature Storage Life **JESD22 A103**	150°C- no bias	500h	Done	Done
			ATE	0/80 All passed	0/80 All passed
			1000h	Done	Done
			ATE	0/80 All passed	0/80 All passed

Fig. 16. Full reliability test result summary

Validation Plan NOTE:1 cycle=2 strips, 25 cycle=50strips

Y (or mini Y)	Unit of Measure	Y treated as	X	True nature of X	Levels of X, if discrete or converted into discrete	Hypothesis Statement: Null Hypothesis	Hypothesis Statement: Alternative Hypothesis	Graphical Analysis	Statistical Test	Beta	Alpha	Sample Size
Delamination	visual	Discrete	Floor life	Discrete	Narrow:24 hrs Wide:56 hrs	$H_0: P_{Narrow}=P_{Wide}$	$H_a: P_{Narrow}\neq P_{Wide}$	Mosaic Plot	2-Proportion Test	0.1	0.05	25 Cycles
Package Sticking	visual	Discrete	Floor life	Discrete	Narrow:24 hrs Wide:56 hrs	$H_0: P_{Narrow}=P_{Wide}$	$H_a: P_{Narrow}\neq P_{Wide}$	Mosaic Plot	2-Proportion Test	0.1	0.05	25 Cycles
Crumpled strip	visual	Discrete	Floor life	Discrete	Narrow:24 hrs Wide:56 hrs	$H_0: P_{Narrow}=P_{Wide}$	$H_a: P_{Narrow}\neq P_{Wide}$	Mosaic Plot	2-Proportion Test	0.1	0.05	25 Cycles
Warp Strip	Microns (um)	Continuous	Floor life	Discrete	Narrow:24 hrs Wide:56 hrs	$H_0: \mu_{Narrow}=\mu_{Wide}$ $H_0: \sigma_{Narrow}=\sigma_{Wide}$	$H_a: \mu_{Narrow}\neq\mu_{Wide}$ $H_a: \sigma_{Narrow}\neq\sigma_{Wide}$	Oneway Anova	2-Sample T- Test 2-Variance Test	0.1	0.05	42 readings
Package Crack	visual	Discrete	Floor life	Discrete	Narrow:24 hrs Wide:56 hrs	$H_0: P_{Narrow}=P_{Wide}$	$H_a: P_{Narrow}\neq P_{Wide}$	Mosaic Plot	2-Proportion Test	0.1	0.05	25 Cycles
Package Chip-out	visual	Discrete	Floor life	Discrete	Narrow:24 hrs Wide:56 hrs	$H_0: P_{Narrow}=P_{Wide}$	$H_a: P_{Narrow}\neq P_{Wide}$	Mosaic Plot	2-Proportion Test	0.1	0.05	25 Cycles
Voids/Inc. Fill	visual	Discrete	Floor life	Discrete	Narrow:24 hrs Wide:56 hrs	$H_0: P_{Narrow}=P_{Wide}$	$H_a: P_{Narrow}\neq P_{Wide}$	Mosaic Plot	2-Proportion Test	0.1	0.05	25 Cycles

Fig. 17. Statistical validation plan

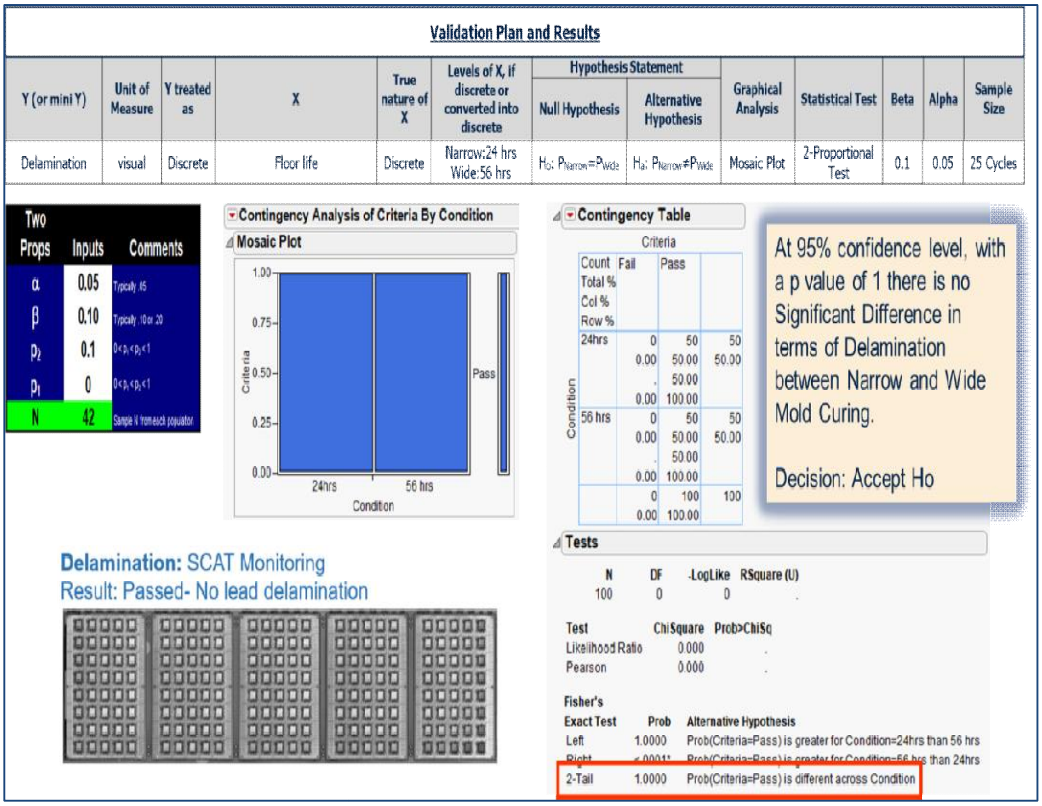


Fig. 18. Statistical validation result for delamination

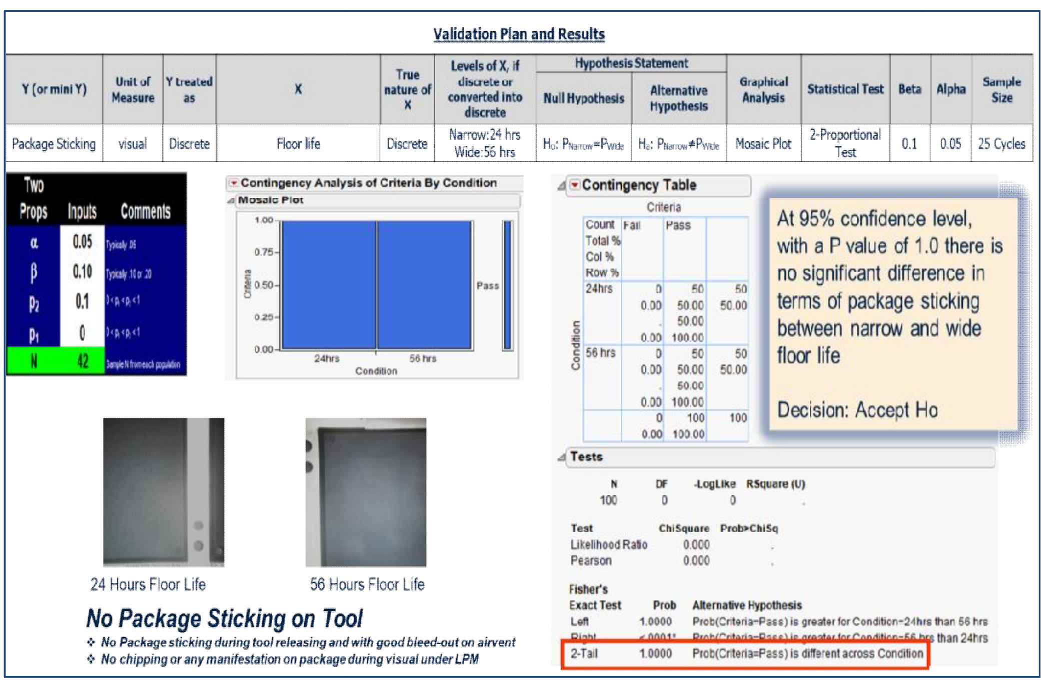


Fig. 19. Statistical validation result for package sticking

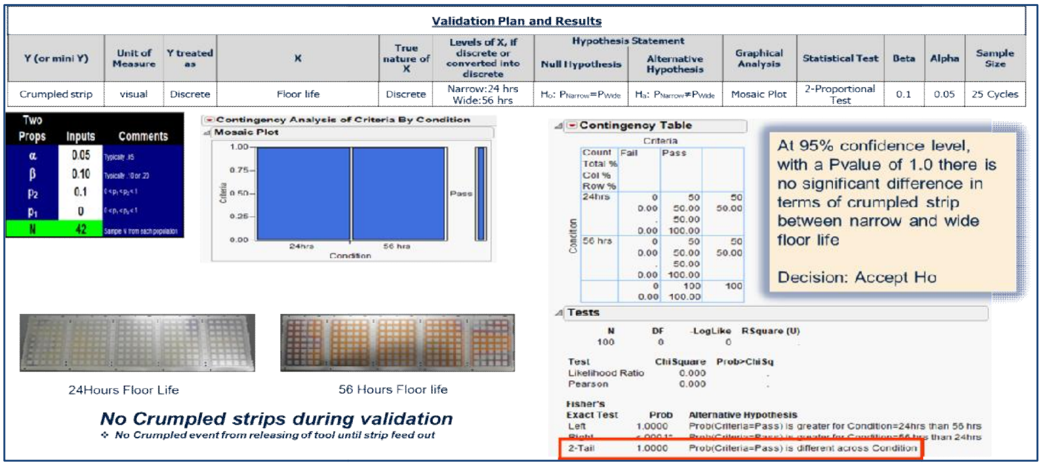


Fig. 20. Statistical validation result for crumpled strip

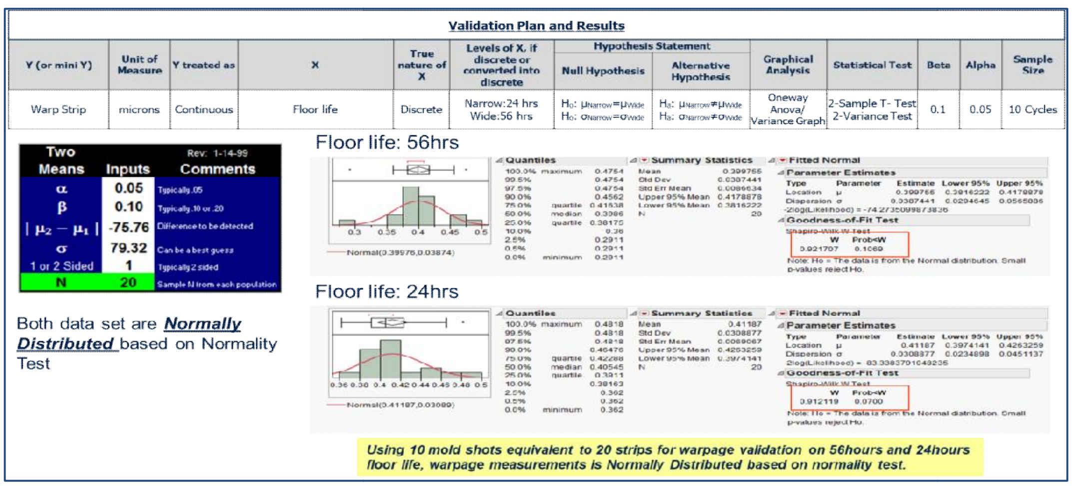


Fig. 21a. Statistical validation result for warp strip

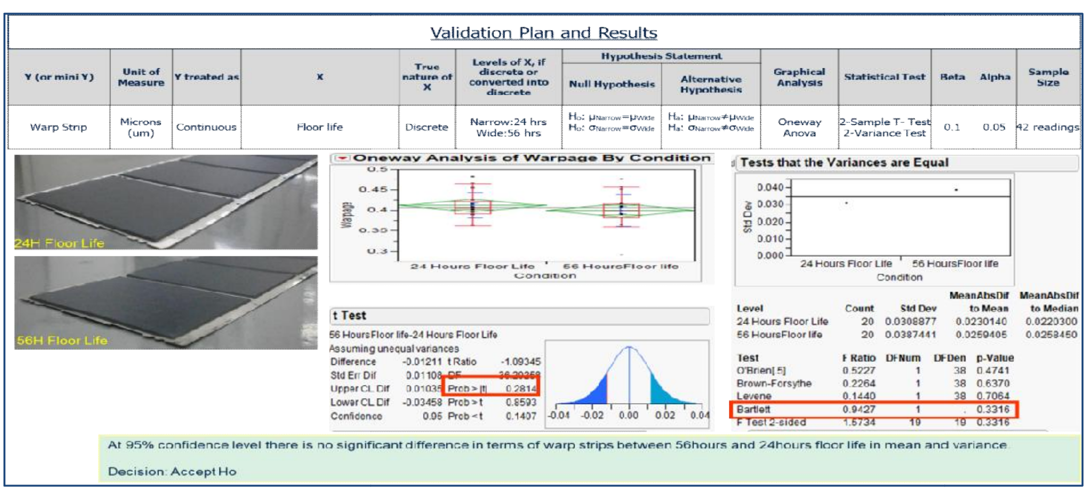


Fig. 21b. Statistical validation result for warp strip

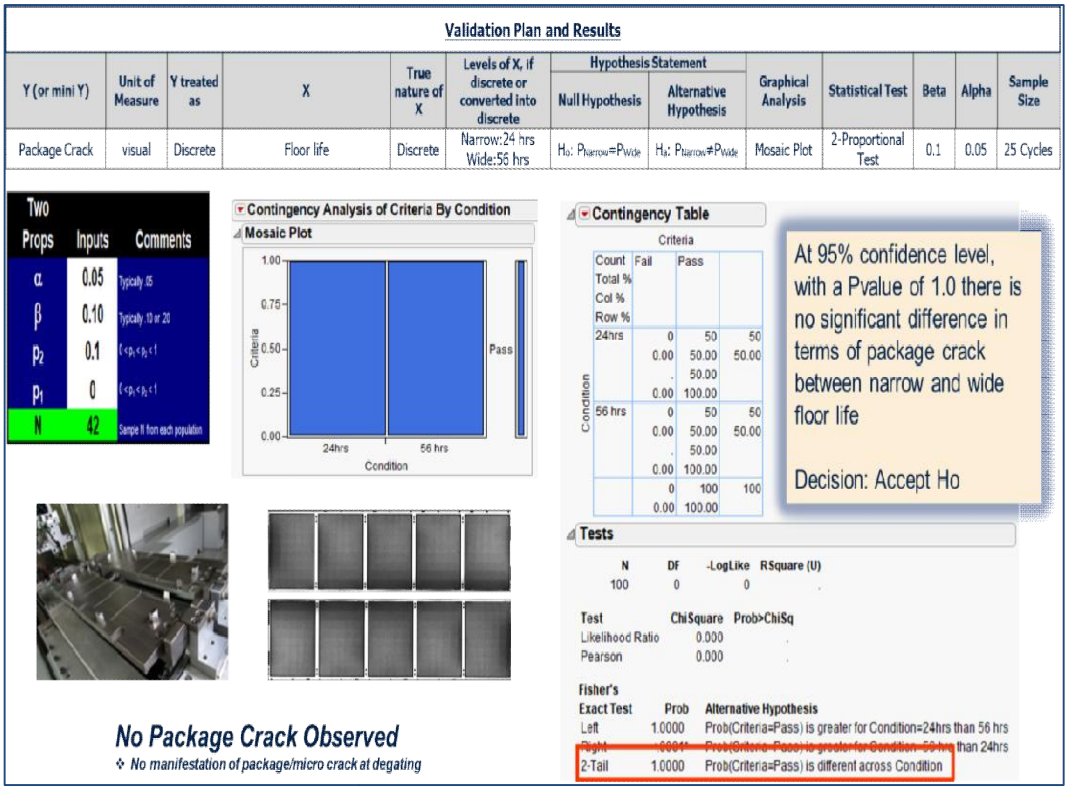


Fig. 22. Statistical validation result for package crack

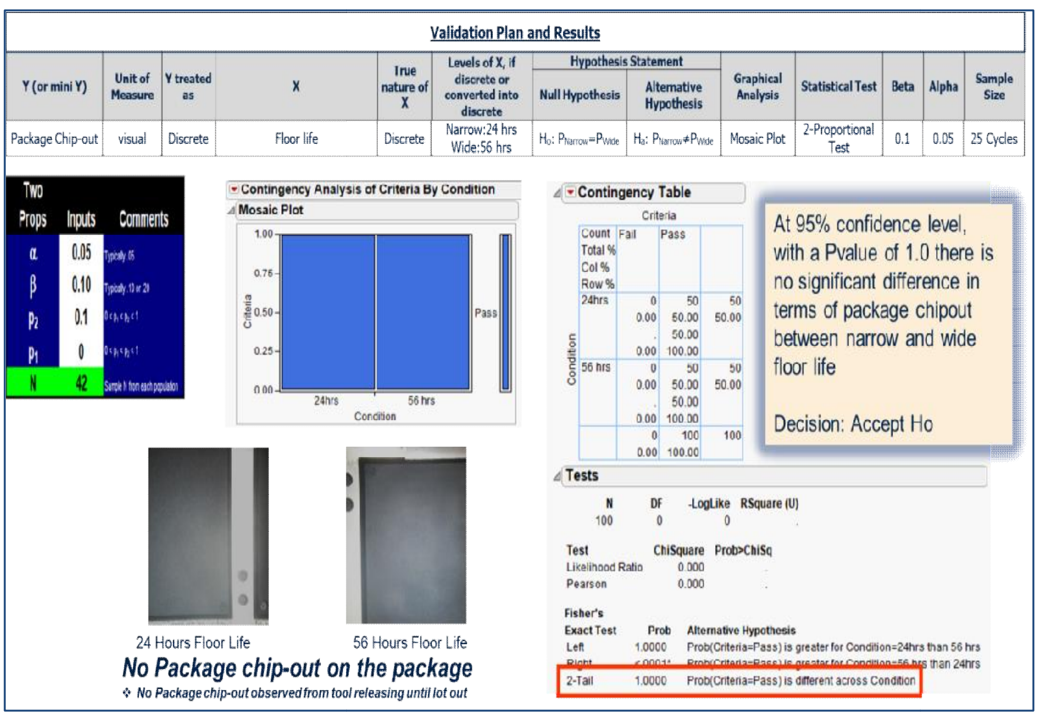


Fig. 23. Statistical validation result for package chip-out

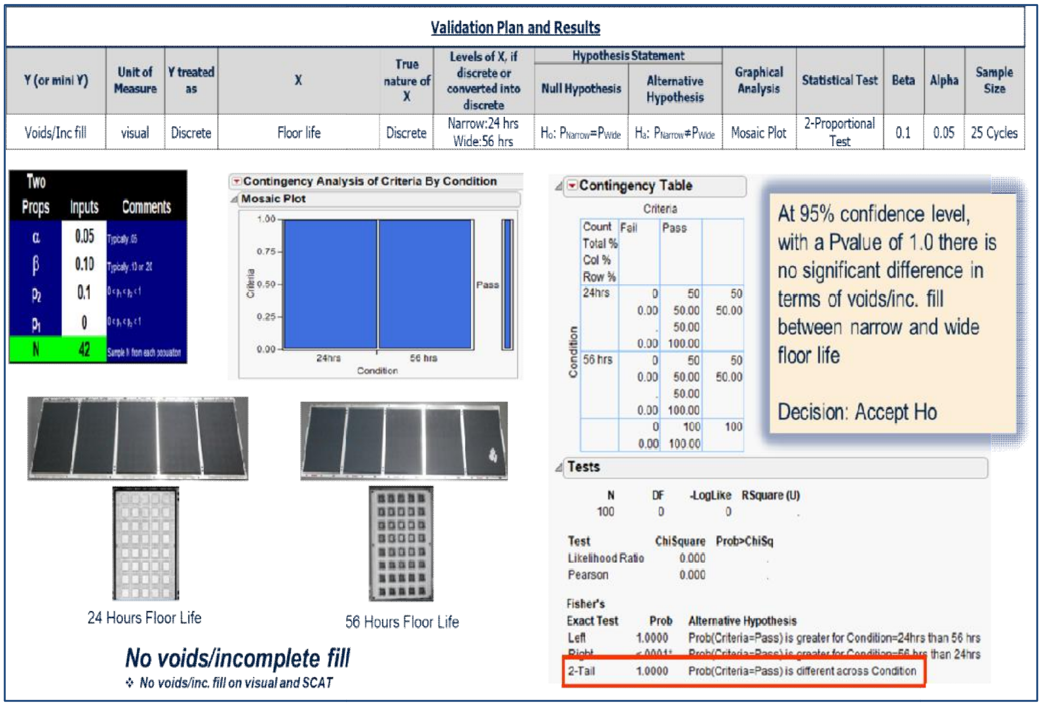


Fig. 24. Statistical validation result for voids/incomplete fill

10Lots Line Stressing Result: TEST YIELD_56H Floorlife

Lot Id	Product Code	QTY IN	QTY OUT	Yield
780440BL05 com 780440BL03, 780440BL08, 780440BL06	CC|U*UAS9BCC	15727	15716	99.93%
780440RR07 com 780440RR05, 780440RR09	CC|U*UAS9BCC	15762	15617	99.08%
780440RR01 com 780440RR08, 780440RR01, 780440RR06	CC|U*UAS9BCC	11750	11623	98.92%
780440LC01 com 780440LC09, 780440LC06	CC|U*UAS9BCC	11445	11437	99.93%
780440V601 com 780440V608, 780440V609, 780440V60V	CC|U*UAS9BCC	15606	15598	99.95%
780440RR03 com 780440RR04	CC|U*UAS9BCC	7721	7716	97.94%
780440BL04 com 780440BL0C, 780440BL09	CC|U*UAS9BCC	13590	13583	99.95%
780440RR0B com 780440RR0A	CC|U*UAS9BCC	7747	7745	99.99%

Test Yield for QFN-MR: 97% Yield Limit Acceptance

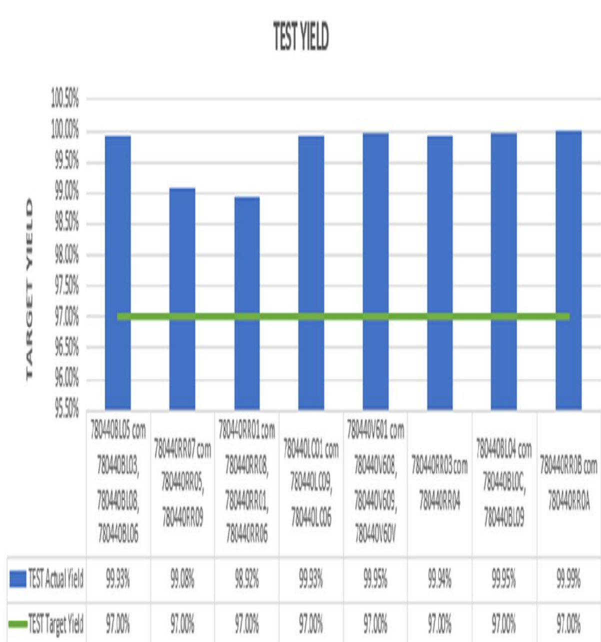


Fig. 25. Production lots line stressing

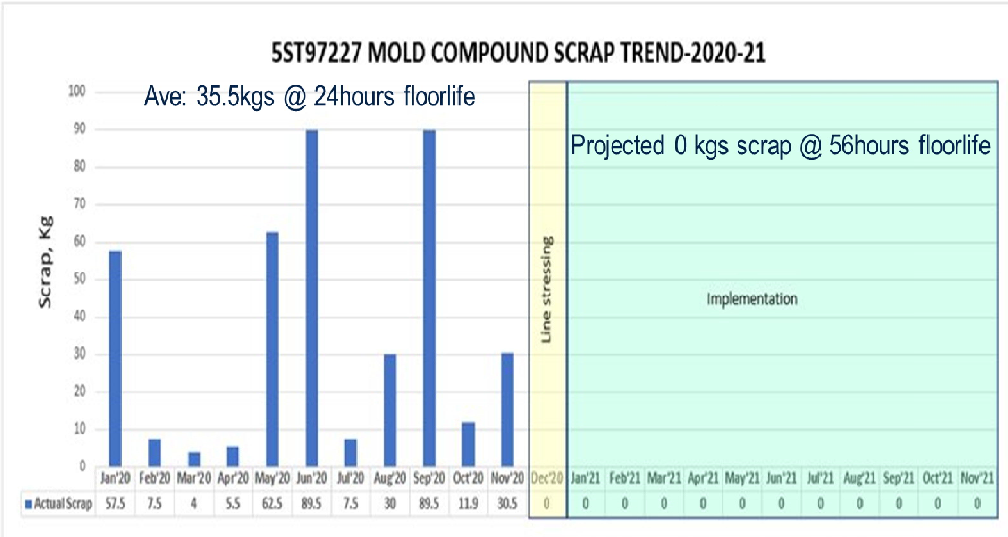


Fig. 26. Projected zero wastage in molding compound

Result revealed that the performance of the 56hrs usage window is comparable with the existing 24hrs floor life (shown on Fig. 15).

A full reliability run also resulted to passing performance (summarized on Fig. 16)

A validation plan (Fig. 17) was made to check if the change in floor life will affect product functionality and quality. There are several inspection and quality check made and use statistical tools to validate if there is/are significant difference between the original floor life versus the new expanded floor life.

Based on validation plan, a statistical test was conducted per identified quality risk with below data and result.

To summarize all statistical validation results, at 95% confidence level there is no significant difference in terms of all quality risk identified to affect product performance if to change floor life from 24hrs to 56hrs.

Line stressing on live production lots confirmed that the expanded floor life of 56hrs did not affect product performance as shown on Fig. 25.

It is projected based in line stressing results and the required floor life extension to deplete expired compound and zero out mold scrap by 2021.

5. CONCLUSION

With the detailed analysis and study on molding compound response to IC product, the expanded usage window of molding compound is statistically validated acceptable with passing functionality and quality test performance. The expanded usable window of molding compound can absorb the delays in manufacturing process that leads to a compound wastage.

6. RECOMMENDATIONS

With the convincing results even on Full reliability and Line Stressing, it is recommended to use:

1. Thawing time to 16hrs
2. New floor life to 56hrs

Which is applicable in all tablet and pellet type molding compound.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Borricks R, et al. Hitachi chemicals. Molding Compound Technical Data Sheet and Laboratory Data; 2018.
2. Wei Tan, Hongjie Liu, Et al. The study on the moldability and reliability of epoxy molding compound. 2017 China Semiconductor Technology International Conference (CSTIC). 2017;1-3.
3. Lay Tatt Tan, Yin Yin Teo, et al. Perfect molding challenges and the limitations. 2017 IEEE 19th Electronics Packaging Technology Conference (EPTC). 2017;1-6.
4. Jeromerajan Premkumar Narasimalu Srikanth. Moisture absorption mechanism in epoxy molding compounds used in IC encapsulation. 2006 8th Electronics Packaging Technology Conference. 2006;61-62.
5. Ranjan Rajoo, Xiaowu Zhang. Fast characterization for moisture properties of moulding compounds: influence of Temperature and Humidity. 2011 IEEE 13th Electronics Packaging Technology Conference. 2011;1-6.
6. Shufeng ZHAO. Moisture absorption of molding compound and organic substrate. 2011 International Symposium on Advanced Packaging Materials (APM). 2011;388-392.
7. Xingming Cheng, Wei Tan et al. Study on the high reliability performance and high thermal conductivity epoxy molding compound. China Semiconductor Technology International Conference (CSTIC). 2018;1-3.
8. Yeong-Jyh Lin, Sheng-Jye Hwang, Et al. Modeling of Viscoelastic behavior of an epoxy molding compound during and after curing'. IEEE Transactions on Components, Packaging and Manufacturing Technology. 2011;1755-1759.
9. Eric Nguegang, Jochen Franz, et al. Aging effects of epoxy moulding compound on the long-term stability of plastic packag. 11th International Thermal, Mechanical & Multi-Physics Simulation, and Experiments in Microelectronics and Microsystems (EuroSimE). 2010;1-6.
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