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Full Length Research Paper

Electrostatic discharge (ESD) improvement to reduce customer complaint

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Electrostatic discharge (ESD) / electrical over stress (EOS) factors cannot be avoided when an organization running daily manufacturing activity. ESD problems are increasing in the electronics industry because of the trends toward higher speed and smaller device sizes which normally these devices are easy to be damaged by ESD. One of the manufacturing company in Malaysia which produces car radio is also facing the same problem. The failure trend related to ESD is become an alarming condition at 0 km (the product still at automotive customer assembly - 0 mileages which the vehicle is not yet sell to end user). In this study, the problem related to ESD and improvement to reduce the failure were conducted. These includes improvements in ESD protection and control which minimize yield losses and 0 km failures, and maintain the company reputation as a supplier of high-quality and reliable products. Findings from this study showed that virtually all materials, even conductors, can be triboelectrically charges. The level of charge is affected by material, speed of contact, separation and humidity. Electrostatic discharge can occur throughout the manufacturing test, handling and operational process. The improvement activity consist of two phases which is 3rd quarter 2009 (July – September) and 4th quarter 2009 (October – November). This followed by the continuous improvement activity take place on the 1st quarter 2010 (January – March). With this improvement, failure trend at customer related to ESD showed a reducing pattern.

Key words: Electrostatic discharge, electrical over stress, customer complaint.

INTRODUCTION

Electrostatic discharge (ESD) is a sudden transfer (discharge) of static electricity from one object to another due to difference in electrostatic potential (Voldman, 2004). Static electricity is often generated through tribocharging (Jones, 2005). The separation of electric charges consist of positive (+) and negative (-) elements that occurs when two materials are brought into contact or rubbed together and then separated. Charges of static electricity build up from all the materials rubbing together and then pass through human body when they are able to escape. Large volts of ESD can create a visible spark, with the most impressive being that of lightning. Static electricity is generated when the electrons or positive ion on the surface of one object pass onto another causing it to become positively charged. The additional electrons are waiting for the opportunity to escape through a conductive object that allows the passing of electricity. The heat from ESD is extremely hot, and if it occurs to an electrical device then it can cause immediate or delayed damage (Voldman, 2001a). A charge of a mere 30 volts is enough to damage the most sensitive electrical components, with most at risk from charges of 100 - 200 volts. One of the most common causes of electrostatic damage is the direct transfer of electrostatic charge through a significant series resistor from the human body or from a charged material to the electrostatic discharge sensitive (ESDS) device (Okoniewska et al., 2004).

It is the phenomenon that gives one a mild shock when walk across a carpeted floor and then touch a doorknob (Voldman, 2001b). While this discharge gives a harmless shock to humans, it is lethal to sensitive electronics. For example, the simple act of walking across a vinyl floor

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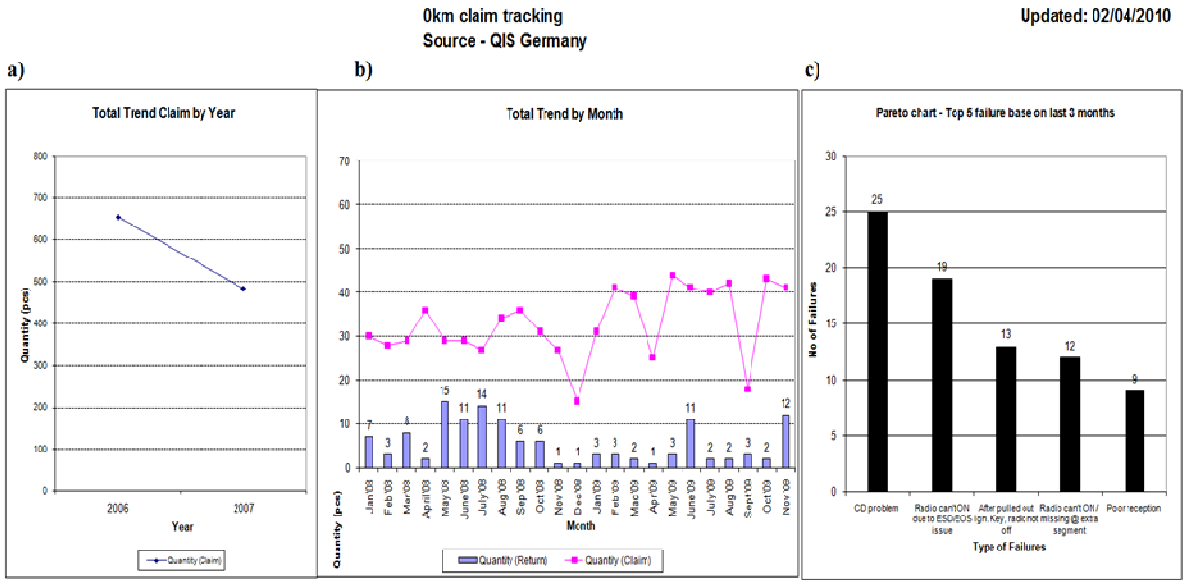


No	Description	2006	2007	Jan'08	Feb'08	Mar'08	April'08	May'08	June'08	July'08	Aug'08	Sep'08	Oct'08	Nov'08	Dec'08	Jan'09	Feb'09	Mas'09	Apr'09	May'09	June'09	July'09	Aug'09	Sept'09	Oct'09	Nov'09
	Number Of Claim	655	484	30	26	29	36	29	29	27	34	36	31	27	15	31	41	39	25	44	41	40	42	18	43	41
	Number Of Return			7	3	8	2	15	11	14	11	6	6	1	1	3	3	2	1	3	11	2	2	3	2	12
1	CD mechanism problem			12	11	11	15	12	9	15	7	12	11	7	2	6	8	8	1	9	16	11	11	2	12	13
2	Radio cant ON due to EOS/ESD issue			2	1	4	0	1	2	1	2	1	0	1	0	0	3	4	4	1	12	3	6	6	7	7
3	After pulled out ign. Key, radio not off			3	0	1	2	1	1	5	6	6	3	5	2	2	0	0	0	1	2	5	1	1	5	5
4	Radio cant ON / missing @ extra segment			5	5	6	3	4	3	6	6	3	2	5	1	4	2	0	2	1	5	3	3	4	5	1
5	Poor reception			3	2	5	2	3	2	3	3	2	4	4	1	2	4	2	0	0	1	1	2	1	6	3

Figure 1. Yearly failure claims.

can generate up to 12,000 volt of static electricity. 100 volts or less can damage components but to feel a discharge, it must be about 3000 volts. Electrical overstress (EOS) is a failure mechanism wherein the device is subjected to excessive voltage, current or power.

ESDS is a range of certain component specially integrated circuit component to withstand electrostatic charge that applied to it. Even a low voltage can kill an ESDS component and pose high risk of failure at customer. Therefore it is important to have a robust protection design at component level, packaging and finally at the production line where the device is assemble.

ESD can affect production yields, manufacturing costs, product quality, product reliability, and profitability (Voldman, 2001c). Industry experts have estimated average product losses due to static to range from 8 - 33%. The cost of damaged devices ranges from only a few cents for a simple diode to several hundred dollars for complex hybrids. When associated costs of repair and rework, shipping, labour, and overhead are included, clearly the opportunities exist for significant improvements.

Figure 1 shows the overall yearly 0 km failure trend for the manufacturing for the year 2008 and 2009. 0 km means the product still at automotive customer assembly - 0 mileage which the product (vehicle in this study) is not yet sell to end user. Several key points have been identified from the line chart (Figure 1b) and pareto chart (Figure 1c) related to ESD issues as listed thus:

(a) Base on the failure trend, EOS/ESD issue is constantly one of the top 0km failure faced by manufacturing company. The average reject quantity is 6 pcs/month out of total monthly production of 2000 pcs/month giving the failure rate of 3000 ppm (6/2000). This is really high for a manufacturing company and it is over the plant target. Therefore action is needed to bring down the figures to a more stable and accepted rate.

(b) No ESD task force team in the company to concentrate and drive for the ESD improvement activity and lack of understanding and awareness through the whole company. This is essential and become more

important especially to the production operator as their daily jobs in the assembly are direct handling of the product and component. If they are not being educated in terms of ESD failure root-cause and prevention, the product will have risk and might fail at customer plant.

This work gives an overview and understanding of the ESD concept and improvement activity related to ESD problem. One of the manufacturing company has been chosen to carryout this work. The objectives of this study are:

(a) To reduce monthly failure quantity, 6 pcs per month to 3 pcs per month, which lower down the failure rate from 3000 to 1500 ppm (50% improvement).
(b) To set up a task force team that leads and drives investigation work. The team shall defines potential root-cause and weak point in the current practice, perform data collection and measurement, analyze data, set the improvement activity and proper control and training for all staff and new employee.

In order to meet this objective, it requires a clear understanding of ESD concept, causes and prevention and improvement activity throughout all area, directly and indirectly at the supplier side, production and both employer and employee within the company. The outcome of this study shall affect the long term where return of financial investment can be seen by eliminating rework, recall back product for sorting and transportation cost. This able to gain customer's confident and build up reputation for the company.

MATERIALS AND METHODS

The flow chart of this study is shown in Figure 2. Generally, the methodology for this study can be divided into seven main sections as listed thus:

(1) ESD task force team set up
(2) Define the critical area and material with poor ESD control
(3) Measurement and data analysis
(4) Implementation of the improvement item
(5) Monitoring on the corrective action effectiveness
(6) Control on the action and training
(7) Continous improvement – to have a visit from the ESD specialist

Task force team set up is improtant initial step to identy the resources and expertise to plan and focus throughout the ESD improvement activity. This team will also have the authority to perform investigation and analysis where they need to go into certain area within the company to get some data and measurement. The material or production line facilities which have poor ESD control is identified by ESD/EOS measurement. Data will then be analyzed and justify to the suspected area where ESD failure possible to occur. Action of improvement will be implemented. After five months of monitoring at customer 0 km complaint, the corrective action or improvement is verified whether effective to reduce the ESD related failure. The proven action will

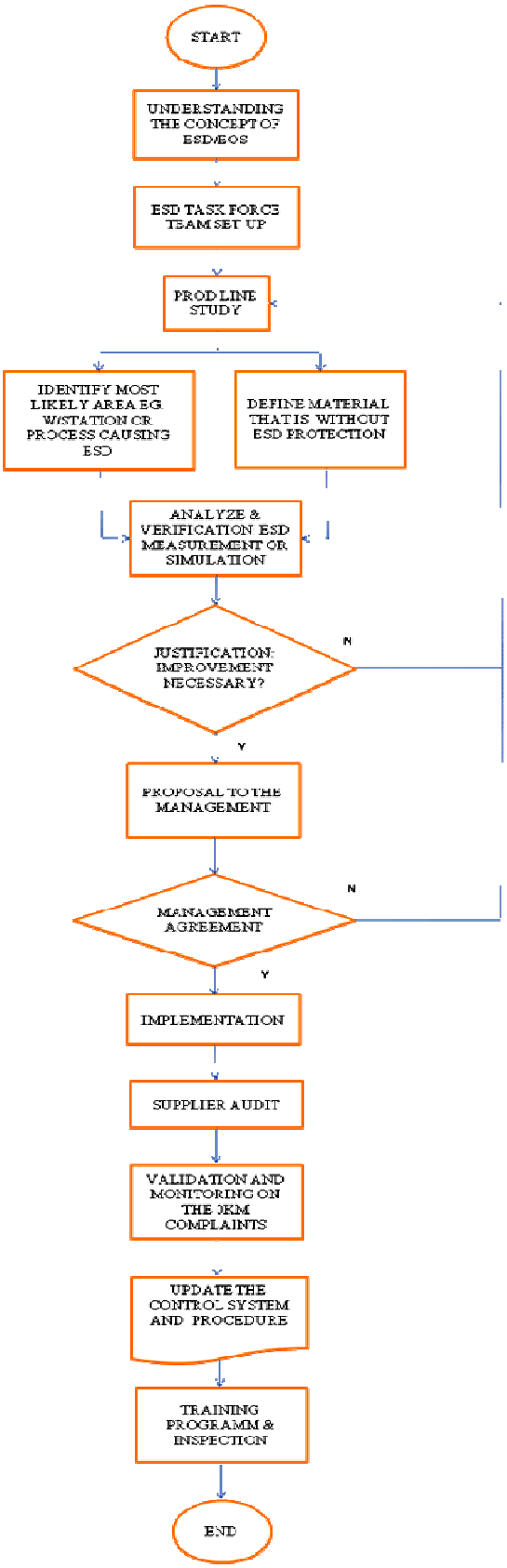


Figure 2. Flow chart.

Table 1. Improvement action.

No	Action	Due date
1	Implement ESD garment and smock	09/07/2009
2	Implement ESD material containers, PCB magazine and table mat.	11/08/2009
3	Implement ESD material trolleys and rack	21/08/2009
4	Implement dissipative jig	15/10/2009
5	Implement ESD dust bin, kanban card and holder	07/11/2009

Table 2. Continuous improvement action.

No	Action	Due date
1	Change fixtures with dissipative material	14/02/2010
2	Linkage of grounding points	31/03/2010
3	Further enhancement of manual soldering irons	31/03/2010
4	Modification of electric screw drivers	29/02/2010
5	Impose grounding chain for trolleys	31/03/2010

be permanently implemented and maintained and control by proper training plan. For a continous improvement plan, a team of ESD specialist from Germany will be invited to identify further area for improvement on the ESD/EOS scope. The input from them will be used as an important benchmark to further enhance the quality and proper management control on the ESD/EOS issue. Their visit was important to pin point the weakneasess in the production line in term of ESD/EOS control that all the while is overlooked or neglected. The tools that was used in this work are Fualt Tree analysis (FTA) and Eight Diciplines (8D) in order to identify the possible rootcause of the ESD failure.

RESULTS AND DISCUSSION

The effectiveness of all improvement activity taken on 3rd (July – September) quarter 2009 and 4th (October – November) quarter 2009 were stated in Table 1. This followed by the continuous improvement activity took place on the 1st quarter 2010 (January – March) as in Table 2 such as fixtures with dissipative material, linkage of grounding points, modification of electric screw drivers and impose grounding chain for trolleys.

The first phase of ESD improvement has already implemented on the 3rd and 4th quarter 2010, it was able to reduce the failure rate related to ESD issue. Further continuous action and overall improvement has been implemented and base on the monitoring result, it has definitely achieved the work target and objective. For the first phase of implementation, the data should be matured enough by February 2010, and for the second phase, the data can be seen around March of 2010.

ESD specialist visit

The visit of the specialist team from Germany has been carried out to help on further improvement activity on the ESD/EOS issue. The visit was followed by a two days workshop which involved representatives of each department, to discuss and measure the computer station base on 0 km complaint. A line walk to the production area is more like an audit that enable the team to identify few loop holes and weaknesses in ESD control that can be further improved. Two major findings which required improvement were highlighted:

(1) Improvement on solder frame design. PCB was placed on the solder frame as a supportive jig inside the wave soldering machine. The action has been completed and lead to a better performance to avoid failures due to ESD and EOS because of solder short. This finally reduced the 0 km complaint from the customer (Table 3).
(2) Better cleaning process using new brushing machine at solder wave station. This improvement focused on cleaning the solder frame from solder residue by enhancing the brushing process (Table 4).

Figure 3 showed customer claim on 0 km from December, 2009 until March, 2010, an average of three pieces claim per month from customer is recorded. This is in line with the objective of this study which is to reduce average monthly claims from six pieces to three pieces per month (50% improvement). From the data, it showed that the corrective action plan during this study is also effective to reduce the customer 0 km claims related to ESD issue. However, there are still room for improvement to achieve zero defects and this can be achieved by maintaining whatever corrective action in place with proper management control and procedure updates, and always alert for opportunity to make an improvement.

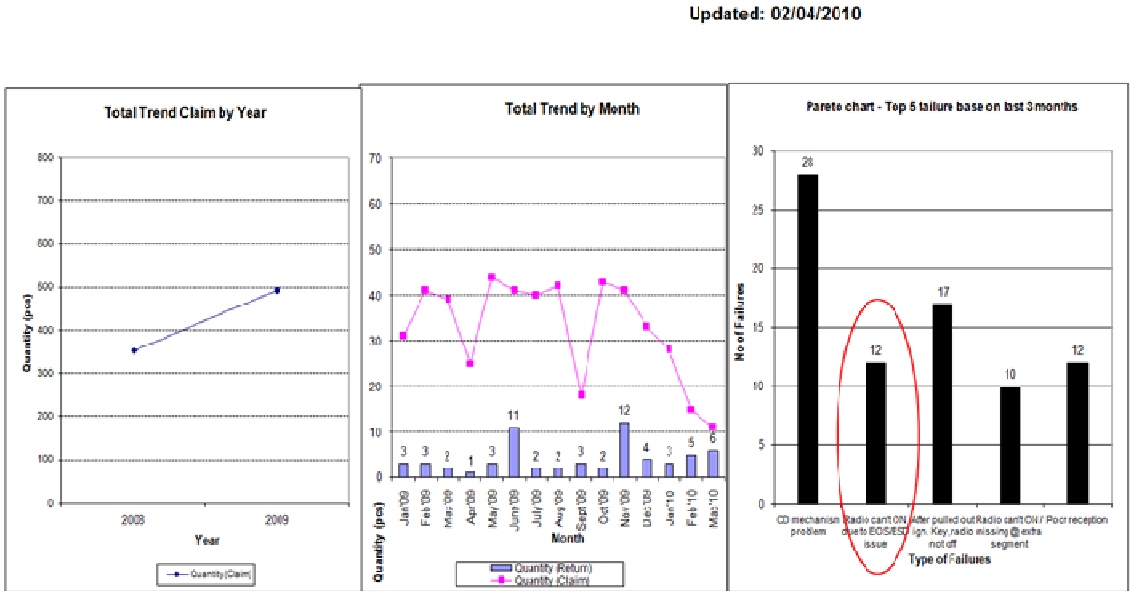
Figure 4 showed the bar chart on the differences of PPM in different phases. The corrective action taken contributed to the PPM reduction and validation on the effectiveness. During initial kick off of this work, the

Table 3. Improvement action on the solder frame design.

No	Improvement action	Due date
Solder frame design		
1	Solder laminate must be flat/smooth at bottom surface. No add-on cover plate is allowed (applicable for epoxy material) to prevent solder lump. Status: Negotiation on raw material cost.	28/8/09 (Done)
2	Approved PCB design violation that needs add-on cover plate must use 'Durastone' material to achieve no add-on plate requirement status. Status: Negotiation on raw material cost.	28/8/09 (Done)
3	Only "minus head" screw is allowed along the edge of solder frame,	28/8/09 (Done)
4	Implement four additional support tools at conveyer to maintain the parallelism.	12/6/09 (Done)
5	Use modified EPROM from Braga to enable adjustment of the standby wave flow rate from 60 to 40% (Epm CIG 400) to avoid thermal shock.	12/6/09 (Done)
6	Brushing machine to be installed at Line 1 after wave process to remove solder ball, Order 1 unit from Braga and duplicate the rest locally; containment using manual brushing for all lines.	31/3/10 (Done)

Table 4. Cleaning process improvement.

No	Improvement action	Due date
Cleaning process improvement		
1	To evaluate and replace solder frame that trap solder and drop after soldering process (Selected pilot line 4)	28/3/10 (Done)
2	To install brushing machine at Line 4 after soldering process.	16/3/10 (Done)



No	Description	2008	2009	Jan'09	Feb'09	Mac'09	Apr'09	May'09	June'09	July'09	Aug'09	Sept'09	Oct'09	Nov'09	Dec'09	Jan'10	Feb'10	Mac'10
	Number Of Claim	351	492	31	41	39	25	44	41	49	42	18	43	41	33	28	15	11
	Number Of Return	85	62	3	3	2	1	3	11	2	2	3	2	12	4	3	5	6
1	CD mechanism problem	124	48	6	8	8	1	9	16	11	11	2	12	13	6	7	10	5
2	Radio cant ON due to EOS/ESD issue	15	24	0	3	4	4	1	12	8	6	6	7	7	4	3	3	2
3	After pulled out sgn. Key, radio not off	37	5	2	0	0	0	1	2	5	4	4	5	5	6	4	2	5
4	Radio cant ON / missing @ extra segment	49	14	4	2	0	2	1	5	3	3	4	5	1	6	1	2	1
5	Poor reception	34	9	2	4	2	0	0	1	4	2	1	6	3	3	5	3	1

Figure 3. Monthly claim.

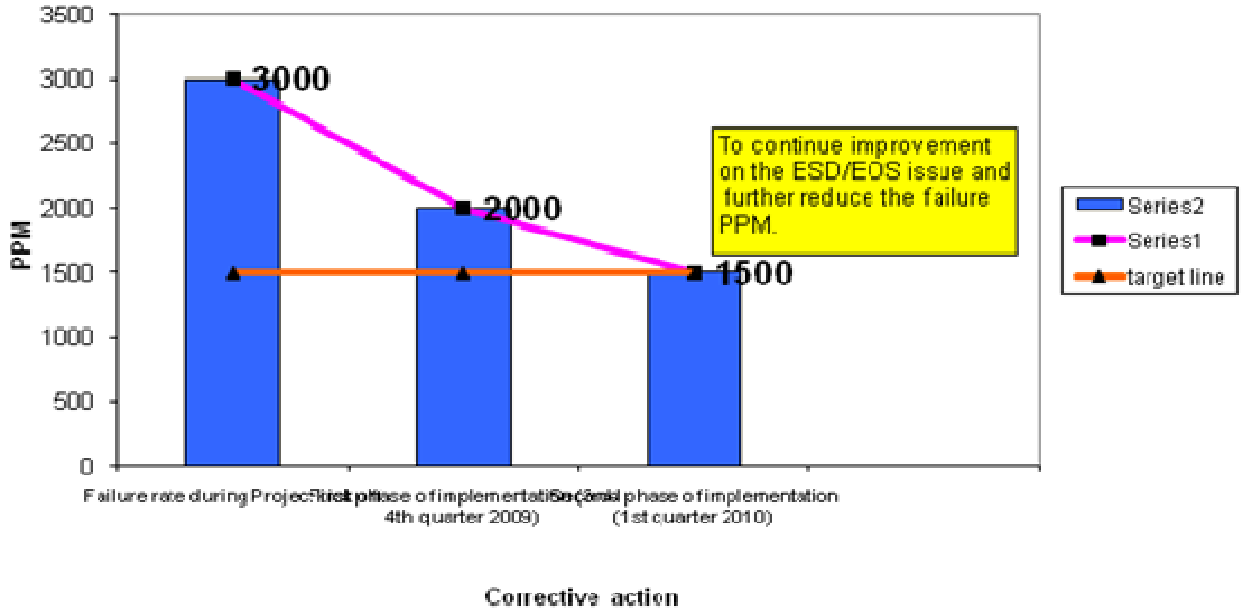


Figure 4. ESD improvement step down chart.

failure rate is 3000 ppm. Several corrective actions was implemented in two main stages : the 3rd to 4th quarter of 2009 which allows reduction of failure rate to 2000 ppm and 1st quarter of 2010, it reduces the failure rate to 1500 ppm as per the objective of this study.

Conclusion

The ESD/EOS improvement activity is implemented by manufacturing company in order to reduce the 0 km complaint from customer. These work had identified and achieved the objectives. It is important to understand the definition regarding the issues of ESD/EOS and how the effect gave impact to the manufacturing company. In terms of cost of poor quality such as rework, recall for sorted activity and transportation for replacement parts to the customer. The company name and good reputation was also effected by the 0 km complaint and future bussiness will have great risk. The ESD sensitive components in the product is easy to be damaged by the ESD effects. The improvement activity was conducted in two stages. The first phase of the implementation was around 2nd and 3rd quarter of year 2009 and continue on the early 2010.

The improvement activity such as ESD effective work place, ESD protective material, ESD jigs and assembly equipments were the key factors for eliminating the ESD failure at customers place. The management support in terms of control and training is also important in order to achieve the objective of this study. With this improvement activity, the objective and target of this study which is to reduce customer 0 km complaint that related to ESD/EOS from average 6 pcs per month (3000 ppm) to 3 pcs per month (1500 ppm) has been achieved with a reduction of 50% by end of this study duration.

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