MOTOROLA INC.

Material Quality Engineering
Land Mobile Product Sector
Plantation Florida

Interoffice Correspondence

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From: Rae Levy and Ishayau Perelman (MCIL)
To: Distribution

Vacuum Oven Study

Abstract

Processes for drying moisture sensitive devices has been a problem issue for the manufacturing industry. Most manufacturers unreel and bake the devices at 125°C and then re-reel the devices. Motorola Israel helped design a vacuum oven that allowed the whole reel of devices to be dried without removing the devices from the reel. In order to determine if the vacuum oven was a good alternative, an experiment was designed that compared the vacuum oven to a conventional oven set at 125°C and a conventional oven set at 70°C. It was concluded from this experiment that the vacuum oven is an excellent alternative to the conventional oven.

Introduction:

It has long been a problem with moisture sensitive devices that when they have exceeded their time in ambient conditions they must be baked to remove the moisture that has been absorbed. Usually this baking procedure consists of removing the devices from the reel prior to baking, baking at 125°C for 24 hours and then re-reeling the devices afterwards. Removing the devices from the reel is necessary because the reel material, polystyrene, can not withstand temperatures above 80°C. This procedure has many problems associated with it. The damage caused by having to handle devices can cause coplanarity problems and Electro Static Discharge (ESD) failures. The repeated baking temperature of 125°C can cause intermetallics to form between the solder ball and the printed circuit board carrier on Ball Grid Arrays (BGA).

Since Motorola Israel did not have tape and reel capabilities within their facility, they approached the problem from a physics point of view (1995 TCS project in Israel and European competition). An oven using vacuum would boil water at a lower temperature. They contacted a vacuum system manufacturer (Vacuum System & Technology) with their specifications and the manufacturer was able to design a vacuum oven to meet their needs. Although Motorola Israel has not had a delamination problem since they instituted the vacuum oven, there has not been any data to determine the amount of moisture that is removed by the vacuum oven process. In order to quantify what Motorola Israel has experienced with the vacuum oven, an experiment was designed to measure actual moisture weight loss of devices and compare a conventional oven with the vacuum oven. The results of this investigation are summarized in this report.

Experimental:

This system is capable of an ultimate pressure of 35 m Torr and the heating elements are located around the circumference of the chamber for even heat distribution. The vacuum oven was designed with a center rod so that reels could be held without touching the sides of the oven. Motorola Israel has been using this system for more than three years with no delamination problems. Their system pulls 0.0001 Torr and uses a temperature of 70°C. The reels are in the vacuum oven for 36 hours.

The experiment consisted of using 48 Over Molded Pad Array Carrier (OMPAC) devices that were known to be extremely sensitive to moisture. The device chosen was an HC-16 used in the iDEN radio, part number 5105329V90. The devices were dried for 24 hours at 125°C using a conventional oven, this was considered to be the be zero percent or ideal moisture level. The devices were then weighed, using a Sartorius analytical scale, and recorded. The devices were then saturated for 168 hours in an 85°C/85%RH chamber. The 168 hours at 85°C/85%RH was used as this is the conditioning for JEDEC[1] level 1 devices. The devices were weighed and recorded. The 48 devices were separated into three groups. Fifteen devices were placed in a conventional oven (125°C), fifteen devices were placed in the vacuum oven (70°C), and thirteen devices were kept as the control group. After 24 hours the devices were taken out of the ovens and weighed. It was noticed at that time that the vacuum oven was not set correctly. The vacuum pump had been shut off by a production associate. This prevented the oven from pulling the correct vacuum. Also because the vacuum pump was not continuously working, it prevented the seals from being lubricated properly as the vacuum pump is supposed be on all the time. The two groups of devices from the ovens were re-saturated and weighed. The groups of devices were then placed in the vacuum and conventional ovens. After

24 hours the devices were weighed and placed back in the ovens. The devices were taken out and weighed after 48 hours in the ovens and reflowed. For the first 24 hours the conventional oven set at 125°C removed 100% of the moisture as opposed to 75% for the vacuum oven, but after 48 hours the vacuum oven had removed 90% of the moisture (see FIGURE 1). This figure may actually be higher when the vacuum oven is working at optimum. The devices were sent back to Motorola Plantation, and were inspected using a C-mode Scanning Acoustical Microscope (C-SAM) for signs of delamination.

Results and Discussion:

C-SAM analysis revealed that the fifteen devices that were dried in the vacuum oven for 48 hours had no delamination, but one of the fifteen devices dried in the 125°C conventional oven for 48 hours was delaminated. This makes sense as the standard is to dry devices for a maximum of 24 hours at 125°C.

The question arose as to whether a conventional oven set at 70°C would not perform the same as the vacuum oven. In order to address this question an additional experiment was proposed. The experiment consisted of fifteen devices that were dried for 24 hours at 125°C using a conventional oven The devices were then weighed, using a Sartorius analytical scale, and recorded. The devices were then saturated for 168 hours in an 85°C/85%RH chamber. The devices were weighed and recorded and placed in a conventional oven set at 70°C. Every 24 hours the devices were removed, weighed, recorded and then placed back in the oven. This was repeated for 168 hours (7 days). The moisture removed during the first 24 hours was 64%, at 48 hours 74%, and then it removed moisture very slowly until at 168 hours it had removed 85% of the moisture (see FIGURE 1). Three devices were reflowed and checked for delamination using the C-SAM. No delamination was detected.

Also to determine if enough moisture was being removed to prevent delamination from occurring long term, the remaining (12) devices were left at ambient conditions of 30°C / 60%RH. Every 24 hours three devices were weighed, reflowed, and checked for delamination using the C-SAM. After 96 hours (4 days) no delamination had occurred. The percent of moisture gain (see FIGURE 2) was not significant enough to cause delamination which proves that devices that are dried can be resealed and when opened again will have an ambient shelf life of at least 96 hours.

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[1] JEDEC level 1 is a device that has no moisture sensitivity. It can stay at ambient conditions indefinitely

Conclusion:

The vacuum oven set at 70°C for 48 hours definitely increases the amount of moisture that is removed from devices versus a conventional oven set at 70°C for 168 hours. However, the vacuum oven is not as fast as a conventional oven set at 125° for 24 hour. Nevertheless, when the time and effort associated from removing parts from the reel and placing them back is considered, the vacuum oven alternative competes favorably with the conventional oven. The results confirm that although the vacuum oven does not remove as much moisture, the moisture that it does remove is sufficient to eliminate the delamination problem and allow the devices to be used in ambient conditions for another 96 hours. When the vacuum oven is compared with the conventional oven set at 125°C, where devices must be removed from the reels prior to baking and must be re-reeled afterwards which leads to handling issues, the vacuum oven is a very good alternative for baking out moisture sensitive devices. Besides the damage that can be caused from handling the devices during un-reeling and re-reeling, there is also the added of cost of manpower to perform the un-reeling and re-reeling tasks and the added cycle time to perform the tasks. Another issue that must be taken into consideration is the fact that the vacuum oven was not running at peak efficiency because of the pump problem. It is believed that when the vacuum oven is running properly, it removes the same amount of moisture as the conventional oven set at 125°C for 24 hours in 36 hours. That part of the study will be revisited when the vacuum oven that has been ordered by iDEN is installed in the Plantation facility in approximately two months. In addition, a study is in progress, aimed to evaluate 3M bakable reels technology.

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without needing to be baked to remove moisture.

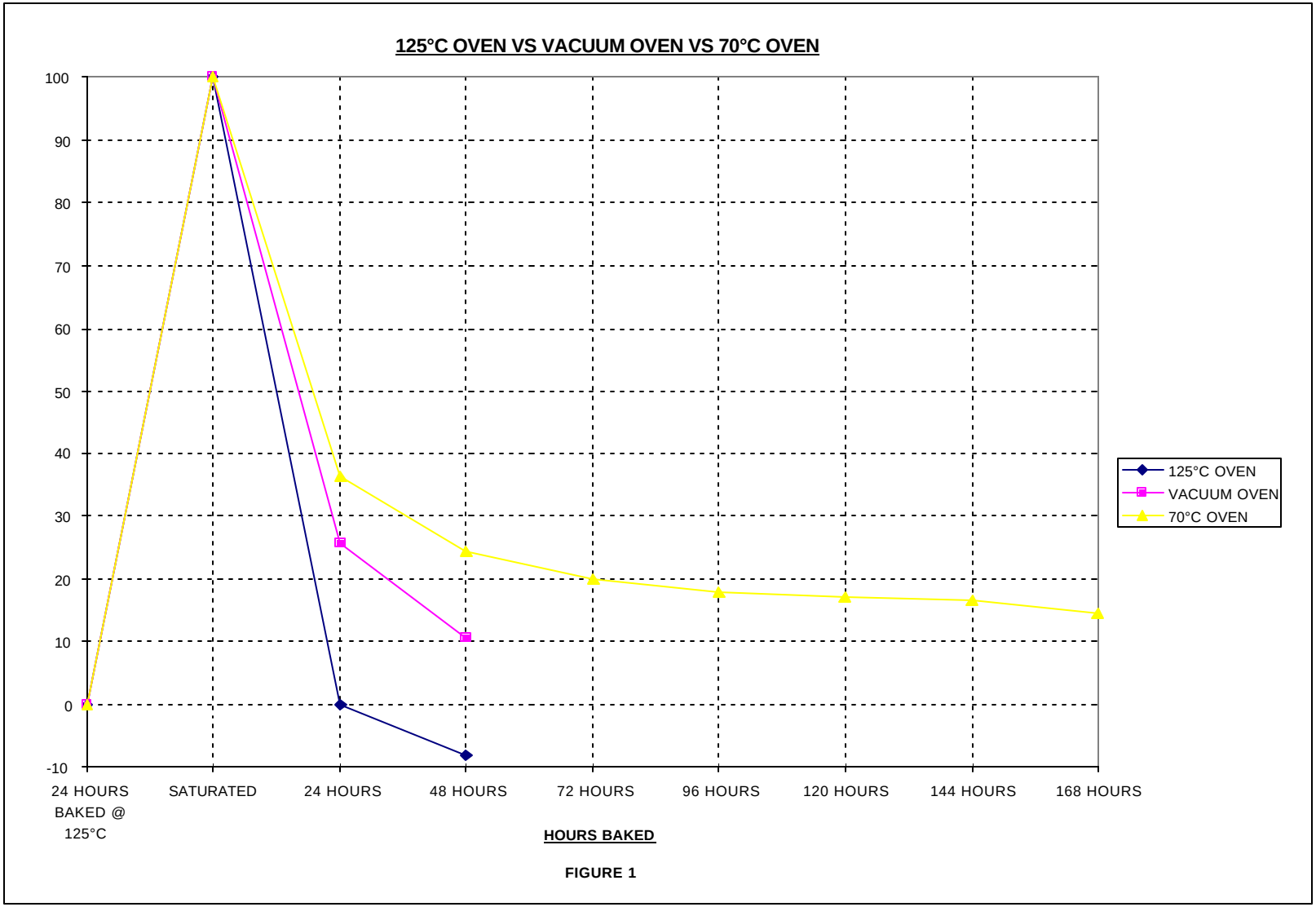
125°C OVEN VS VACUUM OVEN VS 70°C OVEN
100
90
80
70
60
50
40
30
20
10
0
-10
24 HOURS BAKED @ 125°C
SATURATED
24 HOURS
48 HOURS
72 HOURS
96 HOURS
120 HOURS
144 HOURS
168 HOURS
HOURS BAKED
125°C OVEN
VACUUM OVEN
70°C OVEN

FIGURE 1

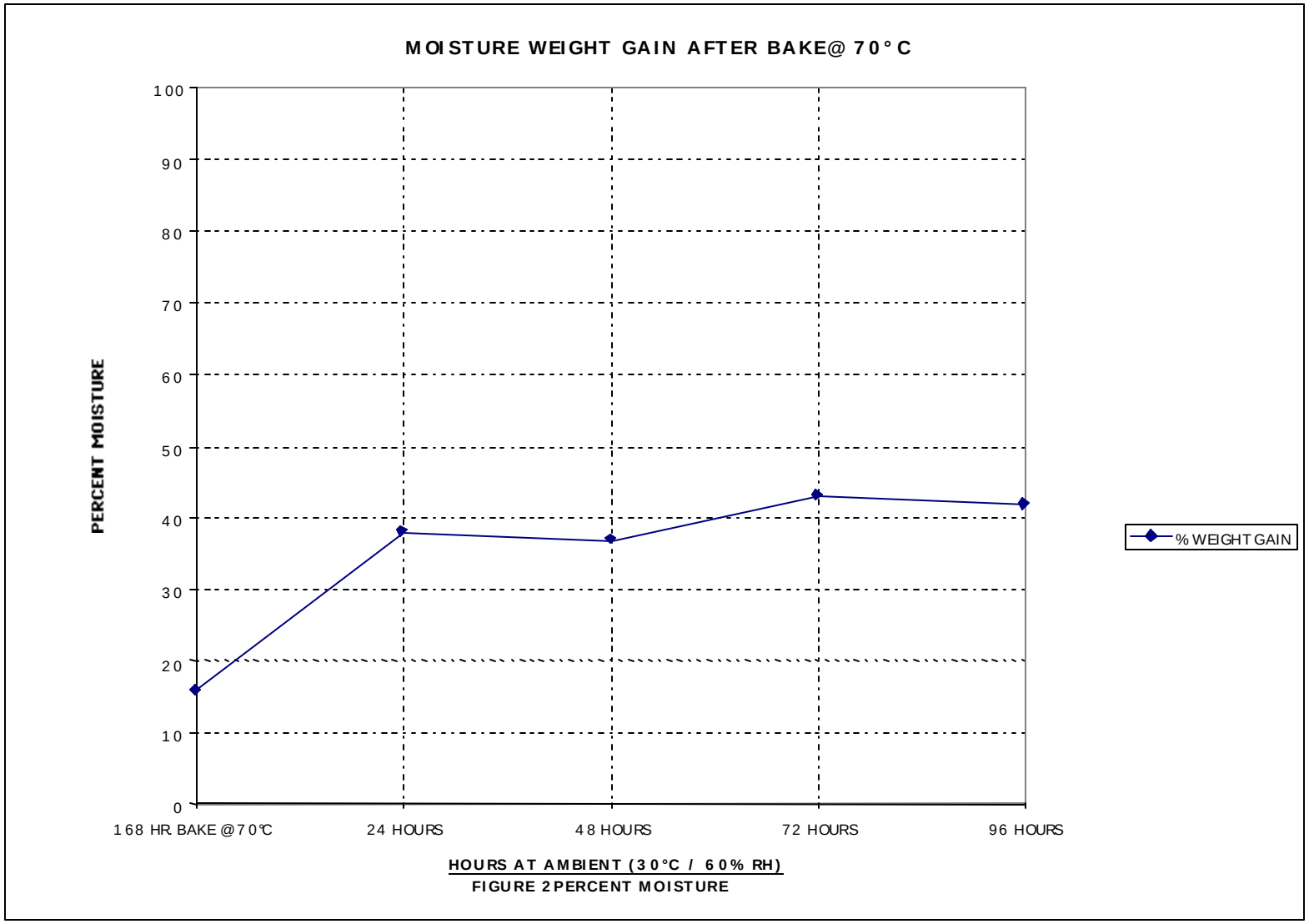

FIGURE 2 PERCENT MOISTURE