

Silicone tubing for coffee machine application

I had a complaint after doing a full refurbishment on an old La Pavoni pump machine that the coffee tasted "funny". After a process of elimination it turned out to be the silicone tube which ran from the water reservoir to the pump. On replacing this, the "chemical taste" disappeared. I had never had this problem before so I did some investigation and it seems not all Silicone is "created equal"

Silicone is quantified by its curing process and the amount of fillers in the formulation. The crosslinking or polymerisation of the silicone is achieved in the main by Platinum (addition polymerisation) or by organic peroxides (free radical polymerisation). Organic (aromatic) acids in peroxide-cured tubings are believed to contribute to the pH reduction and Total Organic Carbon seen in water extracts and increased organic extractables

Is peroxide cured silicone tube suitable for the specific application of potable water delivery in coffee machines? My answer based on the available studies is a yes but must be coupled with a significant and careful post-cure procedure.

Post-Curing

Post-cure is a process that removes the volatiles from the cross-linked silicone rubber by diffusion and evaporation and is carried out at a temperature greater than the service temperature for the part. (The post-cure process is analogous to water removal in the kiln drying of wood.) Once the volatiles are 'vaporized' they are no longer available to outgas. If the volatiles are not removed from the rubber and then exposed to elevated temperatures with poor ventilation, we can expect a reduction in strength, elongation, compression set properties accompanied by chemical decomposition.

Figure 1 illustrates the key concepts of post-cure. The first 4 hours consist of a typical post-cure at 200°C. In this phase about 2.7% mass-loss occurs. Even after 'operation' at 177°C (350°F) for 24 hours, mass-loss is less than 0.5%.

Figure 1. Post Cure and Outgassing after Post-Cure

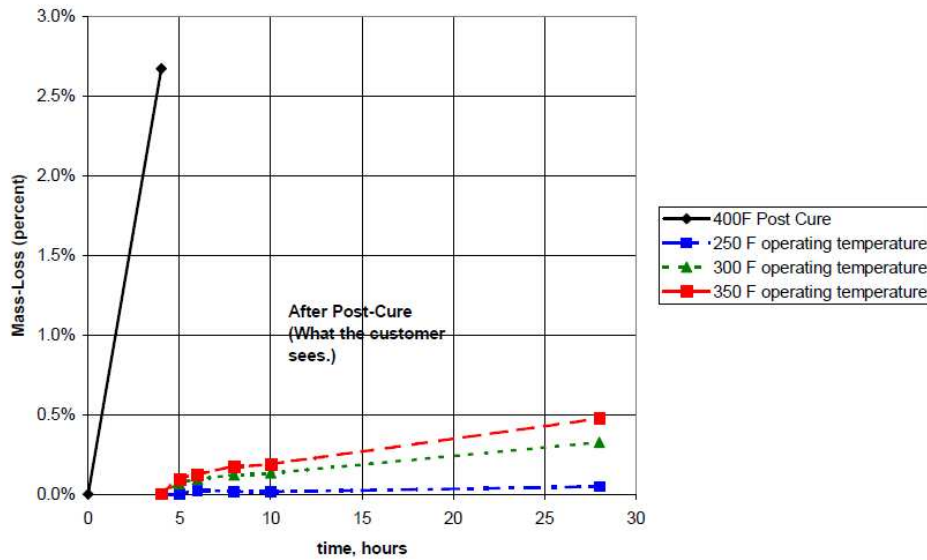
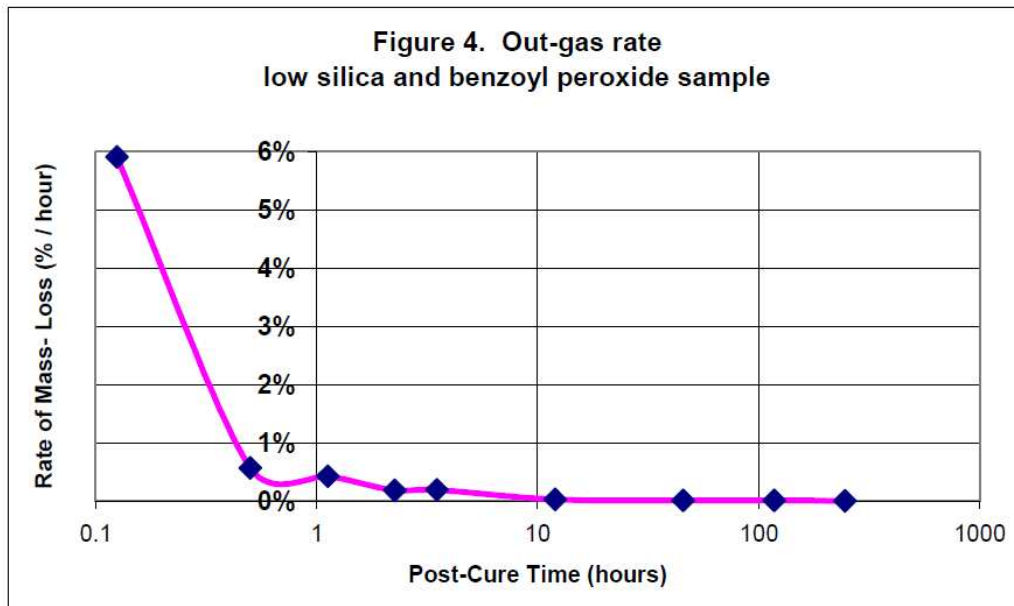


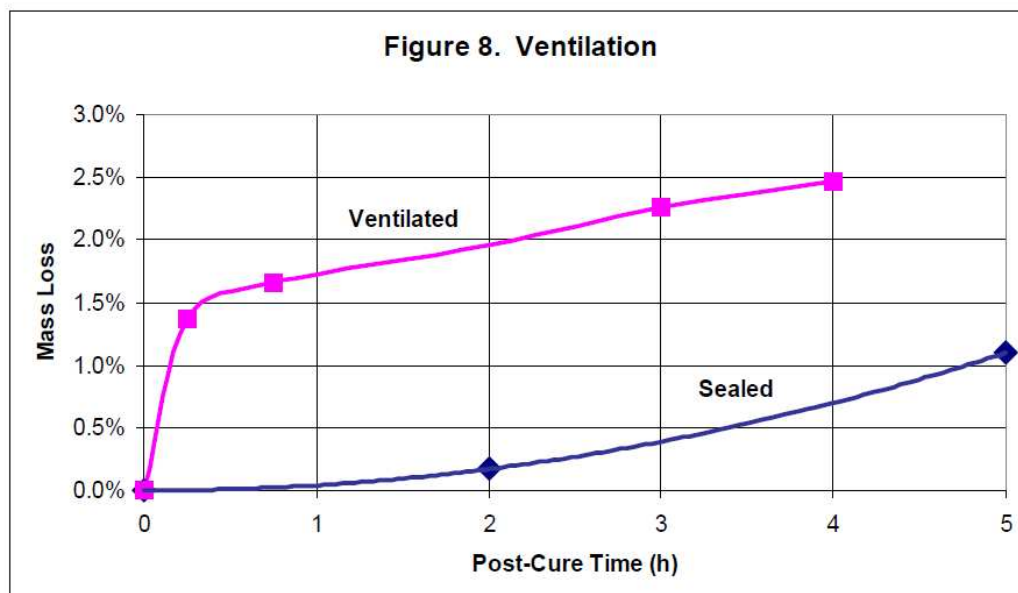
Figure 4 represents the outgassing rate versus time for post-curing at a temperature of 204°C (400°F). The rate is low after only 2 to 4 hours. The two major organic peroxide curing agents are benzoyl peroxide and 2,4-dichlorobenzoyl peroxide. Tests show that benzoyl peroxide is rapidly removed by post-cure.



Effect of Post-Cure Temperature and Ventilation

The higher the post-cure temperature the greater effect on outgassing, up to a maximum of 230°C.

Figure 8 compares well-ventilated samples to samples sealed in aluminum foil.



Species Outgassed

Gas chromatography / mass spectrometry was used to identify the outgassing species from a post-cured silicone in order of relative amounts. Much of the material are low molecular weight silicone oils, used to incorporate pigments, additives and catalyst into the compound.

Principal species from a post-cured silicone rubber

Component	Probable Source
cyclohexasiloxane	LMW silicone fluid
phenyl benzoate	catalyst byproduct
linear hexasiloxane	LMW silicone fluid
linear pentasiloxane	LMW silicone fluid
propanoic acid ester	catalyst byproduct
diethylphthalate	pigment wetting agent
Cx hydrocarbons	Silane coupling agent
cyclopentasiloxane	LMW silicone fluid
biphenyl hydrocarbon	catalyst byproduct
linear heptasiloxane	LMW silicone fluid
Cx aldehydes	catalyst decomposition product
cyclotrisiloxane	LMW silicone fluid

The conclusions are:

- 1) Post-curing is very effective in minimizing out-gassing during end use.
- 2) The rate of volatile removal during post-cure rapidly drops off after the first hour.
- 3) Ventilate during post-cure.
- 4) Silicone material will continue to outgas for extended periods of time at elevated temperatures.
- 5) Thickness has a minor effect, for thin silicone up to 2mm
- 6) Post cure is not necessary for platinum cure silicone except in the most extreme of application when cytotoxic effects need to be eliminated.

Recommended post-cure procedure for 5mmx8mm peroxide cured tubing for application in coffee machines

- 1) 1 meter lengths are heated to 200 °C monitored by a thermostat control for 4 hours high airflow oven (approx 50 litre per minute)
- 2) 50 °C detergent spray wash
- 2) Water washed at room temp and air dried

There is legislation in place in the USA and Europe to identify suitability for food application (FDA listing US - Code of Federal Regulations Title 21 and WRAS/WRC carrying out testing to BS6920 standard in UK).

References

<http://www.watson-marlow.dk/pdfs-global/b-post-curing.pdf>
<http://www.arlonstd.com/Library/Guides/Outgassing%20of%20Silicone%20Elastomers.pdf>
<http://www.dowcorning.com/content/publishedlit/52-1077-01.pdf>