# Composition of Ceramic Mixtures used in Electric Heaters

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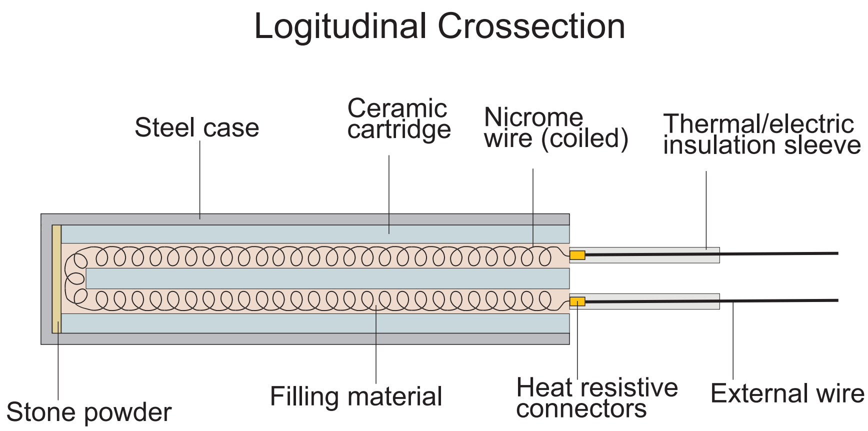
July 15, 2009

## 1 Main Objective

Our main objective was to find out the optimum composition of material filled in cartridge heaters. This material should be a good thermal conductor, a poor electrical conductor and should be thin enough to pass through the narrow cartridge holes. Most importantly, it should be able to hold the element in place during excessive heating and prevent it from cracking under a thermal shock.

A longitudinal section of the cartridge heater is shown in Figure .




## 2 Purpose of using Filling Material

Electric filament heaters use a filament that heats up rapidly as current passes through it. As the filament goes through thermal shock there is a high chance that it might break at the site of a kink or impurity in the heating element. To avoid this unwanted result and to transfer the heat delivered by the filament to the outer casing of the cartridge heater as efficiently as possible, we need to fill the heater body with a material that fulfills the above stated criteria. The filling material also allows the heat from the filament to spread uniformly to allow for more diffused heating. We also want the specific heat capacity of the material to be slightly higher than that of the metal wire so that it acts as a thermal shock absorber and supplies the heat from the element slowly and uniformly. Commercially, a ceramic material is used for this purpose in Pakistan which we now describe.

## 3 Composition of the Filling Material

According to our prior knowledge, obtained from local shops that specialize in heaters, the filling material is composed of the following items.

1. Sodium silicate
2. Ceramic Resin
3. Marble Powder
4. Water (solvent)

However, we do not know the exact proportion in which we have to mix these ingredients to get the optimum mixture. Nor are we aware of any previous studies on this important subject. We will be happy to know if such a study exists as it can help the local market.

### 3.1 Chemical Analysis

Resin and marble powder samples have been sent for chemical analysis to the PCSIR. Their exact scientific names/formulae will be known once the results are back.

## 4 Experimental Results

In order to find the optimum composition, we performed a series of experiments with different compositions of the given ingredients and tested out their physical properties in order to find the best match. The compositions thus made and the results obtained are recorded in the following table:

**Results with no marble powder used:**

| **COMPOSITION** (W: S : R)[a] | **RESULT** | **REMARKS** |
|---|---|---|
| 3 : 1 : 2[b] | Distinct layer of Sodium Silicate; Great deal of scraping-off; Poor strength. | Excess of Silicate. |
| 10 : 1 : 10[b] | No layer of Sodium Silicate; Poor strength. | More Silicate required. |
| 8 : 1 : 8[b] | Thin layer of Sodium Silicate; Powdery form underneath; Poor strength. | |
| 6 : 1 : 4[b] | Thin Silicate layer; High degree of scraping-off; Poor strength. | |
| 10 : 1 : 12[b] | Thin Silicate layer; Tough, resistant to scraping; Good strength. | This result proved to be non-reproducible because it was attained through heating in a furnace which provided non-uniform heating over different experiments and thus lead to different results when the experiment was repeated. |
| 15 : 1 : 15[b] | No Silicate layer; Powdery form; Poor strength. | |
| 3 : 1 : 6[b] | Thin Silicate layer; Soft Clumps; Poor strength. | |
| 6 : 1 : 12[b] | No Silicate layer; Poor strength. | |
| 10 : 1 : 12[b] | No Silicate layer; Poor strength. | |
| 3 : 1 : 10 | No distinct Silicate layer; Resistant to scraping; Good strength. | Upon scraping, some powdery form was lost. Its mass was weighed and remaining proportion was found to be 3:1:6 which appeared to be the optimum proportion. |
| 3 : 1 : 6 | No Silicate layer; Little scraping-off; Good strength. | This is the best proportion considering all the results obtained earlier. |

[a] W=water, S=silicate, R=resin, M=marble.
[b] Dried by heating in a furnace.
Poor strength denotes breakage upon removing disc from the cup.
Good strength denotes resistance to breakage even upon applying pressure by hand.
Degree of scraping is tested using fingernails.

**Results with marble powder added:**

| COMPOSITION (W: S : R : M)[a] | RESULT | REMARKS |
|---|---|---|
| 3 : 1 : 3 : 3[c] | Silicate layer on top; Powder underneath. | Granular marble powder was used which did not bind with resin. Hence we should use finer marble powder. |
| 3 : 1 : 6 : 3[c] | | |
| 3 : 1 : 6 : 6[c] | | |
| 3 : 1 : 6 : 12[c] | | |
| 3 : 1 : 2 : 2[d] | Thin Silicate layer; Broke only upon applying pressure. | |
| 3 : 1 : 3 : 3[d] | Thin Silicate layer; Broke only upon applying pressure. | |
| 3 : 1 : 3 : 6[d] | Some resistance to scraping; Poor strength. | |
| 3 : 1 : 5 : 5[d] | Very resistant to scraping; Good strength. | Excellent results obtained with this composition. These are the best results yet using marble powder. |
| 3 : 1 : 6 : 3[d] | Degree of scraping between 3 : 1 : 5 : 5 and 3 : 1 : 3 : 3 mixtures; Good strength. | |
| 5 : 1 : 7 : 7[d] | Scraps off easily; Poor strength. | |

[a] W=water, S=silicate, R=resin, M=marble.
[c] Granular marble powder used.
[d] Fine marble powder used.
Poor strength denotes breakage upon removing disc from the cup.
Good strength denotes resistance to breakage even upon applying pressure by hand.
Degree of scraping is tested using fingernails.

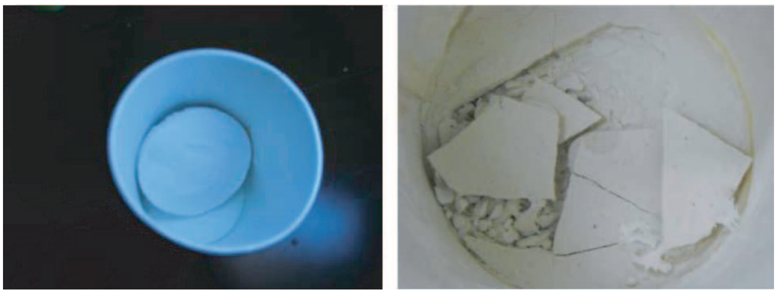
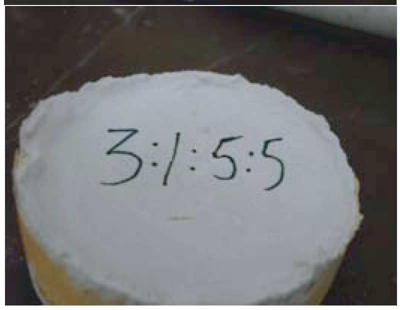


Figure 1: Pictures showing relative strengths, good and poor, in the same order.

# 5 Discussion and conclusions


The optimum proportion turned out to be 3 : 1 : 6 (water:silicate:resin) when no marble powder was used. Although this proportion had the right physical properties in terms of strength and resistance to scraping, we noticed that cracks often appeared on the surface of the material. These cracks and the resulting movement of the material could have caused the heating element to break.

To avoid this undesired property, we decided to use marble powder in the preparation of our mixture. After several experiments, we arrived at the final proportion of 3 : 1 : 5 : 5 (water:silicate:resin:marble powder). This gave results which had the optimum physical properties and most importantly, these results proved to be reproducible. During the course of our experiments we came to the conclusion that although heating in a furnace speeds up the process of drying, it leads to results that are non-reproducible as the heater does not heat uniformly over different experiments. We also found out that mixing the contents until a homogenous looking mixture is obtained lead to better results. Proper mixing (6±1 minutes) allowed the reaction between the mixture contents to reach completion, thus stoping the formation of bubbles. This allowed for a homogenous disc to be obtained after drying.

## 5.1 Cartridge Heater

Nichrome wire is used as a heating element that is placed inside the cartridge. The wire is very thin in most of the cases. In order to connect this heating element with the main power supply, a specific metallic connector is used that has a small cavity on one end (for the nichrome wire) and another space for the main power supply wire of larger diameter. In order to fill the heater case completely we need to use two different fillings. Initially the cartridge is filled with marble powder. The top of the cartridge is then covered with the 3 : 1 : 5 : 5 paste and left to dry, preferably at room temperature.

## 5.2 Disc Heater

The casing is filled with the 3 : 1 : 5 : 5 ratio mixture and is left to dry, preferably at room temperature.