

Crystal Clear

Where the water goes in gypsum-bonded investments, and why it matters

BY J. TYLER TEAGUE

In this Tech Sheet, J. Tyler Teague delves into the material science behind how gypsum-bonded investment sets, and how that chemistry can affect your casting success. You'll find an expanded version of this article at MJSA.org.

GLOSS OFF AND GREEN STRENGTH EXPLAINED

Gypsum-bonded investments usually contain about 25 to 30 percent gypsum (CaSO_4) with the remainder comprising some form of silica (cristobalite or quartz) and a small percentage of additives that control the setting time, fluidity, wetting, vacuum rise, and in some cases, the release of respirable silica. When mixed with water, the gypsum dissolves to form a hemihydrate in which each molecular compound contains at least 0.5 but fewer than 2 molecules of H_2O . As you pour this mix into the flask and vacuum it, the increasingly soluble hemihydrate continues to suck up the mixture's water and morph into the dihydrate form (1 molecule of $\text{CaSO}_4 \cdot 2$ molecules of H_2O). It keeps on doing so for as long as 1 to 1.5 hours until no free water remains.

During this absorption process, the gypsum dihydrate begins to form crystals in the spaces between the silica particles. (Go figure: more liquid = solid formation.) This process of taking water out of the slurry to form crystals creates the effect we call “**gloss off**,” which makes it appear as if the investment is drying. The formation of these gypsum crystals locks all the crystal structures into place. In addition, their growth causes the investment to expand (between 0.10 and 0.45 percent) and leads to a compressive force as the mold material is contained by both the metal flask on the outside and the parts on the inside. The combination of lockup and compression creates what is known as “**green strength**.”

HOW TO USE WATER TO YOUR ADVANTAGE

I'm telling you about “gloss off” and “green strength” to explain why the mold *isn't dry*—all the water remains in the investment. Here's how you can take advantage of this chemistry to improve mold strength.

- Use a lower water-to-powder ratio; this makes the silica crystals settle closer together, so the gypsum crystals don't need to fill as much space. Typically, I use a 40:100 water-to-powder ratio, but

to increase green strength I might go down to 38 percent water. On the downside, using less water also makes the investment mold less porous, and any gases generated by the metal-mold reaction won't pass as easily through the mold material. If you're casting metals with a reactive copper content, such as brass, copper, sterling, or rose gold, I would opt for more water (40:100) for greater gas dispersal (particularly if you're casting heavy pieces).

- Apply **hygroscopic expansion**, which is more commonly used in the dental industry, although some jewelers apply it as well. I recently saw this used in a small mass-customization factory northwest of Chicago and was given permission to tell others (so I am).



As I said earlier, the dihydrate crystal formation uses the water available in the investment; when all the water has been used, the formation stops. But if you gently immerse a just-invested flask under warm water before it has set, hygroscopic expansion takes over: The water surrounding the flask will replace what's being absorbed by the gypsum transformation,

enabling you to increase the size and number of the gypsum crystals and thus create greatly enhanced green strength. Using warm water (boiling water is *way too hot*) and keeping the flask in for an hour or so will give you the maximum expansion—up to 4 percent.

Since the water will make contact with the exposed investment only at either end of the flask, this trick works well primarily for small flasks. I imagine that a jeweler using large 4 x 8 perforated flasks might get some benefit, but the water has a long way to travel. However, if there were a permeable wrap that allowed some water to also pass through the perforated sides, without the CaSO_4 hemihydrate leaking out—that would be perfect. So to all you readers out there: Anyone up for inventing a microporous shrinkwrap that can cover perforated flasks?

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