A STAINED GLASS SUNDIAL WITH A MAGNETIC GNOMON

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My dialling friends know that I've had an ongoing love affair with stained glass sundials (SGS) for many years now. It began during a BSS conference tour when I saw Chris Daniel's wonderful SGS at The Merchant Adventurers' Hall in York. Since then, I jump at the rare opportunity to design or make one, and I've made several. Because few people realize they even exist, commissions don't come along often. In December of 2010, I received an order to make a rather large (2 ft × 3 ft) vertical declining stained glass sundial for a private home in Boulder City, Nevada, USA. The client wanted to install it permanently in his bedroom's south-facing window and wanted it to tell the time and date from inside his house. It would show Solar Standard Time with built-in longitude correction. He also wanted it to be embellished with lots of colourful artwork. He likes frogs. So he wanted frogs incorporated into the design somehow (Fig. 1).

My first thought was to make the gnomon in the shape of a frog. That idea came from my research on painted wall sundials which turned up many wall dials that have unusual gnomons resembling common objects. Most of these unusual gnomons are on Italian wall dials. I love this idea! Diallists should use them more often. There are unusual gnomons that look like boats, swords, rockets, hands, suns, anchors, birds, arrows and all sorts of unusual objects. There's no gnomonic rule that says a gnomon or parts of a gnomon can't be these things. You can be very creative in designing a gnomon especially if your sundial design requires a nodus-based or point-in-space type gnomon. All you need is something with a point, a ball, or even a hole on it. The frog idea worked out fine because the frog's nose is pointed and acts like a nodus. I just cut a frog shape out of brass sheet and soldered it to a brass rod.

Since the 16th century, stained glass sundial makers have struggled with the problem of how to attach gnomons to these fragile and breakable glass sundials. Typically, they would drill a hole in the glass and bolt the gnomon directly onto the glass. As you might suspect, this practice resulted in many of these wonderful dials being cracked and damaged over the years. A careless window-cleaner, a housepainter, a bird or even a hailstone could accidentally hit the gnomon, moving it and causing it to crack the glass. Some SGS designers avoided this problem by attaching the gnomon to the lead 'came' or to the window frame. But often the lead came or window frame are not in the right gnomonic place, especially for nodus-based dials. Also, when attaching a long polar axis rod gnomon to the window frame, ugly support struts are sometimes needed. Support struts can create confusing shadows for the users. Naturally, I really wanted to avoid all these things with this dial.

My first thought was to bolt the perpendicular rod and frog gnomon to a brass disk that would be incorporated into the leaded window. I made one of these gnomons for a SGS at Oxford University several years ago. Since the brass disk is firmly attached to the surrounding glass by lots of soldered lead came, it is harder to break the glass if the gnomon is impacted by something. This idea worked well for that dial, and has since been used by other SGS makers: see Fig. 2.

But in the back of my mind was a different idea that has been simmering for years. I thought that gnomons might be

Fig. 1. Interior view of the new SGS with its frog gnomon.

Fig. 2. Oxford SGS with a gnomon bolted to brass disk.

safely attached to stained glass sundials with magnets and conjectured that a magnetically attached gnomon would protect the glass from damage from impacts by simply falling off the sundial when hit. Also, gnomon installation would be a breeze without any bolting, soldering or gluing. To my knowledge, there were no known examples of magnetically attached gnomons on stained glass sundials or on any type of sundial for that matter. Finally, I had a chance to try it. But it's not so simple as I soon found out. As always, I had to test my idea first with experiments. Theory is nice and can provide guidance, but theory sometimes fails in practice. An experiment removes all doubt and proves that a new idea will actually work or fail.

I began these experiments without much knowledge of magnets. All I knew was that opposite poles attract and similar poles repel, and that big magnets are stronger than small ones. Using two common ceramic disk refrigerator door magnets, I saw that they stuck together only if the opposite poles were pointed to each other. (Think of a disk magnet as if it were a coin—heads attract tails, but heads repel heads, and tails repel tails.) My first thought was to attach a disk magnet to the bottom of the gnomon rod and place it on the outside of the glass, and then place another disk magnet on the inside of the glass. The gnomon's magnet would stick to the window by attracting the opposite pole of the other magnet on the inside of the glass. This test highlighted four problems:

1. The disks must have the same diameter or they don't stick to each other when stacked.
2. Glass is slippery, and the weak ceramic magnets tended to slide down the glass especially if the gnomon was heavy.
3. Magnets rust so I was worried about the external magnet rusting over time.
4. The attractive force was decreased when glass was placed in between the two magnets.

The magnets needed something to keep them from moving and rusting, and needed to be stronger. I could prevent rusting if the outer magnet were coated with something, and movement could be prevented if the magnets were surrounded by lead came. I almost used this configuration, but then I came up with an even better idea. Read on….

NASS member Art Krenzel told me about a company, K & J Magnetics,[1] that makes all sorts of very strong rare earth neodymium 'mounting magnets'. These new revolutionary magnets are ten times stronger than common ceramic or iron magnets. This means you can use smaller magnets. They are mounted in protective stainless steel casings that come with threaded holes that can be used to screw in a gnomon rod. How convenient! The magnets are even triple-plated with nickel and copper that prevents rusting. They come in many sizes and attractive strengths and weren't too expensive, so I ordered about twenty different ones for testing. I also tested neodymium disk magnets without the steel mounting casings. My tests told me the size and strength of the mounting magnet I needed for the size and weight of the gnomon. The tests also showed that I did not need two magnets. A magnet attracts a steel disk almost as well as another magnet, and by using a steel disk, you don't need two matching diameter disk magnets. Tests also revealed something important. Window glass is ⅛″ thick. A magnet's attractive force diminishes quickly with distance. A piece of glass sandwiched between two magnets or between a magnet and a steel disk greatly decreases the attractive force. Therefore, you must use a stronger magnet in a sandwich configuration.

The configuration I finally settled on is probably the safest and easiest way to attach a gnomon to the face of a stained glass sundial. The mounting magnet on the gnomon rod attaches directly to a steel disk which is incorporated into the design of the glass sundial face with soldered lead came. This direct high-strength contact between the magnet and the steel disk allowed me to use the smallest possible magnet and a small steel disk. You really need to feel it to see how well it works. Since the gnomon rod acts like a lever when moved, when I violently hit the gnomon with my hand to test what would happen, the gnomon rod 'pried' off the mounting magnet and it simply fell to the ground. The glass was saved and even the gnomon was undamaged and unbent! I just stuck it back on the sundial and everything was as good as new! See Fig. 3.

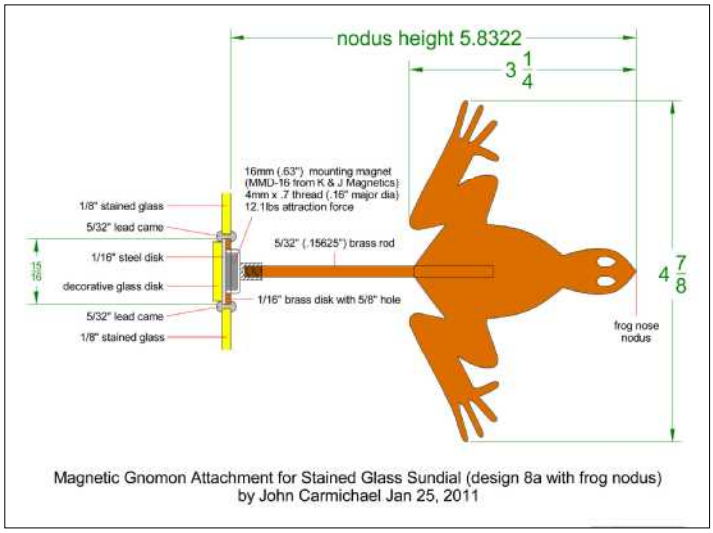


Fig. 3 Magnetic gnomon design drawing.

I obtained the round ⅞″ diameter, 1/16" thick zinc-plated steel disk from an electrical junction box hole cutout. The zinc plating prevents it from rusting. Then I placed a flat brass ring of the same diameter on top of the steel disk. The 1/16″ thick brass ring has a ⅝″ hole in it and looks like a brass washer. Together, the steel disk and brass ring have a thickness of ⅛″ which is the same as glass, so the two stacked together fit nicely into the slot of lead came. I surrounded the disks with lead came (Fig. 4). The 16 mm mounting magnet on the gnomon sits nicely in the hole of the brass disk so the magnet is in direct contact with the steel disk. The hole in the brass disk keeps the mounting magnet from sliding around. The gnomon has a 5/32"

Fig. 4. Steel disk with brass ring surrounded by lead came.

Fig. 5. The mounting magnet fits nicely inside a brass ring and sits on the steel disk.

threaded brass rod that is screwed into the mounting magnet (Fig 5). I cut the brass frog from a 1/16" thick sheet of brass and soldered it to the brass rod. Installation was simple, and no nuts and bolts were required! Although the frog nose nodus works well at any time of the day, its shadow changes shape depending on the time and season. The owner can twist the frog gnomon into any rotational orientation that produces the most pleasing shadow for the time of day when he most uses his sundial. The magnetic frog gnomon only cost me ten dollars to make (disregarding the cost of the experiments of course). Just to make sure that the magnet and steel are well-protected from rust, I painted them with a couple of coats of clear enamel.

Magnetic gnomons could also be used for other types of sundials. I envision them being used for table-top analemmatics that have moveable gnomons (like magnetic pieces on a chessboard). Come to think of it, a magnetic bishop from a chess set would make a pretty nice gnomon! I also see them being used on traditional wall sundials or cast iron or steel horizontal dials.

There are 218 pieces of stained glass in the sundial window. I delineated the sundial using a combination of Shadows Pro and ZW 2000 dialling software. Then I exported those drawings into DeltaCAD where I added the artwork, and the sundial face numerals. I designed the artwork myself and borrowed some designs from my stone sundials. DeltaCAD is fantastic for designing stained glass window pat-

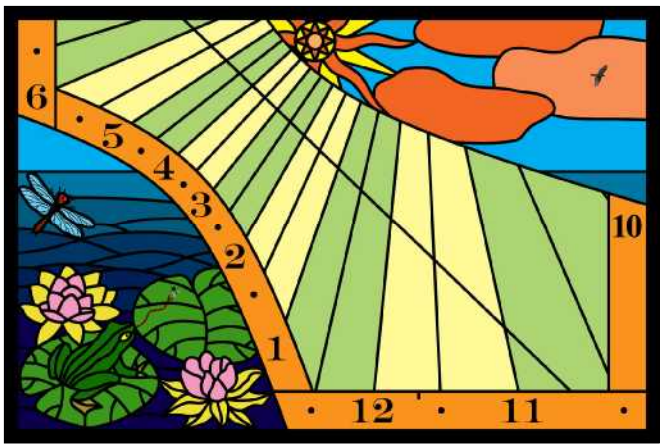


Fig. 7. SGS Photoshop coloured glass pattern.

Fig. 8. SGS aquatic scene, interior view.

Fig. 9 (below). The decorative glass sun on the interior hides ugly steel disk underneath it.

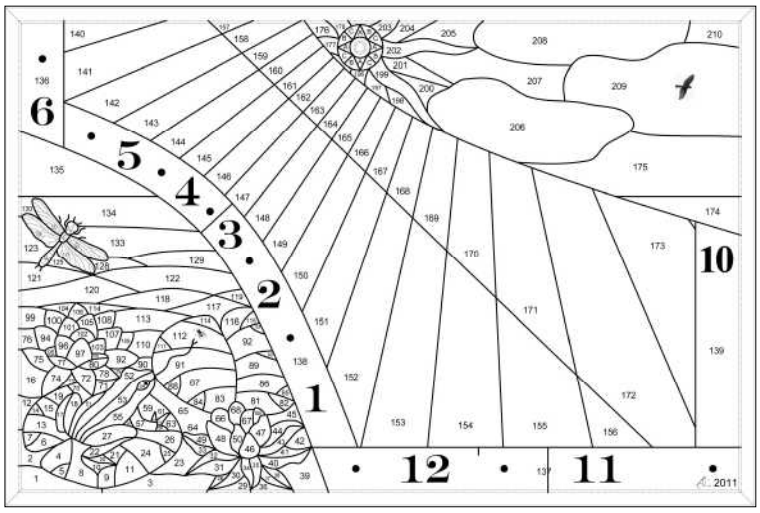
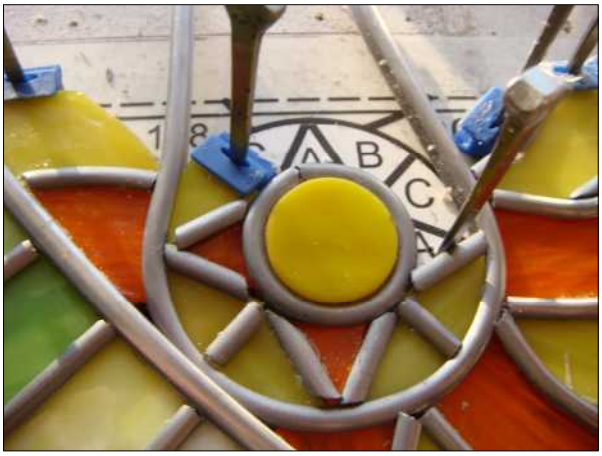


Fig. 6. SGS DeltaCAD glass pattern.



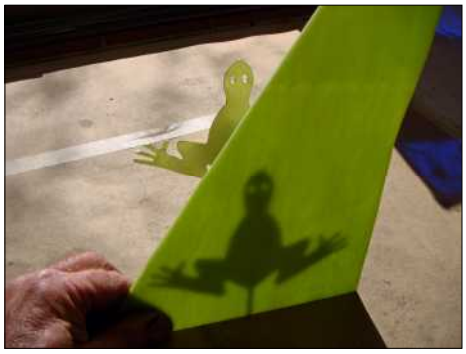


Fig. 10. Shadow test of the frog gnomon's shadow on glass.

Fig. 11 Exterior view of the frog gnomon's shadow.

Fig. 13. Extra rod & ball magnetic gnomon.

Fig. 12. Interior view of the frog gnomon's shadow.

Fig. 14. Exterior view of the sundial under reflected light. Compare the colours to those in transmitted light in Fig. 1.

terns. The spline tool lets you draw nice curved lines, and the program lets you control the critical line thickness needed for stained glass patterns. The local blueprint shop plotted out the full-sized glass pattern on water-proof Mylar plastic paper that I used on my workbench to guide me during assembly (Fig. 6). Finally, I made a PDF copy of the finished DeltaCAD drawing and played with it in Photoshop Elements to pick the best glass colours for the project (Fig. 7). In keeping with the frog theme, I decorated the non-dial parts of the window with an aquatic scene featuring blooming water lilies, a dragonfly and a frog catching a fly. It had to have the traditional SGS fly! And a frog eats flies (Fig. 8). Perfect! At the top is a sky scene with clouds, a hawk, and a sun with many sun rays. The sunrays have lots of soldered lead came which adds beauty and strength to the steel disk that is hidden behind the ⅞″ diameter yellow glass sun that is glued to the disk with silicone (Fig. 9).

Before selecting and using the pastel green and yellow streaky opalescent glass of the hour segments, I tested the glass to make sure that the gnomon would cast a highly visible shadow through the glass (Figs. 10, 11, 12). The hour numerals and much of the detailed artwork are made from oven-baked enamel that is painted onto abraded portions of the glass. Abrading the glass before painting allows the paint to adhere firmly to the roughed up glass behind it. I abraded the glass using the same high speed diamond burrs that I use to engrave my stone sundials. I used both lead and zinc came to give the panel extra strength. Then for even more strength and to waterproof the panel, I spread silicone in the lead grooves and to the edges of the glass pieces during assembly. After the panel was assembled and soldered, I painted the interior lead and zinc with two coats of satin black Rustoleum enamel to give the metal came a clean black look. I also supplied the client with an extra magnetic traditional rod and ball gnomon just in case he loses or breaks the frog gnomon (Fig. 13). Viewed from exterior of the building, the glass looks different with reflected light. Note that the painted engravings are almost invisible from the outside (Fig. 14).

REFERENCES and NOTES

1. See: *http://www.kjmagnetics.com*
2. Visit the Flickr website to see more photos of this new sundial: *http://www.flickr.com/photos/jlcarmichael/*
3. You can see a large inventory of stained glass sundials from around the world at this educational website: *http://www.stainedglasssundials.com*

John Carmichael (b. 1954) lives in Tucson, Arizona, and is a member of the British and North American Sundial Societies. He has been designing and making sundials professionally since 1994. Mostly, he makes exquisite hand-carved stone sundials with lots of individualized artwork, but also designs large public monumental sundials built by others. Occasionally, he makes stained glass, porcelain, ceramic and painted wall sundials. His sundial business is Sundial Sculptures at *www.sundialsculptures.com*.