Evacuated tubes: observations by Dave Oxford and Stewart MacLachlan (UK)

After testing an evacuated tube prototype that broke, Dave Oxford and Steward MacLachlan (UK) proposed several potential causes for the breakage during use. Solar Cookers International thanks Oxford and MacLachlan for sharing the results of their trial-and-error for the benefit of the global solar cooking sector. – Julie Greene, Executive Director, SCI

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"Basically, in this sloping design, stuff obviously tends to fall to the bottom under gravity. With water or soup, no problem. In my view, the horizontal design is superior for non-liquid foodstuffs. However, you can just about see the capsicum peeping out from the pile of glass. We were over optimistic about the amount we could get in there, and one piece of the capsicum—straight out of the freezer at -20C crept over the edge of the tray, and vented some liquid down the side of the food tray, and then underneath it, where it promptly produced flash steam, which in confined space produced enough pressure to put a slight hollow in the bottom of the stainless steel tray at that point, and also shatter the tube.

If we were right about the flash steam, then that wouldn't be thermal shock, it would just be an explosion. The alternative is that the capsicum oozed some juice and this was sufficiently cool, compared with the bottom of the tube to cause shattering due to thermal shock.
These tubes are made of borosilicate 3, and this means that they will stand up to a ~190°C temperature gradient before they shatter - that's very large, but just about possible in that set of circumstances. In truth, we just don't know for sure which of these two analyses is correct. I prefer the former because of the dent in the food tray, but I don't think we can come to a definitive conclusion.

As you see, the tubes implode because of the vacuum, so tend to fall into a pile rather than send glass fragments all over the place, but it's not a good sight. Also, it sounds alarming, and is not a good advertisement for solar cooking. My opinion is that sloping tube designs (except for liquids), like our prototype, are just inviting thermal shock or explosion breakages like ours. If there is a solution, it is to pay particular attention to reducing thermal gradients to a minimum. Of course, we still only have six full day's experience of cooking with tubes so far, so we are newbies and it is too soon to tell how well we will do in getting our tubes to give us a long service life. It may turn out that they are not robust enough, even with care. "

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"We have had three other tube breakages. Our analyses are as follows.

Firstly, frozen foods are a no-no. They definitely cause too much of a thermal gradient. We inadvertently used some very cold (I won't say frozen, but cold enough) food in one of our SM70 cookers, and the tube shattered. This was almost certainly thermal shock, with the very cold food imposing too much of a thermal gradient via the food tray. You can see a picture of the SM70 on our website here: http://www.slicksolarstove.com. This is a stove of Chinese manufacture which we are marketing in the UK, hoping it will compete with small barbecues.

The second breakage was a bit of a mystery, but again, we have a theory. It was one of the Rand tubes that are available in the US. We imported a few to the UK last year for our experiments. We left it on a table, wrapped in bubble wrap. It was intact when left, and in the shade, but had shattered by the time we returned to it. We can only think that the 'bubbles' of the bubble wrap concentrated rays as the sun came round and shone on one end of the tube and this led to differential heating. Again, this seems unlikely given that these are also made of borosilicate 3, but we can offer no other explanation.

Finally, we were using another Rand in the vertical position to heat water. As it has a capacity of a US gallon (about the only thing that is smaller in the US than in the UK) it is quite heavy. It shattered when moved, and since the water was not at all hot, we can only assume that the munsen rings, which in the cheap prototype had no flexible silicone between them and the tube, imposed a bending moment as we moved it. We conclude that these tubes don't bend. At all.

In the instructions that we pack with the SM70, we do our best to reduce the likelihood that the user will expose the tube to thermal shock - no pre-heating, no leaving the tube empty in the sun, no unthawed frozen foods, no overloading, no washing while still hot - overcautious perhaps, but we are adopting the precautionary principle until we have more data.

There were a couple of breakages in transit, but only of the samples sent. You'll appreciate that palletised products have few opportunities to get damaged. Three or four episodes with fork-lift truck drivers, and two episodes with container crane drivers. We imported 100 SMs on three pallets, and they all arrived intact. On the other hand, much smaller packages are often moved by hand many times. One of the sample SM70s looked as if it had been crushed by a considerable force at one end, judging by the distorted case. On another occasion, a consignment of just two spare tubes arrived with only one intact. Our cookers now have to face trial by British couriers, some of whom have impossible delivery schedules, and have been known to toss parcels over garden gates in an attempt to save time (you can see some footage on Youtube).

We've not had any mishaps so far, and polyethylene is our friend, but we still have our fingers firmly crossed. I remember reading that someone who imported three of those small, individually boxed tubes from Canada into the US found that they arrived broken, so I think this is still a live issue.

So, in conclusion, although tubes represent the pinnacle of cooker efficiency at the time of writing (because of the vacuum, and the selective surface) they are, compared with other solar cooker types, less robust. At least one person on the SCI FB forum has been cooking regularly with a Rand tube for a couple of years so we know that they can last for a reasonable time. If we get any complaints, it is that the capacity is limited.

These are our experiences so far. These tubes perform so well that they will certainly continue to have their place, especially in our climate.

At the moment, the ones on the market are quite expensive, though the only really high tech parts are the tubes and the reflectors, and possibly the silicone rings that cushion contact with the supports.

The other components could be made out of just about anything."