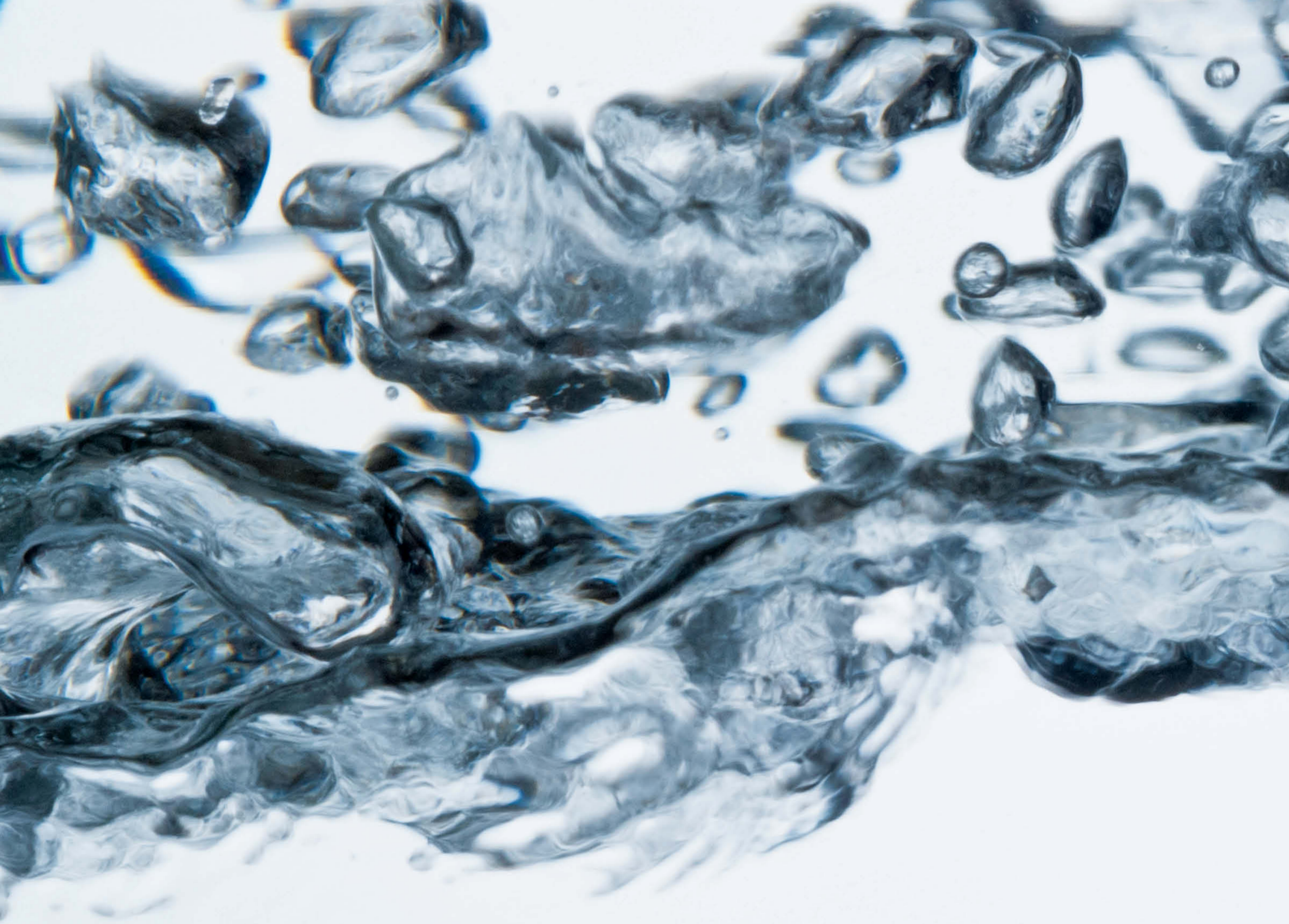

Fluid thinking

Can adding a special ingredient to coolants stir up an energy revolution? Katharine Sanderson reports

IMAGINE you could cut your electricity bill simply by adding a pinch of special powder to the coolant in your fridge. What if the same stuff could also reduce your car's fuel consumption, improve your home's central heating and make electricity that little bit cheaper? It might sound fanciful, yet it turns out that there is more to this dream than fairy dust.

Back in the early 1990s, engineers made a remarkable discovery: adding nanometre-sized particles to a liquid makes it far more effective at carrying away heat than anyone expected. This was exciting news. Keeping machinery cool is a hugely expensive business, in the power industry, in motor vehicles and in electronics of all kinds. Improvements of just a few per cent could potentially save billions. It seemed that there were fortunes to be made, and saved, thanks to nanopowders.

Conflicting results soon left experts scratching their heads, and excitement gave way to confusion. Now 20 years after the effect was uncovered, the first commercial uses are finally in sight. So why the delay? And can nanoparticle coolants live up to their promise?

The story began in 1993 when Hidetoshi Matsuda and his team at Tohoku University in Sendai published a curious result in a Japanese journal called *Netsu Bussei*. They had found that water's thermal conductivity – its ability to transfer heat – could be increased by adding nanometre-sized particles of aluminium and titanium oxides. Intriguingly, the more of the particles they mixed in, the more the liquid's heat-carrying capacity went up.

This wasn't simply of academic interest. Devices that transfer heat from one place to another are vital in all kinds of technologies – from radiator systems in cars and refrigeration circuits in air conditioning to the tiny metal fins that cool processor chips inside every computer. Any improvement, however tiny, could cut costs significantly.

On the other side of the world, Stephen Choi at the Argonne National Laboratory near Chicago, who could read Japanese, came across Matsuda's paper. Choi and his colleague Jeff Eastman had also seen evidence of this strange effect. They had lost out to Matsuda in the race to publish first, but they now set out to explore the benefits the materials could offer. Choi even coined the term "nanofluids" to describe these liquids.

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Engineers had already tested metallic powders as additives in liquid coolants. Metals like copper have a thermal conductivity hundreds of times higher than water, so it makes sense that these additives should help shift more heat. Yet experiments with micrometre-sized particles were a failure – the grains tended to sink unless the fluid was mixed vigorously. Worse, they damaged the cooling system as they circulated, abrading pipes and wearing out pumps and bearings.

High hopes

This is where nanoparticles have the advantage. They are small enough to remain in suspension, and because they are only about the size of a large molecule, they don't wreck pumping machinery. Couple this with their intriguing chemical properties and enormous surface areas and perhaps nanoparticles could offer a new way to keep things cool.

Sure enough, when Choi and Eastman added a tiny amount of copper nanoparticles to ethylene glycol – a liquid coolant commonly used in vehicle engines – they measured a 40 per cent enhancement in the liquid's heat transfer properties. Copper oxide nanoparticles in water performed even better, but the most impressive result came when Choi added carbon nanotubes to silicone oil, boosting the liquid's thermal conductivity by 160 per cent. It was remarkable. "We even got calls from Formula-1 racing teams" wanting to know if nanofluids could give their cars an edge over their competitors by cooling their engines more efficiently, Eastman recalls. "It got a lot of people excited."

Exhilaration soon turned to consternation. While some researchers found nanoparticles enhanced heat transfer, others reported no effect. A few even suggested that the stuff made heat transfer worse. "They weren't able to duplicate the data," says Thomas McKrell, a nanomaterials specialist at the Massachusetts Institute of Technology. So researchers began to devise new physical mechanisms to explain the effect.

A century-old theory, developed by Scottish physicist James Clerk Maxwell, already explains how well a liquid will transfer heat ›