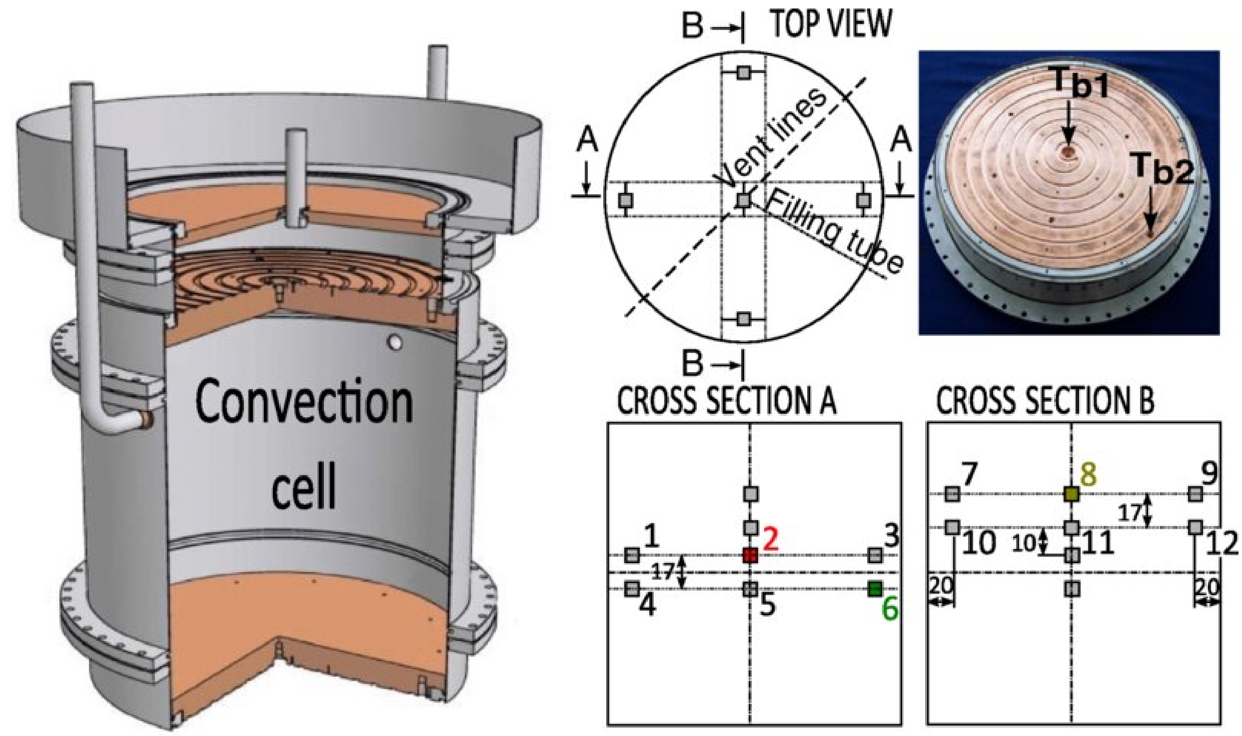
Heat flow shown to be more efficient when temperature is oscillating than when static

April 27 2022, by Bob Yirka



Left: the L=30cm tall aspect ratio G=D/L=1 RBC cell with 28 mm thick top and bottom plates D=30cm in diameter made of thermally annealed copper of thermal conductivity λ_p=2210$Wm^{-1}K^{-1}$ and thermal capacity c_p=0.144$Jkg^{-1}K^{-1}$ at $T_{He}=(T_T+T_B)/2\approx5K$, where T_T and T_B are typical temperatures of the top and bottom plates. From the top plate, most of the heat is removed via the heat exchange chamber to the liquid He vessel above it. The top plate temperature $T_T(t)$ is roughly set by pressure in the heat exchange chamber and more precisely tuned and modulated by the uniformly distributed heater glued in the spiral grove on the upper side of the top plate. A similar heater delivers either steady or harmonically modulated heat to the bottom plate. The temperature of the convective flow at locations as shown (distances in millimeters) is probed by small Ge sensors (numbered 1–12) and that of the plates by the finely calibrated Ge sensors T_{t1}, T_{t2}, T_{b1}, and T_{b2} embedded in them; see the photograph in the top right, showing their positions and the spiral heater grove. Credit: *Physical Review Letters* (2022). DOI: 10.1103/PhysRevLett.128.134502

A team of researchers from the Institute of Scientific Instruments working with a colleague from Charles University, both in the Czech Republic, has shown that heat flows more efficiently when the temperature of the material through which it is flowing oscillates, as opposed to remaining steady. In their paper published in the journal *Physical Review Letters,* the group describes experiments they conducted with heating and cooling helium in a container and its relevance to a theory proposed just two years ago.

In 1916, physicist John William Strutt, 3rd Baron Rayleigh, showed an example of oscillating heat flow. He filled a container with a fluid and then placed a heated coil below it and a cooling plate on top. This forced the liquid to rise and fall in the container. The effect has come to be known as Rayleigh-Bénard convection—it can be seen in the action of lava lamps. Two years ago, a team at the University of Twente proposed that heat flow in a Rayleigh-Bénard convection system would be more efficient if the heat coming from the base was oscillating. In this new effort, the researchers have shown this theory to be correct.

The work involved creating a container with a heating device at the bottom that could move through a temperature gradient over time. And like Strutt, they placed a cooling device on top. Unlike Strutt, however, they used a gas rather than a liquid—in their case, helium. They also carried out their experiments under cooler than ambient temperatures. To learn more about the impact of such oscillations on the heat flowing through the system, they conducted multiple runs during which the speed at of the oscillations ranged from 0.006 to 0.2 Hz.

They found that, as predicted, an oscillating heat source moved heat through the system more efficiently—as much as 25% more. Earlier theory suggested that the improvement in efficiency arises due to a destabilization between the boundaries of the liquids in the chamber, allowing the liquid areas in them to move past one another more easily.

More information: P. Urban et al, Thermal Waves and Heat Transfer Efficiency Enhancement in Harmonically Modulated Turbulent Thermal Convection, *Physical Review Letters* (2022). DOI: 10.1103/PhysRevLett.128.134502

Citation: Heat flow shown to be more efficient when temperature is oscillating than when static (2022, April 27) retrieved 26 April 2024 from https://phys.org/news/2022-04-shown-efficient-temperature-oscillating-static.html