**The Theoretical Global Cooling Capability of the Fiztop System**

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# Introduction

A method has been designed to increase the albedo (reflectiveness) and evaporation of surface ocean waters in order to cool them and to restore coral reefs, fisheries and a liveable climate. It would do this by increasing the number of air bubbles in the 0-1mm thick Sea Surface Microlayer (SML), or pneumoneustron, in particular those invisibly small bubbles, nanobubbles, that have a diameter of less than 0.001mm or one micron (μm).

To do this, a table-sized, lightweight, floating unit has been designed to use solar photovoltaic power to inject air bubbles into the organic-rich microlayer. It is called a Fiztop because it is in the shape of a child’s conical toy top and it produces a fizz of monodisperse (same-sized) bubbles under its circular base. Unlike other bubbles, the nanobubbles can last for months as they are stabilised by surrounding ‘shells’ of naturally-occurring surfactant (a surface-active agent that changes the surface tension of a liquid surface or bubble) organics, ions and gas-saturated liquid. The thin, invisible sheet of nanobubbles moves away from the Fiztop and disperses widely under the influence of wind, current and turbulence, thereby allowing new surfactant to move under the Fiztop. New surfactant also wells up from below, where it is exuded from marine organisms. The Fiztops may be either moored or free-floating in a current or gyre.

It has just been learned from Professor Will Zimmerman of Perlemax and Sheffield University that Desai-Zimmerman Fluidic Oscillators (DZFO), operating at ~20kHz (20,000 cycles per second) can produce clouds of nanobubbles down to the diameter of 100-200nm (nanometres). However, as these do not reflect visible light, being below its wavelengths, larger reflecting bubbles of one micron (1,000nm) diameter are chosen to be produced that diffuse in the microlayer down to the wavelength of red light, **800nm**. It is surmised that these might be formed at the lower rate of **3kHz** (one bubble per cycle) because of their larger size. The DZFO method of bubble production requires no moving parts and comes fairly close to being 100% efficient in terms of the energy required to produce the bubbles. A new concept in ultra-thin, diffuser design, using Ti/PET (titanium-PET plastic laminate) foil, should increase the energy efficiency still further. Taking account of this new information, a theoretical estimation has been made of the likely effect of deploying a single Fiztop unit, as described in terms of the lateral area of reflective nanobubble generated by it. Others may care to make the calculation of the net cooling effect provided by the increment in ocean surface albedo and that derived from any increase in evaporation. Modelling and experimentation should be able to establish the actual cooling and other effects when the Fiztop system is applied at different intensities, in different locations, weather conditions and seasons. These activities, as well as risk-reward evaluation and costings, are beyond the scope of this introductory paper.

# Assumptions and Calculations

The **primary** assumption is that sufficient power would be derived from the photovoltaics on each Fiztop to operate its DZFOs, micropumps and equipment at an acceptable level during daylight hours under most conditions, including that of cloud cover. Allow a **75% reduction** from the assumed maximum Fiztop capacity in average sunlight conditions at the Tropics for this composite factor.

Now, the base area of the Fiztop is πr2 or 3.142x0.8x0.8= 2.01m2 . However, it is expected that only 85% of this area will be available for diffusers and that only about 30% of this would actually be required. Hence, the potential diffuser area is 2.01x0.85x0.3=**0.513m2**.

Now, assuming that there are 667nm diameter pores in each diffuser, each of which might produce a string of 1,000nm diameter nanobubbles, and that the average spacing between roughly circular pore centroids is six pore diameters in order to allow for adequate pore separation, given the mode of their construction and the need to keep bubble strings from interfering with each other, this leaves only 3.3%, or 0.513x0.033= **0.0169m2****of pore opening area (13x13cm).** As each pore has an approximate radius of 333nm and area of 3.142x333x333= 348,413nm2, this means that for each Fiztop there would be 0.0169x1018/348,413= 4.86x1010 pores in a Fiztop.

However, it is assumed that only an average of 70% of these pores will be available for nanobubble exit between cleans because of micropump failure, biofilm build-up, marine encrustation, diffuser and pore imperfections, diffuser edge and other effects. Hence, the average number of active pores will be around 4.86x1010x0.7 = **3.40x1010 pores**.

Now, the expected rate of nanobubble formation from each active pore, under DZFO operation at 3kHz is 3,000cycles/sec. Hence, over the assumed average nanobubble lifetime in the microlayer or near the sea surface of, perhaps, two months, each pore should deliver 3,000x60x60x24x60= 1.56x1010, less the 75% reduction is **0.390x1010 nanobubbles**.

Now, each issuing nanobubble will have a diameter of some 1,000nm. However, over a short time in the ocean it is likely that some of the contained gas will diffuse into the adjacent, organically-rich liquid before the nanobubbles are stabilised in size. Furthermore, the gas inside the bubble may adiabatically reduce in volume as a consequence of the atmospheric temperature gas being cooled by contact with the water. Thus, it seems appropriate to reduce the longer term nanobubble diameter by, perhaps, 20% to 800nm. Hence, its maximum cross-sectional area becomes 3.142x400x400= **50,272nm2**.

Hence, the final area brightened by an assumed single layer of close-packed nanobubbles from a single Fiztop, dispersed and separately invisible as they will be, becomes 3.40x1010x0.390x1010x50,272/1018= 6.67x106m2 or **~7km2**.

Of course, with movement by wind, spume, breaking waves and ocean currents over a two month period, the nanobubbles would tend to spread much more thinly and across a far wider area, perhaps to an areal bubble concentration of only a few percent. This percentage should still be enough to protect corals from bleaching, to keep ocean stratification at bay through cooling the surface waters, to make it less necessary for marine species to migrate, and, if deployed globally, substantially to help reverse global warming.

# Wavelength Effects

Fiztop bubbles, as they reduce in size in the ocean as a result of gas diffusing out of them, or because the gas inside them cools, or if they are moved into deeper water where the increased pressure compresses them, may come to have diameters within the range of the wavelengths of solar radiation. Those having diameters larger than this will typically appear as white or silver bubbles. Those which have diameters less than the wavelength of blue light will tend to disappear to the naked eye, as may be seen in some of the video clips at the end of this document, though their presence may still be revealed by their refraction of laser light.

It is surmised that Fiztop nanobubbles with diameters somewhat less than that of the shortest wavelength of green light (~520nm), in the microlayer and below it, will reflect and refract the higher-energy cyan, blue and up to ultraviolet (UV) rays with shorter wavelengths, whilst passing the longer wavelength rays, including infrared (IR) or heat ones, unaffected. This should have some macro-effects, including: making the sea appear slightly bluer; reducing the harmful effects of UV rays on coral and phytoplankton; lessening the effects of solar heating on the surface waters, including stratification; increasing evaporative cooling at the microlayer; and a possibly-negative effect of reducing the thickness of the euphotic zone.

# Conclusion

For Small Island Developing States (SIDS), as well as other nations keen to restore our climate and oceans to health, researching, modelling, evaluating, developing and deploying Fiztop technology in cautiously graduated stages would appear to be a relatively affordable, low risk, sustainable and locally controllable option. Major powers and smaller countries with strong research bases should be encouraged to perform the necessary R&D, whilst keeping the more basic parts of the Fiztop intellectual property royalty free. SIDS might provide many of the field trial sites, whilst being funded to undertake much of the ongoing maintenance and logistic work. Scientific institutes might be funded to perform surveillance of ocean parameters and the marine environments affected by the deployments. One prospective method of funding is for government to provide the re-insurance industry with the necessary political cover for it to place a global insurance levy on fossil fuel exploration and extraction activities. Companies not paying the levy would lose market value because of the uncertainty and, because they could not obtain insurance, would be in danger of bankruptcy from rapidly escalating costs, external litigation claims and reputational damage from the environmental damage, hardship and loss of life to which they contributed.

# References

An appreciation of nanobubbles, the microlayer, and their interactive environmental effects may be gleaned from these online sources and videos:

<http://www1.lsbu.ac.uk/water/nanobubble.html> <https://www.frontiersin.org/articles/10.3389/fmars.2017.00165/full>

<https://www.youtube.com/watch?v=mvBiHcWT1B8> <https://www.liebertpub.com/doi/full/10.1089/ees.2018.0203>

<https://www.youtube.com/watch?v=Dqxj7BdCPb8> <https://www.elementascience.org/articles/10.1525/elementa.228/>

<https://www.youtube.com/watch?v=r4rJKypLijA> <https://www.youtube.com/watch?v=HfTICue7QOY>

<http://perlemax.com>