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Scalable Antarctic Thermoelectric Generator for Harvesting Ocean Thermal Energy In-Situ for Free Floating or Ice-Tethered Antarctic Observation Buoys

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A key problem for Antarctic and Arctic forecasting is the lack of meteorological and oceanographic observational data at night. Improvements in environmental characterization and forecasting capabilities will depend on increasing the number of observations within the region. Modern sensor and communication systems make it possible to create extensive networks for automatic measurements of necessary parameters for polar research, but their continuous use are limited by their power draw. Large capacity batteries are usually used, but these are heavy and require frequent service. Solar and wind power generation are available, but these techniques are compromised by limited hours of sunlight and strong winds that require large, expensive structures to survive. The use of radioisotope thermoelectric generators is restricted for safety reasons, and organic fuel generators are suboptimal due to the need to regularly replenish fuel reserves. One of the available sources of energy in these conditions is the temperature gradient between atmospheric air and seawater to harness the reliability of Seebeck generators. Arctic air temperature varies widely from -50 to 32°C, while ocean surface temperature varies less with annual averages of -1.8 to 4°C (Fig.1). These temperature gradients are sufficient to produce the required power levels. To use this potential, the Scalable Arctic Thermoelectric Generator (SATEG) was developed, capable of providing electricity to such well-known observation systems as Communications Ice Buoy, Tethys LRAUV, and REMUS600. The main problem in creating such a generator is the need to harvest the required amount of low-potential thermal energy and transform heat flows to a level that ensures acceptable mass-dimensional characteristics of the device.

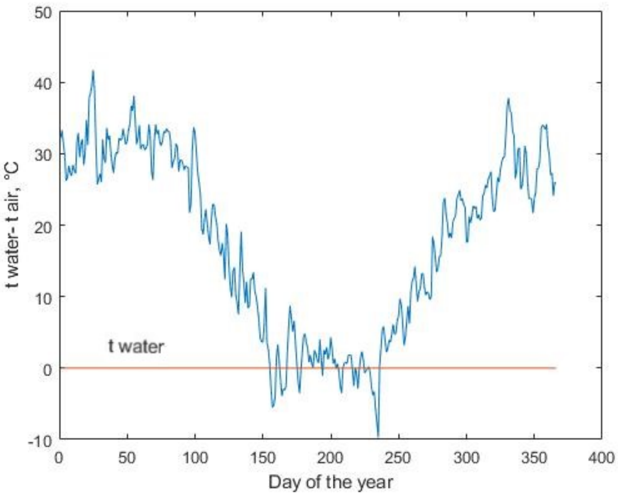

Fig.1. Annual distribution of water and air temperature difference

This is because the scientific principle behind the SATEG is thermoelectric energy conversion. This process converts a heat flux directly into electricity. The main challenge in the Arctic is that temperature differences are small and dispersed over a large area. This challenge could be partially mitigated by operating in colder Antarctic regions. The core power generation unit of the SATEG is a module comprised of water- and air-side finned heat exchangers linked to a generator body containing commercial thermoelectric modules through two ammonia-filled thermosyphons. One or more SATEG modules connected to a battery through a power conditioning unit comprise the energy system. There are no moving parts or consumables. The unique SATEG design thus enables the concentration of Antarctic thermal energy through multiple phase change cycles using limited resources. A single module that weighs approximately 40 kg, when deployed through an 8-inch borehole in an ice floe produces 75-150 kWh of electricity per year, depending on location (Fig.2).

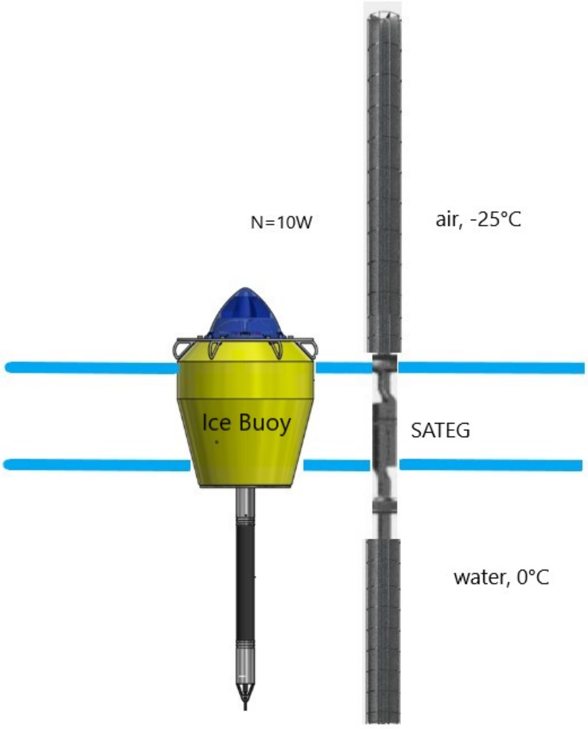

Fig.2. Scheme of SATEG

The conducted feasibility study confirms the viability of such a system, and the calculated data are verified by experimental studies of the SATEG laboratory prototype under controlled temperature gradients. A comparison of experimental (markers) and calculated (curve) data is shown in Fig.3. These results are in excellent agreement with the results of the mathematical model.

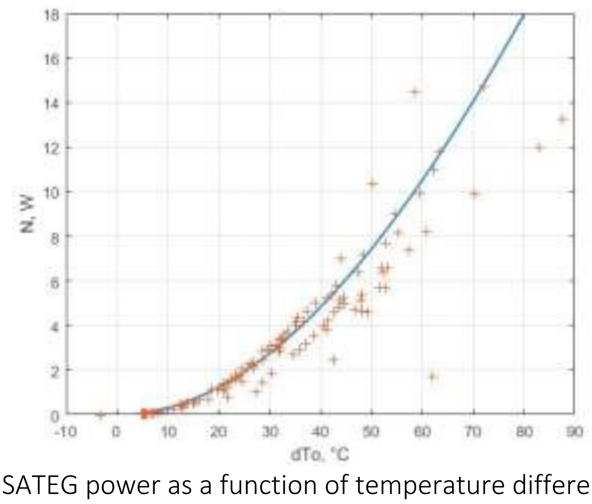

Fig.3. SATEG power as a function of temperature difference dTo

In the future, potential research opportunities include conducting a study of the performance of the SATEG in the field and creating a commercial prototype of such a generator for use in various polar research projects. These include using the Seebeck effect within SATEG units to continuously measure ocean and land temperatures several meters beneath polar ice. This data could be used to improve meteorological models. To support these efforts, modeling for land based units should also be conducted using ice core temperature profiles and heat transfer data for various candidate heat exchange fin materials.