Development of a Catalytic Heater Assembly

for use with

Radiometers Deployed under Arctic conditions

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ABSTRACT

The formation of leads of open water in the Arctic ocean cause warm ocean water to be exposed to the cold atmosphere. The resulting supercooled ice fogs which make rime-ice and frost are a persistent problem for instrumentation deployed on the Arctic sea-ice. To alleviate the problem of frosting, a catalytic heater assembly was developed for use with ventilated short and long wave radiometers deployed in the Arctic.

1. Introduction

Radiation from the Sun controls the energy budget of our entire earth: the ocean currents, winds, light and warmth. Studying this radiation helps us to understand the way the world functions, and the way the weather and climate is controlled. Short wave radiometers measure the amount of visible radiation from the sun, and the amount of this reflected off the ground, while long wave radiometers measure the amount of infrared or heat radiation incoming from the sky and outgoing from the earth's surface.

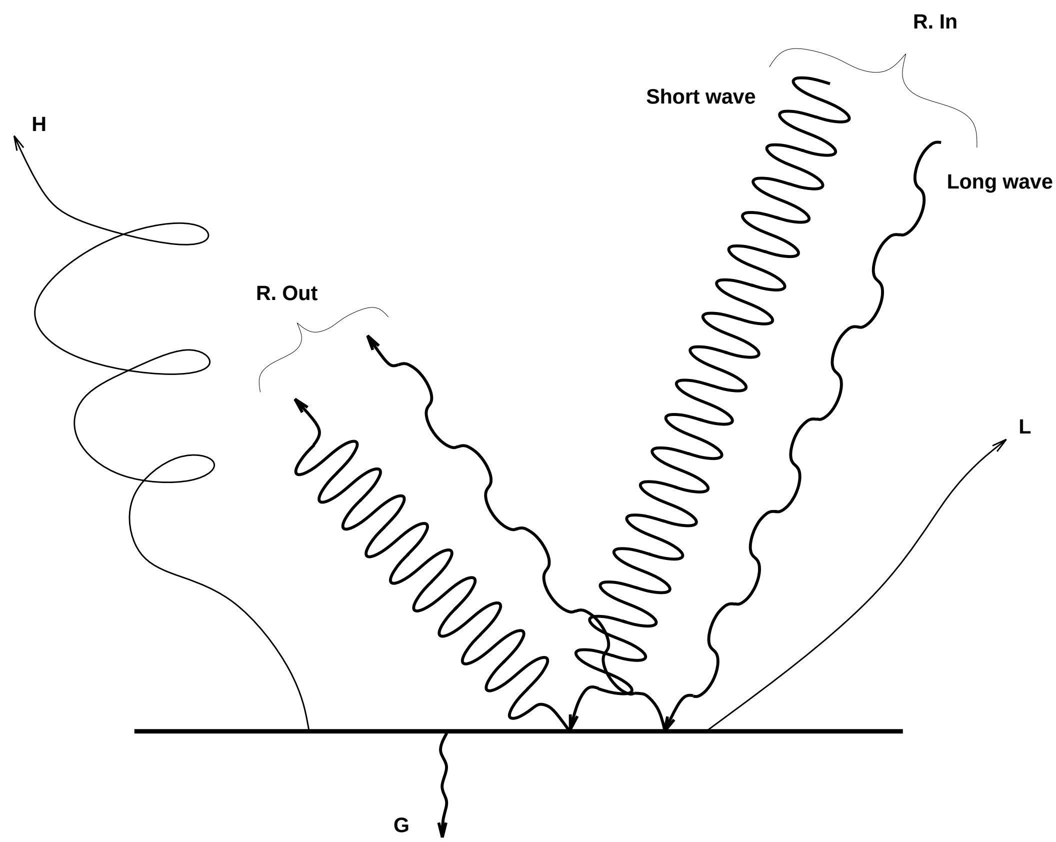

Figure 1: Radiation balance showing both long and short wave radiation, conduction, convection and evaporation.

Figure 1 illustrates short wave radiation (Visible light) and long wave radiation (Infrared rays). The total net energy of these rays, known as R, is the total energy budget available. L is the energy lost through evaporation, and H is the energy lost through heat in the atmosphere. G is the energy absorbed into the ground, thus R = G + H + L

Four radiometers monitor the short and long wave radiation arriving at the surface, and also how much of this is reflected back into the atmosphere. Two face upwards, each monitoring one type of radiation, and two more monitor the ground. (Delany & Semmer, 1998). Such radiometer arrays are deployed in the Arctic during the **S**urface **H**eat **E**nergy **B**alance, **A**rctic, SHEBA. (Gibbs W.W., 1998).

These radiometers need to be placed in an open area, where there is no obstruction to their field of view, and where they can be isolated. In the Arctic, extreme weather conditions cause major problems, such as the problem of frost build-up on the sensory domes of the radiometers. The frost is caused when the two meter thick ice, floating on the ocean, cracks. The warmer ocean causes water to evaporate in clouds of steam. The water vapor condenses into droplets which become super-cooled, and upon instant contact with the radiometers, freezes into a layer of hoarfrost. This impairs the visibility of the sensitive radiometers, so they cannot function.

One suggestion for preventing this frost is to use a fan, to blow air over the radiometers, so the frost will sublime into the un-saturated air. However, this is a very slow and inefficient process. Artificial heating is an ideal solution, but for a sufficient heat supply, a large amount of electricity is needed.

Power for the remote weather station is on an extremely tight budget. It is generated using a Thermo Electric Generator (TEG). Propane cylinders are used to provide fuel to burn as a flame. This flame heats one side of the TEG, while cooling fins are attached to the other side. This process generates a total power output of around 18 watts, the majority of which is used to power the equipment, leaving only a small amount, 7 watts, spare for ventilation and heating. So, using electrical heaters would require a large amount of power to provide sufficient heat.

Therefore, an idea to use the propane gas itself to power a heater was considered. A small amount of propane gas would supply a catalytic heater, generating about 50 watts of heat to each of the four radiometers. For this amount of propane, if used on the TEG, only a very small amount of power would be generated. Thus the catalytic heater system is very efficient.

2. Radiometer ventilator / heater

The basic model heater was a small supply of propane gas, lead by the Teflon tube into a catalytic unit, small amounts of platinum, woven into a fiberglass fabric, which catalyses the combustion.

The propane flow needs to be small, ideally generating around 50 watts of heat, so the flow from the propane cylinder needs to be controlled, until an economical but sufficient gas flow is obtained. Since **Flow = k.Pressure,** if the pressure is kept constant, the flow will depend solely on the constant, k. This will be altered by crimping a piece of copper tubing, so the total flow will be dependent on the extent of the crimp in the supply tubing.

In the initial design, the crimped tube was placed on the outside of the radiometer housing, controlling the flow entering. To initiate the propane combustion, a small electrical filament wrapped around the catalytic heater, which when a current of 1 amp is supplied, should provide just enough heat to start the reaction.

As propane liquefies at -40^{o}C, there was a chance that the propane can liquefy in the supply tube. If this is the case, more propane will be forced through the crimp than required, overheating the equipment. Therefore, the crimped portion of the tube was located inside the radiometer housing, sheltering it from the outside temperature. Copper tubing was chosen, as the catalytic heater and crimp could easily be worked into one piece.

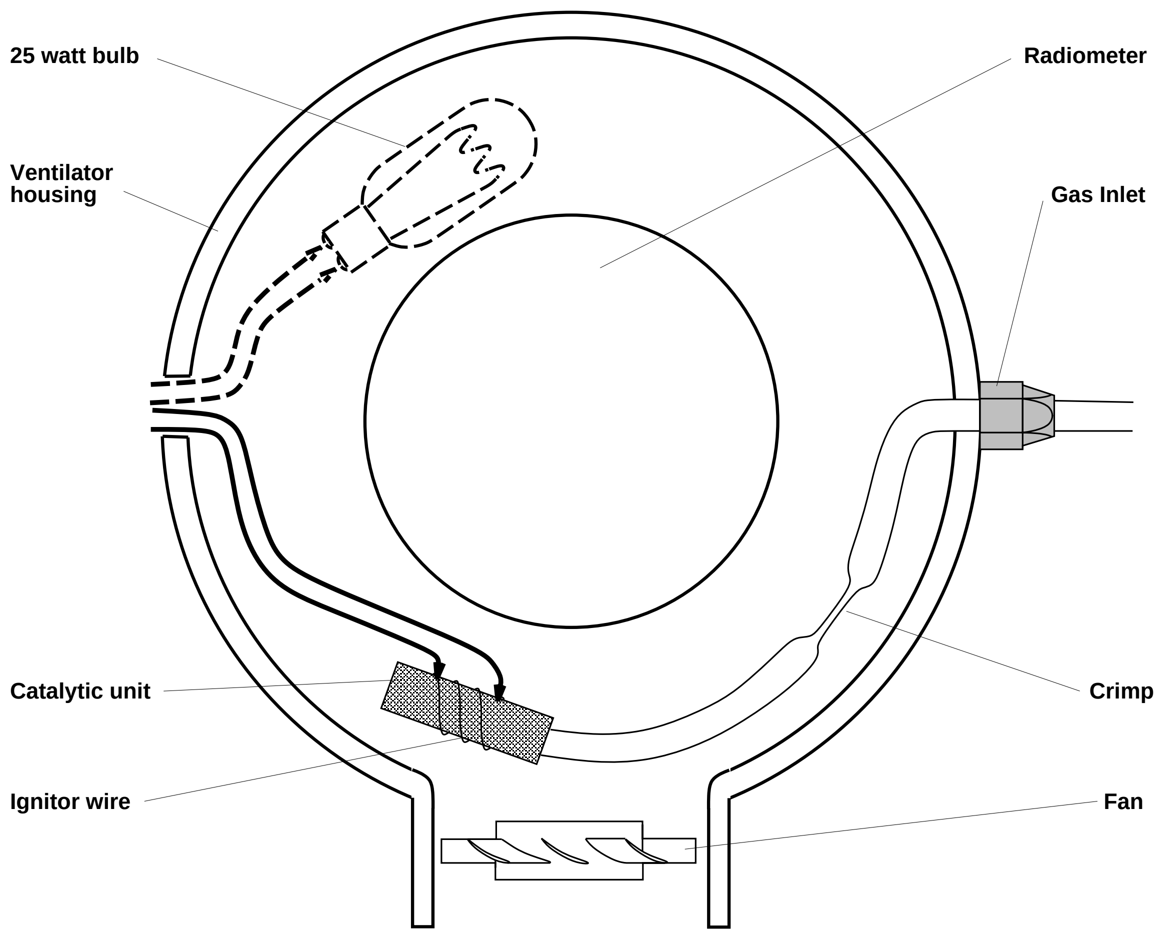

Figure 2: A schematic of the radiometer housing, showing the positioning of the catalytic filament, and later, the 25 watt bulb.

3. Results

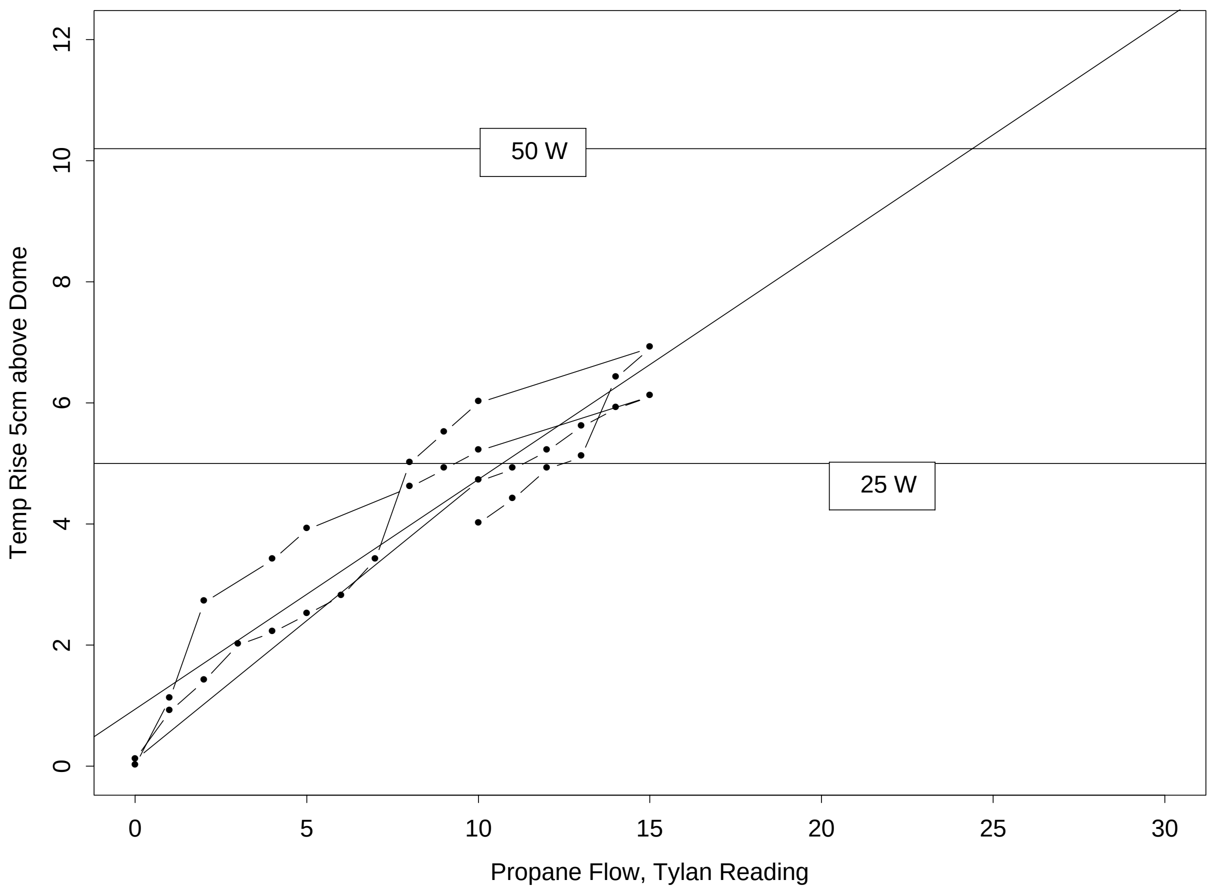

Figure 3: The temperature enhancement of exhaust air flowing over the dome of the radiometer as the supply of propane to the catalytic heater is increased.

Figure 3 shows a distinct correlation between the propane gas flow, and the temperature rise above the radiometer. The 25 watt and 50 watt readings relate to the temperature difference reached when a 25 watt electric bulb, and a 50 watt electric bulb, fitted inside the ventilator housing were lit, and used instead of the catalytic heater.

Some hysteresis occurs because the whole ventilator housing is heated. After some time, results are higher due to the warmer housing.

The propane flow was monitored in Tylan readings. This was later corrected to true flow, so that the Tylan readings could be transferred to sccpm (cm^3min^{-1})

TABLE 1 : **Results obtained from passing a flow of propane gas through a gas-volume meter.**

Tylan reading	Volume (cm^3)	Time (min)	Flow (cm^3min^{-1})	Flow / Tylan Reading
25.0	2240	40	56	2.24
25.0	5710	102	56	2.24
10.0	670	30	22.3	2.23

1 mole of propane (C_3H_8) occupies a volume of 22414 cm^3 and has a mass of 44g

Therefore, 22414 cm^3 = 44 g

Therefore, 1 cm^3min^{-1} = 0.00196 $gmin^{-1}$

To maintain 25 watts of heating,

$$10 \text{ Tylan units} = 22.3\ cm^3min^{-1} = 0.044\ gmin^{-1}$$

is required. This corresponds to 63.4 g propane per day.

To maintain 4 radiometers with 25 watts of heating in each will require 253.6 g propane per day.

4. Testing

The radiometer heating system was taken to the ‘cold-room’, an indoor room with a temperature of -20^{o}C. The system was set up with the propane and power supply outside, fed into the cold-room.

Also placed outside was a nebulizer, to provide water droplets. Inside was placed the radiometer housing / heater, with all power supplies and propane supplies connected. Initially, the catalytic heater had problems lighting with the fan blowing freezing air. This was resolved by boosting the current in the electrical filament to 2 amps. Ignition was successful and the catalytic heater functioned well. Frost started building up on the dome, but after the heater had been burning for several minutes, all the frost had been melted. Although the initial experiments were promising, more tests will be needed.

5. Conclusions

The catalytic heated proved to be successful and economic, in all the tests it was put through. However, the cold-room did not seem to provide extreme enough conditions, as only a small amount of frost was deposited. The tests will continue, and harsher condition will be put to the test. Thick frost will have to be overcome, and the heated casing is to be tested in Barrow, in the Arctic itself.

At present, condition in the Arctic are becoming milder, due to the approach of summer. It will be a long time before this design can be fully tested, and put into practice at all.

Acknowledgments

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References

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This superb report can be found at: /a/h/3/delany/harris/chrisreport.fm