

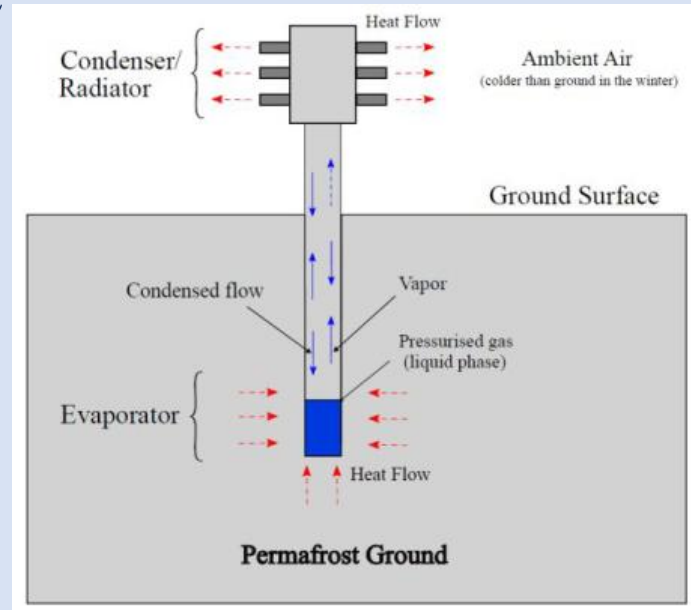
Introduction & Background



Adaptations for Arctic Airports

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Arctic airports are one of the hardest hit areas due to climate change because of the thawing of permafrost. Permafrost is used as a solid base to build on and when it thaws it can cause cracks in runways and buildings (Schurr, 2011).



One way to combat this is to use a thermosiphon to supercool the ground. The build up of ice in culverts under runways can also cause runways to deteriorate faster than needed (Hinkel, 2019). Both of these problems need solutions in order for Arctic airports to remain sustainable.

Thermosiphon Design

Problem Solving Approach

The team implemented a design thinking approach to solving the problem of climate change at airports. This approach is centered on empathizing with the customer and what the real need is in the industry. After researching various climate change issues, the team decided to focus on arctic airports due to them being underrepresented, having high costs, and low funding, yet facing some of the worst problems. The design process was iterative and the team repeatedly sought feedback from people in the industry to improve the design.

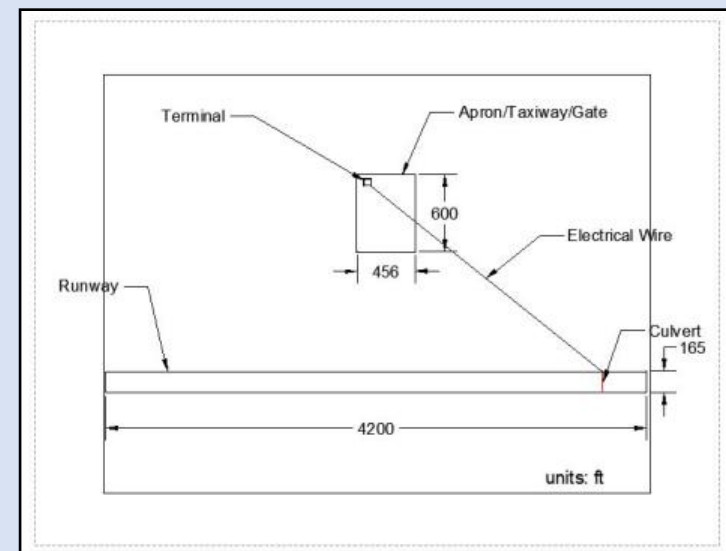
Industry Interactions

Torsten Mayrberger is an engineer at PND Engineering, a civil engineering firm based in Alaska. He talked to the team about costs of construction and techniques used to help combat thawing permafrost.

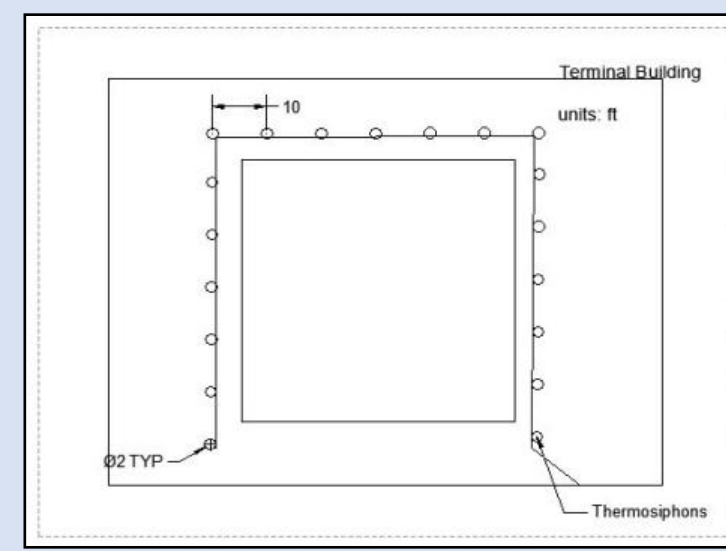
Dr. Ken Hinkel helped the team understand how thawing permafrost damages infrastructure and what the team could focus on to improve arctic airports.

System Design

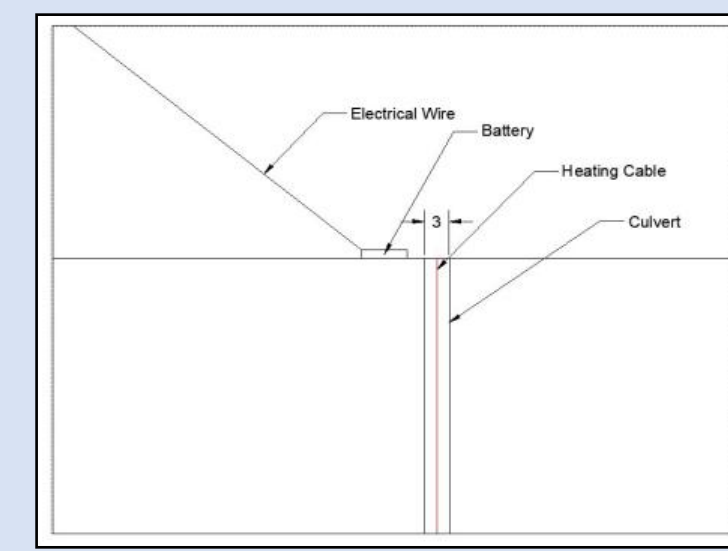
This design contains a series of heat pipe turbines placed strategically around the terminal building connected by a buried, insulated electrical wire. The radius of influence of the turbines is estimated to be 5.6 ft (Markov et al., 2019), therefore they will be spaced 10 ft apart to allow for some overlap. The turbines surround three sides of the building to offer maximum stability without hindering operations in or out of the building. The dimensions for the design are an average of randomly selected Alaskan airports in rural areas. The terminal buildings were all simple rectangular structures with gravel apron/taxiway areas. The turbines connect to a battery near the culvert. This battery will be trickle charged by the turbines throughout the fall and winter, when the air is cooler than the ground. The battery will power a heating cable that runs linearly along the bottom of the culvert. Culverts will need to be deiced in late winter and early spring time, as temperatures fluctuate and snow begins to repeatedly melt and freeze. By this time, the turbines have had all season to sufficiently charge the battery.



Airport Schematic



Terminal Building with Thermosiphon Placement



Culvert Design Integration

Impact of Design

This design impacts the long term resistance of arctic airports to climate change through the use of thermosiphons, which improve the longevity of the permafrost and increase infrastructure stability. Reducing the thawing of permafrost also reduces the release of CO2 from the ground, which helps to slow the impact of climate change. Additionally, by having an energy output from the thermosiphons for the use of heating a wire to keep culverts from freezing, airports can reduce the chance of having water damage on runways, and save costs on having to otherwise buy the necessary energy.

References

Markov, E. V., Pulnikov, S. A., & Sysoev, Y. S. (2019). Calculation of Freezing Radius Around Vertical Two-Phase Thermosyphon in Subarctic Climate. *Journal of Engineering Science and Technology*, 14(5). Retrieved from http://jestec.taylors.edu.my/Vol 14 issue 5 October 2019/14_5_32.pdf
Hinkel, K. (2019, November 19). Personal Interview
Schuur, E., Abbott, B. High risk of permafrost thaw. *Nature* 480, 32–33 (2011). <https://doi.org/10.1038/480032a>
Cordova, G. (2019, June 10). Runway work to be completed at Ted Stevens International Airport this summer, other projects outlined in \$85M upgrades.
Steen. (2017, October 2). Arctic Foundations

Safety Risk Assessment

The largest concerns found through a Failure Modes & Effects Analysis (FMEA) were:

- Wire getting too hot
- Exposed wire causing trips
- Engine failure
- Heat pump explosion

However, it was found that through burying the heating wire, having backup engines, and ensuring proper/regular maintenance, all of the Risk Priority Numbers (RPNs) were significantly lowered.

Cost-Benefit Assessment

It was determined that the implementation of this design could potentially save arctic airports millions of dollars by avoiding having to completely reconstruct runways.

Thermosiphons cost approx. \$1,600 each, weatherproof wire costs approx. \$1.50/ft, and heating cable is approx. \$2/ft (Steen, 2017). Thus, the design pictured with 19 thermosiphons, 2,500ft of electrical wire, and 165ft of heating cable would cost around \$33,600. However, this does not include the cost of labor or a battery.

Comparatively, gravel berm roads (similar to arctic runways) cost approx. \$1 million per mile, and electric prices in Alaska are about double the US average. Specifically for the airport in Anchorage, AK, a new runway costs approx. \$63 million to construct as of 2019 (Cordova, 2019).