Operation and Maintenance of the Frozen Barrier at the HRE Pond

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Abstract: The frozen barrier at the HRE Pond at Oak Ridge National Laboratory (ORNL) was implemented in September of 1997 to contain radiologically contaminated subsurface soil using hybrid thermosyphon technology. This barrier was installed as a full-scale demonstration project for the DOE. During the 12-month demonstration period, the barrier was evaluated by the EPA's SITE program and found to be effective in impeding groundwater flow. After the demonstration period was completed, the barrier has remained on-line and was incorporated into the daily operations of ORNL. The hybrid thermosyphon technology used for this project is an efficient freezing system for creating and maintaining a long-term containment barrier. This technology transfers heat via evaporation and condensation of a two-phase working fluid. The working fluid used is benign to the barrier and the environment and requires much smaller piping than a single-phase fluid. Conventional ground freezing systems that are used for short-term construction ground freezing projects typically utilize single-phase (antifreeze) liquids that can cause barrier degradation if a leak were to occur. On the average, the frozen barrier at ORNL uses less than 280 kWh of power per day. The contracted maintenance and technical support for FY-00 totaled $27,510. This included the costs for replacement of one of the refrigeration compressors at the site after a bearing failure.

Since 1862, ground freezing has been used to enhance soil facilitate construction (Sullivan, et. al 1984). In 1962, the Atomic Energy Commission disposed of over 6,800 kilograms of radioactively contaminated material at the Project Chariot site in northwestern Alaska. The burial mound situated in naturally occurring frozen soil, permafrost, at the site was deemed to be the perfect containment medium (Vandegraft 1993). Indeed, upon remediation in 1995, it was found that virtually no transport of radionuclides into the permafrost had occurred (Dasher 1993). Thermosyphons were first commercially used in 1960 to maintain permafrost and have been used since 1990 to either create or maintain permafrost barriers.

Thermosyphons are passive heat removal devices that move heat against gravity without the need for an external energy source. In the pure passive form, thermosyphons function with no moving parts. Thermosyphons operate because of a two-phase working fluid. Whenever the upper portion of the unit is subjected to a temperature that is cooler than the lower portion, heat is released to the upper end by condensation of vapor. The condensate flows via gravity to the lower portion where it evaporates and the vapor return to the top. The cycling repeats as long as the upper end of the unit is cooler than the lower end (Long & Yarmak 1988). Hybrid thermosyphons incorporate an integral heat exchanger in the upper portion to allow the units to be driven with a standard mechanical refrigeration system.

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The freezing system installed at the HRE Pond utilized an array of 50 hybrid thermosyphons embedded vertically to a depth of 9.1m around the concerned area of subsurface contamination. These units were designed to freeze from the ground surface to the bedrock and to lock the base of the frozen barrier into the bedrock, thereby using the bedrock as the base of the containment vessel. A system of surface insulation and a waterproof membrane was installed to provide a top and seal for the containment vessel. A temperature monitoring and data collection system was installed to provide barrier and systems status via a remote phone link.

The thermosyphons, as shown in Figure 1, were fitted with internal heat exchangers designed to condense the carbon dioxide working fluid. Carbon dioxide was chosen as the working fluid for the thermosyphons because of previous experience of the thermosyphon manufacturer. An active refrigeration system was installed to cool the heat exchangers utilizing two 22.4 kilowatt air-cooled condensing units configured to operate at suction pressures as low as -40°C with R-404a.

The system was activated in September of 1997 with the refrigeration condensing units driving the thermosyphons at approximately –32°C. The frozen cylinders began coalescing in mid-October and completely joined at the surface of the asphalt pavement on November 1, 1997. The barrier reached its design thickness of 3.66 meters in mid January of 1998. Once the design thickness was achieved, barrier's effectiveness was independently evaluated by the EPA's SITE program with assistance from the TDEC and the ORNL Groundwater Hydrology Group. The conclusion of the integrity studies is that the barrier is performing as planned (EPA 2000, Moline 1999). The barrier was then made a part of the daily operations at ORNL at the beginning of FY-99.

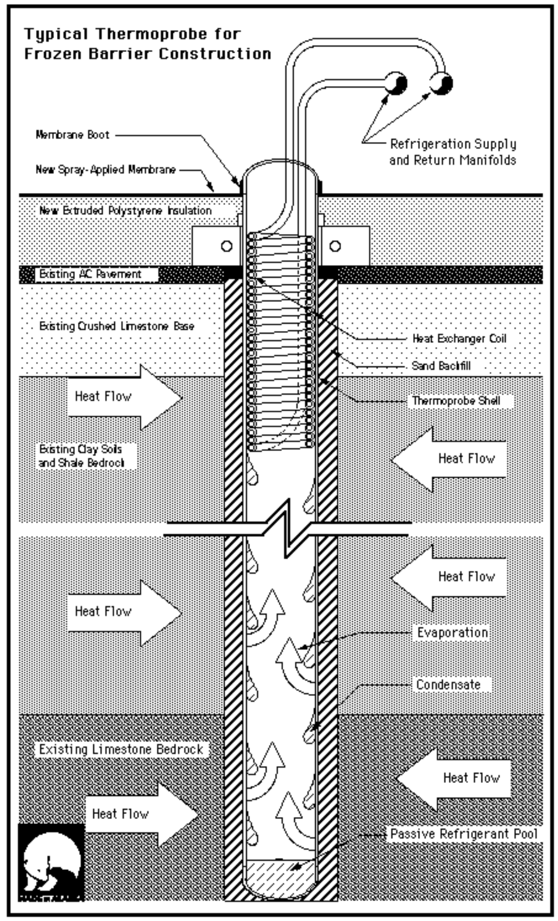

Figure 1 - Typical Hybrid Thermosyphon used at HRE Pond

From the beginning of FY-99, the barrier has been operated continuously to date. The contracted maintenance and preventative maintenance expended during FY-99 and FY-00 was $9,120 and $17,110, respectively. The technical support, data collection and data storage expenses for FY-99 and FY-00 were $12,628 and $10,400, respectively. The FY-00 maintenance costs reflect the cost of replacing one of the compressors on the condensing units in the field. One of the 11.2-kilowatt compressors failed during the summer of FY-00. The service technicians discovered an electrical short to ground within the refrigerant cooled compressor. It is thought that this was initiated by a bearing failure in the compressor, however, system filters were all in-place and there was no apparent reason for the failure.

Electrical power consumption for the barrier for FY-99 and FY-00 was 103,161 and 100,266 kWh, respectively. At the ORNL rate for power, the annual costs compute to be $5,364 and $5,214 or just under $14.50 per day to energize the 91.4m long barrier. The electrical cost data for the operation of the frozen soil barrier is shown on figure 2.

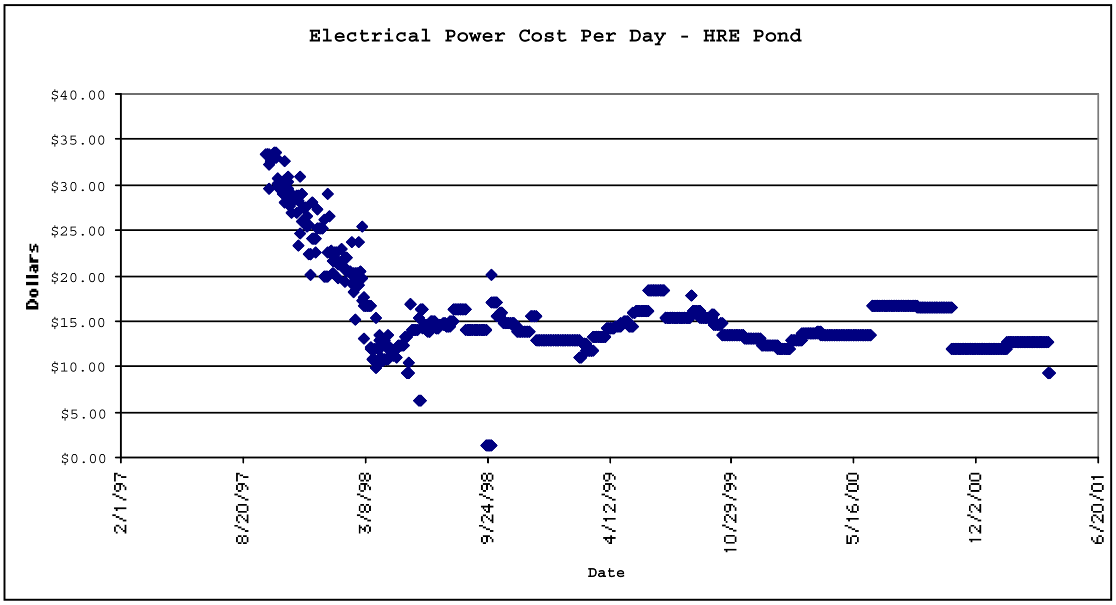

Figure 2 – Daily Electrical Power Cost For Frozen Barrier

The fact that the frozen barrier at the HRE Pond was installed as a demonstration project for the DOE and has since been incorporated into the operations at ORNL speaks volumes with regard for the success of the project. Had the system been too expensive or difficult to operate, it surely would have been scrapped after its demonstration period was completed.

References

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