APPLICATION OF TWO-PHASE HEAT PIPES WITH THERMO-MODULE COOLING OF CONDENSATION ZONE FOR STABILIZATION OF SOILS IN COLD REGIONS

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Abstract

New heat pipes with all-year-round operation have been developed, manufactured and applied to soils freezing and cooling and to the stabilization of pile foundations on permafrost soils. They are thermo-stabilizers with thermoelectric modules (TTM). Their technical parameters and test results are given, their use in the North of Western Siberia is analyzed and further applications are discussed.

KEYWORDS

Heat pipes, all-year-round operation, permafrost soils, cooling, freezing, stabilization.

INTRODUCTION

A great number of buildings, roads, dams, pipelines, power transmission towers, etc. have experienced movement or have failed, because of loss of bearing capacity, perennial thawing or freezing and frost heave, with the latter playing the main role. Thermal stabilization of soils (including freezing of thawed soils and cooling of permafrost) is known to be the effective method providing stable support for buildings and structures in cold regions. Seasonal cooling devices are mainly used in construction. The predicted climate warming under the influence of natural and man-caused factors determines wide application of seasonal thermo-stabilizers in permafrost regions.

The long-time experience has shown that, in many cases, a soil cooling during winter only is not enough. All-year-round cooling is needed to prevent negative cryological processes and provide the stability of foundations. For this purpose we have developed and manufactured new devices – thermo-stabilizers with thermoelectric modules (TTM). TTMs permit all-year-round controlled cooling of soils, underground structures, water etc.

OVERALL PERFORMANCE

A TTM represents a sealed metallic thin-walled tube containing dosed amount of two-phase, vapor-liquid, working fluid. It transfers heat from the underground part (evaporator) to the aboveground part (condenser) owing to a cyclic process: working fluid evaporates absorbing heat from soil, the vapor lifts and condenses with heat release and dissipation to the ambient air, then liquid working fluid trickles down. A condenser of TTM consists of finned part providing seasonal cooling, at negative air temperatures, and thermo-module part working in summer. The latter is presented by one or more Peltier elements (called thermo-modules) cooling the condenser under low voltage (12 V, 3 A) from an external source of electricity.

Each thermo-module (thermal power is up to 50 W) produces temperature difference of 67 degrees at its opposite faces, e.g. at the air temperature +20 °C the cool face has minus 47 °C. One or more such modules are placed at the condenser fins (they may be removable). It permits controlled freezing and cooling of soils during the warm season, whereas for the rest of the time, new thermo-stabilizers are operating in a normal manner.

The efficiency of TTM has been studied experimentally and by the computer simulation [1, 2]. The results have been compared with those for seasonal thermo-stabilizers TMD-5, the prototype of TTM. The depth and radius of freezing/cooling zones for soils and water have been determined.

TESTS AND EXPERIENCE

Fig. 1 represents the radius of the ice cylinder around TTM and TMD-5 in sweet water as a function of time (zero corresponds to the beginning of winter). During winter both devices operate identically. Then TTM continues cooling and freezing at positive air temperatures, whereas TMD-5 does not, so the ice cylinder melts partly during summer. Use of TTMs seems to be effective support for ice crossroads, wharves and so on. These new devices accelerate the formation of temporary ice and ice-soil structures, increase their strength and lifetime.

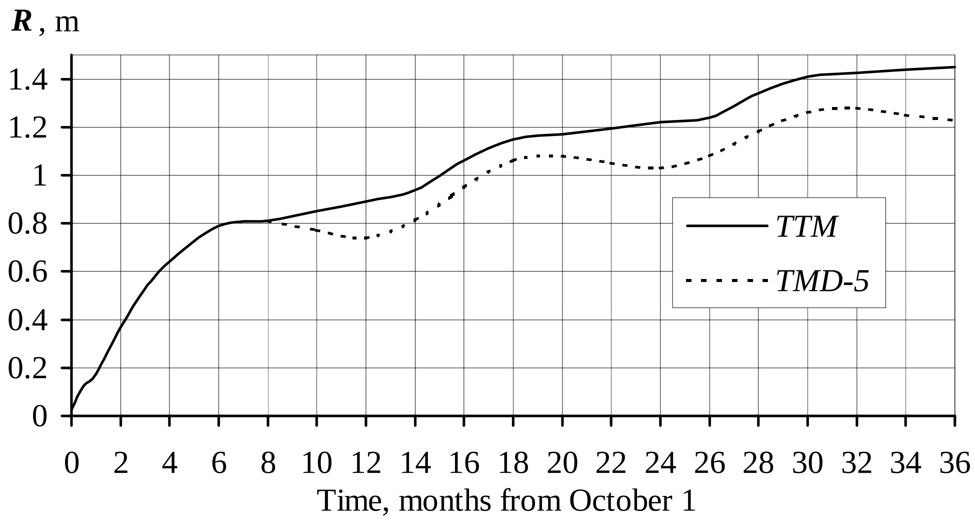

Fig.1. The radius R of the ice cylinder around TTM and TMD-5 in sweet water with the initial temperature +4 °C.

The field tests for TTM have been performed near Novy Urengoy (Western Siberia). The measurements showed that the temperature of evaporator walls decreased sharply after thermo-modules had been switched on (Table). Afterwards, the soil temperature near evaporator walls retained negative (in the thawed surrounding soils) though the air temperature remained positive during the test period (from July to the 1-st decade of October), and it ran up to +20 °C and more.

Depth, m	Soil temperature, °C					
	July 8		October 15		December 12	
	natural background	near TTM's wall	natural background	near TTM's wall	natural background	near TTM's wall
0,5	7,4	2,5	0,6	-4,2	-4,4	-15,0
1,0	4,0	2,1	1,8	-3,9	-0,6	-13,9
1,5	0,4	-0,1	2,3	-3,8	0,1	-13,4
2,0	0,4	-0,8	2,6	-3,3	0,3	-12,5
2,5	0,0	-0,9	2,3	-3,4	0,4	-12,2
3,0	0,1	-0,9	2,9	-3,3	0,4	-10,9
3,5	0,2	-0,9	2,7	-3,4	0,6	-10,5
4,0	0,4	-1,5	2,6	-2,5	0,5	-10,5
5,0	0,4	-1,9	2,4	-2,5	0,8	-9,9

Temperature fields in soils when cooling by means of TMD-5 and TTM (Figs. 2,3) show that the "cold domain" with the temperature below -2 ^{o}C around TTM retains during the whole warm season. It provides high bearing capacity of piles and their stability against frost heave. In contrast, seasonal thermo-stabilizers (TMD-5) cannot retain low temperature, so bearing capacity of permafrost soils decreases 3…5 times towards the end of warm season requiring more expensive foundations [3].

The forming of stable cold domains (-2…-5 ^{o}C) with great radius (2…3.5 m) around high power TTMs (200 W and more) permits their application at the objects producing high thermal fluxes into soils, as well as at any objects based on soils with high ice content. Note that TTMs may be placed into housings with positive air temperature, where other types of thermo-stabilizers are unusable. Their application is also indispensable for construction on permafrost soils during warm season.

CONCLUSIONS

TTMs have been installed and are successfully operating at high-voltage substation in Novy Urengoy (Fig. 4). Tests and experience proved high efficiency and appropriateness of new cooling devices: thermo-stabilizers with all-year-round operation.

References

1. Bayasan, R.M., Korotchenko, A.G., Lobanov, A.D., Berezin, A.V., Benchmark test of thermo-stabilizer with all-year-round operation, *Potential*, 2001, No.3, pp.47-49.
2. Bayasan, R.M., Korotchenko, A.G., Lobanov, A.D., Lyazgin, A.L., Ostroborodov, S.V., Berezin, A.V., Developing and testing of thermo-stabilizer with all-year-round operation for stabilization of foundations on permafrost soils, *The Second Conference of Geocryologists of Russia*, Moscow, 2001, Vol.4, pp.17-21.
3. Bayasan, R.M., Korotchenko, A.G., Pustovoit, G.P., Foundation stability on permafrost: probability, determinism and new technique, *Soil Mechanics and Foundation engineering*, 2002, No.5, pp.26-31.

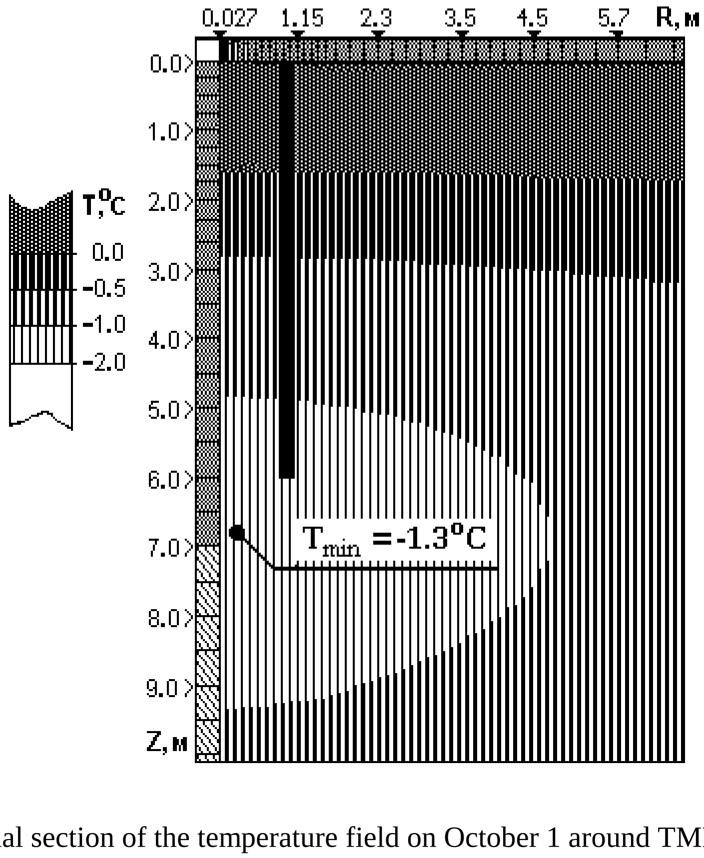

Figure 2. The radial section of the temperature field on October 1 around TMD-5 (vertical black bar represents probable position of pile, *R* – radius from thermo-stabilizer axis)

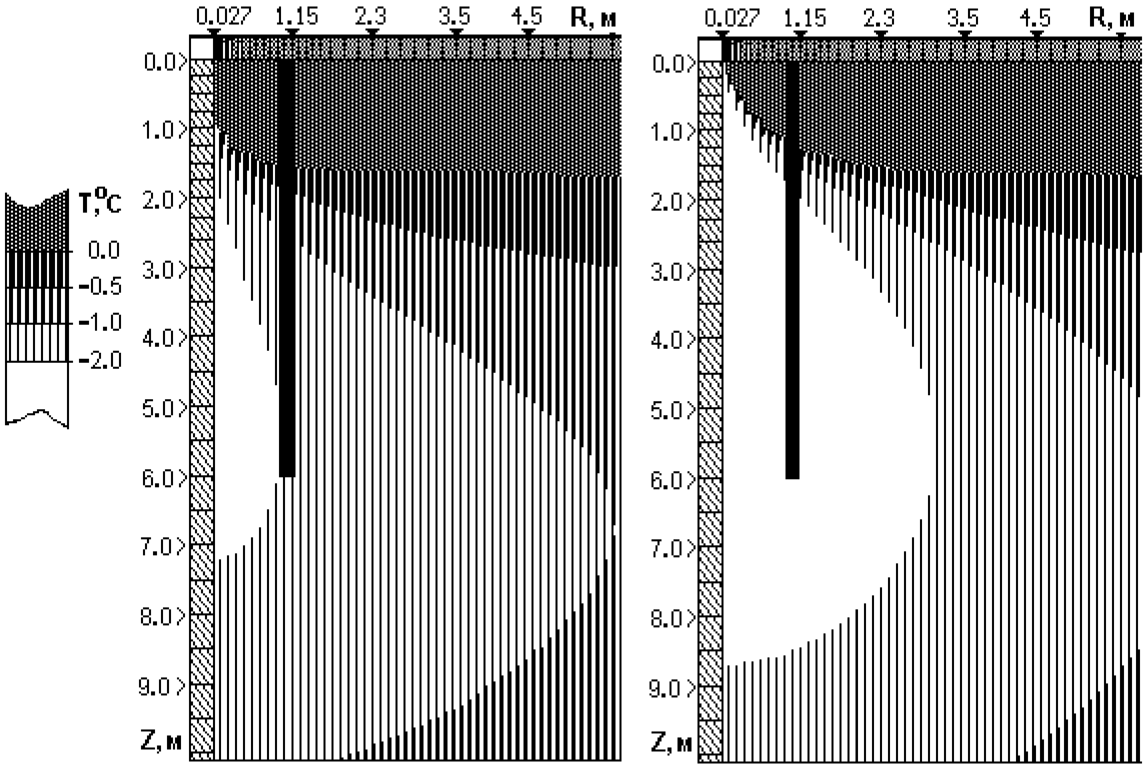

Figure 3. The radial section of the temperature field on October 1 around TTM
with the power 50 W (left) and 200 W (right)

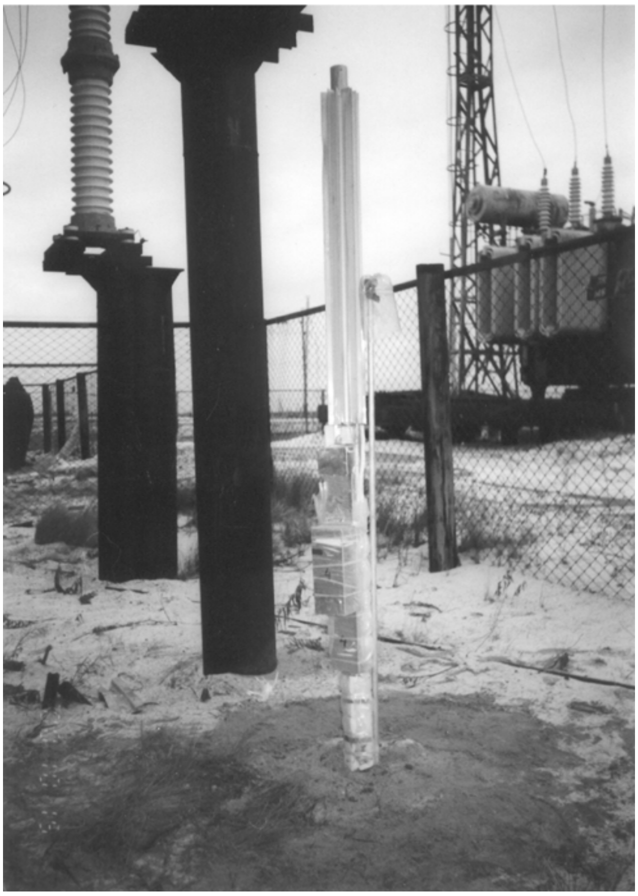

Figure 4. Thermo-stabilizer TTM stated near pile at high-voltage substation in Novy Urengoy