USE OF GEOTHERMAL ENERGY FOR DEICING APPROACH PAVEMENT SLABS AND BRIDGE DECKS: PHASE II EXTENSION

Pilot-Geothermal Bridge Deicing System Operation Manual

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Table of Contents

1. Introduction 1
2. Control Algorithm 1
3. Control System of Geothermal Heating System 2
4. Operation Procedures of Control System 3
5. Conclusions 3
6. Recommendations 3

List of Figures

Figure 1. Control system: a) wiring diagram of the heat pump and thermostat; b) Tekmar 519 thermostat and control sensor attached to the inlet pipe. 3

1. Introduction

A 28-ton geothermal heat pump system (GHPS) was installed to deice a pilot bridge on SH 180 in the Dallas/Fort Worth Metroplex in North Texas. The bridge consists of 8 spans and has 2 lanes on each bound. It is 200 ft. long and 48 ft. wide, and the bridge deck is approximately 18 in. thick. The total bridge deck area is 9,600 ft^2; however, the bottom surface of the deck, which would be used to install the hydronic heating loops, has an area of about 8,650 ft^2. Consequently, a vertical ground loop heat exchanger (GLHE) with 16 vertical boreholes (300 ft. deep) was constructed in the field. The GHPS consists of 16 GLHEs, 4 heat pumps, 10 circulating pumps, 1 dirt-air separator, 2 expansion tanks, 1 storage tank, and 1 heat pump control. The installation of the entire heating system was completed before winter 2023. Details on the construction of boreholes and hydronic heating panels on the bridge side and the installation of pumps and other equipment can be found in TM 9 and TM 10a, submitted to RTI.

The objective of the control system is to run the deicing system efficiently and effectively under different winter weather conditions. The system can be operated for bridge deicing in heat pump or bypass mode. The heat pump mode involves all four heat pumps and the GLHE during bridge deicing, while the bypass mode only relies on GLHE to heat the bridge. The original control design was one Tekmar 670 as the control module to automatically control all heat pump and water pump units. However, the implementation of Tekmar 670 was delayed. Instead, an alternative control using four Tekmar 519 was implemented for snow-melting operations in the winter of 2023. In this alternative control, each heat pump was controlled by one Tekmar 519 directly. The drawback of this alternative is that the system is operated manually.

This operational manual outlines the control system for the pilot bridge deicing system using Tekmar 519, including the control module, control algorithm, and operation procedure.

2. Control Algorithm

The heating system for the pilot bridge includes 4 heat pumps, 10 circulating pumps, 2 expansion tanks, and 1 storage tank, which are located in the control room, as shown in Figure 1. One control module (Tekmar 519) only controls one heat pump independently during the heating stage. The circulating pumps are controlled by four power switches, meaning they need to be manually turned on or off.

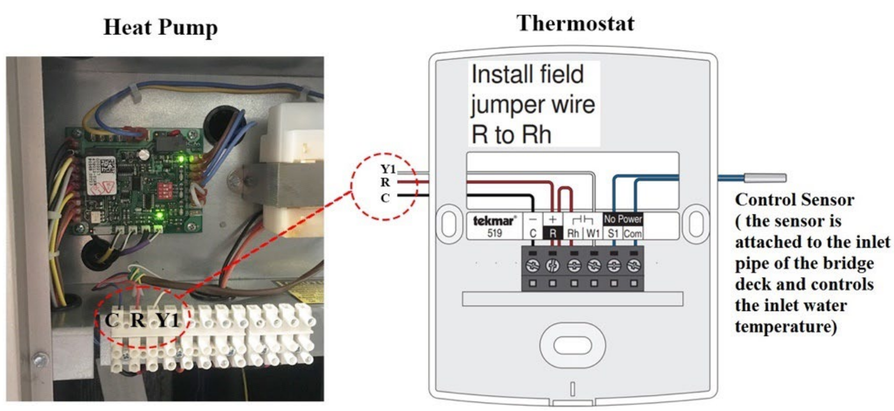
To make the system economically viable, the controller may eventually be the most important part of the geothermal deicing system. The previous control system used in the mockup bridge geothermal deicing system relied on simple control strategies since only one heat pump and two flow centers were involved. The new pilot bridge deicing system utilized a total of 4 heat pumps and 10 flow centers, creating a complex flow system. Therefore, each heat pump was paired with one thermostat (Tekmar 519) to control the operation of the heat pump. Tekmar 519 operates on a temperature sensor attached to the inlet pipe to the bridge to detect the heat pump output temperature. The flow centers were controlled manually using electrical switches.

For the current pilot bridge heating system, there are two heating modes, namely, heat pump mode and bypass mode. The heat pump mode involves heat pumps, GLHE, and the Tekmar 519 control module. The control module controls the heat pump operation based on the set temperature.

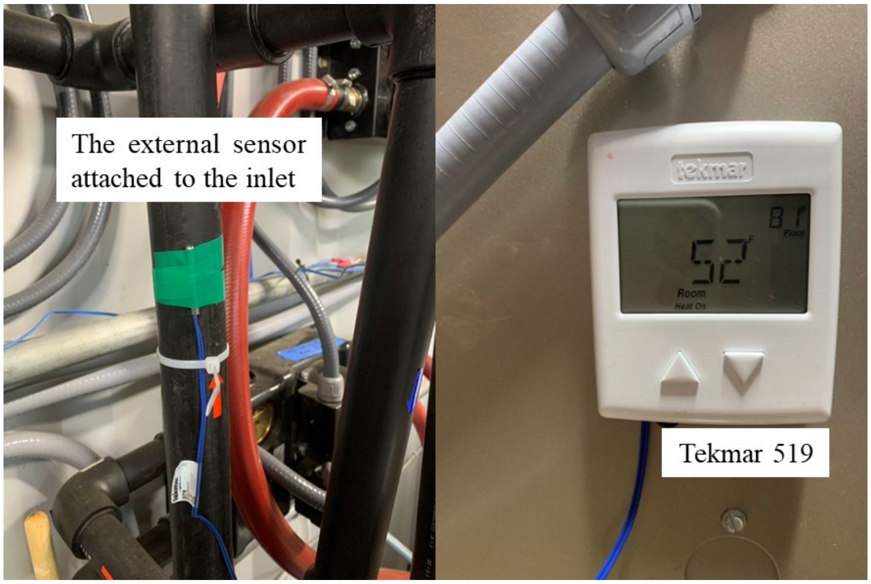
For example, if the set temperature is 100 °F when the detected heat pump output temperature (via temperature sensors attached to the inlet pipes to the bridge loop) is less than 100 °F, Tekmar 519 will turn on the heat pump. If the detected temperature exceeds 100 °F, the control will shut off the heat pump. In this mode, the circulating pumps keep running. The bypass mode operates by circulating the heat carrier fluids from GLHE directly to the hydronic loops underneath the bridge, bypassing heat pumps. Therefore, the heat pumps and control module do not participate in this mode, and only circulating pumps keep running to transfer heat from GLHE to the bridge surface. The detailed operation steps for the 2023 winter event are in the appendix.

3. Control System of Geothermal Heating System

As shown in Figure 2, an example thermostat (Tekmar 519) was wired to the heat pump to control its operation. Moreover, the thermostat was controlled by an external thermistor attached to the inlet pipe to the bridge deck to measure the inlet heat carrier fluid temperature. However, it should be noted that the system, including the 10 circulating pumps, was turned on and off manually, and four thermostats only controlled four heat pumps when the power supply was active. The system was completed before the 2023 winter events.



(a)



(b)

Figure 1. Control system: a) wiring diagram of the heat pump and thermostat; b) Tekmar 519 thermostat and control sensor attached to the inlet pipe.

4. Operation Procedures of Control System

During the deicing/snow-melting operation, the heat and circulating pump power switches are first turned on. Then, the four Tekmar 519 thermostats are set to the desired temperature, which controls the heat fluid temperature supplied to the bridge loop inlet and is monitored by the thermocouple from Tekmar 519. The thermostat then oversees the operation of the heat pumps, continuously monitoring the heat pump output temperature to avoid overheating. Detailed operation procedures for the heating system can be found in the appendix.

5. Conclusions

This report presents the control module, control algorithm, and operational procedures of the control system for the geothermal heating system. This report also details the operation manual for the control system. The objective of the control system is to ensure that 4 heat pumps work smoothly during winter events. During 10 days of operation, the control system worked smoothly during the Jan. 2024 winter event.

6. Recommendations

Although the current Tekmar 519 demonstrated its feasibility in controlling the pilot bridge geothermal heating system, the drawback of this system is that all circulating pumps need to be manually turned on/off. An automatic control system that operates on its own depending on the weather conditions is ideal for the operation of the deicing system. Therefore, the research team recommends using Tekmar 670 to automate the operation of the current deicing system. The Tekmar 670 system can automatically control the operation of heat pumps and circulating pumps and automatically shut off the system based on the detected bridge surface temperature.

APPENDIX: Deicing Operation Manual

Bridge Deicing Operation Example: Heat Pump Mode
(Operation based on Tekmar 519 Thermostat)

This operation mode is based on the following operation scenario. Based on the winter freezing/storm alert, the system shall be turned on at least 1 day before the forecasted freezing event. This mode operates at the full heating capacity of the deicing system. The on-and-off of the system is operated manually and determined by the bridge deck icing condition.

Step 1: Valve check

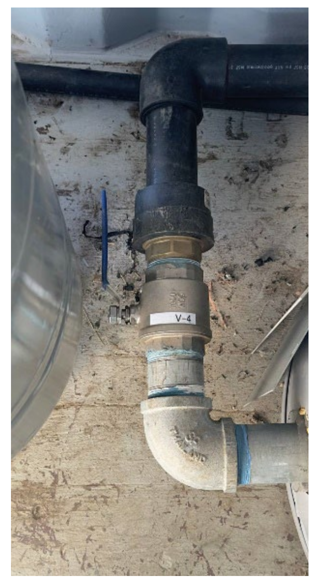
1.1. Ensure all system valves are switched to the right position, as shown below (labeled ***<u>V1, V2, V3, and V4</u>***)

V-1

V-2

V-3

V-4



1.2. Check and set all the manifold balancing valves and ball valves.

- **Balancing valves set to 5.0 GPM:** the 5.0 GPM setting is achieved by rotating the valve until the number 5.0 is aligned with the indicator on the dial. This controls the flow rate to ensure it matches the required setting of 5.0 gallons per minute.
- **The red valves are set to open.** The red handle of the ball valve is turned clockwise until it is in line with the pipe.

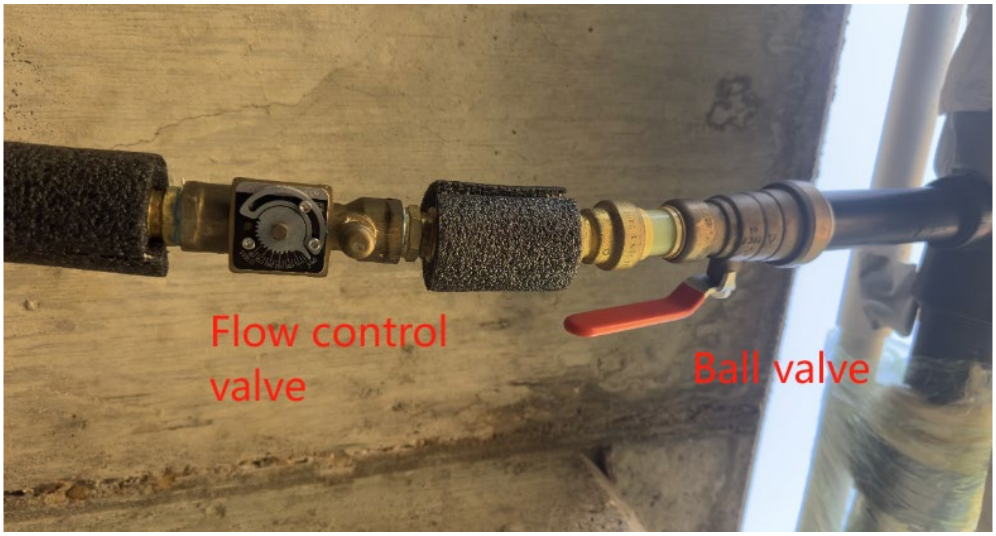
Manifolds

Manifold Balancing Valves

1.3. Verify the closure of the two bypass valves (V-Bypass) to ensure that the arrow mark stays in the position shown in the photo.

V-Bypass

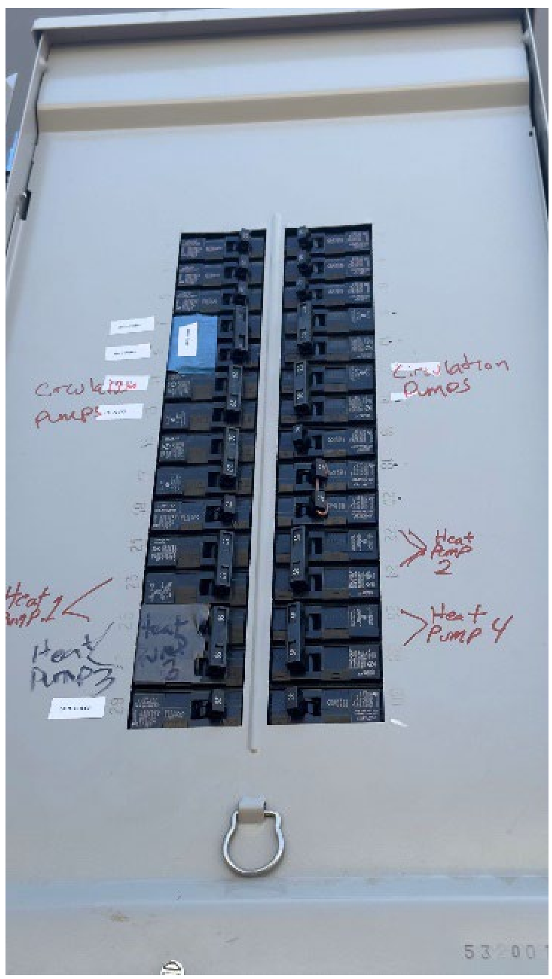
1.4. Check the ball valves installed on the inlet and outlet pipes for each bridge span to ensure they are open. Also, check that the flow control valve, as shown below, is set to maximum.



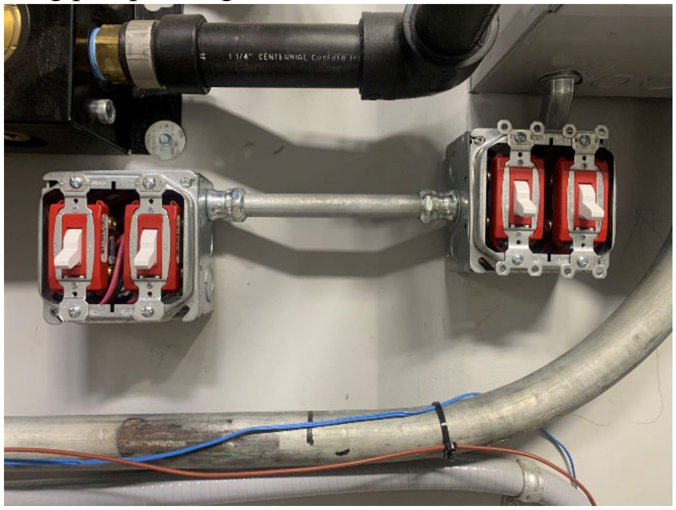
Taco flow setter (maximum) and ball valve (open) for the bridge heating panel

Step 2: Power Supply

2.1. Turn on switches for heat pumps and circulating pumps on the electrical panel located at the back of the control room.



2.2. Turn on the circulating pumps using switches located inside the control room

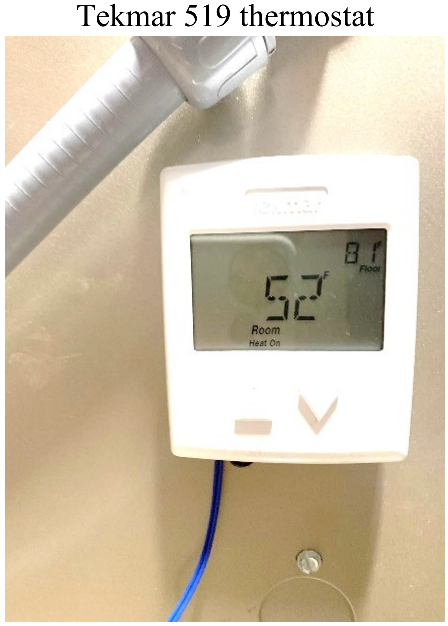


Step 3: Temperature Setting on Tekmar 519

3.1. Use the two triangle buttons below the display on the thermostat to set the heat pump's desired output temperature. The maximum setting temperature allowed is 105 °F. For mild winter events (air temperature is between 27 °F to 32 °F), 95 °F is the suggested thermostat setting temperature. If the air temperature is below 27 °F, the setting temperature is 105 °F. However, in most cases, setting thermostat temperatures to 105 °F is probably not the most energy-efficient temperature. If we want to save energy, the setting temperature can be obtained from the weather forecasted air temperature in the design chart, as summarized in TM12.

- Note: The Number 81 shown in the thermostat interface means the setting temperature. The number 52 shown in the thermostat interface indicates the heat pump output fluid temperature measured by the thermocouple attached to Tekmar 519.

Tekmar 519 thermostat



Step 4: Monitoring the Operation Status of Heat Pumps and Circulating Pumps

4.1. Once you have finished setting the temperature on the Tekmar 519, stay on site for 10-15 minutes until the heat pump output temperature reaches the set temperature and no overheating occurs.

- Note: For example, as shown in the thermostat interface, the setting temperature is 81 °F, and the output fluid temperature is 52 °F. The heat pump will start working, and the number 52 will blink and increase to 81. When the output fluid temperature reaches 81°F, the heat pump will stop, meaning that no overheating occurs.

Step 5: Monitoring the Working Status of Bridge Heating Panels

5.1. Visually check the operation status of the bridge heating panels underneath the bridge to ensure no leakage occurs.

Step 6: Turn off the Heat Pump and Circulating Pump

6.1. When the weather forecast indicates the winter event has passed and the air temperature for the next few days is larger than 32 °F, the system can be shut off.
6.2. First, turn off switches that control circulating pumps, as shown in Step 2.2.
6.3. Then turn off the switches on the electrical panel, as shown in Step 2.1.
6.4. Ensure all valves, as shown in Step 1, are set to close.

Startup Sequence for Bypass Mode without Heat Pumps
(for bridge heating or summer recharging)

This operation mode is based on the following operation scenario. The forecasted winter event is a freezing alert, with temperatures slightly below freezing (a few hours 31/32 during early mornings of the day, no freezing rain and snow). Based on the winter freezing/storm alert, the system shall be turned on at least 1 day before the forecasted freezing event. This mode operates without activating the heat pumps. The on-and-off of the system is operated manually and determined by your preference. During summer, this operation mode allows the ground to be charged with solar heat to increase the ground temperature for winter deicing operations.

Step 1: Valve Check

1.1. Ensure that all manifold valves, the bypass valve (labeled V-Bypass), and four buffer tank valves (labeled V-1, V-2, V-3, and V-4) are at the right position, as shown in the photos.

- Note: Please pay attention to the orientation of the Bypass valve. It is considered open when the arrow on the valve is parallel to the pipe.
- Note: Please ensure all the manifold flow setters have been set at 5 GPM.

V-Bypass

V-1

V-4

V-Manifolds

Manifold Flow setter

- Note: Two flushing vales (V-Flushing) must be in the position as shown in the photo.

V-Flushing

Step 2: Power Supply
2.1. Confirm a stable power supply to the main pump (behind the Buffer Tank) and bypass flow pump (manual Switch labeled Bypass).

Main Pump	*Bypass Flow Pump*	*Manual Switch*
		

Step 3: Monitoring circulation pump working status, pressure, and temperature
3.1. Ensure proper water flows through the loop.
3.2. Monitor the pumps for any unusual noises or vibrations.
3.3. Continuously monitor the system's pressure and temperature gauges to ensure they are within the recommended operating range.
3.4. Promptly address any abnormal readings.

Step 4: Check for leaks
4.1. Inspect the entire system for any signs of leaks.
4.2. Address any identified leaks immediately.

Step 5: Turn off the circulating pump
5.1. When the weather forecast indicates the winter event has passed and the air temperature for the next few days is larger than 32 °F, the system can be shut off during a mild winter event.
5.2. First, turn off switches that control circulating pumps, as shown in Step 2.1.
5.3. Ensure valves V-1 and V-4, as shown in Step 1, are set to close.

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