Providing insights for today's
HVAC system designer

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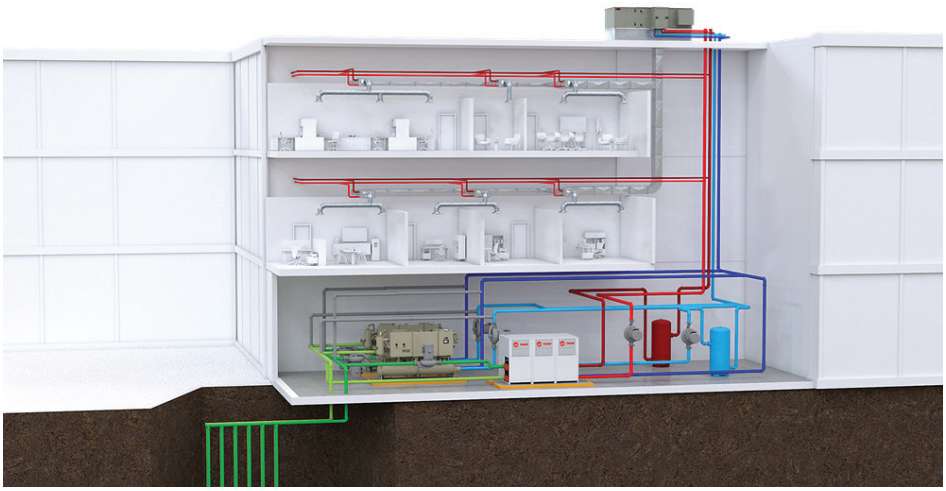
Central Geothermal Systems

The use of central geothermal systems has gained popularity in the last decade, and heat pump manufacturers have released new equipment that offers new design options for central geothermal systems. Five configurations have emerged as the most commonly used central geothermal systems. This *Engineers Newsletter* describes the five base system types and provides criteria to help designers select the right system for each project.

A growing number of building owners are favoring geothermal HVAC systems to achieve premium efficiency without the use of boilers for heating. Premium efficiency is achieved by using moderate earth temperatures as the heat sink and heat source instead of the wider range of ambient air temperatures. Gas boilers can be eliminated by using heat pump chillers that provide both cooling and heating capability.

Geothermal systems are used for a wide range of building types, from a 2-ton residential unit to a 10,000-ton central plant. These systems may include distributed heat pumps installed in zones, or a central plant design with hydronic distribution.

Figure 1. Central Geothermal System Illustration



Geothermal Heat Pumps

Central geothermal systems use water-to-water heat pumps (WWHP) to transfer heat between the ground loop and a hydronic distribution loop(s). Since geothermal heat pump technology has evolved in recent years, the following definitions are needed:

- **Water-to-water heat pump (WWHP):** A unit that regulates a heating or cooling temperature by transferring heat between two fluid sources. It may or may not include a reversing valve to change the roles of the heat exchanger.
- **Modular heat pump:** A heat pump consisting of multiple modules that function together as a bank. Each module includes an independent refrigerant circuit. In some cases, a standalone, single module can be used.
- **Modular multi-pipe heat pump:** A cooling and/or heating unit typically consisting of three or more refrigeration modules and accessory modules assembled together to create a multi-pipe bank. Modular multi-pipe units are normally characterized by their field-assembled nature whereby individual modules are shipped separately to the job site and assembled together with integral interconnecting valves, piping, and controls with a single power connection to create the complete modular multi-pipe unit.
- **Packaged heat pump:** A factory-assembled heat pump operating in a standalone manner—typically lower in cost and available in higher capacity compared to modular heat pumps.

Central Geothermal System Selection

Two primary factors influence which central geothermal system type is best suited for a project: heating and cooling system type, and system capacity. Of course, project cost will also be an important consideration!

- **Heating & Cooling System Type**

  Two-pipe changeover systems operate in heating mode ***or*** cooling mode. Changeover between modes may be achieved with refrigerant reversing (valves in heat pumps) or hydronic reversing (valves in the hydronic system).

  Four-pipe systems can operate in simultaneous heating ***and*** cooling mode with separate heating and cooling distribution loops. The central plant must be capable of simultaneous production of heating and cooling capacity.

- **System Capacity**

  <100T systems may be too small for packaged heat pumps. Designers should consider modular heat pumps with smaller increments of capacity.

  100-300T systems may be designed around modular or packaged heat pumps. Modular heat pumps simplify the system control by integrating some control functions into the heat pump equipment controller. Packaged heat pumps typically offer lower equipment cost and higher system capacity.

  >300T systems are likely to require multiple packaged heat pumps or multiple banks of modular heat pumps. Additional valves, pumps, and controls are needed in the system to coordinate operation of multiple heat pumps.

Five central geothermal system types are outlined in this newsletter. The figure and table below provide a high-level comparison of the five base configurations. Additional details for each system type follow. Revision D of the *Central Geothermal Systems* Application Manual SYS-APM009D-EN provides further details and alternatives for each system type, including the following:

- Component descriptions
- Operating modes
- Scaling to higher and lower capacity
- Auxiliary coolers, auxiliary boilers
- Valve and pump control
- Ground loop free cooling
- Alternative valve and pump arrangements
- Loop temperature regulation
- High temperature booster heat pumps

Table 1. Comparison of the Five Base Central Geothermal Systems

	Two-pipe Changeover		Four-pipe Heating & Cooling		
	Refrigerant Changeover Central Geothermal System	Hydronic Changeover Central Geothermal System	Modular Multi-pipe Central Geothermal System	Blended Loop Central Geothermal System	Parallel Central Geothermal System
Possible Design Range	20-960T(1)	80-10,000T+(2)(3)	90-600T(1)	80-500T(2)	240-10,000T+(2)(3)
Typical Systems	<200T(4)	>100T	<200T(4)	100-300T	>200T
Heat Pump Type	Modular	Packaged	Modular Multi-pipe	Packaged	Packaged
Efficiency	Good(5)	Good(5)	Better(5)	Better(5)	Best(5)
Controls Complexity	Low(6)	Low(6)	Med-Low(6)	Med(6)	Med-High(6)

(1) Based on four-pipe modular WWHP with capacity 20-80T per module, up to 12 modules and modular multi-pipe with capacity 30-60T per module, up to 10 modules (minimum of 3 modules).

(2) Based on screw compressor packaged heat pumps with capacity 80-250T (typical for geothermal). Up to two packaged heat pumps for blended loop geothermal systems.

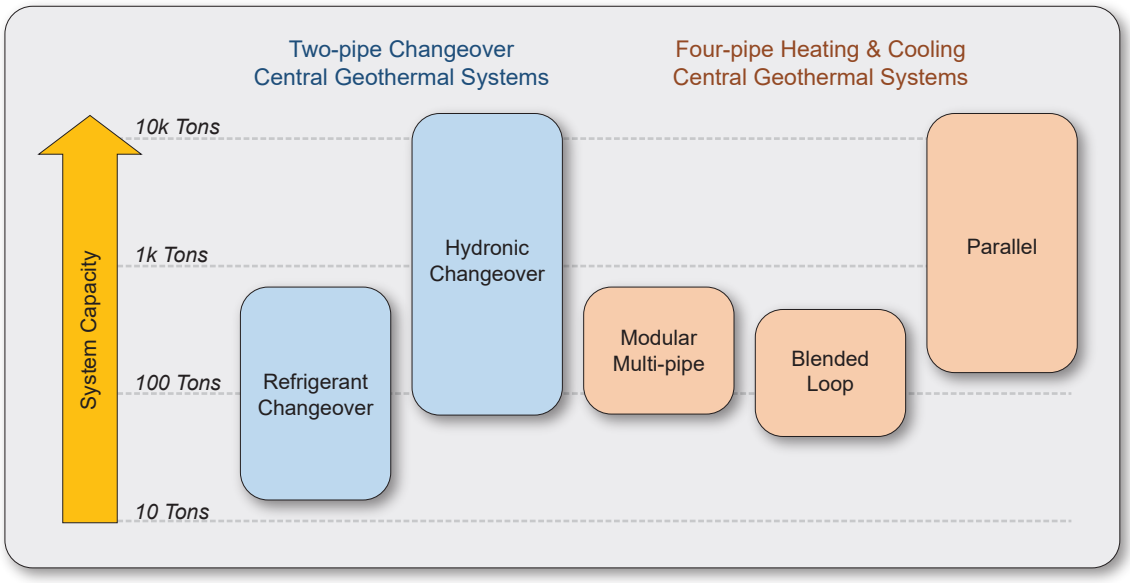
(3) Higher capacity central geothermal systems may include higher quantity of heat pumps or higher capacity heat pumps.

(4) Above 200T, packaged heat pumps likely result in a lower system cost.

(5) Geothermal systems are a premium efficiency system. All system types are "Good" to start with. Modular multi-pipe and blended loop systems are marked "Better" due to built in heat recovery function. Parallel central geothermal is marked "Best" due to heat recovery and ability to select higher efficiency heat pumps.

(6) Four-pipe systems have more controls complexity than two-pipe systems due to additional pumps and flow control logic. Of the three different four-pipe systems, the modular multi-pipe system is the simplest because more functionality is integrated into the heat pump controls. Parallel central geothermal system has more controls complexity due to heat pump and valve staging.

Figure 2. Capacity Comparison of the Central Geothermal System Types



Refrigerant Changeover Central Geothermal System

This system allows heating or cooling mode operation with the use of reversible refrigeration cycle water-to-water heat pumps. The reversing valves, actuators, and control logic are built into the heat pump. The system controller or Building Automation System (BAS) determines the need for heating or cooling and enables the heat pump with an operating mode and setpoint temperature.

Fluid in the ground loop and distribution loop is isolated from each other and only connect thermally through the refrigerant circuit (Figure 3).

The refrigerant changeover central geothermal system operates according to the following strategies:

- Heat pump HP-1 regulates cooling or heating supply temperature, depending on system mode.
- Pump P-1 maintains flow in the heat pump and ground loop.
- Pump P-2 maintains flow in the heat pump and the distribution loop.
- Valve V-1 is used for head pressure control when ground temperature is too cold during cooling mode. If the heat pump has integrated head pressure control, V-1 may be omitted.
- Valve V-2 is an end of loop bypass valve. It allows minimum flow to be maintained in the heat pump when distribution flow rate is low.

The refrigerant changeover and hydronic changeover central geothermal systems must comply with the changeover requirements in ASHRAE 90.1-2022, section 6.5.2.2.2. These requirements are intended to limit the amount of wasted energy when changing between heating and cooling modes.

6.5.2.2.2 Two-pipe Changeover System. Systems that use a common distribution system to supply both heated and chilled water are acceptable, provided all of the following are met:

a. The system is designed to allow a dead band between changeover from one mode to the other of at least 15°F outdoor air temperature.

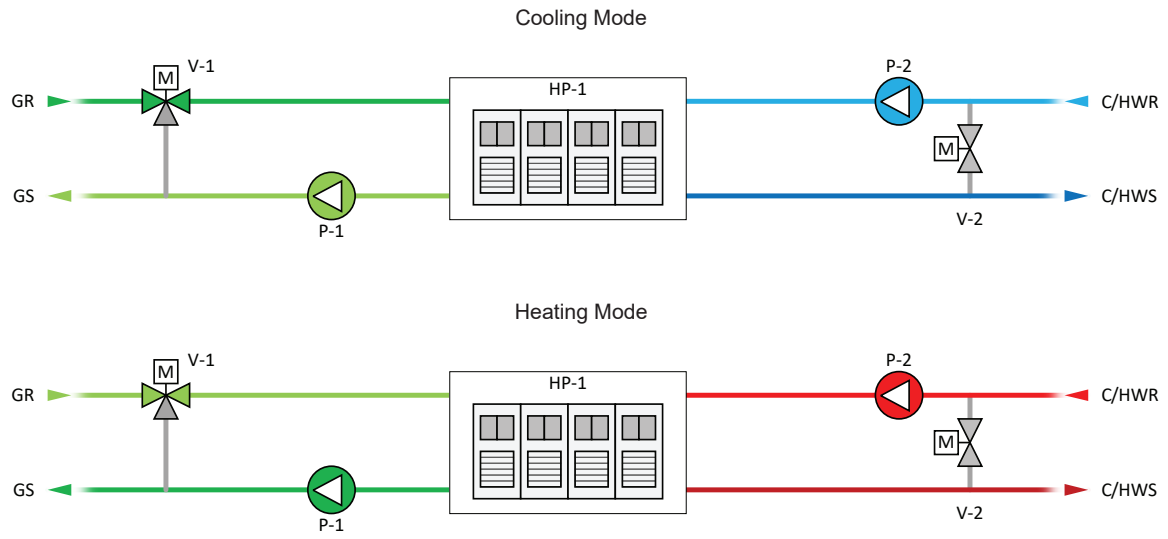
b. The system is designed to operate and is provided with controls that will allow operation in one mode for at least four hours before changing over to the other mode.

c. Reset controls are provided that allow heating and cooling supply temperatures at the changeover point to be no more than 30°F apart.

Table 2. Advantages and Considerations for Refrigerant Changeover Central Geothermal System

Advantages	Considerations
• Reversing function is built into heat pumps. • Piping layout and system controls are simple. • Fluid in the ground loop and distribution loop is isolated.	• System does not provide simultaneous heating and cooling. • Airside heat recovery for ventilation is recommended or possibly required by code. • Energy may be wasted when changing between cooling and heating modes.

Figure 3. Refrigerant Changeover Central Geothermal System



Hydronic Changeover Central Geothermal System

This system allows heating or cooling mode operation with the use of hydronic changeover valves, enabling designers to select non-reversible, packaged heat pumps. Packaged heat pumps are typically available at lower cost and higher capacity than modular heat pumps. Hydronic changeover central geothermal systems may be scaled to very high capacity.

The system controller or BAS determines the need for heating or cooling, positions the hydronic changeover valves for the correct mode, then enables the heat pump with an operating mode and setpoint temperature.

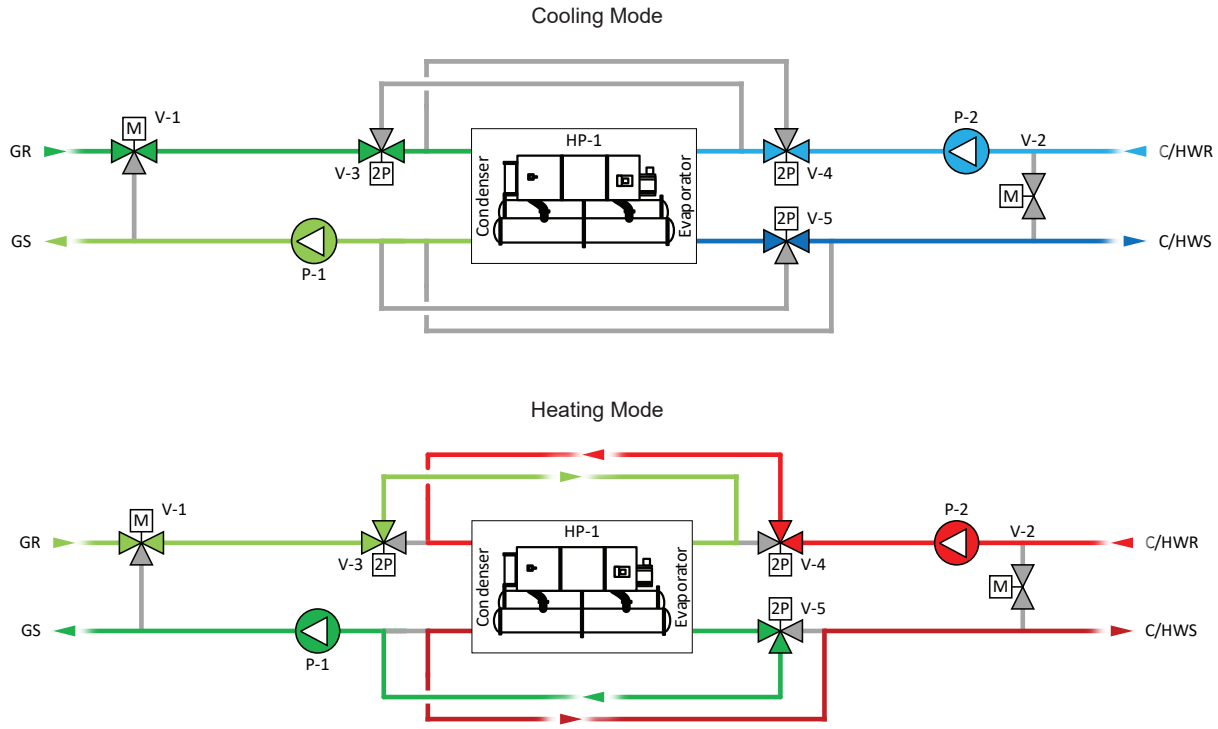
The hydronic changeover central geothermal system operates according to the following strategies:

- Heat pump HP-1 regulates cooling or heating supply temperature, depending on system mode.
- Pump P-1 maintains flow in the heat pump and ground loop.
- Pump P-2 maintains flow in the heat pump and the distribution loop.
- Valve V-1 is used for head pressure control when ground temperature is too cold during cooling mode. If the heat pump has integrated head pressure control, then V-1 may be omitted.
- Valve V-2 is an end of loop bypass valve. It allows minimum flow to be maintained in the heat pump when distribution flow rate is low.
- Valves V-3, V-4, and V-5 are the hydronic reversing valves. These valves switch connections of the heat pump evaporator and condenser, depending on operating mode.

Table 3. Advantages and Considerations for Hydronic Changeover Central Geothermal Systems

Advantages	Considerations
• Non-reversible, packaged heat pumps may be used with lower cost and higher capacity compared to modular heat pumps. • System is scalable to very high capacity.	• Reversing function requires additional valves and controls. • Airside heat recovery for ventilation is recommended or possibly required by code. • Fluids in the ground loop and distribution loop mix during system changeover unless an isolation heat exchanger is added. • Energy may be wasted when changing between cooling and heating modes.

Figure 4. Hydronic Changeover Central Geothermal System



Modular Multi-pipe Central Geothermal System

This system is designed around modular multi-pipe heat pumps, which are intended to simplify the system design by incorporating more functionality into the heat pump itself. Modular multi-pipe heat pumps simultaneously control the cooling and heating supply temperatures by changing the operating mode of individual modules in the heat pump bank.

Fluids in the ground loop, cooling loop, and heating loop are isolated from each other and only connect thermally through the refrigerant circuit.

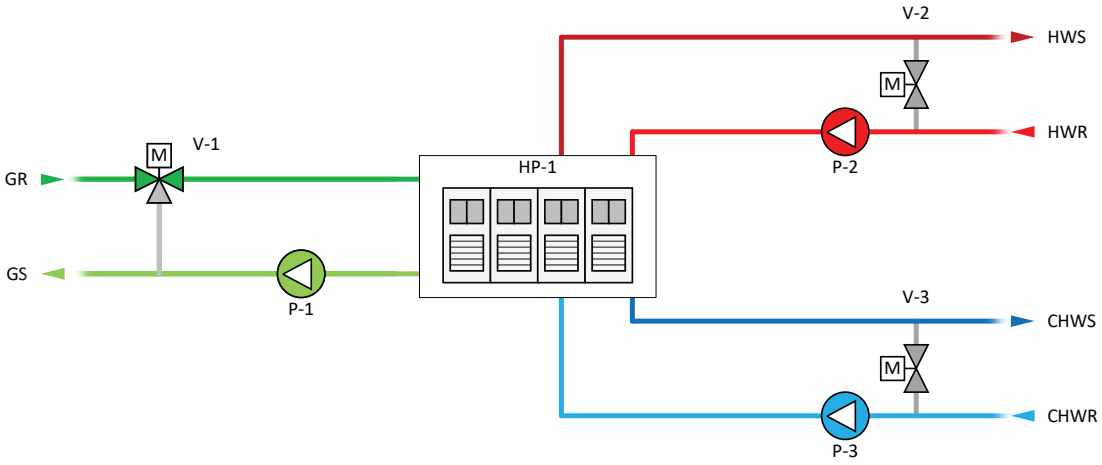
The modular multi-pipe central geothermal system operates according to the following strategies:

- Heat pump HP-1 regulates cooling and heating supply temperatures.
- Pump P-1 maintains flow in the heat pump and ground loop.
- Pump P-2 maintains flow in the heat pump and the heating distribution loop.
- Pump P-3 maintains flow in the heat pump and the cooling distribution loop.
- Valve V-1 is used for head pressure control when ground temperature is too cold during cooling mode. If the heat pump has integrated head pressure control, then V-1 may be omitted.
- Valve V-2 and V-3 are end of loop bypass valves. They allow minimum flow to be maintained in the heat pump when distribution flow rates are low.

Table 4. Advantages and Considerations for Modular Multi-pipe Central Geothermal Systems

Advantages	Considerations
• Reversing function and compressor staging control is built into heat pump bank controller. • Heat recovery function improves system efficiency when simultaneous heating and cooling loads exist. • Fluids in the ground loop and distribution loops are isolated.	• Modular multi-pipe heat pumps are more expensive than packaged heat pumps. • Temperature regulation may be less precise than packaged heat pumps.

Figure 5. Modular Multi-pipe Central Geothermal Systems



Blended Loop Central Geothermal System

This system allows simultaneous heating and cooling mode operation with control of both heating and cooling loop supply temperatures. Packaged, non-reversible heat pumps are connected in a heat recovery manner (between the cooling loop and heating loop), with the ground loop used to balance loading between evaporator and condenser.

When simultaneous loads exist, the heat pump regulates the larger (dominant) load, while the BAS or system controller regulates the smaller (non-dominant) load by modulating ground loop flow. Some refer to this as false loading the non-dominant loop.

The blended loop central geothermal system is intended as a simple, low-cost option for buildings that can be served by one or two packaged heat pumps. Buildings that require three or more packaged heat pumps should consider the parallel central geothermal system.

The design of this system results in fluid mixing between the ground loop, cooling loop, and heating loop. Isolation heat exchanger(s) may be added to the system to prevent mixing of fluids.

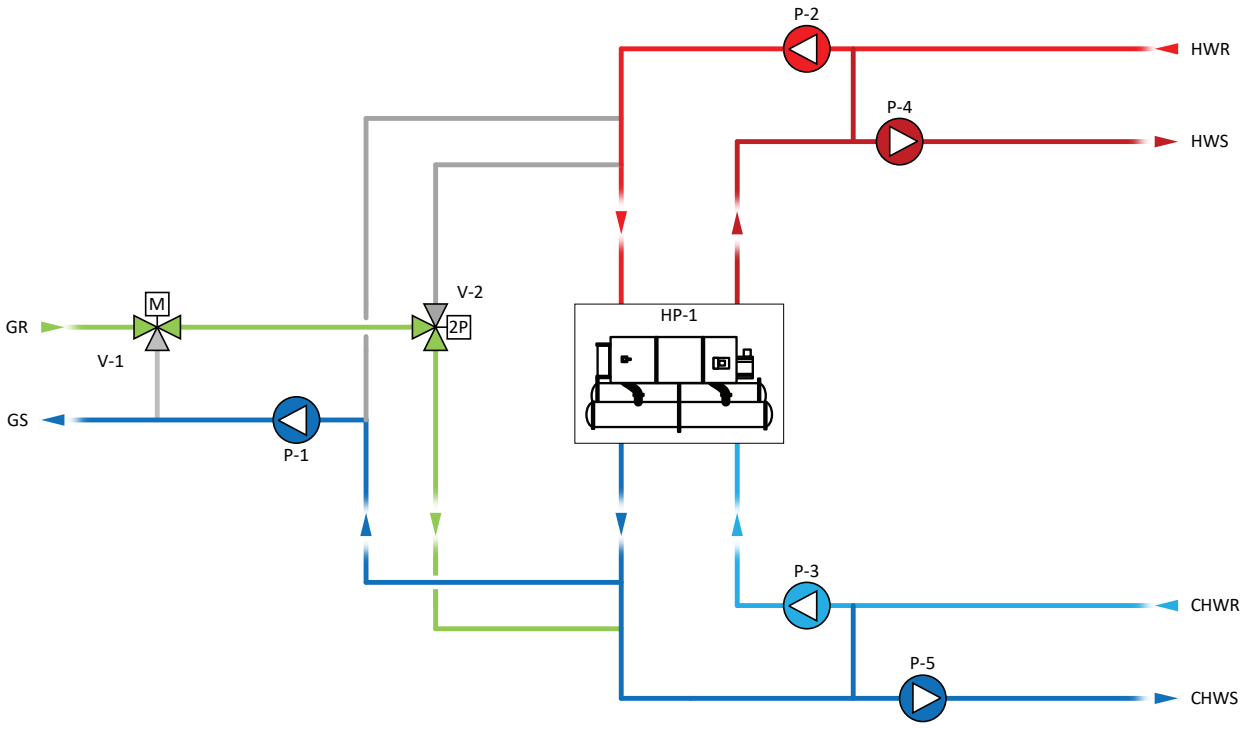
The blended loop central geothermal system operates according to the following strategies:

- Heat pump HP-1 regulates cooling or heating supply temperature, depending on system operating mode.
  - When the system is heating dominant, HP-1 regulates the heating supply temperature.
  - When the system is cooling dominant, HP-1 regulates the cooling supply temperature.
- Pump P-1 regulates ground loop flow to maintain heating or cooling supply temperature, depending on system operating mode.
  - When the system is heating dominant, ground loop flow is modulated to maintain cooling loop supply temperature.
  - When the system is cooling dominant, ground loop flow is modulated to maintain heating loop supply temperature.
  - If P-1 modulates down to minimum speed, V-1 may be used for additional modulation range, bypassing the ground heat exchanger.
- Pump P-2 maintains flow in the heat pump condenser.
- Pump P-3 maintains flow in the heat pump evaporator.
- Pump P-4 maintains flow in the heating distribution loop.
- Pump P-5 maintains flow in the cooling distribution loop.
- Valve V-1 is used for head pressure control when the system is in cooling mode with low ground temperature. V-1 also provides a second stage of ground loop modulation when pump P-1 is at minimum speed.
- Valve V-2 is the geothermal mode switching valve, determining which side of the system that the ground loop is connected to.

Table 5. Advantages and Considerations for Blended Loop Central Geothermal Systems

Advantages	Considerations
• Packaged heat pumps provide lower equipment cost compared to modular multi-pipe heat pumps. • Heat recovery function improves system efficiency when simultaneous heating and cooling loads exist.	• Heat pumps operate at full compressor lift (heating temperature minus cooling temperature) whenever simultaneous loads exist. • Fluids in the ground loop, cooling loop, and heating loop mix.

Figure 6. Blended Loop Central Geothermal System



Parallel Central Geothermal System

This system uses multiple non-reversible heat pumps, connected in a parallel arrangement. Each heat pump can operate in cooling mode, heating mode, or heat recovery mode, depending on the position of valves in the system. Parallel central geothermal systems are highly efficient due to the built-in heat recovery function and the ability to stage heat pumps for optimal efficiency.

The BAS or system control must coordinate valve position and pump control, depending on the operating mode of each heat pump in the system.

The parallel central geothermal system is easily scalable with more heat pumps operating in parallel.

The parallel central geothermal system operates according to the following strategies:

- Heat pumps HP-1, HP-2, and HP-3 are staged in heating mode, cooling mode, or heat recovery mode, depending on the building demand.
  - Heating only and cooling only capacity is staged left to right in the diagram.
  - Heat recovery capacity is staged right to left in the diagram.
- Pump P-1 maintains flow rate in the ground loop and in the heat pumps operating in heating only or cooling only mode.
- Pump P-2 maintains flow in the condensers of the heat pump that operate in heat recovery mode.
- Pump P-3 maintains flow in the evaporators of heat pumps that operate in heat recovery mode.
- Pump P-4 maintains flow in the heating distribution loop.
- Pump P-5 maintains flow in the cooling distribution loop.
- Valve V-1 bypasses the ground heat exchanger as needed for head pressure control.
- Valves V-2 and V-3 are the geothermal mode switching valves, determining which side of the system that the ground loop is connected to.
- Valves V-4 through V-9 are "boundary" valves and determine which loop that each heat pump condenser and evaporator are connected to. Boundary valve position determines the operating mode for each heat pump.
- Valves V-10 through V-15 are the heat pump isolation and flow control valves.
  - Modulating control valves at V-10, V-12, and V-14 may be used for head pressure control instead of V-1.

Conclusion

Central geothermal systems offer versatile, high-efficiency solutions for a wide range of building types and capacities. By understanding the characteristics, advantages, and considerations of each system configuration, designers can better match system performance with project goals. Whether prioritizing simplicity, cost effectiveness, or advanced heat recovery capability, the five system types outlined in this newsletter provide a clear framework for informed decision-making. Thoughtful selection and proper design ensure reliable operation, optimized energy use, and long-term sustainability for geothermal HVAC applications.

By Ben Sykora, applications engineer, Trane.
You can find this and previous issues of the *Engineers Newsletter* at www.trane.com/EN.
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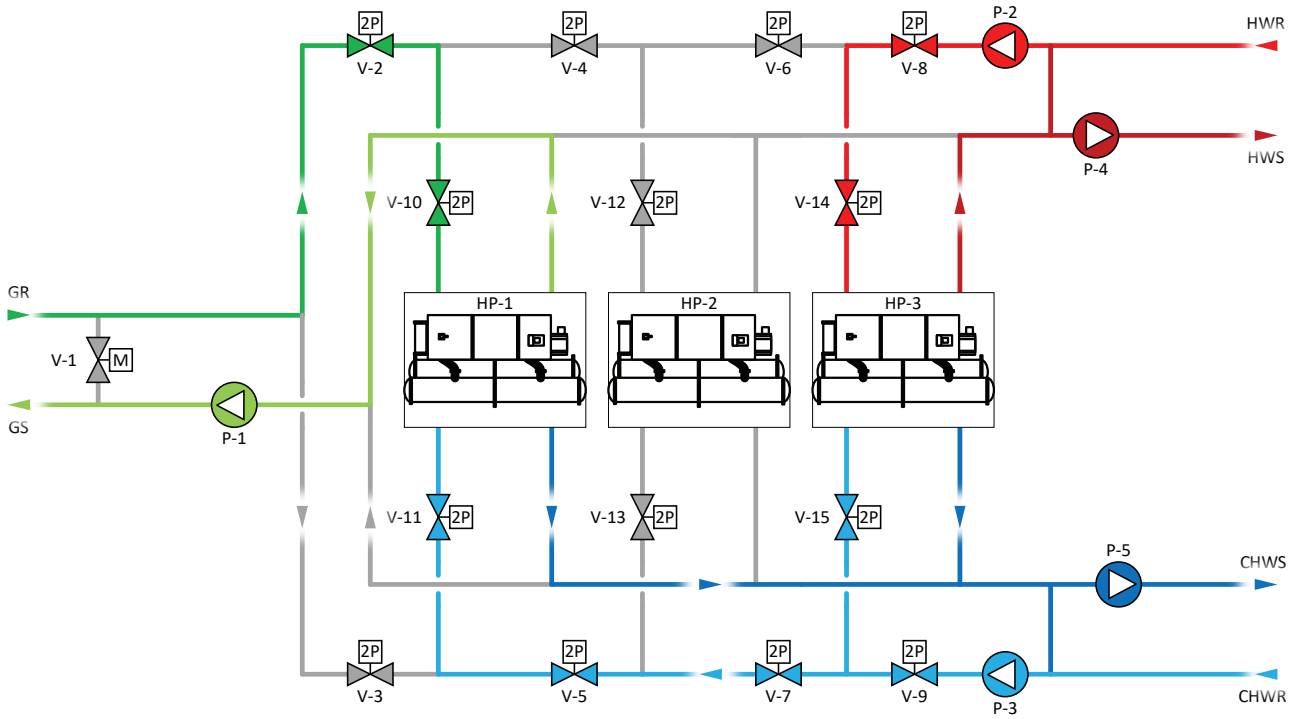
Table 6. Advantages and Considerations for Parallel Central Geothermal Systems

Advantages	Considerations
• System is scalable to very high capacity. • Heat recovery function improves system efficiency when simultaneous heating and cooling loads exist. • Heat pump staging allows for optimal system efficiency by reducing compressor lift for heat pumps not operating in heat recovery mode.	• System controls require more valve and pump logic than other central geothermal system types. • Fluids in the ground loop, cooling loop, and heating loop mix.

Figure 7. Parallel Central Geothermal System



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References

[1] Trane. *Central Geothermal Systems* applications engineering manual. SYS-APM009*-EN. 2020.

[2] Trane. *Water-Source and Ground-Source Heat Pump Systems* applications engineering manual. SYS-APM010*-EN. 2025.

[3] ANSI/ASHRAE/IES. Standard 90.1-2022, *Energy Standard for Buildings Except Low-Rise Residential Buildings*. Atlanta: ASHRAE 2022.

[4] ASHRAE. *Geothermal Heating and Cooling - Design of Ground-Source Heat Pump Systems*. RP-1674. ASHRAE, 2014.

Further information about each system type—including component descriptions, system operation/control, and system alternatives—will be available in the updated Trane Applications Manual SYS-APM009D-EN, *Central Geothermal Systems*, which is **scheduled for release in late March.**

Information about modular air-to-water heat pump systems will be available in the updated Trane Applications Guide APP-APG021B-EN, *Thermafit™ Modular (AXM/MAS) Air-to-Water Heat Pump System.*

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