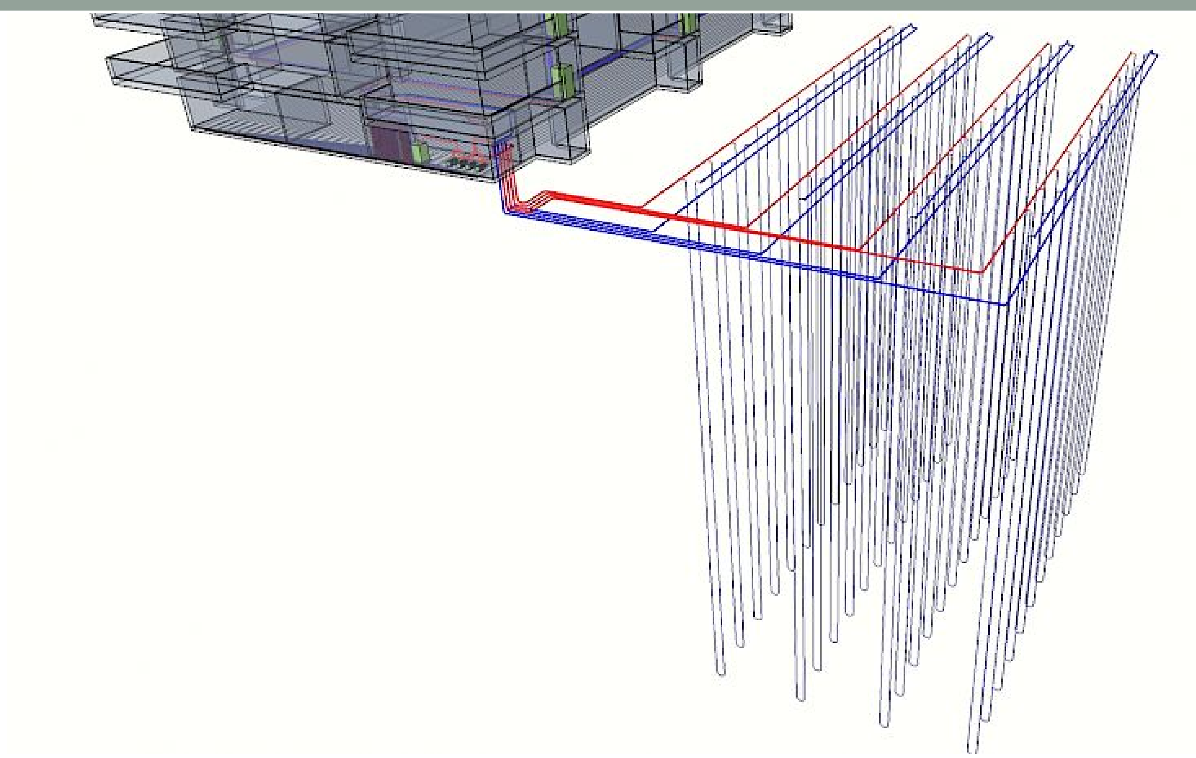
BULLDOG HEAT PUMP
No other heat pump does more, with less.

GEOTHERMAL DESIGN GUIDE

BENEFITS OF THE BULLDOG SYSTEM



CGC Version

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INTRODUCTION

There are two very important design criteria's that will positively affect the success of a geothermal project in a cooling dominant building (and most of the buildings are cooling dominant… even in cold climates) (schools are most likely heating dominant).

The HVAC system that can address these two requirements will be most advantageous for the success of the project.

The Bulldog system has the unique advantage over conventional GSHP with positively contributing to both of these two requirements:

"A" MINIMIZE THE AMOUNT OF HEAT REJECTED TO THE GEOTHERMAL FIELD

Not operating our heating compressors is major contributing factor in a reducing the amount of heat rejected to the geothermal field.

"B" MAXIMIZE THE AMOUNT OF HEAT EXTRACTED FROM THE GEOTHERMAL FIELD.

The hydronic heating Bulldog system provides more design flexibility, which allows **ALL** of the heating loads to connect onto one common loop, thereby maximizing the heat sharing capabilities of the system. This allows for more options in utilizing the stored heat and can potentially eliminate other sources of heating fuels that might otherwise be required.

CHALLENGES FACING CONVENTIONAL GSHP SYSTEMS

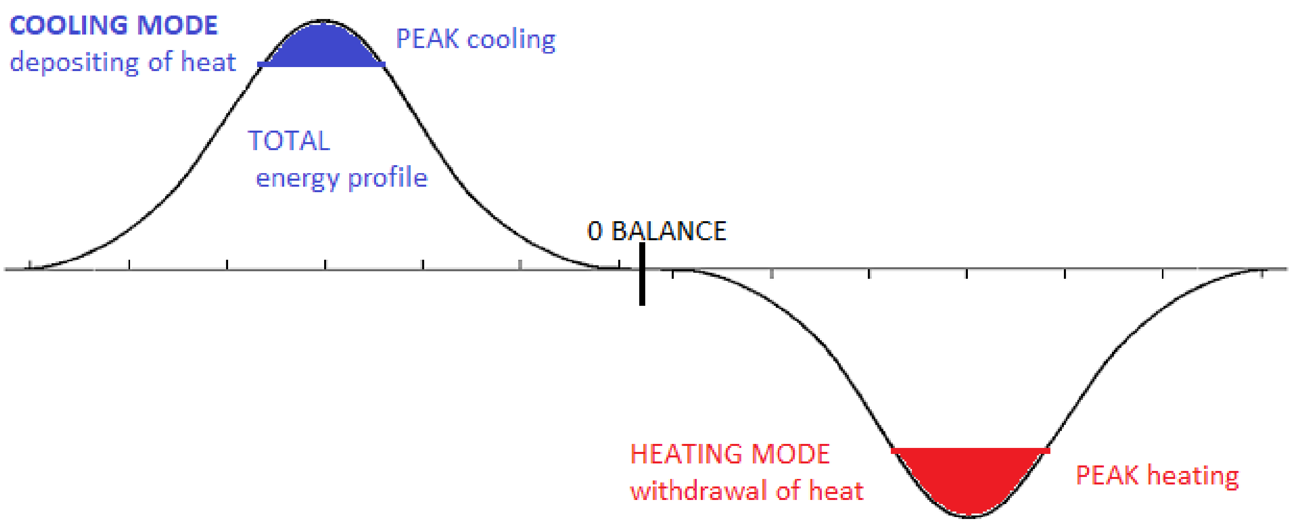
- Multiple fluid loops may be required
- Other fuels source (gas fired MUA or boilers) may be required
- Hybrid system may be used (Hybrid meaning supplemental gas heat or supplemental fluid cooler)
- Risk of overheating the geo field by not maximizing the heat sharing capabilities of the building

FACTORS WHICH IMPACTS THE SIZE OF THE GEOTHERMAL HEAT EXCHANGERS (GHX) OR GEOTHERMAL FIELD

The GHX effectiveness and longevity is impacted by two major considerations;

- Annual energy profile – This is the annual aggregate energy transferred to and from the GHX as a result of heating and cooling.
- Peak load – Energy transferred to and from the GHX during peak heating or peak cooling

The Annual energy profile deals with a total amount of storage capacity (think of it as a thermal storage tank), while the Peak loads deal with a maximum load over a set time frame (think of it as a Cooling Tower or Boiler operating at the warmest or coldest hour of the year).



ANNUAL TOTAL ENERGY PROFILE (HEAT EXTRACTED AND REJECTED FROM GHX)

The annual load is the most import consideration when designing a GHX to ensure long term performance. Miscalculating this or lack of understanding is why so many geothermal systems fail after a few years. The easiest way to understand this is to think of the GHX as a bank account. It is a bank account in which at some point during the year we want to have a balance of $0. Cooling is the act of depositing and heating is the act of withdrawing. It is most important to focus on the end goal of $0, not how or when we get there as we have 365 days to achieve this. In most regions, commercial or multifamily buildings are cooling dominant with regards to the geothermal field. Cooling dominant means that there is more “depositing” of heat in the cooling mode than “withdrawal” of heat in the heating season. The system is thus said to be imbalanced.

Somehow, this “depositing of heat” needs to be counterbalanced over the course of the year by withdrawals in order to be at 0 balance at some point of the year (typically in the Spring before the cooling season begins).

This is where selecting a HVAC system that has the least amount of heat rejection and the most amount of heat extraction is critical. This feature is unique to geothermal designs and has little benefit in a conventional system.

Cooling dominant – common misconception

It is important to note that when using the term “cooling dominant” we are referring only to the amount of heat rejected to and from the GHX. Traditional mechanical building designers are far more accustomed to and will default to the actual amount of energy consumption of the building with respect to heating and cooling operation. In cold climates, it is possible that heating will consume more energy than cooling even if the building is cooling dominant.

A geothermal field that experiences different cooling (deposits) & heating (withdrawals) loads is said to be unbalanced.

In the **cooling** mode, heat pumps may operate with a COP of approximately 6 to 7 **with respect to the geothermal field**.

Meaning - a heat pump in the cooling mode may reject 7 times more energy (in the form of heat) than it consumes (in the form of electricity).

Let us look at what this means with respect to building energy consumption vs geothermal impact.

Cooling capacity of a 2 ton unit at EWT 70°F = 27,198 BTUs

Energy consumption is 4,880 BTUs (1.43 kW) – This is the amount of energy **consumed** by the compressor and fan that is of concern to an energy modeller.

Heat Rejection into the loop – 32,003 BTUs – This is what concerns the Geothermal Field Designer.

Heat rejected / Energy IN = 32,003/4,888 = COP of 6.5 with respect to geo field

Cooling load COP = 27,198/4,888 = 5.5

Energy Modellers and Mechanical Building Designers will focus on the amount of energy consumed by the compressors and fans, while Geothermal Designers are concerned with the total heat rejection to the GHX, which can be 6 to 7 times greater than the energy consumed.

One of the major factors creating an imbalanced energy profile between heating & cooling are the internal loads. Internal loads produce heat year round and not just in the summer:

- People
- Lighting
- Computers
- Fridges/ cooking
- Personal electronics
- **Heat Pump Compressors**

What is important to remember and often overlooked is the total heat rejected into the ground is calculated on an annual basis. **Heat produced in the winter also contributes to the aggregate load on the geothermal system.**

We now know that the total annual heat rejected into the GHX is very important and it does not matter where it comes from or when it is produced. Designers may focus on the AMOUNT of heat being rejected in the summer and sometimes forget about the importance of the total annual impact.

Peak load

As the name implies, the peak load is the energy being rejected ***to*** or extracted ***from*** the GHX during the peak cooling or peak heating. Peak load is the other major consideration when designing geothermal systems. The GHX needs to handle the total heat rejection during this period without overheating. Peak load is primarily driven by building loads. Equipment efficiency also impacts the amount of heat rejected to the geo field. The higher the EER rating the less heat that is rejected into the field. The EER is a relationship between total cooling capacity output and the total energy input in kW (compressor & fan energy).

Rejecting heat into the geothermal field during peak load conditions can be a challenge since the geothermal field is dealing with the maximum amount of heat in a short period of time. In this case, the approach temperature between the field and the return fluid can have an impact on the ability of the geothermal system to absorb heat.

How do designers typically manage peak and annual load when the building loads are imbalanced?

In order to deal with these two issues, Designers can leverage a few different options:

- Increase the size of the GHX (i.e. over design)
- Utilize a hybrid approach which requires additional & expensive mechanical heat rejection equipment such as fluid coolers
- Address ventilation heating and cooling loads separately from the internal loads (i.e. Air Cooled DX & Gas fired MUA) (this approach results in a higher risk of overheating the geo Field)
- Reduce cooling loads architecturally (smaller and better windows)

These options can be effective but come at an increased capital cost.

How does the Bulldog unit affect peak loads?

Cooling Efficiency (EER) The size of a geothermal field is impacted by two design parameters:

- annual aggregate heat rejection
- summer peak heat rejection

In many cases, the cooling peak will be greater than the heating peak. Cooling peaks are much more difficult to address than heating. If needed small boilers are a cost effective way to mitigate peak heating but cooling peaks require fluid coolers, which are inconvenient and expensive. Higher EERs mean lower heat of compression which means less heat rejection from the compressor. Because Bulldog compressors are designed to operate as cooling only utilizing a shell and tube heat exchanger, the cooling EER can be 10 to 20% higher than some other manufactures. This provides operational savings but it also is a significant factor when sizing a geothermal GHX. A 15% increase in EER can result in a 15% reduction in GHX size or more depending on conditions.

EWT – Because of the tube in shell heat exchanger of the Bulldog, our units can operate with fluid temperatures up to 120°F easier than other manufacturers. NOTE: Other manufacturers can also operate with elevated EWT but with a greater reduction in EER and capacity. This can have a significant impact on their ability to perform during peak cooling season. If the GHX temperature goes above the design temperature, some heat pumps may struggle or lock out on high head pressure.

> *It is interesting to note we rarely see reversing heat pumps designed with warm EWT in either a geothermal design or even a cooling tower design. However, the Bulldog system is regularly designed with warm EWT in Dry cooler applications and geothermal design. This is due to our tube in shell condenser.*

While designers will rarely want to see the geothermal field operate with fluid temperatures above 85°F, having the flexibility of the equipment with a higher EWT operating range provides a safety net or buffer in the design.

During PEAK cooling mode, the GHX needs to absorb the maximum amount of heat in a given period of time.

Consider a standard GSHP system rejecting heat into the GHX with a return water temperature to the GHX of 90°F or 95°F. The approach temperature difference between the GHX (80°F) and the fluid is 10°F to 15°F. Since the GHX is essentially a heat exchanger, it needs to operate with this approach temperature and these operating conditions to determine how much heat can be absorb in a given time period. This affects the size of the GHX that is required to absorb the heat.

Now consider the Bulldog system, which can operate better with warmer design fluid temperatures due to the tube in shell heat exchanger (maximum = 120°F). Say the design fluid temperature returning from the Bulldog units is now 110°F instead of 95°F. The approach temperature is now 15°F greater than with the GSHP (total approach now 25°F). This larger approach temperature means that the GHX can absorb heat much easier, OR may be sized smaller. Either way the Bulldog system has a positive impact on the absorption ability of the GHX.

NOTE : the designer must take into consideration the reduction in cooling capacity and lower EER's while operating Bulldog units with elevated fluid temperatures.

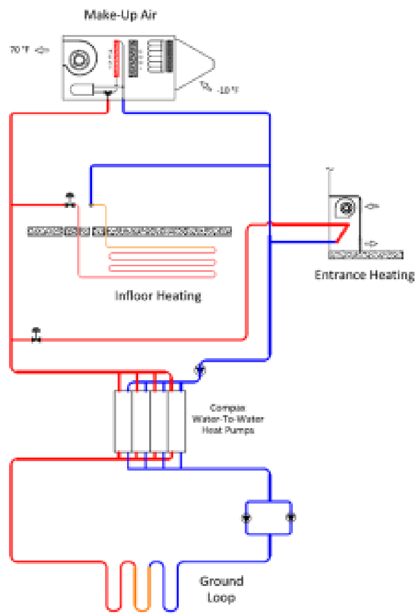
Traditional GSHP system design for ventilation air

Since traditional GSHP systems operate with cold evaporator fluid in the winter (45°F to 55°F), it may be difficult for the Designer to use a Heat Pump MUA. These have limitations when it comes to cold air entering the condenser (minimum 40°F or 50°F) and cold fluid entering the evaporator.

In the heating mode, traditional reversing heat pumps can operate fine with EWT of 40°F into the evaporator & 68°F EAT into the condenser. However, MUA heat pumps cannot operate with EWT of 40°F into the evaporator and -10°F EAT into the condenser.

One method to overcome this limitation is to use exhaust air heat recovery to pre-treat the fresh air to a minimum of 40°F. This is a great idea, but comes at a considerable expense. Another approach is to use gas fired MUA's. This however can cause stress on the geothermal field, since it uses another source of fuel for heat instead of removing excess heat stored in the geo field.

Yet another approach is to place the GSHP MUA on a warmer and **<u>separate</u>** loop with water-to-water units. If they use this approach, they would not take advantage of shared heat opportunities between the suite units and the ventilation load and would incur higher capital costs since there would be two separate fluid loops.



The diagram above shows an actual design in Ontario, Canada, where the Engineer's design consisted of a building fluid loop tied into the geothermal field for the heating equipment as shown, while using another separate building loop for the reversing WSHP (this loop not shown).

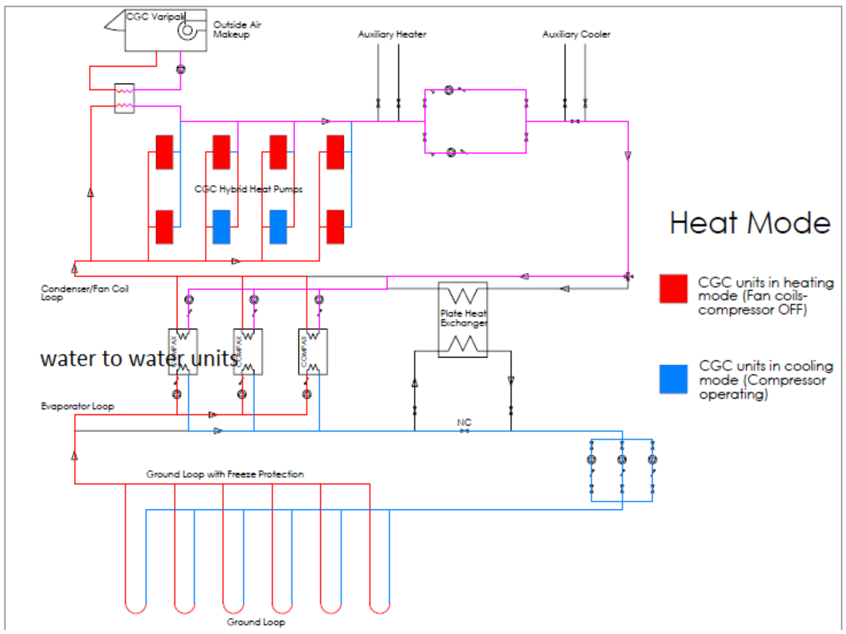
This practice is common because there are limitations when placing MUA's on the same loop as the reversing WSHP's.

A Bulldog system design would have only ONE common fluid loop, which would result in <u>lower capital cost</u> and <u>maximize the heat sharing capability</u> of the system.

What makes the Bulldog different and why is this significant for geothermal?

Since the Bulldog units operate as fan coils in the heating mode, they are not able to extract heat directly from the GHX on their own. The Bulldog system requires water-to-water units in order to extract heat stored in the geothermal field. The Bulldog system therefore operates on a warm fluid loop (105°F +) instead of a cold loop (45°F) as is the case with a standard GSHP system.

BULLDOG GEOTHERMAL DESIGN IN HEATING MODE
(Cooling is also available represented by units in blue)



The Bulldog Heat Pump solution in a Boiler / Tower application is quite simple. Utilize in suite units as water-cooled DX for cooling and hydronic heat (fan coils). Heating water is supplied by a central boiler heating plant. Compressors only operate in cooling mode, which increases performance and longevity and reduces maintenance costs associated with compressor replacement. During shoulder seasons, the heat rejected by the compressors operating in cooling is captured by the building water loop and utilized by the units in heating (fan coils). The process is a very efficient form of heat recovery and we call it Freeheat™.

The geothermal operation of the Bulldog system is similar, except the Heat Source and Heat Sink are now a geothermal field. In 100% cooling mode, the Bulldog units would reject heat directly to the geothermal field, much like a traditional GSHP system. However, since the Bulldog units operate as fan coils in heating, the Compax Water to Water units are required to extract heat from the GHX. The sole purpose of the water-to-water units is to extract heat from the geothermal field and deliver this heat to the building loop. The building loop will operate as a hydronic heating loop but also as the condenser loop, should any Bulldog unit require to be in the cooling mode. In the past, the requirement for these water-to-water units was perceived to be a negative for the Bulldog system since these additional refrigeration units were seen as doubling up on the compressors thereby adding significant capital cost. It is now understood by Geothermal Designers that the addition of the water-to-water units is **NOT** a negative, but actually a **positive** for the geothermal design. The reasons why the Bulldog system is better suited for geothermal applications is that there now exist only **ONE** shared hydronic heating loop that offers many design opportunities which help balance the geothermal field and potentially reduce the capital costs.

ALL heating loads can be tied directly onto one common loop with the Bulldog System.

BENEFITS OF THE BULLDOG WARM WATER LOOP

Only one hydronic heating loop

The many benefits of the Bulldog system stem from the fact that it is designed to operate as a hydronic heating unit i.e. fan coil.

This means that **<u>any and all</u>** building heating devices can now be connected on the very same loop as the Bulldog system. This will result in more sharing of heat and reduction in capital costs by minimizing the quantities of building loops.

As previously mentioned, traditional GSHP systems may not be able to place the MUA's on the same loop as the suite units.

That problem is now eliminated with the Bulldog system. We can simply tie in the MUA's (Varipak units by CGC Group) on the very same loop as **<u>All</u>** the Bulldog units. Not only does that eliminate a separate water loop, but it also places the ventilation load onto the geothermal field. This will greatly assist in balancing the heat content of the field.

This unique solution also addresses the following concerns when designing a geothermal system.

- **Heat Pump Run Time** – One of the greatest risks and challenges of utilizing gas fired MUA for the ventilation load, is the impact on the suite heat pump run time. If the MUA set point is too high, part of the heating load for the suites will be met by the fresh air migrating into the suites. This will reduce the much needed run time of the suite units during the heating mode, which extracts heat from the GHX. This will also cause a potentially unbalanced energy profile to be even more unbalanced, which may overheat the GHX within a few years. With the Bulldog Varipak unit, this risk is eliminated since **<u>100% of the MUA heating will be addressed by extracting heat from the GHX.</u>** Now the entire heating requirements of hallways and suites are met by equipment connected to the GHX. Concerns regarding over-heating hallways or reducing heat pump run times are eliminated, and operators can set temperatures at their discretion.

- **Load Balancing Opportunity** - Integrating the MUA onto the geothermal system provides the opportunity to manage the annual energy profile as it pertains to the geothermal GHX. For example, in cold climates, the annual ventilation heating requirements will probably be greater than the cooling requirements. Buildings with cooling dominant loads can now balance the system and extract more heat in the winter. The amount of heat extracted or the total load being addressed by the geothermal GHX can be managed much better. In a traditional GSHP system, separating the hallway MUA results in a missed opportunity and may need to be made up in other ways. This will add cost and reduce efficiency.

Heat sharing

By allowing more sharing of heat, the bulldog system rejects LESS heat to the GHX.

This is a result of heating and cooling functions operating simultaneously. This typically happens during the shoulder seasons and can be caused by exposure to opposite orientation (i.e. North vs South, East vs West), internal loads, or simply due to different occupancy requirement. This period of operation can be one the best operating periods for Bulldog Heat Pumps but also the most difficult to model.

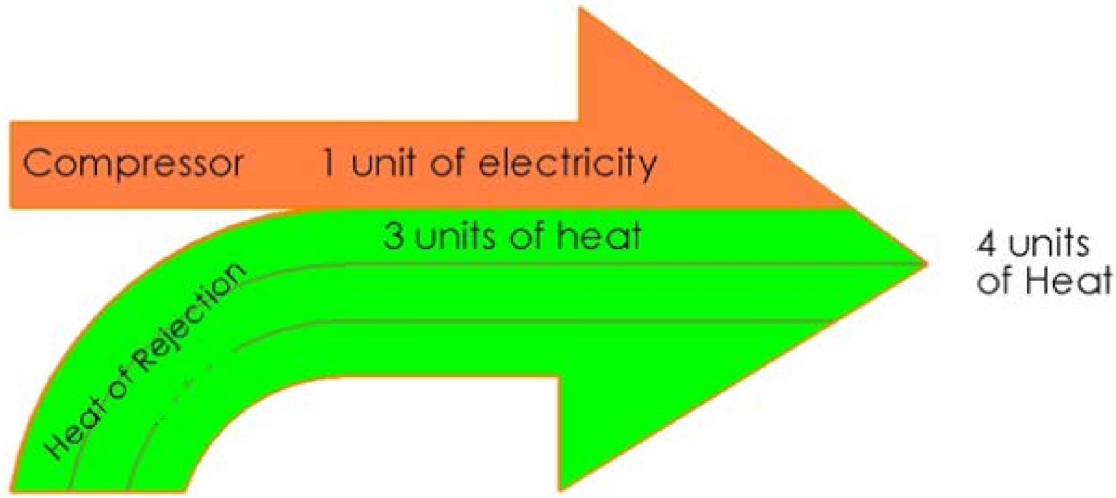
Freeheat™

Since the Bulldog compressors do NOT consume power while in the heating mode, they do NOT produce any heat. This is a significant benefit of the Bulldog system, which is often overlooked & misunderstood by Designers.

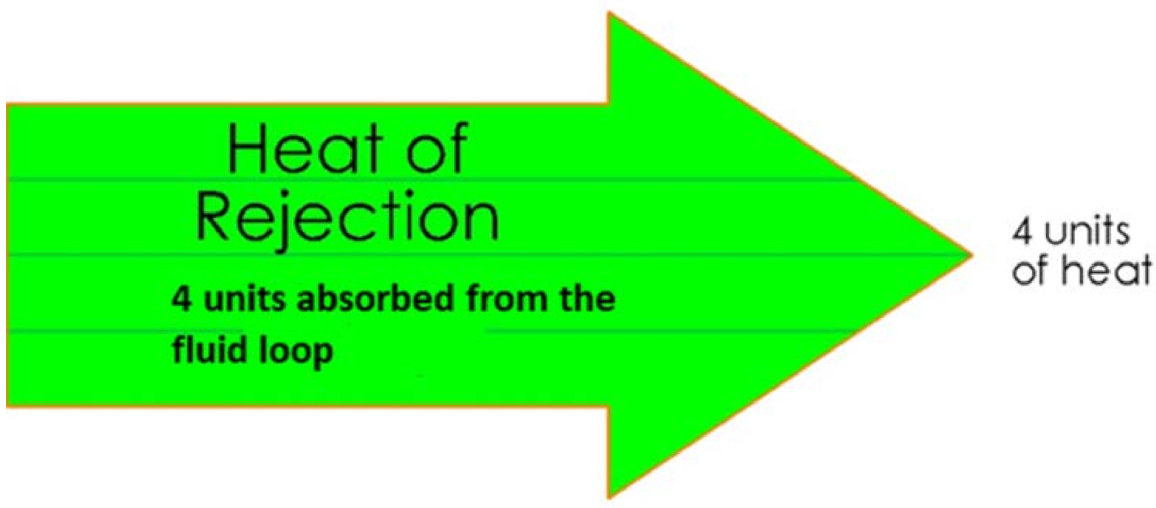
In the shoulder seasons (6 months?), during times of simultaneous heating and cooling operation, the Bulldog system can simply take the heat of rejection from the cooling units to directly satisfy the heat requirements of the " fan coils ". We call them fan coils since the compressors are not required to absorb the heat from the cooling units (FREEHEAT™). Conversely, with reversing WSHP in the heating mode, the compressor is responsible for 15 to 20% of the total heat being delivered by the units. The Bulldog units simply do not produce the 15% to 20% extra heat**.**

Therefore, the Bulldog units won't have the compressor energy to reject to the GHX.

With Reversing GSHP, it is possible that the 15% to 20% compressor heat is not required for heating purposes and they will have to reject that excess heat to the Geo field. This will cause more heat being rejected to the geo field than the Bulldog system.



If a standard GSHP has a COP (Coefficient of Performance) of 4 it only absorbs perhaps 75 % or 80 % of the available heat of rejection from the cooling units.



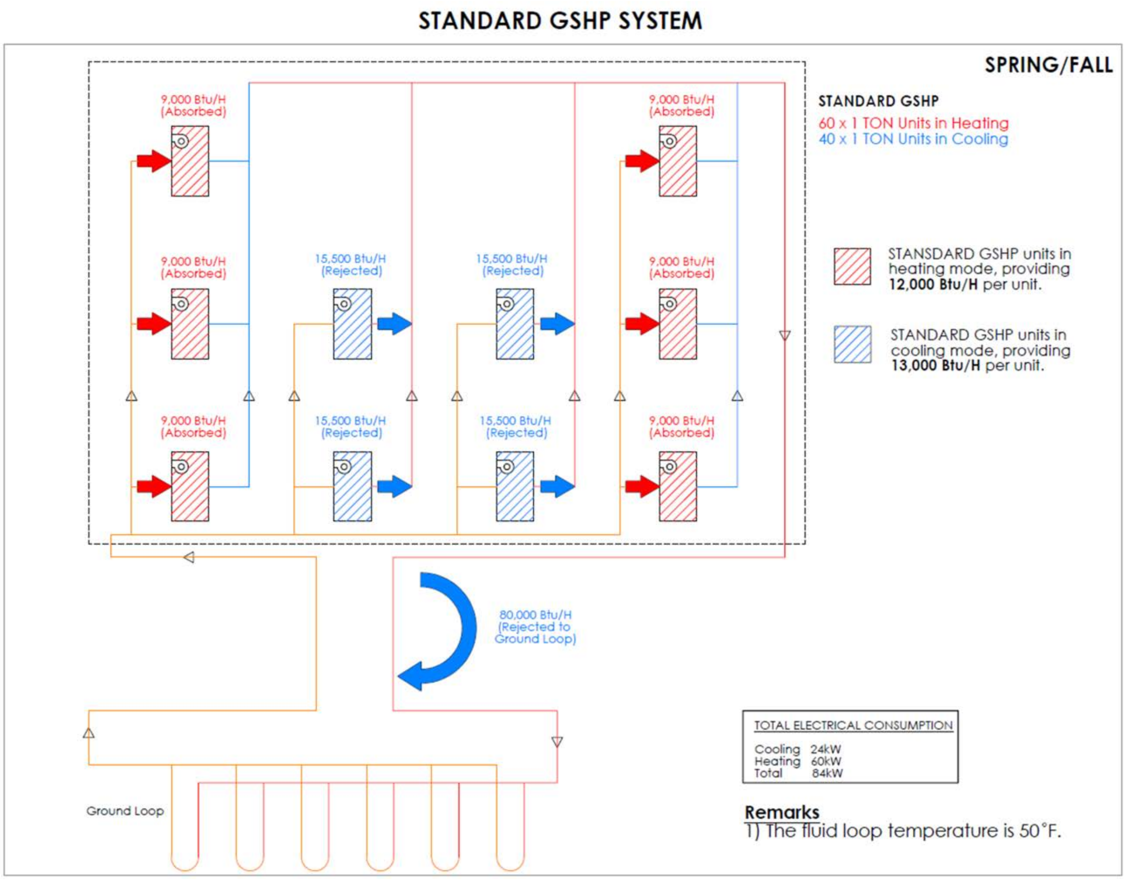
The Bulldog units will deliver the same amount of heat to the space, but with more heat being absorbed from the fluid loop. This can result in less heat being rejected to the GHX.

FREEHEAT™ can result in more heat being removed from the GHX

For identical operating periods, it is possible that the Bulldog system could be extracting heat stored in the GHX while a GSHP system would rejecting heat to the GHX. This is possible since the Bulldog fan coil units are not producing any heat, while the GSHP generate extra heat from their heating compressors.

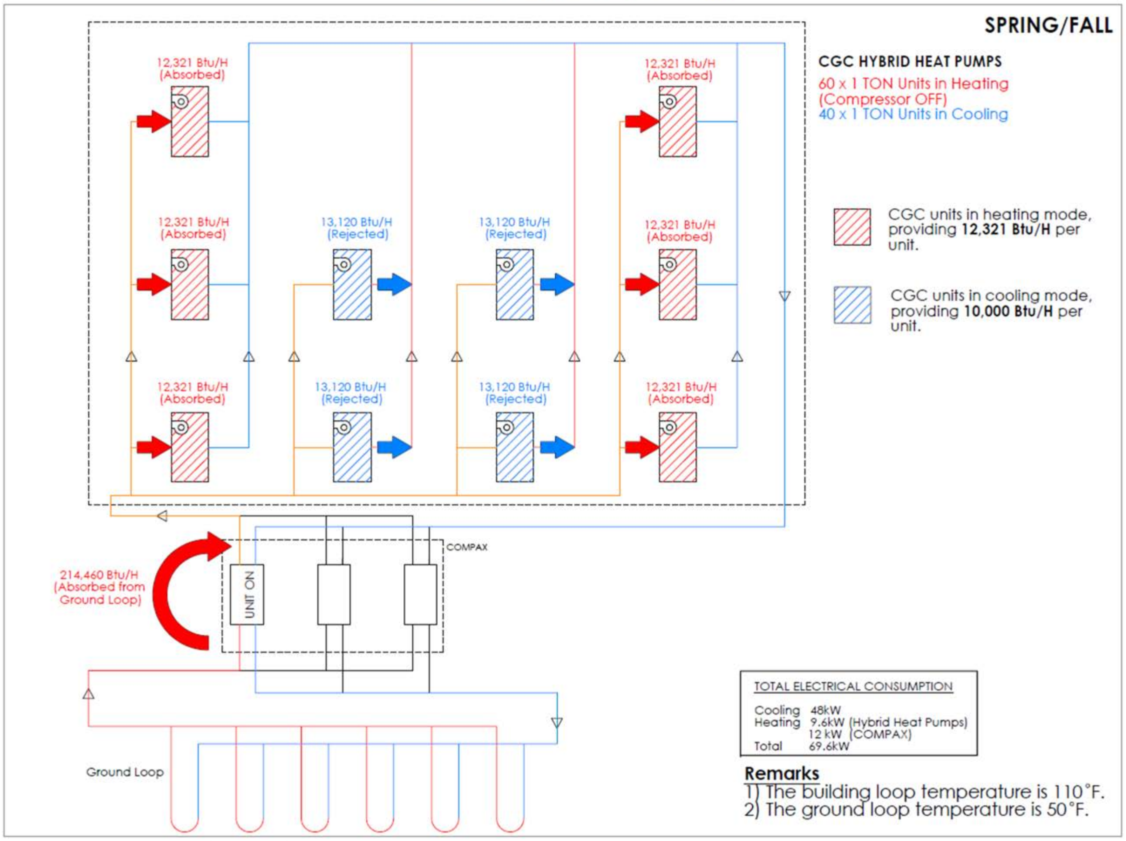
At certain operating periods, the Bulldog system may already be removing heat from the GHX while the GSHP is still charging the GHX.

The Bulldog system rejects less and removes more heat.



In this example of a standard GSHP system with 40 % of the units in the cooling mode and 60 % in the heating mode there is an abundance of heat in the loop since the WSHP compressors (electrical heat) are generating heat that is being delivered to the space. Since there is an abundance of heat, the geothermal field must be used as the sink.

CGC GEOTHERMAL SYSTEM



Since the Bulldog heating compressors do not consume any power and do not generate heat, for the same day of operation (40% cooling – 60% heating), the Bulldog system is already removing heat from the GHX and helping to bring back to balance mode. In order to make up for the lack of heat from the heating compressors, the heat stored in the geo field must be used. It must be noted, the Compax compressors would be contributing to the heat being delivered to the space and this heat is electrical heat much like a reversing GSHP.

However, the Compax Water to Water units would only be required while removing heat from the GHX. Consequently, the electric heat from the Compax operation would only be generated while removing heat stored in the geothermal field.

More Benefits by incorporating all heating requirements on the same fluid loop

Utilizing a central hot water heating system provides the designer options not normally available with a conventional distributed heat pump system.

DHW - For buildings that are cooling dominant, we have discussed the importance of integrating ALL heating load onto one common loops. For multifamily buildings, the DHW loads are significant.

Addressing most or potentially all of the DHW needs with the Compax units will increase the heat removal capability in both winter and summer. This process reduces the aggregate annual heating load on the geothermal field. This will complement the Designer's quest to balance the loads/energy profile. Because DHW needs are the same all year, the ability to heat water in the summer helps reduce peak cooling loads.

The benefits of utilizing the Compax Chiller for DHW in a geothermal application are as follows:

- additional heating demand placed on the GHX
- Reduces heat rejection to GHX during peak cooling operation
- Displaces natural gas – local incentives, carbon reduction, potential for emissions free building

Snow melt

Many buildings in northern climates require snowmelt for walkways or entranceways for safety purposes. Even the smallest application can have a significant impact on the geothermal GHX performance. Servicing the snowmelt requires minimal effort and cost since the Compax units are already in place and there is hot water available for heating. This increases the heating demand placed on the GHX in the winter and assists in balancing the load**.** This may also provide an opportunity to dump heat in the shoulder season. Heat can be rejected passively through the snowmelt system when the outdoor ambient temperature is lower than the loop temperature.

ECONOMICS

There's a common misconception that if a product is more efficient or provides more features it must be more expensive. Product costing is typically done by comparing one supplier versus another. Even when doing a cost benefit analysis there is often several significant factors that are overlooked. Because the uniqueness of the Bulldog system it is critical to perform a full analysis and take a more holistic approach. When creating a financial analysis there are several key things to consider:

1) Size and cost of GHX - If a geothermal system is being considered, it is important to recognize the impact that the Bulldog system has on the GHX cost. There will be a significant impact on the entire financial profile if the Bulldog system can reduce the size of the geo field by 20 – 30%. Actual projects have seen a reduction of the GHX due to the Bulldog design. Reducing GHX size will also reduce drilling time, which will have a positive impact on the construction schedule. Quite often, construction schedules have a financial cost associated with delays.
2) Hybrid requirements – In many cases the way to deal with an unbalanced load or high cooling peaks is to provide a hybrid system (GHX + Boiler or Tower). The capital cost of the fluid cooler can be quite high. The more significant impact can be the cost to own the fluid cooler. Maintenance, water consumption, chemicals and capital reserve required for future replacement, all impact the building financial pro forma. Because the Bulldog system helps to balance the load and can operate at higher EWT, there may be an opportunity to eliminate the need for a fluid cooler.
3) Long term performance of GHX.

GEOTHERMAL UTILITY MODEL

The CGC Group has partnered with a geothermal utility company, which offers a third party ownership model that provides the developer a no cost approach to geothermal. Diverso Energy will design, build, own and operate the GHX, pumps and controls. Not only does this remove the cost of the geothermal bore field, it also transfers the performance and operational responsibility to Diverso who has over 10 years of design and operating experience. Developers can still leverage the sales, marketing, building code compliance, and all other benefits of geothermal, minus the cost and responsibility.

Why Diverso Energy supports Bulldog

Diverso takes full responsibility for the performance of the GHX during the entire 30-year contract. The GHX performance is directly related to the building performance including the mechanical system. The Bulldog system is not only efficient but it also reduces the BTU's being extracted and rejected to the ground which provides better opportunities to manage the heat exchange to the ground. Diverso sees the Bulldog system as a way to mitigate risk.

Leverage for the Bulldog Rep

As a Sales Rep, you are always looking for ways to differentiate your product. The Bulldog/Diverso relationship in Ontario has resulted in owners switching to Bulldog based on the advice of Diverso. Owners receive lots of advice from designers and others involved in the project, but how often is there a financial commitment. In other words, Diverso's opinion carries a lot of weight because they are investing their own capital into the project just like the owner. Diverso's ability to recover that capital is 100% dependent on the operation of the geothermal GHX. This makes their endorsement far more significant.

Bulldog Reps can leverage this influence by partnering with Diverso on projects where the owner is considering at geothermal, or where geothermal may make sense. Often owners are often aware of geothermal but immediately associate it as a premium. If they were made aware that with a model like Diverso's, it may actually provide cost savings especially when coupled with a solution like Bulldog they may be willing to take a much closer look. Attaching the Bulldog system to a no cost geothermal and presenting it as a long term risk reduction should ease some of the concerns sometimes associated with Geothermal systems.

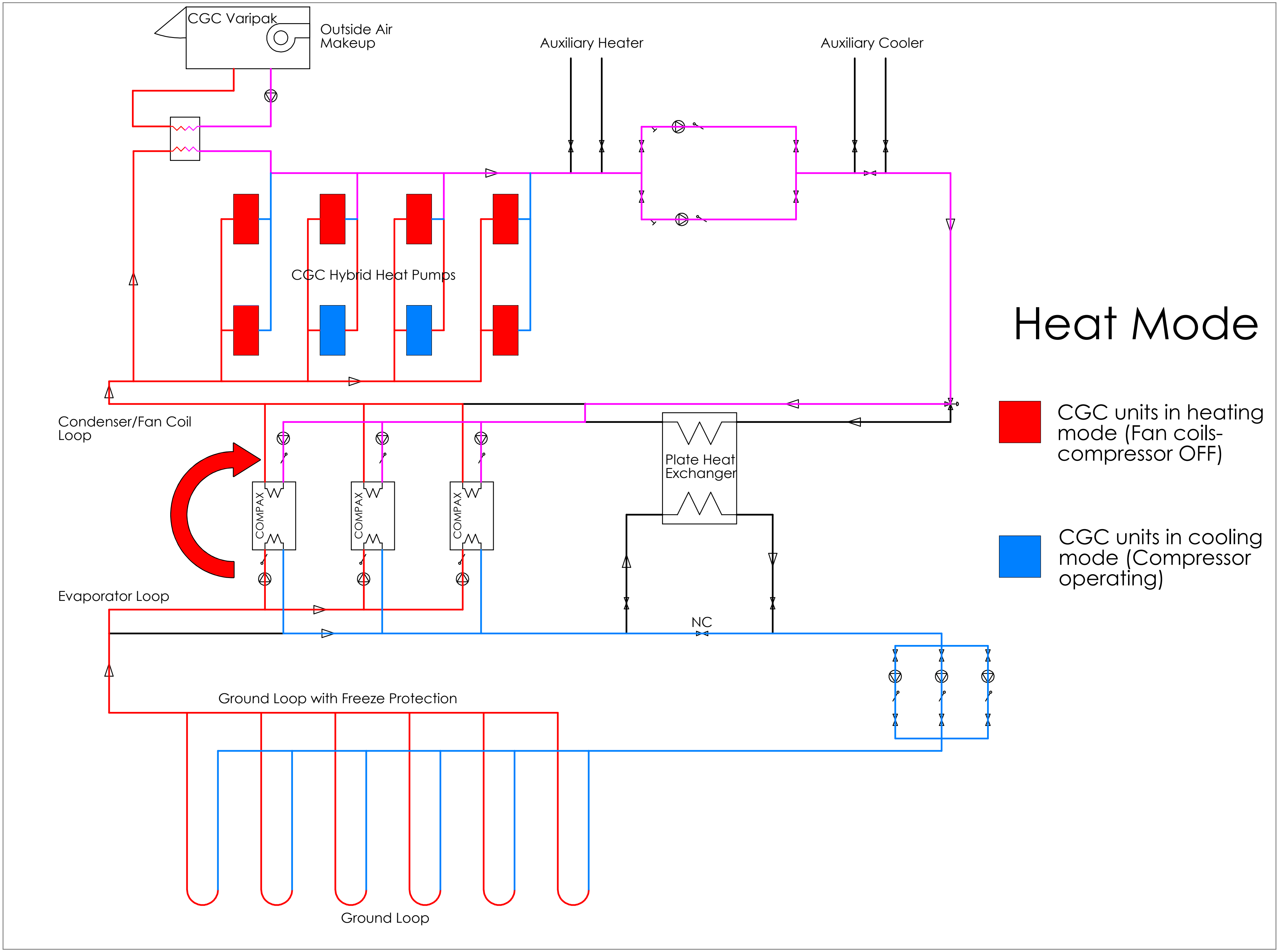
Tim Weber

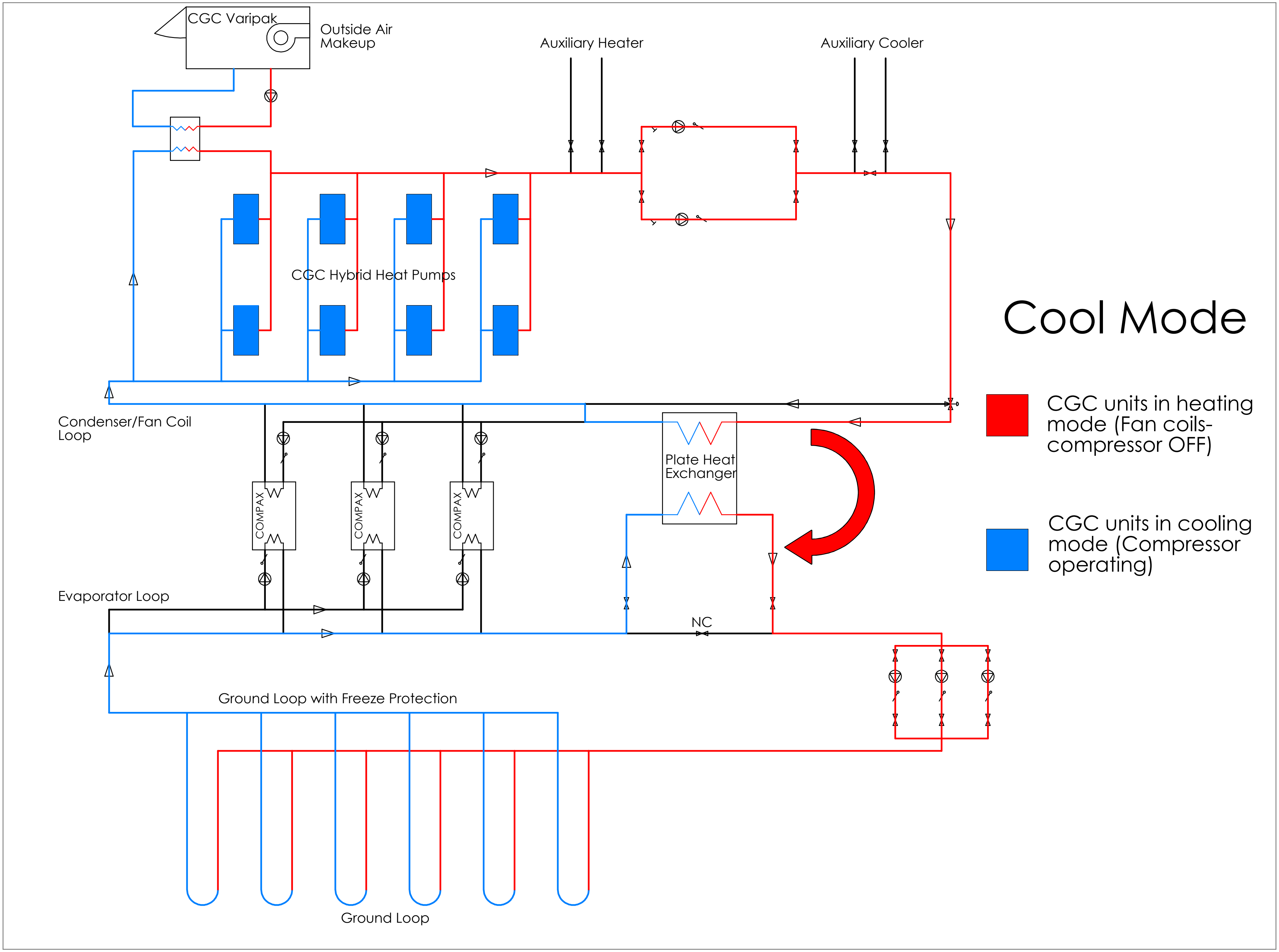
https://www.diversoenergy.com/

Tim Weber brings over 20 years of HVAC and Geothermal experience to the Diverso Energy management team.

In 2004, Tim joined NextEnergy, the largest supplier of geothermal heatpumps in Canada. Tim's initial role as Technical Service Manager included design, installation and service training to contractors across Canada. During that time, he contributed to the development of the new CSA 448 geothermal standard, while also creating the training material for geothermal design, sizing, installation and service. Tim was often called in to provide his expertise regarding problems with existing geothermal systems. In 2006 he became the Sales Manager for North America. Leveraging his expertise and knoweldge in the industry, he trained over 30 conventional HVAC firms in how to excel as geothermal contractors. From 2004 to 2010, these contractors under his leadership completed over 5,000 geothermal installations. While providing design and onsite support for several commercial projects during that time, Tim shifted his focus to commercial systems in 2010 both in Canada and the US. During that time, he worked directly with Engineers and Architects helping them better understand geothermal applications and provide assistance to the integration of geothermal into their conventional designs.

APPENDIX


CGC Varipak
Outside Air Makeup
Auxiliary Heater
Auxiliary Cooler
CGC Hybrid Heat Pumps
Heat Mode
CGC units in heating mode (Fan coils-compressor OFF)
CGC units in cooling mode (Compressor operating)
Condenser/Fan Coil Loop
Plate Heat Exchanger
COMPAX
COMPAX
COMPAX
Evaporator Loop
NC
Ground Loop with Freeze Protection
Ground Loop



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CGC units in heating mode (Fan coils- compressor OFF)
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Loop
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Exchanger
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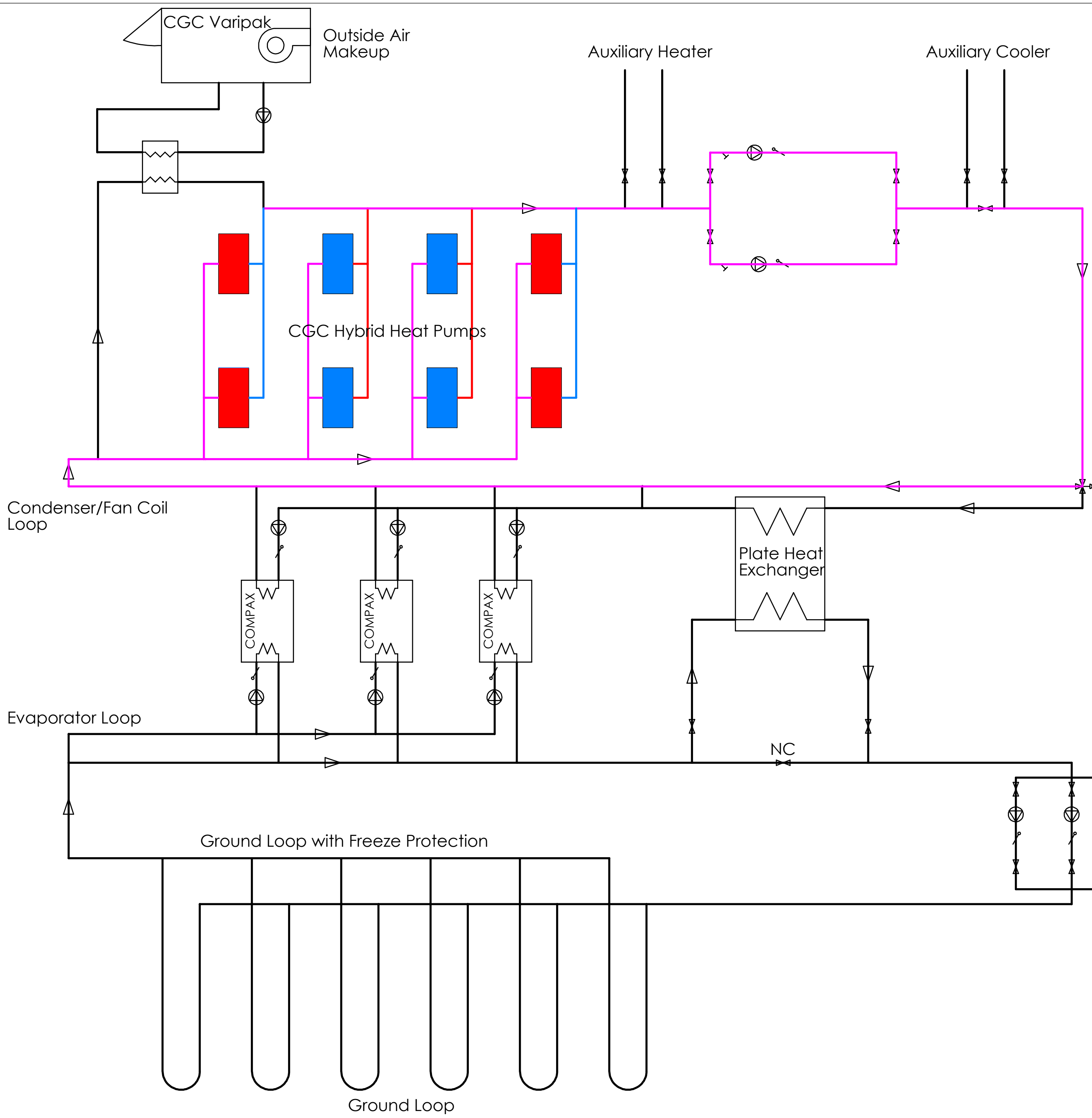
COMPAX
Evaporator Loop
NC
Ground Loop with Freeze Protection
Ground Loop

Balance Mode



CGC units in heating mode (Fan coils-compressor OFF)

CGC units in cooling mode (Compressor operating)