THERMAL GRADIENT HEADER (TGH)

HVAC REIMAGINED

Presented by:

THERMENEX

TECHNOLOGY INTRODUCTION AND BACKGROUND

THERMAL GRADIENT HEADER (TGH)

WHAT IS A TGH?

A piping framework and standardized control sequence, upon which HVAC engineers develop their schematic designs.

A TGH is a continuous pipe filled with water or glycol that has a hot end and a cold end with a gradient of variable temperature zones in between. It functions as a smart hub for thermal energy transport by moving thermal energy within a zone or from zone to zone depending on demand.

The TGH integrates, and also separates. systems based on supply and return fluid temperatures, independent of whether they are used for ‘heating’ or ‘cooling’ or both.

The TGH allows HVAC engineers to use standard HVAC equipment and components to develop designs that provide the most efficient and cost effective method to manage thermal energy resources in and around a building.

A TGH increases a building’s overall thermal efficiency by eliminating waste thermal energy. The energy is collecting and relocated to other building areas that need it.

A TGH is based on understanding that heating and cooling are the results at opposite sides of every thermal transfer. Heating something always results in cooling the thing that the heat came from. Every heat transfer is always simultaneously both heating and cooling.

A Thermal Gradient Header is an HVAC solution conceived on the basis of exergy preservation to reduce energy consumption and carbon emissions by the holistic integration of all building thermal energy systems.

THERMAL ENERGY TEMPERATURE = QUALITY

Utilizing thermal energy resources in and around a building reduces the amount of non-thermal resources that need to be consumed. The preservation of non-thermal resources allows them to be used for higher quality work, creating a much better use of their *exergy* - the quality of our energy resources.

A TGH optimizes thermal energy in a building by using lower temperature heating and higher temperature cooling systems to recycle thermal energy and maintain building conditions.

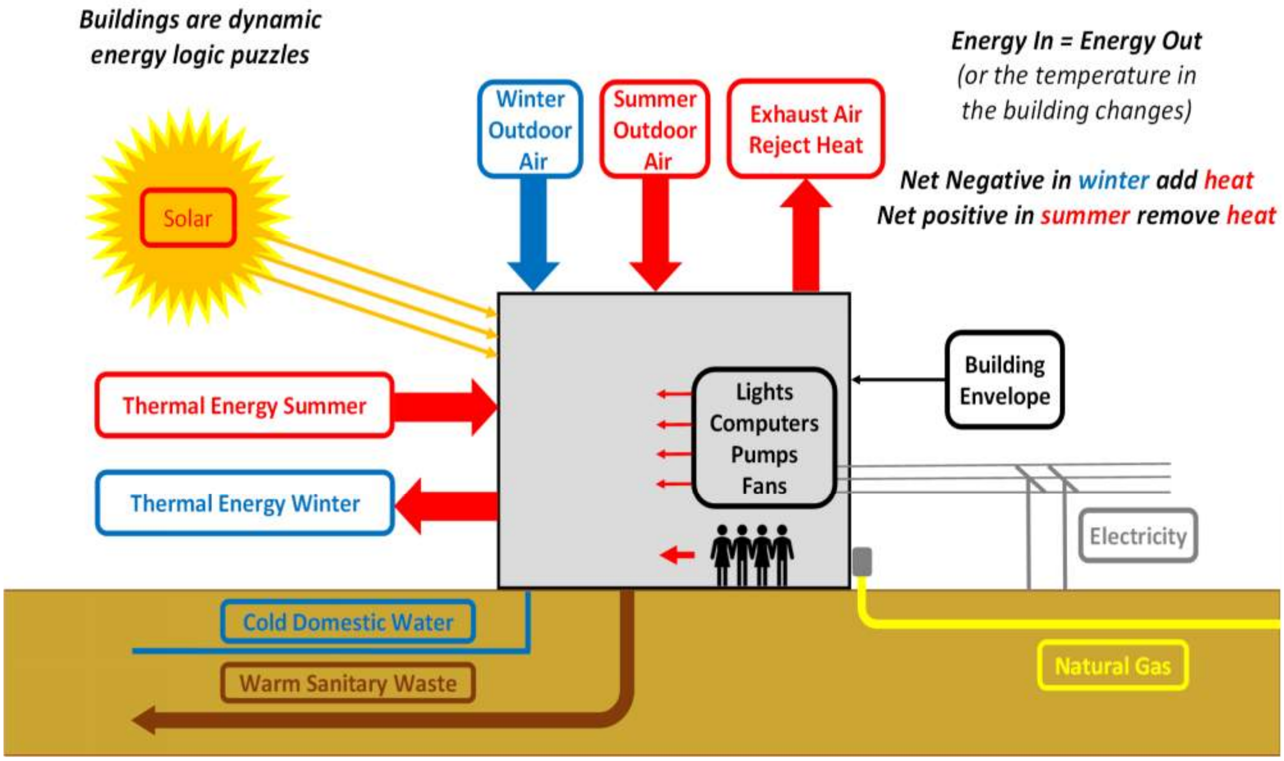
Lower temperature heating and higher temperature cooling systems consume less energy because there are:

- Fewer thermal loses
- More efficient equipment options (Condensing Boiler, Heat Reclaim Chiller)
- More energy sources (Building Thermal, Outdoor Air, Waste Water Heat Recovery, Solar Thermal, Geo-Exchange...)

Heating is the transfer of thermal energy from one object to another.
Cooling is the transfer of thermal energy from one object to another.

HEATING is COOLING

QUESTION: WHAT IS A BUILDING?



HOW DO CONTEMPORARY BUILDINGS OPERATE?

From a heat transfer perspective, a building is an enclosure that maintains a controlled interior environment regardless of the changing environment outside. Heat energy passes through the building's envelope, which and must be managed to ensure a constant indoor environment.

Maintaining a constant indoor environment is the process of ensuring the quantity of energy entering the building equals the quantity of energy leaving the building.

When too much heat energy is leaving through the building envelope, like in the winter, the building gets cold. Thermal energy must be added by the HVAC system to replace the heat that was lost.

If too much energy is entering through the building envelope, like in the summer, the building gets warm. Thermal energy must be removed by the HVAC system to remove the heat that was gained.

A TGH optimizes a building's intrinsic thermal energy before relying external resources.

The goal: Zero Thermal Waste.

ANSWER: A THERMAL ENERGY RESOURCE

OPTIMIZING THERMAL ENERGY RESOURCES

Optimized heating and cooling return water temperatures overlap.
Leaving no reason to separate heating and cooling piping systems.

Buildings need heat for up to 5 things:

- Domestic Hot Water Final Heat
- Domestic Hot Water Pre-heat
- Building envelope thermal loss
- Outdoor Air Final Heat
- Outdoor Air Pre-heat

Each use has a different temperature requirement, meaning there can be five *different* heating water supply and return temperatures required to optimize energy use in a building.

The amount of energy required to satisfy these different loads varies daily and seasonally - meaning to optimize performance, the heating system sources must also be able to respond to the changes.

Optimizing a heating system for pre-heating outdoor air can provide return fluid cooler than a chiller can produce, which can be used to passively and efficiently reclaim more heat.

Traditionally buildings needed cooling for 3 things:

- Building envelope thermal gain
- Tempering of Outdoor Air
- Building internal heat gains

Unlike heating, only one temperature of chilled water is required for these cooling loads.

Optimizing a cooling system with the highest possible return temperature can provide useful heating to other parts of the building for 'free'.

A high-performance building needs cooling for a 4th thing:

- Collecting heat from thermal resources

A TGH employs a heat pump to create a second colder cooling temperature that is used to collect more heat from non-building load thermal resources, like exhaust and outdoor air. The colder the fluid, the more energy can be collected.

BURNING NON-RENEWABLE RESOURCES IS NOT THE CLEANEST OR MOST EFFICIENT METHOD TO PROVIDE THERMAL COMFORT FOR YOUR BUILDING

APPROACH

The experts at Thermenex have proven that the application of TGH technology is a cost effective way to achieve a Resource Sustainable Large Building - a building that has no wasted energy and minimum destroyed exergy (energy from high quality external resources).

Achieving thermal efficiency using a pipe with hot water at one end and cold water at the other may seem counterintuitive.

The obvious question:

Wouldn't the heating and cooling just mix?

Thermenex has developed the answer:

The TGH has six distinct temperature regions that are separated using a simple hydronic design so they do not mix. This enables matching of source temperatures with the variable load requirements of a building.

Conventional systems have only two temperatures - one hot and one cold. All the various heating systems mix to the one hottest supply temperature and the various cooling systems mix to the one coldest supply temperature. TGH Systems don't mix, and thus they are more efficient than conventional systems.

RESULT

Having a patent gave Thermenex an opportunity to do what others would love to, but could not - build various configurations of the gradient technology and test them on operating buildings in real world conditions.

Thermenex gained valuable expertise and knowledge based on lessons learned during the real world testing on 20 systems, serving over 30 buildings - some operating for more than 10 years.

One painful lesson - it was too complex. So in late 2018, Thermenex reimagined the gradient technology and developed another innovative piping arrangement that is now patent pending: A ***Single Primary, Dual Secondary*** piping arrangement. (See schematic on next page)

This innovation provides automatically optimized dual heating temperatures from a heat pump plant - all controlled with a single temperature setpoint, making the high performing system easier for programmers to program and building operators to understand and manage.

The TGH is the result of this research and development

Large buildings are complex dynamic thermal energy logic puzzles.

The solution must be *"as simple as possible, but not simpler."* *- Albert Einstein*

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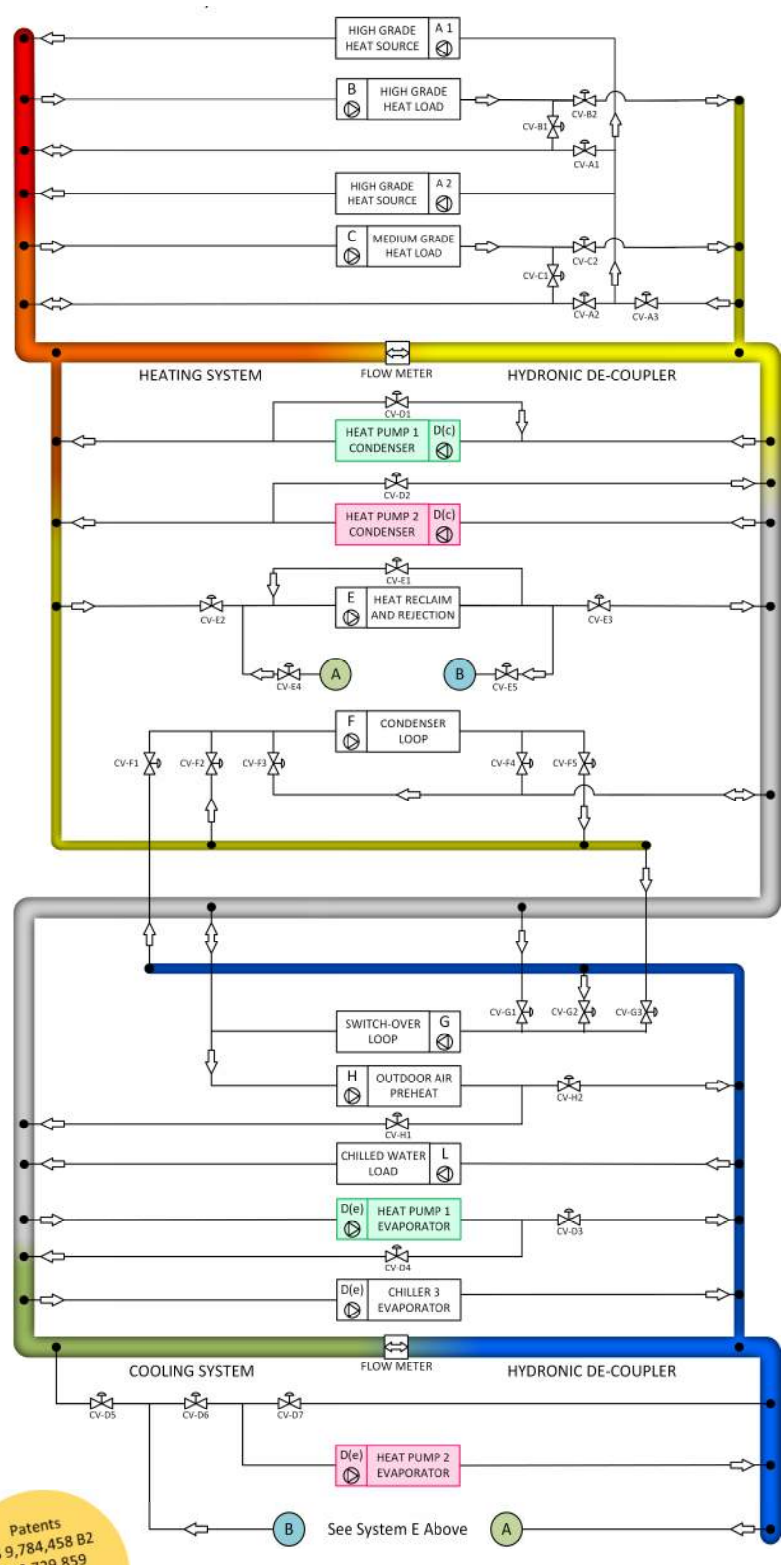
TGH - FRAMEWORK



A is piped to A B is piped to B

Sub-Systems	Sample Options
A: High Grade Heat Source	Boilers District Energy CHP
B: High Grade Heat Load	Perimeter heat Radiant panels DHW Final Heat
C: Medium Grade Heat Load	Terminal Coils DHW Preheat
D(c): Heat Pump Condenser	R-134a screw chiller R410a Scroll Heat Pump
E: Heat Rejection and/or Reclamation	Exhaust Air Cooling Tower Adiabatic Cooler/OA Source District Energy Sharing Geo-Exchange Sewer Exchange Ice Rink Cooling
F: Condenser Loop	Process Cooling Low Temp District Heat ETS High Temp Cooling Ice Rink Condenser
G: Switch-Over Loop	Main AHU Coils Peaking District H/C ETS
H: Outdoor Air Preheat	Preheating creates CHW in winter (Active and Passive)
L: Chilled Water Loop	Fan coils, Chilled Beams District Cooling ETS
D(e): Heat Pump Evaporator	R-134a screw chiller R410a Scroll Heat Pump

If desired, thermal storage would be integral to the TGH and become the hydronic de-couplers.

In Ice Rink applications the ice plant chiller can be ammonia, R-134a or R410a and the chiller provides comfort cooling in the summer for the rest of the building if the ice has been taken out. Heat Pump 1 is selected so it can provide back-up to the main ice plant chiller.

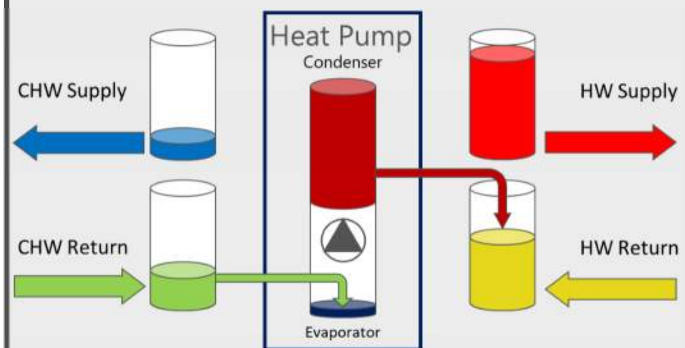
Patents
US 9,784,458 B2
CA 2,729,859
EPO 10,751B
Plus additional pending

General Framework - Not all systems apply to all projects

HEAT RECLAIM EFFICIENCY

Thermal energy flows naturally across a temperature differential toward colder regions.

This natural flow of thermal energy is reversed by heat pumps and chillers, which take thermal energy from something cooler and move it to something warmer.



A heat pump is a thermal energy quality increaser. It collects heat from a lower temperature fluid and makes it warmer so it can flow into another warmer fluid.

This heat extraction is against the natural flow of thermal energy, and so electrical energy is required to make it happen. This electrical energy is not wasted when the building needs heat as it too becomes heat.

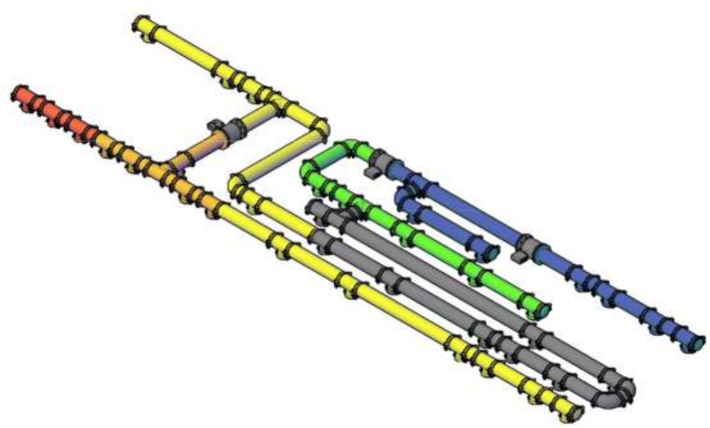
Highest efficiency occurs when the CHW supply is warmer and the HW supply is cooler.

TGH APPLICATION LOGIC

Temperature requirements for different zones dictate the relative location of supply and return water connections.

With the TGH, thermal energy is collected from anywhere in a building or near a building and is made available to anything in the building. Not until the building system has optimally reused all of its intrinsic internal thermal energy and all available external thermal resource, are any external non-thermal resources consumed.

This TGH compact piping framework allows an engineer to design a solution with the minimum in HVAC component utilization, energy use, and carbon emissions.



Maximum efficiency is achieved with Heat Pumps that collect thermal energy from sub-systems connected to the lower temperature sections of the TGH and deliver it to sub-systems connected to the warmer temperature sections of the TGH.

Heat pump efficiency or Coefficient of Performance (COP) increases significantly if it cools something warm and heats something cool

APPLICATION LOGIC CONTINUED

Heat is collected from anything and everything available by cooling anything and everything possible. Heat transfer between simultaneous building heating and cooling loads is the obvious first choice. Return air and exhaust air are often the second choice. Outdoor air is another choice.

Any hydronic system, at any temperature, can be selected and connected to the header. All choices can operate simultaneously. If simultaneous heating and cooling is not providing enough heat, you simply and seamlessly start cooling, or collecting heat, from another available choice using the same equipment that was cooling the building.

Sub-systems and equipment can easily be dual purpose for both heating and cooling by simply connecting them to multiple locations on the TGH using control valves, reducing the overall number of components and cost.

A sanitary waste water heat exchanger, and/or geo-exchange can be directly connected to the header to either reclaim or reject heat.

'Free cooling' , commonly used in sustainable building design, is the free removal of heat in the winter - an irrational practice if another part of the building could use the heat.

TGH CONTROLLOGIC

TGH Control Sequence maximizes the effectiveness of reclaiming thermal energy from all available sources across the header. The Logic Control synchronizes demand-based feedback from various sub-systems and is used to optimize heating and cooling temperatures to satisfy every building load.

Managing interactions throughout the header allows the logic control to maximize the re-use of thermal energy before consuming energy from an external resource or removing energy using heat rejection equipment like a cooling tower. An additional feature of the control logic is to prioritize certain thermal loads over others based on temperature needs and building manager preferences.

An example of the logic control's process is: when there is a condenser water loop in the building, the temperature of this loop is controlled by the logic control within a range to make the loop temperature useful for heating of outside air or radiant slabs. In this way, the heat is re-used directly before being upgraded using the heat pumps.

On colder days, the lower portion of the TGH becomes a passive run-around loop between the chilled water or exhaust reclaim coils and the outdoor air pre-heat coil, providing both passive and active heat reclaim.

TGH CONSTANTLY MANAGES THE EVER CHANGING THERMAL ENERGY TRANSFER BETWEEN SUB-SYSTEMS.

WHY CONNECT HEATING AND COOLING TOGETHER

Efficiency: Continuous optimizations of multiple temperatures make the heat pumps dynamically optimized; operating actively when required and passively whenever possible.

Simplicity: Because all loops are connected to the header, changeover can be accomplished very easily to reduce the number of components required. For example, existing cooling coils can be used as heating coils - simplifying retrofits. Exhaust coils can reclaim and reject heat.

Resiliency: With all systems interconnected there is inherent resiliency and redundancy; an important consideration for a critical environment. The total TGH system will keep working even when some components fail.

Capital Cost: Individual components can be configured to provide heating, cooling and by default heat reclaim, resulting in fewer components, control valves and piping needed for a building.

Life-cycle Cost: There is no requirement for proprietary equipment. The system employs standard components that are less expensive to replace. The header pipe will last the life of the building.

Guarantee: Assuming our product application guide is followed, if it doesn't function properly, Thermenex will fix it - backed by a $5,000,000 general liability insurance policy.

RESOURCE SUSTAINABLE DESIGN PRINCIPLES

1. The first stage of heating shall be provided by building thermal energy.
2. No external resources are to be used as a heat source at the same time recoverable heat is being rejected.
3. Heating systems are to be designed to <u>return</u> the lowest heating water temperature to satisfy each load, with control logic to automatically reset the supply temperature based on demand.
4. Cooling systems are to be designed to <u>return</u> the highest cooling water temperature to satisfy each load, with control logic to automatically reset the supply temperature based on demand.
5. Larger exhaust and relief air systems must be equipped with heat recovery.
6. Heat reclaim is to take precedence over air-side and water-side economizing.
7. Heat reclaimed from all sources must be holistically available for any load.
8. Whenever possible utilize 'passive' heat recovery from reclaim source to load.

DESIGN METHODOLOGY

The performance of a TGH System depends on the ingenuity of the integrated mechanical system design. The following innovations have proven to achieve excellent performance:

- A TGH system treats the building as a thermal resource. It takes a holistic view to the thermal inputs to the building. Thermal energy is a resource to be conserved and reused. Examples: DHW heating helps cool your building.
- The Control Logic differentiates loads and sources into temperature categories. Allowing the engineer to design optimized variable temperature systems that lower the heating temperature and raise the cooling temperature based on demand.
- Engineers can design outdoor air supply systems that heat and cool the air <u>before</u> mixing it with return air. Instead of specifying the traditional 'mixing' section of an air handling unit.
- Designing cooling, heating and reclaim systems around variable temperature chilled water.
- Designing with the ability to cool exhaust air. This reclaims heat out of the exhaust and makes it holistically available for any building heating load.
- "Free Cooling" occurs only when the total building cooling demand exceeds the heating demand. Most "free cooling" systems waste heat by rejecting heat when the building needs it.
- Focusing on optimizing part load performance over peak load performance.
- Appropriately sizing system selections for low temperature heating and high temperature cooling. Focusing design on return water temperatures.
- Utilizing components for multiple uses wherever possible – e.g. using cooling coils for heating to reduce airside pressure drop and reducing heating water temperature.
- Standardizing control sequence for repeatability and easy troubleshooting.
- Considering some form of thermal storage. Short term thermal storage results in less installed instantaneous equipment capacity. ***Seasonal thermal storage can achieve net-zero carbon***.

DISTRICT ENERGY

A TGH at the district level is a hybrid of a traditional district system, an ambient temperature district energy sharing system, and also a stand-alone building system. The hybrid takes the best of each system while addressing these issues:

- Traditional District Energy performance is limited by the need to supply heating fluid at one temperature.
- Ambient 'energy sharing' loops provide unwanted mixing of heating and cooling fluids.
- Stand-alone buildings lose the benefit of economies of scale for resource sustainable energy options.

COMMON MISCONCEPTIONS

The TGH is used to store heat.

The TGH is not a thermal storage device, it is a dynamic thermal energy exchange hub. The fluid does not thermally stratify, and the pipe can be in any orientation. Thermal storage, such as geo-exchange, water tanks or phase-change materials, can be added as desired.

The TGH is sized as a low-loss header.

All main systems have variable flow so most of the time the TGH functions with low loss. However, based on tested hydronic strategies and arrangements, oversizing the TGH can create unwanted cross-circuiting within the header. The pumps are carefully arranged for minimal hydraulic interference or configured in a way to aid each other during operation.

The temperature at each connection node is maintained at a constant temperature.

The temperatures at each node are dynamically reset based on demand. The program automatically adjusts the dual heating water temperatures and the dual chilled water temperatures based on the variable demands.

The TGH is only useful for simultaneous heating and cooling.

The TGH is ideal for simultaneous heating and cooling but is not limited to this condition. When the heating load exceeds the cooling load, the header provides simultaneous heating, cooling and heat reclaim. When the cooling load exceeds the heating load, the TGH provides simultaneous heating, cooling and heat rejection.

THE THERMAL GRADIENT HEADER

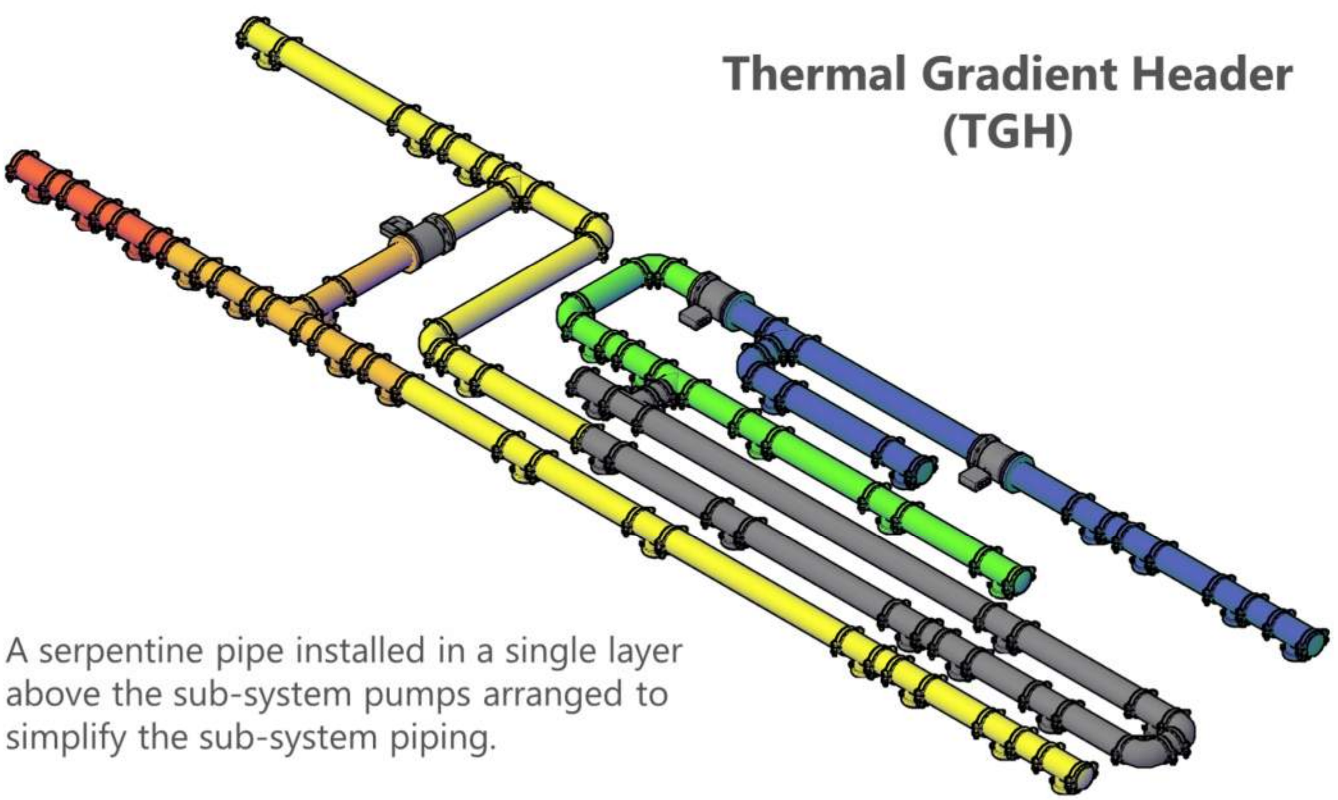
A TGH System offers a unique approach for engineers to achieve a Resource Sustainable Building. Its advantages are often best applied to the heating and cooling of large buildings and building systems in cool climates.

The greatest barrier to the prevalence of TGH systems is a lack of knowledge. Many building owners, architects and engineers are not aware of the energy conservation benefits of a TGH.

A TGH System, when combined with good engineering in certain buildings, can outperform every other system available on the market in both carbon emissions and energy costs.

TGH Systems are delivered in a collaborative manner with a single point of responsibility for functional performance.

Contact us at: info@thermenex.com



A Resource Sustainable Building minimizes the destruction of exergy - the potential of an energy resource