Loopfields and Piping Design Workshop

Week 2 – Piping Optimization with GLD2014

Welcome!

Instructor: Dan Bernstein

Welcome! Week 2: Piping Design and Optimization

The objective of this workshop is to provide the geothermal designer with an in-depth look at designing practical and purgeable piping system designs using the industry leading Ground Loop Design GLD2014 Software Suite.

You are encouraged to interact with your instructor. We are seeking to provide the geothermal professional with the tools and familiarity that he/she needs to optimize a wide range of GSHP systems.

By extending the user's mastery of the GLD program, it is possible to eliminate the design and field guesswork that has often been used to connect loopfields to the load systems. Designers will quickly discover that the drudgery of hand calculations can be eliminated and replaced by a much more accurate and practical tool that designs piping systems which can be effectively purged and can be built with pipe sizes and types that are appropriate to your operations.

Workshop Outline - The CFD Module

- **What is the CFD Module?**
- What are we Trying to Accomplish?
- Brief Review of General Fluid Dynamics Calculations
- Reality Check
- Learn Standard Nomenclature for Geothermal Piping Systems
- Basic Standard Configurations: Direct Return & Reverse Return Systems
- Purging Design & Performance: Direct Return & Reverse Return Systems
- Good Design Practices
- Using the GLD 2014 CFD Module to Design Piping Systems

The CFD Module

What is the CFD Module?

The computational fluid dynamics (CFD) module enables designers to easily design, build, simulate and optimize the piping systems that comprise the foundation of ground heat exchanger systems.

Why does one want to optimize a piping system?

To ensure that the system can be purged and to ensure that the system provides effective heat transfer with minimal circulation pump costs.

Can't I do this by hand?

Not really. Modeling reverse return systems is very complex and impossible to do with any accuracy by hand or even with a spreadsheet. Plus, it takes hours to make modifications and redo calculations. With the CFD Module, it takes a few seconds.

The CFD Module

What can the CFD Module model do?

The CFD module can model piping systems that consist of a wide possible range of connected components including : Manifolds/Vaults, Supply and Return Runouts, Supply and Return Headers, single and double u-bends, the fittings that connect the systems together and circulation pumps.

How does it do this?

Utilizing a new, patent-pending visual interface for viewing and creating a design via a drag and drop methodology, the CFD module can automatically design optimal flow-balanced (direct and reverse return) systems while providing designers with the flexibility they need for standard and non-standard systems.

The CFD Module

What results do I get out of the Module?

Outputs include flow rates, fluid velocities, Reynold's numbers, pressure drop, fluid volume and the like for every single point in a dynamic geothermal piping system.

Workshop Outline – What are we Trying to Accomplish

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What are we Trying to Accomplish?

- We want to design geothermal heat exchangers that are easily purged and perform well.
- We want a system that is easily purged so that we can get all the air bubbles out and ensure stable performance.
- We want a system that performs well so that the circulation pumps do not consume unnecessary energy.

Pump hp/100 tons of load	Efficiency
< 5	Excellent
5 – 7 ½	Good
7 ½ - 10	Ok
10-15	Poor
> 15	Bad

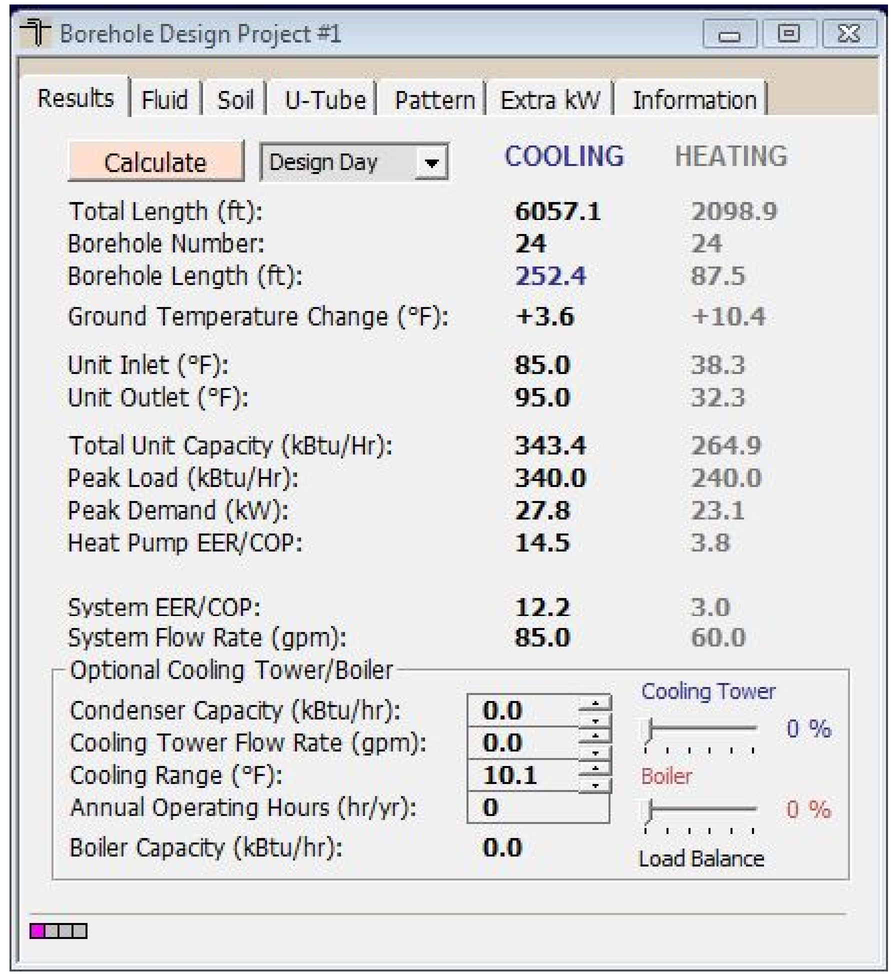
What are we Trying to Accomplish?

A sample system:

22,000kWh cooling
5,000 kWh heating

<u>Well Designed piping system:</u>
12 x 2 borefield
10 ft. hd @ 45gpm
~ 0.5 hp pump with 85% efficiency = 3,504 kWh
Pump penalty = 11%

<u>Poorly Designed System:</u>
12 x 2 borefield
34 ft. hd @ 45 gpm
~ 1 hp pump with 85% efficiency = 7,884 kWh
Pump penalty = 22%



What are we Trying to Accomplish?

To achieve the goal of designing an easy-to-purge and high performance system we need to look at and understand these parameters in our designs:

- Flow Rate (gpm)
- Velocity (ft/s)
- Reynolds Numbers
- Pressure Drop (ft. head)

GHX Module - Supply-Return Runout	24.00 gpm	2.60 ft/s	21814	1.2 ft. hd
Circuit #01	2.91 gpm	1.03 ft/s	4776	0.8 ft. hd
GHX Header Section #01	21.09 gpm	2.28 ft/s	19171	0.1 ft. hd
Circuit #02	3.00 gpm	1.06 ft/s	4922	0.8 ft. hd
GHX Header Section #02	18.10 gpm	1.96 ft/s	16448	0.1 ft. hd
Circuit #03	3.04 gpm	1.07 ft/s	4987	0.8 ft. hd
GHX Header Section #03	15.06 gpm	1.63 ft/s	13689	0.1 ft. hd
Circuit #04	3.06 gpm	1.08 ft/s	5028	0.8 ft. hd
GHX Header Section #04	12.00 gpm	1.30 ft/s	10907	0.0 ft. hd
Circuit #05	3.06 gpm	1.08 ft/s	5028	0.8 ft. hd
GHX Header Section #05	8.94 gpm	1.51 ft/s	10159	0.1 ft. hd
Circuit #06	3.04 gpm	1.07 ft/s	4987	0.8 ft. hd
GHX Header Section #06	5.90 gpm	1.31 ft/s	7677	0.1 ft. hd
Circuit #07	3.00 gpm	1.06 ft/s	4922	0.8 ft. hd
GHX Header Section #07	2.91 gpm	1.03 ft/s	4776	0.1 ft. hd
Circuit #08	2.91 gpm	1.03 ft/s	4776	0.8 ft. hd

Workshop Outline – Review of Fluid Dynamics Calculations

- What is the CFD Module?
- What are we Trying to Accomplish?
- **Brief Review of General Fluid Dynamics Calculations**
- Reality Check
- Learn Standard Nomenclature for Geothermal Piping Systems
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Brief Review of Fluid Dynamics Calculations

We use the following equations:

1) Darcy-Weisbach (calculates pressure drop from friction factor, pipe parameters, fluid density and fluid velocity)

$$\Delta p = f \cdot \frac{L}{D} \cdot \frac{\rho V^2}{2}$$

2) Reynolds Number (calculates Reynolds Number from density, velocity, pipe parameters and viscosity)

$$\mathrm{Re} = \frac{\rho V D_H}{\mu}$$

3) A range of "equivalent resistance" calculations for determining pressure drops across "network nodes."

4) The Hazen-Williams equation is not used (due to very limited applicability)

Workshop Outline – Reality Check

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Reality Check:

Driscopipe 5400 Climate Guard

Pipe Information				
Cell Class. =	PE355434C		DR =	11
Pipe Size =	1", 3035		Pipe I.D. =	1.075
Vol. / 100 ft. =	4.71		Max. Vel. =	15

Flow Characteristics — **WATER - No Inhibitors**

Fluid Information	Temp. (F)	Freeze Pt. (F)	Visc. (cp)	Density
	40.0	32.0	1.55	62.43

GPM	Vel. (ft/sec)	Re Number	HL* (ft./100 ft)	PD (lbs./100 ft)
0.50	0.18	950	0.04	0.02
1.00	0.35	1,900	0.07	0.03
1.50	0.53	2,849	0.21	0.09
2.00	0.71	3,799	0.35	0.15
2.50	0.88	4,749	0.52	0.22
3.00	1.06	5,699	0.71	0.31
3.50	1.24	6,648	0.81	0.35
4.00	1.41	7,598	1.03	0.45
4.50	1.59	8,548	1.27	0.55
5.00	1.77	9,498	1.54	0.67
5.50	1.94	10,447	1.82	0.79
6.00	2.12	11,397	2.13	0.92
6.50	2.30	12,347	2.46	1.07
7.00	2.47	13,297	2.81	1.22
7.50	2.65	14,246	3.18	1.38

Reality Check:

Layout Design and Optimization

Auto-Flow

U Circuit | 1" | 100.0 ft | 5.66 gpm | 2.00 ft/s | 9298 | 4.7 gal | 2.2 ft. hd |

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Reality Check:

Driscopipe 5400 Climate Guard

Pipe Information				
Cell Class. =	PE355434C		DR =	11
Pipe Size =	1 1/4", 3035		Pipe I.D. =	1.358
Vol. / 100 ft. =	7.52		Max. Vel. =	15

Flow Characteristics — WATER - No Inhibitors

Fluid Information	Temp. (F)	Freeze Pt. (F)	Visc. (cp)	Density
	40.0	32.0	1.55	62.43

GPM	Vel. (ft/sec)	Re Number	HL* (ft./100 ft)	PD (lbs./100 ft)
1.50	0.33	2,255	0.07	0.03
2.00	0.44	3,007	0.12	0.05
2.50	0.55	3,759	0.17	0.07
3.00	0.66	4,511	0.23	0.10
3.50	0.78	5,263	0.31	0.13
4.00	0.89	6,015	0.34	0.15
4.50	1.00	6,766	0.42	0.18
5.00	1.11	7,518	0.50	0.22
5.50	1.22	8,270	0.60	0.26
6.00	1.33	9,022	0.70	0.30
6.50	1.44	9,774	0.80	0.35
7.00	1.55	10,526	0.92	0.40
7.50	1.66	11,277	1.04	0.45
8.00	1.77	12,029	1.17	0.50
8.50	1.88	12,781	1.30	0.56
9.00	1.99	13,533	1.44	0.62
9.50	2.10	14,285	1.59	0.69
10.00	2.22	15,037	1.74	0.75
10.50	2.33	15,788	1.90	0.82
11.00	2.44	16,540	2.06	0.89

Reality Check:

Layout Design and Optimization

Auto-Flow

U Circuit | 1 1/4" | 100.0 ft | 9.03 gpm | 2.00 ft/s | 11743 | 7.5 gal | 1.6 ft. hd |

Driscopipe 5400 Climate Guard

Pipe Information				
	Cell Class. =	PE355434C	DR =	11
	Pipe Size =	1 1/4", 3035	Pipe I.D. =	1.358
	Vol. / 100 ft. =	7.52	Max. Vel. =	15

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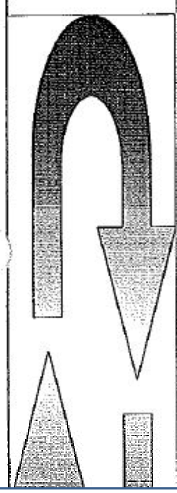

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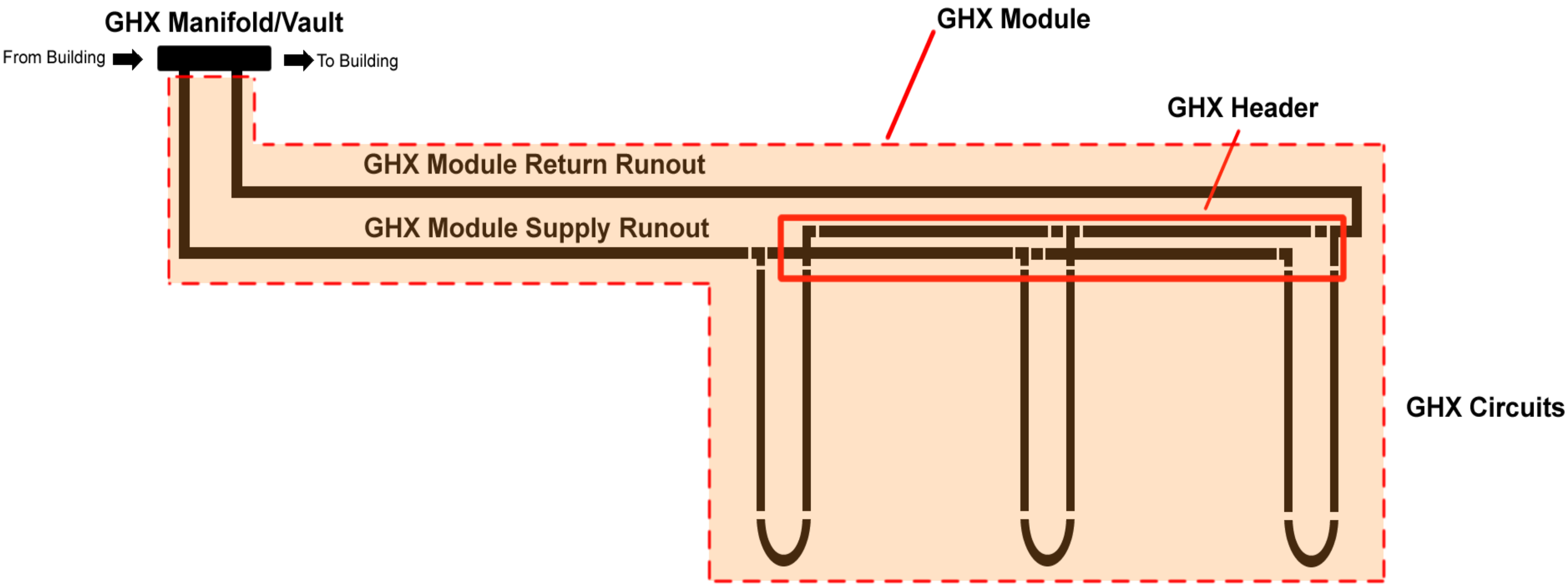
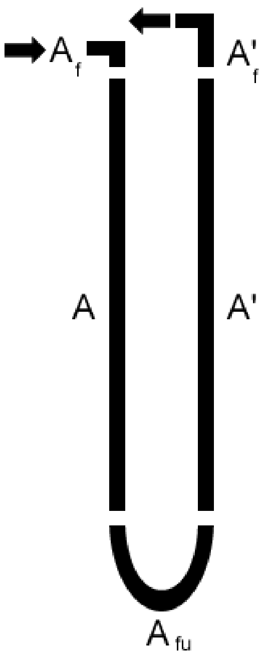
Introduction to Nomenclature

Standardized Nomenclature is critical to clear communication.



Introduction to Nomenclature

U-Tube: An assembly of two lengths of HDPE pipe connected on one end with a molded, purpose built U-bend.

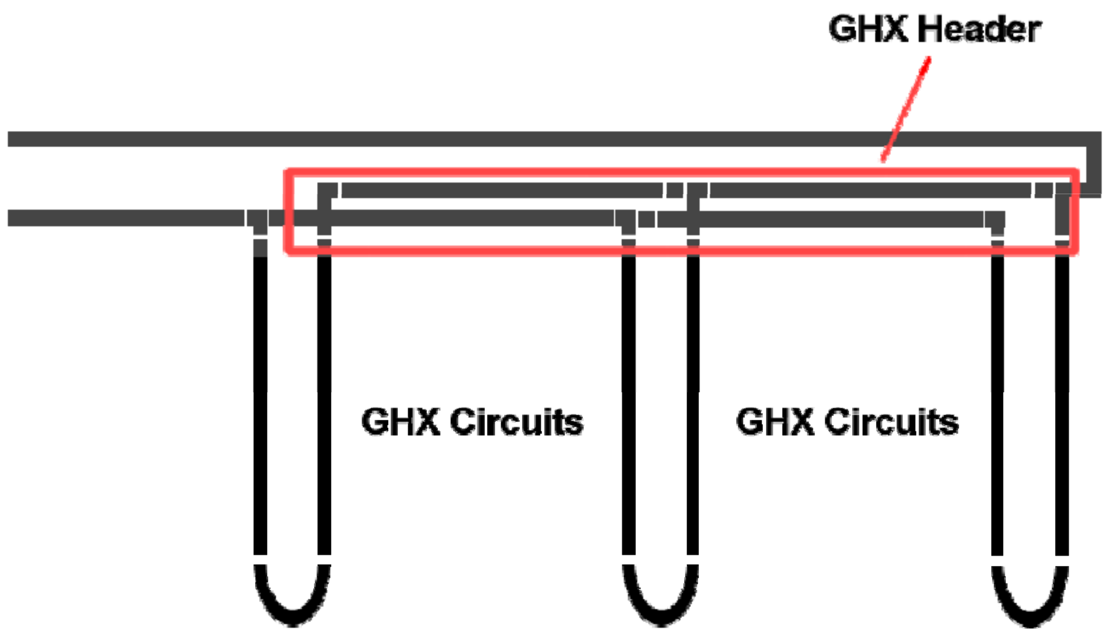


GHX: Refers to a **g**round **h**eat e**x**changer, and may include vertical, horizontal trenching, horizontal boring, pond or lake heat exchanger buried in the ground or submerged in a body of water.

Introduction to Nomenclature

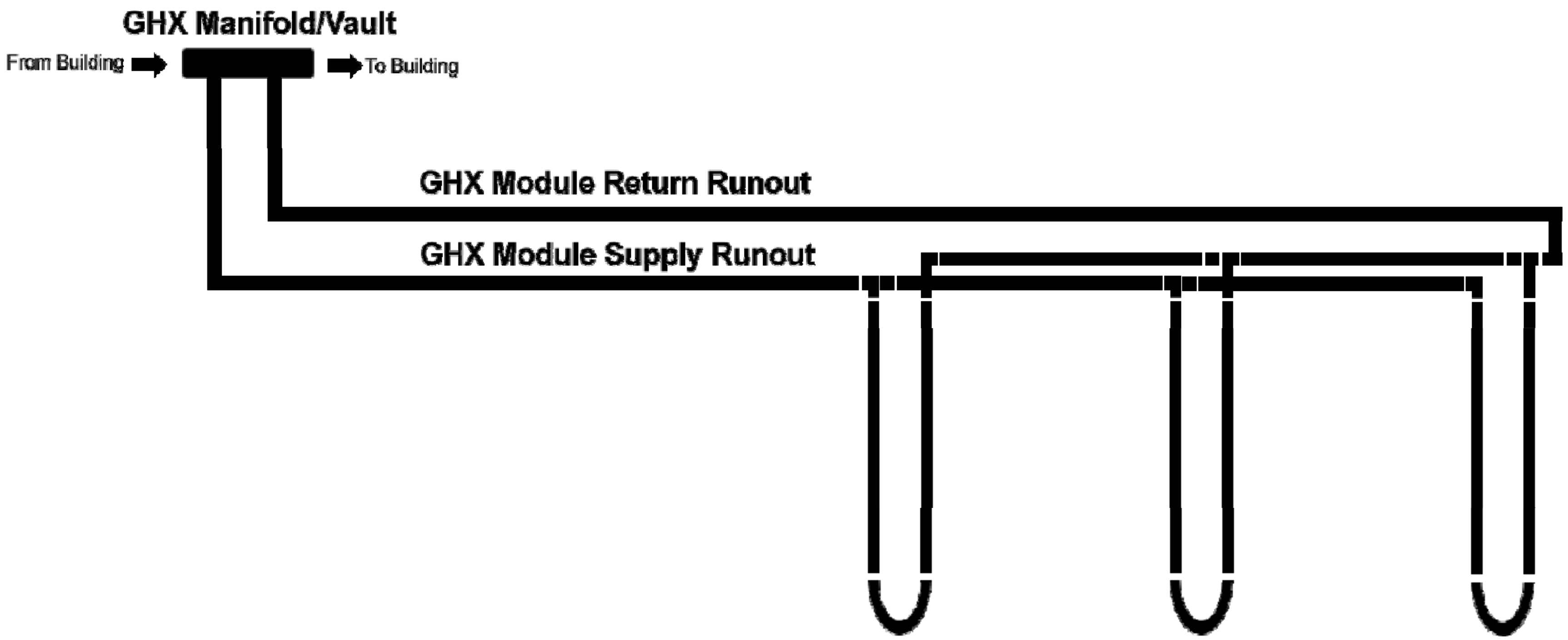
GHX Circuits: HDPE pipe buried in the ground in horizontal or vertical orientation designed to transfer energy to and from the ground. Typically a number of GHX Circuits are fusion welded to a GHX Header that is in turn fusion welded to a Supply-Return Runout. Heat transfer fluid is circulated through the assembly to a building.

GHX Header: Connection points between Supply-Return Runout piping and GHX Circuits. GHX Headers are buried in the ground adjacent to the GHX Field and are comprised of an assembly of fusion welded fittings and pipe. Fittings and pipe are manufactured using HDPE resin and are connected using heat fusion (butt fusion, socket fusion or electro-fusion). Most GHX Headers are "Reducing Headers"



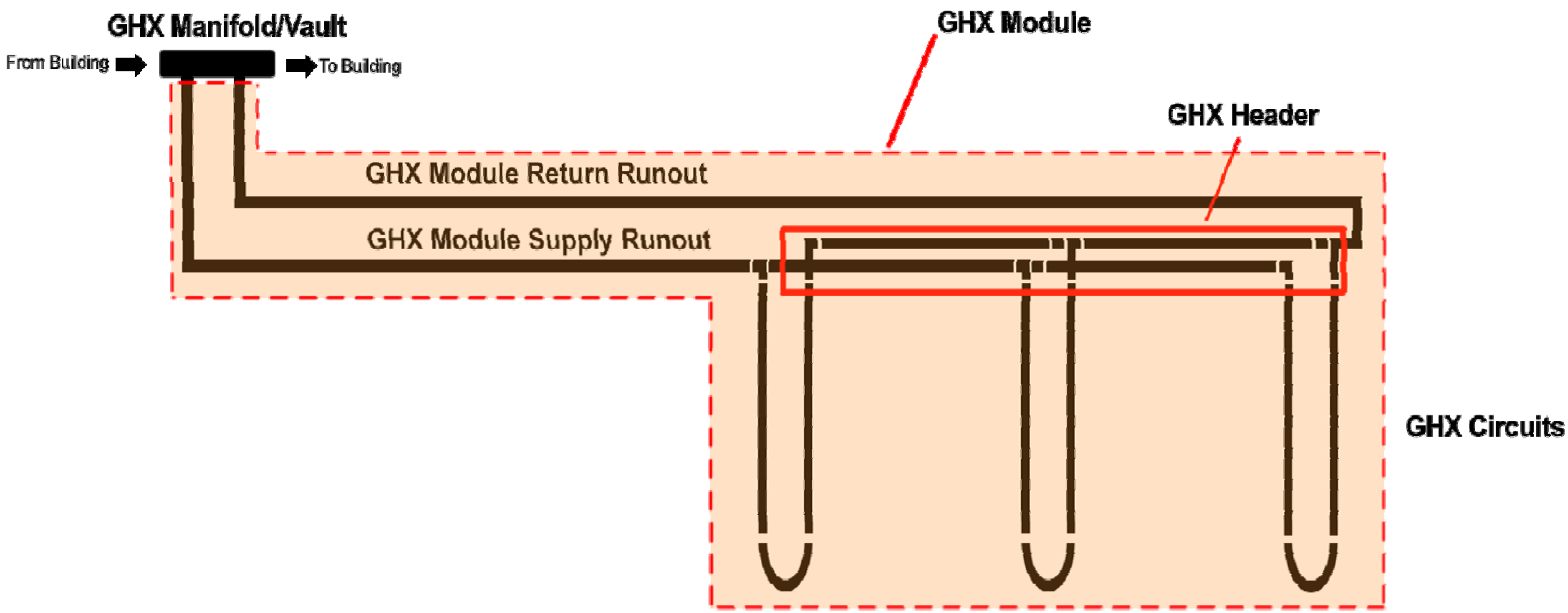
Introduction to Nomenclature

GHX Module Supply-Return Runout : Supply-Return Runout refers to the high-density polyethylene (HDPE) piping installed to connect the GHX Circuit piping to the Pump House header. The Supply-Return Runout has both a supply pipe and a return pipe.



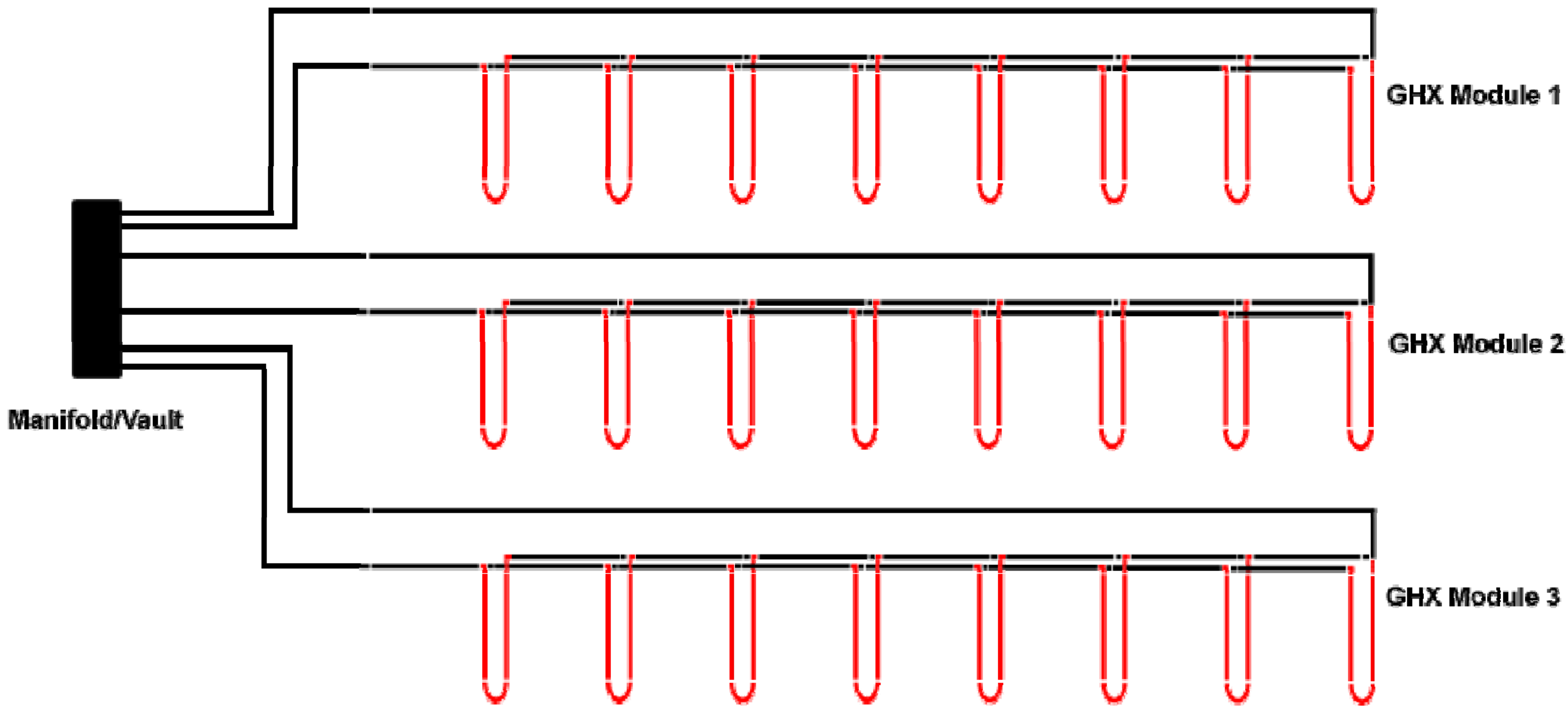
Introduction to Nomenclature

GHX Module: Completed assembly of GHX components, including GHX Supply and Return Runouts, GHX header and GHX Circuits.



Introduction to Nomenclature

GHX Field: Assembly of all GHX Modules connected to a single building or group of buildings via GHX Manifold(s)/Vault(s).



Workshop Outline – Basic Standard Configurations

- What is the CFD Module?
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- **Basic Standard Configurations: Direct Return & Reverse Return Systems**
- Purging Design & Performance: Direct Return & Reverse Return Systems
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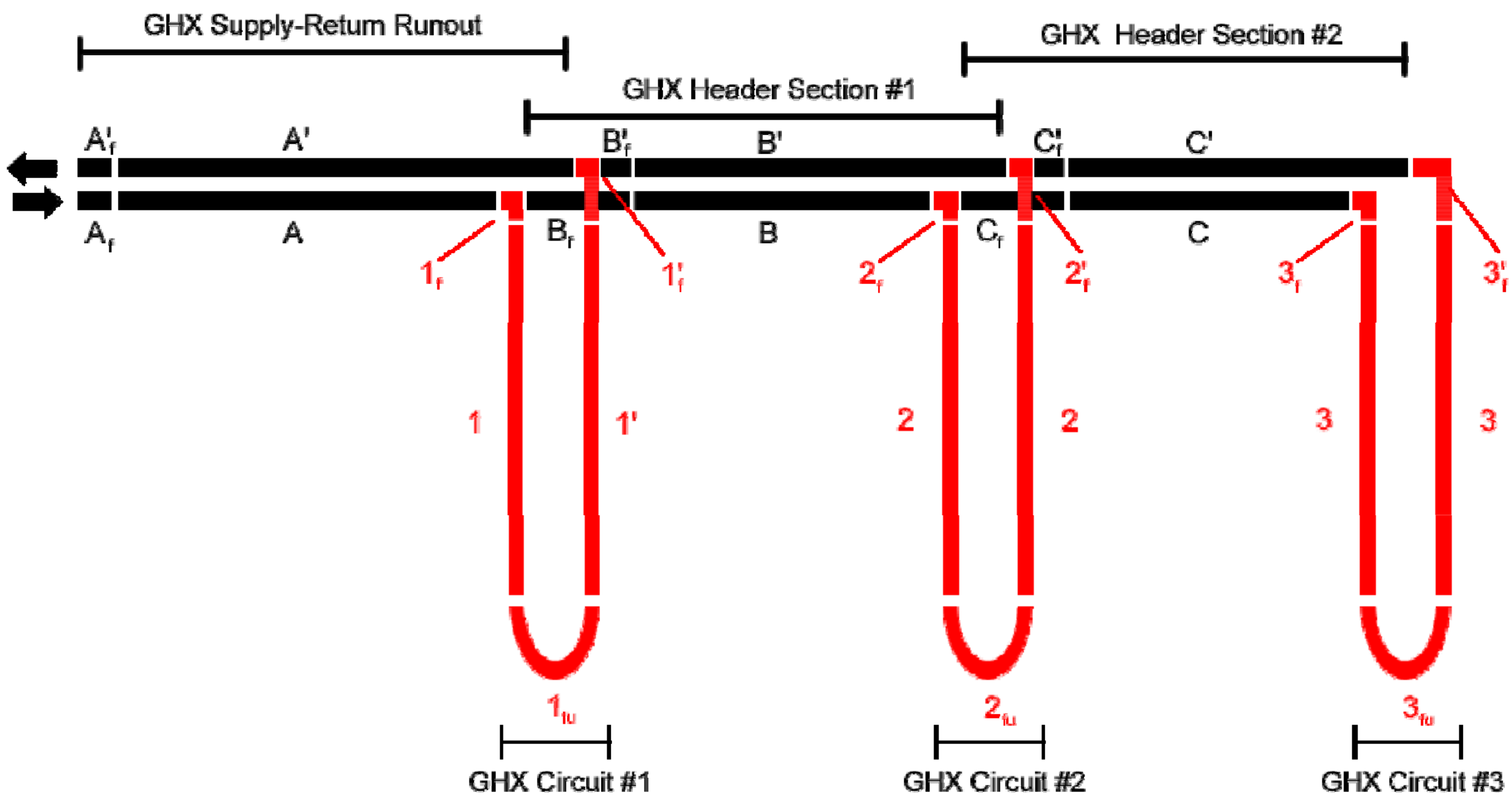
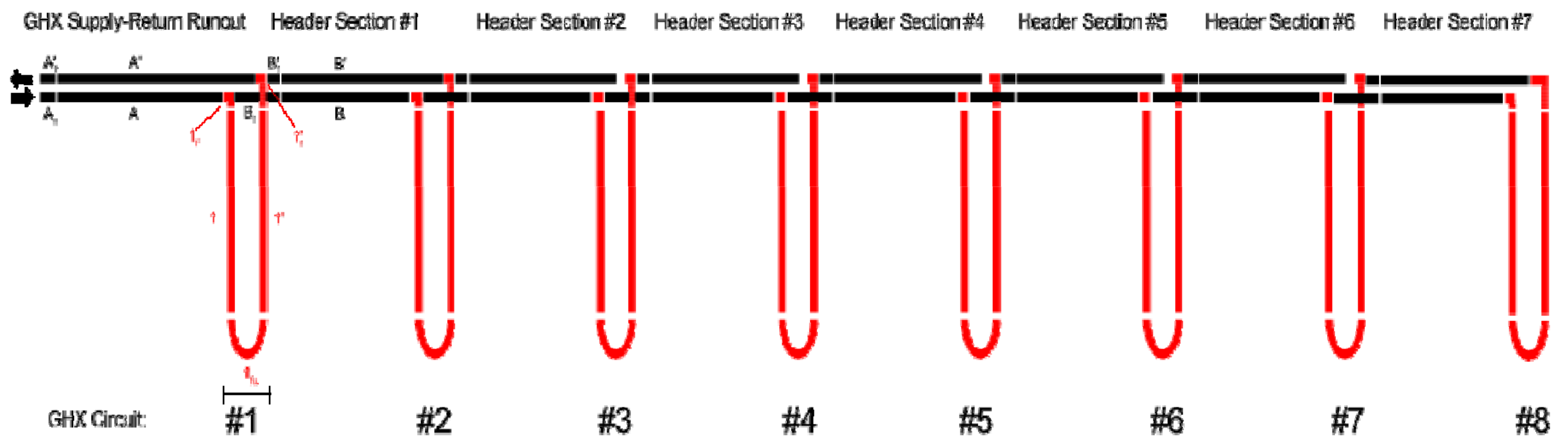
Basic Standard Configuration: Direct Return (DR) Systems



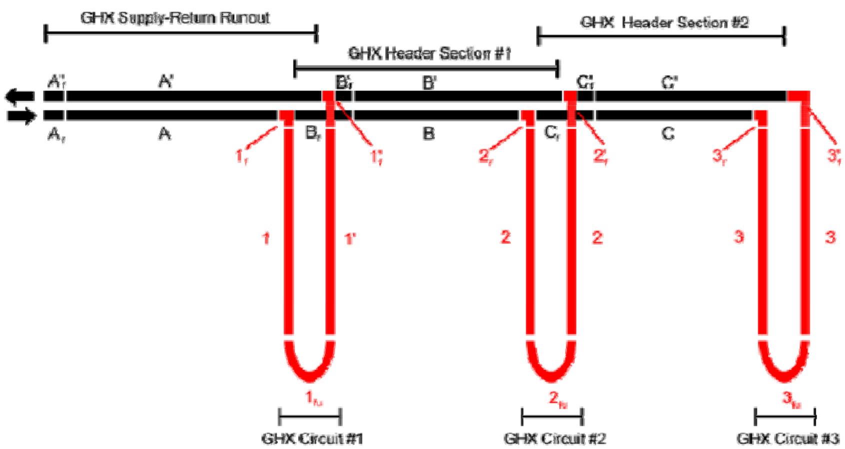
Note: Direct Return (DR) systems uncommon but useful for illustrative purposes

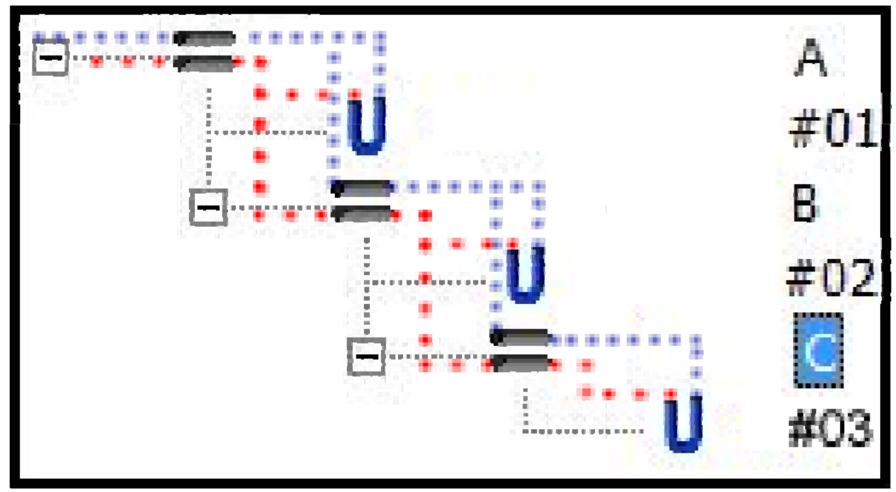
Basic Standard Configuration: Direct Return (DR) Systems



- GHX Module - Supply-Return Runout
  - Circuit #01
  - GHX Header Section #01
    - Circuit #02
    - GHX Header Section #02
      - Circuit #03
      - GHX Header Section #03
        - Circuit #04
        - GHX Header Section #04
          - Circuit #05
          - GHX Header Section #05
            - Circuit #06
            - GHX Header Section #06
              - Circuit #07
              - GHX Header Section #07
                - Circuit #08

Basic Standard Configuration: Direct Return (DR) Systems

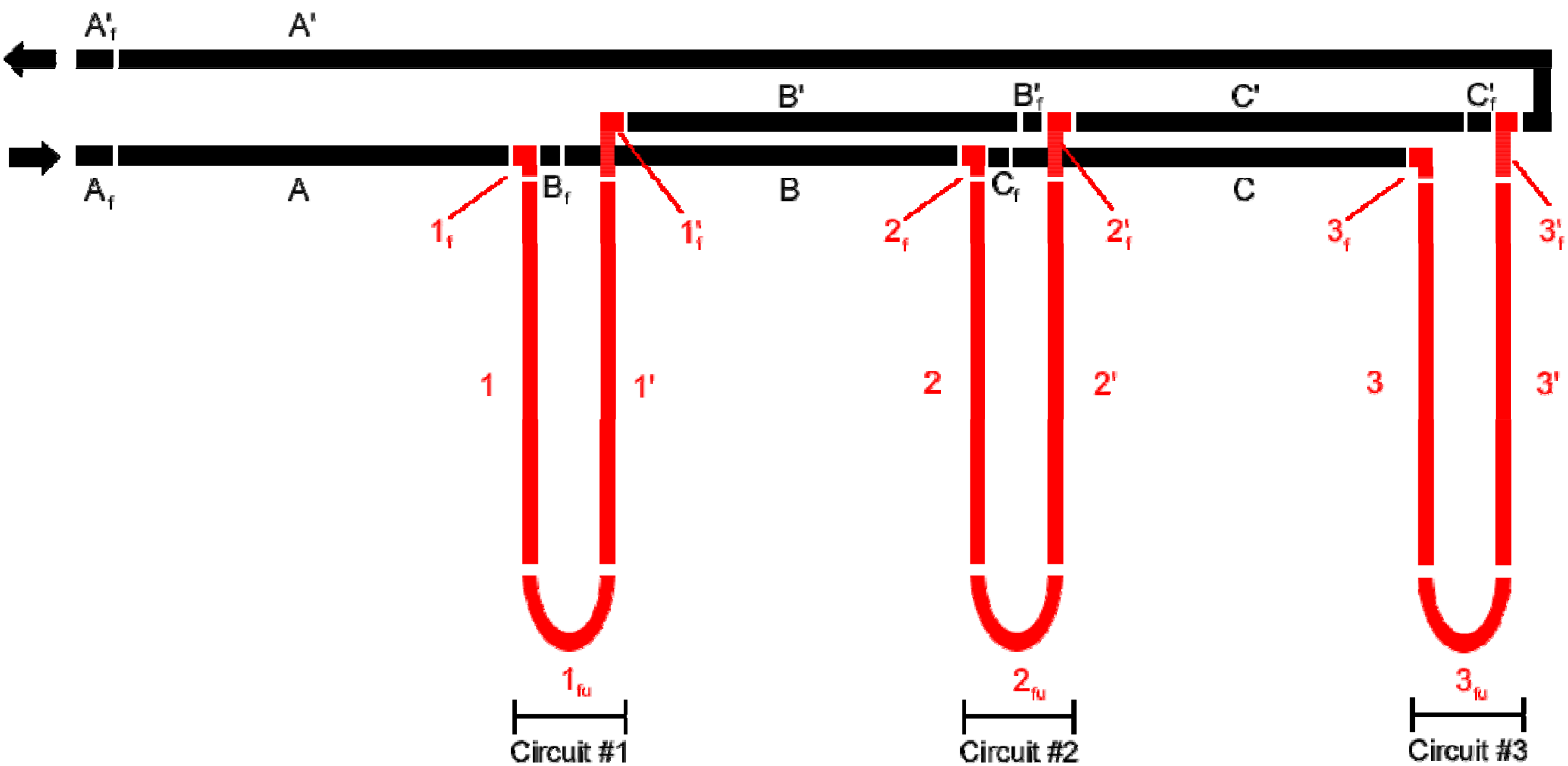




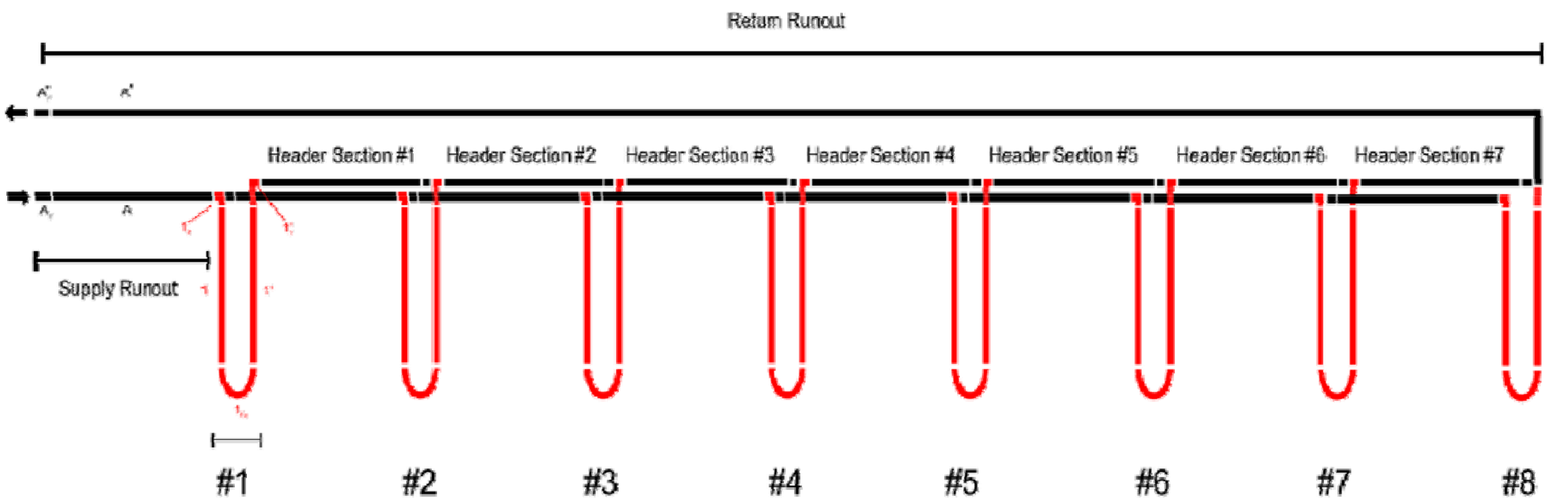
······ = fluid supply flow paths

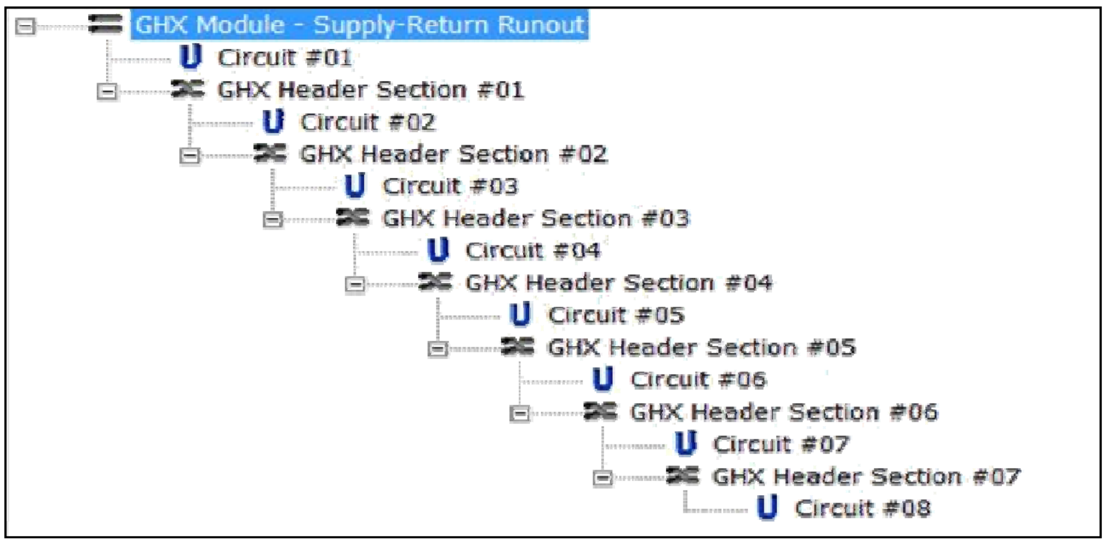
······ = fluid return flow paths

Basic Standard Configuration: Reverse Return (RR) Systems

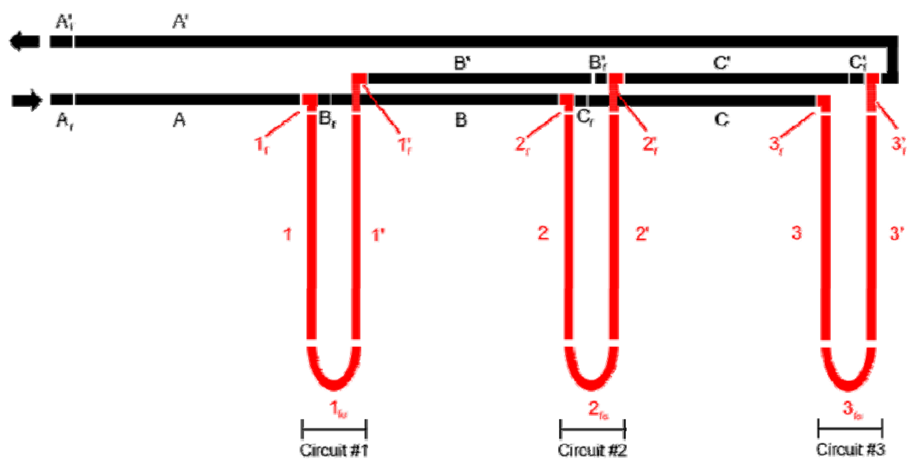


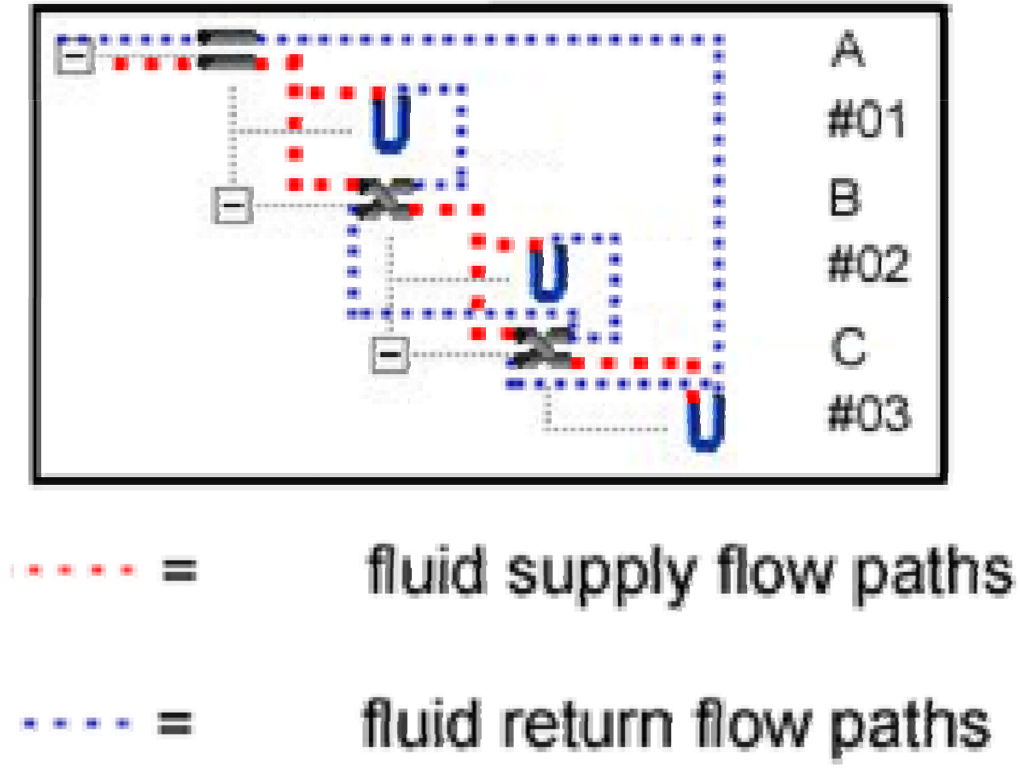
Basic Standard Configuration: Reverse Return (RR) Systems





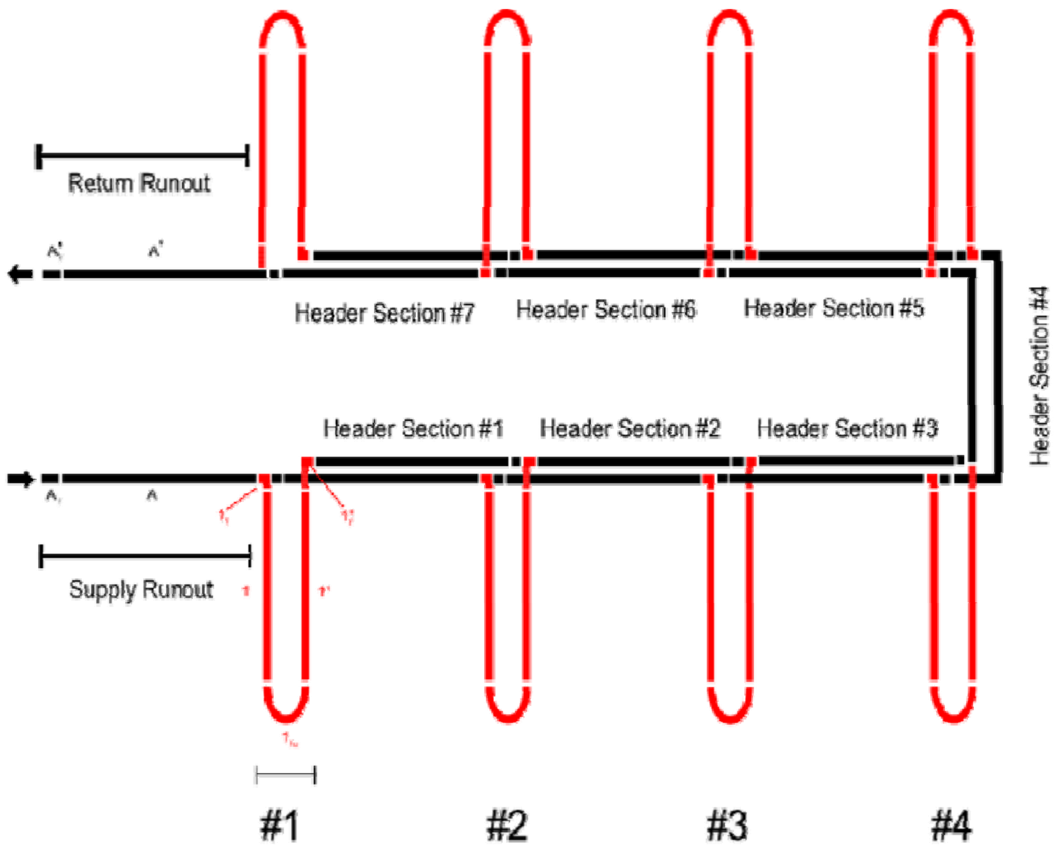
Basic Standard Configuration: Reverse Return (RR) Systems



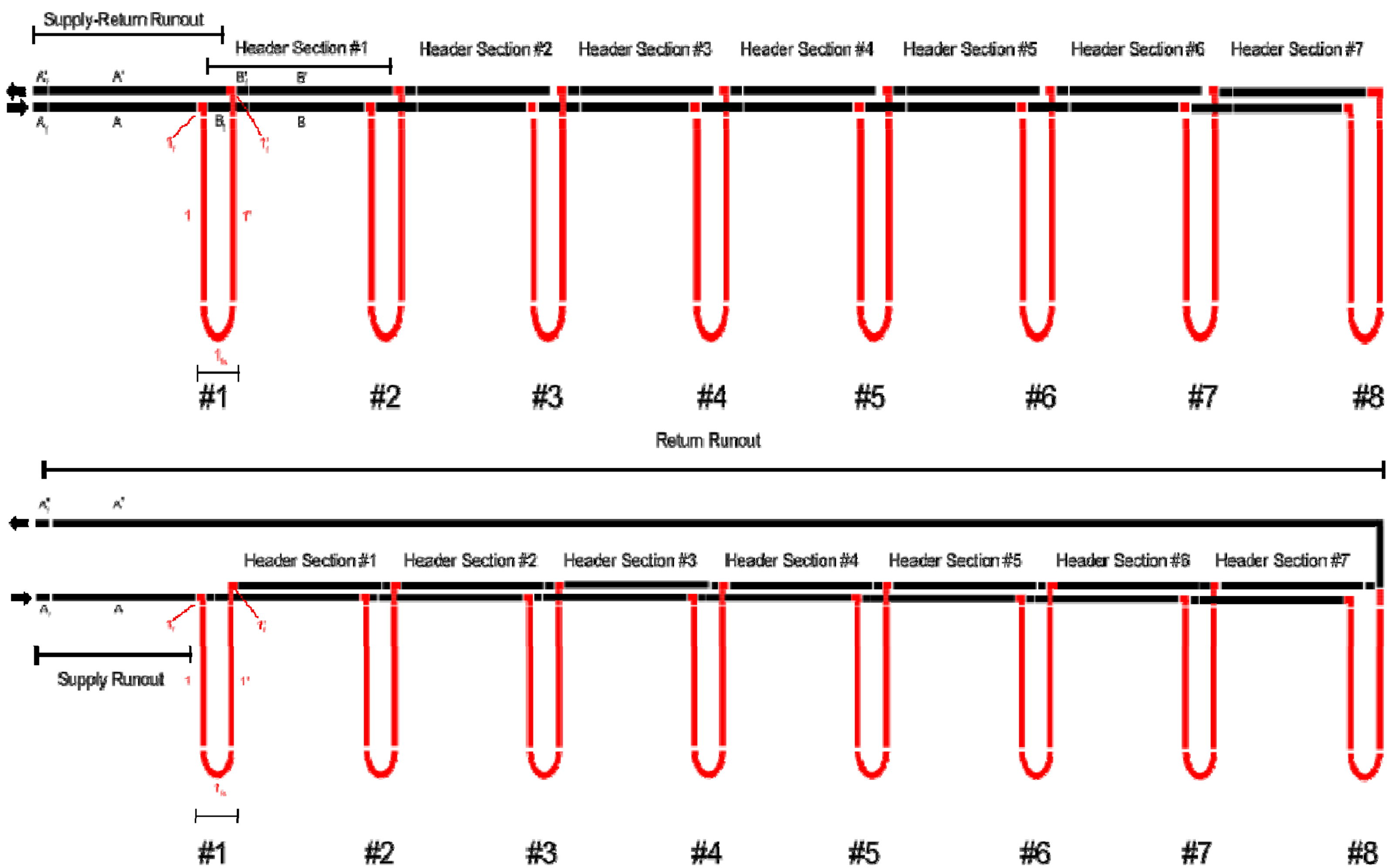


Basic Standard Configuration: Reverse Return (RR) Systems

This RR GHX Module is know as the “horseshoe”. It can offer lower pressure drops compared to standard RR GHX Modules (i.e. 8.3 vs 10.3 ft head) . Do you know why? Note that the default layout in the CFD is a “horseshoe.”



Basic Standard Configuration : DR vs RR Systems



Basic Standard Configuration : DR vs RR Systems

Issue	Direct Return	Reverse Return
Design	Easier	Harder
Materials	Maybe Less	Maybe More
Construction	Easier	Harder
Flow Balance		
Performance		

Workshop Outline – Purging Design & Performance

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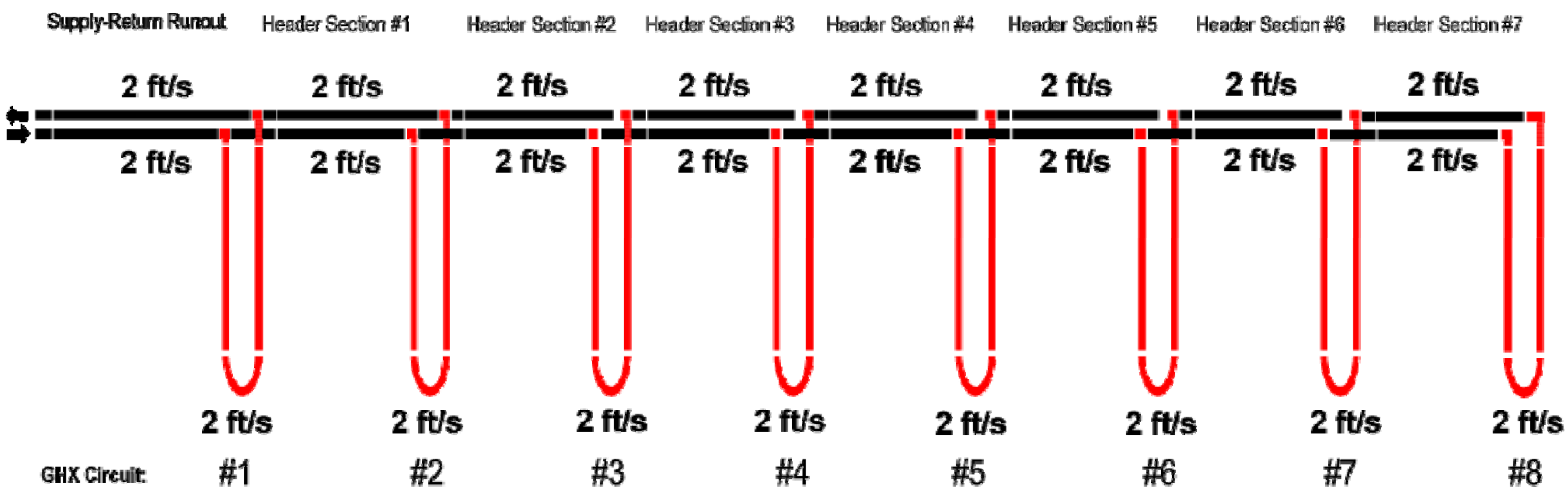
Purging Design: DR Systems

- You want to have a piping system that you can purge with available purge pumps.
- A <u>2 ft/sec</u> fluid velocity throughout entire system is required to purge air effectively.
- Systems are purged with water and all calculations must be done with water.



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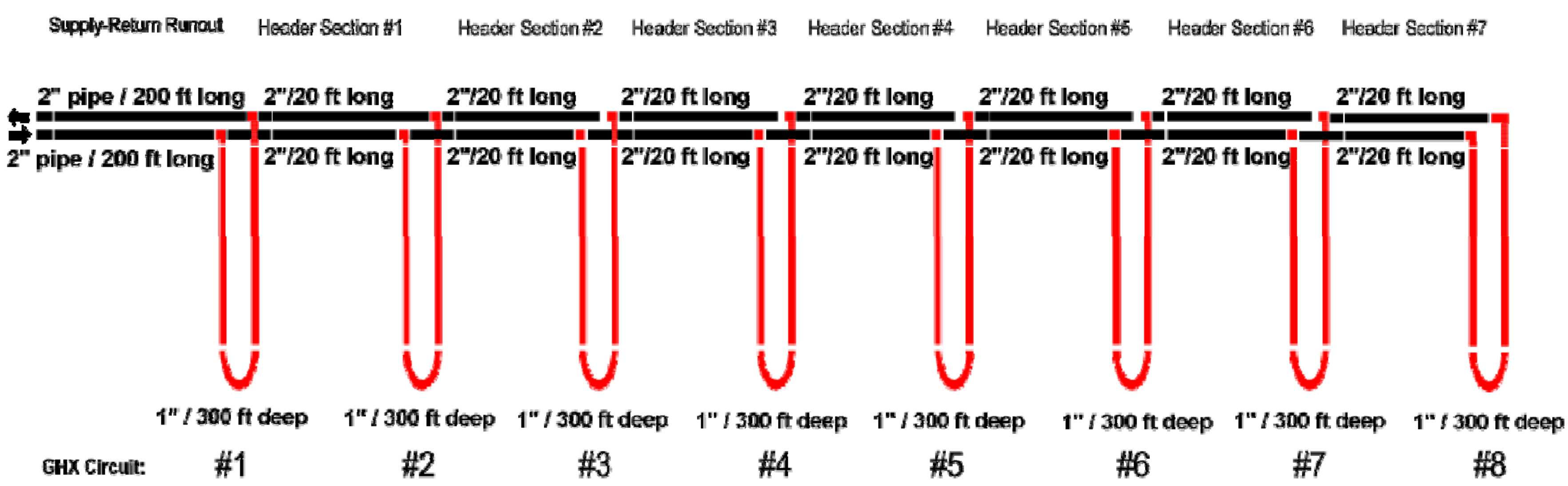

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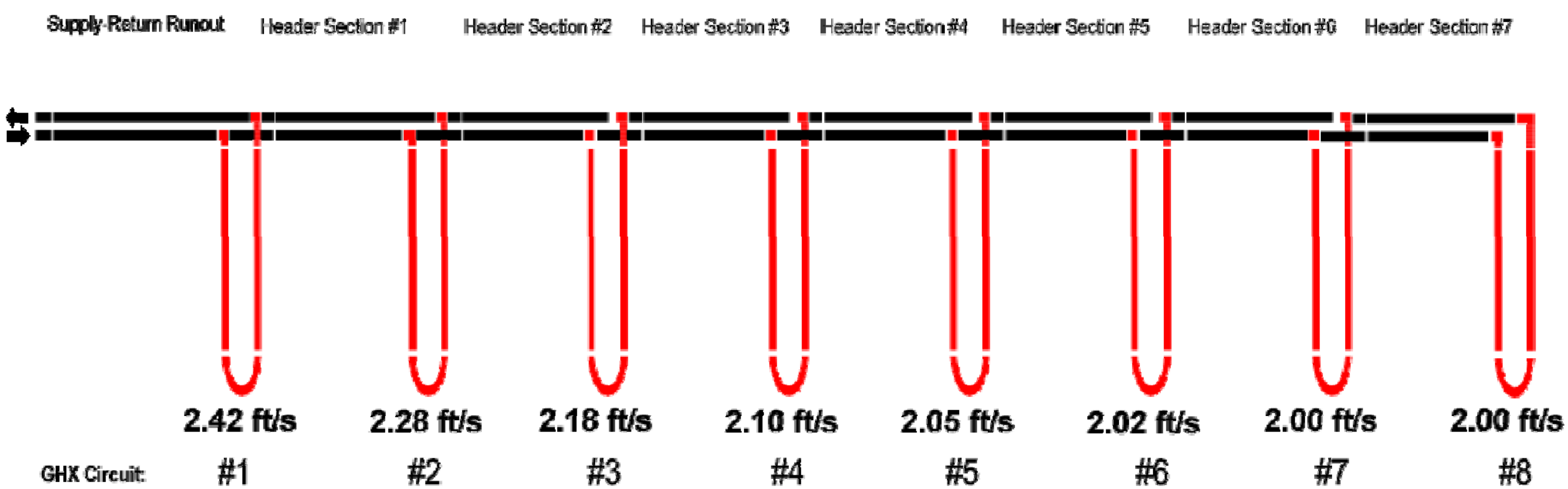
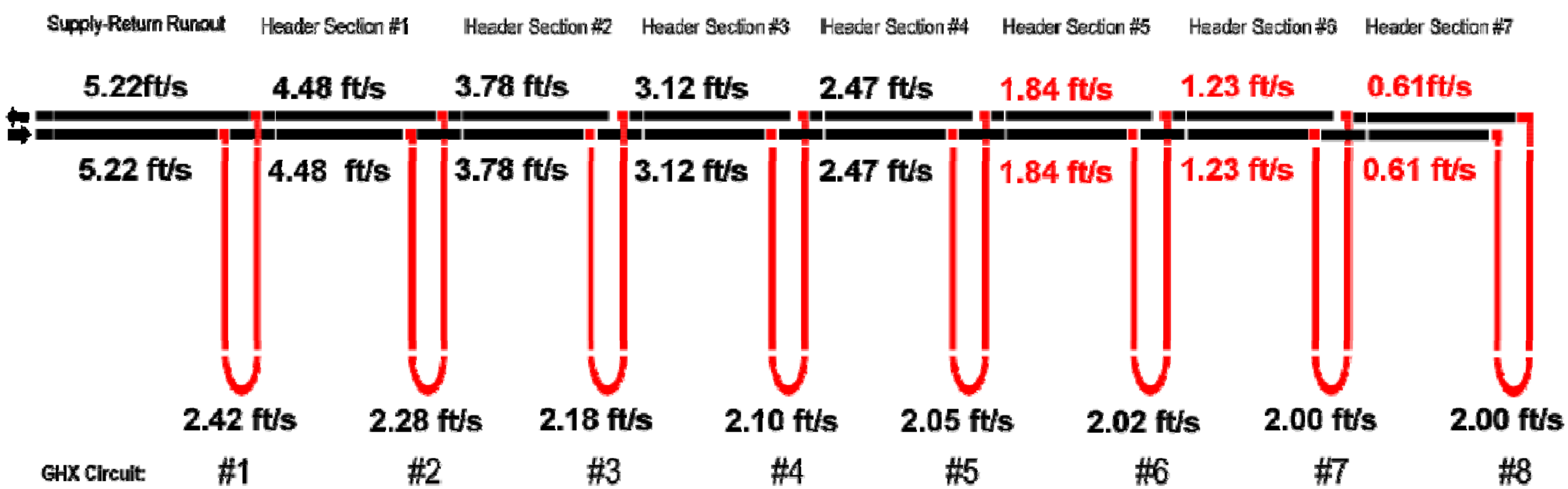
48.27 GPM and 18.4 ft. hd:



Purging Design: DR Systems

48.27 GPM and 18.4 ft. hd:

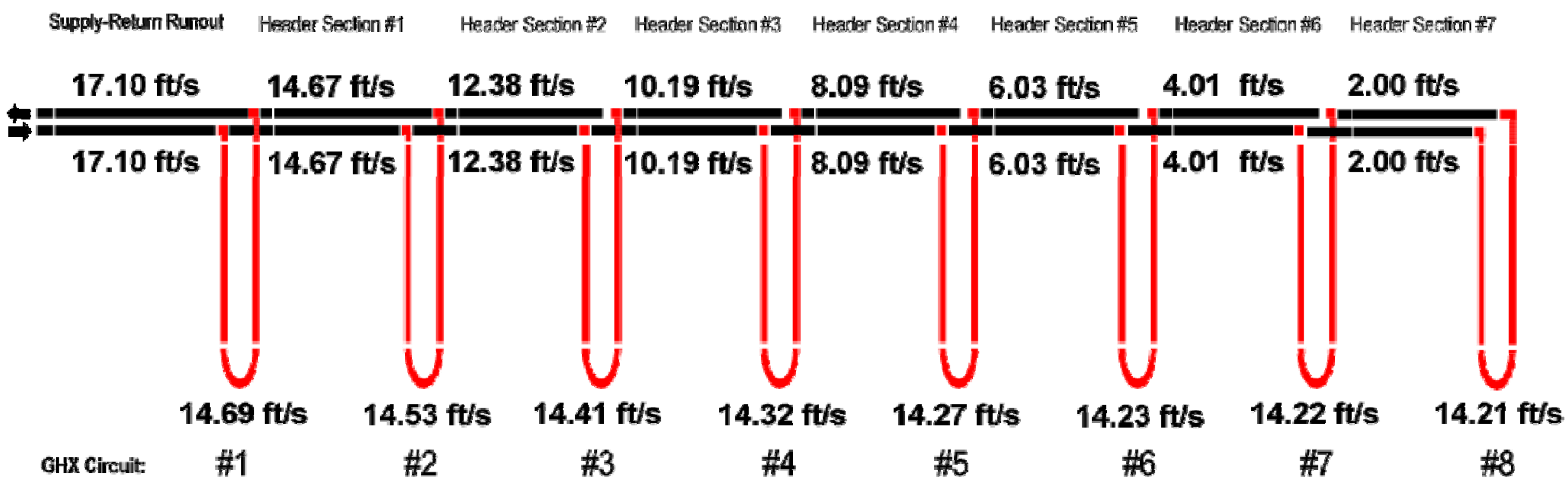


Clearly, we need a higher flow rate to purge the GHX Header Sections on this GHX Module.

Purging Design: DR Systems

Based on this configuration, to achieve 2 ft/s flow rates across the headering system requires:

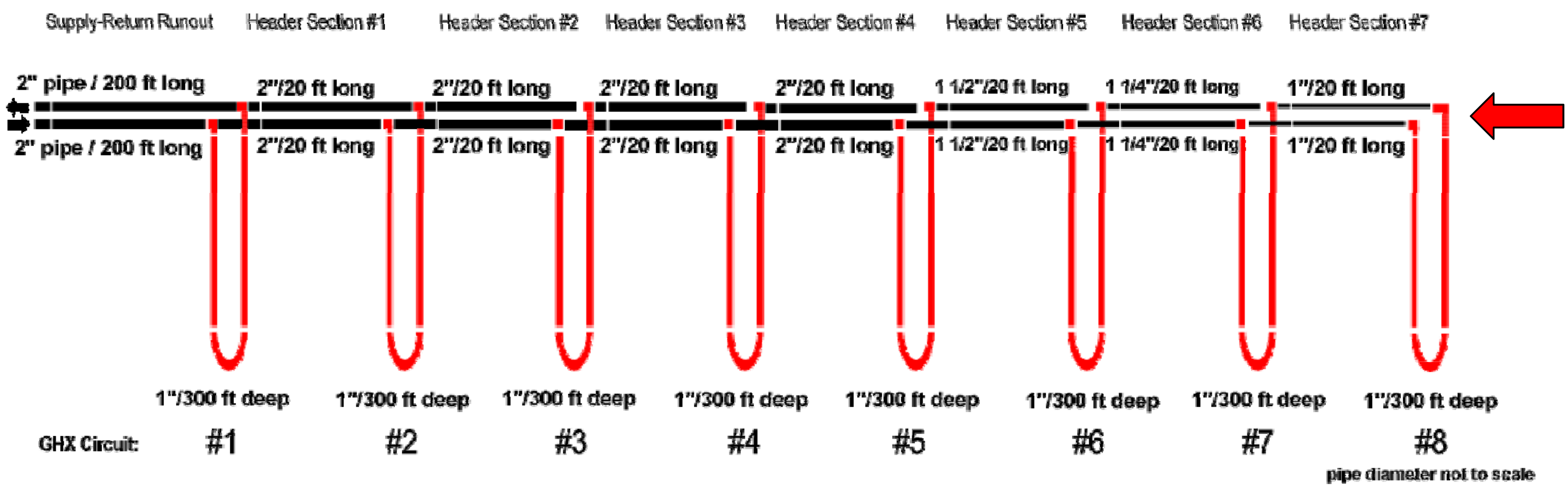
158 GPM and 331 ft. hd



This clearly is unreasonable and justifies the use of a reducing headering system

Purging Design: DR Systems

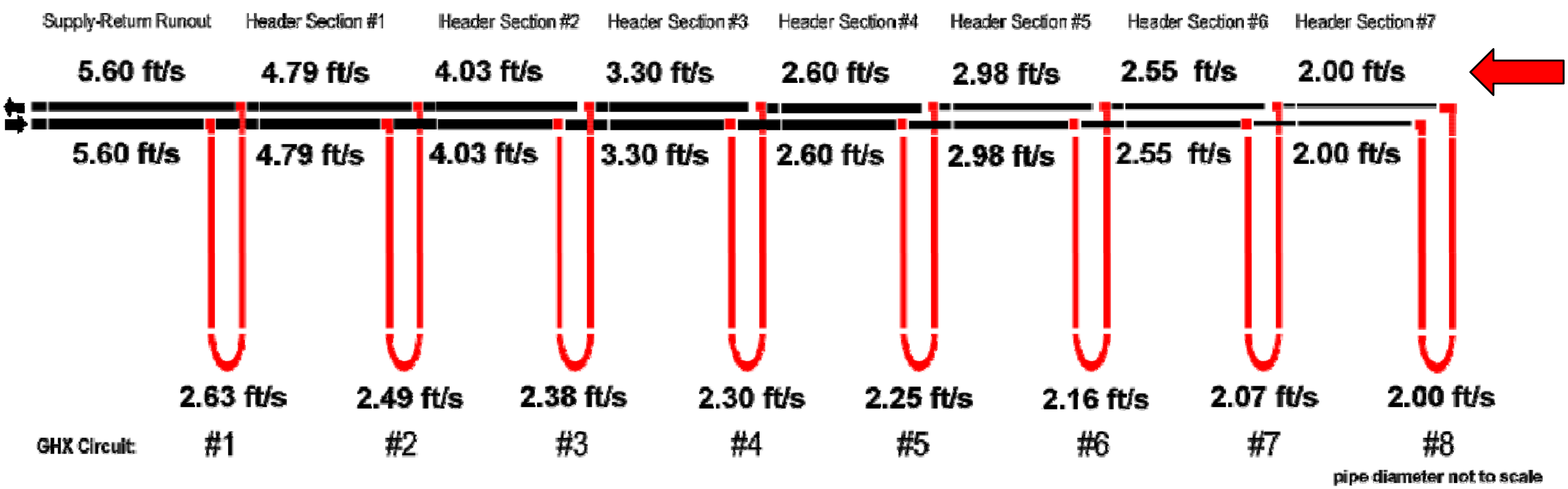
Reducing headering systems will enable purging velocities throughout a system while maintaining reasonable flow rates and pressure drops.



Purging Design: DR Systems

Reducing headering systems enable purging velocities throughout a system while maintaining reasonable flow rates and pressure drops.

51.75 GPM and 46.7 ft. hd



Purging Design: DR Systems

Other Reducing Header Options:

Header Section	Example	Velocity (ft/s)	Design Option 1	Velocity (ft/s)	Design Option 2	Velocity (ft/s)
Runout	2”/2”	5.60 ft/s	2”/2”	5.79 ft/s	2”/2”	8.63
1	2”/2”	4.79 ft/s	2”/2”	4.96 ft/s	2”/2”	7.41
2	2”/2”	4.03 ft/s	2”/2”	4.18 ft/s	2”/2”	6.25
3	2”/2”	3.30 ft/s	2”/2”	3.43 ft/s	2”/2”	5.14
4	2”/2”	2.60 ft/s	2”/2”	2.71 ft/s	2”/2”	4.07
5	1 ½”/1 ½‘”	2.98 ft/s	2”/2”	2.00 ft/s	2”/2”	3.03
6	1 ¼”/1 ¼”	2.55 ft/s	1 ¼”/1 ¼”	2.68 ft/s	2”/2”	2.00
7	1”/1”	2.00 ft/s	1”/1”	2.10 ft/s	1”/1”	3.21
Flow Rate		51.75 gpm		53.5 gpm		79.8 gpm
PD		46.7 ft. hd		49.1 ft. hd		99 ft. hd

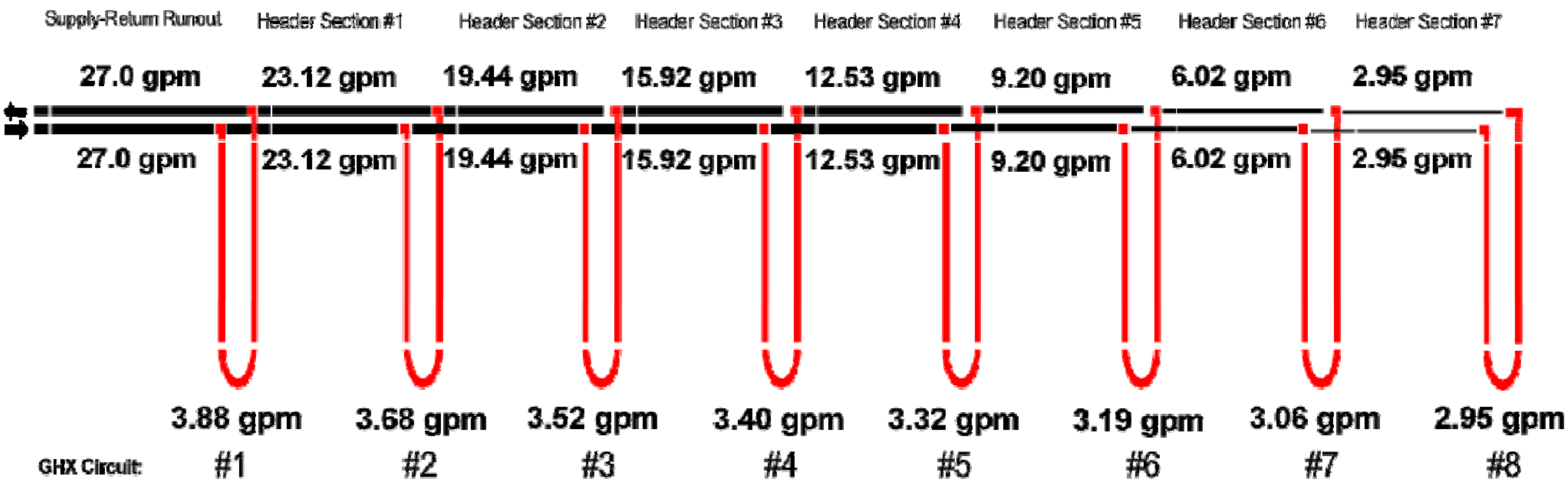
Design and Performance: DR Systems

Flow Balance and Reynolds Numbers

Flow balance is very important to ensure that all of the GHX circuits transfer an equal # of BTUS to and from the ground. Unbalanced systems perform poorly.

This DR system has GHX Circuit flow rates that decrease from 3.88 gpm to 2.95 gpm, a nearly 21% imbalance, across the entire GHX Module.

Note: Propylene Glycol with freeze protection down to 20F, 27 gpm, 17.5 ft hd.



Design and Performance: DR Systems

Flow Balance and Reynolds Numbers

Name	Group Name	Pipe 1 Size	Pipe 1 Length	Pipe 1 Flow Rate	Pipe 1 Velocity	Pipe 1 Reynold's Number
Circuit #01	GHX Module #01	1"	300.0 ft	4.58 gpm	1.62 ft/s	7530
Circuit #02	GHX Module #01	1"	300.0 ft	4.40 gpm	1.55 ft/s	7224
Circuit #03	GHX Module #01	1"	300.0 ft	4.23 gpm	1.49 ft/s	6946
Circuit #04	GHX Module #01	1"	300.0 ft	4.07 gpm	1.44 ft/s	6694
Circuit #05	GHX Module #01	1"	300.0 ft	3.94 gpm	1.39 ft/s	6467
Circuit #06	GHX Module #01	1"	300.0 ft	3.81 gpm	1.35 ft/s	6265
Circuit #07	GHX Module #01	1"	300.0 ft	3.70 gpm	1.31 ft/s	6086
Circuit #08	GHX Module #01	1"	300.0 ft	3.61 gpm	1.28 ft/s	5929
Circuit #09	GHX Module #01	1"	300.0 ft	3.53 gpm	1.25 ft/s	5793
Circuit #10	GHX Module #01	1"	300.0 ft	3.46 gpm	1.22 ft/s	5677
Circuit #11	GHX Module #01	1"	300.0 ft	3.40 gpm	1.20 ft/s	5580
Circuit #12	GHX Module #01	1"	300.0 ft	3.35 gpm	1.18 ft/s	5501
Circuit #13	GHX Module #01	1"	300.0 ft	3.31 gpm	1.17 ft/s	5437
Circuit #14	GHX Module #01	1"	300.0 ft	3.28 gpm	1.16 ft/s	5387
Circuit #15	GHX Module #01	1"	300.0 ft	3.14 gpm	1.11 ft/s	5151
Circuit #16	GHX Module #01	1"	300.0 ft	3.03 gpm	1.07 ft/s	4981
Circuit #17	GHX Module #01	1"	300.0 ft	2.96 gpm	1.05 ft/s	4866
Circuit #18	GHX Module #01	1"	300.0 ft	2.84 gpm	1.00 ft/s	4670
Circuit #19	GHX Module #01	1"	300.0 ft	2.73 gpm	0.97 ft/s	4488
Circuit #20	GHX Module #01	1"	300.0 ft	2.63 gpm	0.93 ft/s	4324

- 8 GHX circuits per GHX module: 15-25% imbalance
- 20 GHX circuits per GHX module: 40-60% imbalance
- 24 GHX circuits per GHX module: 50-80% imbalance

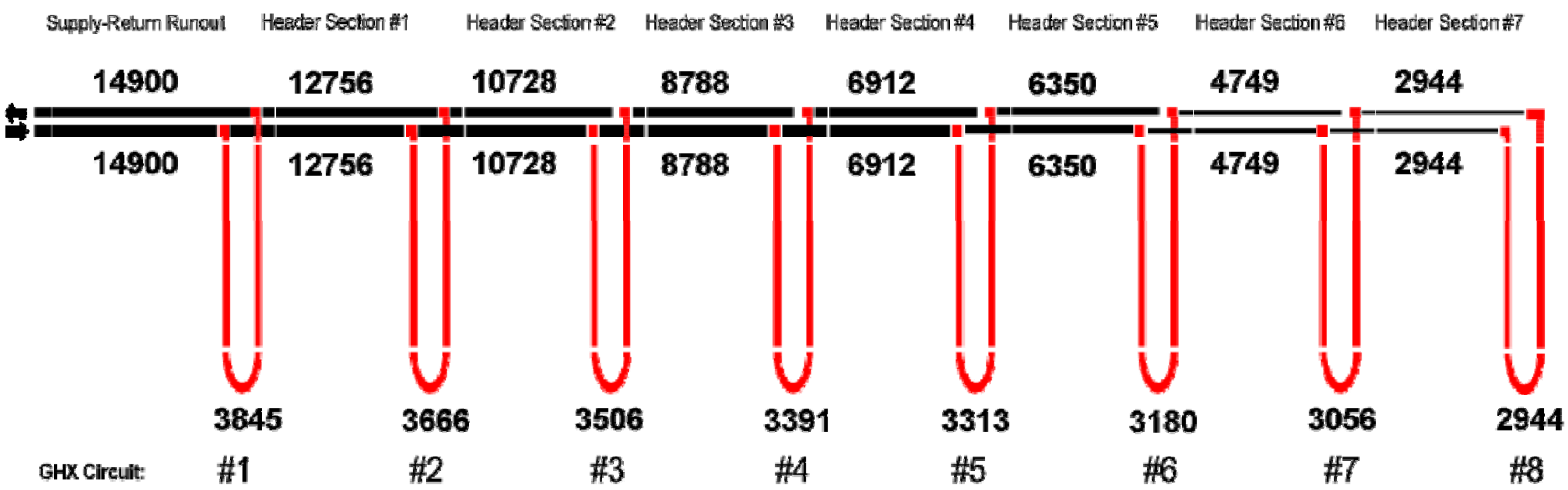
Conclusion: DR Systems Not Balanced

Design and Performance: DR Systems

Balanced Flow and <u>Reynolds Numbers</u>

Reynolds indicate flow type (turbulent, laminar, etc). Turbulent flow is optimal for efficient heat transfer.

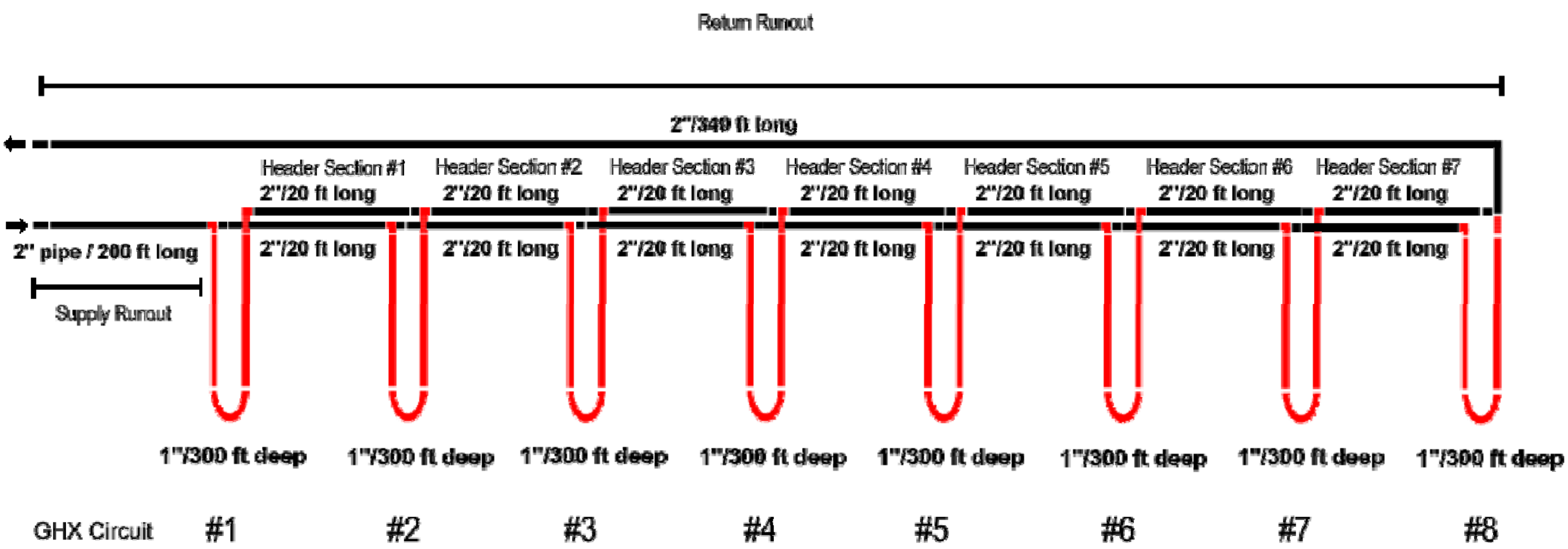
This direct return system has GHX circuit flow Reynolds numbers that drop as the distance from the supply-return runout to GHX circuit increases. In this example, the Reynolds numbers drop from 3,845 to 2,944: again, a ~20% drop.



What about compact headering systems?
Do reverse return systems perform better?

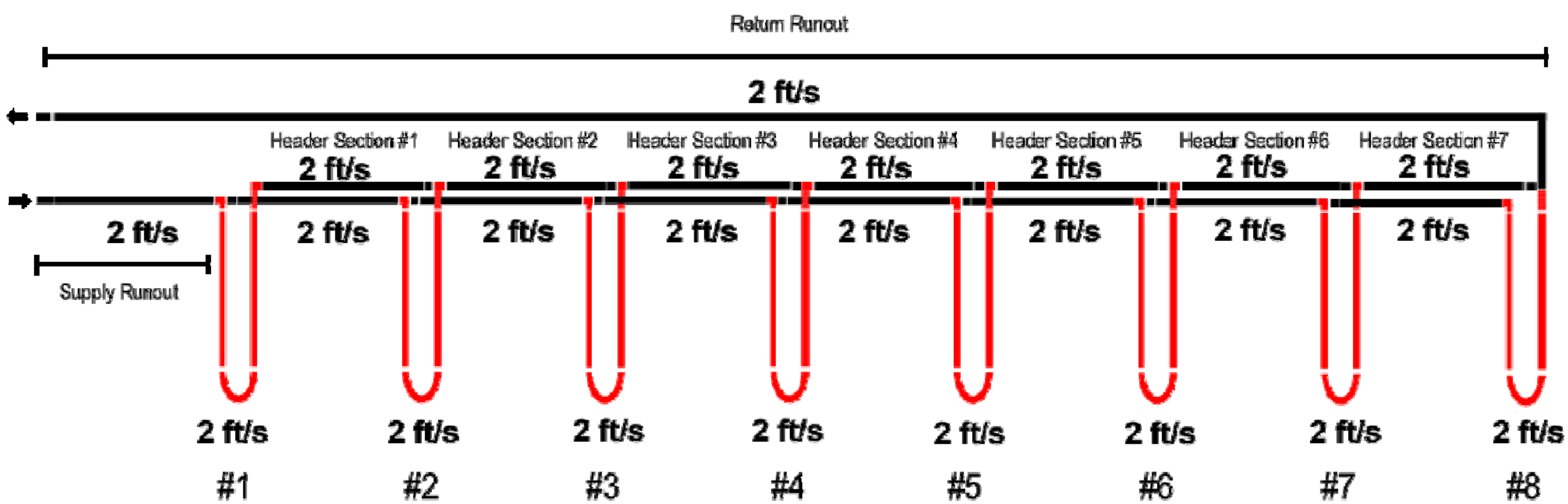
Purging Design: RR Systems

- You want to have a piping system that you can purge with available purge pumps.
- A 2 ft/sec fluid velocity throughout entire system is required to purge air effectively.
- Systems are purged with water and all calculations must be done with water.



Purging Design: RR Systems

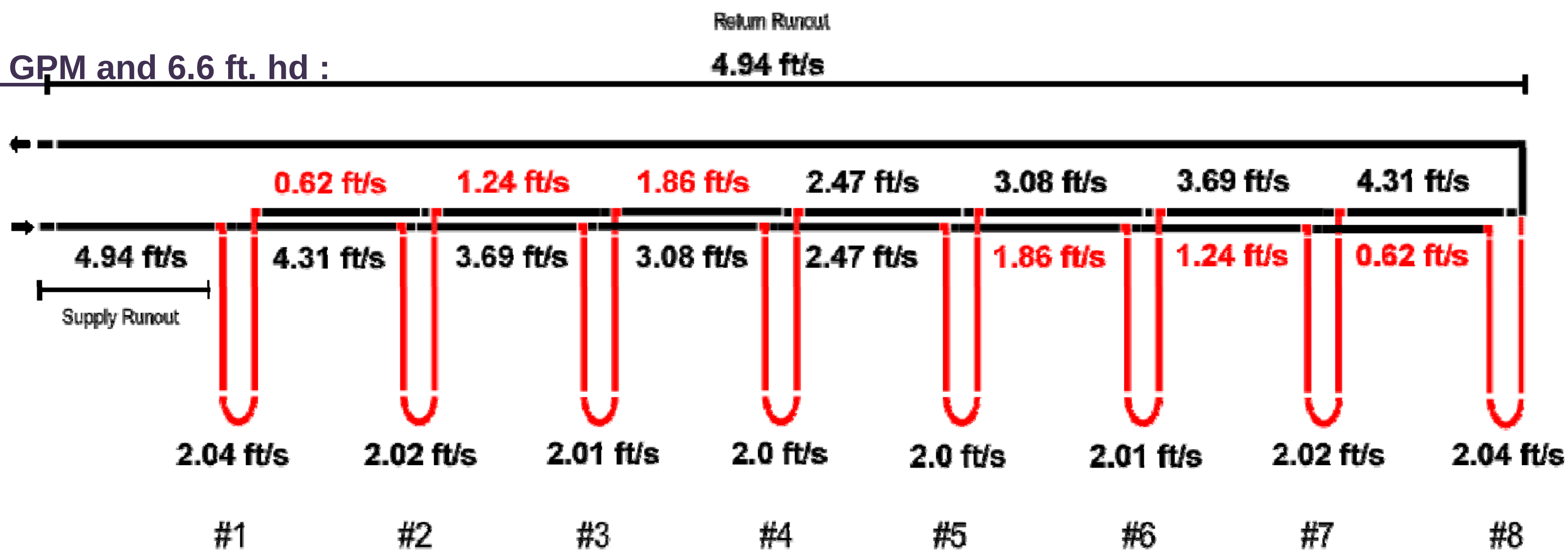
- You want to have a piping system that you can purge with available purge pumps.
- A 2 ft/sec fluid velocity throughout entire system is required to purge air effectively.
- Systems are purged with water and all calculations must be done with water.



Purging Design: RR Systems

- You want to have a piping system that you can purge with available purge pumps.
- A 2 ft/sec fluid velocity throughout entire system is required to purge air effectively.
- Systems are purged with water and all calculations must be done with water.

45.32 GPM and 6.6 ft. hd :

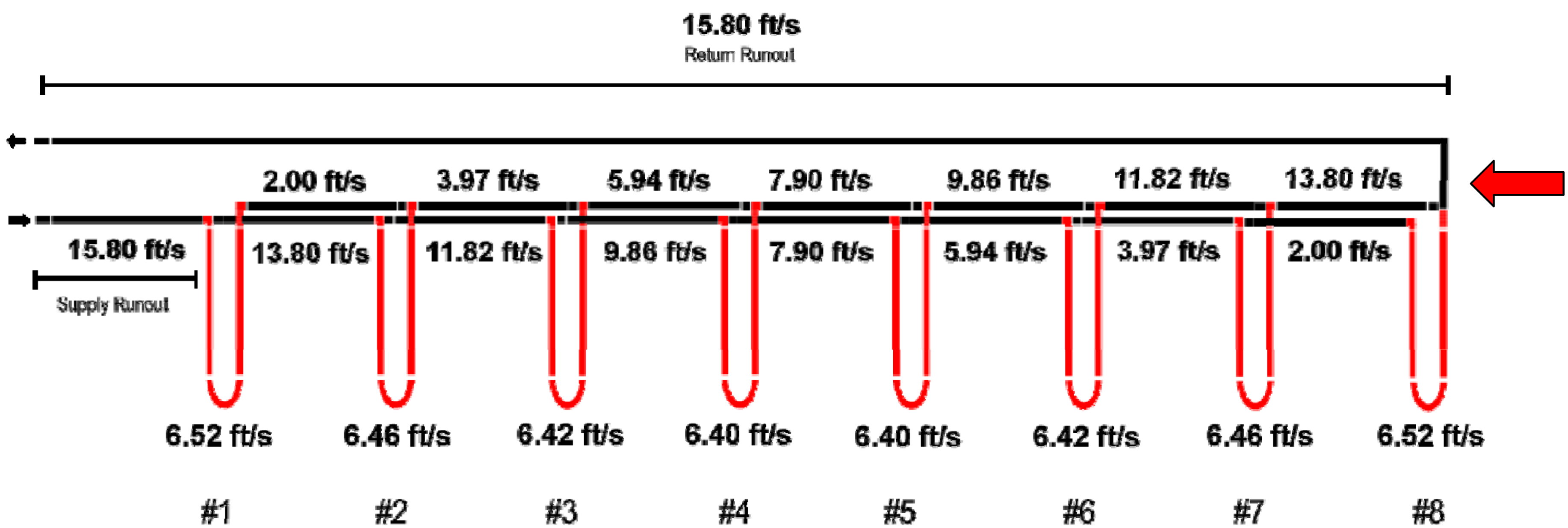


The GHX circuits are being purged but the headering is not.

Purging Design: RR Systems

Based on this configuration, to achieve 2 ft/s flow rates across the headering system requires:

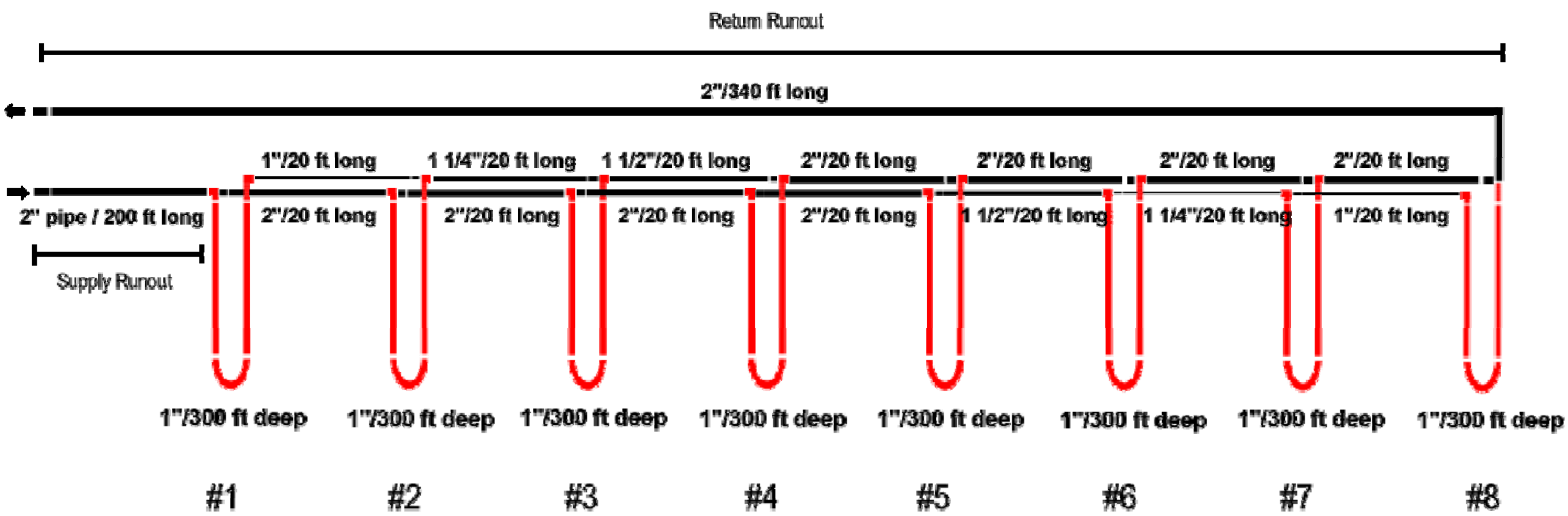
146 GPM and 345 ft. hd.



This clearly is unreasonable and justifies the use of a reducing headering system.

Purging Design: RR Systems

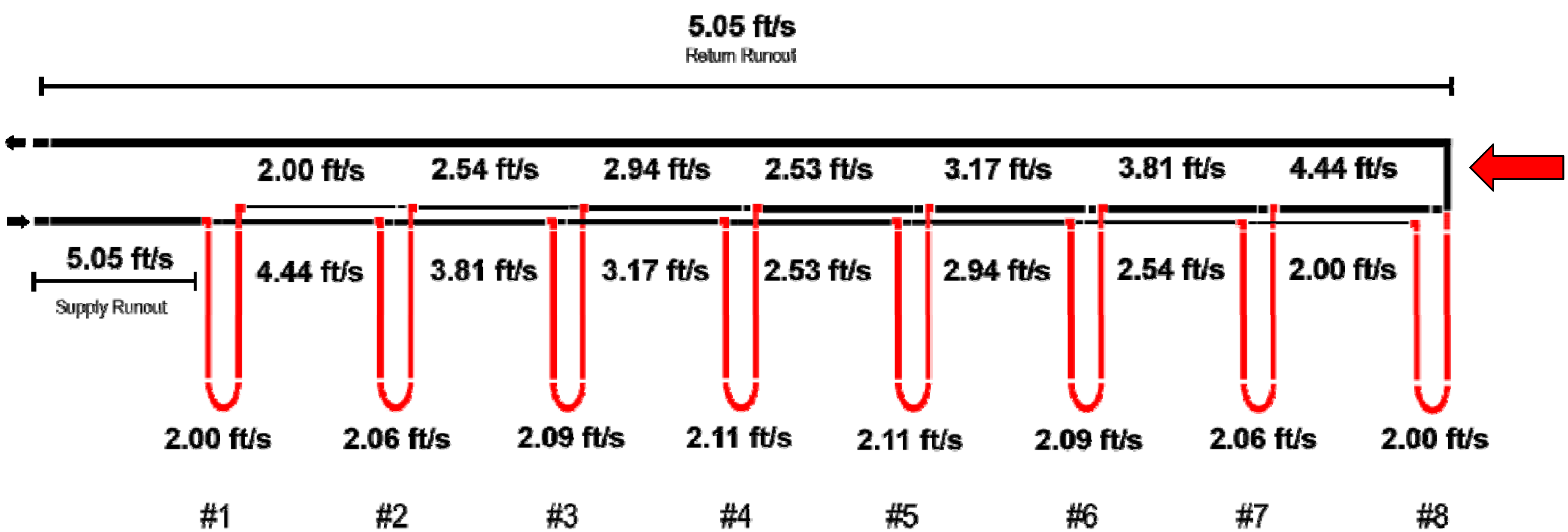
Reducing headering systems enable purging velocities throughout a system while maintaining reasonable flow rates and pressure drops.



Purging Design: RR Systems

Reducing headering systems enable purging velocities throughout a system while maintaining reasonable flow rates and pressure drops.

46.7 GPM and 46.2 ft. hd.



Purging Design: RR Systems

Other Reducing Header Options:

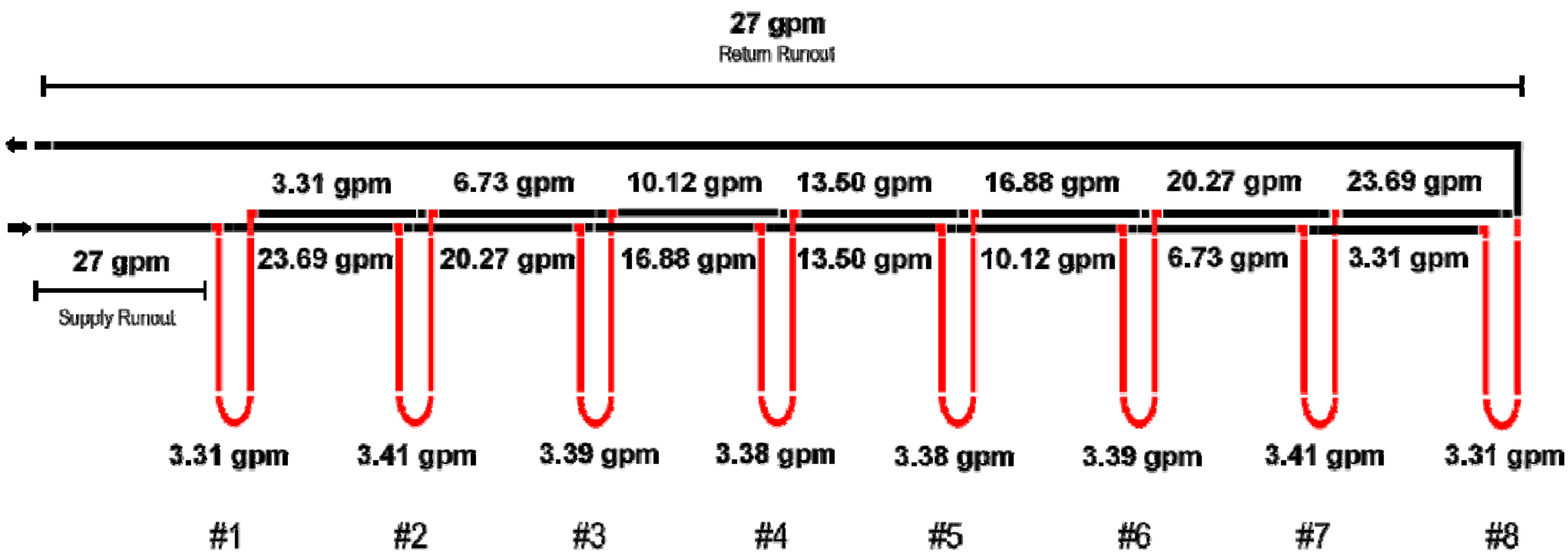
Header Section	Example	Velocity (ft/s)	Design Option 1	Velocity (ft/s)	Design Option 2	Velocity (ft/s)
Runout	2”/2”	5.05 /5.05	2”/2”	2.34/2.34	2”/2”	2.69/2.69
1	2”/1”	4.44/2.00	2”/1”	2.06/2.00	2”/1”	2.37/2.29
2	2”/1 ¼”	3.81/2.54	2”/1 ½”	3.84/2.56	2”/2”	2.03/2.93
3	2”/1 ½”	3.17/2.94	2”/2	3.20/2.96	2”/2”	3.67/2.18
4	2”/2”	2.53/2.53	2”/2”	2.55/2.55	2”/2”	2.92/2.92
5	1 ½”/2”	2.94/3.17	2”/2”	2.96/3.20	2”/2”	2.18/3.67
6	1 ¼”/2”	2.54/3.81	1 ½”/2”	2.56/3.84	2”/2”	2.93/2.03
7	1”/2”	2.00/4.44	1”/2”	2.00/2.06	1”/2”	2.29/2.37
Flow Rate		46.7 gpm		49.5 gpm		71.9 gpm
PD		37.6 ft. hd.		42.5 ft. hd		84 ft. hd.

Design and Performance: RR Systems

Flow Balance and Reynolds Numbers

Flow balance is important to ensure that all of the GHX circuits exchange an equal # of BTUS with the ground. Unbalanced systems perform poorly.

This RR system has GHX circuit flow rates that range from 3.31 gpm to 3.41 gpm, a less than 5% imbalance across the entire GHX Module. Note: Propylene Glycol with freeze protection down to 20F, 27 gpm, 20.2 ft hd.



Design and Performance: RR Systems

Flow Balance and Reynolds Numbers

Name	Pipe 1 Size	Pipe 1 Length	Pipe 1 Flow Rate	Pipe 1 Velocity	Pipe 1 Reynold's Number
Circuit #01	1"	300.0 ft	4.17 gpm	1.47 ft/s	4156
Circuit #02	1"	300.0 ft	4.33 gpm	1.53 ft/s	4323
Circuit #03	1"	300.0 ft	4.43 gpm	1.57 ft/s	4417
Circuit #04	1"	300.0 ft	4.49 gpm	1.59 ft/s	4483
Circuit #05	1"	300.0 ft	4.52 gpm	1.60 ft/s	4508
Circuit #06	1"	300.0 ft	4.55 gpm	1.61 ft/s	4539
Circuit #07	1"	300.0 ft	4.59 gpm	1.62 ft/s	4578
Circuit #08	1"	300.0 ft	4.64 gpm	1.64 ft/s	4624
Circuit #09	1"	300.0 ft	4.64 gpm	1.64 ft/s	4626
Circuit #10	1"	300.0 ft	4.64 gpm	1.64 ft/s	4630
Circuit #11	1"	300.0 ft	4.64 gpm	1.64 ft/s	4630
Circuit #12	1"	300.0 ft	4.64 gpm	1.64 ft/s	4626
Circuit #13	1"	300.0 ft	4.64 gpm	1.64 ft/s	4624
Circuit #14	1"	300.0 ft	4.59 gpm	1.62 ft/s	4578
Circuit #15	1"	300.0 ft	4.55 gpm	1.61 ft/s	4539
Circuit #16	1"	300.0 ft	4.52 gpm	1.60 ft/s	4508
Circuit #17	1"	300.0 ft	4.49 gpm	1.59 ft/s	4483
Circuit #18	1"	300.0 ft	4.43 gpm	1.57 ft/s	4417
Circuit #19	1"	300.0 ft	4.33 gpm	1.53 ft/s	4323
Circuit #20	1"	300.0 ft	4.17 gpm	1.47 ft/s	4156

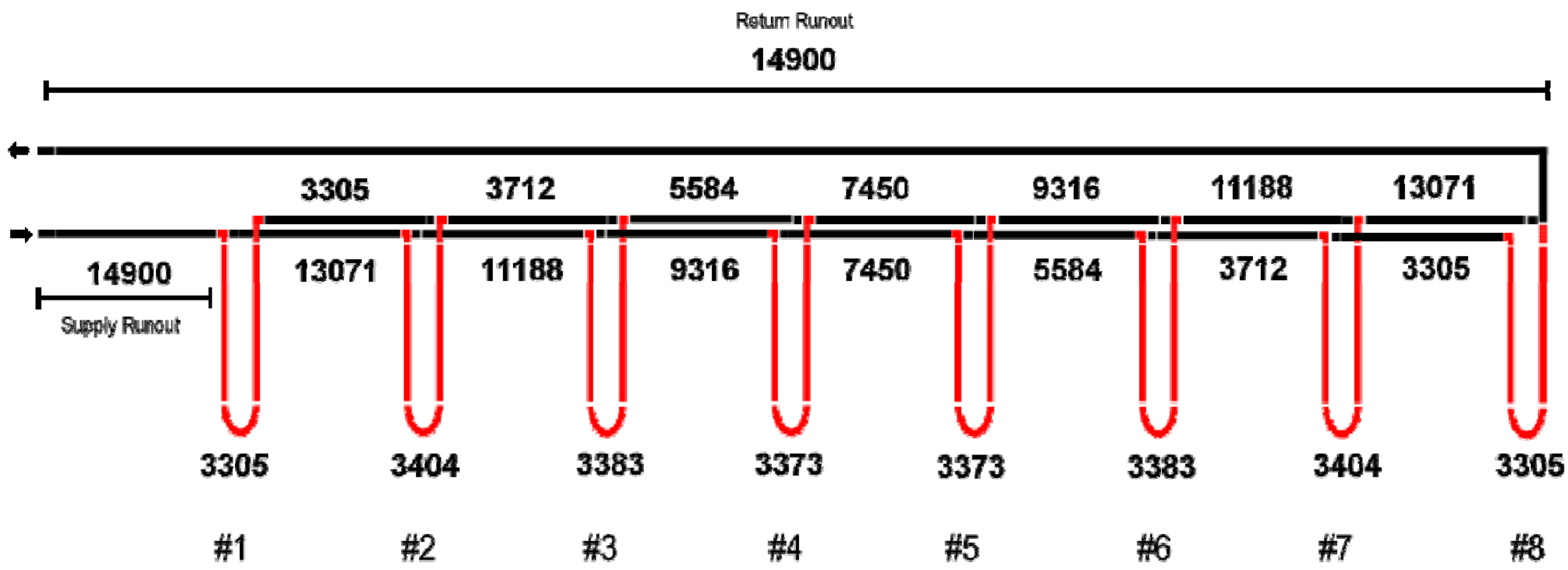
Conclusion: RR systems of all sizes are inherently balanced GHX modules.

Design and Performance: RR Systems

Balanced Flow and Reynolds Numbers

Reynolds indicate flow type (turbulent, laminar, etc). Turbulent flow is optimal for efficient heat transfer.

This RR system has GHX circuit flow Reynolds Numbers drop from 3,404 to 3,305, a 5% drop.



Design and Performance: DR vs RR

Design:

- Direct Return Systems are mirror images on the supply and return lines
- Reverse Return Systems are palindromes on the supply and return lines

Performance:

- Reverse return systems provide more balanced flow, more balanced heat transfer and are therefore superior. For this reason they are considered to be the "gold standard" design methodology.

DR vs RR : Conclusion

Issue	Direct Return	Reverse Return
Design	Easier	Harder
Construction	Easier	Harder
Pressure Drop	Maybe Lower	Maybe Higher
Flow Balance	Worse	Better
Performance	Lower	Higher

Workshop Outline – Good Design Practices

- What is the CFD Module?
- What are we Trying to Accomplish?
- Brief Review of General Fluid Dynamics Calculations
- Reality Check
- Learn Standard Nomenclature for Geothermal Piping Systems
- Basic Standard Configurations: Direct Return & Reverse Return Systems
- Purging Design & Performance: Direct Return & Reverse Return Systems
- **Good Design Practices**
- Using the GLD 2014 CFD Module to Design Piping Systems

Good Design Practices

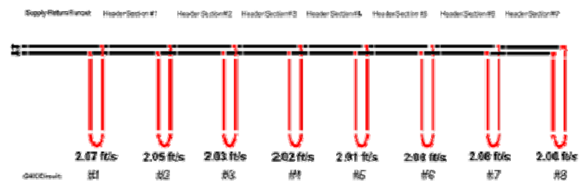
Good design practices help ensure that:

- A system can be purged (we've seen this already)
- A system is fairly well balanced (we've seen this already)
- A system has a low pressure drop (under 30 ft head per module)

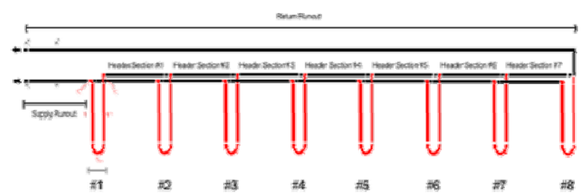
To achieve these goals we need to be aware of how our design decisions affect performance. Critical design decisions include:

GHX Circuit Lengths and Pipe Diameter Selection
Number of Circuits in a GHX Module
Supply Return Pipe Size Selection

Good Design Practices: GHX Circuit Lengths/Pipe Diameter Selection



Name	Pipe 1 Size	Pipe 2 Size	Pipe 1 Length	Pipe 2 Length	Total Branch Pressure Drop
U Circuit #08	3/4"	3/4"	500.0 ft	500.0 ft	15.1 ft. hd
U Circuit #08	1"	1"	500.0 ft	500.0 ft	5.0 ft. hd
U Circuit #08	1 1/4"	1 1/4"	500.0 ft	500.0 ft	1.8 ft. hd
U Circuit #08	1 1/2"	1 1/2"	500.0 ft	500.0 ft	1.0 ft. hd



Name	Pipe 1 Size	Pipe 2 Size	Pipe 1 Length	Pipe 2 Length	Total Branch Pressure Drop
U Circuit #08	3/4"	3/4"	500.0 ft	500.0 ft	14.6 ft. hd
U Circuit #08	1"	1"	500.0 ft	500.0 ft	4.8 ft. hd
U Circuit #08	1 1/4"	1 1/4"	500.0 ft	500.0 ft	1.4 ft. hd
U Circuit #08	1 1/2"	1 1/2"	500.0 ft	500.0 ft	0.6 ft. hd

Conclusion: Choose the right pipe size for the circuit length

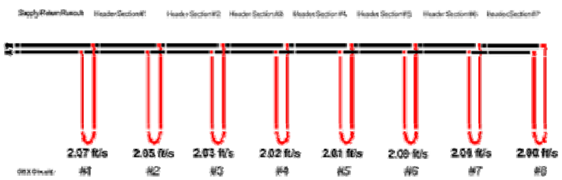
Good Design Practices: GHX Circuit Lengths/Pipe Diameter Selection

General Guidelines:

One Way Circuit Length	Pipe Size
200’	¾”
250’	¾”
300’	1”
350’	1”-1 ¼”
400’	1 ¼”
500’ +	1 ½”

Good Design Practices: GHX Circuit Lengths/Pipe Diameter Selection

BAD NEWS: Circuits of Different Lengths in a Single DR GHX Module



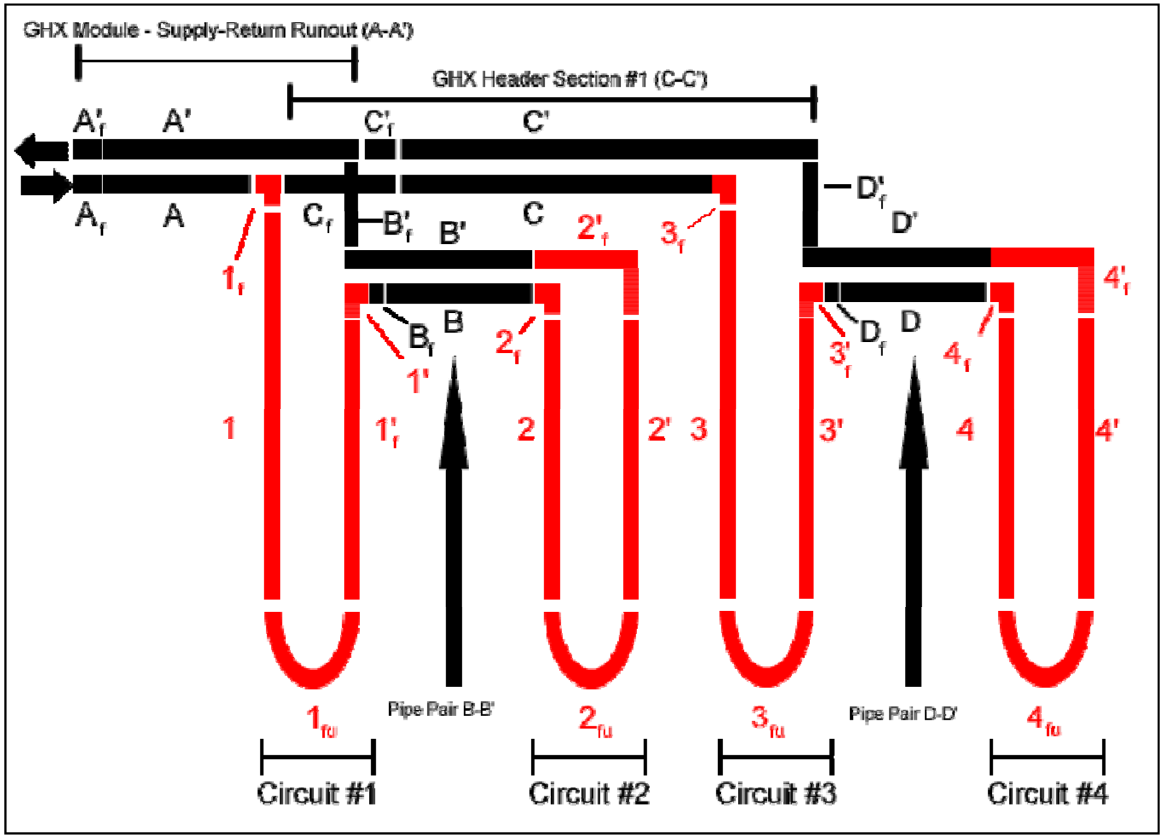
Name	Pipe 1 Length	Pipe 1 Flow Rate	Pipe 1 Velocity	Pipe 1 Reynold's Number
Circuit #01	300.0 ft	3.32 gpm	1.17 ft/s	5454
Circuit #02	300.0 ft	3.29 gpm	1.16 ft/s	5404
Circuit #03	300.0 ft	3.15 gpm	1.11 ft/s	5167
Circuit #04	300.0 ft	3.04 gpm	1.08 ft/s	4996
Circuit #05	300.0 ft	2.97 gpm	1.05 ft/s	4882
Circuit #06	300.0 ft	2.85 gpm	1.01 ft/s	4685
Circuit #07	300.0 ft	2.74 gpm	0.97 ft/s	4502
Circuit #08	300.0 ft	2.64 gpm	0.93 ft/s	4337

Name	Pipe 1 Length	Pipe 1 Flow Rate	Pipe 1 Velocity	Pipe 1 Reynold's Number
Circuit #01	300.0 ft	3.11 gpm	1.10 ft/s	5112
Circuit #02	300.0 ft	3.08 gpm	1.09 ft/s	5059
Circuit #03	300.0 ft	2.92 gpm	1.03 ft/s	4799
Circuit #04	300.0 ft	2.80 gpm	0.99 ft/s	4602
Circuit #05	300.0 ft	2.72 gpm	0.96 ft/s	4463
Circuit #06	300.0 ft	2.55 gpm	0.90 ft/s	4196
Circuit #07	150.0 ft	3.53 gpm	1.25 ft/s	5799
Circuit #08	150.0 ft	3.29 gpm	1.16 ft/s	5397

Conclusion: DR Module imbalance exacerbated by 7%. Therefore don't do it unless…

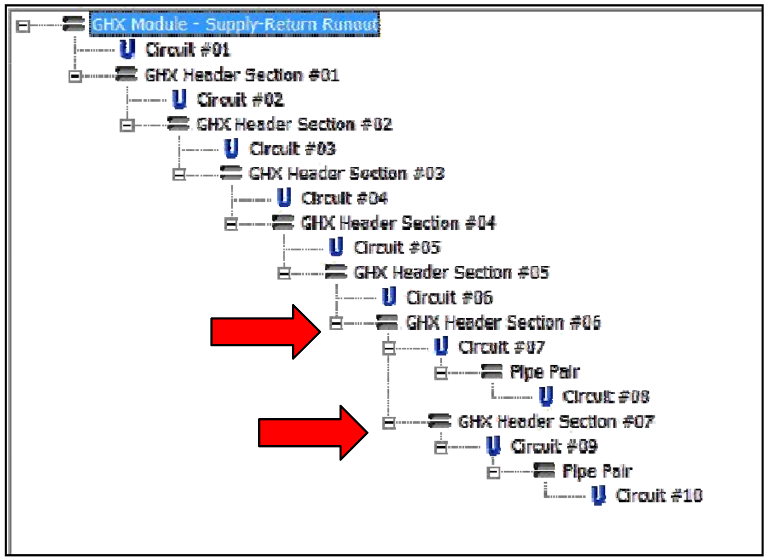
Good Design Practices: GHX Circuit Lengths/Pipe Diameter Selection

Partially mitigate problem by having two GHX circuits in series (two bores per circuit for example):



Good Design Practices: GHX Circuit Lengths/Pipe Diameter Selection

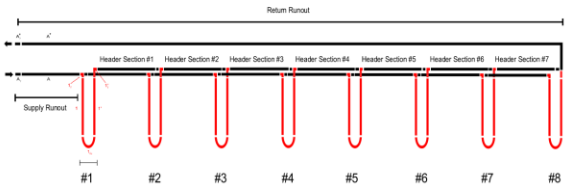
Partially mitigate problem by having two GHX circuits in series (two bores per circuit for example):



Name	Pipe 1 Length	Pipe 1 Flow Rate	Pipe 1 Velocity	Pipe 1 Reynold's Number
Circuit #01	300.0 ft	3.46 gpm	1.22 ft/s	5682
Circuit #02	300.0 ft	3.27 gpm	1.16 ft/s	5374
Circuit #03	300.0 ft	3.13 gpm	1.11 ft/s	5139
Circuit #04	300.0 ft	3.02 gpm	1.07 ft/s	4969
Circuit #05	300.0 ft	2.96 gpm	1.04 ft/s	4855
Circuit #06	300.0 ft	2.84 gpm	1.00 ft/s	4661
Circuit #07	150.0 ft	2.71 gpm	0.96 ft/s	4455
Circuit #08	150.0 ft	2.71 gpm	0.96 ft/s	4455
Circuit #09	150.0 ft	2.61 gpm	0.92 ft/s	4294
Circuit #10	150.0 ft	2.61 gpm	0.92 ft/s	4294

Good Design Practices: GHX Circuit Lengths/Pipe Diameter Selection

BAD NEWS: Circuits of Different Lengths in a Single RR GHX Module



Name	Pipe 1 Length	Pipe 1 Flow Rate	Pipe 1 Velocity	Pipe 1 Reynold's Number
Circuit #01	300.0 ft	2.91 gpm	1.03 ft/s	4776
Circuit #02	300.0 ft	3.00 gpm	1.06 ft/s	4922
Circuit #03	300.0 ft	3.04 gpm	1.07 ft/s	4987
Circuit #04	300.0 ft	3.06 gpm	1.08 ft/s	5028
Circuit #05	300.0 ft	3.06 gpm	1.08 ft/s	5028
Circuit #06	300.0 ft	3.04 gpm	1.07 ft/s	4987
Circuit #07	300.0 ft	3.00 gpm	1.06 ft/s	4922
Circuit #08	300.0 ft	2.91 gpm	1.03 ft/s	4776

Name	Pipe 1 Length	Pipe 1 Flow Rate	Pipe 1 Velocity	Pipe 1 Reynold's Number
Circuit #01	300.0 ft	2.23 gpm	0.79 ft/s	3662
Circuit #02	300.0 ft	2.29 gpm	0.81 ft/s	3762
Circuit #03	300.0 ft	2.31 gpm	0.82 ft/s	3800
Circuit #04	300.0 ft	2.32 gpm	0.82 ft/s	3819
Circuit #05	300.0 ft	2.32 gpm	0.82 ft/s	3805
Circuit #06	300.0 ft	2.27 gpm	0.80 ft/s	3733
Circuit #07	150.0 ft	5.30 gpm	1.87 ft/s	8707
Circuit #08	150.0 ft	4.95 gpm	1.75 ft/s	8137

Conclusion: RR Systems are “integrated systems” that are systemically very sensitive to changes. Therefore, all GHX circuits should be the same length.

Good Design Practices

We can focus on a number of variables to ensure a good design:

1) GHX Circuit Lengths and Pipe Diameter Selection
2) Number of Circuits in a GHX Module
3) Supply Return Pipe Size Selection

Good Design Practices: Number of Circuits per GHX Module

General Guidelines:

	2" Supply/Return	3" Supply/Return
0.75" circuits	8-14 circuits	14-20 circuits
1.00" circuits	6-10 circuits	10-15 circuits
1.25" circuits	4-6 circuits	6-10 circuits

Good Design Practices

We can focus on a number of variables to ensure a good design:

1) GHX Circuit Lengths and Pipe Diameter Selection
2) Number of Circuits in a GHX Module
3) Supply Return Pipe Size Selection

Good Design Practices: Supply Return Runout Pipe Size Selection

Supply Return Runout Pipe Size Selection

Remember to not spec anything greater than 4” on the supply/return pipe size because anything bigger is very difficult to install in the field. Even 4” are hard to handle and require butt fusion.

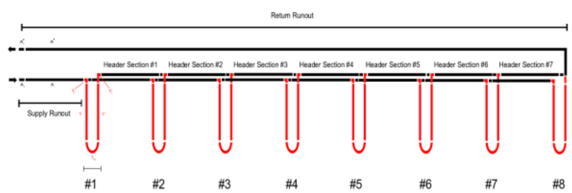
Selection of a Supply Return Runout pipe size is based on:

•The number of GHX circuits on the headering system: more GHX circuits = larger diameter runouts

•Purging flow rate and pressure drop goals. If your supply return pipe diameter is small your purging pressure drop could be huge

Good Design Practices: Supply Return Runout Pipe Size Selection

Two Inch vs Three Inch Supply Return Runouts



200 ft Supply/Return runouts
14 GHX Circuits

	2” Supply/Return	3” Supply/Return
Purging PD	31.3 ft. hd	10.3 ft. hd
Equipment PD	13.1 ft. hd.	4.2 ft. hd
Reynolds #s	~ 5,700	~ 5,700

50 ft Supply/Return runouts
14 GHX Circuits

	2” Supply/Return	3” Supply/Return
Purge PD	13.3 ft. hd	9.4 ft. hd
Equipment PD	5.9 ft. hd.	3.9 ft. hd
Reynolds #s	~ 5,800	~ 5,900

Conclusion: Larger diameter pipe = smaller purge pumps and lower cost performance

Good Design Practices: Supply Return Runout Pipe Size Selection

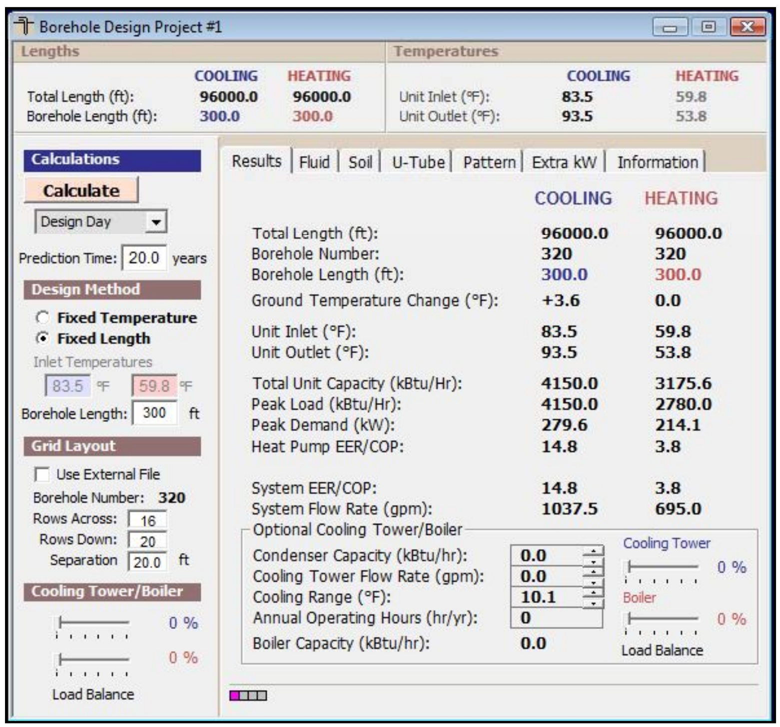
GHX Module - Supply-Return Runout | 2" | (2") | 7.11 ft/s | (7.11 ft/s) | [22.2 ft. hd] |
U Circuit #01 | 1" | (1") | 2.05 ft/s | (2.05 ft/s) | [5.1 ft. hd] |
GHX Header Section #01 | 2" | (1") | 6.48 ft/s | (2.05 ft/s) | [0.0 ft. hd] |
U Circuit #02 | 1" | (1") | 2.11 ft/s | (2.11 ft/s) | [5.3 ft. hd] |
GHX Header Section #02 | 2" | (1 1/4") | 5.84 ft/s | (2.61 ft/s) | [0.0 ft. hd] |
U Circuit #03 | 1" | (1") | 2.13 ft/s | (2.13 ft/s) | [5.4 ft. hd] |
GHX Header Section #03 | 2" | (1 1/2") | 5.19 ft/s | (3.01 ft/s) | [0.0 ft. hd] |
U Circuit #04 | 1" | (1") | 2.14 ft/s | (2.14 ft/s) | [5.4 ft. hd] |
GHX Header Section #04 | 2" | (2") | 4.53 ft/s | (2.58 ft/s) | [0.0 ft. hd] |
U Circuit #05 | 1" | (1") | 2.13 ft/s | (2.13 ft/s) | [5.4 ft. hd] |
GHX Header Section #05 | 2" | (2") | 3.88 ft/s | (3.23 ft/s) | [0.0 ft. hd] |
U Circuit #06 | 1" | (1") | 2.12 ft/s | (2.12 ft/s) | [5.4 ft. hd] |
GHX Header Section #06 | 2" | (2") | 3.23 ft/s | (3.88 ft/s) | [0.0 ft. hd] |
U Circuit #07 | 1" | (1") | 2.13 ft/s | (2.13 ft/s) | [5.4 ft. hd] |
GHX Header Section #07 | 2" | (2") | 2.58 ft/s | (4.53 ft/s) | [0.0 ft. hd] |
U Circuit #08 | 1" | (1") | 2.14 ft/s | (2.14 ft/s) | [5.4 ft. hd] |
GHX Header Section #08 | 1 1/2" | (2") | 3.01 ft/s | (5.19 ft/s) | [0.0 ft. hd] |
U Circuit #09 | 1" | (1") | 2.13 ft/s | (2.13 ft/s) | [5.4 ft. hd] |
GHX Header Section #09 | 1 1/4" | (2") | 2.61 ft/s | (5.84 ft/s) | [0.0 ft. hd] |
U Circuit #10 | 1" | (1") | 2.11 ft/s | (2.11 ft/s) | [5.3 ft. hd] |
GHX Header Section #10 | 1" | (2") | 2.05 ft/s | (6.48 ft/s) | [0.0 ft. hd] |
U Circuit #11 | 1" | (1") | 2.05 ft/s | (2.05 ft/s) | [5.1 ft. hd] |

GHX Module - Supply-Return Runout | 3" | (3") | 3.27 ft/s | (3.27 ft/s) | [8.4 ft. hd] |
U Circuit #01 | 1" | (1") | 2.00 ft/s | (2.00 ft/s) | [4.8 ft. hd] |
GHX Header Section #01 | 3" | (1") | 2.99 ft/s | (2.00 ft/s) | [0.0 ft. hd] |
U Circuit #02 | 1" | (1") | 2.08 ft/s | (2.08 ft/s) | [5.2 ft. hd] |
GHX Header Section #02 | 3" | (1 1/4") | 2.70 ft/s | (2.56 ft/s) | [0.0 ft. hd] |
U Circuit #03 | 1" | (1") | 2.13 ft/s | (2.13 ft/s) | [5.4 ft. hd] |
GHX Header Section #03 | 3" | (1 1/2") | 2.40 ft/s | (2.97 ft/s) | [0.0 ft. hd] |
U Circuit #04 | 1" | (1") | 2.16 ft/s | (2.16 ft/s) | [5.5 ft. hd] |
GHX Header Section #04 | 3" | (2") | 2.09 ft/s | (2.56 ft/s) | [0.0 ft. hd] |
U Circuit #05 | 1" | (1") | 2.17 ft/s | (2.17 ft/s) | [5.6 ft. hd] |
GHX Header Section #05 | 2" | (2") | 3.89 ft/s | (3.22 ft/s) | [0.0 ft. hd] |
U Circuit #06 | 1" | (1") | 2.17 ft/s | (2.17 ft/s) | [5.6 ft. hd] |
GHX Header Section #06 | 2" | (2") | 3.22 ft/s | (3.89 ft/s) | [0.0 ft. hd] |
U Circuit #07 | 1" | (1") | 2.17 ft/s | (2.17 ft/s) | [5.6 ft. hd] |
GHX Header Section #07 | 2" | (3") | 2.56 ft/s | (2.09 ft/s) | [0.0 ft. hd] |
U Circuit #08 | 1" | (1") | 2.16 ft/s | (2.16 ft/s) | [5.5 ft. hd] |
GHX Header Section #08 | 1 1/2" | (3") | 2.97 ft/s | (2.40 ft/s) | [0.0 ft. hd] |
U Circuit #09 | 1" | (1") | 2.13 ft/s | (2.13 ft/s) | [5.4 ft. hd] |
GHX Header Section #09 | 1 1/4" | (3") | 2.56 ft/s | (2.70 ft/s) | [0.0 ft. hd] |
U Circuit #10 | 1" | (1") | 2.08 ft/s | (2.08 ft/s) | [5.2 ft. hd] |
GHX Header Section #10 | 1" | (3") | 2.00 ft/s | (2.99 ft/s) | [0.0 ft. hd] |
U Circuit #11 | 1" | (1") | 2.00 ft/s | (2.00 ft/s) | [4.8 ft. hd] |

Good Design Practices: An Example

For this heat exchanger system we want less than 30 ft head for each GHX Module. We can achieve this by using good design practices:

A) Optimize the number of GHX circuits in each GHX Module
B) Optimize the supply/return runout pipe size
C) Consider using a geothermal vault to reduce the length of the Supply-Return Runout
D) And of course, ensure that we choose the right diameter pipe for the circuits



Good Design Practices: Maximum Pressure Drop

Optimize the number of GHX circuits in the GHX Module:

First look at 16 GHX Circuits per GHX Module (Propylene Glycol, 20F freeze protection)
Pressure drop is 56 ft. hd = too high

Borehole Number:	320
Rows Across:	16
Rows Down:	20
Separation	20.0 ft

Name	Pipe 1 Size	Pipe 1 Length	Pipe 1 Flow ...	Pipe 1 Reyn...	Total Branch Pressure Drop
GHX Module - Supply-Return Runout	2"	200.0 ft	60.00 gpm	33111	56.0 ft. hd
Circuit #01	1"	300.0 ft	3.75 gpm	3743	7.7 ft. hd
GHX Header Section #01	2"	20.0 ft	56.25 gpm	31040	0.0 ft. hd
Circuit #02	1"	300.0 ft	3.83 gpm	3818	8.0 ft. hd
GHX Header Section #02	2"	20.0 ft	52.42 gpm	28928	0.0 ft. hd
Circuit #03	1"	300.0 ft	3.80 gpm	3786	7.9 ft. hd
GHX Header Section #03	2"	20.0 ft	48.62 gpm	26833	0.0 ft. hd
Circuit #04	1"	300.0 ft	3.79 gpm	3777	7.9 ft. hd
GHX Header Section #04	2"	20.0 ft	44.84 gpm	24743	0.0 ft. hd
Circuit #05	1"	300.0 ft	3.75 gpm	3736	7.7 ft. hd
GHX Header Section #05	2"	20.0 ft	41.09 gpm	22677	0.0 ft. hd
Circuit #06	1"	300.0 ft	3.71 gpm	3705	7.6 ft. hd
GHX Header Section #06	2"	20.0 ft	37.38 gpm	20627	0.0 ft. hd
Circuit #07	1"	300.0 ft	3.69 gpm	3685	7.6 ft. hd
GHX Header Section #07	2"	20.0 ft	33.68 gpm	18588	0.0 ft. hd
Circuit #08	1"	300.0 ft	3.68 gpm	3674	7.5 ft. hd
GHX Header Section #08	2"	20.0 ft	30.00 gpm	16555	0.0 ft. hd
Circuit #09	1"	300.0 ft	3.68 gpm	3674	7.5 ft. hd
GHX Header Section #09	2"	20.0 ft	26.32 gpm	14522	0.0 ft. hd
Circuit #10	1"	300.0 ft	3.69 gpm	3685	7.6 ft. hd
GHX Header Section #10	2"	20.0 ft	22.62 gpm	12484	0.0 ft. hd
Circuit #11	1"	300.0 ft	3.71 gpm	3705	7.6 ft. hd
GHX Header Section #11	2"	20.0 ft	18.91 gpm	10434	0.0 ft. hd
Circuit #12	1"	300.0 ft	3.75 gpm	3736	7.7 ft. hd
GHX Header Section #12	2"	20.0 ft	15.16 gpm	8367	0.0 ft. hd
Circuit #13	1"	300.0 ft	3.79 gpm	3777	7.9 ft. hd
GHX Header Section #13	1 1/2"	20.0 ft	11.38 gpm	7849	0.0 ft. hd
Circuit #14	1"	300.0 ft	3.80 gpm	3786	7.9 ft. hd
GHX Header Section #14	1 1/2"	20.0 ft	7.58 gpm	5230	0.0 ft. hd
Circuit #15	1"	300.0 ft	3.83 gpm	3818	8.0 ft. hd
GHX Header Section #15	1"	20.0 ft	3.75 gpm	3743	0.0 ft. hd
Circuit #16	1"	300.0 ft	3.75 gpm	3743	7.7 ft. hd

Reduce the number of circuits to 11 per GHX module

Good Design Practices: Maximum Pressure Drop

Borehole Number:	320
Rows Across:	16
Rows Down:	20
Separation	20.0 ft

Optimize the number of GHX circuits in the GHX Module:

With 11GHX Circuits per GHX Module (Propylene Glycol, 20F freeze protection)
Pressure drop is 30.7 ft. hd = ok

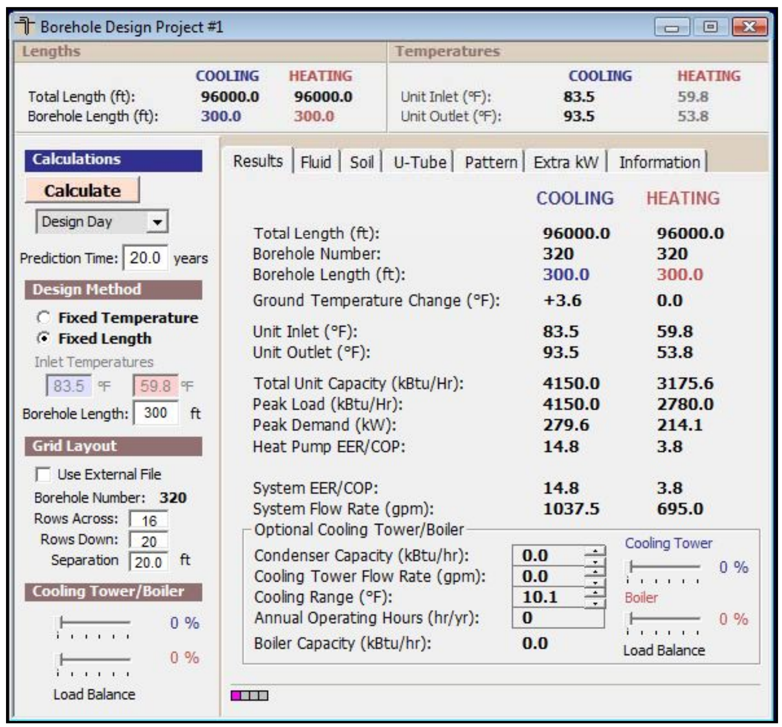
Name	Pipe 1 Size	Pipe 1 Length	Pipe 1 Flow Rate	Pipe 1 Reynold's Number	Total Branch Pressure Drop
GHX Module - Supply-Return Runout	2"	200.0 ft	41.00 gpm	22626	30.7 ft. hd
Circuit #01	1"	300.0 ft	3.63 gpm	3617	7.3 ft. hd
GHX Header Section #01	2"	20.0 ft	37.37 gpm	20625	0.0 ft. hd
Circuit #02	1"	300.0 ft	3.72 gpm	3712	7.6 ft. hd
GHX Header Section #02	2"	20.0 ft	33.65 gpm	18571	0.0 ft. hd
Circuit #03	1"	300.0 ft	3.76 gpm	3745	7.8 ft. hd
GHX Header Section #03	2"	20.0 ft	29.90 gpm	16499	0.0 ft. hd
Circuit #04	1"	300.0 ft	3.77 gpm	3760	7.8 ft. hd
GHX Header Section #04	2"	20.0 ft	26.13 gpm	14418	0.0 ft. hd
Circuit #05	1"	300.0 ft	3.75 gpm	3744	7.8 ft. hd
GHX Header Section #05	2"	20.0 ft	22.37 gpm	12347	0.0 ft. hd
Circuit #06	1"	300.0 ft	3.75 gpm	3738	7.7 ft. hd
GHX Header Section #06	2"	20.0 ft	18.63 gpm	10279	0.0 ft. hd
Circuit #07	1"	300.0 ft	3.75 gpm	3744	7.8 ft. hd
GHX Header Section #07	2"	20.0 ft	14.87 gpm	8207	0.0 ft. hd
Circuit #08	1"	300.0 ft	3.77 gpm	3760	7.8 ft. hd
GHX Header Section #08	1 1/2"	20.0 ft	11.10 gpm	7660	0.0 ft. hd
Circuit #09	1"	300.0 ft	3.76 gpm	3745	7.8 ft. hd
GHX Header Section #09	1 1/4"	20.0 ft	7.35 gpm	5801	0.0 ft. hd
Circuit #10	1"	300.0 ft	3.72 gpm	3712	7.6 ft. hd
GHX Header Section #10	1"	20.0 ft	3.63 gpm	3617	0.0 ft. hd
Circuit #11	1"	300.0 ft	3.63 gpm	3617	7.3 ft. hd

Aim for 28 GHX Modules with 11 GHX Circuits and 1 GHX Module with 12 GHX Circuits for 320 Circuits

Good Design Practices: An Example

For this heat exchanger system we want less than 30 ft head for each GHX Module. We can achieve this by using good design practices:

A) Optimize the number of GHX circuits in each GHX Module
B) Optimize the supply/return runout pipe size
C) Consider using a geothermal vault to reduce the length of the Supply-Return Runout
D) And of course, ensure that we choose the right diameter pipe for the circuits



Good Design Practices: Maximum Pressure Drop

Optimize the supply return runout pipe size

First look at 16 GHX Circuits per GHX Module with 2” Supply-Return Runouts
Pressure drop is 56 ft. hd = too high

Borehole Number:	320
Rows Across:	16
Rows Down:	20
Separation	20.0 ft

Name	Pipe 1 Size	Pipe 1 Length	Pipe 1 Flow ...	Pipe 1 Reyn...	Total Branch Pressure Drop
GHX Module - Supply-Return Runout	2"	200.0 ft	60.00 gpm	33111	56.0 ft. hd
Circuit #01	1"	300.0 ft	3.75 gpm	3743	7.7 ft. hd
GHX Header Section #01	2"	20.0 ft	56.25 gpm	31040	0.0 ft. hd
Circuit #02	1"	300.0 ft	3.83 gpm	3818	8.0 ft. hd
GHX Header Section #02	2"	20.0 ft	52.42 gpm	28928	0.0 ft. hd
Circuit #03	1"	300.0 ft	3.80 gpm	3786	7.9 ft. hd
GHX Header Section #03	2"	20.0 ft	48.62 gpm	26833	0.0 ft. hd
Circuit #04	1"	300.0 ft	3.79 gpm	3777	7.9 ft. hd
GHX Header Section #04	2"	20.0 ft	44.84 gpm	24743	0.0 ft. hd
Circuit #05	1"	300.0 ft	3.75 gpm	3736	7.7 ft. hd
GHX Header Section #05	2"	20.0 ft	41.09 gpm	22677	0.0 ft. hd
Circuit #06	1"	300.0 ft	3.71 gpm	3705	7.6 ft. hd
GHX Header Section #06	2"	20.0 ft	37.38 gpm	20627	0.0 ft. hd
Circuit #07	1"	300.0 ft	3.69 gpm	3685	7.6 ft. hd
GHX Header Section #07	2"	20.0 ft	33.68 gpm	18588	0.0 ft. hd
Circuit #08	1"	300.0 ft	3.68 gpm	3674	7.5 ft. hd
GHX Header Section #08	2"	20.0 ft	30.00 gpm	16555	0.0 ft. hd
Circuit #09	1"	300.0 ft	3.68 gpm	3674	7.5 ft. hd
GHX Header Section #09	2"	20.0 ft	26.32 gpm	14522	0.0 ft. hd
Circuit #10	1"	300.0 ft	3.69 gpm	3685	7.6 ft. hd
GHX Header Section #10	2"	20.0 ft	22.62 gpm	12484	0.0 ft. hd
Circuit #11	1"	300.0 ft	3.71 gpm	3705	7.6 ft. hd
GHX Header Section #11	2"	20.0 ft	18.91 gpm	10434	0.0 ft. hd
Circuit #12	1"	300.0 ft	3.75 gpm	3736	7.7 ft. hd
GHX Header Section #12	2"	20.0 ft	15.16 gpm	8367	0.0 ft. hd
Circuit #13	1"	300.0 ft	3.79 gpm	3777	7.9 ft. hd
GHX Header Section #13	1 1/2"	20.0 ft	11.38 gpm	7849	0.0 ft. hd
Circuit #14	1"	300.0 ft	3.80 gpm	3786	7.9 ft. hd
GHX Header Section #14	1 1/2"	20.0 ft	7.58 gpm	5230	0.0 ft. hd
Circuit #15	1"	300.0 ft	3.83 gpm	3818	8.0 ft. hd
GHX Header Section #15	1"	20.0 ft	3.75 gpm	3743	0.0 ft. hd
Circuit #16	1"	300.0 ft	3.75 gpm	3743	7.7 ft. hd

Good Design Practices: Maximum Pressure Drop

Borehole Number: **320**
Rows Across: 16
Rows Down: 20
Separation 20.0 ft

Increase the pipe size of the supply return runout to 3”

With 16GHX Circuits per GHX Module with 3” runouts: Pressure drop is 15.8 ft. hd = good

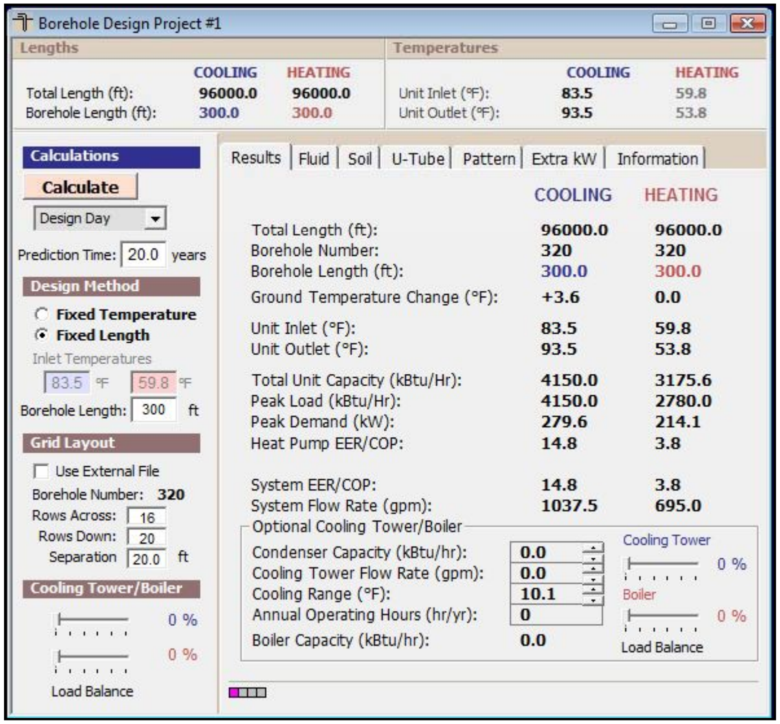
Name	Pipe 1 Size	Pipe 1 Length	Pipe 1 Flow Rate	Pipe 1 Reynold's Number	Total Branch Pressure Drop
GHX Module - Supply-Return Runout	3"	200.0 ft	60.00 gpm	22463	15.8 ft. hd
Circuit #01	1"	300.0 ft	3.52 gpm	3508	6.9 ft. hd
GHX Header Section #01	3"	20.0 ft	56.48 gpm	21146	0.0 ft. hd
Circuit #02	1"	300.0 ft	3.65 gpm	3645	7.4 ft. hd
GHX Header Section #02	3"	20.0 ft	52.83 gpm	19778	0.0 ft. hd
Circuit #03	1"	300.0 ft	3.73 gpm	3719	7.7 ft. hd
GHX Header Section #03	3"	20.0 ft	49.10 gpm	18382	0.0 ft. hd
Circuit #04	1"	300.0 ft	3.78 gpm	3771	7.9 ft. hd
GHX Header Section #04	3"	20.0 ft	45.32 gpm	16967	0.0 ft. hd
Circuit #05	1"	300.0 ft	3.80 gpm	3788	7.9 ft. hd
GHX Header Section #05	3"	20.0 ft	41.52 gpm	15545	0.0 ft. hd
Circuit #06	1"	300.0 ft	3.82 gpm	3811	8.0 ft. hd
GHX Header Section #06	3"	20.0 ft	37.70 gpm	14114	0.0 ft. hd
Circuit #07	1"	300.0 ft	3.85 gpm	3841	8.1 ft. hd
GHX Header Section #07	3"	20.0 ft	33.85 gpm	12673	0.0 ft. hd
Circuit #08	1"	300.0 ft	3.85 gpm	3840	8.1 ft. hd
GHX Header Section #08	3"	20.0 ft	30.00 gpm	11231	0.0 ft. hd
Circuit #09	1"	300.0 ft	3.85 gpm	3840	8.1 ft. hd
GHX Header Section #09	3"	20.0 ft	26.15 gpm	9790	0.0 ft. hd
Circuit #10	1"	300.0 ft	3.85 gpm	3841	8.1 ft. hd
GHX Header Section #10	2"	20.0 ft	22.30 gpm	12306	0.0 ft. hd
Circuit #11	1"	300.0 ft	3.82 gpm	3811	8.0 ft. hd
GHX Header Section #11	2"	20.0 ft	18.48 gpm	10197	0.0 ft. hd
Circuit #12	1"	300.0 ft	3.80 gpm	3788	7.9 ft. hd
GHX Header Section #12	2"	20.0 ft	14.68 gpm	8101	0.0 ft. hd
Circuit #13	1"	300.0 ft	3.78 gpm	3771	7.9 ft. hd
GHX Header Section #13	1 1/2"	20.0 ft	10.90 gpm	7520	0.0 ft. hd
Circuit #14	1"	300.0 ft	3.73 gpm	3719	7.7 ft. hd
GHX Header Section #14	1 1/4"	20.0 ft	7.17 gpm	5662	0.0 ft. hd
Circuit #15	1"	300.0 ft	3.65 gpm	3645	7.4 ft. hd
GHX Header Section #15	1"	20.0 ft	3.52 gpm	3508	0.0 ft. hd
Circuit #16	1"	300.0 ft	3.52 gpm	3508	6.9 ft. hd

Aim for 20 GHX Modules with 16 GHX Circuits for a total of 320 Circuits

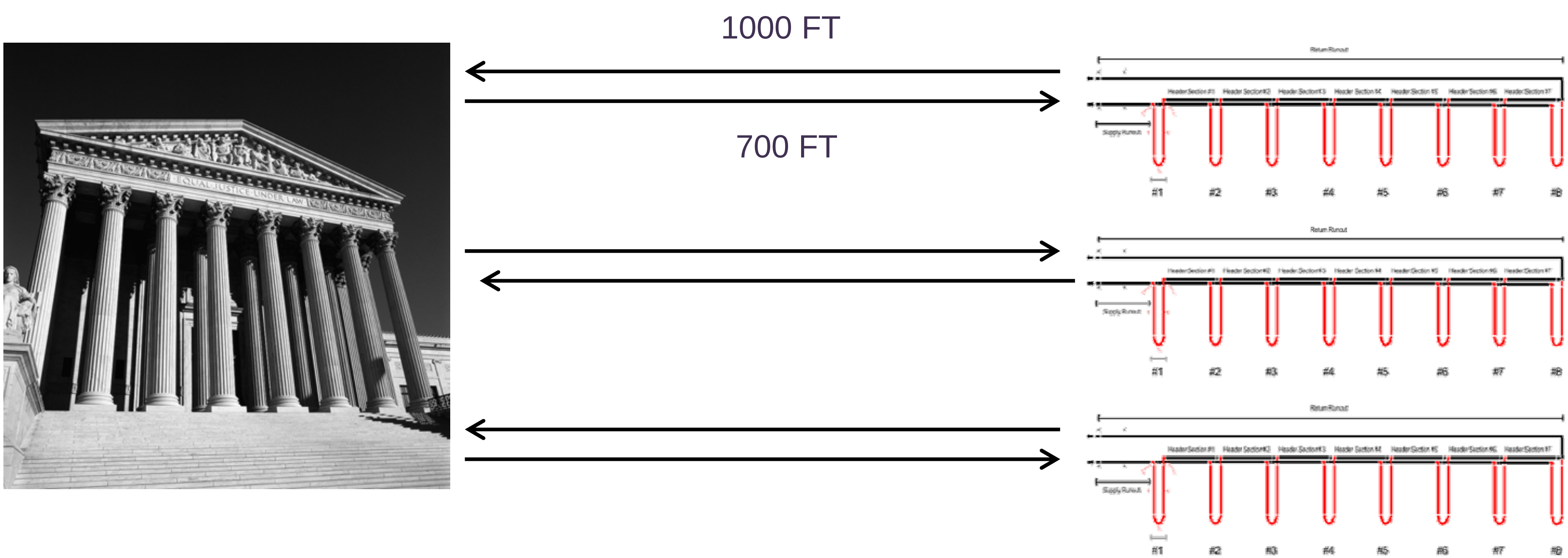
Good Design Practices: An Example

For this heat exchanger system we want less than 30 ft head for each GHX Module. We can achieve this by using good design practices:

A) Optimize the number of GHX circuits in each GHX Module
B) Optimize the supply/return runout pipe size
C) <u>Consider using a geothermal vault to reduce the length of the Supply-Return Runout</u>
D) And of course, ensure that we choose the right diameter pipe for the circuits



Maximum Pressure Drop



Maximum Pressure Drop

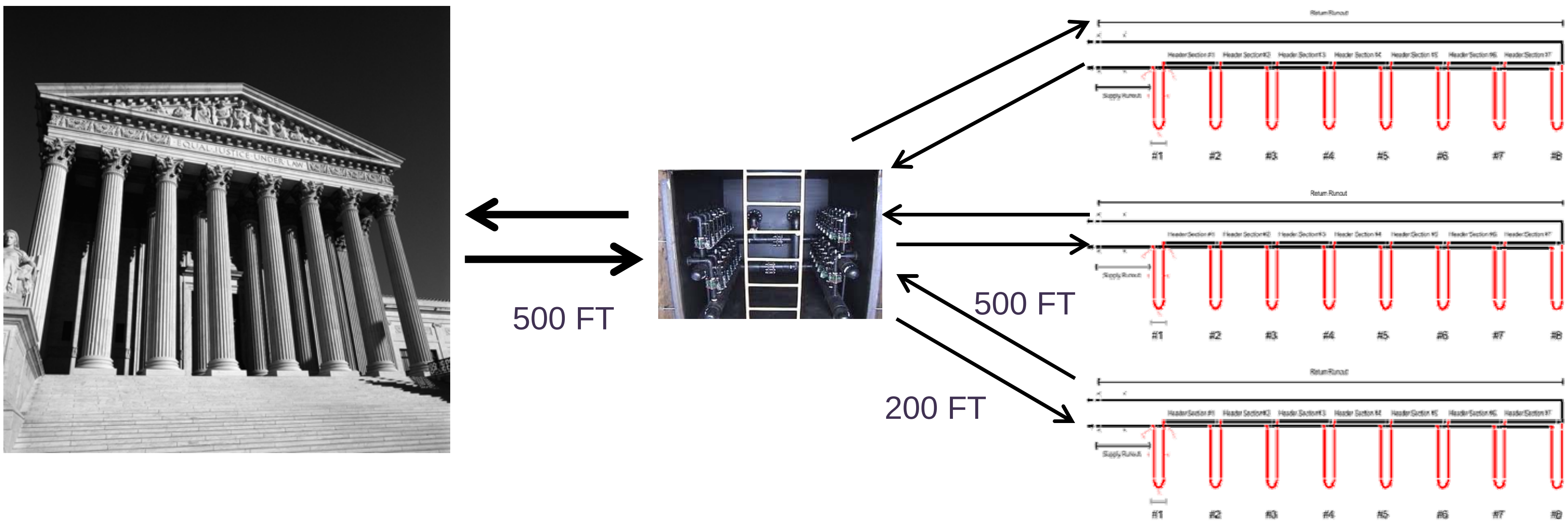
Assume the GHX Modules are 700ft/1000ft from the building
First look at 16 GHX Circuits per GHX Module with 3" Runouts
Pressure drop is 35.2 ft. hd = high

Borehole Number: 320
Rows Across: 16
Rows Down: 20
Separation 20.0 ft

Name	Pipe 1 Size	Pipe 2 Size	Pipe 1 Length	Pipe 2 Length	Pipe 1 Flow Rate	Pipe 1 Reynold's Number	Total Branch Pressure Drop
GHX Module - Supply-Return Runout	3"	3"	700.0 ft	1000.0 ft	60.00 gpm	22463	35.2 ft. hd
Circuit #01	1"	1"	300.0 ft	300.0 ft	3.52 gpm	3508	6.9 ft. hd
GHX Header Section #01	3"	1"	20.0 ft	20.0 ft	56.48 gpm	21146	0.0 ft. hd
Circuit #02	1"	1"	300.0 ft	300.0 ft	3.65 gpm	3645	7.4 ft. hd
GHX Header Section #02	3"	1 1/4"	20.0 ft	20.0 ft	52.83 gpm	19778	0.0 ft. hd
Circuit #03	1"	1"	300.0 ft	300.0 ft	3.73 gpm	3719	7.7 ft. hd
GHX Header Section #03	3"	1 1/2"	20.0 ft	20.0 ft	49.10 gpm	18382	0.0 ft. hd
Circuit #04	1"	1"	300.0 ft	300.0 ft	3.78 gpm	3771	7.9 ft. hd
GHX Header Section #04	3"	2"	20.0 ft	20.0 ft	45.32 gpm	16967	0.0 ft. hd
Circuit #05	1"	1"	300.0 ft	300.0 ft	3.80 gpm	3788	7.9 ft. hd
GHX Header Section #05	3"	2"	20.0 ft	20.0 ft	41.52 gpm	15545	0.0 ft. hd
Circuit #06	1"	1"	300.0 ft	300.0 ft	3.82 gpm	3811	8.0 ft. hd
GHX Header Section #06	3"	2"	20.0 ft	20.0 ft	37.70 gpm	14114	0.0 ft. hd
Circuit #07	1"	1"	300.0 ft	300.0 ft	3.85 gpm	3841	8.1 ft. hd
GHX Header Section #07	3"	3"	20.0 ft	20.0 ft	33.85 gpm	12673	0.0 ft. hd
Circuit #08	1"	1"	300.0 ft	300.0 ft	3.85 gpm	3840	8.1 ft. hd
GHX Header Section #08	3"	3"	20.0 ft	20.0 ft	30.00 gpm	11231	0.0 ft. hd
Circuit #09	1"	1"	300.0 ft	300.0 ft	3.85 gpm	3840	8.1 ft. hd
GHX Header Section #09	3"	3"	20.0 ft	20.0 ft	26.15 gpm	9790	0.0 ft. hd
Circuit #10	1"	1"	300.0 ft	300.0 ft	3.85 gpm	3841	8.1 ft. hd
GHX Header Section #10	2"	3"	20.0 ft	20.0 ft	22.30 gpm	12306	0.0 ft. hd
Circuit #11	1"	1"	300.0 ft	300.0 ft	3.82 gpm	3811	8.0 ft. hd
GHX Header Section #11	2"	3"	20.0 ft	20.0 ft	18.48 gpm	10197	0.0 ft. hd
Circuit #12	1"	1"	300.0 ft	300.0 ft	3.80 gpm	3788	7.9 ft. hd
GHX Header Section #12	2"	3"	20.0 ft	20.0 ft	14.68 gpm	8101	0.0 ft. hd
Circuit #13	1"	1"	300.0 ft	300.0 ft	3.78 gpm	3771	7.9 ft. hd
GHX Header Section #13	1 1/2"	3"	20.0 ft	20.0 ft	10.90 gpm	7520	0.0 ft. hd
Circuit #14	1"	1"	300.0 ft	300.0 ft	3.73 gpm	3719	7.7 ft. hd
GHX Header Section #14	1 1/4"	3"	20.0 ft	20.0 ft	7.17 gpm	5662	0.0 ft. hd
Circuit #15	1"	1"	300.0 ft	300.0 ft	3.65 gpm	3645	7.4 ft. hd
GHX Header Section #15	1"	3"	20.0 ft	20.0 ft	3.52 gpm	3508	0.0 ft. hd
Circuit #16	1"	1"	300.0 ft	300.0 ft	3.52 gpm	3508	6.9 ft. hd

Consider using a vault because going up to 4" Supply Return runouts can be difficult

Maximum Pressure Drop



Maximum Pressure Drop

Borehole Number: 320
Rows Across: 16
Rows Down: 20
Separation 20.0 ft

Use a vault that connects to a building via 500 ft 4" pipe
With 16GHX Circuits per GHX Module with 3" runouts
Pressure drop is 20.3 ft. hd = ok

Name	Pipe 1 Size	Pipe 2 Size	Pipe 1 Length	Pipe 2 Length	Pipe 1 Flow Rate	Pipe 1 Reynold's Number	Total Branch Pressure Drop
GHX Module - Supply-Return Runout	3"	3"	200.0 ft	500.0 ft	60.00 gpm	22463	20.3 ft. hd
Circuit #01	1"	1"	300.0 ft	300.0 ft	3.52 gpm	3508	6.9 ft. hd
GHX Header Section #01	3"	1"	20.0 ft	20.0 ft	56.48 gpm	21146	0.0 ft. hd
Circuit #02	1"	1"	300.0 ft	300.0 ft	3.65 gpm	3645	7.4 ft. hd
GHX Header Section #02	3"	1 1/4"	20.0 ft	20.0 ft	52.83 gpm	19778	0.0 ft. hd
Circuit #03	1"	1"	300.0 ft	300.0 ft	3.73 gpm	3719	7.7 ft. hd
GHX Header Section #03	3"	1 1/2"	20.0 ft	20.0 ft	49.10 gpm	18382	0.0 ft. hd
Circuit #04	1"	1"	300.0 ft	300.0 ft	3.78 gpm	3771	7.9 ft. hd
GHX Header Section #04	3"	2"	20.0 ft	20.0 ft	45.32 gpm	16967	0.0 ft. hd
Circuit #05	1"	1"	300.0 ft	300.0 ft	3.80 gpm	3788	7.9 ft. hd
GHX Header Section #05	3"	2"	20.0 ft	20.0 ft	41.52 gpm	15545	0.0 ft. hd
Circuit #06	1"	1"	300.0 ft	300.0 ft	3.82 gpm	3811	8.0 ft. hd
GHX Header Section #06	3"	2"	20.0 ft	20.0 ft	37.70 gpm	14114	0.0 ft. hd
Circuit #07	1"	1"	300.0 ft	300.0 ft	3.85 gpm	3841	8.1 ft. hd
GHX Header Section #07	3"	3"	20.0 ft	20.0 ft	33.85 gpm	12673	0.0 ft. hd
Circuit #08	1"	1"	300.0 ft	300.0 ft	3.85 gpm	3840	8.1 ft. hd
GHX Header Section #08	3"	3"	20.0 ft	20.0 ft	30.00 gpm	11231	0.0 ft. hd
Circuit #09	1"	1"	300.0 ft	300.0 ft	3.85 gpm	3840	8.1 ft. hd
GHX Header Section #09	3"	3"	20.0 ft	20.0 ft	26.15 gpm	9790	0.0 ft. hd
Circuit #10	1"	1"	300.0 ft	300.0 ft	3.85 gpm	3841	8.1 ft. hd
GHX Header Section #10	2"	3"	20.0 ft	20.0 ft	22.30 gpm	12306	0.0 ft. hd
Circuit #11	1"	1"	300.0 ft	300.0 ft	3.82 gpm	3811	8.0 ft. hd
GHX Header Section #11	2"	3"	20.0 ft	20.0 ft	18.48 gpm	10197	0.0 ft. hd
Circuit #12	1"	1"	300.0 ft	300.0 ft	3.80 gpm	3788	7.9 ft. hd
GHX Header Section #12	2"	3"	20.0 ft	20.0 ft	14.68 gpm	8101	0.0 ft. hd
Circuit #13	1"	1"	300.0 ft	300.0 ft	3.78 gpm	3771	7.9 ft. hd
GHX Header Section #13	1 1/2"	3"	20.0 ft	20.0 ft	10.90 gpm	7520	0.0 ft. hd
Circuit #14	1"	1"	300.0 ft	300.0 ft	3.73 gpm	3719	7.7 ft. hd
GHX Header Section #14	1 1/4"	3"	20.0 ft	20.0 ft	7.17 gpm	5662	0.0 ft. hd
Circuit #15	1"	1"	300.0 ft	300.0 ft	3.65 gpm	3645	7.4 ft. hd
GHX Header Section #15	1"	3"	20.0 ft	20.0 ft	3.52 gpm	3508	0.0 ft. hd
Circuit #16	1"	1"	300.0 ft	300.0 ft	3.52 gpm	3508	6.9 ft. hd
Manifold - Supply-Return Runout	4"	4"	500.0 ft	500.0 ft	60.00 gpm	17473	24.9 ft. hd
Manifold Pipe Section #01	3"	3"	1.0 ft	1.0 ft	60.00 gpm	22463	20.4 ft. hd

Aim for 20 16 Circuit GHX Modules coming off of the vault

Good Design Practices: Summary

In summary, if the pressure drop in a GHX Module is greater than around 30 ft. hd under normal operation, the design should:

A) Reduce the number of GHX circuits in the GHX Module AND/OR

B) Increase the pipe size for the supply/return runout AND/OR

C) Consider using a geothermal vault to reduce the length of the Supply-Return Runout

D) Ensure that circuit pipe diameters are appropriate for the circuit length

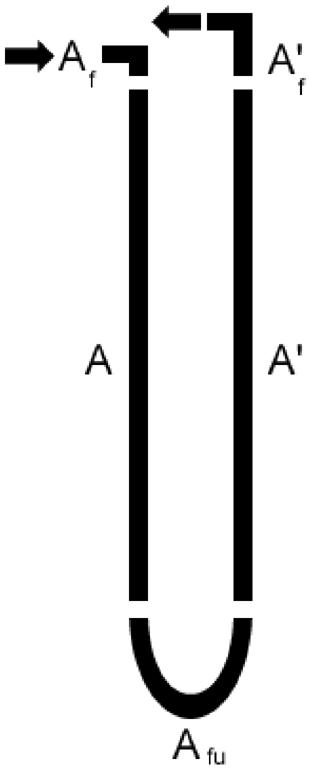
Workshop Outline – Using the GLD2014 CFD Module

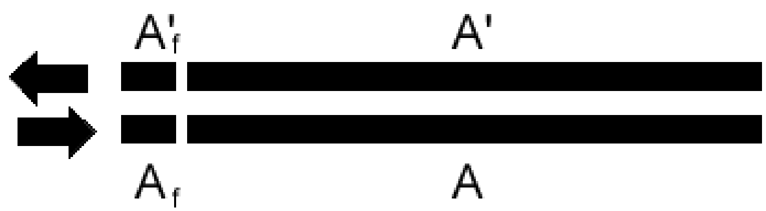
- What is the CFD Module?
- What are we Trying to Accomplish?
- Brief Review of General Fluid Dynamics Calculations
- Reality Check
- Learn Standard Nomenclature for Geothermal Piping Systems
- Basic Standard Configurations: Direct Return & Reverse Return Systems
- Purging Design & Performance: Direct Return & Reverse Return Systems
- Good Design Practices
- **Using the GLD 2014 CFD Module to Design Piping Systems**

The CFD Module - Nomenclature

Basics:

Two Key Components: the **GHX Circuit** and the **Pipe Pair**





The CFD Module - Nomenclature

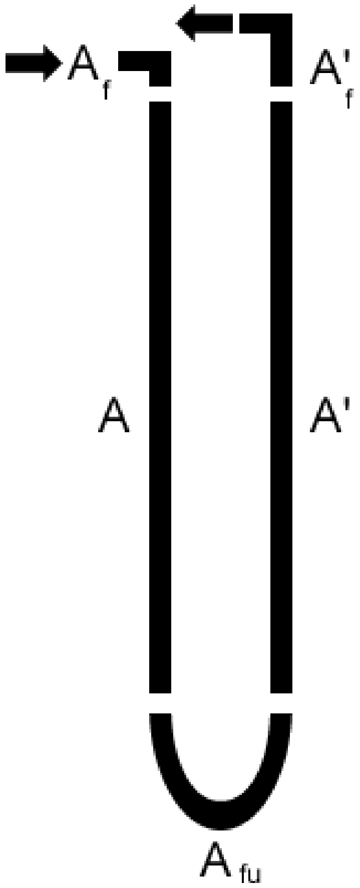
The GHX Circuit

An individual GHX Circuit consists of the following five subcomponents:

A_f - Fitting for attachment to parent header pipe (optional)
A - Supply side pipe
A_{fu} - End fitting that connects Pipe A and Pipe A' (optional)
A' - Return side pipe (usually length A = length A')
A'_f - Fitting for attachment to child header pipe (optional)

Definable features for each subcomponent:

- Fitting type (socket tee branch, butt tee branch, etc.)
- Fitting pipe size
- Fitting equivalent length
- Fitting name
- Fitting volume
- Pipe size, type, inner & outer diameter
- Pipe length, Extra pipe length
- Pipe name, volume



Using the CFD Module

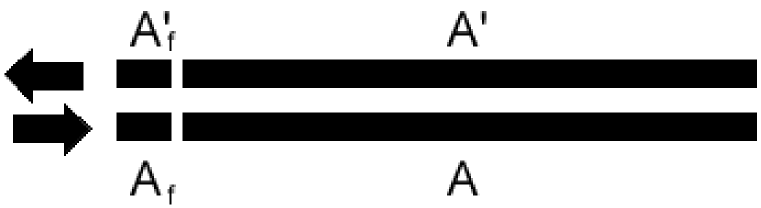
The Pipe Pair

An individual Pipe Pair consists of the following four subcomponents:

A_f - Supply side fitting (generally before the supply side pipe)
A - Supply side pipe
A' - Return side pipe
A'_f - Return side fitting (generally after the return side pipe)

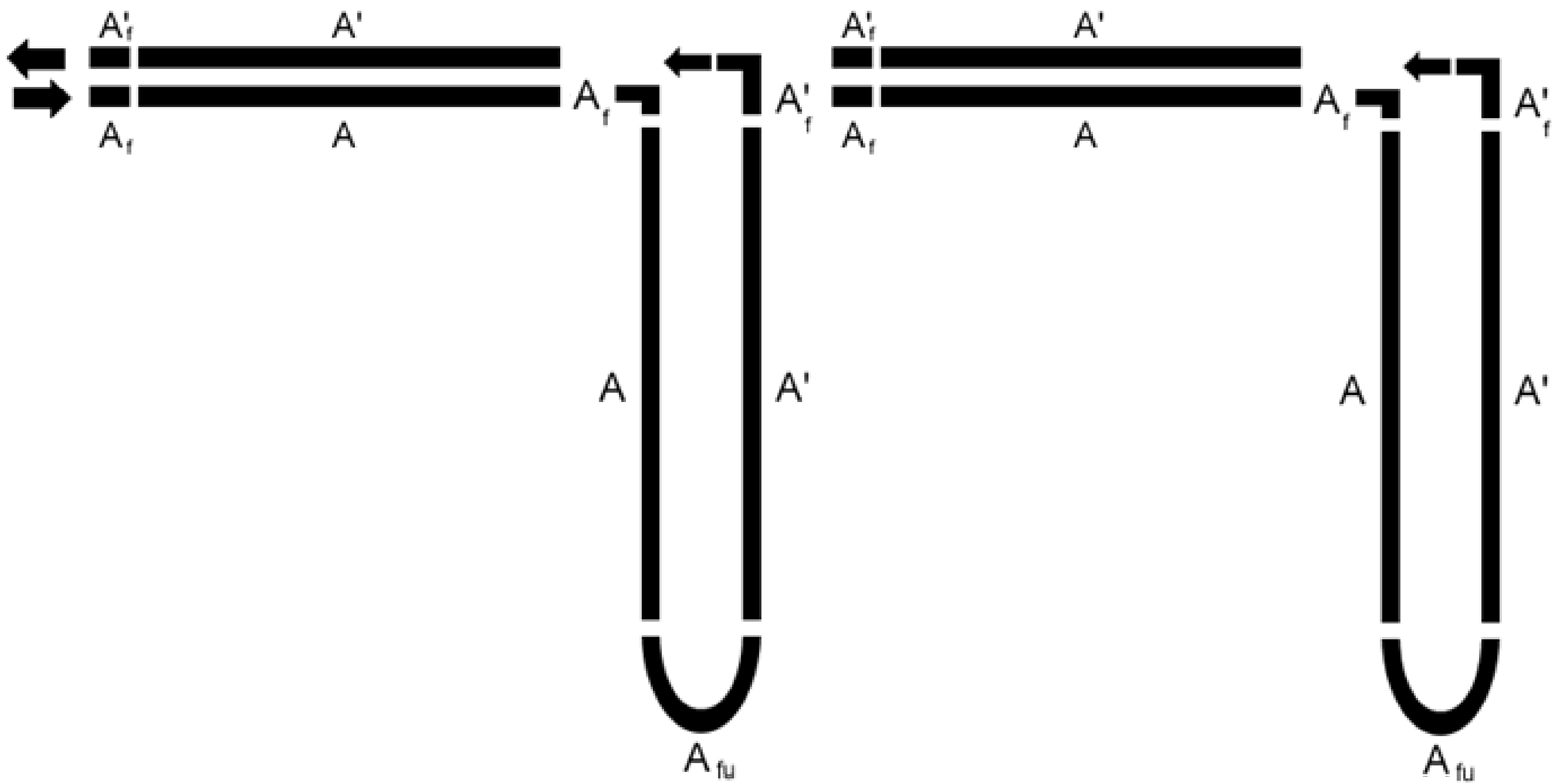
Definable features for each subcomponent:

- Fitting type (socket tee branch, butt tee branch, etc.)
- Fitting pipe size
- Fitting equivalent length
- Fitting name
- Fitting volume
- Pipe size, type, inner & outer diameter
- Pipe length, Extra pipe length
- Pipe name, volume



Using the CFD Module

"Snapping" The Components Together to Form a System



Using the CFD Module

- Manual Design Methods
- Automatic Design Methods
- Headering Design
- Adding Circulation Pumps
- System Performance Review

Thank You!

Q & A

Thank you for using GLD Software and for learning how to use it correctly! Please try to use some of what you have learned prior to the next session

- For more information about GLD Software, visit our website at:

www.groundloopdesign.com

- Additional training is available for advanced GSHP systems. Visit the Geothermal Training Institute website at:

Geothermal Training Institute www.geotrainers.com