VARIABLE SPEED PUMPING: SYSTEM DESIGN AND APPLICATIONS

March 11, 2020

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Overview

This presentation will discuss variable speed pumping systems for multi-unit geothermal heat pump installations for large residential and light commercial buildings. We will discuss basic loop design principles, component selection and layout, and various practical solutions for systems with large head loss. This information will be useful for contractors and engineers designing or installing multiple geothermal heat pumps on a common ground loop heat exchanger.

Goals

- Understand basic loop design for the most efficient variable speed pump systems
- Learn to verify flushing flow rates
- Identify the important components to include in a VS pumping system, and where they should be located
- Learn several options for implementing VS pumping when the system pressure drop is higher than preferred

Drivers for Geothermal Heat Pump System Efficiency

- Geothermal heat pump unit efficiency
- Duct design and installation
- Ground loop design and installation
- Pumping efficiency

Ground Loop Guidelines for VS Pump Systems

- Keep head loss in loop as low as practical
  - Allows more pump choices
  - Requires less pumping energy (lower first and operating costs)
  - Good goal is 40-50 ft-hd maximum
    - Allows the use of commonly available ECM pumps
    - These pumps are very efficient, and have built-in controls that allow simple setup
    - ECM pump manufactures include:
      - Grundfos (Magna3)
      - Taco (00e Series)
      - Wilo (Stratos)
      - Bell & Gosset, Armstrong, others





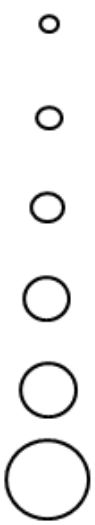
(Taco Catalog #100-121, 2016)



(Wilo IOM 172323, 2018)

Ground Loop Guidelines for VS Pump Systems

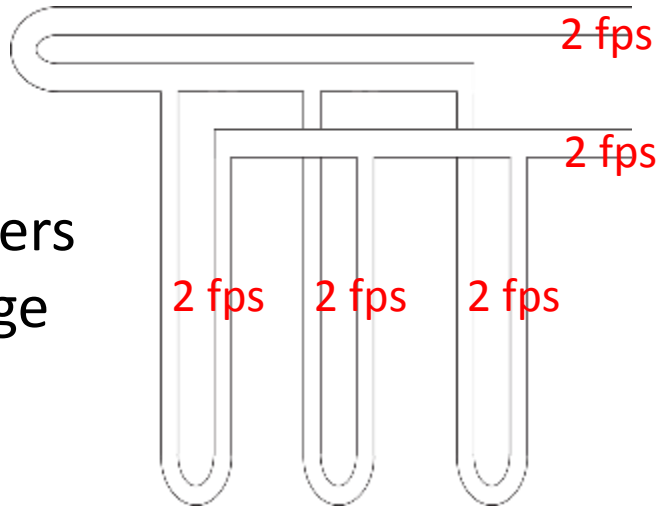
- Head loss is function of pipe type, diameter, and length, fluid characteristics, and flow rate
  - Consider upsizing pipe in high flow rate, long loop sections
  - Consider splitting flow into multiple parallel loops, or ***separate loops***, to keep flow rate per circuit lower



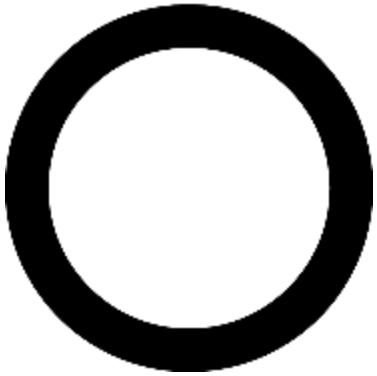
Nominal pipe size	Head loss (ft-hd) per 100 ft of HDPE, DR-11, Water Only			
	3 GPM	6 GPM	15 GPM	30 GPM
3/4"	2	7	34	115
1"	0.7	2.4	12	40
1-1/4"	0.2	0.7	3.6	12
1-1/2"		0.4	1.7	6
2"			0.5	2
3"				0.2

Ground Loop Guidelines for VS Pump Systems

- Limit system to 12-15 tons per ground loop unless you or your subcontractor has equipment (fusion and flushing) for 3” or larger HDPE
- Keep flushing in mind when designing/installing the loop
  - Must have 2 feet/second in all sections of piping to purge air
  - Use reverse-return, reducing headers
  - Be sure you provide adequate purge input/output sizes



Flushing GPM/Pressure Drop @ 2 fps*

		Flow Rate (GPM)	Pressure Drop (Ft. of Head)
3/4” HDPE (3408/3406)		3.6	2.2 per 100 ft.
1” HDPE (3408/3406)		5.7	1.9 per 100 ft.
1-1/4” HDPE (3408/3406)		9.3	1.2 per 100 ft.
2” HDPE (3408/3406)		20.9	0.9 per 100 ft.

*Water (no antifreeze)

Ground Loop Guidelines for VS Pump Systems

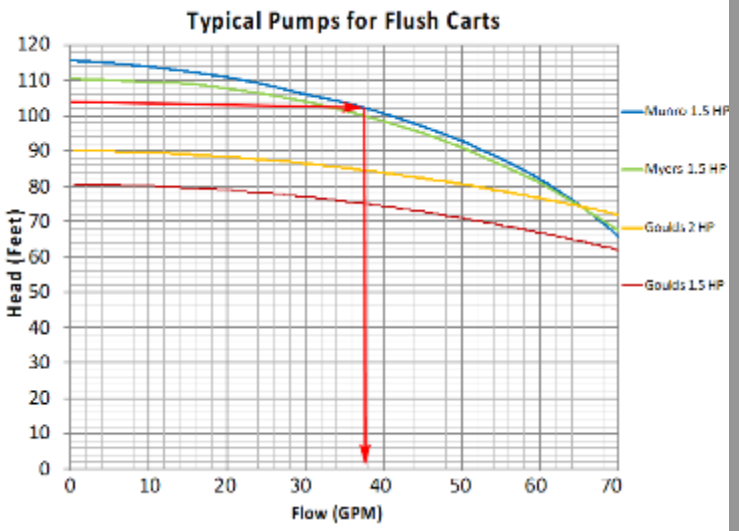
- How do you verify/estimate flushing flow rate to ensure 2 fps?
  - Measure total head at discharge of flush cart pump
  - Convert PSIG to Feet of head
    - Ft-Hd=PSIG X 2.31
  - Use flush cart pump curve to determine flow rate at this head loss
  - Divide flow rate by number of parallel circuits to determine the flow rate per circuit
  - Compare to minimum flow rate required for each pipe section



Ground Loop Guidelines for VS Pump Systems

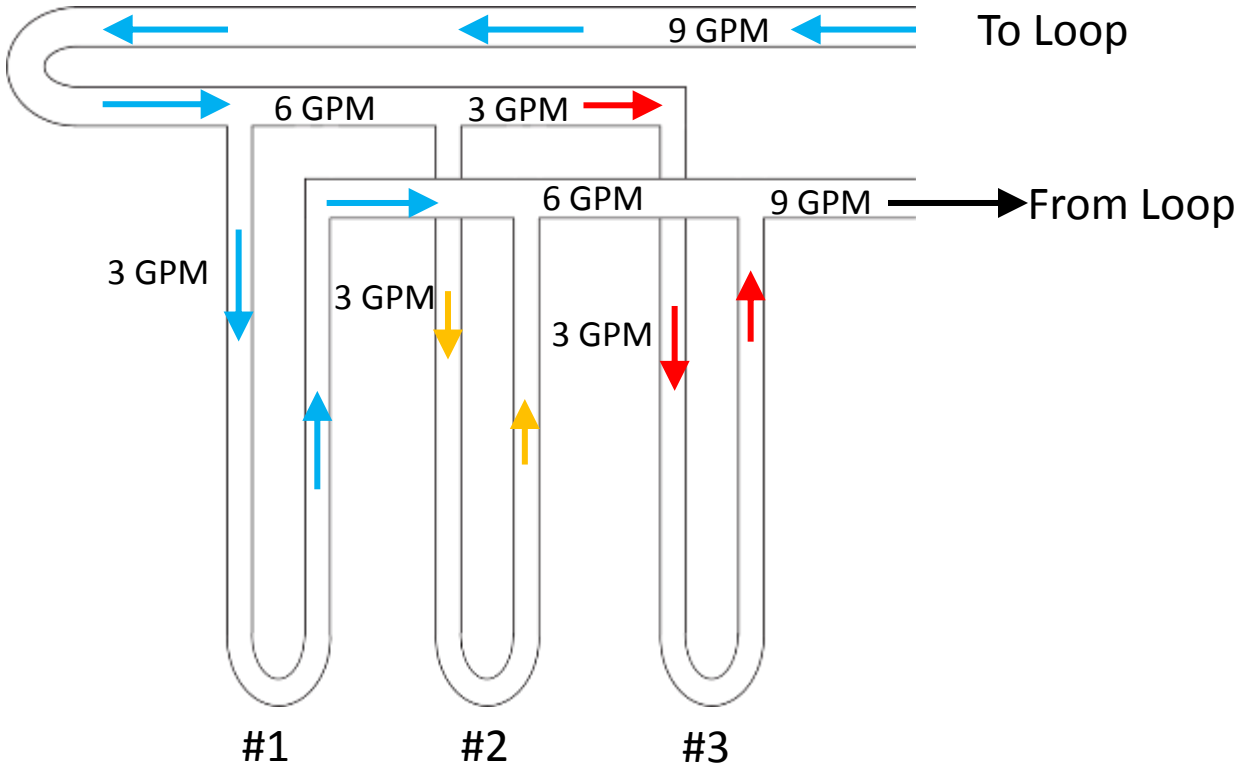
- Example: Verifying flushing flow rates on a 5-circuit loop
  - (1) Measure pressure drop at discharge of pump while pump is running
  - Convert: 45 psig X 2.31ft-hd/psig = 104 ft-hd
  - Find flow rate from your flush cart pump curve
    - ~38 GPM
  - Divide by number of circuits:
    - 38 GPM/5 Circuits= 7.6 GPM/circuit
  - Compare to chart to verify 2 fps





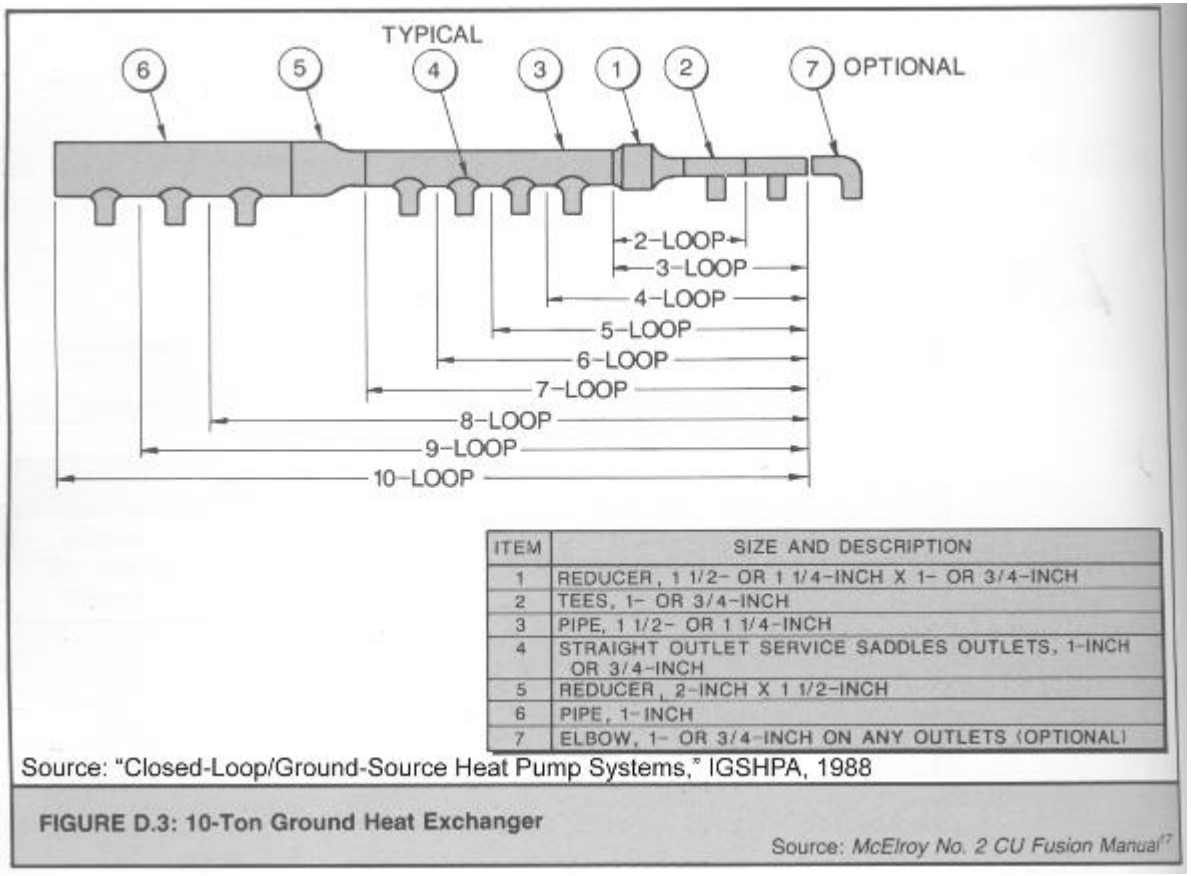
Reverse Return Headers

- First circuit to branch to header is last to return to header.
- Balances head loss through loop



Reducing Headers

- Header steps down from first circuit to last circuit



ITEM	SIZE AND DESCRIPTION
1	REDUCER, 1 1/2- OR 1 1/4-INCH X 1- OR 3/4-INCH
2	TEES, 1- OR 3/4-INCH
3	PIPE, 1 1/2- OR 1 1/4-INCH
4	STRAIGHT OUTLET SERVICE SADDLES OUTLETS, 1-INCH OR 3/4-INCH
5	REDUCER, 2-INCH X 1 1/2-INCH
6	PIPE, 1-INCH
7	ELBOW, 1- OR 3/4-INCH ON ANY OUTLETS (OPTIONAL)

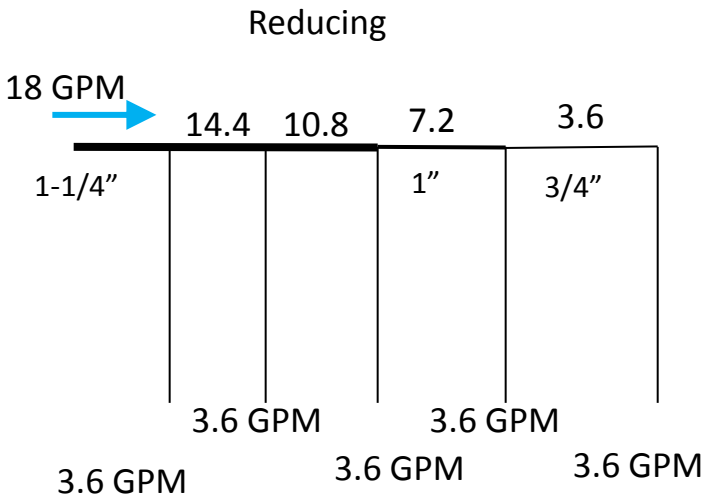
Source: "Closed-Loop/Ground-Source Heat Pump Systems," IGSHPA, 1988

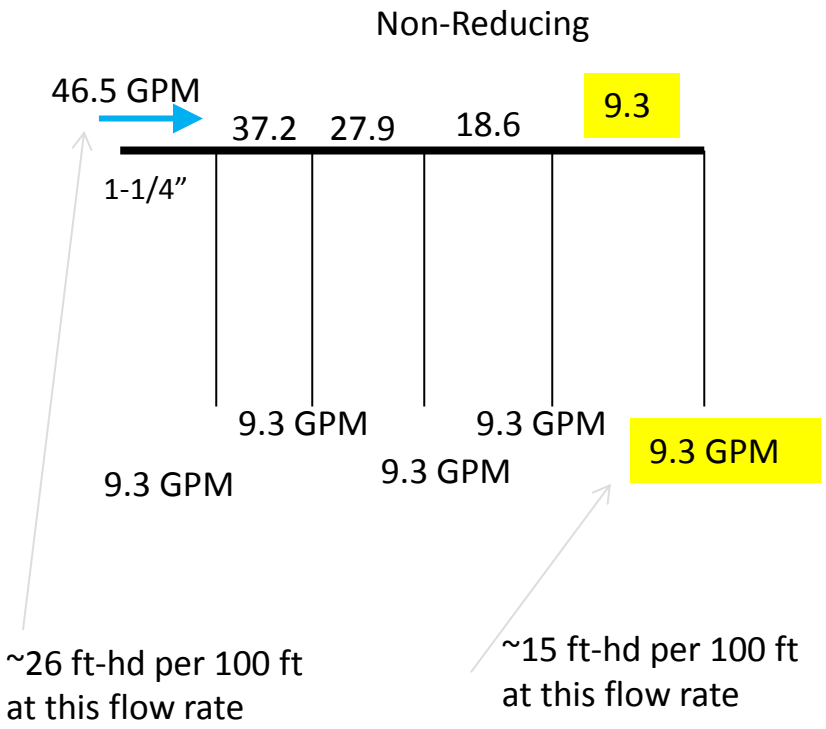
FIGURE D.3: 10-Ton Ground Heat Exchanger

Source: *McElroy No. 2 CU Fusion Manual*[7]

Reverse Return Reducing Headers

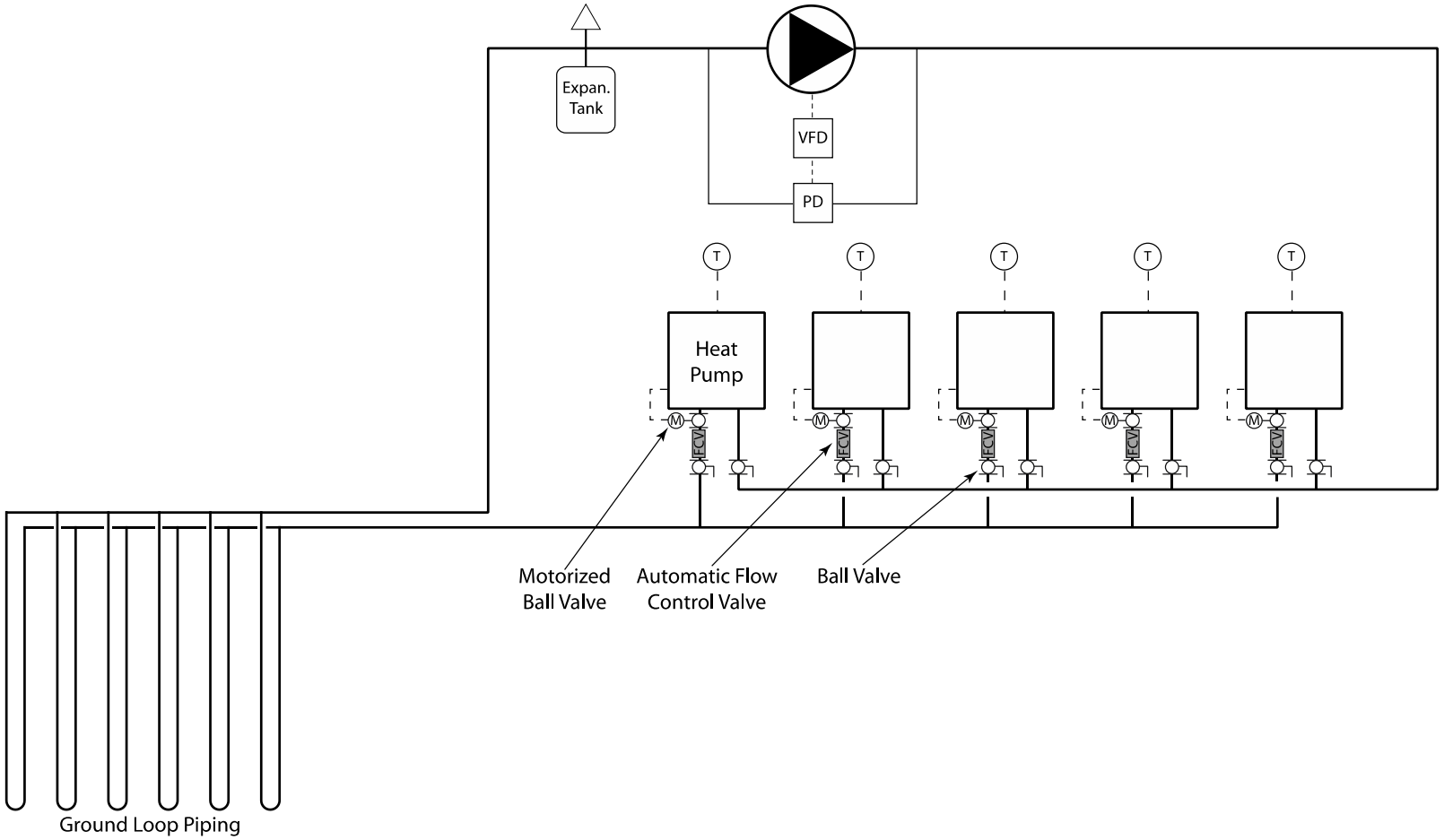
- Allows loops to be able to be flushed
- Example: ¾” HPDE circuits





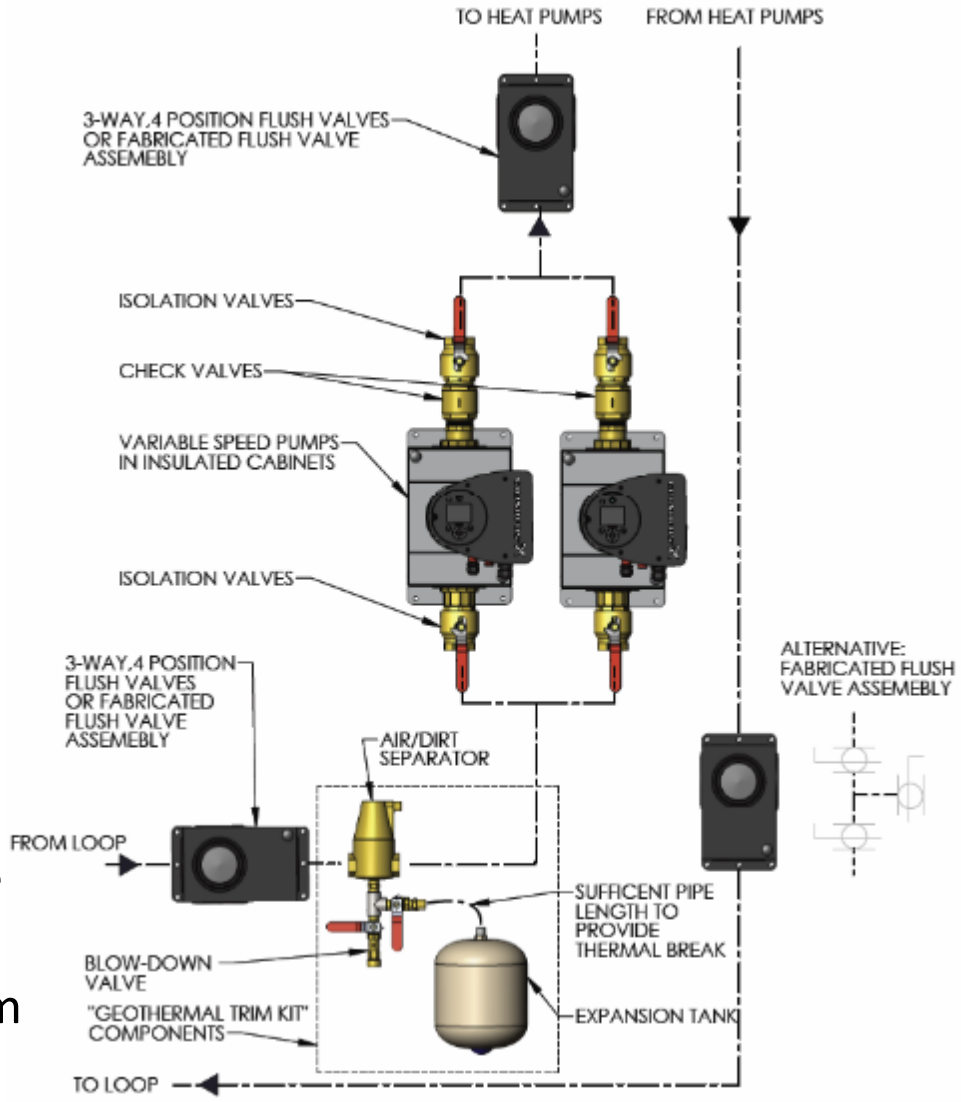
Central VS/ECM Pump system

- Typical Central System Schematic



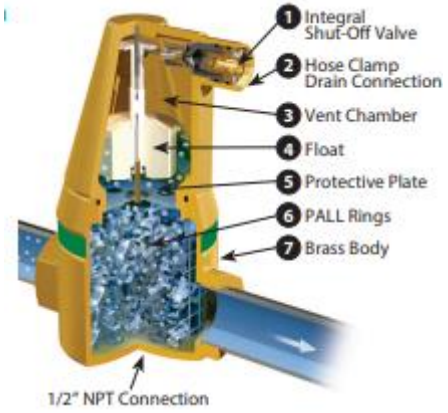
Components for Central VS/ECM Pump system

- ECM pump(s)
  - Need start/stop control
- Isolation valves
- Flush/purge valves
  - Can be 3-way, 4 position valves or fabricated assemblies
- Expansion Tank
  - To prevent low loop pressures (usually)
  - Size properly
  - Provide thermal break to keep tank from sweating
  - Locate at lowest pressure point in system, typically suction side of pump from loop field



Components for Central VS/ECM Pump system

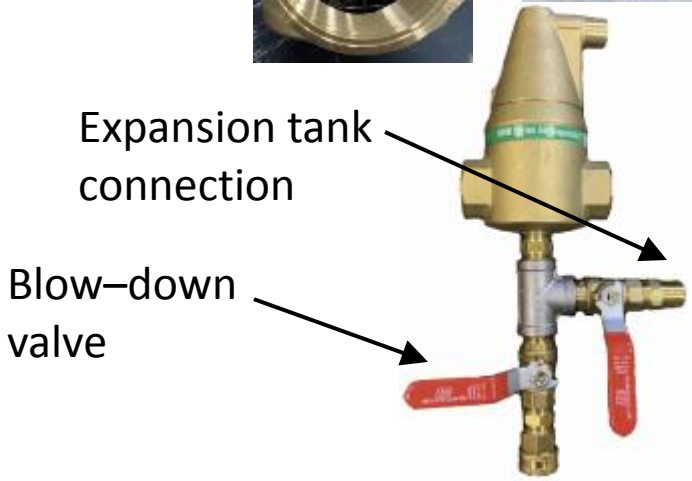
- Air/dirt Separator
  - Be aware of Cv
  - Keep in mind max flow rate of device
- Air/Dirt Separator Features:
  - Coalescing media (traps air/dirt) OR
  - Sufficient body diameter to lower flow rate to less than 2 ft/s, AND, sufficient length between inlet/outlet to allow air to separate (think flush cart)
  - Air vent
  - Blow-down valve (can also be used to fill/pressurize system)



(Taco Catalog # 100-2.9, 2016)



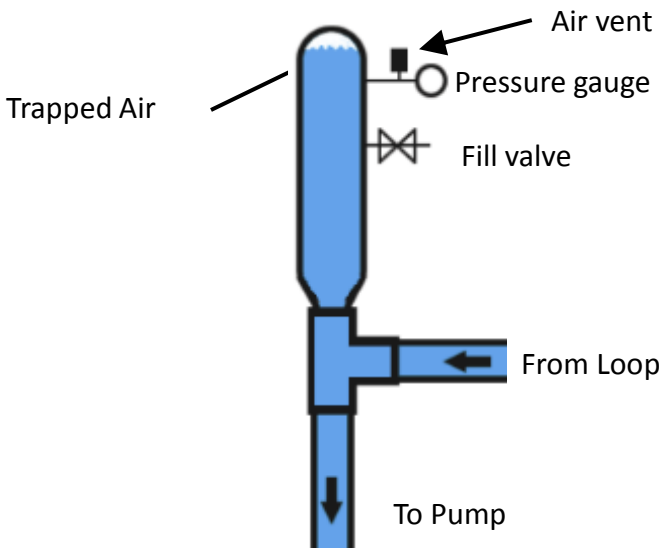




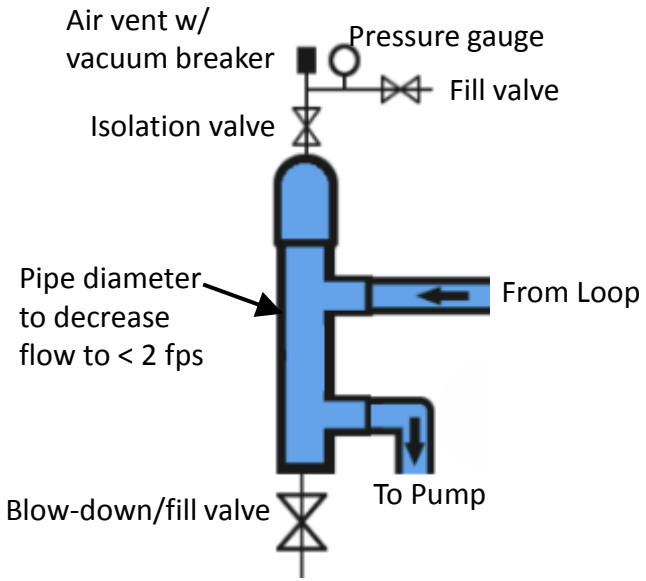
Components for Central VS/ECM Pump system

- Be aware that stand-pipe designs without above features lack air separation function when system is running
  - Stand-pipe will provide NPSH due to standing column of water
  - Unit will release air when pump stops
  - No dirt separation
  - Air space at top will act as very small, ineffective, expansion tank

Limited Functionality
(currently sold in industry)



Improved Design

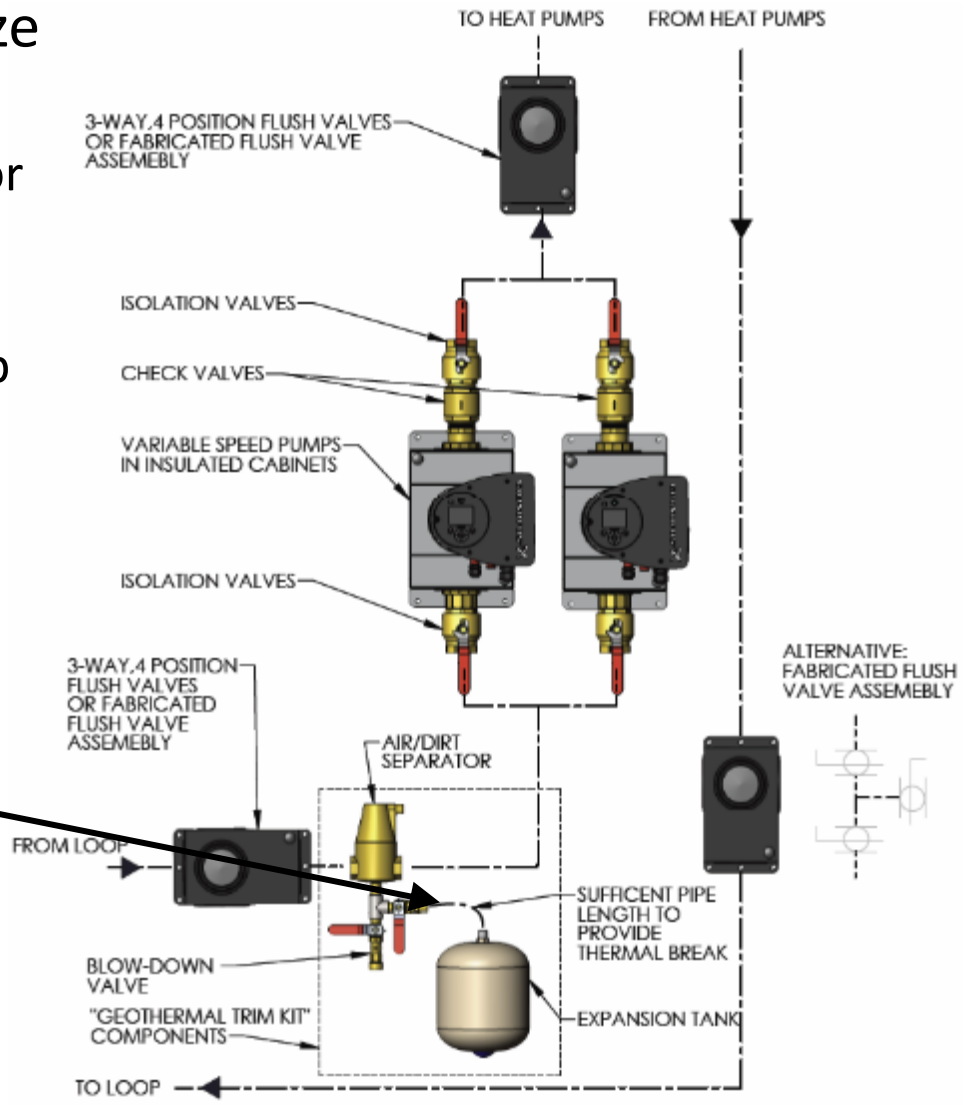


Components for Central VS/ECM Pump system

- Optional: fluid/antifreeze makeup system
  - Can be used in place of, or in addition to, expansion tank
  - Avoid auto water makeup in systems when using antifreeze



(Calefactio website, *2020)*



HP Components Needed in VS Pump system

- PT plugs to verify flow rate and EWT/LWT
- Zone or modulating valves*
  - Be aware of Cv
  - Should have end switch or other means to prevent compressor from running w/o flow
- Isolation valves*
  - Allow HP maintenance
  - Can help with balancing
- Optional: auto balancing /circuit setter valves
  - Be aware of the Cv
  - Be aware of minimum delta-P
  - Use caution when selecting fixed orifice valves (may need to avoid due to high delta-P)
  - Be aware of max flow rate
  - Size based on flow rate, not pipe size









(Caleffi website, 2020)

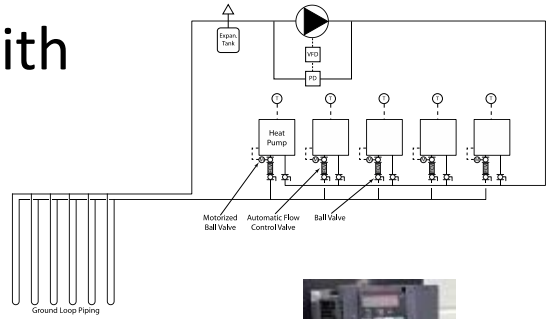
*These can be located on discharge header of pump

Situations Requiring Other Options

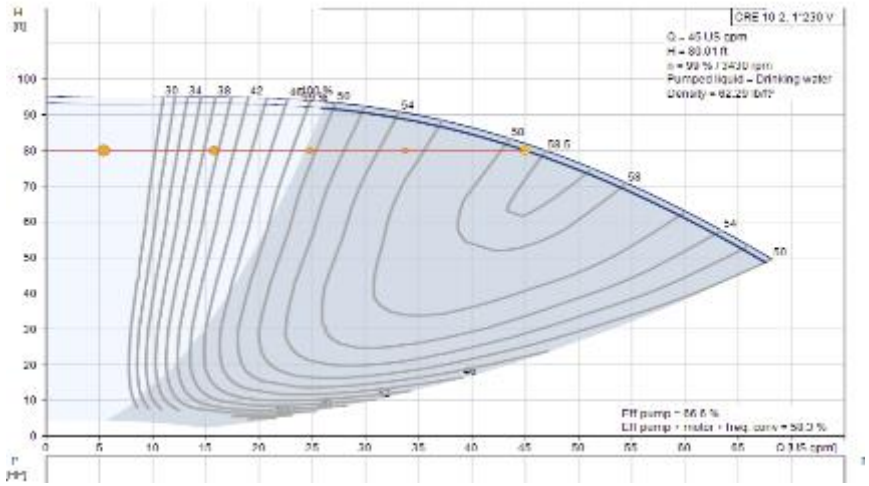
- Standard Central System may not work in every case
  - Engineer as specified a pump
  - Loop has already been installed
  - Loop contractor has limited equipment, or is uncomfortable with splitting loop
- Solutions exist for each of these situations, including:
  - Breaking up large central system into multiple small systems (for example, three 10-ton systems instead of one large 30 ton)
  - Central system with high head VFD pump
  - Central system with additional pump(s)
  - Central system with ECMs in series
  - Primary/Secondary systems

Central System with Single Large VFD pump

- Typically vertical multi-stage pumps with external or built-in VFD drive
- Typically limited to around 2 HP in 230/60/1
- Advantages
  - Capable of scaling to very large systems (high head-high flow)
  - Simple plumbing
  - Rugged, industrial pumps stainless impellers







(Grundfos Website, 2020)



(Grundfos Website, 2020)

Single Large VFD pump

- Disadvantages
  - Can have higher complexity installation and setup
  - Typically higher cost
  - Limited turn-down (20-30% of full speed)
  - Higher operating costs than ECM pumps
  - Higher sound level
  - Maintenance issues (mechanical seal)
  - Higher NPSHr
  - Difficult to insulate

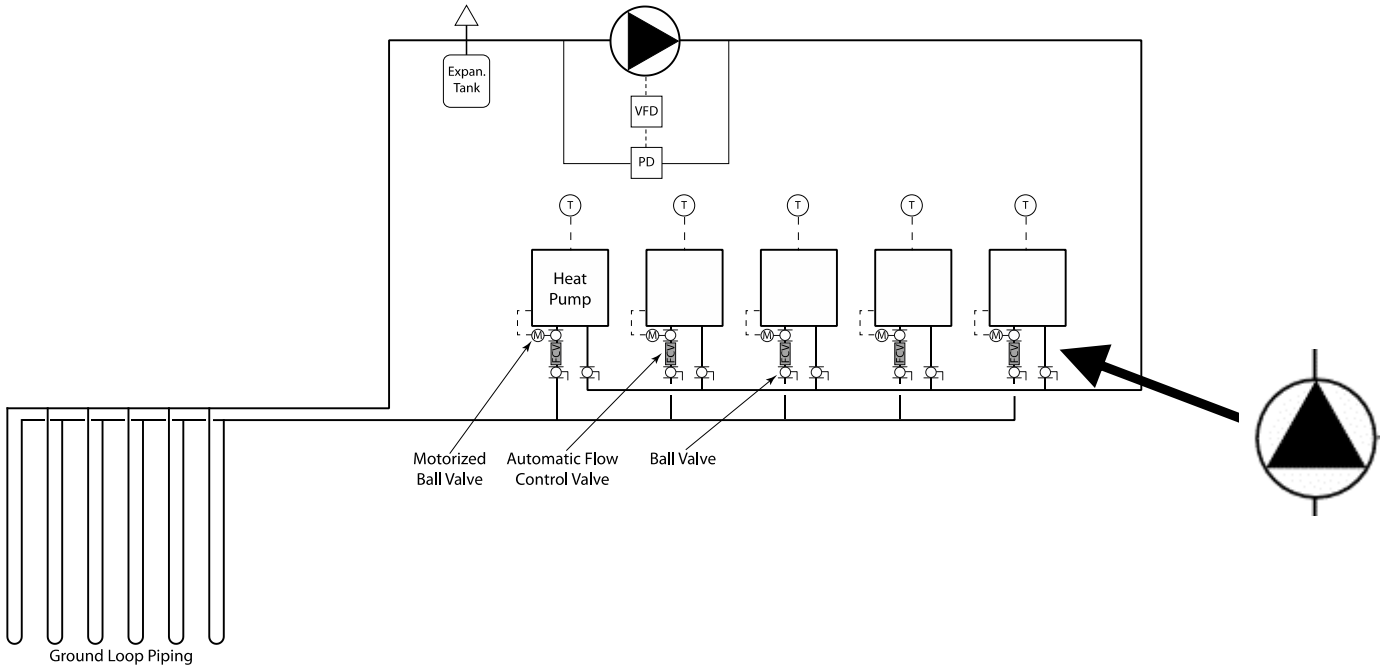




(Grundfos Website, 2020)

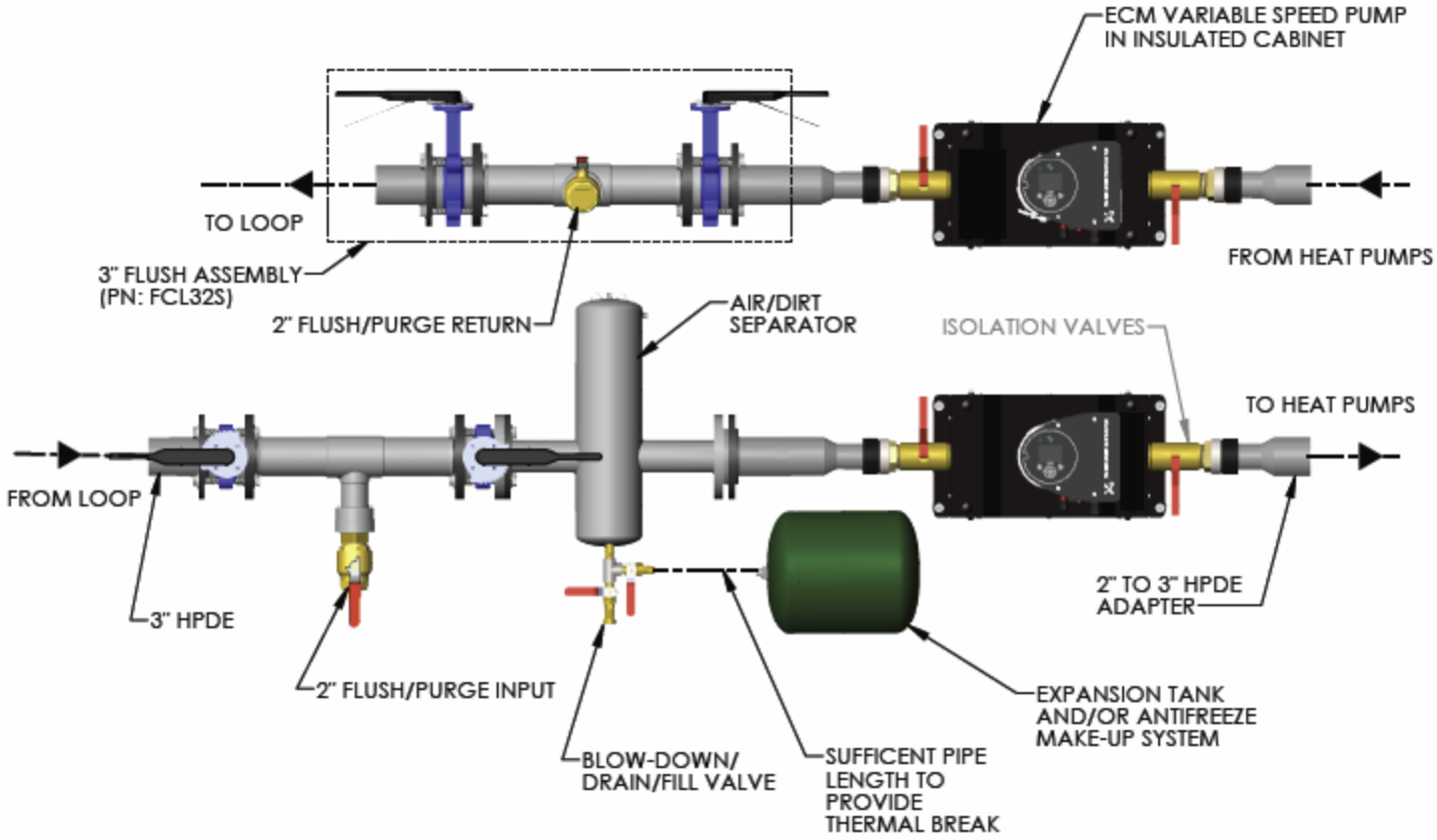
Central VS/ECM Pump system with additional pump

- Add dedicated circulator in series with system pump for specific unit
- Good solution in situations were there is a remote HP, or high head loss unit
- Dedicated circulator overcomes head loss in unit; VS pump overcomes remaining system head loss



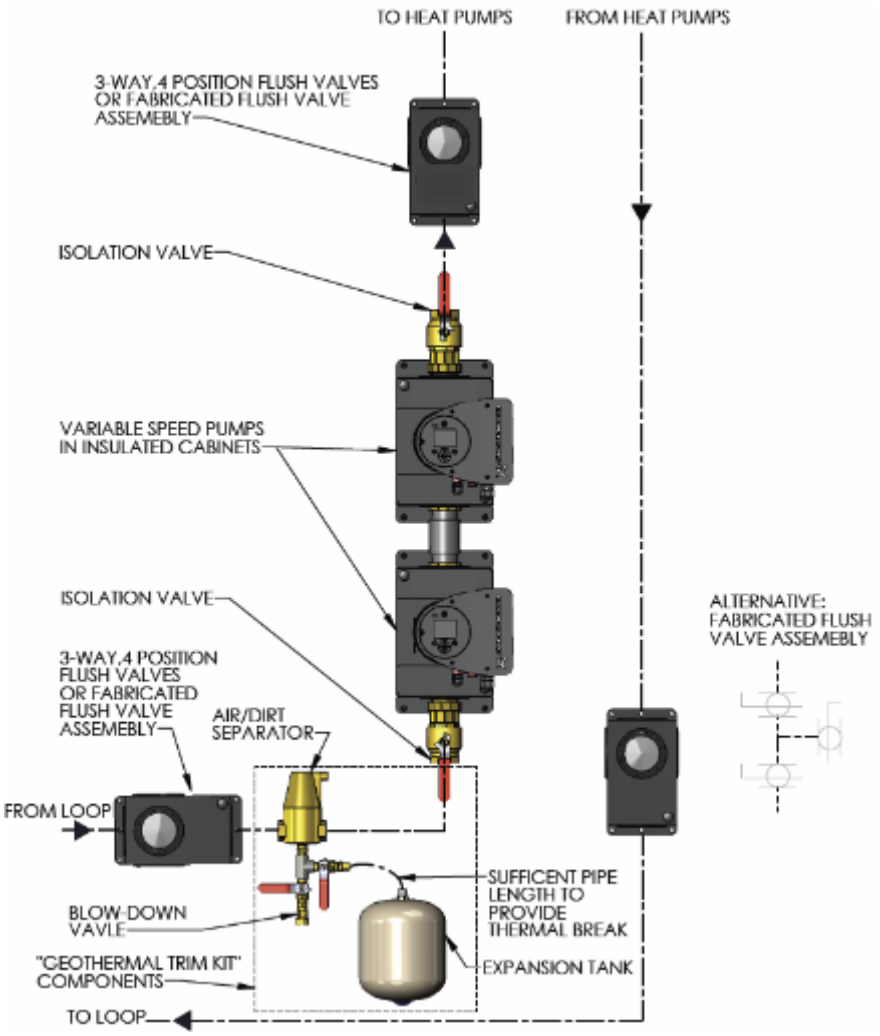
Two ECM Pumps in Series (Central System)

- Very similar to system in Slide 18
- Pumps set to Constant Pressure mode
- Pumps will “split” system pressure drop
- Pumps can be arranged separated (below) inline (next slide)



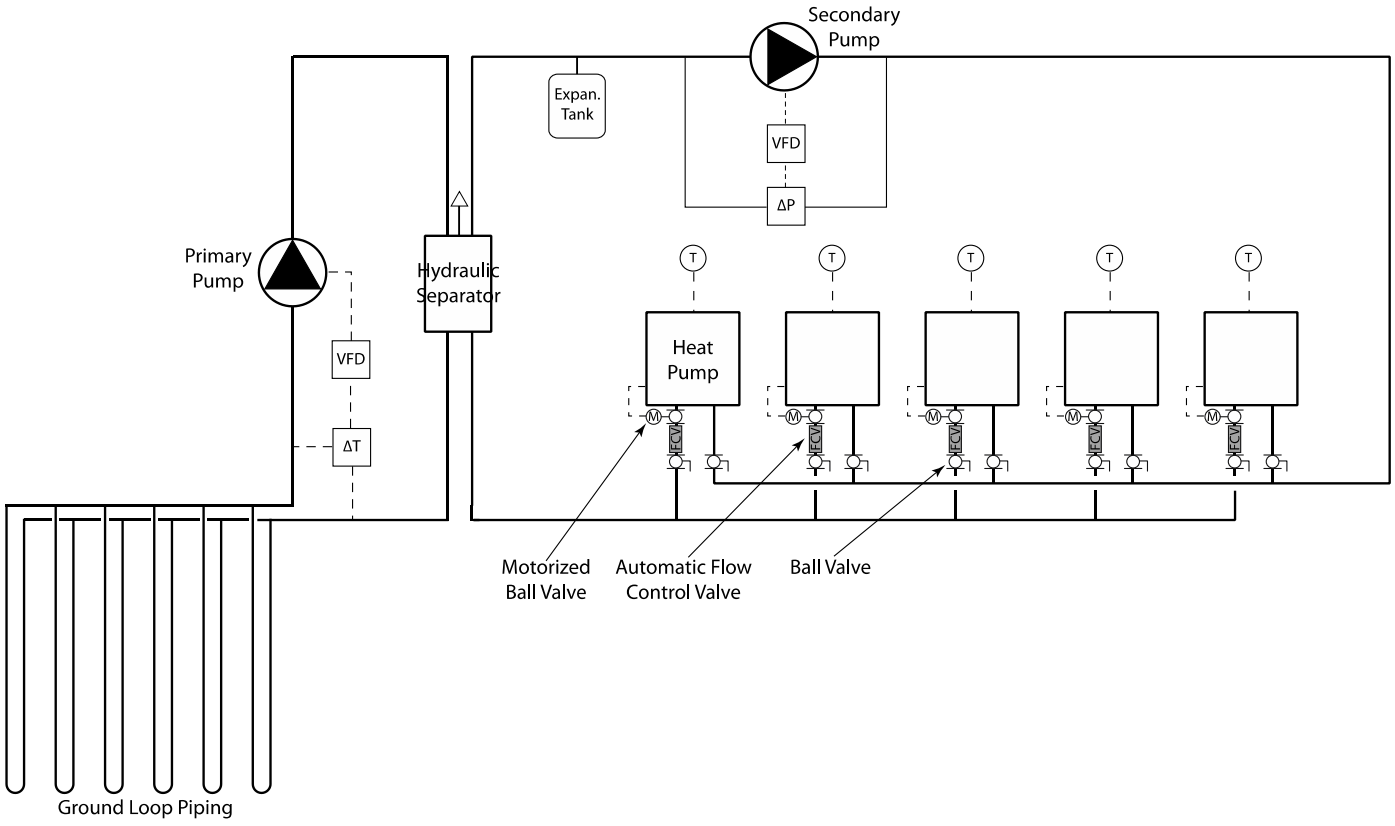
Two ECM Pumps in Series (Central System)

- Pumps can be arranged inline



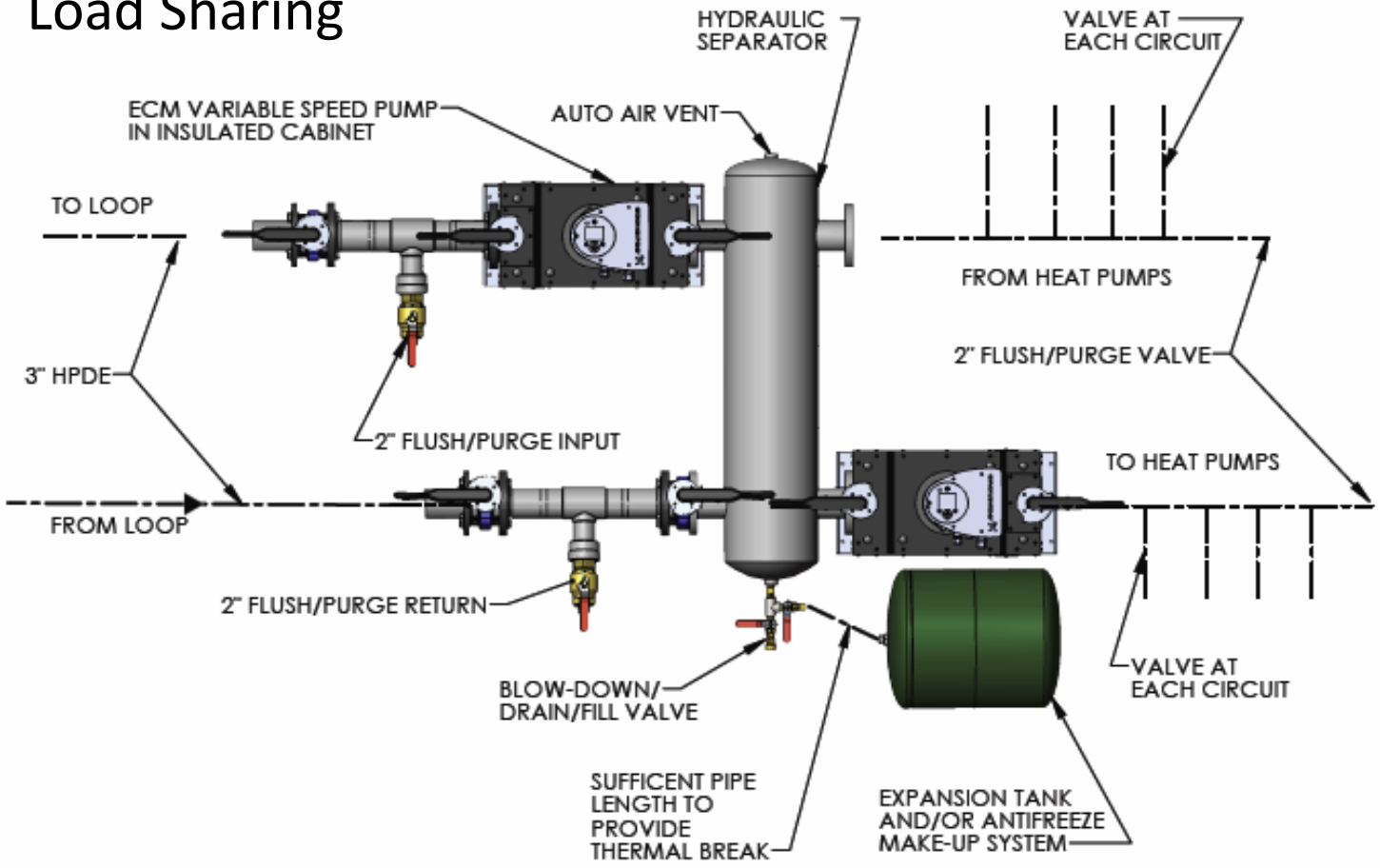
Primary/Secondary Systems

- Separates ground loop head loss from building head loss
- Typical schematic for primary/secondary systems:



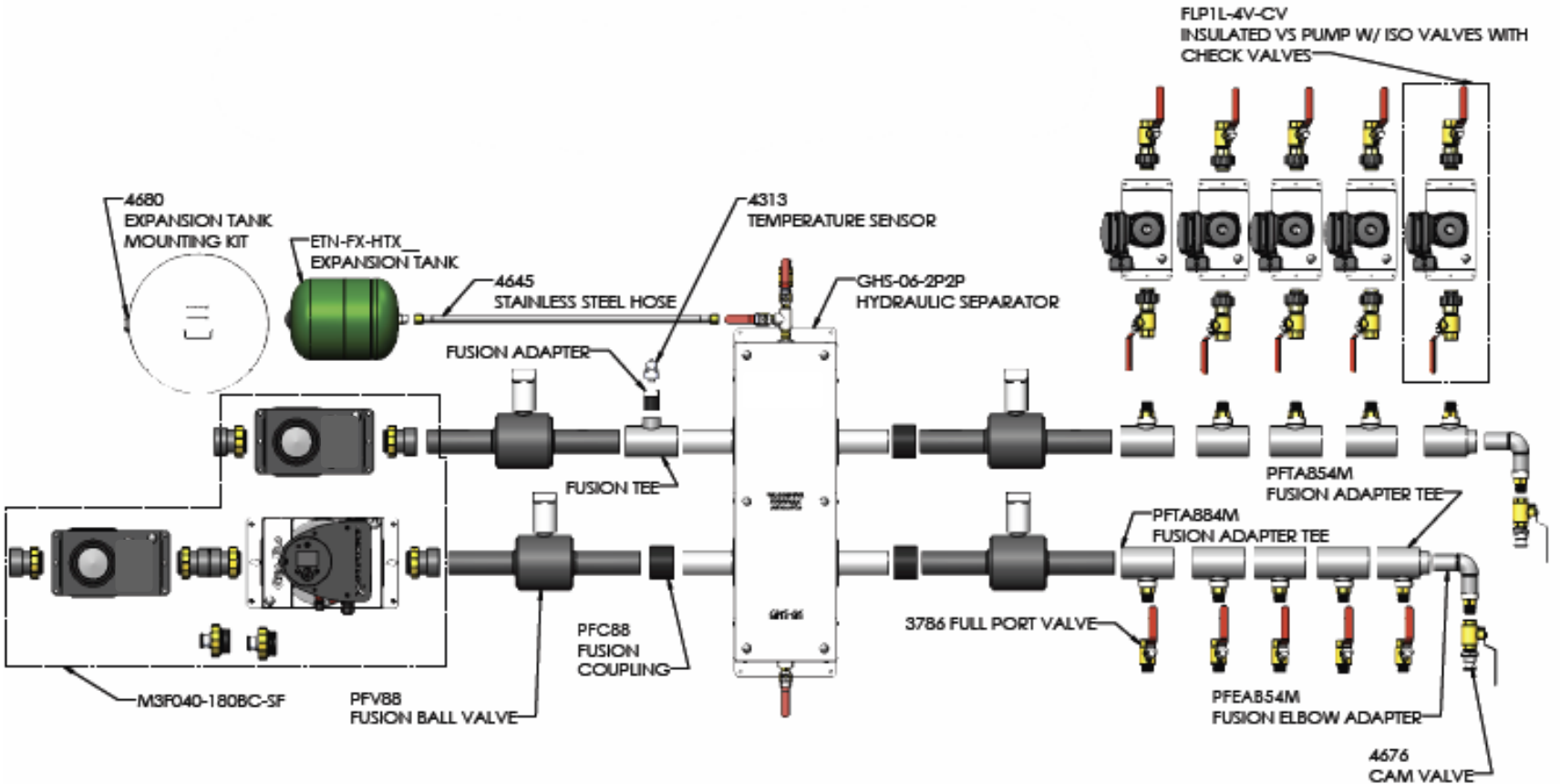
Primary/Secondary Systems

- VS Primary, set to delta-T (differential temperature)
- VS Secondary, set to delta-P (differential pressure)
- Pumps sized for each side of system (may be different)
- Load Sharing



Primary/Secondary Systems

- VS Primary, set to delta-T (differential temperature)
- Individual pumps Secondary (CS or VS pumps)
- Load sharing
- Good solution when pumps are internal



Summary

- Design and install ground loop for low head loss
- Chose and include proper system components for system longevity
- Separate loop fields for simplicity, where possible
- Implement proven alternative strategies when system is not ideal

QUESTIONS?

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Sources:

- *Taco Catalog #100-121, 2016*
- *Wilo IOM 172323, 2018*
- *Closed-Loop/Ground-Source Heat Pump Systems, IGSHPA 1988*
- *Taco Catalog # 100-2.9, 2016*
- *Calefactio, https://www.calefactio.com/en/product/gmp6/, 2020)*
- *Caleffi, https://www.caleffi.com/usa/en-us/catalogue/quicksettertm-balancing-valve-132432a, 2020*
- *Grundfos, https://product-selection.grundfos.com/product-detail.product-detail.html?from_suid=158135256357301290250581503407&pumpsystemid=798108619&qcid=826401825, 2020*