Ground Source Heat Pump Association Webinar Series 2020

Design of closed loop borehole systems - (Part 2)

Hydraulics

Robin Curtis – GeoScience / GSHPA

18th June 2020

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GeoScience

Objectives ?

- To raise awareness of the issue

- Illustrate the impact on performance

- Show basic GSHP hydraulic design approach

- Audience

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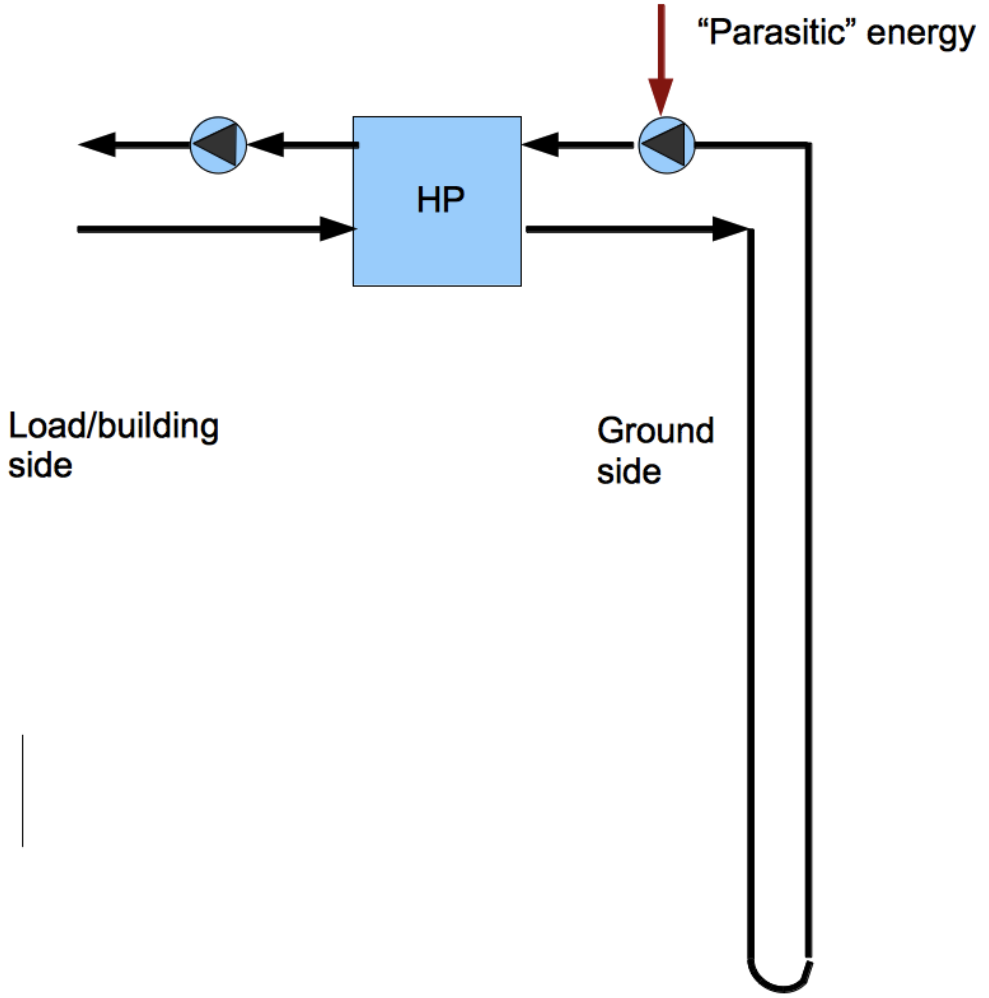
(Closed loop) Ground source “hydraulics” - the issue

The forgotten bit….

Why does this matter ?

..protect the technology



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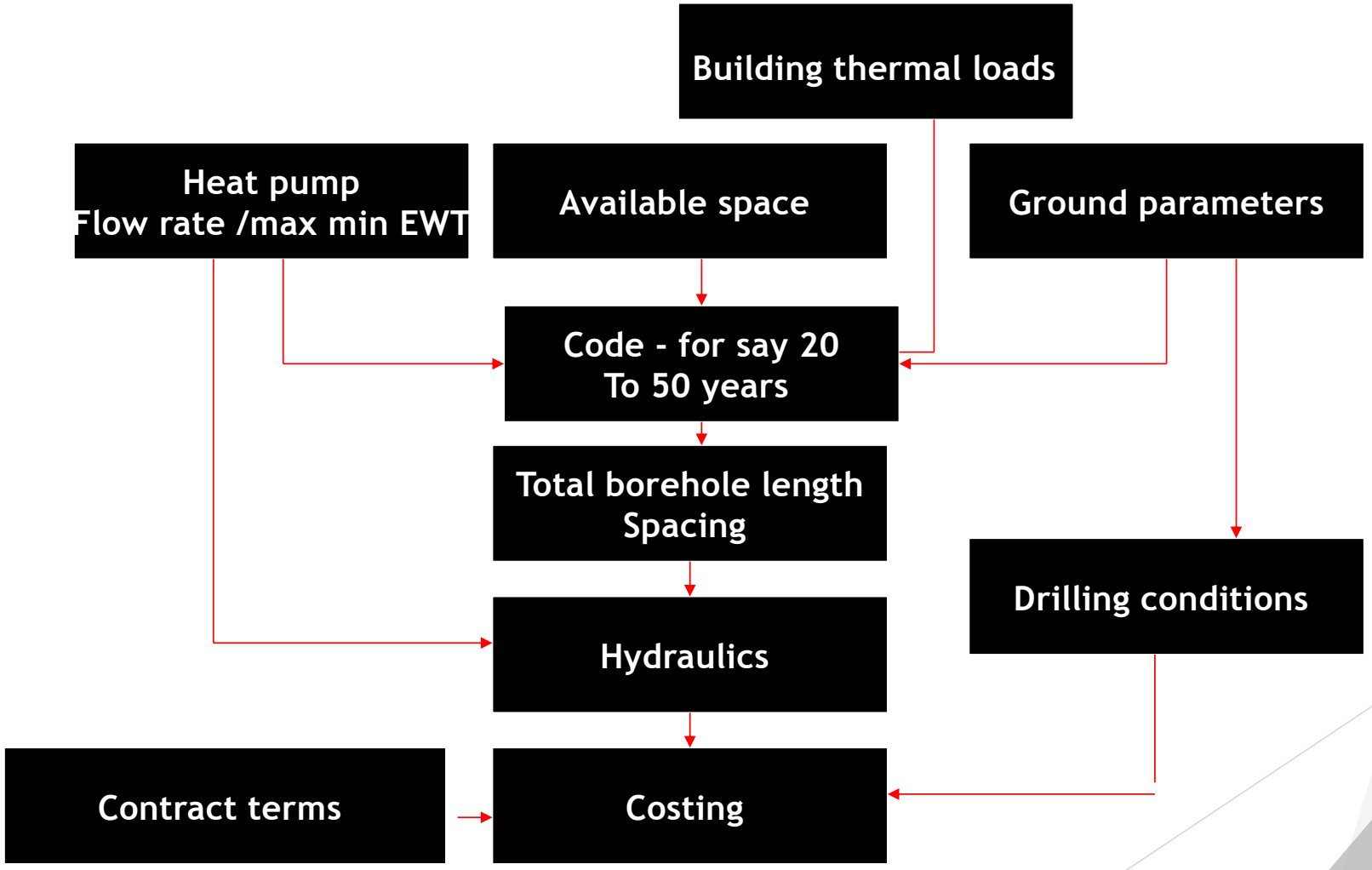
CL GSHP Design



from GSHP Rogues Gallery >

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Why ? - Do the numbers…

50kW heat pump
COP ? ~4
Electrical input = 50/4 = 12.5 kW

Pump power 11kW !!
Effective COP = 50/(12.5+11)
= 2.12 !!

(that's the first bit of bad news)

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The real bad news?

There’s nothing anyone can do about it.

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Simple example - (of getting it wrong)

12 kW heat pump

Flow rate = 0.6 l/s

Told manufacturer = 3 x 60 metre boreholes in 32mm

Pressure drop per hole = ~15kPa (Re ~ 3200)

Pump selection = ~ Wilo 30/7

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Simple example - (of getting it wrong)

12 kW heat pump

Clever driller - decides on 1 hole.

180m of 40mm !!

Pressure drop now: ~120kPa (Re ~ 8000)

Pump size - off the graph > Parasitic power = huge!

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Other warning signs

“We only use 40mm U-tubes…….”

“GSHP boreholes are always 100m deep……”

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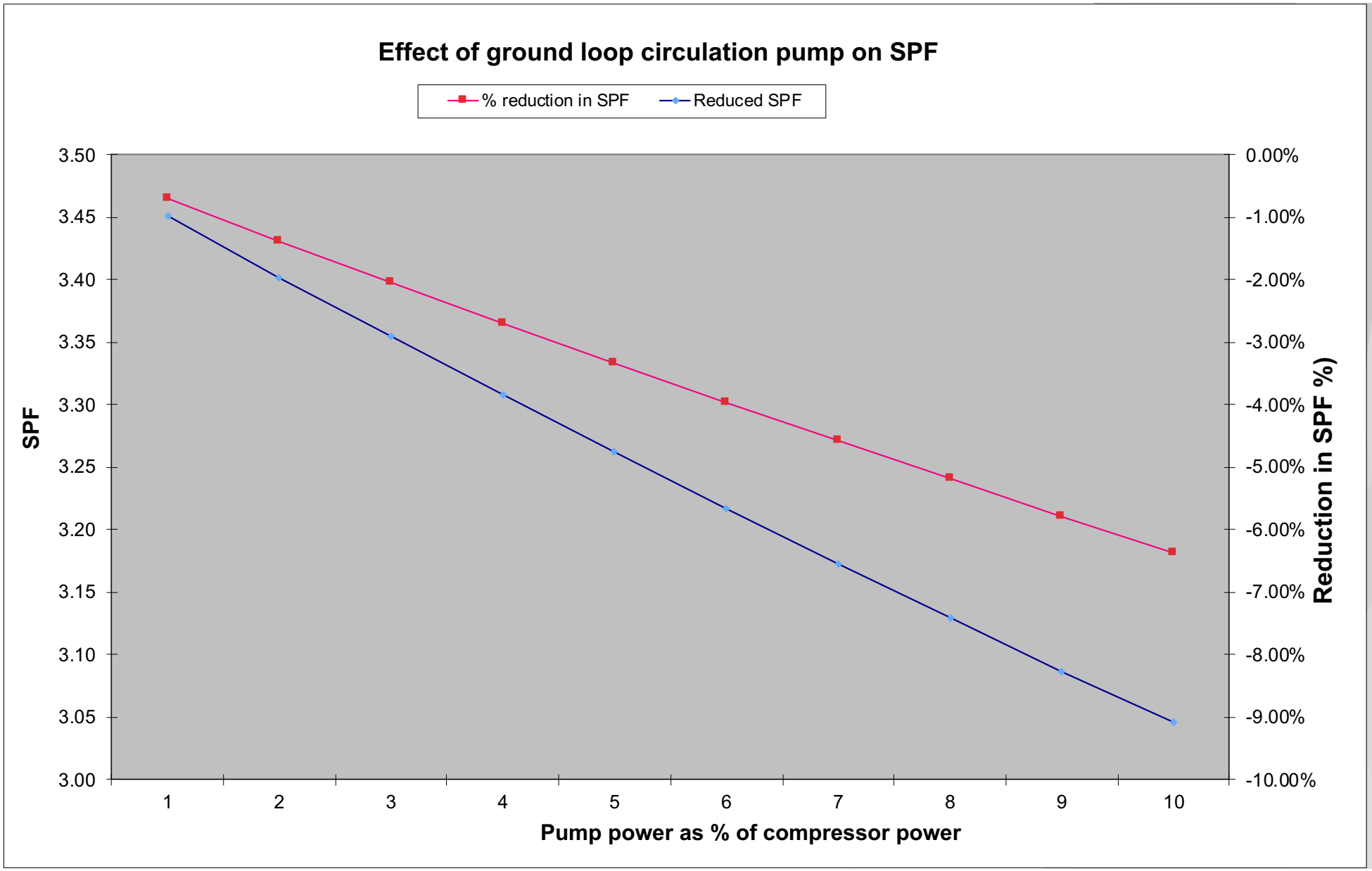
Effect of ground loop circulation pump on SPF
% reduction in SPF
Reduced SPF
SPF
Reduction in SPF %)
3.50
3.45
3.40
3.35
3.30
3.25
3.20
3.15
3.10
3.05
3.00
0.00%
-1.00%
-2.00%
-3.00%
-4.00%
-5.00%
-6.00%
-7.00%
-8.00%
-9.00%
-10.00%
1
2
3
4
5
6
7
8
9
10
Pump power as % of compressor power

Where / how of ground loop heat transfer

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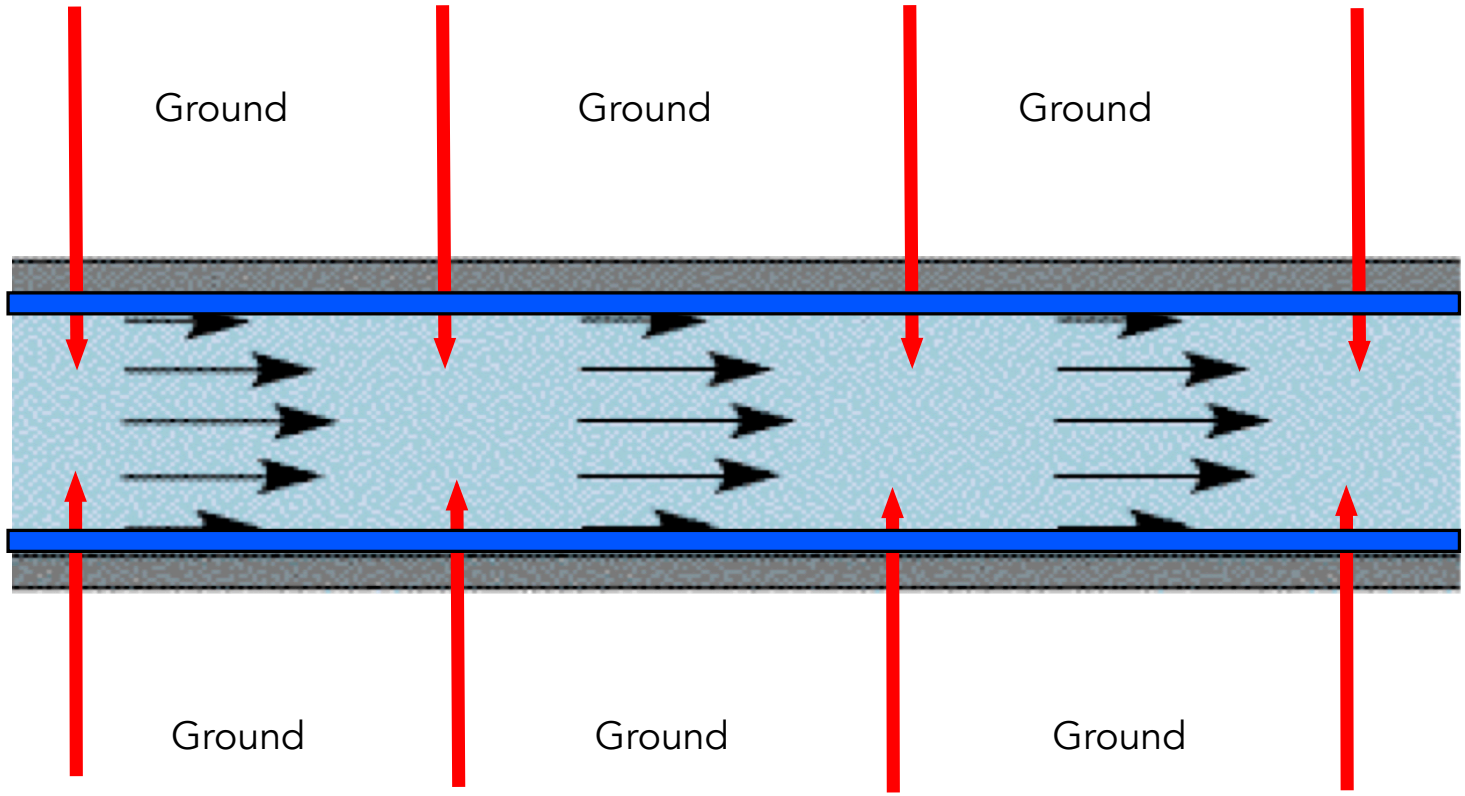
Laminar flow in pipe



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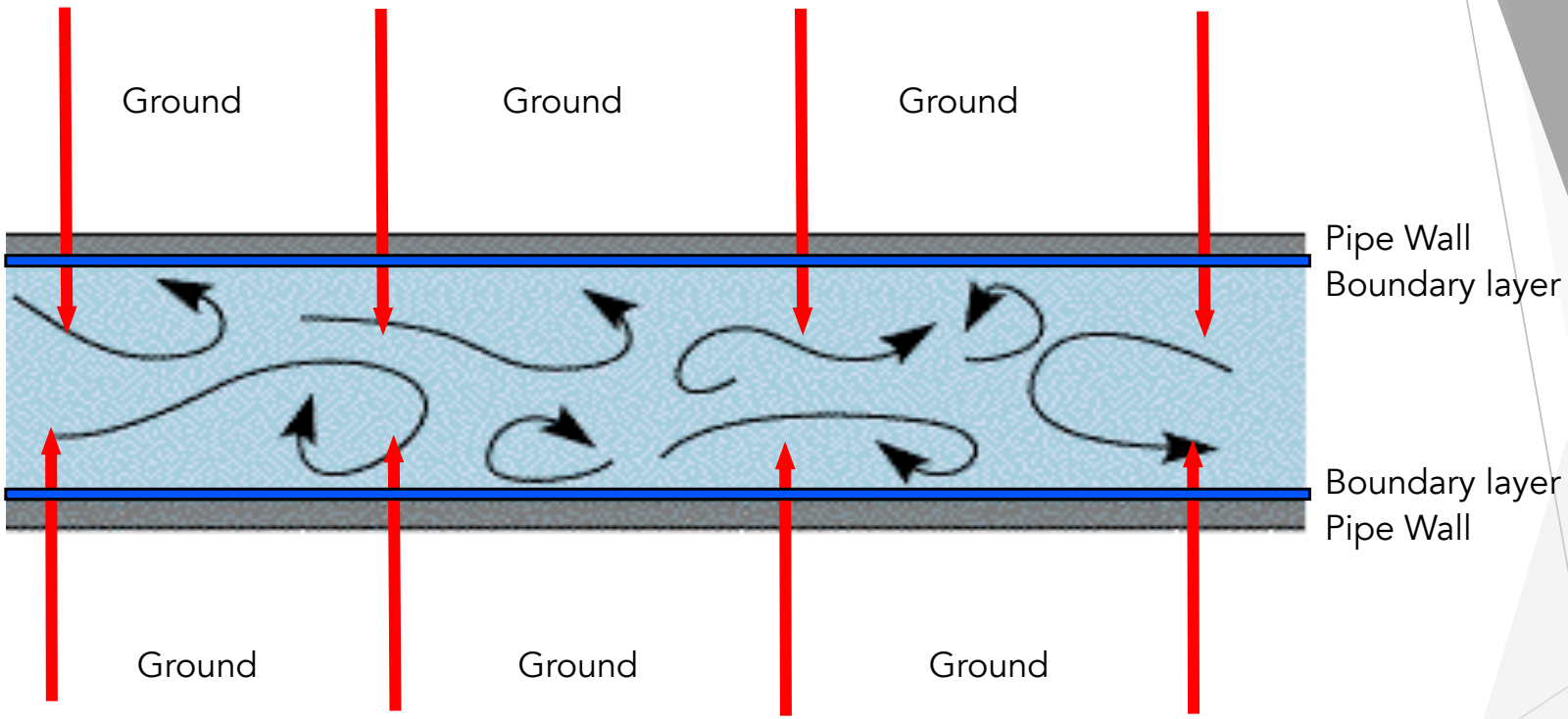
= Heat flow

Non-Laminar flow in pipe



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Reynold's number

$$Re = \rho VD / \mu$$

ρ = density
V=fluid velocity
D=hydraulic diameter
μ =dynamic viscosity

(dimensionless - NO units !)

Laminar < 2000
Turbulent > 4000

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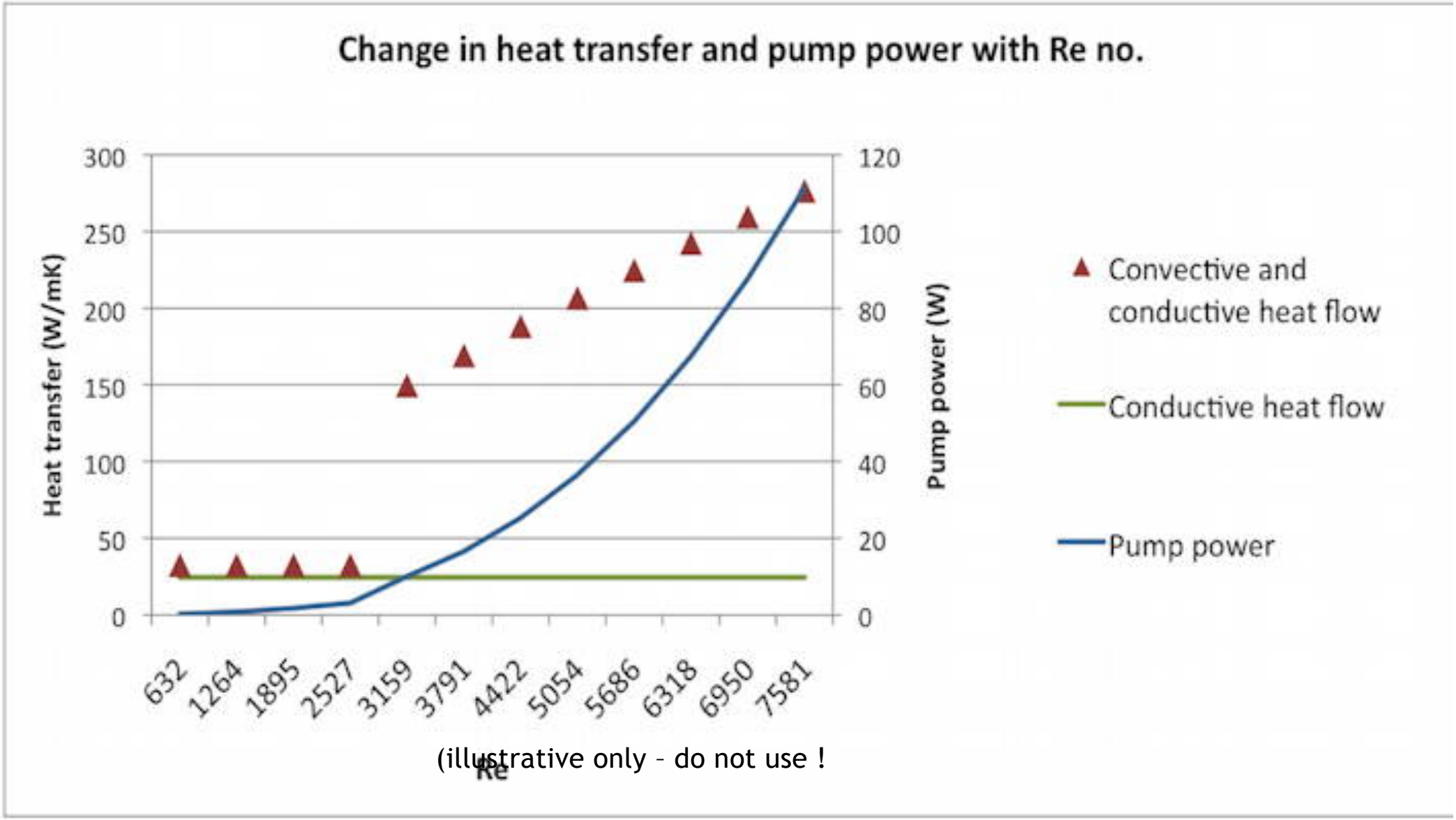

(illustrative only – do not use !

So > Increase Reynolds No:

Heat transfer improves

but……

Pump power also goes up

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Designer’s hydraulic balancing act:

Maximise heat extraction/rejection

Minimise (circulation) pump power

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ISSUE 1.1

MCS GUIDANCE DOCUMENT

Hydraulics Design Guide for MIS 3005

Procedure and charts for designing the hydraulics and associated pumping power of closed loop GSHP systems under MCS

Design Target

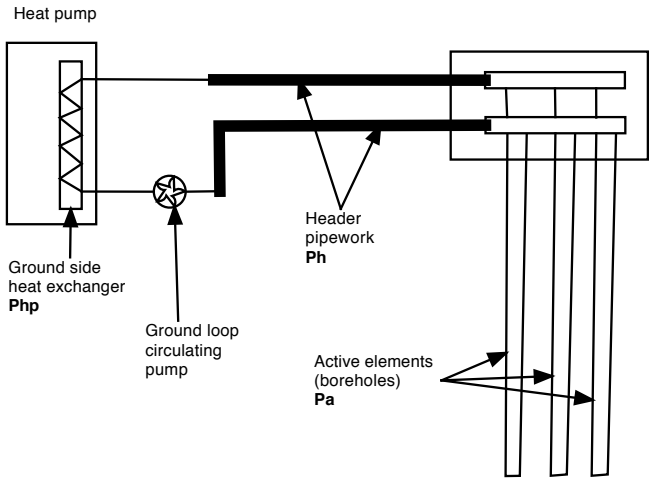
Ground loop circulating pump power
< 2.5 - 3 %
of heat pump thermal output.
(from MIS 3005)

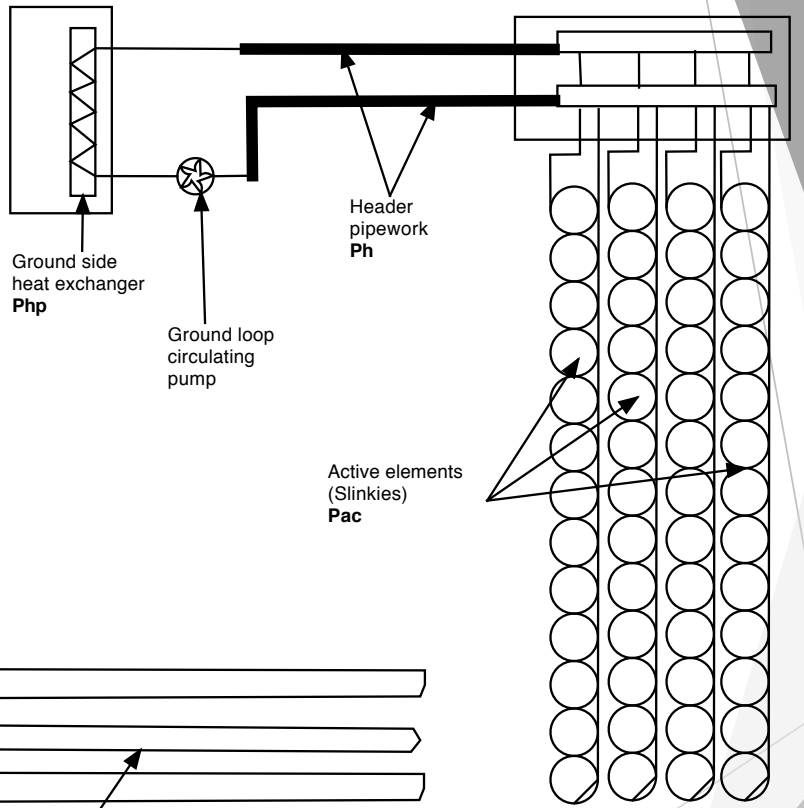
(Prefer a few % of compressor
electrical power : <5%)

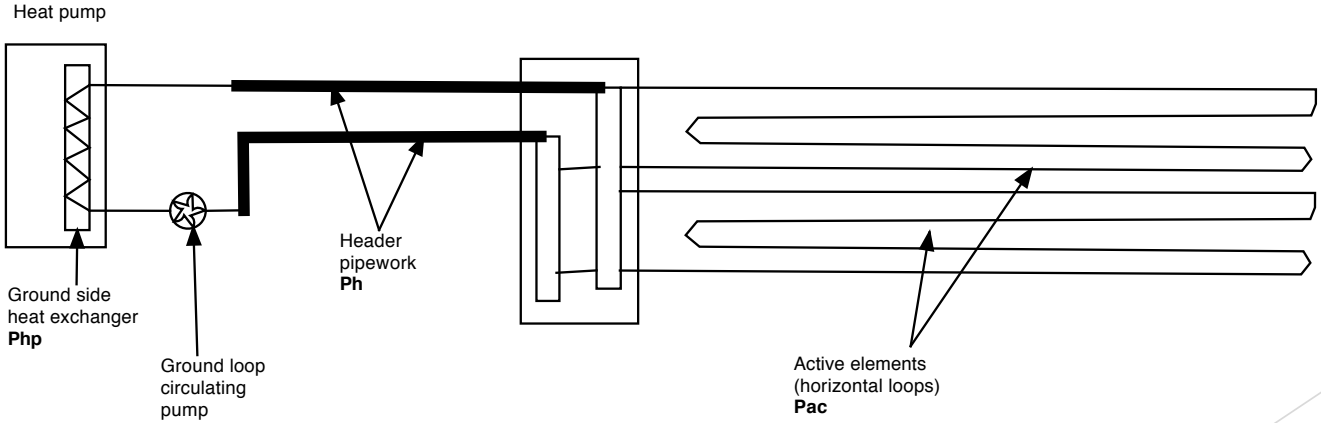
Hydraulics - Pressure drop components:

1) Active element(s)
2) Headers
3) Heat pump
4) + contingency/fittings

Ground loop hydraulic components







Hydraulics - “fixed” parameters

- minimum Heat Pump flow rate
- minimum freeze protection limit
- Pressure drop in heat pump – (beware !)

- Non-laminar – (transition zone) Re >2100

Antifreeze issues (another Webinar !)

- Viscosity > low at low temperatures
- Concentration for minimum freeze protection

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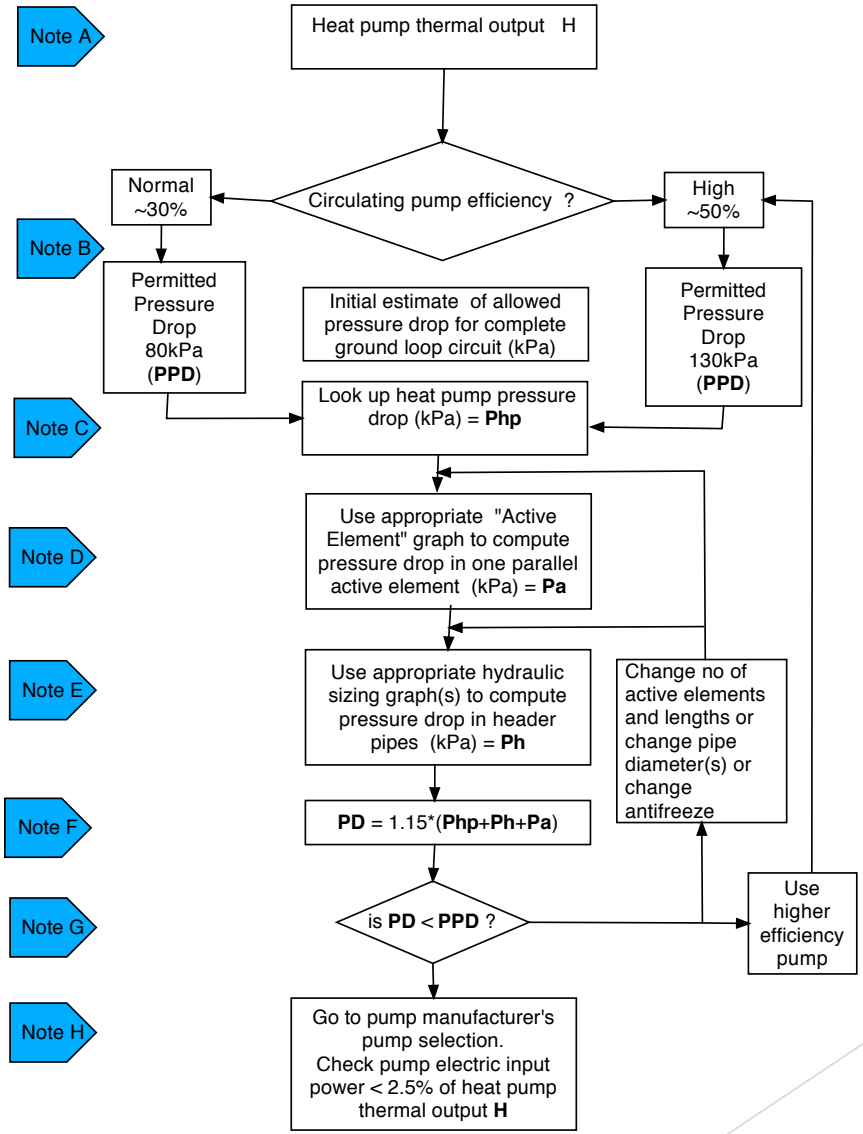
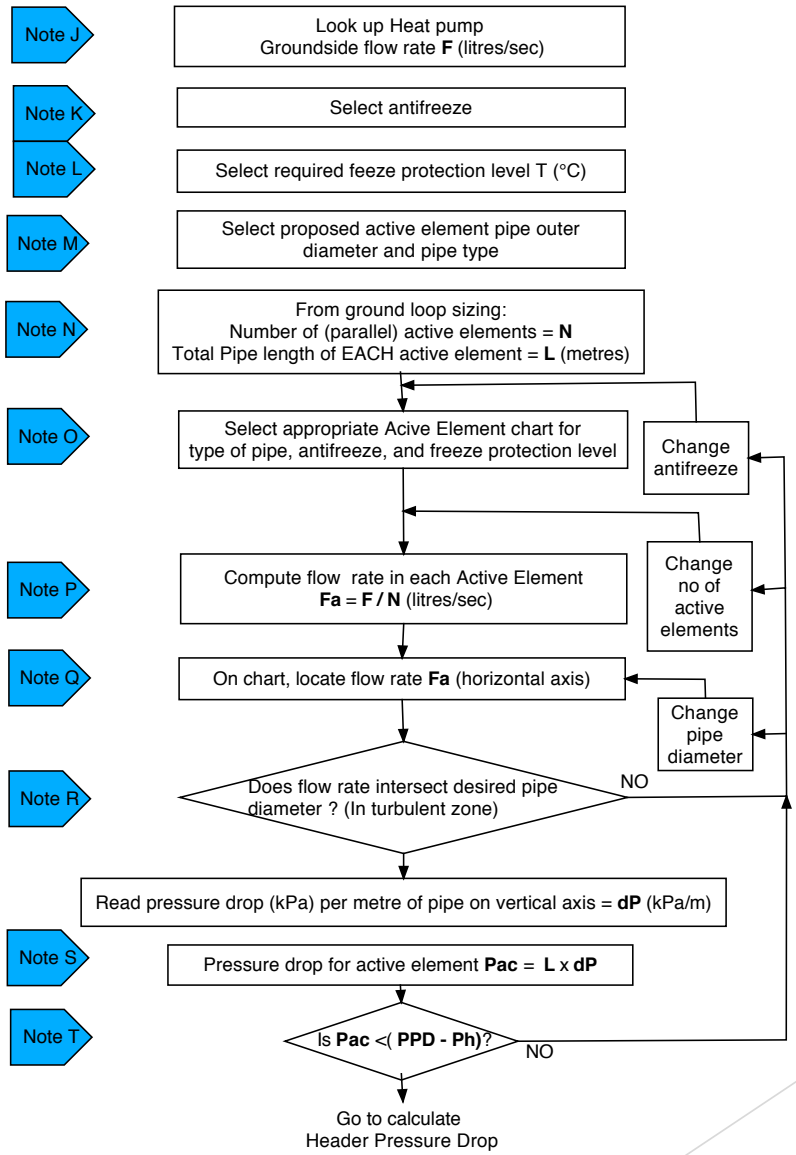
Hydraulics - the variables

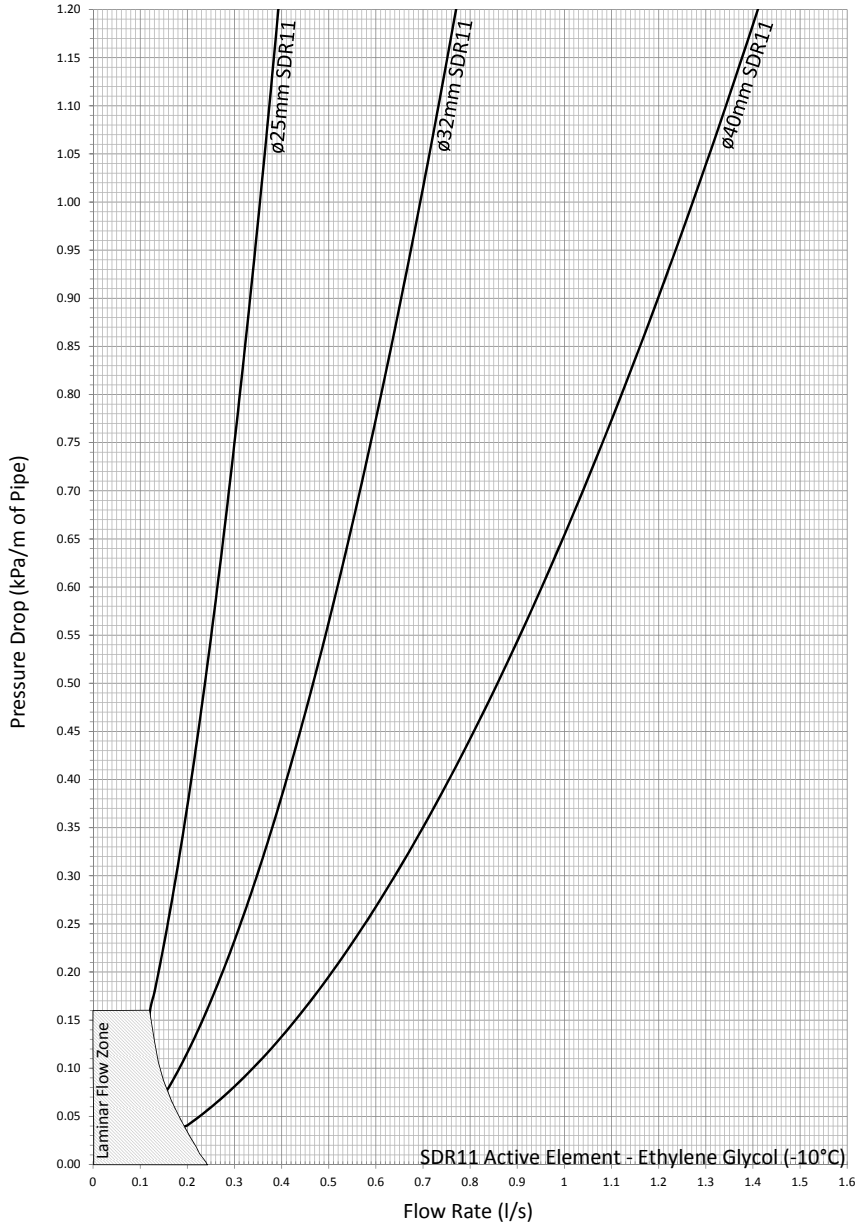
- Borehole/loop lengths vs number
- Pipe diameter
- Borehole pipe configuration (eg 1U / 2U)
- Header arrangements

Closed loop GSHP Hydraulic Sizing Flow Chart



Flow chart to compute Active Element Pressure Drop





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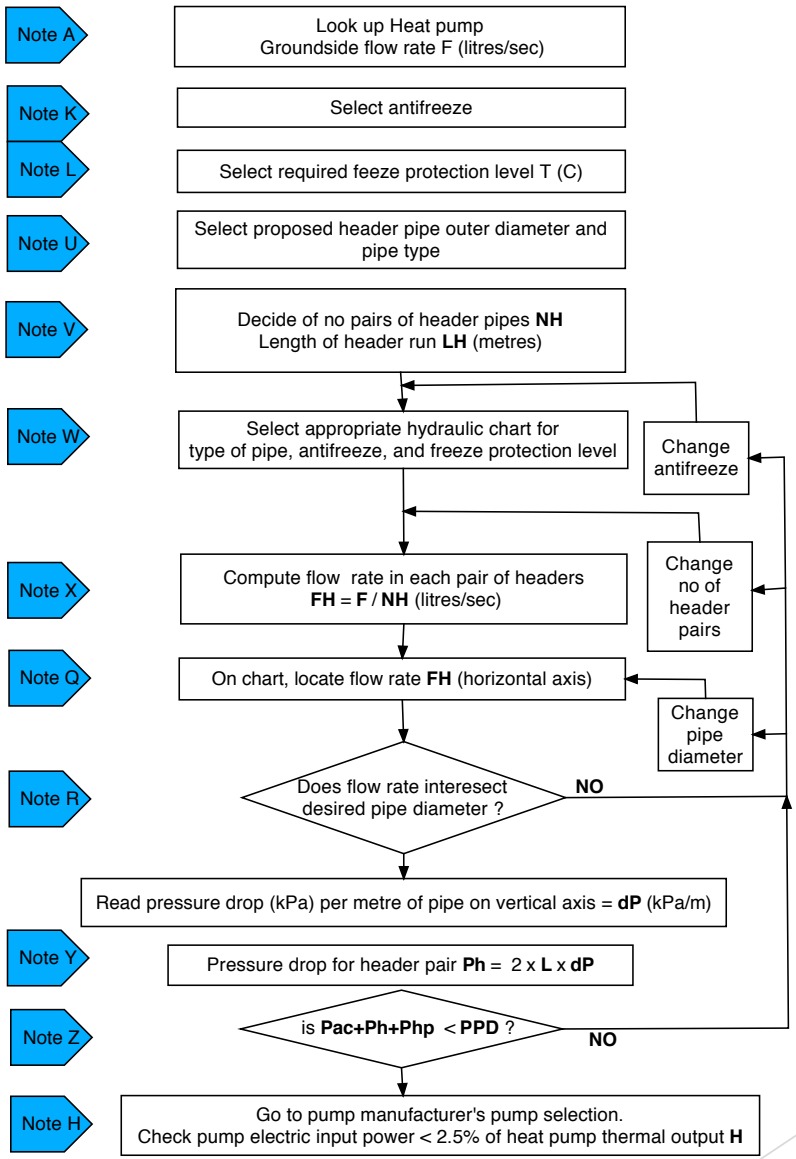
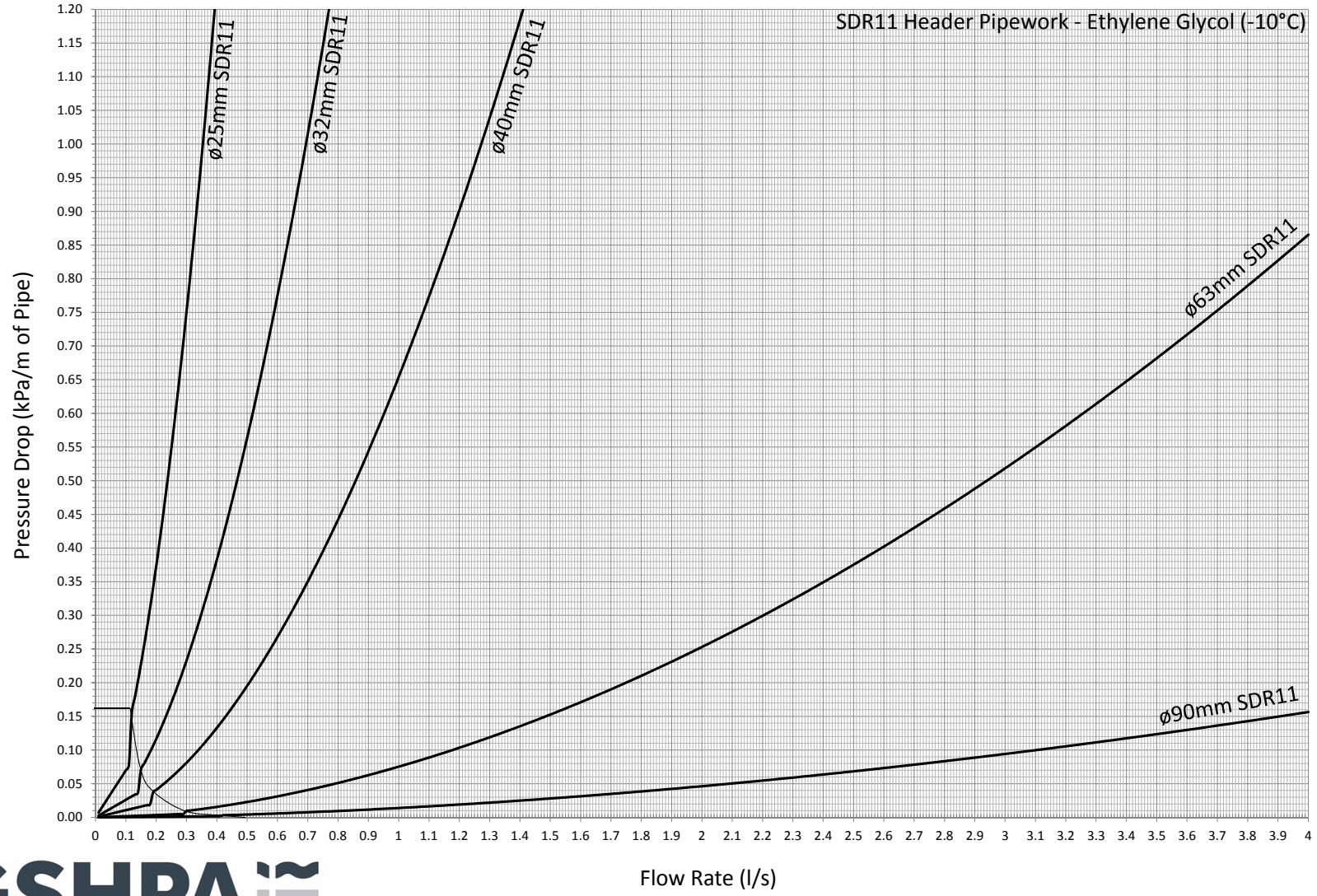
Flow chart to compute Header Pressure Drop





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Pressure drop calculator

Input - pipe diameter (internal)
flow rate
pipe length
viscosity

Output - Reynolds number,
Turbulent pressure drop
Laminar pressure drop

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Simple example

Given: 20kW HP. HP flow rate = 0.95 l/s

Using EED or GLHEPRO or equivalent - get 1st attempt at Borehole depth, number and layout.

6 holes ~ 67m deep ie 400m of hole.

Simple example

6 holes ~ 67m deep ie 400m of hole.
(flow rate = 0.16 l/s per hole)

Using PD calculator

3 common pipe sizes - 25mm, 32mm, 40mm:

	Re	ΔP
25 =	2740	36 kPa
32 =	2140	11 kPa
40 =	1710	4 kPa

Simple example

	Re	ΔP
25mm	2740	36 kPa
32mm	2140	11 kPa
40mm	1711	4 kPa

2nd go –

25mm – 7 holes 57m flow = 0.135 l/s Re = 2346 ΔP = 23 kPa
32mm – 6 holes 67m flow = 0.16 l/s Re = 2140 ΔP = 11 kPa
40mm – 5 holes 80m flow = 0.24 l/s Re = 2053 ΔP = 6 kPa

Repeat thermal calculations – iterate

Simple example

Component	ΔP	
Boreholes =	~12kPa	
Headers =	~ 25kPa	(depends on distance to plant room, and pipe diameter)
Total =	~27 kPa	
Allow say 15%	~30kPa	- fittings / manifolds / plant room etc.

(ok < 50kPa)

Add heat pump 10 kPa

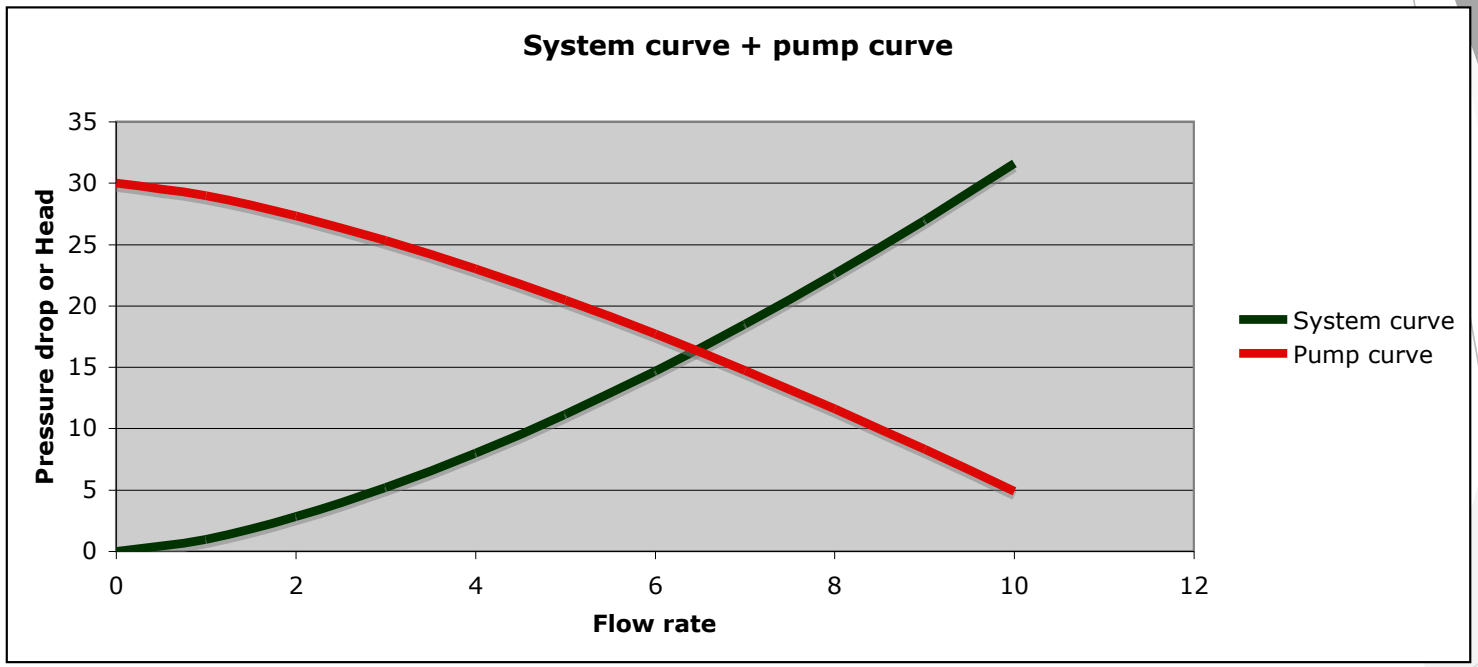
For pump - need 40kPa (~ 4m head) at 0.95 l/s

Simple example

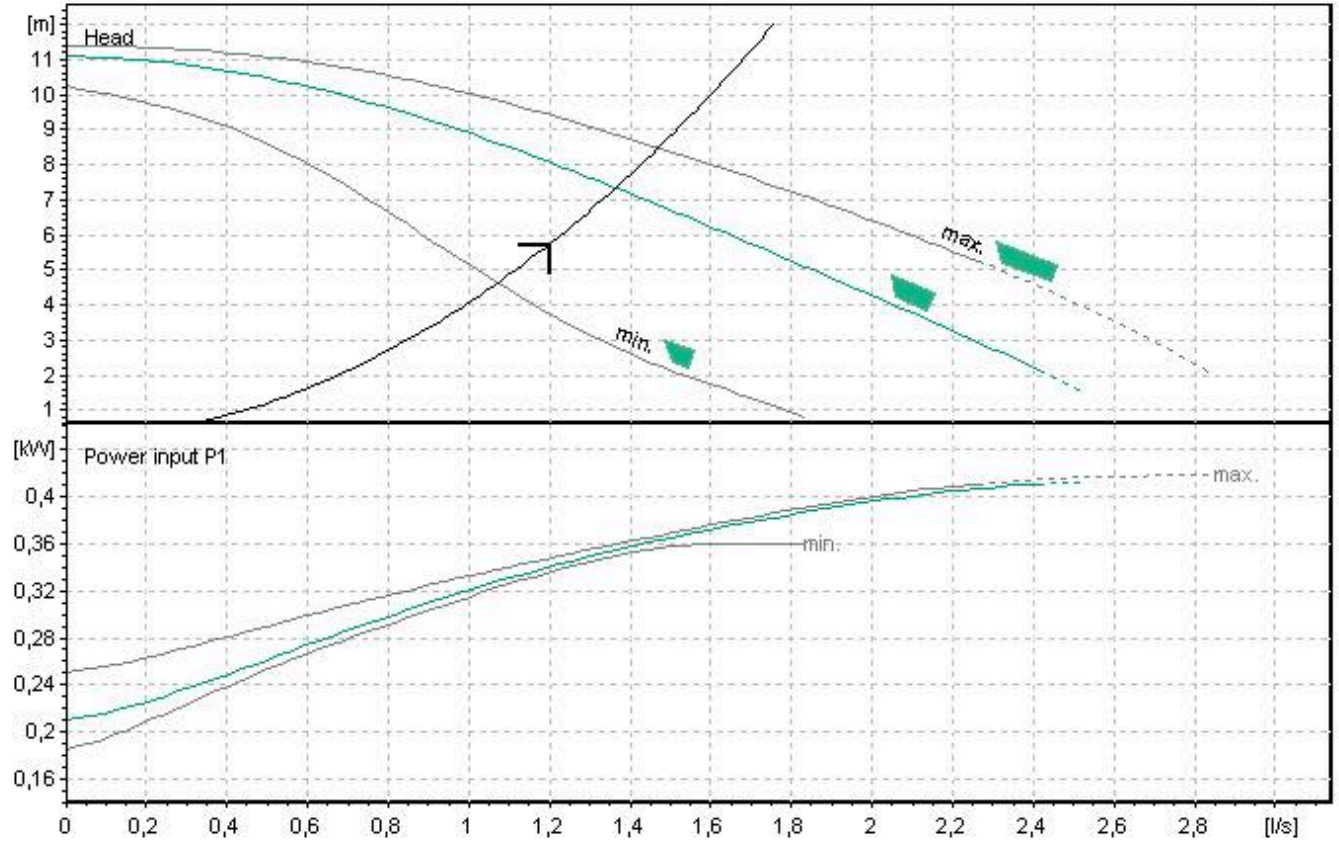
Pump selection parameters

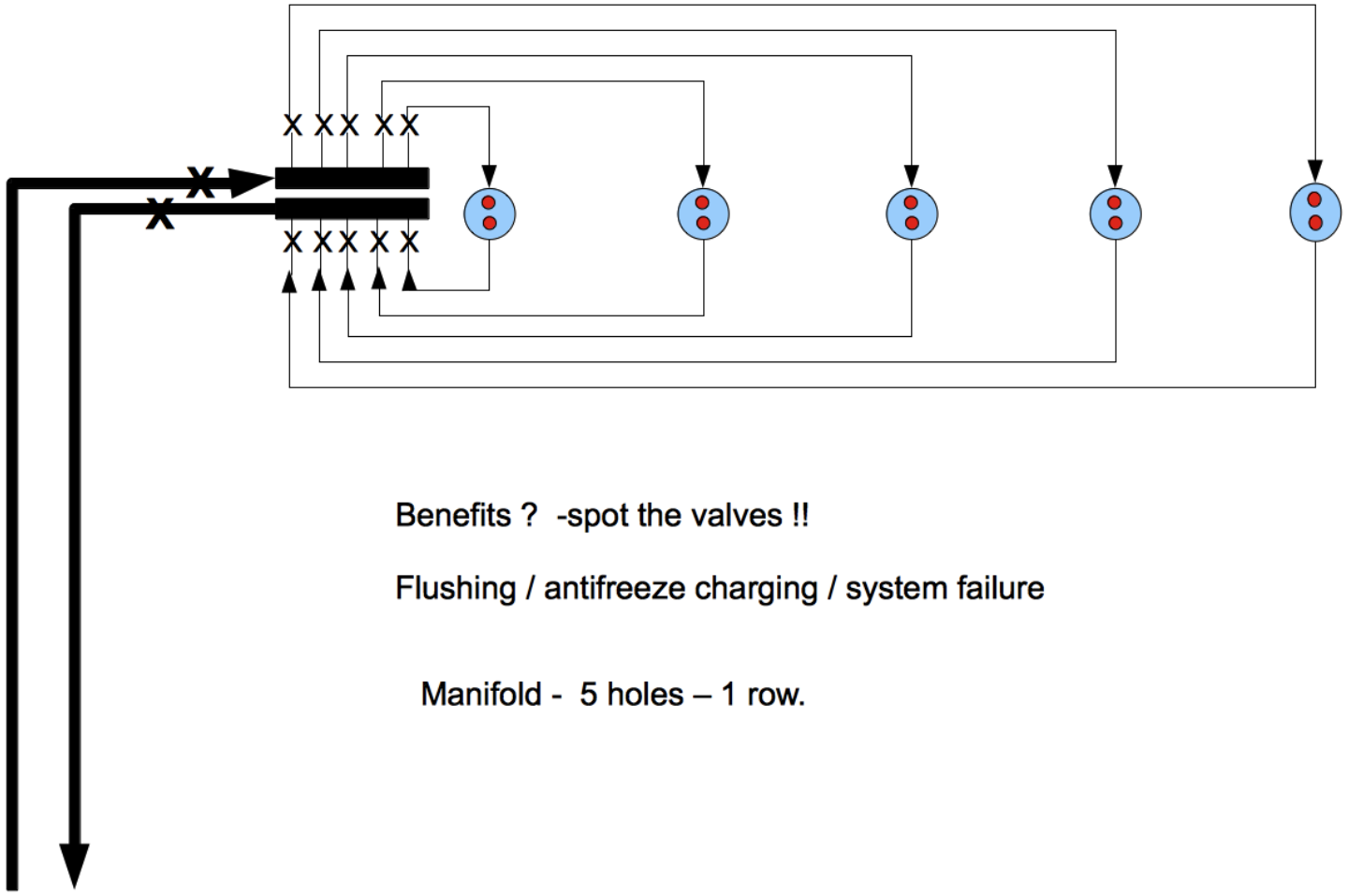
Flow rate = 0.95 l/s

Working pressure / head = ~ 40 kPa


System curve + pump curve
Pressure drop or Head
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
Flow rate
System curve
Pump curve

Pump sizing


[m]
Head
11
10
9
8
7
6
5
4
3
2
1
max.
min.
[kW]
Power input P1
0,4
0,36
0,32
0,28
0,24
0,2
0,16
max.
min.
0
0,2
0,4
0,6
0,8
1
1,2
1,4
1,6
1,8
2
2,2
2,4
2,6
2,8
[l/s]

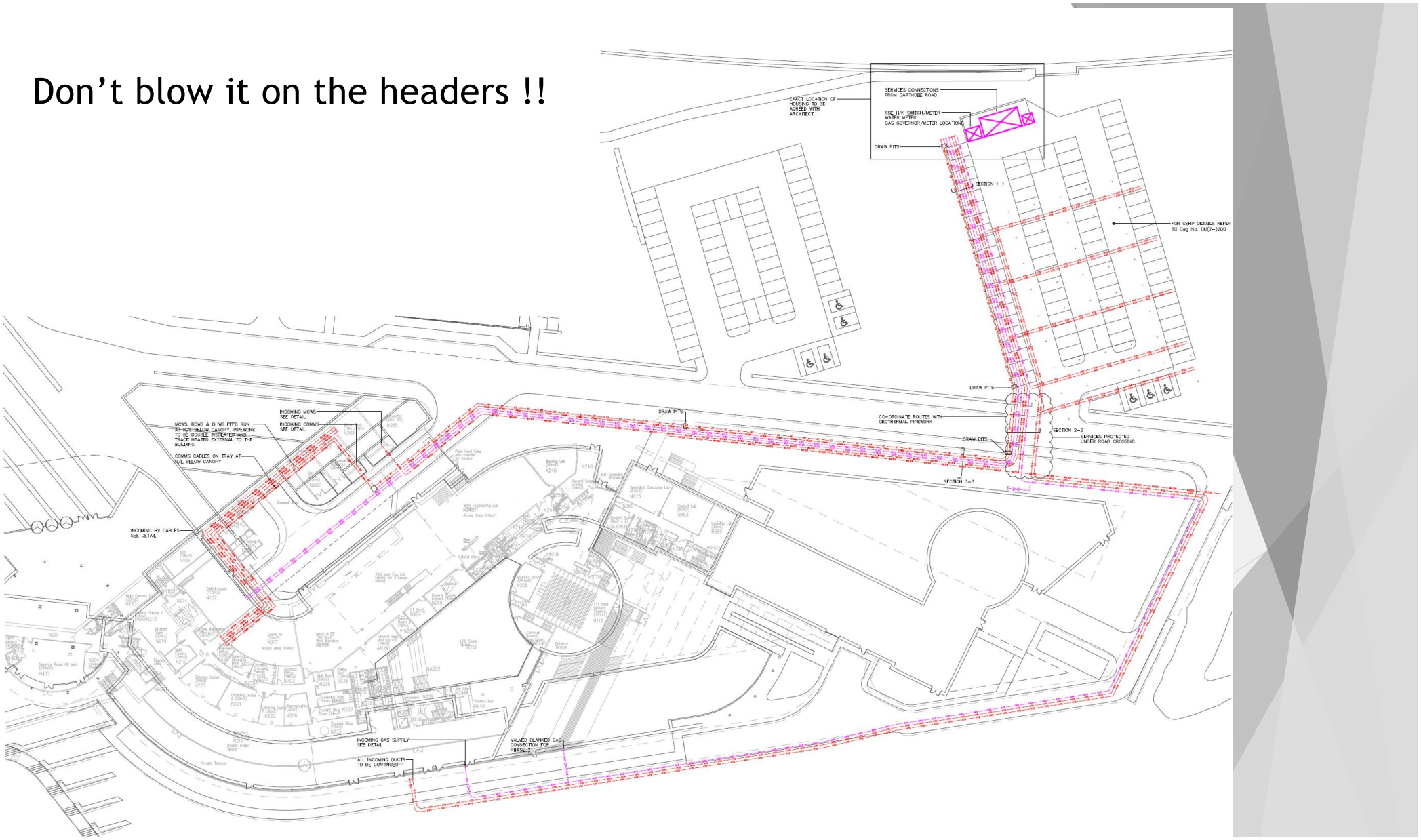


Benefits ? -spot the valves !!

Flushing / antifreeze charging / system failure

Manifold - 5 holes – 1 row.

Don’t blow it on the headers !!



Don’t blow it on the headers !

eg 200m or 300 metre long runs. = Large, costly, pipe installs.

Does the plant room really have to be this far away ?

Remember - we are installing for 50 - 100 years.

Pumps will be running 2000 to 4000 hours per annum - for 50 years +

Once the ground array is installed - it is IRREVERSIBLE !

COP > ENERGY / CARBON / RUNNING COST

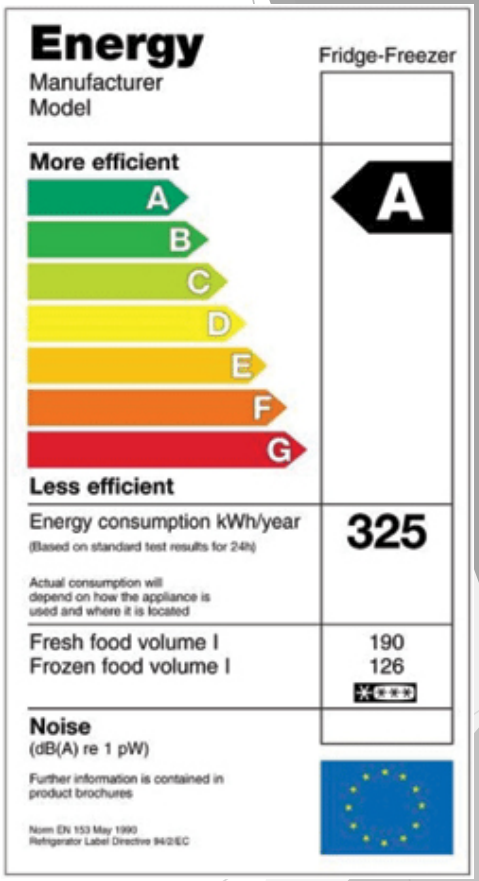
Don’t blow it on the Manifolds

- Use properly designed low pressure drop GSHP manifolds
- Not underfloor heating assemblies!!

Variable speed pumps

and

high efficiency pumps



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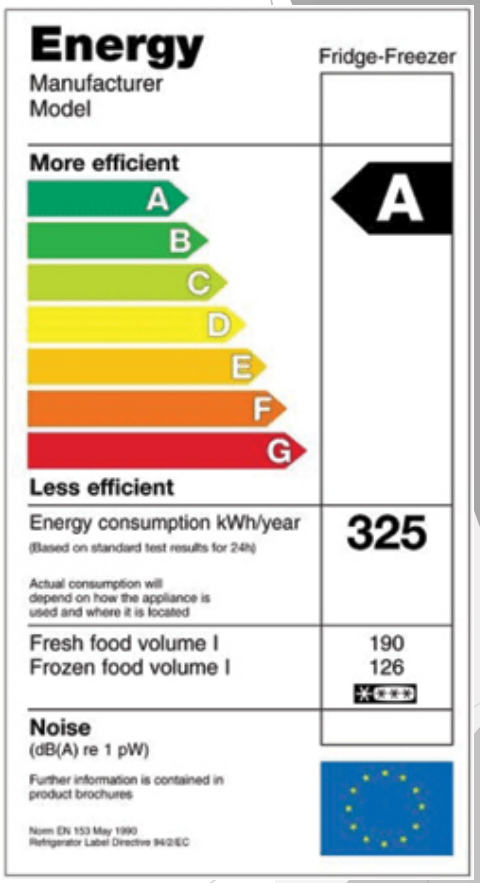
Variable speed pumps

Beware new pumps with
automatic speed control
based on reducing flow as pressure
Increases.

Opposite of what is required for ground loop!



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Miracle Nano-Fluids ?

Avoid on ground loops –

(salesmen don’t get it)

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MCS Hydraulics Design Guide materials

https://mcscertified.com/standards-tools-library/

https://mcscertified.com/wp-content/uploads/2019/08/GSHP-Hydraulics-Design-Guide-.pdf

https://mcscertified.com/wp-content/uploads/2019/08/MCS-Hydraulics-Design-Pressure-Drop-Charts-v1.0-1.pdf

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no
more
of
these

please.....

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Questions…..

and thank you

www.gshp.org.uk

Robin Curtis

info@gshp.org.uk

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