KTH ROYAL INSTITUTE OF TECHNOLOGY

2016 GSHP Convention

Alternative ethyl alcohol based secondary fluid - GSHP application

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Resurseffektiva kyl- och värmepumpssystem samt kyl- och värmelager

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PRESENT TRENDS

USA and Canada: ethyl or methyl alcohol, ethylene glycol

Europe: ethyl alcohol, salts or propylene glycol

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Nordic countries: ethyl alcohol (**Sweden: 70-75% GSHP**)
Western Europe: propylene glycol (strict regulation)

New trends:
Switzerland and Netherlands => shifting from PG to EA

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ETHYL ALCOHOL

Advantages:

- environmentally friendly (fermentation product),
- low toxicity (leakages),
- good thermophysical properties,
- low pumping power (compared to propylene glycol).

Disadvantages:

Flammability risk (limitation: 30 wt-% => T_f = -20.5ºC)

Sweden => common conc. – between 20 and 24 wt-%

Reality: up 10 wt-% denaturing agents (ketones, methyl alcohol, propyl and n-butyl alcohols)

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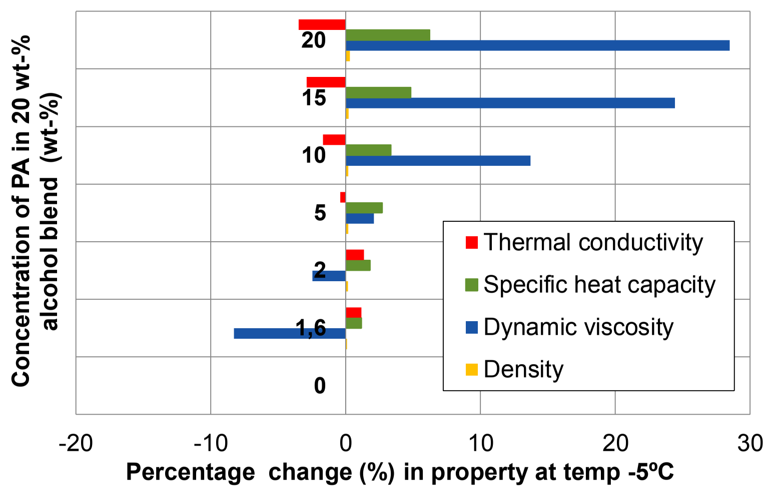
ALTERNATIVE SOLUTIONS



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ALTERNATIVE SOLUTIONS

Sample	Conc. of EA (wt-%)	Conc. of PA (wt-%)	Conc. of BA (wt-%)
1	20	0	0
2	18.0	2	0
3	18.0	1.6	0.4
4	18.4	1.6	0
5	0	0	0

EA – Ethyl alcohol
PA – Propyl alcohol
BA – Butyl alcohol

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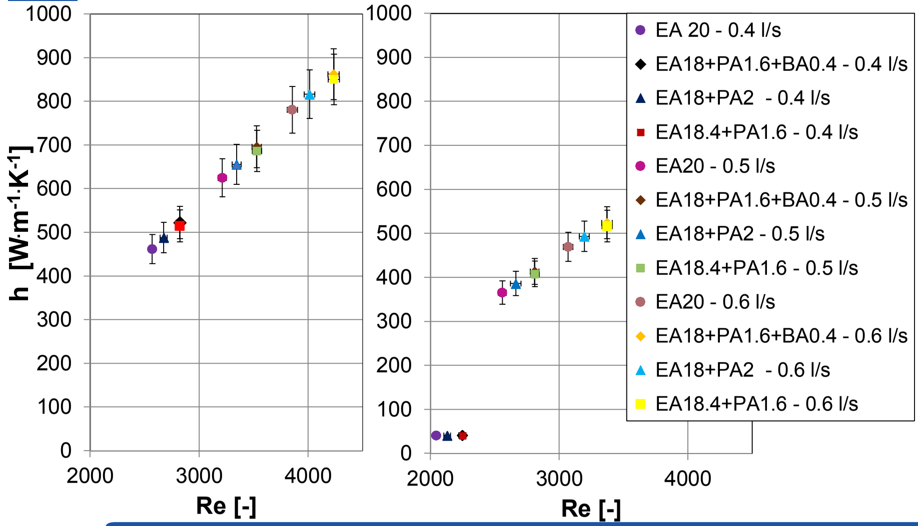
RESULTS



(a) PE40 x 2.4 mm; (b) PE50 x 2.9 mm

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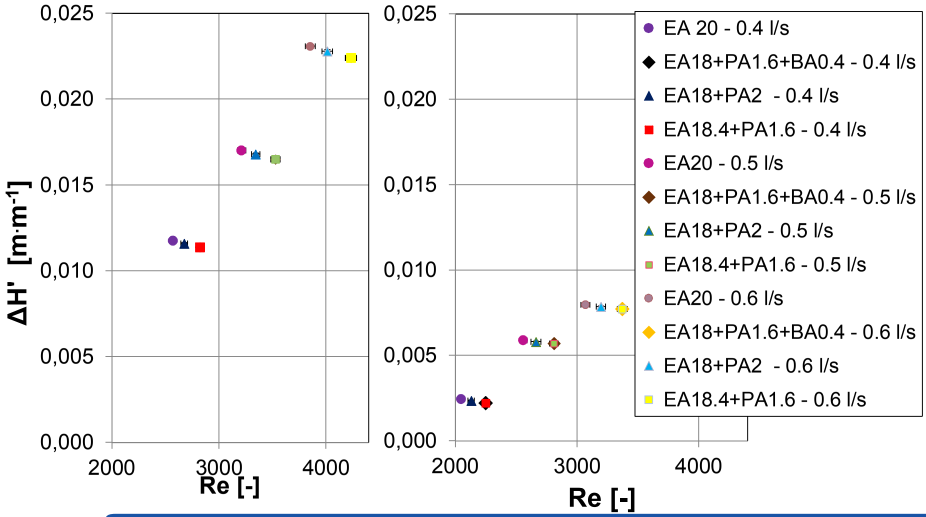
RESULTS



(a) PE40 x 2.4 mm; (b) PE50 x 2.9 mm

CONCLUSIONS

1. EA18 + PA1.6 + BA0.4 and EA18.4 + PA1.6 presented the best characteristics in terms of heat transfer and pressure drop.
2. EA18 + PA1.6 + BA0.4 gives higher heat transfer coefficient by **9.4 %** and EA18.4 + PA1.6 by **8.1 %** than EA20.
3. Both blends are giving lower pressure drop than EA20 by up to **2.7 %** (EA18 + PA1.6 + BA0.4) and **3 %** (EA18.4 + PA1.6).
4. EA18 + PA1.6 + BA0.4 gives **1.4 %** higher heat transfer coefficient and EA18.4 + PA1.6 gives lower pressure drop by up to **0.4 %**.

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Methods of BHE flushing, charging and purging in Sweden

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PROBLEM

Operational lifetime of any GSHP depends heavily on system design, installation and operation

Three aspects:
Flushing,
Charging,
Purging.

PROBLEM: no specific standards or guidelines in Sweden
=> vary from contractor to contractor

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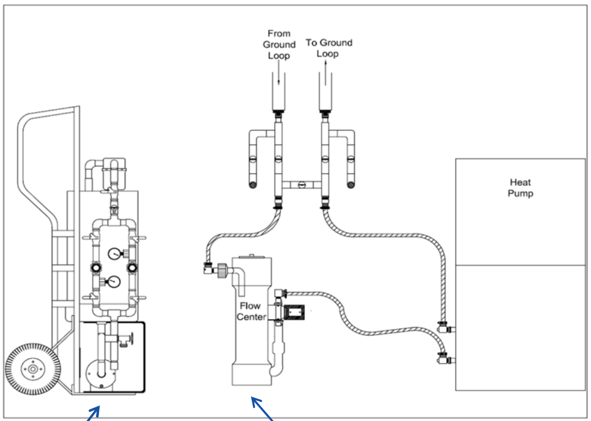
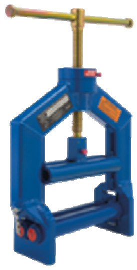
RECOMMENDED METHOD IN USA



Flush cart   Pressurized flow center



Pinch off tool

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MINIMUM FLUSHING VELOCITY

Recommendation:

0.6 m·s⁻¹ (2 ft·s⁻¹) or **135 % of design flow**

Flushing flow rate for a ground loop:

$$Q_{GLflush} = n \cdot [K \cdot (D_{pi})^2]$$

n – Total number of flow paths (-)

K – flushing constant, K = 0.4896 $(mm \cdot s^{-1})$

D_{pi} – Inner pipe diameter (mm)

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SWEDISH RECOMMENDATIONS

- Turbulent flow
- No specific flushing velocity
- No reversing flow method
- No pressurized flow centers
- Strainer or filter recommended
- Simple flush carts
- Ready made fluids
- Deionized /distilled water
- Purging – thermal method (30-35°C)

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MINIMUM FLUSHING VELOCITY

If adapting the same recommendation: 0.6 m·s⁻¹

U-Pipe Collector	$Q_{GLflush}$ ($l \cdot s^{-1}$)	$Q = u \cdot A$ ($l \cdot s^{-1}$)
32x2.0 PN10 PE100	0.38	0.37
40x2.4 PN10 PE100	0.61	0.58
50x3.0 PN10 PE100	0.95	0.91
40x3.7 PN16 PE100	0.52	0.50

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SWEDISH CASE STUDIES

- New installation
- Exisitng installation – change of secondary fluid



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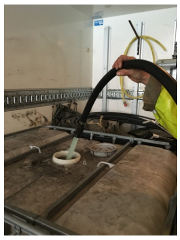
CONCLUSIONS

DIFFERENCES:

- No minimum flushing velocity in Sweden
- Flushing directly with ready-made secondary fluid
- Flushing, charging and purging before sinking collector
- Flushing velocity: 1.27 - 1.34 m· s^{-1} (> 200 %)
- 2 stage purging - manual high point air purges
- No pinch off tool

SIMILARITIES:

- "Bubble method"
- Last visual check of flow pattern



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ACKNOWLEGMENT

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ADDCON NORDIC, Avantherm AB, Danfoss, Svensk Energi & Kylanalys AB, Oy Granula Ltd, Grundfos, Gränges AB, ICT Ventilationkyl, Industri Laboratoriekyl AB, Kemetyl AB, NIBE, Nowab AB, Swed Handling AB, Stainless Engineering AB, TEO-KYL Sweden AB, Temper Technology AB, WILO Sverige

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Thank you!

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METHODOLOGY (1)

$$\Delta H' = f \frac{\bar{u}^2}{2 \cdot g \cdot D_h}$$

for $\boldsymbol{Re} > \mathbf{2300} \Rightarrow \quad f = (0{,}79 \cdot \ln(Re) - 1{,}64)^{-2}$

for $\boldsymbol{Re} \leq \mathbf{2300}$ (Poiseuille's Law) $\Rightarrow \quad f = \frac{64}{\mathrm{Re}}$

$$Re = \frac{\bar{u} \cdot D_h \cdot \rho}{\mu}$$

$$Pr = \frac{\mu \cdot c_p}{k}$$

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METHODOLOGY (2)

$$Nu = \frac{h \cdot D_h}{k}$$

for $\boldsymbol{Re} > \mathbf{2300} \quad Nu = \frac{(f/8)\,(Re-1000)Pr}{1+12{,}7 \cdot (f/8)^{\frac{1}{2}}\left(Pr^{\frac{2}{3}}-1\right)}$

for $\boldsymbol{Re} \leq \mathbf{2300} \quad \overline{Nu} = 3{,}66 + \frac{0{,}0688 \cdot Gz}{1+0{,}04 \cdot Gz^{\frac{2}{3}}} \Rightarrow$

$$Gz = Re \cdot Pr \cdot \left(\frac{D_h}{l}\right)$$

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