



REPORT

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Testing of an direct exchange ground coupled heat pump (5 appendices)

Work requested

Performance testing of an direct exchange ground coupled heat pump according to prEN 15879-1, parts performance test and safety test.

Items for testing

Heat pump unit	
Type of heat pump:	Ground (DX)/ water
Manufacturer:	Octopus Energi AB
Type number:	-
Serial number:	-
Heat transfer medium, hot:	Water
Refrigerant:	R290 (Propan) 950g

The test item arrived to SP in Borås on the 5th of October 2009. The heat pump had no visually detectable damage and seemed to be in normal condition at arrival. The test item was selected by the client.

Place and date of testing

The tests were performed during October and November 2009 at the department of Energy Technology at SP in Borås.

Method of testing

The heat pump was tested in accordance with parts of prEN 15879-1 Testing and rating of direct exchange ground coupled heat pumps with electrically driven compressors for space heating and/or cooling – Part1: Direct exchange-to-water heat pumps, performance test and safety test.

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Design and dimensions of the in-ground heat exchanger

Number of parallel loops:	1 loop
Tube length per loop:	62 m
Inside diameter of the windings:	1156 mm
Inside diameter of loop tube:	20.22 mm
Wall thickness of the loop tube:	1 mm
Material of the refrigerant lines and of the loop tubes:	Copper
Length of refrigerant lines outside bath:	7.15 m

Test equipment

The following instrumentation was used for the tests:

Name	SP inventory number
Test rig	FV4
Data acquisition system	201 405
Electric power meter	200 450
Flow meters	202 687, 701 280
Differential pressure sensors	201 542
Pt 100 resistive temperature sensors	

Settings

The heat pump was tested with factory settings, except for the heat curve, which has set to the maximum value.

Results

The test results in this report relate only to the actual heat pump which were tested under the actual conditions.

Performance testing

Table 1. *Test points for performance testing*

DX/Water or DX/brine	In ground heat exchanger	Indoor heat exchanger	
	Bath temperature (°C)	Inlet temperature (°C)	Outlet temperature (°C)
1. Standard rating conditions low temp	4	30	35
2. Standard rating conditions medium temp	4	40	45
3. Standard rating conditions high temp	4	50	60
4. Application rating conditions low temp	4	25	30
5. Application rating conditions low temp	1.5	30	35
6. Application rating conditions medium temp	1.5	40	45
7. Application rating conditions high temp	1.5	50	60

The following is a summary of the results from the test points in table 1, with reference to more detailed presentation of the results in appendix 1.

Table 2. *Results of tests: performance testing*

Test point, °C	After correction in accordance with prEN15879-1 Testing Regulations			
	P _H	P _E	COP	q _w (m³/h)
4/W30-35	8.99	2.21	4.07	1.57
4/W40-45	8.91	2.73	3.26	1.59
4/W50-60	8.57	3.48	2.46	0.75
4/W25-30	9.05	1.96	4.62	1.59
1.5/W30-35	8.58	2.16	3.97	1.48
1.5/W40-45	8.33	2.67	3.12	1.44
1.5/W50-60	8.22	3.46	2.38	0.73

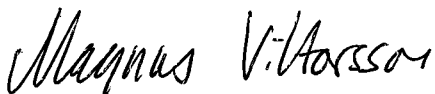
Safety test

The safety tests consisted of blocking the heat transfer media flow, simulating a complete power failure and triggered the low-pressure safety device. The tests were performed with the heat pump operating at stable conditions at test condition no. 1 according to table 1. The results from the safety tests are summarized in table 3.

Table 3. *Results from safety test*

Simulated malfunction	
7.2.2 Pressure drop (triggered the low-pressure safety device)	passed
7.2.3 Shutting off the heat transfer medium flow	passed
7.2.4 Complete power supply failure	passed

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Appendices

1. Results, Thermal Performance test
2. Uncertainty of measurement
3. List of components
4. Short description of the heat pump
5. Designations

Bilaga 1

Test point		1	2	3	4	5	6	7
Heat transfer medium temperature in/out	°C	30/25	35/30	45/40	60/50	35/30	45/40	60/50
Bath temperature	°C	4	4	4	4	1.5	1.5	1.5
Mesured quantities								
<i>Temperature</i>	°C							
Heat transfer medium, hot, outlet	t _{w2}	25.0	35.0	45.0	59.9	35.0	45.0	59.8
Heat transfer medium, hot, inlet	t _{w1}	29.9	30.0	40.1	49.9	30.0	40.0	49.9
Bath temperature	t _{a5}	4.0	4.0	4.0	4.1	1.5	1.6	1.5
<i>Flow</i>	m ³ /h							
Volume flowrate of heat transfer medium, hot	q _w	1.59	1.57	1.59	0.75	1.48	1.44	0.73
<i>Pressure difference</i>	kPa							
Heat transfer medium, hot	Δp _w	15.0	15.1	15.0	3.3	12.6	11.7	3.1
<i>Electrical power</i>	kW							
Total	P _T	1.94	2.19	2.71	3.47	2.14	2.66	3.46
Calculated quantities								
<i>Thermal power</i>	kW							
Total thermal output power to the heat sink	P _{thps}	9.02	8.97	8.89	8.57	8.57	8.31	8.21
<i>Coefficient of performance</i>	(-)							
total	COP _{hps}	4.66	4.10	3.28	2.47	3.99	3.13	2.38
Correction in accordance with prEN 15897-1								
Test point		1	2	3	4	5	6	7
Heat transfer medium temperature in/out	°C	35/25	35/30	45/40	60/50	35/30	45/40	60/50
Air temperature dry/ wet bulb	°C	4	4	4	4	1.5	1.5	1.5
<i>Correction, pump power</i>	W							
Heat transfer medium pump, hot	P _{epw,s}	22.0	21.9	22.1	2.3	17.4	15.7	2.1
<i>Electrical power after correction</i>	kW							
Total	P _E	1.96	2.21	2.73	3.48	2.16	2.67	3.46
<i>Thermal power after correction</i>	kW							
delivered	P _H	9.05	8.99	8.91	8.57	8.58	8.33	8.22
<i>COP after correction</i>	(-)							
Total	COP	4.62	4.07	3.26	2.46	3.97	3.12	2.38

Bilaga 2

Uncertainty of measurement

The results from testing are based partly on direct measurements and partly on calculations. The estimates apply to the total uncertainties including both systematic and random uncertainties. Unit terms and designations are as given in Appendix 5.

Measured data

Temperatures

t_{wo}, t_{wi}	$\pm 0.1 \text{ K}$
t_{ci}, t_{co}	$\pm 0.1 \text{ K}$
$t_{wo} - t_{wi}$	$\pm 0.05 \text{ K}$
$t_{co} - t_{ci}$	$\pm 0.05 \text{ K}$

Differential pressures

Δp_c	$\pm 1 \text{ kPa}$
Δp_w	$\pm 1 \text{ kPa}$

Flows

q_w	$\pm 1 \%$
q_c	$\pm 1 \%$

Electric Power

P_{em}	$\pm 0.5 \%$
P_T	$\pm 0.5 \%$

<i>Weight of refrigerant</i>	$\pm 10 \text{ g}$
<i>Measured length</i>	$\pm 100 \text{ mm}$

Table values

Density

ρ_w	$\pm 1 \text{ kg/m}^3$	(source: SP REPORT 1994:01)
ρ_c	$\pm 2 \%$	(source: SP REPORT 1994:01)

Specific heat capacity at constant pressure

c_{pw}	$\pm 10^{-4} \text{ kJ/(kg. K)}$	(source: SP REPORT 1994:01)
c_{pc}	$\pm 6 \%$	(source: SP REPORT 1994:01)

Calculated data

P_{1hps}, P_H	$\pm 1.4 \%$
COP_{hps}, COP	$\pm 1.5 \%$

Bilaga 3

List of Components for Octopus

Part name	Producer and Type
Compressor:	HRP048 Danfoss Scroll
Expansion valve:	Octopus TUB48
Refrigerant/mass:	R290 (0.950 kg)
Heat transfer medium pump (warm):	none
Heat transfer medium pump (Sanitary hot water):	none
Heat transfer medium pump (cold):	none
Evaporator:	DX
Condenser:	CB52-30H Alfa Laval
Control equipment:	OctoEL10
Pressure switch, high pressure:	Saginomiya, Danfoss ACB-JB206
Pressure switch, low pressure:	Saginomiya, Danfoss LCB-JA83
Reversing valve:	none
Drying filter:	Danfoss DML 033S
Immersion heater:	none
Water heater:	none
Thermostat:	none
Shunt valve:	none
Shunt Valve motor:	none
Construction year:	2009

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Operation

Two copper pipes are connected to the evaporator. One pipe transfers fluid to the evaporator. The other pipe transfers energy filled gas to the heat pump module. Energy is transferred to the buildings water-bourne system by the heat pump module. The heated water is then pumped around the building.

1. The heat gathering part - low pressure

This part of the heat pump is called the evaporator. A refrigerant (propane) with a low temperature flows through the evaporator. The evaporator is heated by its surrounding environment.

2. The preasure rising part - High pressure

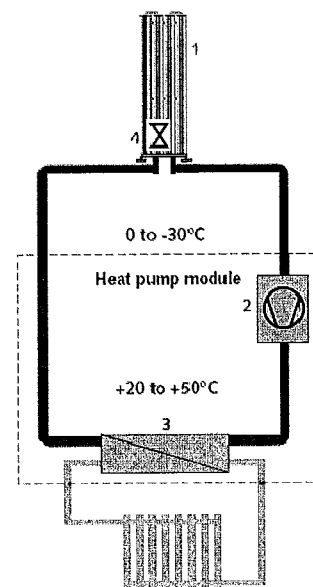
This part consists of a compressor. The heated and evaporated refrigerant is compressed by the compressor. The increase in pressure raises the temperature and condensation point (the point where gas returns to liquid form).

3. The heat emitting part - High pressure

This part of the heat pump transfers the heat to the house and is called the condensor. The refrigerant passes through the condensor at a high temperature and condensation point. In the condensor, the refrigerant is cooled down by the heating system of the house (such as radiators or floor heating), leading to the condensation of the refrigerant (returning it to liquid form).

4. Pressure lowering part - Low pressure

This part consists of a throttling device. The cooled refrigerant expands and both the temperature and the boiling point of the refrigerant is significantly lowered as a result of the lower pressure.



Bilaga 5

Beteckningar
Designations

COP	Värmefaktor	Coefficient of performance
COP	Värmefaktor; total; rumsuppvärmning; korrigerad enligt EN 14511	Coefficient of performance; total; space heating; corrected according to EN 14511
COP _{hp}	Värmefaktor. kompressor. rumsuppvärmning; korrigerad enligt EN 14511	Coefficient of performance; motor; space heating; corrected according to EN 14511
COP _{hps}	Värmefaktor; total. rumsuppvärmning	Coefficient of performance. space heating for heat pump system
COP _t	Värmefaktor; tappvattenvärmning; korrigerad enligt EN 255-3	Coefficient of performance; production of sanitary hot water; corrected according to EN 255-3
Q, W	Energi; el eller värme	Energy; electric or thermal
Q _{max}	Värmemängd; tappvarmvatten; tappning nummer 4; enligt EN 255-3	Thermal heat content; tapped sanitary hot water draw-off number 4; according to EN 255-3
Q _{t,x}	Värmemängd; tappvarmvatten; tappning nummer x; enligt EN 255-3	Thermal heat content; tapped sanitary hot water; draw-off number x; according to EN 255-3
W _{eh}	Energi; el; totalt tillförd under uppladdningsperiod	Energy; electrical; total supplied during heating-up period
W _{es}	Energi. el; totalt tillförd under tomgångsperiod enligt EN255-3	Energy; electrical; total supplied during stand-by loss period. corrected according to EN255-3
W _{et}	Energi; el; total tillförd under tidsperiod från andra tappningens början till kompressor stoppar. korrigerad enligt EN255-3	Energy; electrical; total supplied during the period of time from start of second draw-off to next compressor stop. corrected according to EN255-3
P	El- och värmeeffekt	Power: electric (active) or thermal
P _E	Effekt; el; totalt tillförd till värmepumpsystemet; korrigerad enligt EN 14511	Power; electrical; total input to heat pump system; corrected according to EN 14511
P _{em}	Effekt; el; tillförd till kompressormotor	Power; electrical; input to compressor motor
P _{epw}	Effekt; el; tillförd till cirkulationspump; värmeöverförande medium; varm	Power; electrical; input to pump; heat transfer medium; warm
P _{epc}	Effekt; el; tillförd till cirkulationspump; värmeöverförande medium; kall	Power; electrical; input to pump; heat transfer medium; cold
P _{es}	Tomgångsförbrukning; totalt tillförd till värmepumpsystem under tomgångsperioden; korrigerad enligt EN 255-3	Power; electrical; total input to heat pump system during the standby period; corrected according to EN 255-3
P _H	Effekt; värme; från värmepumpsystem till värmesänka. korrigerad enligt EN 14511	Heating capacity; from heat pump system to heat sink; corrected according to EN14511
P _{1hps}	Effekt; värme; från värmepumpsystem till värmesänka	Heating capacity; from heat pump system to heat sink
P _{2hps}	Effekt; värme; från värmekälla till	Heating capacity; from heat source to

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P_T	värmepumpssystem Effekt; el; totalt tillförd till värmepumpsystemet	heat pump system Power; electrical; total input to the heat pump system
q	Volymflöde	Volume flow rate
q_c	Volymflöde; värmeöverförande medium; kall	Volume flow rate; heat transfer medium; cold
q_w	Volymflöde; värmeöverförande medium; varm	Volume flow rate; heat transfer medium; warm
q_{wh}	Volymflöde; varmvatten	Volume flow rate; sanitary water; hot
t	Temperatur	Temperature
t_{amb}	Temperatur; omgivning	Temperature; ambient
t_c	Temperatur; värmeöverförande medium; kall	Temperature; heat transfer medium; cold
t_w	Temperatur; värmeöverförande medium; varm	Temperature; heat transfer medium; warm
t_{wc}	Temperatur. kallvatten; enligt EN 255-3. θ_{wc}	Temperature; sanitary water; cold; according to EN 255-3. θ_{wc}
t_{wh}	Temperatur. tappvatten; varm; enligt EN 255-3. θ_{wh}	Temperature; sanitary water; hot; according to EN 255-3. θ_{wh}
t'_{wh}	Temperatur. tappvatten. varm; tappning nummer 3; enligt EN 255-3. θ'_{wh}	Temperature; sanitary water; hot; at draw off number 3; according to EN 255-3. θ'_{wh}
t''_{wh}	Temperatur. tappvatten; varm; tappning nummer 4; enligt EN 255-3. θ''_{wh}	Temperature; sanitary water; hot; at draw off number 3; according to EN 255-3. θ''_{wh}
t_{wr}	Temperatur; tappvatten; medelvärde; $\theta_{wr} = (\theta_{wh}' + \theta_{wh}'')/2$; enligt EN 255-3. θ_{wr}	Temperature; sanitary water; hot; mean value; $\theta_{wr} = (\theta_{wh}' + \theta_{wh}'')/2$; according to EN 255-3. θ_{wr}
c_p	Specifik värmekapacitet	Specific heat capacity
c_{pc}	Specifik värmekapacitet. värmeöverförande medium; kall	Specific heat capacity ;heat transfer medium; cold
c_{pw}	Specifik värmekapacitet. värmeöverförande medium; varm	Specific heat capacity; heat transfer medium; warm
Δp	Differenstryck	Differential pressure
Δp_c	Differenstryck; yttre; värmeöverförande medium; kall	Differential pressure; external; heat transfer medium; cold
Δp_w	Differenstryck; yttre; värmeöverförande medium; varm	Differential pressure; external; heat transfer medium; warm
ρ	Densitet	Density
ρ_c	Densitet. värmeöverförande medium; kall	Density; heat transfer medium; cold
ρ_w	Densitet. värmeöverförande medium; varm	Density; heat transfer medium; warm
V	Volym	Volume
V_{max}	Volym; tappvatten; varm; ekvivalent 40 °C; enl. EN 255-3	Volume; sanitary hot water; equivalent to 40 °C; according to EN 255-3

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V_{wh}	Volym. varmvatten	Volume. sanitary hot water
τ	Tid	Time
τ_h	Tid; uppladdningsperiod; tappvattenprov; angiven som t_h enligt EN 255-3	Time; heating up period; according to EN 255-3. t_h
τ_s	Tid; tomgångsperiod; tappvattenprov; angiven som t_s i EN 255-3	Time; standby power period; according to EN 255-3. t_s
τ_t	Tid; från andra tappningens början till nästföljande kompressorstopp; tappvattenprov; angiven som t_t i EN 255-3	Time; from start of the second draw-off until next heat pump shut-off; according to EN 255-3. t_t

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amb	Omgivning
c	Värmeöverförande medium; kall
def	Avfrostning
e	Elektrisk
h	Uppladdning
hp	Värmepump
hps	Värmepump system
i	In till värmepump
m	Motor; kompressor
max	Maximal
o	Ut från värmepump
p	Pump
s	Tomgång
s	Standardiserad
t	Tappning varmvatten
w	Värmeöverförande medium; varm
wc	Tappvatten; kall
wh	Tappvatten; varm

Indices

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