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 copmpressors for space heating and/or cooling – Part1: Direct exchange-to-water heat pumps, performance test and safety test.

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*

	In ground heat exchangeer	Indoor heat exchanger	
DX/Water or DX/brine	**Bath temperature (°C)**	**Inlet temperature (°C)**	**Outlet temperatur e (°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 S hutting 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

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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								
Temperature	°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
Flow	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
Pressure difference	*kPa*							
Heat tranfer medium, hot	Dp_w	15.0	15.1	15.0	3.3	12.6	11.7	3.1
Electrical power	*kW*							
Total	P_T	1.94	2.19	2.71	3.47	2.14	2.66	3.46
Calculated quantities								
Thermal power	*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
Coefficient of performance	*(-)*							
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
Correction, pump power	*W*							
Heat transfer medium pump, hot	$P_{epw,s}$	22.0	21.9	22.1	2.3	17.4	15.7	2.1
Electrical power after correction	*kW*							
Total	P_E	1.96	2.21	2.73	3.48	2.16	2.67	3.46
Thermal power after correction	*kW*							
delivered	P_H	9.05	8.99	8.91	8.57	8.58	8.33	8.22
COP after correction	*(-)*							
Total	COP	4.62	4.07	3.26	2.46	3.97	3.12	2.38

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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}	± 0.1 K
t_{ci}, t_{co}	± 0.1 K
$t_{wo} - t_{wi}$	± 0.05 K
$t_{co} - t_{ci}$	± 0.05 K

Differential pressures

Δp_c	± 1 kPa
Δp_w	± 1 kPa

Flows

q_w	± 1 %
q_c	± 1 %

Electric Power

P_{em}	± 0.5 %
P_T	± 0.5 %

Weight of refrigerant	± 10 g
Measured length	± 100mm

Table values

Density

ρ_w	± 1 kg/m^3	(source: SP REPORT 1994:01)
ρ_c	± 2 %	(source: SP REPORT 1994:01)

Specific heat capacity at constant pressure

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

Calculated data

P_{1hps}, P_H	± 1.4 %
COP_{hps},COP	± 1.5 %

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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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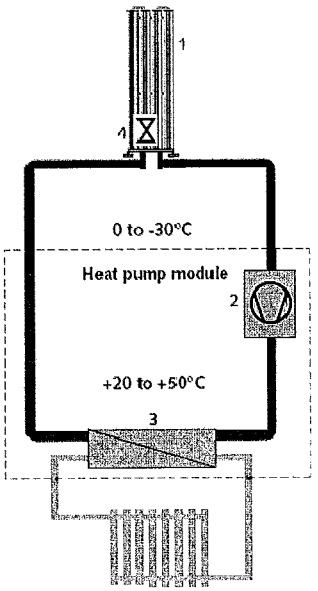
Operation

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 preassure 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 signifi cantly lowered as a result of the lower pressure.

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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

	värmepumpssystem	heat pump system
P_T	Effekt; el; totalt tillförd till värmepumpsystemet	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

Index		**Indices**
amb	Omgivning	Ambient
c	Värmeöverförande medium; kall	Heat transfer medium; cold
def	Avfrostning	Defrost
e	Elektrisk	Electrical
h	Uppladdning	Heating up period
hp	Värmepump	Heat pump
hps	Värmepump system	Heat pump system
i	In till värmepump	Inlet to heat pump
m	Motor; kompressor	Motor; compressor
max	Maximal	Maximum
o	Ut från värmepump	Outlet from heat pump
p	Pump	Pump
s	Tomgång	Stand by
s	Standardiserad	Standardised
t	Tappning varmvatten	Draw off sanitary water; warm
w	Värmeöverförande medium; varm	Heat transfer medium; warm
wc	Tappvatten; kall	Sanitary water; cold
wh	Tappvatten; varm	Sanitary water; hot