TEST REPORT

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EVALUATION CENTER

Intertek Testing Services Shenzhen Ltd. Guangzhou Branch
Block E, No.7-2 Guang Dong Software Science Park,
Caipin Road, Guangzhou Science City,
GETDD, Guangzhou, China
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RENDERED TO
Sonnenwärme Direkt GmbH
Dammholmer Str.3 24873 Havetoft

MANUFACTURER
Same as Above

PRODUCT EVALUATED: Model SWD Röhrenkollektor HP-12, SWD Röhrenkollektor HP-30 solar collector
EVALUATION PROPERTY:
EN12975-1:2006 + A1:2010
Thermal solar systems and components – Solar collectors – Part 1:General Requirements
EN12975-2:2006
Thermal solar systems and components – Solar collectors – Part 2: Test methods

Report of testing model SWD Röhrenkollektor HP-12,SWD Röhrenkollektor HP-30 **solar collector is compliance with the applicable requirements of the following criteria: EN 12975-1:2006+A1:2010/EN 12975-2:2006. All samples are normal before test.**

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1 Summary of test results

Qualification of solar collectors according to EN 12975-1:2006+A1:2010/EN 12975-2:2006

Manufacturer: Sonnenwärme Direkt GmbH
Brand name: SWD
Serial No: 2011SPA12-1, 2011SPA30-1/-2/-3
Drawing document No.: SPA-D-100×130-1800-58-01/001/002/004/005/010/017
Collector reference No.: S11121720-001/002/003/004

Test		Date		Summary of main test results
		Start	End	
Internal pressure		2012-4-12	2012-4-12	Pass
High-temperature resistance		2012-1-31	2012-1-31	Pass
Exposure		2012-2-17	2012-3-31	Pass
External thermal shock	First	2012-2-26	2012-2-26	Pass
	Second	2012-2-28	2012-2-28	
Internal thermal shock	First	2012-2-29	2012-2-29	Pass
	Second	2012-3-5	2012-3-5	
Rain penetration		2012-3-17	2012-3-17	Pass
Freeze resistance		NA	NA	NA
Mechanical load (positive)		2012-4-12	2012-4-12	Pass
Thermal performance		2012-1-31	2012-2-14	Pass
Impact resistance (optional)		NA	NA	NA
Final inspection		2012-4-13	2012-4-13	Pass

Submitted samples are tested in accordance with specified requirement, the test results are listed in the report.

INTERTEK TESTING SERVICES Shenzhen Ltd. Guangzhou Branch

Reported by: Jonas Feng
Engineer
Intertek

Reviewed by:
Team Leader
Intertek

2 General Specification

2.1 Sample selection

Samples were selected based on the SolarKeymark rules by Intertek inspector and submitted to Intertek directly from the client. Samples were received at the Evaluation Center on Dec.31, 2011.

2.2 Sample and assembly description

According to the SolarKeymark Scheme rules, there is an agreement concerning collectors, which differ only in size, so called series or families. Only the biggest (SWD Röhrenkollektor HP-30) and the smallest collector (SWD Röhrenkollektor HP-12) have to be tested in this case. A complete collector test according to EN 12975-1:2006+A1:2010/ EN 12975-2:2006 has to be performed on the biggest collector (SWD Röhrenkollektor HP-30). The thermal performance test is sufficient on the smallest collector (SWD Röhrenkollektor HP-12). The SolarKeymark label based on this test is valid for the whole series.

(MS): means manufacture specification.

Brand name	Test collector	Number of tubes	Length of tubes
SWD Röhrenkollektor HP-12	YES	12	1800mm(MS)
SWD Röhrenkollektor HP-15	NO	15	1800mm(MS)
SWD Röhrenkollektor HP-18	NO	18	1800mm(MS)
SWD Röhrenkollektor HP-20	NO	20	1800mm(MS)
SWD Röhrenkollektor HP-22	NO	22	1800mm(MS)
SWD Röhrenkollektor HP-24	NO	24	1800mm(MS)
SWD Röhrenkollektor HP-30	YES	30	1800mm(MS)

2.2.1 Specific data of the smallest collector of the series (SWD Röhrenkollektor HP-12)

Brand name:	SWD
Serial no.:	2011SPA12-1
Year of production:	2011
Collector reference no.(Intertek):	S11121720-004
Gross area:	1.056m×1.983m=2.09 m^2
Aperture area:	1.73m×0.0548m×12=1.14 m^2
Absorber area:	1.73m×0.047m×12=0.98 m^2
Height:	100mm

Weight empty:	51kg(MS)
Volume of the fluid:	1.0 L(MS)

2.2.2 Specific data of the largest collector of the series (SWD Röhrenkollektor HP-30)

Brand name:	SWD
Serial no.:	2011SPA30-1/-2/-3
Year of production:	2011
Collector reference no.(Intertek):	S11121720-001/002/003
Gross area:	2.496m×1.983m=4.95 m^2
Aperture area:	1.73m×0.0548m×30=2.84m^2
Absorber area:	1.73m×0.047m×30=2.44m^2
Height:	100 mm
Weight empty:	112 kg(MS)
Volume of the fluid:	2.5L(MS)

2.2.3 Specification of the tubes

Type:	Vacuum tube
Material of the cover tube:	Borosilicate glass
Number of covers:	1
Transmission of the cover tube:	≥91%(MS)
Outer diameter of the cover tube:	58mm×1.6 mm
Outer diameter of the inner tube:	47mm×1.6mm
Distance between two tubes:	80mm

2.2.4 Absorber

Solar absorptance α:	93% (MS)
Hemispherical emittance ε:	10% (MS)
Surface treatment:	AL-N/CU (MS)
Material of header pipe:	Copper
Outer diameter of the header pipe:	22mm
Construction of the absorber:	Heat Pipe with one fin
Material of the fin:	Aluminium
Thickness of the fin:	0.3mm

2.2.5 Thermal insulation and casing

Insulation material:	Mineral wool
Density:	140kg/m^3 (MS)
Thermal conductivity:	≤0.04W/(m k) (MS)
Heat capacity:	1 KJ/(kg K) (MS)
Sealing material:	Silicon rubber
Casing material:	Aluminum alloy

2.2.6 Limitations

Maximum operation temperature:	95 °C
Maximum operation pressure:	600kPa(MS)
Flow rate range:	3.5 - 8 L/min
Heat transfer medium:	Water/antifreeze
Stagnation temperature:	210.3°C

3 Testing and Evaluation Methods

3.1 Condition

The specimens were held in standard laboratory conditions before testing for at least 48 hours at a temperature of 23 ± 2℃ and a relative humidity of 50 ± 5%.

3.2 Specimen Preparation

4 test specimens (which contain one SWD Röhrenkollektor HP-12 and three pieces SWD Röhrenkollektor HP-30) were submitted and received in good condition.

3.3 Test Standard

EN 12975-1:2006+A1:2010 – Thermal solar systems and components – Solar collectors – Part 1: General requirements.
EN 12975-2: 2006 – Thermal solar systems and components – Solar collectors – Part 2: Test methods.

4 Execution and Evaluation

4.1 Internal pressure test

Collector reference No.:S11121720-001
Lead through and boundary conditions acc. to EN12975-2:2006-part 2, clause 5.2

4.1.1 Collector type

Cover:	☑ Glazed	☐ Unglazed
Maximum collector operation pressure specified by manufacturer:	0.6 MPa	

4.1.2 Test conditions

Test temperature [°C]	Test pressure [MPa]	Test duration [min]
24.8	0.9	15

4.1.3 Test results

Conclusion: No major failure appears acc. to EN12975-1:2006+A1:2010, clause 5.3.1

4.2 High temperature resistance

Collector reference No.: S11121720-002

Lead through and boundary conditions acc. to EN12975-2:2006-part 2, clause 5.3

4.2.1 Method used to heat collectors

☑ Out door testing	☐ In solar simulator

4.2.2 Test conditions

Collector tilt angle[degrees form horizontal] [°]:	25
Average irradiance during test [W/ m^2]:	1027
Average surrounding air temperature [^{o}C] :	17.5
Average surrounding air speed [m/s]:	<1,
Duration of test [h]:	1

4.2.3 Stagnation temperature

Average irradiance [W/m^2]:	1027
Average absorber temperature [a] [^{o}C]:	215.5
Average ambient temperature [^{o}C] :	17.5

a. The stagnation temperature t_{stg} for required ambient conditions G_s =1000 W/m^2 and $t_{as} = 30°C$ is calculated according to

$$t_{stg} = t_{as} + \frac{G_S}{G_m}(t_{sm} - t_{am})$$

Therefore, t_{stg} = 210.3 ^{o}C

4.2.4 Test results

Conclusion: No major failure appears after test acc. to EN12975-1:2006+A1:2010, clause 5.3.1

4.3 Exposure test

Collector reference No.: S11121720-002

Lead through and boundary conditions acc. to EN12975-2:2006-part 2, clause 5.4

Collector tilt angle (degree from horizontal): 25°

4.3.1 Climatic conditions for all days during the test

Date	H (MJ/m^2)	t_a (^{o}C)	Rain (mm)	Date	H （MJ/m^2）	t_a （^{o}C）	Rain (mm)
2012-2-17	24.68	20.2	0	2012-3-3	3.7	9.9	22.4
2012-2-18	21.26	19.8	0	2012-3-4	16.2	13	0
2012-2-19	17.89	18.8	0	2012-3-5	25.1	15.5	0
2012-2-20	26.08	20.5	0	2012-3-6	19.4	15.7	0
2012-2-21	16.97	20.1	0	2012-3-7	15.3	16.9	0
2012-2-22	23.55	21.8	0	2012-3-8	11	17.9	0
2012-2-23	21.44	21.3	0	2012-3-9	23.2	19.5	0
2012-2-24	21.5	21.5	0	2012-3-10	23.55	17.5	0
2012-2-25	26.03	22	0	2012-3-11	23.77	20.3	0
2012-2-26	26.17	22.4	0	2012-3-12	24.4	21.7	0
2012-2-27	12.94	19.2	0	2012-3-13	20.08	18.4	0
2012-2-28	21.27	20.3	0	2012-3-14	17.38	20.1	0
2012-2-29	14.6	18.4	0	2012-3-15	20	19	0
2012-3-1	13.53	17.2	0	2012-3-16	17.79	20.2	0
2012-3-2	6.7	12.5	9.7	2012-3-17	18.4	18.7	0

2012-3-18	20.13	19.5	0	2012-3-25	15.67	17.7	0
2012-3-19	20.23	20.1	0	2012-3-26	14.53	18.9	0
2012-3-20	21.89	21.9	0	2012-3-27	16.06	20.5	0
2012-3-21	18.42	21.8	0	2012-3-28	20.7	21.7	0
2012-3-22	17.41	21.1	0	2012-3-29	17.3	19.5	0
2012-3-23	22.4	15.2	0	2012-3-30	20.3	20.8	0
2012-3-24	15.78	16.7	0				

Total: 38 days in which H > 14 MJ/m^2, Maximum daily rain fall: 22.4 mm

4.3.2 Time periods in which irradiance and surrounding air temperature have values greater than those specified Table 4 which is in clause 5.4.3 of EN12975-1:2006

Date	H MJ/m^2	t_a ^{o}C	Time periods min	Date	H MJ/m^2	t_a ^{o}C	Time periods min
2012-2-17	24.68	20.2	250	2012-3-9	23.2	19.5	213
2012-2-18	21.26	19.8	160	2012-3-10	23.55	17.5	225
2012-2-19	17.89	18.8	200	2012-3-11	23.77	20.3	240
2012-2-20	26.08	20.5	248	2012-3-12	24.4	21.7	251
2012-2-22	23.55	21.8	222	2012-3-13	20.08	18.4	170
2012-2-23	21.44	21.3	178	2012-3-14	17.38	20.1	112
2012-2-24	21.5	21.5	242	2012-3-15	20	19	174
2012-2-25	26.03	22	248	2012-3-16	17.79	20.2	103
2012-2-26	26.17	22.4	255	2012-3-17	18.4	18.7	107

2012-2-28	21.27	20.3	205	2012-3-20	21.89	21.9	187
2012-2-29	14.6	18.4	155	2012-3-21	18.42	21.8	163
2012-3-5	25.1	15.5	234	2012-3-22	17.41	21.1	93
2012-3-6	19.4	15.7	175	2012-3-23	22.4	15.2	218
2012-3-7	15.3	16.9	73	2012-3-24	15.78	16.7	124
2012-3-8	11	17.9	30	2012-3-25	15.67	17.7	45
2012-3-9	23.2	19.5	213	2012-3-26	14.53	18.9	113
2012-3-10	23.55	17.5	225	2012-3-27	16.06	20.5	70
2012-3-11	23.77	20.3	240	2012-3-28	20.7	21.7	142
2012-3-12	24.4	21.7	251	2012-3-29	17.3	19.5	113
2012-3-13	20.08	18.4	170	2012-3-30	20.3	20.8	136
2012-3-14	17.38	20.1	112				
2012-3-15	20	19	174				
2012-3-16	17.79	20.2	103				
2012-3-17	18.4	18.7	107				
2012-3-18	20.13	19.5	144				
2012-3-19	20.23	20.1	107				

Total time: 128.7 hours in which G > 850 W/m^2

4.3.3 Test Results

Conclusion: Evaluate each potential problem according to the following scale:

0 – No problem

1 – Minor problem

2 – Severe problem

* - Inspection to establish the condition was not possible

Collector component	Potential problem evaluation	Result
Collector box/fasteners	Cracking/warping/corrosion/ rain penetration	0
Mounting/structure	Strength/safety	0
Seals/gaskets	Cracking/adhesion/elasticity	0
Cover/reflector	Cracking/crazing/buckling/ delamination	0
Absorber coating	Cracking/crazing/blistering	0
Absorber tubes and headers	Deformation/corrosion/leakage/ loss of bonding	0
Absorber mountings	Deformation/corrosion	0
Insulation	Water retention/outgassing/degradation	0

And there are no major failure appears after test acc. to EN12975-1:2006+A1:2010, clause 5.3.1.

4.4 External thermal shock test

Collector reference No.: S11121720-002

Lead through and boundary conditions acc. to EN12975-2:2006-part 2, clause 5.5

4.4.1 Test conditions

☑ Test performed outdoors	☑ Combined with exposure test
☐ Test performed indoors in solar simulator	☐ Combined with high temperature resistance test

	First shock		Second shock	
Collector tilt angle[°]	25		25	
Min & mean irradiance [W/m^2]	981.5	992.2	904.5	915.6
Min & mean surrounding air temperature[^{o}C]	18.0	18.4	16.6	17.1
Period during which the required operating conditions were maintained prior to shock [min]	60		60	
Flow rate of water spray [kg/s · m^2]	0.04		0.04	
Temperature of water spray [^{o}C]	17.5		17.3	
Duration of water spray [min]	15		15	
Absorber temperature immediately prior to water spray [^{o}C]	Not detected		Not detected	

4.4.2 Test results

Conclusion: No major failure appears after test acc. to EN12975-1:2006+A1:2010, clause 5.3.1

4.5 Internal thermal shock test

Collector reference No.: S11121720-002

Lead through and boundary conditions acc. to EN12975-2:2006-part 2, clause 5.6

4.5.1 Test conditions

☑ Test performed outdoors	☑ Combined with exposure test
☐ Test performed indoors in solar simulator	☐ Combined with high temperature resistance test

	First shock		Second shock	
Collector tilt angle[°]	25		25	
Min & mean irradiance [W/m^2]	916.8	940.0	1018.6	1031.4
Min & mean surrounding air temperature[^{o}C]	17.3	18.4	15.7	16.0
Period during which the required operating conditions were maintained prior to shock [min]	60		60	
Flow rate of heat transfer fluid [kg/s · m^2]	0.04		0.04	
Temperature of heat transfer fluid [^{o}C]	17.2		16.4	
Duration of heat transfer fluid flow [min]	5		5	
Absorber temperature immediately prior to heat transfer fluid flow [^{o}C]	Not detected		Not detected	

4.5.2 Test results

Conclusion: No major failure appears after test acc. to EN12975-1:2006+A1:2010, clause 5.3.1

4.6 Rain penetration

Collector reference No.: S11121720-002

Lead through and boundary conditions acc. to EN12975-2:2006-part 2, clause 5.7

4.6.1 Test conditions

Collect mounted on:	☑ Open frame	☐ Simulated roof
Collector tilt angle[°]:	30	
Collector experienced exposure days:	25 days	
Method used to keep absorber warm:	☐ Hot water circulation	■ Exposure of collector to solar radiation
Water spray flow rate[kg/(s · m^2)]:	0.05	
Water temperature[^{o}C]:	19.5	
Duration of water spray [h]:	4	

4.6.2 Test results

Area with visible sign of water penetration [expressed as a percentage of aperture area]	--
Give details of water penetration, reporting the place where water penetrated	--
The time the sign of rain penetration took to vanish	--
Collector weight before test [g]:	91795
Collector weight after test [g]:	91830

And no major failure appears after test acc. to EN12975-1:2006+A1:2010, clause 5.3.1

4.7 Freeze resistance test (NA)

Collector reference No.:--

Lead through and boundary conditions acc. to EN12975-2:2006-part 2, clause 5.8

4.7.1 Collector type and tilt angle

☐ Freeze-resistant when filled with water ☐ Drain down

Tilt angle of collector during test [°]:

4.7.2 Test conditions

No. of freeze-thaw cycles	Freeze conditions		Thaw conditions	
	Test temperature[°C]	Duration [min]	Test temperature[a][°C]	Duration [min]
1	--	--	--	--
2	--	--	--	--
3	--	--	--	--

[a] For freeze-resistant collectors, this is the temperature of the contents of the collector, e.g. water, ice

For drain-down collectors, this is the temperature measured inside the absorber close to the inlet

Rate of chamber cooling [K/h]:	--
Rate of chamber cooling[K/h]:	--

4.7.3 Test results

Give details of leakage, breakage, distortion or deformation and any of the failures denoting ‘’major failure’’, defined in 5.3.1 of EN12975-1:2006+A1:2010

4.8 Mechanical load test

Lead through and boundary conditions acc. to EN12975-2:2006-part 2, clause 5.9

4.8.1 Positive pressure test of the collector cover

Collector reference No.: S11121720-001

4.8.1.1 Method used to apply pressure

☐ Loading with gravel or similar material	☑ Loading with water
☐ Suction cups	☐ Pressurization of collector cover

4.8.1.2 Test condition

Maximum pressure load [Pa]:	2500

4.8.1.3 Test result

Conclusion: The test pressure was increased to 2500Pa with one tube broken acc. to EN12975-1:2006+A1:2010, clause 5.3.1.

4.8.2 Negative pressure test of fixing between the cover and the collector box (NA)

Collector reference No.: --

4.8.2.1 Method used to apply pressure

☑ Suction cups	☐ Pressurization of collector box

4.8.2.2 Test condition

Maximum pressure load [Pa]:	-- Pa

4.8.2.3 Test result

Conclusion: --

NOTE: Not relevant on vacuum tubes for this test NA.

4.9 Impact resistance test using steel balls (NA)

Collector reference No.:--

Lead through and boundary conditions acc. to EN12975-2:2006-part 2, clause 5.9

4.9.1 Test conditions

Diameter of ball [mm]:	--	
Mass of ball [g]:	--	
Test performed by using:	☑ Vertical impact	☐ Horizontal impact

4.9.2 Test procedure

Drop height [m]	No. of drops
--	--
--	--
--	--
--	--
--	--
--	--
--	--
--	--
--	--

4.9.3 Test result

Conclusion: --

4.10 Final inspection results

Evaluate each potential problem according to the following scale:

0 – No problem

1 – Minor problem

2 – Severe problem

* - Inspection to establish the condition was not possible

Collector component	Potential problem evaluation	Result
Collector box/fasteners	Cracking/warping/corrosion/ rain penetration	0
Mounting/structure	Strength/safety	0
Seals/gaskets	Cracking/adhesion/elasticity	0
Cover/reflector	Cracking/crazing/buckling/ delamination	0
Absorber coating	Cracking/crazing/blistering	0
Absorber tubes and headers	Deformation/corrosion/leakage/ loss of bonding	0
Absorber mountings	Deformation/corrosion	0
Insulation	Water retention/outgassing/degradation	0

5 Test results of thermal performance

Collector reference No.: S11121720-003/004

5.1 Test method according to EN 12975-2:2006

☑ Outdoor-Steady State Method(6.1)	☐ Indoor-Steady State Method(6.2)
☐ Outdoor-Quasi-Dynamic Method(6.3)	

5.2 Test conditions

Collector model:	SWD Röhrenkollektor HP-12	SWD Röhrenkollektor HP-30
Latitude [°]:	North 23.08	North 23.08
Longitude [°]:	East 113.15	East 113.15
Mass flow [kg/(s m^2)]:	0.02	0.02
Aperture area [m^2]:	1.14	2.84
Collector absorber area [m^2]:	0.98	2.44
The instantaneous efficiency is defined by:	$\eta = Q / AG$	

5.3 Test results of thermal performance

Collector model:	SWD Röhrenkollektor HP-12	SWD Röhrenkollektor HP-30
Effective heat capacity c [kJ/(m^2K)]:	12.15	
Incident angle modifier *Kθ* (50):	0.90	0.91
Peak power [W_{peak}] per collector unit (G=1000 W/(m^2K), $t_m - t_a$ =0) [W]:	814	1999

Determination of power output per collector unit (second order fit to data):

$$\dot{Q} = A \cdot G\left(\eta_0 - a_1\left(\frac{t_m - t_a}{G}\right) - a_2 G\left(\frac{t_m - t_a}{G}\right)^2\right)$$

Coefficient based on aperture area

SWD Röhrenkollektor HP-12		SWD Röhrenkollektor HP-30	
η_{0a}	0.714	η_{0a}'	0.704
a_{1a}	1.078	a_{1a}'	1.406
a_{2a}	0.037	a_{2a}'	0.020

Power output per collect

SWD Röhrenkollektor HP-12

$t_m - t_a$ [k]	**Irradiance**		
	400 W/m^2	700 W/m^2	1000 W/m^2
0	326	570	814
10	309	553	797
30	251	495	739
50	159	403	647
70	33	277	521

SWD Röhrenkollektor HP-30

$t_m - t_a$ [k]	**Irradiance**		
	400 W/m^2	700 W/m^2	1000 W/m^2
0	800	1400	1999
10	754	1354	1954
30	629	1229	1828
50	458	1058	1658
70	242	842	1442

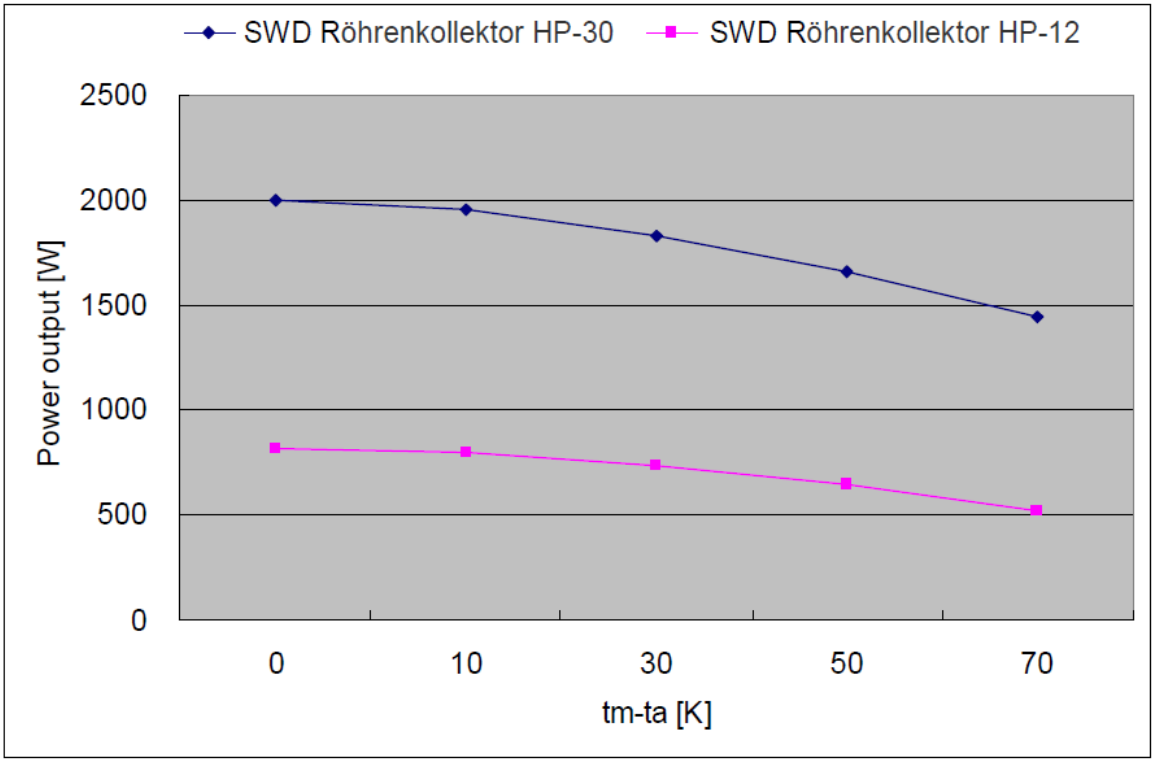

Figure 5.1 Power output per collector unit (for G=1000W/m^2)

Incident angle modifier

SWD Röhrenkollektor HP-12

IAM at ɵ	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
Transversal:	1.00		1.09		1.25		1.44			
Longitudinal:	1.00					0.90				

SWD Röhrenkollektor HP-30

IAM at ɵ	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
Transversal:	1.00		1.07		1.18		1.32			
Longitudinal:	1.00					0.91				

Pressure drop (SWD Röhrenkollektor HP-30**)**

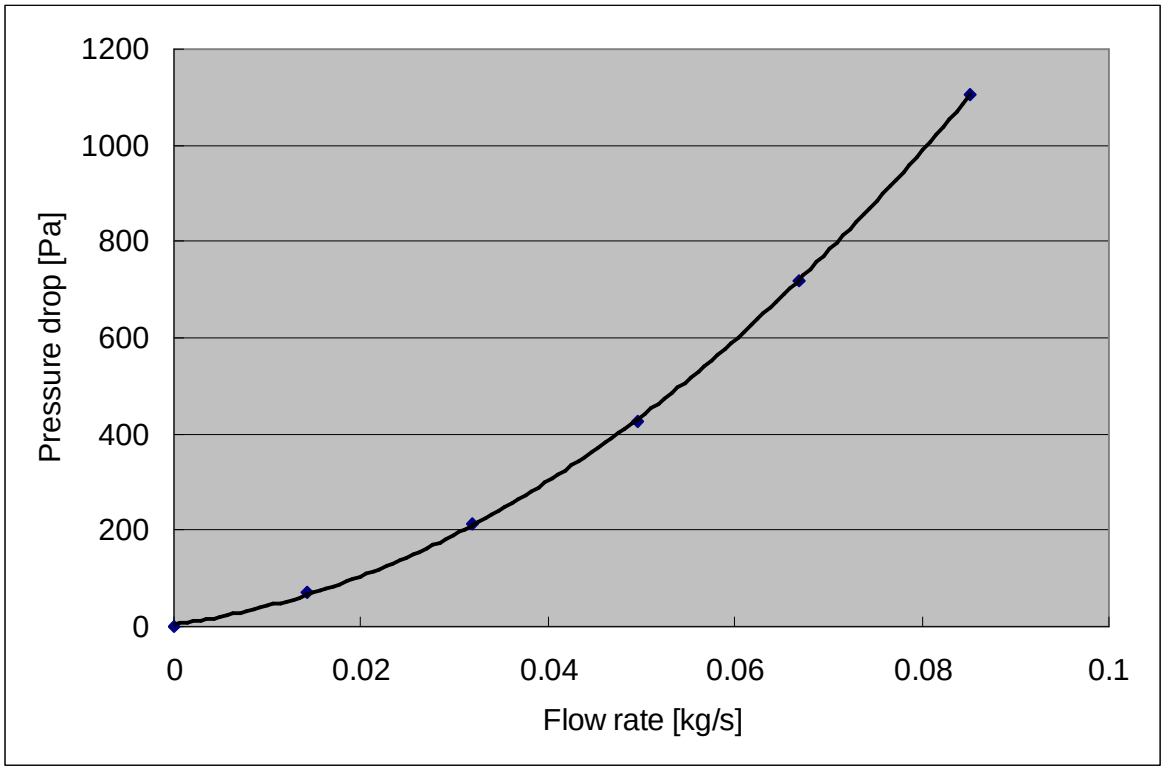

Figure 5.2 Pressure drop of the collector SWD Röhrenkollektor HP-30 (for 19.5 °C water)

Annex A

Measured data

G (W/m^2)	Gd' (W/m^2)	m ($kg/s.\ m^2$)	t_{in} (^0C)	t_e (^0C)	t_e-t_{in} (^0C)	t_m (^0C)	t_a (^0C)	$(t_m-t_a)/G$ (Km^2/W)	η
SWD Röhrenkollektor HP-12									
990	122	0.0197	22.69	31.24	8.55	26.97	24.61	0.00238	0.7123
1007	121	0.0199	22.68	31.24	8.56	26.96	24.57	0.00237	0.7064
999	120	0.0199	22.68	31.25	8.57	26.97	24.68	0.00229	0.7144
993	119	0.0197	22.71	31.32	8.61	27.02	24.13	0.00291	0.7148
1008	124	0.0199	41.13	49.42	8.28	45.27	26.81	0.01832	0.6856
1008	127	0.0200	41.13	49.38	8.25	45.26	27.20	0.01792	0.6834
1009	127	0.0200	41.14	49.38	8.25	45.26	27.14	0.01797	0.6828
1019	127	0.0200	41.13	49.37	8.24	45.25	27.83	0.01710	0.6753
919	187	0.0200	60.28	67.04	6.76	63.66	27.81	0.03903	0.6167
916	186	0.0200	60.32	67.11	6.79	63.72	27.89	0.03911	0.6214
907	194	0.0200	60.30	67.06	6.76	63.68	28.21	0.03912	0.6229
905	200	0.0200	60.29	67.03	6.74	63.66	28.15	0.03923	0.6220
849	195	0.0199	80.42	85.68	5.25	83.05	27.90	0.06498	0.5138
847	197	0.0199	80.51	85.72	5.22	83.11	27.65	0.06547	0.5112
859	198	0.0199	80.49	85.77	5.28	83.13	28.06	0.06409	0.5122
872	197	0.0200	80.43	85.75	5.32	83.09	27.95	0.06321	0.5086
SWD Röhrenkollektor HP-30									
1031	124	0.0200	15.49	24.21	8.72	19.85	16.72	0.00304	0.7061
1035	126	0.0201	15.50	24.14	8.64	19.82	16.09	0.00361	0.7027
1039	124	0.0200	15.53	24.17	8.64	19.85	16.68	0.00306	0.6968
1040	124	0.0200	15.49	24.15	8.66	19.82	16.26	0.00342	0.6957
1009	115	0.0200	36.85	44.84	7.98	40.85	19.37	0.02128	0.6613
1011	114	0.0201	36.88	44.80	7.92	40.84	18.65	0.02194	0.6580
1011	112	0.0201	36.85	44.82	7.96	40.83	18.68	0.02191	0.6607
1010	114	0.0200	36.84	44.75	7.91	40.79	17.98	0.02260	0.6564
975	110	0.0200	58.50	65.49	6.99	61.99	19.25	0.04383	0.6005
966	110	0.0200	58.51	65.53	7.03	62.02	19.90	0.04361	0.6095
959	110	0.0203	58.48	65.44	6.96	61.96	20.39	0.04333	0.6176
955	110	0.0201	58.49	65.44	6.95	61.96	19.80	0.04415	0.6107
909	114	0.0200	80.73	86.22	5.48	83.48	18.60	0.07138	0.5062
914	120	0.0200	80.73	86.26	5.54	83.50	18.71	0.07089	0.5084
899	126	0.0200	80.73	86.31	5.58	83.52	18.65	0.07214	0.5217
901	130	0.0200	80.75	86.19	5.44	83.47	18.33	0.07233	0.5074

Note: The diffuse irradiance has been modified based on the diffuse irradiance pyranometer shade ring.

Annex B

Terms and definitions

Symbol	Term	Unit
A	Area (aperture, gross or absorber)	m^2
η_0	Zero-loss collector efficiency	-
η_{0a}	Zero-loss collector efficiency based on aperture area	-
η_{0a}'	Zero-loss collector efficiency based on aperture area	-
Q	Useful power extracted from the collector	W
G	Solar irradiance	W/ m^2
t_m	Mean temperature of heat transfer fluid	^oC
t_a	Ambient air temperature	^oC
a_1	Heat transfer coefficient	W/ m^2/K
a_{1a}	Heat transfer coefficient based on aperture area	W/ m^2/K
a_{1a}'	Heat transfer coefficient based on aperture area	W/ m^2/K
a_2	Temperature depending heat transfer coefficient	W/ m^2/K^2
a_{2a}	Temperature depending heat transfer coefficient based on aperture area	W/ m^2/K^2
a_{2a}'	Temperature depending heat transfer coefficient based on aperture area	W/ m^2/K^2
m	Mass flow	kg/s
t_{in}	Collector inlet temperature	^oC
t_e	Collector outlet temperature	^oC

Measuring uncertainties

Thermal performance:	±3.1％
Irradiance:	±2.8％
Temperature water:	±0.05K
Temperature air:	±0.25K
Water flow:	±0.1％
Air speed:	±0.3m/s
Aperture:	±0.2%
Mass:	±2.9g

Annex C

Photos

Figure- C.1: Photo of internal pressure test

Figure- C.2: Photo of positive pressure test

REVISION SUMMARY

DATE	SECTION	SUMMARY	INTERTEK INITIALS	
			TECHNICIAN	REVIEWER