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DAP-PL-1491.00

Test Report

0886-09-2

(English Version of Test Report 0886-09-1)

on

Testing of glazed porcelain stoneware

for

Systemceram GmbH & Co. KG

Berggarten 1

56427 Siershahn

Germany

presented by

Forschungsinstitut für Anorganische Werkstoffe

- Glas/Keramik - GmbH

Heinrich-Meister-Straße 2

56203 Höhr-Grenzhausen

Germany

17 August 2012

1. Test Specimen

Glazed samples designated as „chemico-technical porcelain stoneware“.

2. Date of arrival of Test Specimen

01/09/2009

3. Test realization

07/09/ - 22/09/2009

4. Testing methods

- 4.1. Determination of 3-point bending strength according to FGK-AV-Trockenbiegefestigkeit.
- 4.2. Determination of cold compression strength.
- 4.3. Determination of water absorption, DIN EN ISO 10545-3.
- 4.4. Determination of resistance to surface abrasion, PEI-method, DIN EN ISO 10545-7.
- 4.5. Determination of resistance to thermal shock, DIN EN ISO 10545-9.
- 4.6. Determination of crazing resistance, DIN EN ISO 10545-11.
- 4.7. Determination of chemical resistance, DIN EN ISO 10545-13.
- 4.8. Determination of resistance of stains, DIN EN ISO 10545-14.
- 4.9. Determination of linear thermal expansion (DIN 51045).
- 4.10. Determination of scratch hardness according to Mohs, DIN EN 15771.

5. Sampling/sample preparation

Sampling and delivery to the FGK was under responsibility of the customer.

5.1. 3-point-bending strength

10 test bars, each measuring 20 mm x 20 mm x > 100 mm and glazed on one side, were delivered and then tested in the condition as received.

5.2. Cold compression strength

10 samples, each measuring 20 mm x 200 mm x 20 mm and glazed on one side, were delivered.

5.3. Water absorption

5 samples, each measuring 100 mm x 100 mm x 20 mm and glazed on one side, were delivered. The samples were then dried overnight at 110 °C before the test.

5.4. Surface abrasion

15 samples, each measuring 100 mm x 100 mm x 20 mm and glazed on one side, were delivered.

5.5. Thermal shock

5 samples, each measuring 100 mm x 100 mm x 20 mm and glazed on one side, were delivered.

5.6. Crazing resistance

5 samples, each measuring 100 mm x 100 mm x 20 mm and glazed on one side, were delivered.

5.7. Chemical resistance

25 samples, each measuring 100 mm x 100 mm x 20 mm and glazed on one side, were delivered.

5.8. Resistance to stains

5 samples, each measuring 100 mm x 100 mm x 20 mm and glazed on one side, were delivered.

5.9. Linear thermal expansion

A test piece were prepared by using a saw and sharpening with sandpaper.

5.10. Scratch hardness according to Mohs

5 samples, each measuring 100 mm x 100 mm x 20 mm and glazed on one side, were delivered.

6. Results

6.1. 3-point bending strength

9 samples were tested.

The 10th test bar was not used because of something fixed on the surface of its reverse side (logo or similar) that would have affected the test result.

Sample	Bending strength [MPa]
1	45.397
2	46.625
3	47.245
4	47.131
5	47.892
6	48.970
7	45.185
8	44.683
9	48.785
Mean	46.879
Standard deviation	1.460
Minimum	44.683
Maximum	48.970

Measuring parameter:

Support distance:	100 mm
Support diameter:	10 mm
Initial load:	50 N
Test speed:	2500 N/min
Fracture criterion:	75 % drop in force

6.2. Cold compression strength

10 samples were tested.

Sample	Compression strength [MPa]
1	192.289
2	126.853
3	121.498
4	149.742
5	96.724
6	138.389
7	150.863
8	104.275
9	113.393
10	133.086
Mean	132.711
Standard deviation	26.150
Minimum	96.724
Maximum	192.289

Measuring parameter:

Initial load: 750 N
 Test speed: 250 kN/min
 Fracture criterion: 75 % drop in force

6.3. Water absorption

10 specimens were tested.

Sample	Water absorption [Mass-%]	Bulk density [g/cm ³]	Open porosity [%]
1	4.1	2.19	9.04
2	4.4	2.19	9.58
3	4.7	2.18	10.33
4	4.1	2.18	8.99
5	4.7	2.18	10.24
6	4.5	2.19	9.93
7	5.6	2.17	12.15
8	4.9	2.18	10.72
9	5.0	2.18	10.96
10	3.8	2.18	8.37
Mean	4.6	2.18	10.03
Standard deviation	0.51	0.00	1.11

6.4. Surface abrasion

After 12,000 revolutions (stain test passed), the surface exposed to the erosive substance showed no visible changes in comparison with the untreated surface. The sample therewith met the requirements of DIN EN ISO 10545-7 for class 5.

6.5. Thermal shock

5 specimens were tested.

None of the samples showed any damage after ten temperature changes.

6.6. Crazing resistance

5 specimens were tested.

None of the samples showed any crazing after the end of the test.

6.7. Chemical resistance

5 specimens were tested per each test medium.

Test liquid	Class
Ammonium chloride solution, 100 g/l	GA
Sodium hypochlorite solution	GA
Hydrochloric acid, 3 vol.-%	GLA
Potassium hydroxide solution, 30 g/l	GLA
Citric acid solution, 100 g/l	GLA

Class A: No visible change.

Class B: Distinct change in appearance.

Class C: Partial or complete loss of the original surface.

6.8. Resistance to stains

5 specimens were tested per each test medium.

Test liquide	Class	Note
Chromium oxide in oil	5	Stains removed with hot water
Olive oil	5	Stains removed with hot water
Alcoholic iodine solution	5	Stains removed with hot water

6.9. Linear thermal expansion

The expansion curves were measured up to max. 1200 °C without dwell time, using a heating rate of 5 K/min in static air atmosphere. The curve progression, the magnitude (%) of expansion and shrinkage vs. temperature as well as the chosen coefficients of linear thermal expansion are shown in the appendices 0886-09-2-a01 and 0886-09-2-a02.

6.10. Scratch hardness according to Mohs

3 specimens were tested.

The glazed surface of all 3 specimens was scratched with topaz (Mohs' hardness 8).

Quartz (Mohs' hardness 7) left no damage on the glazed surface.

7. Testing uncertainties

7.1. 3-point bending strength

Measurement uncertainty of load cell:	1 %
Measurement uncertainty of micrometer gauge:	0.5 %

7.2. Cold compression strength

Measurement uncertainty of load cell:	1 %
Measurement uncertainty of micrometer gauge:	0.5 %

7.3. Water absorption

Measurement uncertainty of the used balance:	0.1 %
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7.4. Surface abrasion

Visual method, no further specifications possible.

7.5. Thermal shock

Temperature deviation of the used drying cabinet:	3 K
Temperature deviation of the cold water-bath used:	1 K

7.6. Crazing resistance

Measurement uncertainty of the used autoclave:	0.2 bar
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7.7. Chemical resistance

Visual method, no further specifications possible.

7.8. Resistance to stains

Visual method, no further specifications possible.

7.9. Linear thermal expansion

The measurement uncertainty of the dilatometer was checked using a sapphire and an alumina reference standard. The deviation lies at $dL/L_0 < +/- 2.7 \%$ within the temperature range from 200 °C to 1550 °C.

7.10. Scratch hardness according to Mohs

Visual method, no further specifications possible.

8. Epilogue

All investigations were done in view of the latest scientific-technical trends and to the best of one's knowledge and belief.

The testing results exclusively refer to the test specimen.

The report consists of 9 pages and an appendix of 3 pages.

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p.p. Dr. Markus Pohlmann-Lortz
(Laboratory manager)

Höhr-Grenzhausen, 17/08/2012 /pf

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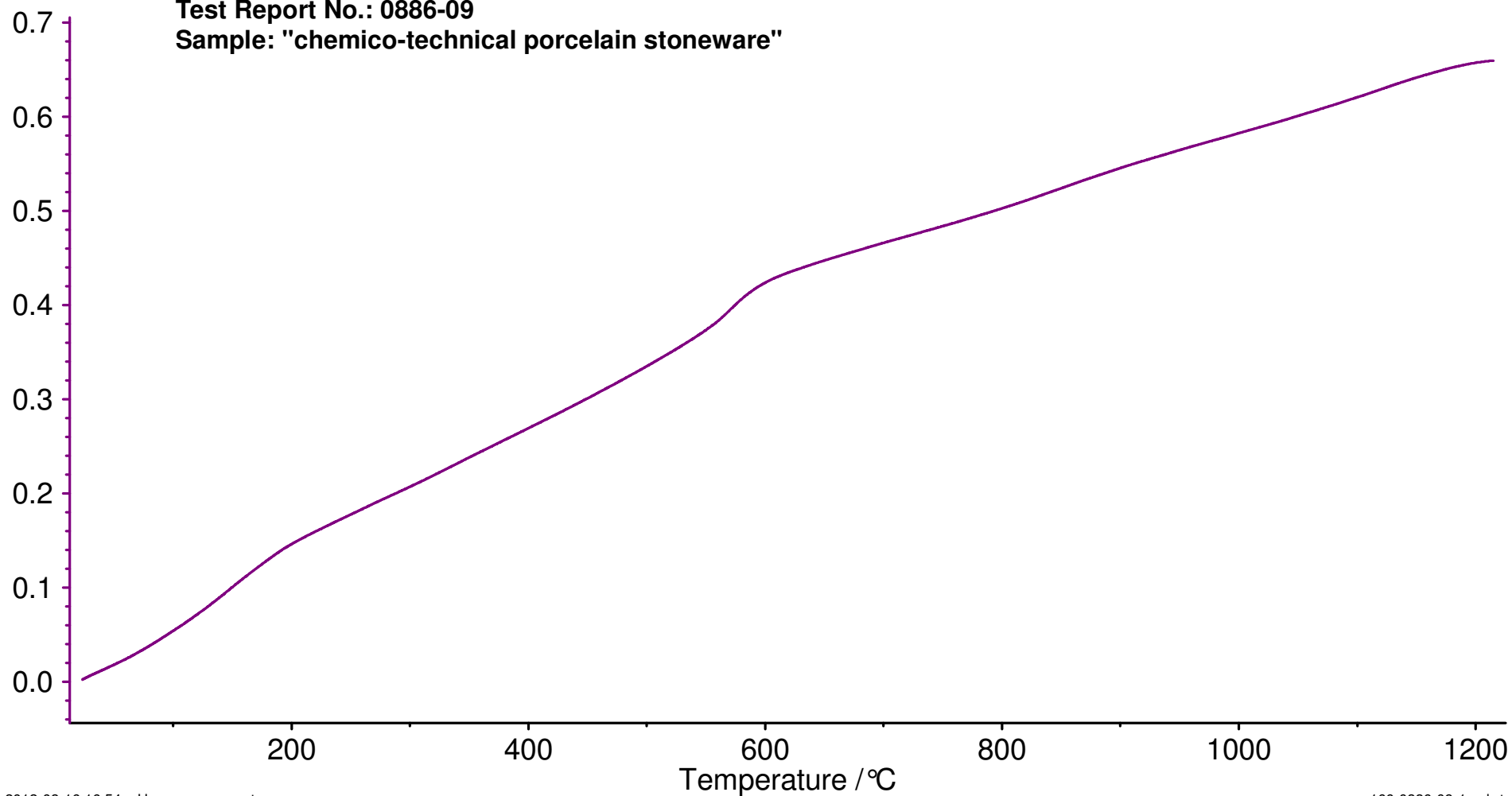
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dL/Lo /%

FGK
Test Report No.: 0886-09
Sample: "chemico-technical porcelain stoneware"



Main 2012-08-16 16:54 User: messgeraet

166-0886-09-1.ngb-taa

Instrument : NETZSCH DIL 4... **File :** C:\altdatenübernahme\ngbwin\ta\data5\Dil402C\2009\166-08... **Remark :** 166-0886-09 Sample: "chemico-technical porcelain stoneware" Correction:149-3005-09 with 5 K/...

Project :	Material : Keramik	Sample holder table : Al2o3ne.scl
Date/time : 09.09.2009 10:24:21	Atmosphere : statisch Luft/---	Sample holder material : Al2O3
Laboratory : Thermisches Labor	Temp. calib. file : Temperaturkalibrierung von 10-2008.tle	Calibration file : 149-3005-09.cle
Operator : Lazer	Range : 25.0/5.0(K/min)/1225.0	Std calib. table : Sapph_ne.scl
Identity : 166-0886-09 K.:149300509	Segments : 1/1	Std calib. material : Sapphire
Sample/load : 166 chem. tech. stoneware., 25.87 mm / 30 cN	Mode/type of meas. : Standard Expansion/sample with correction	Corr/m. range : 020/5000 µm

Instrument:	NETZSCH DIL 402 C	Material:	Keramik
Project:		Sh.Calib.:	Al2o3ne.scl
Filename:	166-0886-09.dle	Sh.Calib. Material:	Al2O3
Sample identity:	166-0886-09 K.:149300509	Correction:	149-3005-09.cle
Date/Time:	09.09.2009 10:24:21	Temp.Calib.:	Temperaturkalibrierung von 10-2008.tle
Laboratory:	Thermisches Labor	Std.Calib.:	Sapph_ne.scl
Operator:	Lazer	Std.Calib. Material:	Sapphire
Mode:	Standard Expansion	Gas / Gas Flow:	statisch Luft/---
Measurement Type:	sample with correction	Segments:	1/1
Sample name:	166 chem. tech. stoneware.	Range:	25.0/5.0(K/min)/1225.0
Sample Length:	25.87 mm	Corr/m. range:	020/5000

Remark: 166-0886-09 Sample: "chemico-technical porcelain stoneware" Correction:149-3005-09 with 5 K/min to 1200 °C.

Temperature °C	Time min	dL/Lo %	T. Alpha (25.0 °C) 1/K	Temperature °C	Time min	dL/Lo %	T. Alpha (25.0 °C) 1/K
25.0	3.9	0.00	6.1637E-06	345.0	74.1	0.24	7.2363E-06
30.0	7.5	0.01	6.1636E-06	350.0	75.0	0.24	7.2225E-06
35.0	10.0	0.01	5.9790E-06	355.0	75.9	0.24	7.2071E-06
40.0	12.0	0.01	5.8907E-06	360.0	76.8	0.24	7.1927E-06
45.0	13.8	0.02	5.8432E-06	365.0	77.7	0.25	7.1784E-06
50.0	15.5	0.02	5.8369E-06	370.0	78.6	0.25	7.1645E-06
55.0	17.0	0.02	5.8651E-06	375.0	79.5	0.25	7.1503E-06
60.0	18.4	0.02	5.9250E-06	380.0	80.4	0.26	7.1365E-06
65.0	19.8	0.03	6.0040E-06	385.0	81.3	0.26	7.1232E-06
70.0	21.1	0.03	6.0946E-06	390.0	82.2	0.26	7.1098E-06
75.0	22.4	0.03	6.1998E-06	395.0	83.1	0.27	7.0979E-06
80.0	23.6	0.04	6.3125E-06	400.0	84.0	0.27	7.0868E-06
85.0	24.8	0.04	6.4261E-06	405.0	84.9	0.27	7.0752E-06
90.0	26.0	0.05	6.5360E-06	410.0	85.8	0.28	7.0643E-06
95.0	27.1	0.05	6.6424E-06	415.0	86.7	0.28	7.0541E-06
100.0	28.2	0.05	6.7454E-06	420.0	87.6	0.28	7.0438E-06
105.0	29.3	0.06	6.8440E-06	425.0	88.6	0.28	7.0352E-06
110.0	30.4	0.06	6.9396E-06	430.0	89.5	0.29	7.0264E-06
115.0	31.5	0.07	7.0355E-06	435.0	90.4	0.29	7.0189E-06
120.0	32.5	0.07	7.1331E-06	440.0	91.3	0.29	7.0123E-06
125.0	33.5	0.08	7.2312E-06	445.0	92.2	0.30	7.0062E-06
130.0	34.5	0.08	7.3320E-06	450.0	93.1	0.30	7.0007E-06
135.0	35.5	0.09	7.4390E-06	455.0	94.0	0.30	6.9957E-06
140.0	36.5	0.09	7.5502E-06	460.0	94.9	0.31	6.9918E-06
145.0	37.5	0.10	7.6573E-06	465.0	95.9	0.31	6.9878E-06
150.0	38.5	0.10	7.7624E-06	470.0	96.8	0.31	6.9847E-06
155.0	39.5	0.11	7.8523E-06	475.0	97.7	0.32	6.9829E-06
160.0	40.4	0.11	7.9282E-06	480.0	98.6	0.32	6.9816E-06
165.0	41.4	0.12	7.9922E-06	485.0	99.5	0.32	6.9802E-06
170.0	42.3	0.12	8.0459E-06	490.0	100.4	0.33	6.9795E-06
175.0	43.3	0.12	8.0916E-06	495.0	101.3	0.33	6.9798E-06
180.0	44.2	0.13	8.1303E-06	500.0	102.3	0.34	6.9813E-06
185.0	45.1	0.13	8.1619E-06	505.0	103.2	0.34	6.9834E-06
190.0	46.1	0.14	8.1791E-06	510.0	104.1	0.34	6.9861E-06
195.0	47.0	0.14	8.1755E-06	515.0	105.0	0.35	6.9890E-06
200.0	47.9	0.15	8.1551E-06	520.0	105.9	0.35	6.9931E-06
205.0	48.8	0.15	8.1230E-06	525.0	106.9	0.35	6.9984E-06
210.0	49.7	0.15	8.0844E-06	530.0	107.8	0.36	7.0051E-06
215.0	50.6	0.16	8.0423E-06	535.0	108.7	0.36	7.0136E-06
220.0	51.6	0.16	7.9973E-06	540.0	109.6	0.37	7.0232E-06
225.0	52.5	0.16	7.9535E-06	545.0	110.6	0.37	7.0351E-06
230.0	53.4	0.17	7.9088E-06	550.0	111.5	0.37	7.0495E-06
235.0	54.3	0.17	7.8645E-06	555.0	112.4	0.38	7.0685E-06
240.0	55.2	0.17	7.8217E-06	560.0	113.3	0.38	7.0947E-06
245.0	56.1	0.17	7.7793E-06	565.0	114.3	0.39	7.1307E-06
250.0	57.0	0.18	7.7405E-06	570.0	115.2	0.39	7.1754E-06
255.0	57.9	0.18	7.7024E-06	575.0	116.1	0.40	7.2203E-06
260.0	58.8	0.18	7.6660E-06	580.0	117.0	0.41	7.2581E-06
265.0	59.7	0.19	7.6323E-06	585.0	118.0	0.41	7.2857E-06
270.0	60.6	0.19	7.5983E-06	590.0	118.9	0.42	7.3023E-06
275.0	61.5	0.19	7.5643E-06	595.0	119.8	0.42	7.3099E-06
280.0	62.4	0.20	7.5298E-06	600.0	120.7	0.42	7.3091E-06
285.0	63.3	0.20	7.4958E-06	605.0	121.7	0.43	7.3007E-06
290.0	64.2	0.20	7.4632E-06	610.0	122.6	0.43	7.2866E-06
295.0	65.1	0.20	7.4323E-06	615.0	123.5	0.43	7.2683E-06
300.0	66.0	0.21	7.4035E-06	620.0	124.5	0.43	7.2469E-06
305.0	66.9	0.21	7.3782E-06	625.0	125.4	0.44	7.2240E-06
310.0	67.8	0.21	7.3545E-06	630.0	126.3	0.44	7.2007E-06
315.0	68.7	0.22	7.3335E-06	635.0	127.3	0.44	7.1763E-06
320.0	69.6	0.22	7.3143E-06	640.0	128.2	0.44	7.1520E-06
325.0	70.5	0.22	7.2963E-06	645.0	129.1	0.45	7.1270E-06
330.0	71.4	0.23	7.2803E-06	650.0	130.1	0.45	7.1013E-06
335.0	72.3	0.23	7.2654E-06	655.0	131.0	0.45	7.0758E-06
340.0	73.2	0.23	7.2504E-06	660.0	132.0	0.45	7.0500E-06

Temperature °C	Time min	dL/Lo %	T. Alpha (25.0 °C) 1/K	Temperature °C	Time min	dL/Lo %	T. Alpha (25.0 °C) 1/K
665.0	132.9	0.45	7.0249E-06	940.0	185.6	0.56	6.0912E-06
670.0	133.8	0.46	6.9995E-06	945.0	186.6	0.56	6.0783E-06
675.0	134.8	0.46	6.9746E-06	950.0	187.6	0.56	6.0655E-06
680.0	135.7	0.46	6.9498E-06	955.0	188.6	0.57	6.0531E-06
685.0	136.7	0.46	6.9250E-06	960.0	189.5	0.57	6.0403E-06
690.0	137.6	0.46	6.9006E-06	965.0	190.5	0.57	6.0273E-06
695.0	138.5	0.46	6.8767E-06	970.0	191.5	0.57	6.0142E-06
700.0	139.5	0.47	6.8530E-06	975.0	192.5	0.57	6.0008E-06
705.0	140.4	0.47	6.8290E-06	980.0	193.5	0.58	5.9883E-06
710.0	141.4	0.47	6.8050E-06	985.0	194.4	0.58	5.9751E-06
715.0	142.3	0.47	6.7816E-06	990.0	195.4	0.58	5.9627E-06
720.0	143.3	0.47	6.7577E-06	995.0	196.4	0.58	5.9503E-06
725.0	144.2	0.47	6.7346E-06	1000.0	197.4	0.58	5.9386E-06
730.0	145.2	0.48	6.7120E-06	1005.0	198.4	0.58	5.9268E-06
735.0	146.1	0.48	6.6899E-06	1010.0	199.3	0.59	5.9151E-06
740.0	147.1	0.48	6.6676E-06	1015.0	200.3	0.59	5.9035E-06
745.0	148.0	0.48	6.6461E-06	1020.0	201.3	0.59	5.8918E-06
750.0	149.0	0.48	6.6249E-06	1025.0	202.3	0.59	5.8801E-06
755.0	149.9	0.49	6.6041E-06	1030.0	203.3	0.59	5.8690E-06
760.0	150.9	0.49	6.5840E-06	1035.0	204.3	0.60	5.8579E-06
765.0	151.8	0.49	6.5646E-06	1040.0	205.2	0.60	5.8474E-06
770.0	152.8	0.49	6.5454E-06	1045.0	206.2	0.60	5.8376E-06
775.0	153.7	0.49	6.5267E-06	1050.0	207.2	0.60	5.8278E-06
780.0	154.7	0.49	6.5083E-06	1055.0	208.2	0.60	5.8183E-06
785.0	155.7	0.50	6.4910E-06	1060.0	209.2	0.60	5.8091E-06
790.0	156.6	0.50	6.4738E-06	1065.0	210.2	0.61	5.7996E-06
795.0	157.6	0.50	6.4571E-06	1070.0	211.2	0.61	5.7906E-06
800.0	158.5	0.50	6.4410E-06	1075.0	212.2	0.61	5.7815E-06
805.0	159.5	0.50	6.4254E-06	1080.0	213.1	0.61	5.7727E-06
810.0	160.5	0.51	6.4111E-06	1085.0	214.1	0.61	5.7647E-06
815.0	161.4	0.51	6.3964E-06	1090.0	215.1	0.62	5.7569E-06
820.0	162.4	0.51	6.3824E-06	1095.0	216.1	0.62	5.7488E-06
825.0	163.3	0.51	6.3687E-06	1100.0	217.1	0.62	5.7408E-06
830.0	164.3	0.52	6.3560E-06	1105.0	218.1	0.62	5.7329E-06
835.0	165.3	0.52	6.3445E-06	1110.0	219.1	0.62	5.7260E-06
840.0	166.2	0.52	6.3329E-06	1115.0	220.1	0.63	5.7199E-06
845.0	167.2	0.52	6.3210E-06	1120.0	221.1	0.63	5.7135E-06
850.0	168.2	0.52	6.3093E-06	1125.0	222.1	0.63	5.7073E-06
855.0	169.1	0.53	6.2987E-06	1130.0	223.1	0.63	5.7005E-06
860.0	170.1	0.53	6.2873E-06	1135.0	224.0	0.64	5.6939E-06
865.0	171.1	0.53	6.2760E-06	1140.0	225.0	0.64	5.6864E-06
870.0	172.0	0.53	6.2649E-06	1145.0	226.0	0.64	5.6792E-06
875.0	173.0	0.54	6.2533E-06	1150.0	227.0	0.64	5.6715E-06
880.0	174.0	0.54	6.2413E-06	1155.0	228.0	0.64	5.6631E-06
885.0	174.9	0.54	6.2299E-06	1160.0	229.0	0.65	5.6539E-06
890.0	175.9	0.54	6.2181E-06	1165.0	230.0	0.65	5.6449E-06
895.0	176.9	0.54	6.2063E-06	1170.0	231.0	0.65	5.6355E-06
900.0	177.8	0.55	6.1942E-06	1175.0	232.0	0.65	5.6259E-06
905.0	178.8	0.55	6.1821E-06	1180.0	233.0	0.65	5.6153E-06
910.0	179.8	0.55	6.1698E-06	1185.0	234.0	0.65	5.6038E-06
915.0	180.8	0.55	6.1570E-06	1190.0	235.0	0.65	5.5912E-06
920.0	181.7	0.55	6.1439E-06	1195.0	236.0	0.66	5.5785E-06
925.0	182.7	0.56	6.1305E-06	1200.0	237.0	0.66	5.5641E-06
930.0	183.7	0.56	6.1174E-06	1205.0	238.0	0.66	5.5480E-06
935.0	184.7	0.56	6.1044E-06	1210.0	239.0	0.66	5.5309E-06