BEREK COMPENSATOR INSTRUCTIONS

Manufactured by:
NICHIKA CORPORATION
JAPAN

2001/8/10

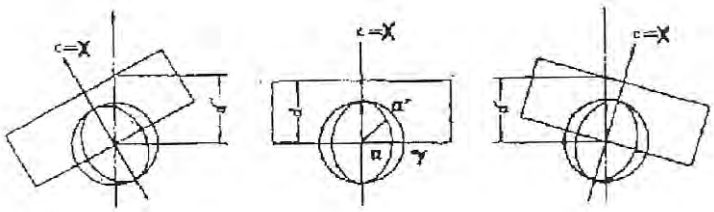
Berek Compensator

The Berek Compensator is a retardation measurement instrument, devised by Berek in 1913, is primarily used as an accessory for a polarizing microscope.

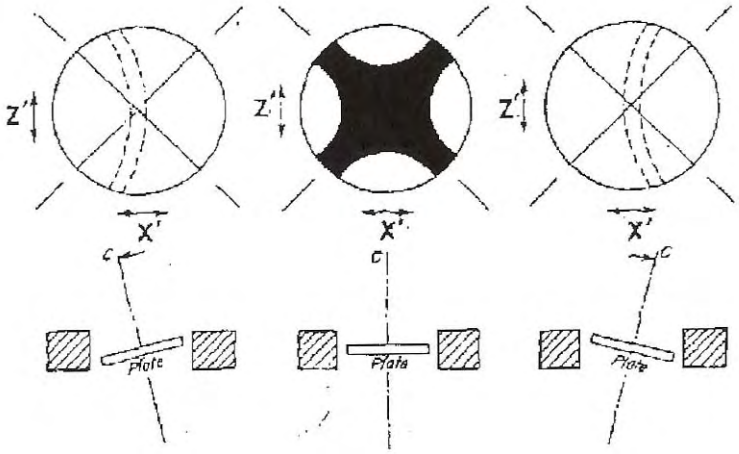
It consists of a uniaxial material with its extraordinary axis perpendicular to the plate. The plate is tilted both clockwise and counterclockwise relative to the horizontal position, and the tilt is indicated on the scale of the drum attached to the end of the rotation axis. Fig. 1, explains the principles of the Berek Compensator and shows the cross-sections of the calcite plate, represented by rectangles, and the refractive-index curved-surfaces corresponding to them. The calcite is a uniaxial negative anisotropic body with a great birefringence. Z', the vibration direction of ordinary light, has the maximum refractive index (), which is constant regardless of the traveling direction. X', the extraordinary light, greatly varies with the traveling direction. It reaches the minimu refractive index (α) when it is in the direction of 90 degrees to the optical axis (C in the figure). The index increases as the direction becomes off from 90 degrees, and equals in the direction of the optical axis. Therefore, as the inclination of the plate increases, the apparent thickness of the plate (d' and d" in the figure) also increases, in addition to the fact that the birefringence (B' = - ') increases, which results in accelerative increase of the retardation ®. Note that, as shown also on the figure, X' is always located in the NE direction of the viewfield on the Berek Compensator.

The Berek Compensator is designed to be nearly at the horizontal position when the drum scale points at 30. By inserting it in the horizontal position, into the microscope (crossed at Nicol), you should find a large dark cross in your viewfield. Its center represents the optical axis of the calcite (i.e., X axis), while the cross represents the vibration directions of the polarizer and analyzer. If you rotate the drum, for monochromatic light, the primary, secondary, and subsequent black stripes appear one after another; for white light, the interference color for R appear, as shown on Fig. 2.

Once a darkfield is obtained by putting an R-unknown specimen and the Berek Compensator together in the crossed Nicols position and rotating the drum, the R of the Compensator equals that of the specimen. The R of the Compensator is obtained on the scale of the drum. If the thickness of the specimen is known, the birefringence can be obtained; if the birefringence is known, the thickness can be found. It can also be used to determine X' and Z' of the specimen by applying the fact that the lengthwise direction of the metal part is always Z'.



F.1 (After Hamano, 1970)



F.2 (After Kerr, 1959)

Operation

(1) The microscope should be carefully adjusted, especially in the centration of the objectives and the condenser as well as the orientation of the transmission direction of the polarizer (East-West) and of the analyzer (North-South) and thereby the exact crossing of the transmission directions. Place the sample in the center of the viewfield.

(2) Rotate the stage into the extinction position and make sure of the relative position of the NS direction of the viewfield and the shape of the specimen.

(3) Rotate the stage through 45 degrees counterclockwise. Then the previous NS direction should have been transferred to NQ, and X' or Z' is now placed at NW.

(4) Identify which of X' and Z' is placed along NW. If it is Z', rotate the stage 90 degrees to bring X' to NW. This causes X' of the specimen to be aligned with Z' of the Berek Compensator inserted in the slot (This is called as the extinction position). Remember that the measurement of R must be made at the extinction position.

(5) X'/Z/ can be identified also with the Berek Compensator. Insert into the slot the Compensator that is at the horizontal position. At this stage no change is found in the interference color on the specimen. Rotate the drum softly and see the sequences of transitions in interference color. If the transition is toward lower levels (e.g., in the following order: red, orange, yellow, green, blue, purple, and red), they are in the extinction position to each other, the X' is in the NW direction. IF the transition is toward higher levels, i.e., in the reverse order of the above, rotate the stage 90 degrees because the Z' is in the NW direction.

Note: Also if monochromatic light is used for the measurement, it is easier to use white light for checking if they are in the extinction position.

(6) Turn the drum until the black band appears in the center of the viewfield, and read the indication on the scale. Make the same operations both clockwise and counterclockwise while always turning the drum in both directions. Obtain the average. If the readings for the clockwise and counterclockwise directions are taken as a and b, respectively, the inclination i is determined by

$$i = (a - b)/2$$

(7) To obtain the retardation R from i, it is convenient to use the Calibration Curb included in the instruction manual in Japanese supplied with the Compensator. To obtain it by calculation, use the following equation:

$$R = f(i)\, C$$

For convenience of logarithmic calculation, the following equation should actually be used instead of the above:

$$\text{Log } R - \log F(i) + \log C$$

Logf (i) is the value obtained by using the following equation:
$F(i) = \sin^2 i\,(1 + 0.2040 \sin^2 + 0.0627 \sin^4 i)$ (After C. Burri, 1950)

This value can be obtained from Table 1.

The log C values are listed, by light source type, in the Machine constant Table included in the instruction manual in Japanese supplied with the compensator.

R, representing the inverse logarithm of log R, can be obtained in nm using Table 2. Determine the position of the decimal point by the value obtained by always subtracting 10 from the resulting exponent.

[Example]

Reading of Compensator	a 45.3 b 13.9
	i = (45.3-13.9)/2 = 15.7
From Table 1	log f (15.7) = 8.871
From Machine Constant Table	log C = 4.004
	12.875

Obtain the inverse logarithm of 0.875, i.e. 7.50, from Table 2, and move the decimal point by 2 (columns), which is obtained by subtracting 10 from the exponent 12. Thus, the resultant is

$$R = 750 \text{ nm}$$

The value of R can be obtained also by multiplication. Use the following equation in this example:

$$R = 10000 f(i) \times C/100000$$

Obtain the value of 10000(i) from Table 3. for C/10000, use the value listed in the Machine Constant Table.

[Example]

Reading of Compensator	a 45.3 b 13.9
	i = (45.3-13.9)/2 = 15.7
From Table 1	10000 f (15.7) = 743
From Machine Constant Table	C/10000 = 1.009
	R = 743 x 1.009 – 750 (nm)

Table 1 log f (*i*)

/	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0		4.484	5.086	5.438	5.688	5.882	6.040	6.174	6.290	6.392
1	6.484	6.566	6.642	6.712	6.776	6.836	6.892	6.945	6.994	7.041
2	7.086	7.128	7.169	7.207	7.244	7.280	7.314	7.346	7.378	7.408
3	7.438	7.466	7.494	7.521	7.547	7.572	7.596	7.620	7.643	7.666
4	7.688	7.709	7.730	7.750	7.770	7.790	7.809	7.828	7.846	7.864
5	7.881	7.898	7.915	7.932	7.948	7.964	7.980	7.995	8.010	8.025
6	7.039	8.054	8.068	8.082	8.095	8.109	8.122	8.125	8.148	8.161
7	8.173	8.185	8.198	8.210	8.221	8.233	8.244	8.256	8.267	8.278
8	8.289	8.300	8.310	8.312	8.331	8.341	8.352	8.361	8.371	8.381
9	8.391	8.400	8.410	8.419	8.429	8.438	8.447	8.456	8.465	8.473
10	8.482	8.491	8.499	8.508	8.516	8.524	8.532	8.541	8.549	8.557
11	8.564	8.572	8.580	8.588	8.595	8.603	8.610	8.618	8.625	8.632
12	8.640	8.647	8.654	8.661	8.668	8.675	8.682	8.689	8.695	8.702
13	8.709	8.715	8.722	8.728	8.735	8.741	8.748	8.754	8.760	7.766
14	8.773	8.779	8.785	8.791	8.797	8.803	8.809	8.815	8.820	8.826
15	8.832	8.838	8.843	8.849	8.855	8.860	8.866	8.871	8.877	8.882
16	8.888	8.893	8.898	8.904	8.909	8.914	8.919	8.924	8.929	8.935
17	8.940	8.945	8.950	8.955	8.960	8.965	8.969	8.974	8.979	8.984
18	8.989	8.993	8.998	9.003	9.007	9.012	9.017	9.021	9.026	8.030
19	9.035	9.039	9.044	9.048	9.053	9.057	9.062	9.066	9.070	9.075
20	9.079	9.083	9.087	9.092	9.096	9.100	9.104	9.108	9.112	9.116
21	9.120	9.124	9.128	9.132	9.136	9.140	9.144	9.148	9.152	9.156
22	9.160	9.164	9.168	9.172	9.175	9.179	9.183	9.187	9.190	9.194
23	9.198	9.201	9.205	9.209	9.212	9.216	9.220	9.223	9.227	9.230
24	9.234	9.237	9.241	9.244	9.248	9.251	9.255	9.258	9.262	9.265
25	9.268	9.272	9.275	9.278	9.282	9.285	9.288	9.292	9.295	9.298
26	9.301	9.305	9.308	9.311	9.314	9.318	9.321	9.324	9.327	9.330
27	9.333	9.336	9.339	9.343	9.346	9.349	9.352	9.355	9.358	9.361
28	9.364	9.367	9.370	9.373	9.376	9.379	9.382	9.384	9.387	9.390
29	9.393	9.396	9.399	9.402	9.405	9.407	9.410	9.413	9.416	9.419
30	9.421	9.424	9.427	9.430	9.432	9.435	9.438	9.441	9.443	9.446
31	9.448	9.451	9.454	9.456	9.459	9.462	9.464	9.467	9.469	9.472

Table 2 No. 1

number	0	1	2	3	4	5	6	7	8	9
1.0	.0000	.0043	.0086	.0128	.0170	.0212	.0253	.0294	.0334	.0374
1.1	.0414	.0453	.0492	.0531	.0569	.0607	.0645	.0682	.0719	.0755
1.2	.0792	.0828	.0864	.0899	.0934	.0969	.1004	.1038	.1072	.1106
1.3	.1139	.1173	.1206	.1239	.1271	.1303	.1335	.1367	.1399	.1430
1.4	.1461	.1492	.1523	.1553	.1584	.1614	.1644	.1673	.1703	.1732
1.5	.1761	.1760	.1818	.1847	.1875	.1903	.1931	.1959	.1987	.2014
1.6	.2041	.2068	.2095	.2122	.2148	.2175	.2201	.2227	.2253	.2279
1.7	.2304	.2330	.2355	.2380	.2405	.2430	.2455	.2480	.2504	.2529
1.8	.2553	.2577	.2601	.2625	.2648	.2672	.2695	.2718	.2742	.2765
1.9	.2788	.2810	.2833	.2856	.2878	.2900	.2923	.2945	.2967	.2989
2.0	.3010	.3032	.3054	.3075	.3096	.3118	.3139	.3160	.3181	.3201
2.1	.3222	.3243	.3263	.3284	.3304	.3324	.3345	.3365	.3385	.3404
2.2	.3424	.3444	.3464	.3483	.3502	.3522	.3541	.3560	.3579	.3598
2.3	.3617	.3636	.3655	.3674	.3692	.3711	.3729	.3747	.3766	.3784
2.4	.3802	.3820	.3838	.3856	.3874	.3892	.3909	.3927	.3945	.3962
2.5	.3979	.3997	.4014	.4031	.4048	.4065	.4082	.4099	.4116	.4133
2.6	.4150	.4166	.4183	.4200	.4216	.4232	.4249	.4265	.4281	.4298
2.7	.4314	.4330	.4346	.4362	.4378	.4393	.4409	.4425	.4440	.4456
2.8	.4472	.4487	.4502	.4518	.4533	.4548	.4564	.4579	.4594	.4609
2.9	.4624	.4639	.4654	.4669	.4683	.4698	.4713	.4728	.4742	.4757
3.0	.4771	.4786	.4800	.4814	.4829	.4843	.4857	.4871	.4886	.4900
3.1	.4914	.4928	.4942	.4955	.4969	.4983	.4997	.5011	.5024	.5038
3.2	.5051	.5065	.5079	.5092	.5105	.5119	.5132	.5145	.5159	.5172
3.3	.5185	.5198	.5211	.5224	.5237	.5250	.5263	.5276	.5289	.5302
3.4	.5315	.5328	.5340	.5353	.5366	.5378	.5391	.5403	.5416	.5428
3.5	.5441	.5453	.5465	.5478	.5490	.5502	.5514	.5527	.5539	.5551
3.6	.5563	.5575	.5587	.5599	.5611	.5623	.5635	.5647	.5658	.5670
3.7	.5682	.5694	.5705	.5717	.5729	.5740	.5752	.5763	.5775	.5786
3.8	.5798	.5809	.5821	.5832	.5843	.5855	.5866	.5877	.5888	.5899
3.9	.5911	.5922	.5933	.5944	.5955	.5966	.5977	.5988	.5999	.6010
4.0	.6021	.6031	.6042	.6053	.6064	.6075	.6085	.6096	.6107	.6117
4.1	.6128	.6138	.6149	.6160	.6170	.6180	.6191	.6201	.6212	.6222
4.2	.6232	.6243	.6253	.6263	.6274	.6284	.6294	.6304	.6314	.6325
4.3	.6335	.6345	.6355	.6365	.6375	.6385	.6395	.6405	.6415	.6425
4.4	.6435	.6444	.6454	.6464	.6474	.6484	.6493	.6503	.6513	.6522
4.5	.6532	.6542	.6551	.6561	.6571	.6580	.6590	.6599	.6609	.6618
4.6	.6628	.6637	.6646	.6656	.6665	.6675	.6681	.6693	.6702	.6712
4.7	6.721	.6730	.6739	.6749	.6758	.6767	.6776	.6785	.6794	.6803

Table 2 No. 1

number	0	1	2	3	4	5	6	7	8	9
4.8	.6812	.6821	.6830	.6839	.6848	.6857	.6866	.6875	.6884	.6893
4.9	.6902	.6911	.620	.6928	.6937	.6946	.6955	.6964	.6972	.6981
5.0	.6990	.6998	.7007	.7016	.7024	.7033	.7024	.7050	.7059	.7067
5.1	.7076	.7084	.7093	.7101	.7110	.7118	.7126	.7125	.7143	.7152
5.2	.7160	.7168	.7177	.7185	.7193	.7202	.7210	.7218	.7226	.7235
5.3	.7243	.7251	.7259	.7267	.7275	.7284	.7292	.7300	.7308	.7316
5.4	.7324	.7332	.7340	.7348	.7356	.7364	.7372	.7380	.7388	.7396
5.5	.7404	.7412	.7419	.7427	.7435	.7443	.7451	.7459	.7466	.7474
5.6	.7482	.7490	.7497	.7505	.7513	.7520	.7528	.7536	.7543	.7551
5.7	.7559	.7566	.7574	.7582	.7589	.797	.7604	.7612	.7619	.7627
5.8	.7634	.7642	.7649	.7657	.7664	.7672	.7679	.7686	.7694	.7710
5.9	.7709	.7716	.7723	.7731	.7738	.7745	.7752	.7760	.7767	.7774
6.0	.7782	.7789	.7796	.7803	.7810	.7818	.7825	.7832	.7839	.7846
6.1	.7853	.7860	.7868	.7875	.7882	.7889	.7896	.7903	.7910	.7917
6.2	.7924	.7931	.7938	.7945	.7952	.7959	.7966	.7973	.7980	.7987
6.3	.7993	.8000	.8007	.8014	.8021	.8028	.8035	.8041	.8048	.8055
6.4	.8062	.8069	8075	.8082	.8089	.8096	.8102	.8109	.8116	.8122
6.5	.8129	.8136	.8142	.8149	.8156	.8162	.8169	.8176	.8182	.8189
6.6	.8195	.8202	.8209	.8215	.8222	.8228	.8235	.8241	.8248	.8254
6.7	.8261	.8267	.8274	.8280.	8287	.8293	.8299	.88306	.8312	.8319
6.8	.8325	.8331	.8338	.8344	.8351	.8357	.8363	.8370	.8376	.8382
6.9	.8338	.8395	.8401	.8407	.8414	.8420	.8426	.8432	.8439	.8445
7.0	.8451	.8457	.8463	.8470	.8476	.8482	.8488	.8494	.8500	.8506
7.1	.8513	.8519	.8525	.8531	.8537	.8543	.8549	.8555	.8561	.8567
7.2	.8573	.8579	.8585	.8591	.8597	.8603	.8609	.8615	.8621	.8627
7.3	.8633	.8639	.8645	.8651	.8657	.8663	.8669	.8675	.8681	.8686
7.4	.8692	.8698	.8704	.8710	.8716	.8722	.8728	.8733	.8739	.8745
7.5	.8571	.8756	.8762	.8768	.8774	.8779	.8785	.8791	.8797	.8802
7.6	.8808	.8814	.8820	.8825	.8831	.8837	.8842	.8848	.8854	.8859
7.7	.8865	.8871	.8876	.8882	.8887	.8893	.8899	.8904	.8910	.8915
7.8	.8921	.8927	.8932	.8938	.8943	.8949	.8954	.8960	.8965	.8971
7.9	.8976	.8982	.8987	.8993	.8998	.9004	.9009	.9015	.9020	.9025
8.0	.9031	.9036	.9042	.9047	.9053	.9058	.9063	.9069	.9074	.9079
8.1	.9085	.9090	.9096.	.9101	.9106	.9112	.9117	.9122	.9128	.9133
8.2	.9138	.9143	.9149	.9154	.9159	.9165	.9170	.9175	.9180	.9186
8.3	.9191	.9186	.9201	.9206	.9212	.9217	.9222	.9227	.9232	.9238

Table 2 No. 1

number	0	1	2	3	4	5	6	7	8	9
8.4	.9243	.9248	.9253	.9258	.9263	.9269	.9274	.9279	.9284	.9289
8.5	.9294	.9299	.9304	.9309	.9315	.9320	.9325	.9330	.9335	.9340
8.6	.9345	.9350	.9355	.9360	.9365	.9.70	.9375	.9380	.9385	.9390
8.7	.9395	.9400	.9405	.9410	.9415	.9420	.9425	.9430	.9435	.9440
8.8	.9445	.9450	.9455	.9460	.9465	.9469	.9474	.9479	.9484	.9489
8.9	.9494	.9499	.9504	.9509	.9513	.9518	.9523	.9528	.9533	.9538
9.0	.9542	.9547	.9552	.9557	.9562	.9566	.9571	.9576	.9581	.9586
9.1	.9590	.9595	.9600	.9605	.9609	.9614	.9619	.9624	.9628	.9633
9.2	.9638	.9643	.9647	.9652	.9657	.9661	.9666	.9671	.9675	.9680
9.3	.9685	.9689	.9694	.9699	.9703	.9708	.9713	.9717	.9722	.9727
9.4	.9731	.9736	.9741	.9745	.9750	.9754	.9759	.9763	.9768	.9773
9.5	.9777	.9782	.9786	.9791	.9795	.9800	.9805	.9809	.9814	.9818
9.6	.9823	.9827	.9832	.9836	.9841	.9845	.9850	.9854	.9859	.9863
9.7	.9868	.9872	.9877	.9881	.9886	.9890	.9894	.9899	.9903	.9908
9.8	.9912	.9917	.9921	.9926	.9930	.9934	.9939	.9943	.9948	.9952
9.9	.9956	.9961	.9965	.9969	.9974	.9978	.9983	.9987	.9991	.9996

Table 3 10000f (*i*)

/	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0	0.0	0.0	0.1	0.3	0.5	0.8	1.1	1.5	1.9	2.5
1	3.0	3.7	4.4	5.1	6.0	6.9	7.8	8.8	9.9	11.0
2	12.2	13.4	14.7	16.1	17.5	19.0	20.6	22.2	23.9	25.6
3	27.4	29.3	31.2	33.2	35.2	37.3	39.5	41.7	44.0	46.3
4	48.4	51.2	53.7	56.3	58.9	61.6	64.4	67.2	70.1	73.1
5	76.1	79.1	82.3	85.5	88.7	92.0	95.4	98.6	102.3	105.9
6	109.5	113.2	116.9	120.7	124.6	128.5	132.5	136.5	140.6	144.8
7	149.0	153.3	157.6	162.0	166.5	171.0	175.6	180.2	184.9	189.6
8	194.5	199.3	204.3	209.3	214.4	219.5	224.6	229.9	235.2	240.5
9	245.9	251.4	257.0	262.6	268.2	273.9	279.7	285.5	291.4	297.4
10	303.4	309.5	315.6	321.8	328.1	334.4	340.7	347.2	343.7	360.2
11	366.8	373.5	380.2	387.0	393.8	400.8	407.7	414.7	421.8	428.9
12	436.1	443.4	450.7	458.1	365.5	473.0	480.6	488.2	495.8	503.5
13	511	519	527	535	543	551	559	567	576	584
14	592	601	609	618	626	635	644	653	661	670
15	679	688	697	706	716	725	734	743	753	762
16	772	781	791	901	910	920	830	840	850	860
17	870	880	890	901	911	921	932	942	953	963
18	974	985	996	1006	1017	1028	1039	1050	1061	1072
19	1084	1095	1106	1118	1129	1141	1152	1164	1175	1187
20	1199	1211	1222	1234	1246	1258	1270	1283	1295	1307
21	1319	1332	1344	1357	1369	1382	1394	1407	1420	1432
22	1445	1458	1471	1484	1497	1510	1523	1537	1550	1563
23	1577	1590	1603	1617	1631	1644	1658	1672	1685	1699
24	1713	1727	1741	1755	1769	1783	1797	1813	1826	1840
25	1855	1869	1884	1898	1913	1927	1942	1957	1972	1987
26	2001	2016	2032	2046	2062	2077	2092	2107	2123	2138
27	2153	2169	2184	2200	2215	2231	2247	2262	2278	2294
28	2310	2326	2342	2358	2374	2390	2407	2422	2439	2455
29	2471	2488	2504	2521	2537	2554	2570	2587	2604	2620
30	2637	2654	2671	2688	2705	2722	2739	2756	2773	2791
31	2808	2825	2843	2860	2877	2895	2912	2930	2947	2965