TWP Timber and Wood Products Research Centre

PARTICLEBOARD PROPERTY PROFILES

R.H. THOMAS
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ROCKHAMPTON, AUSTRALIA 4700. TELEPHONE (079) 361177 TELEX AA49176

SUMMARY:

Results of testing to determine flexural stiffness, flexural strength and density through the thickness of three types of structural particleboard are given.

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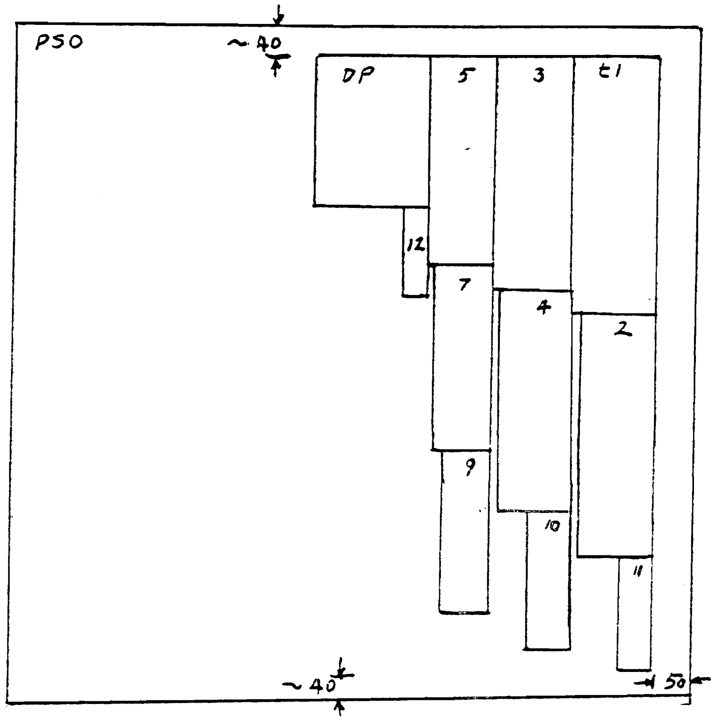
INTRODUCTION

Extensive work to characterise various structural particleboards (Ref. 1) did not product significantly high correlation coefficients between density and stiffness or strength, although such correlation is considered by the particleboard industry to be very good.

TWP Project T74/524 (APRI 6-05) was to investigate variation of flexural stiffness and strength with density through the thickness of three board types.

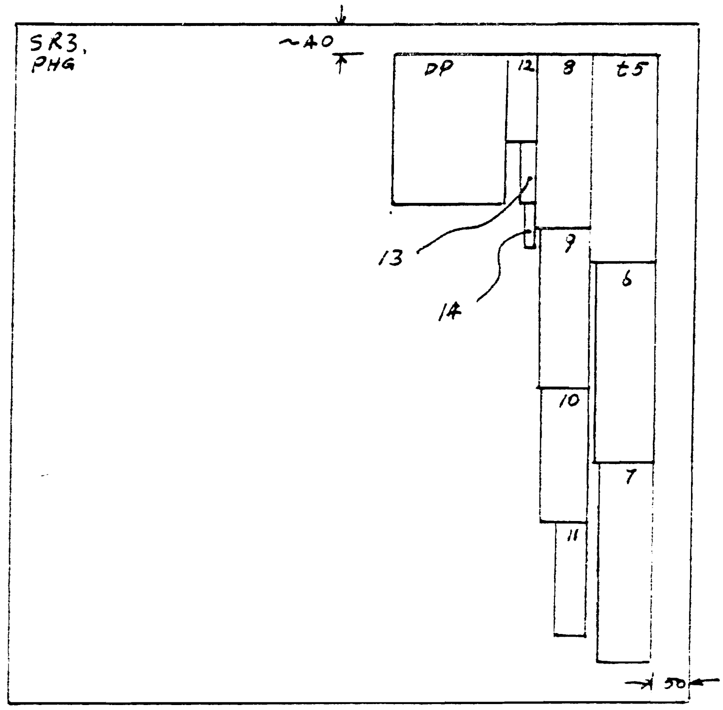
APPROACH

Flexure specimens were prepared after conditioning from three sheets each of three board types to the dimensions shown in Figure 1. Test span/thickness ratio was maintained constant at 16:1. Test span/width ratio for the coupons was constant at 3:1. One sample from each sheet - identified as DP in Figure 1 - was sent to G. Siempelkamp GmbH & Co in West Germany (by courtesy of CSR Pyneboard) for non-destructive density profile determination. Sheets from which coupons were prepared were previously identified (Ref. 1) as: SR3-15, -11, -2, PHG-4, -27, -2 and PSO-17, -31, -24 and represent respectively those sheets of each board type with high, average and low coupon transverse flexural properties.



PSO

SPEC'N. ID	t	L	W (mm)
DP	t	200	150
t1	t	340	107
2	19	324	101
3	18	308	96
4	17	292	91
5	16	276	85
7	14	244	75
9	12	212	64
10	10	180	53
11	8	148	43
12	6	116	32



SR3, PHG

SPEC'N ID	t	L	W (mm)
DP	t	200	150
t5	t	276	85
6	15	260	90
7	14	244	75
8	13	228	69
9	12	212	64
10	10	180	53
11	8	148	43
12	6	116	32
13	4	84	21
14	2	52	11

eg PSO-17-PPt1
(T)SR3-14-PP14
PHG-2-DP

DP & PP COUPON CUTTING PLAN MARCH 1986

DENSITY PROFILE PROPERTY PROFILE

Figure 1

RESULTS

After coupons had been machined to thickness by removal of equal depth of material from both sides, and following further conditioning, densities and flexural properties were measured with results shown in Figures 5, 6 and 7. Coefficients of correlation between density and MOR, MOE are given in Figure 2.

ID	DENSITY - MOR	DENSITY - MOE	MOR - MOE
SR3-15	0.99	0.99	0.95
-11	0.98	0.99	0.99
-2	0.84	0.99	0.99
PHG-4	0.83	0.82	0.92
-27	0.99	0.99	0.99
-2	0.91	0.95	0.97
PSO-17	0.94	0.93	0.97
-31	0.92	0.96	0.88
-24	0.91	0.91	0.98

Figure 2
Correlation Coefficients, r, of Measured Coupon Properties

Note that values in Figure 2 are the correlation coefficient, r, whereas values in Ref. 1 are r^2.

By repeatedly using the expression derived from Bodig, Ref. 2 and shown in Figure 4, the MOE of the various layers through the thickness of the sheets was found - Figures 8, 9 and 10. Corresponding MOR's may be calculated from the layer MOE's by using the method of transformed sections. As up to 10 pairs of terms are required for each of the more than 80 calculations needed, and as it is apparent that variations between coupons from the same sheet are of the same order of magnitude as variations between layers, the calculations were not performed. Instead it has been assumed that the ultimate strain of a layer is given by the ultimate strain of the remainder of the coupon lying immediately beneath it.

Then, starting from the innermost layer (core) and working outwards, the MOR of successive layers may be calculated using:

$$\text{MOR outer layer} = \frac{\text{MOR inner coupon}}{\text{E inner coupon}} \times \text{E outer layer.}$$

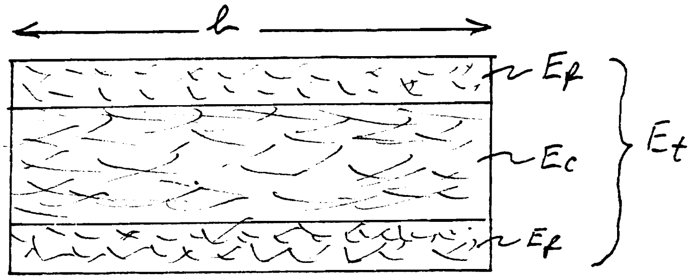
MOR values thus calculated are given in Figures 8, 9 and 10, with densities taken from the West German information (see Appendix).

Note that the inner coupon values, not the inner layer values are used. Using inner layer values would assume that the strain at failure is constant for all layers which may not be so.

Resulting correlations between layer MOE's, MOR's and layer densities taken from the German data are given in Figure 3.

ID	DENSITY - MOR	DENSITY - MOE	MOR - MOE
SR3-15	0.95	0.96	0.99
-11	0.85	0.89	0.99
-2	0.79	0.82	0.99
PHG-4	0.72	0.84	0.95
-27	0.91	0.93	0.99
-2	0.83	0.82	0.99
PSO-17	0.27	0.30	0.99
-31	0.83	0.87	0.99
-24	0.73	0.66	0.98

Figure 3
Correlation Coefficients, r, of Calculated Layer Properties



$$I'_t = b\left(\frac{t_f^3}{6} + \frac{t_f(t_c + t_f)^2}{2} + \frac{E_c t_c^3}{12E_f}\right) \quad \text{- Ref. 2}$$

where I'_t is the moment of inertia of the whole (transformed) cross section assuming that the whole section has the same E as the face (E_f).

then $E_f = \dfrac{P_t L_t^3}{48 I'_t \delta t}$, but $E_t = \dfrac{P_t L_t^3}{48 I'_t \delta t}$

where $I_t = \dfrac{b(t_c + 2t_f)^3}{12}$

so $E_f I'_t = E_t I_t$ and both E_t and I_t known

i.e. $E_f\left[\dfrac{t_f^3}{6} + \dfrac{t_f(t_c + t_f)^2}{2}\right] + \dfrac{E_c t_c}{12} = \dfrac{E_t I_t}{b}$

$$\therefore E_f = E_t\left[\frac{(t_c + 2t_f)^3}{12} - \frac{E_c t_c^3}{12}\right] \Bigg/ \left[\frac{t_f^3}{6} + \frac{t_f(t_c + t_f)^2}{2}\right]$$

$$= \frac{E_t(t_c + 2t_f)^3 - E_c t_c^3}{2t_f^3 + 6t_f(t_c + t_f)^2}$$

Figure 4
Expression to find Layer MOE

ID	t(mm)	DENSITY (kg/m^3)	MOR (MPa)	MOE (MPa)
SR3-15-t5	16.0	768	31.3	4400
-6	15.0	742	31.0	4080
-7	14.1	713	27.3	3710
-8	13.0	692	22.0	3270
-9	12.1	661	19.9	2700
-10	10.2	631	15.0	2230
-11	7.9	588	12.0	1850
-12	6.2	575	10.2	1230
-13	4.0	546	9.4	1070
-14	2.0	560	6.8	940
SR3-11-t5	16.4	735	27.0	3490
-6	15.0	687	19.3	2840
-7	14.1	673	19.9	2640
-8	13.0	671	18.5	2550
-9	12.1	624	15.4	1920
-10	10.1	592	11.1	1550
-11	8.1	582	10.6	1330
-12	6.1	583	7.6	1060
-13	4.1	546	8.4	860
-14	2.0	535	4.1	370
SR3-2-t5	16.3	668	23.4	3070
-6	15.0	637	17.7	2370
-7	14.1	638	18.2	2450
-8	13.0	619	16.3	2250
-9	12.1	592	15.5	1940
-10	10.1	569	11.2	1470
-11	8.1	546	10.4	1280
-12	6.1	533	7.7	1020
-13	4.1	517	7.9	740
-14	2.0	505	7.1	790

Figure 5
Coupon Densities and Flexural Properties for SR3

ID	t(mm)	DENSITY (kg/m^3)	MOR (MPa)	MOE (MPa)
PHG-4-t5	15.8	803	26.5	3590
-6	15.0	687	21.4	3180
-7	14.1	736	17.6	2800
-8	12.9	753	16.0	2610
-9	12.1	709	16.9	2200
-10	10.2	693	15.2	2030
-11	8.1	682	15.1	2180
-12	6.1	694	16.1	1870
-13	4.0	632	12.1	1120
-14	2.0	594	9.8	1440
PHG-27-t5	15.8	783	24.6	3470
-6	15.0	752	20.0	2970
-7	13.9	743	18.1	2650
-8	13.0	706	16.8	2310
-9	12.1	700	16.2	2030
-10	10.1	670	13.7	1720
-11	8.1	671	13.2	1780
-12	6.1	657	12.7	1440
-13	4.0	603	9.0	1020
-14	2.0	575	7.0	610
PHG-2-t5	16.0	736	22.0	3180
-6	15.0	758	15.6	2560
-7	14.1	671	13.3	1990
-8	13.0	692	14.4	2030
-9	12.2	630	12.3	1900
-10	10.1	618	9.9	1420
-11	8.1	598	9.5	1330
-12	6.1	639	13.3	1510
-13	4.0	582	7.2	1040
-14	2.0	535	4.0	580

Figure 6
Coupon Densities and Flexural Properties for PHG

ID	t(mm)	DENSITY (kg/m^3)	MOR (MPa)	MOE (MPa)
PSO-17-t1	20.0	709	23.7	2880
-2	19.0	749	24.5	3310
-3	18.0	710	21.8	2950
-4	17.0	728	20.3	3070
-5	16.0	636	16.0	2420
-7	14.1	666	16.0	2290
-9	12.1	679	16.3	2150
-10	10.0	663	13.5	1810
-11	8.1	616	11.4	1460
-12	6.0	571	6.9	1180
PSO-31-t1	20.1	715	19.2	2580
-2	19.0	738	21.0	2910
-3	18.0	738	22.1	3090
-4	17.0	726	20.0	2910
-5	16.0	681	19.7	2640
-7	14.1	692	16.5	2250
-9	12.1	687	13.7	2150
-10	10.0	656	11.9	1760
-11	8.1	626	11.3	1600
-12	6.1	597	9.8	1180
PSO-24-t1	19.3	569	10.9	1900
-2	19.0	564	9.4	1790
-3	18.0	578	13.2	1820
-4	17.0	545	8.4	1490
-5	16.0	510	8.4	1320
-7	14.0	521	6.6	1090
-9	12.1	522	6.3	830
-10	10.1	527	8.5	920
-11	8.1	478	5.1	650
-12	6.1	477	4.3	720

Figure 7
Coupon Densities and Flexural Properties for PSO

ID	nominal t(mm)	DENSITY (kg/m^3) from Coupon	Germany	MOR (MPA)	MOE (MPA)
SR3-15-t5	0.5	896	1075	44.8	5900
-6		880	1075	43.3	5890
-7		793	1055	35.7	5310
-8		818	985	41.6	5640
-9		704	920	22.9	3400
-10	1.0	677	835	16.6	2560
-11		599	730	20.2	2430
-12		588	665	11.3	1290
-13		543	600	7.9	1090
-14	core = 2.0	560	580	6.8	940
SR3-11-t5	0.5	941	1075	38.1	5610
-6		754	1070	28.8	3820
-7		681	1037	21.6	2970
-8		862	975	41.5	5170
-9		669	875	17.4	2430
-10	1.0	604	775	14.2	1780
-11		581	690	11.0	1530
-12		600	610	11.2	1150
-13		548	550	10.2	924
-14	core = 2.0	535	550	4.1	370
SR3-2-t5	0.5	805	1065	41.4	5540
-6		632	1050	14.7	1980
-7		711	1060	23.0	3170
-8		729	975	28.3	3540
-9		625	880	19.7	2590
-10	1.0	596	745	13.6	1670
-11		556	660	11.1	1470
-12		541	605	12.2	1140
-13		519	575	6.6	733
-14	core = 2.0	505	550	7.1	790

Figure 8
Layer Densities and Flexural Properties for SR3

ID	nominal t(mm)	DENSITY (kg/m^3) from Coupon	DENSITY (kg/m^3) from Germany	MOR (MPA)	MOE (MPA)
PHG-4-t5	0.5	1419	1050	40.5	6020
-6	|	453	1050	31.7	5040
-7	|	673	1035	21.0	3420
-8	|	939	950	35.0	4550
-9	|	732	905	18.3	2450
-10	1.0	705	885	13.0	1880
-11	|	673	735	20.8	2410
-12	|	603	710	23.4	2170
-13	|	633	663	7.3	1070
-14	core = 2.0	594	650	9.8	1440
PHG-27-t5	0.5	948	1025	43.3	6430
-6	|	792	1025	28.8	4220
-7	|	895	985	30.4	4180
-8	|	730	920	27.8	3480
-9	|	743	845	18.8	2360
-10	1.0	669	750	12.3	1660
-11	|	682	710	17.9	2030
-12	|	682	670	14.2	1610
-13	|	608	650	12.4	1080
-14	core = 2.0	575	650	7.0	610
PHG-2-t5	0.5	628	1080	37.1	6080
-6	|	1170	1080	35.8	5350
-7	|	591	1040	13.1	1850
-8	|	955	955	17.2	2650
-9	|	647	870	17.6	2530
-10	1.0	526	760	10.9	1520
-11	|	744	690	10.6	1200
-12	|	665	675	11.8	1700
-13	|	591	670	7.7	1110
-14	core = 2.0	535	645	4.0	580

Figure 9
Layer Densities and Flexural Properties for PHG

ID	nominal t(mm)	DENSITY (kg/m³) from Coupon	DENSITY (kg/m³) from Germany	MOR (MPA)	MOE (MPA)
PSO-17-t1	0.5	474	600	21.8	2950
-2	|	981	675	39.5	5350
-3	|	609	875	15.3	2310
-4	|	1180	925	41.9	6330
-5	|	570	940	18.9	2700
-7	1.0	643	875	19.2	2530
-9	|	701	805	19.3	2590
-10	|	718	720	17.3	2210
-11	|	650	660	9.7	1650
-12	core = 6.0	571	625	6.9	1180
PSO-31-t1	0.5	584	650	5.6	780
-2	|	738	700	13.6	1900
-3	|	805	830	27.8	4050
-4	|	947	875	31.8	4260
-5	|	657	880	25.6	3490
-7	1.0	701	870	15.4	2420
-9	|	730	800	18.0	2660
-10	|	691	750	12.2	1720
-11	|	649	740	15.9	1910
-12	core = 6.0	597	685	9.8	1180
PSO-24-t1	0.5	608	700	22.0	4190
-2	|	481	775	11.8	1620
-3	|	763	825	20.2	3580
-4	|	717	835	14.9	2340
-5	|	486	800	10.8	1790
-7	1.0	519	685	11.8	1560
-9	|	515	590	6.5	705
-10	|	583	550	9.5	1210
-11	|	479	510	3.6	598
-12	core = 6.0	477	500	4.3	720

Figure 10
Layer Densities and Flexural Properties for PSO

DISCUSSION

In retrospect it may have been better to reduce coupon thicknesses in 2 mm steps as property variation between adjacent coupons - indicated by density - was sometimes greater than property variation through the corresponding 0.5 mm of thickness.

Considering particle size it is difficult to have confidence in flexure properties reported for the very small specimens. Specimens numbered -14 are approximately the size of the side of a matchbox.

SR3 exhibited least density variation across the sheet. Density values for that type generally decreased steadily through the sheet thickness both when determined by coupons and by Siempelkamp in Germany. PSO density values tend to indicate variation across the sheet as well as through the thickness. Although the Siemplekamp density plots are reasonably smooth considering chip size the coupon densities do not vary in the same way.

The German density profile curve for PSO-31 shows a distinct 'shoulder' on one side of the sheet centreline, indicating that density varies asymmetrically about the sheet centreline. Such variation could not be apparent from coupon density data as material was milled symmetrically from both faces in coupon preparation.

Correlation between coupon density and MOR/MOE ranges from extremely good to fair (see Figure 2). Taken with correlation data in Ref. 1, the present results tend to indicate that density/flexural properties correlation is usually very good within a sheet, not very good for sheets sampled over a long period, and poor for different types of board. It can be inferred that density/flexural properties correlation for sheets from the same batch should be very good, but that once plant parameters are changed, the relation between density and flexural properties, the regression lines, may also change. Such an influence explains the differences between correlation data reported herein, that reported in Ref. 1, and the industry view mentioned in the Introduction.

Correlation between MOR and MOE of coupons is very good (Figure 2) as is that of the layers (Figure 3). Since layer MOR's have been partially derived from layer MOE's however, their correlation, although very good, may not be significant.

There are differences between densities determined in Germany and calculated layer densities. As no information on condition of samples tested in Germany is available and as layer densities derived from coupon densities are approximate due to across-sheet variations, no conclusions on the reason for the differences can be reached.

CONCLUSIONS

1. MOR and MOE correlations with density are significantly high for an individual sheet of particleboard.

2. Density profiles, and hence flexural property profiles, are of the form shown in the Appendix.

3. Non-symmetrical density variations through a sheet are easily seen when the Siemplekamp technique is used.

REFERENCES

1. Hanley, D.P., Thomas R.H., Leicester, R.H., "Structural Particleboard Characterisation and Stress Grading", TWP Report 126, 1985.

2. Bodig, J., Jayne, B., "Mechanics of Wood and Wood Composites", Van Nostrand Reinhold, 1982.

APPENDIX

Data from G. Siempelkamp GmbH & Co., Krefeld, W. Germany.

Spanplattenmuster der Fa. Pyneboard

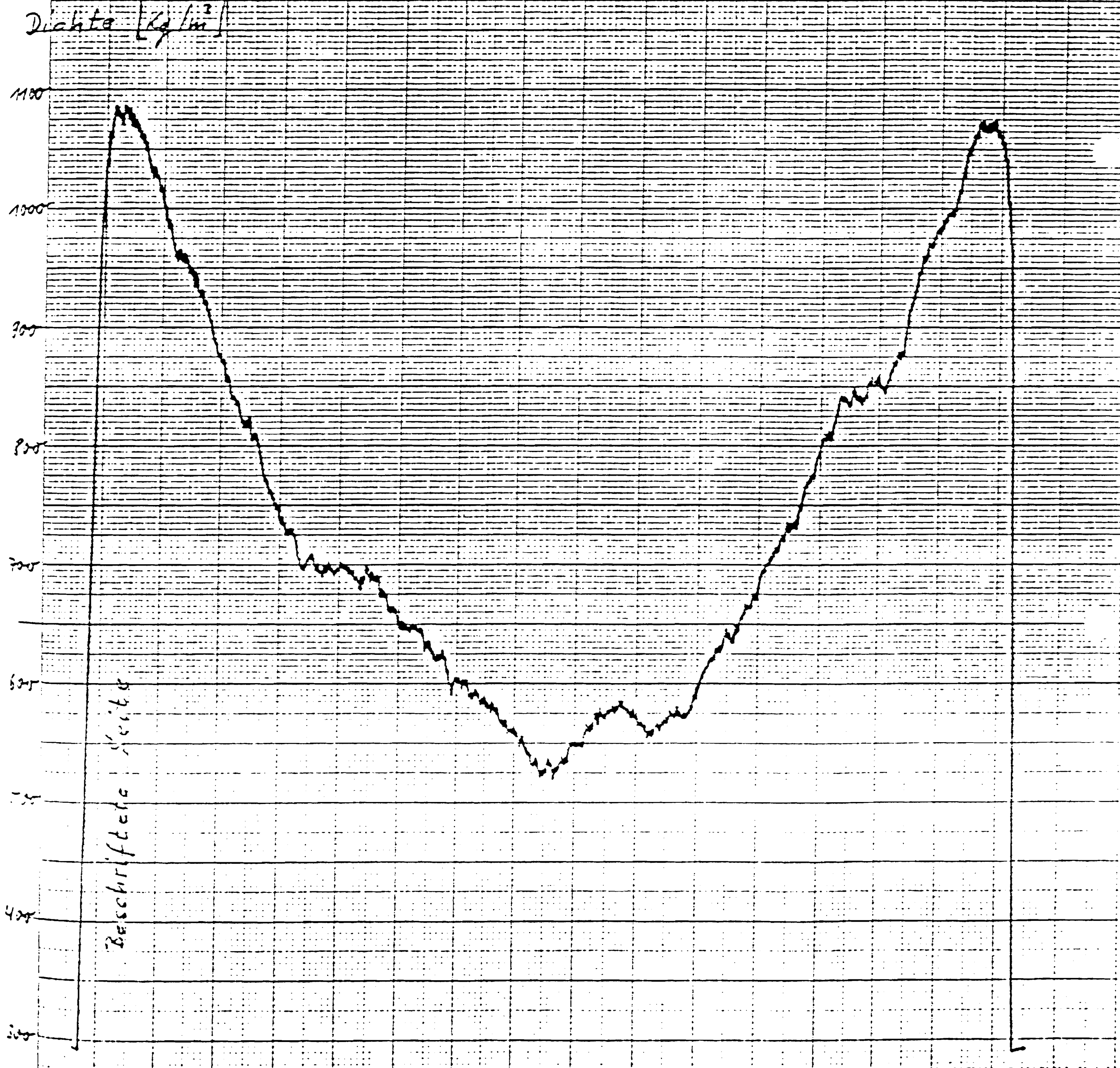
Platten von verschiedenen

Australischen Firmen

Pl. Bezeichnung. DP 5R3 - 15 - B

Pl. Dicke 15,75 mm

Pl. Dichte 750 kg/m^3



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Koch

Spanplattenmuster der Fa. Pyneboard

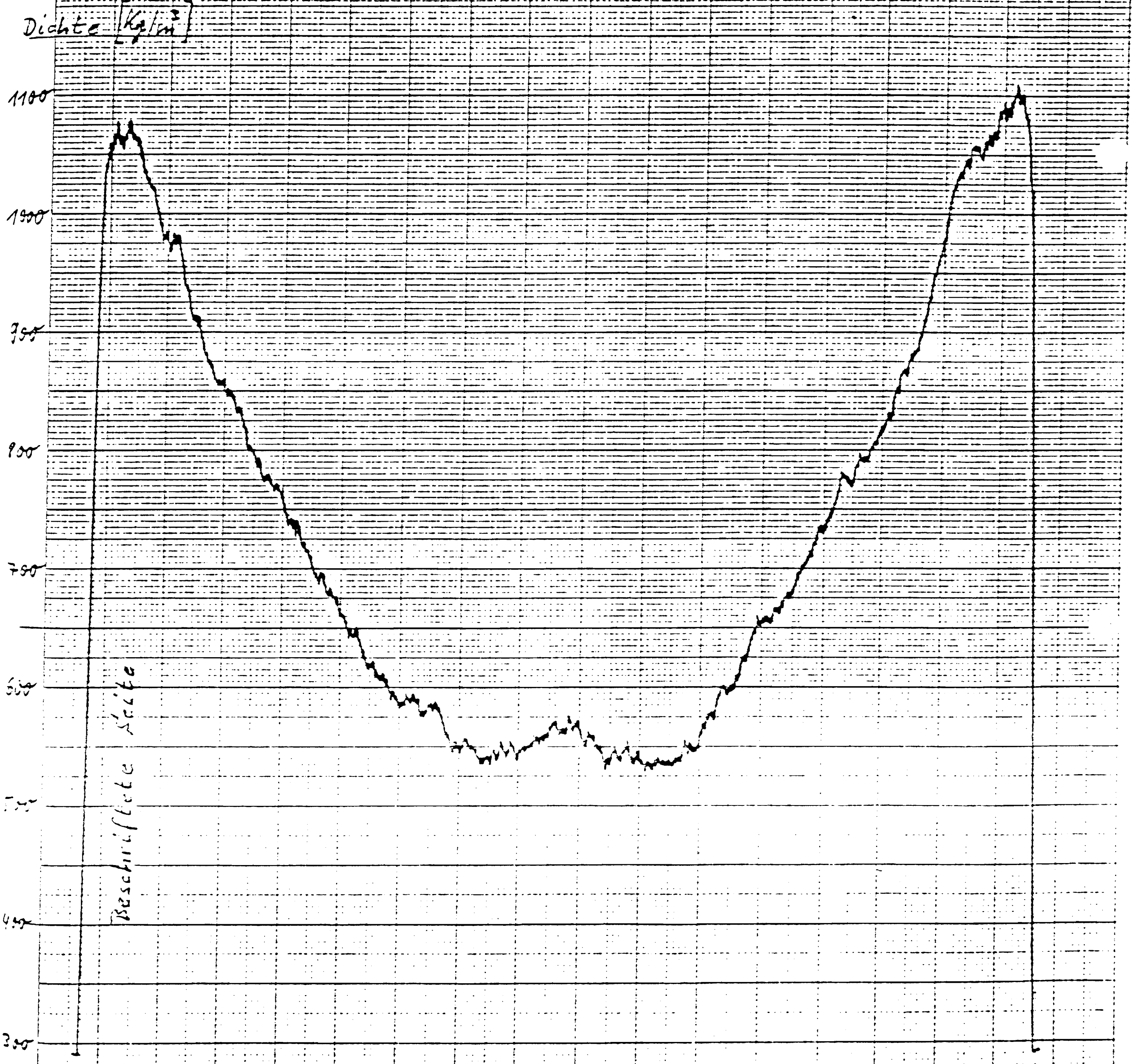
Platten von verschiedenen

Australischen Firmen

Pl. Bezeichnung DP SR3 - II

Pl. Dicke 16,1 mm

Pl. Dichte 742 Kg/m³



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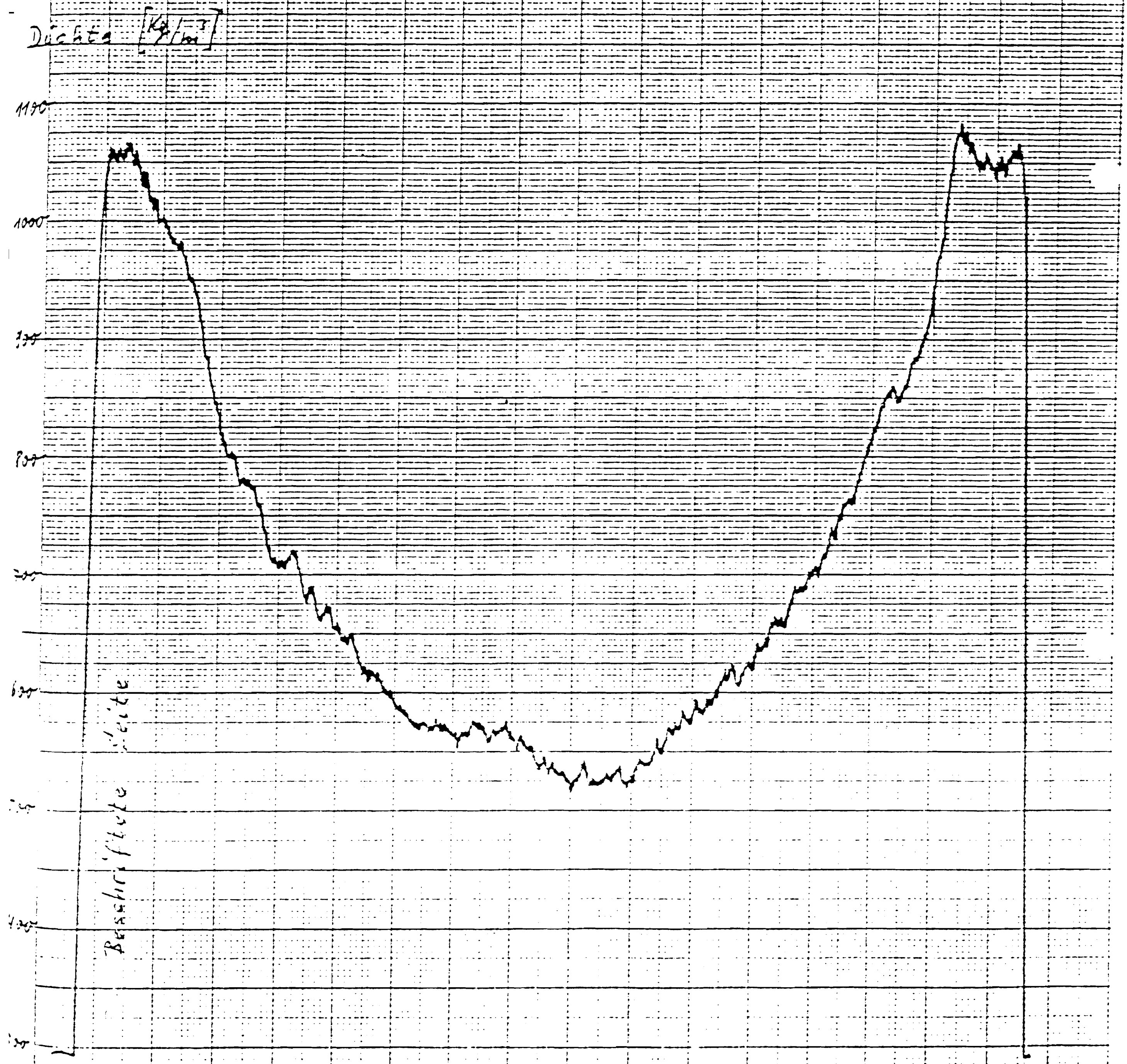
Spanplattenmuster der Fa. Pyneboard

Platten von verschiedenen

Australischen Firmen

Pl. Bezeichnung	DP SR3 - 2
Pl. Dicke	16,05 mm
Pl. Dichte	720 Kg/m³



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Spanplattenmuster der Fa. Pyneboard

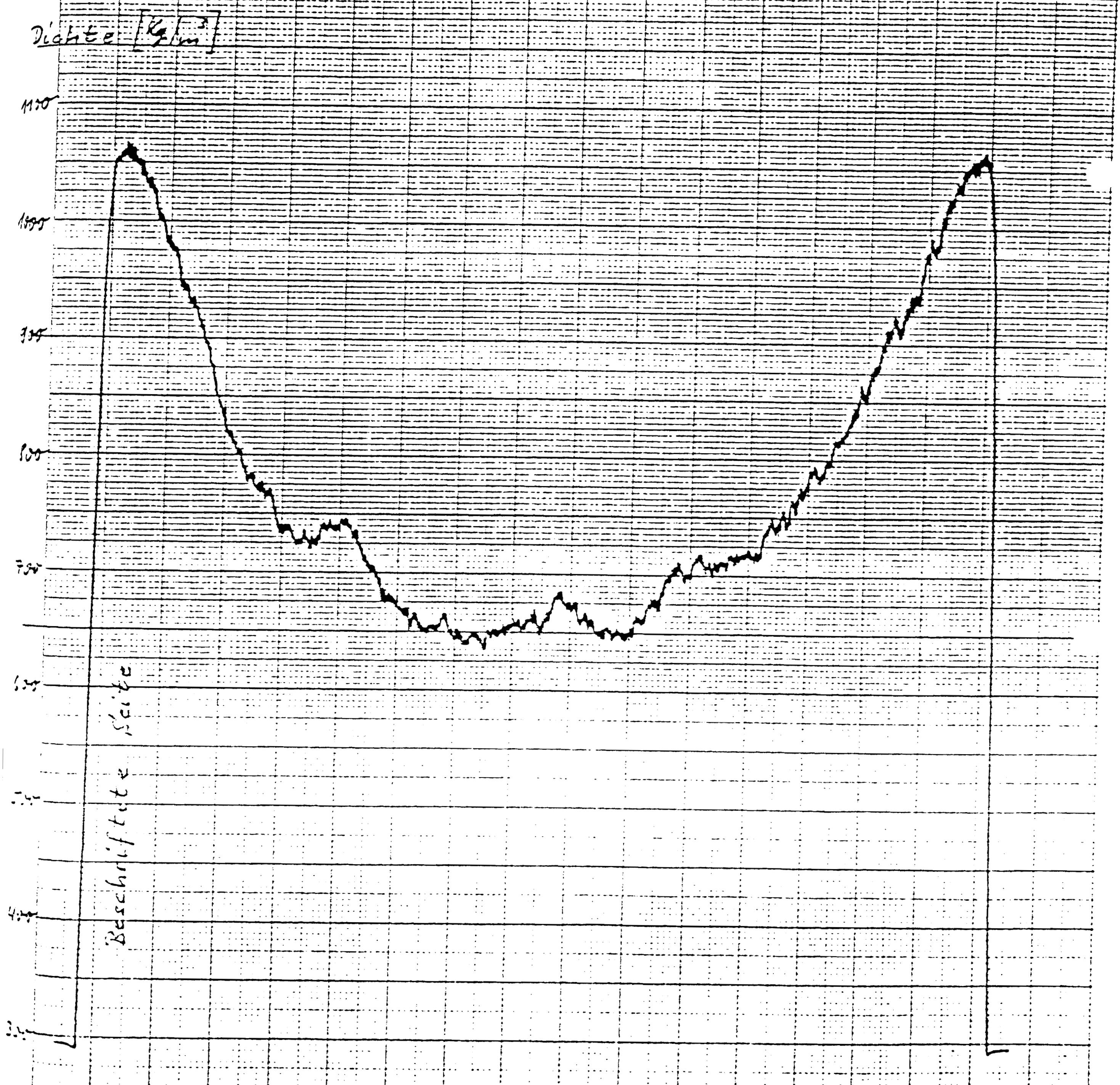
Platten von verschiedenen

Australischen Firmen

Pl. Bezeichng. DP PHG-4-B

Pl. Dicke 15,7 mm

Pl. Dichte 778 Kg/m³



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Sch

Spanplattenmuster der Fa. Pyneboard

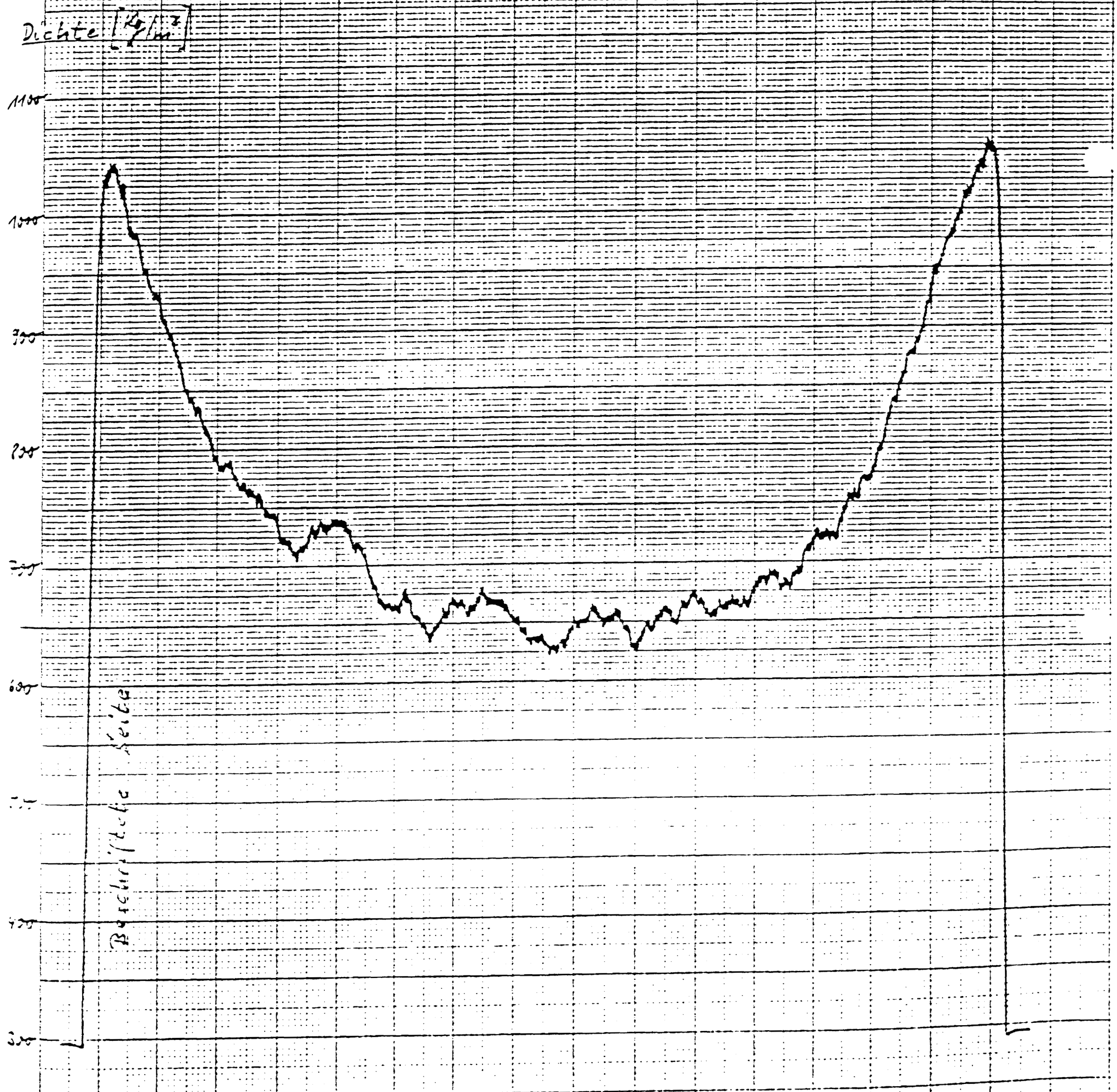
Platten von verschiedenen

Australischen Firmen

Pl. Bezeichung: DP PHG-27-R

Pl. Dicke 15,7 mm

Pl. Dichte 740 kg/m³



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Spanplattenmuster der Fa. Pyneboard

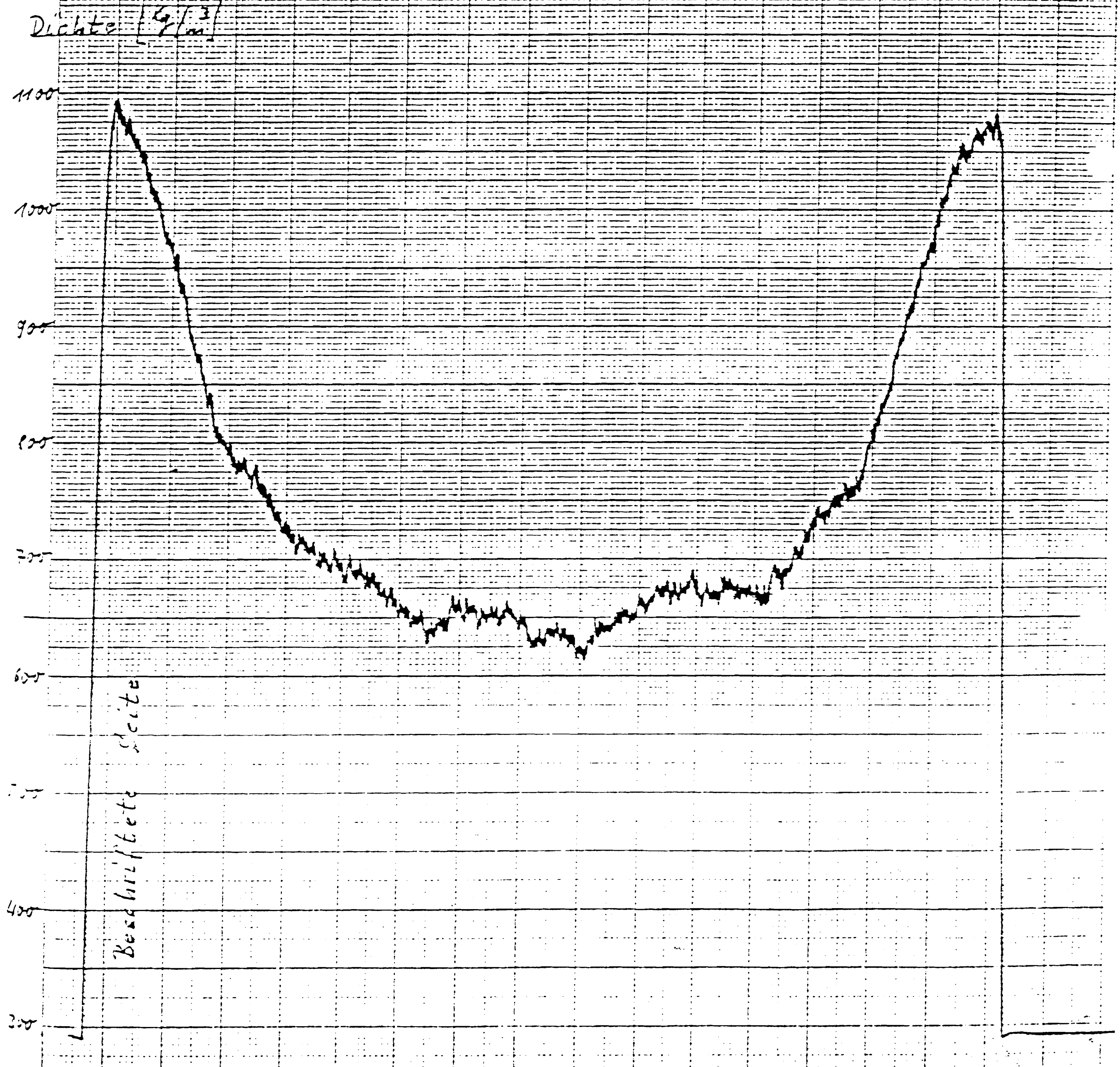
Platten von verschiedenen

Australischen Firmen

Pl. Bezeichng. DP PHG-Z-B

Pl. Dicke 15,7 mm

Pl. Dichte 752 kg/m^3



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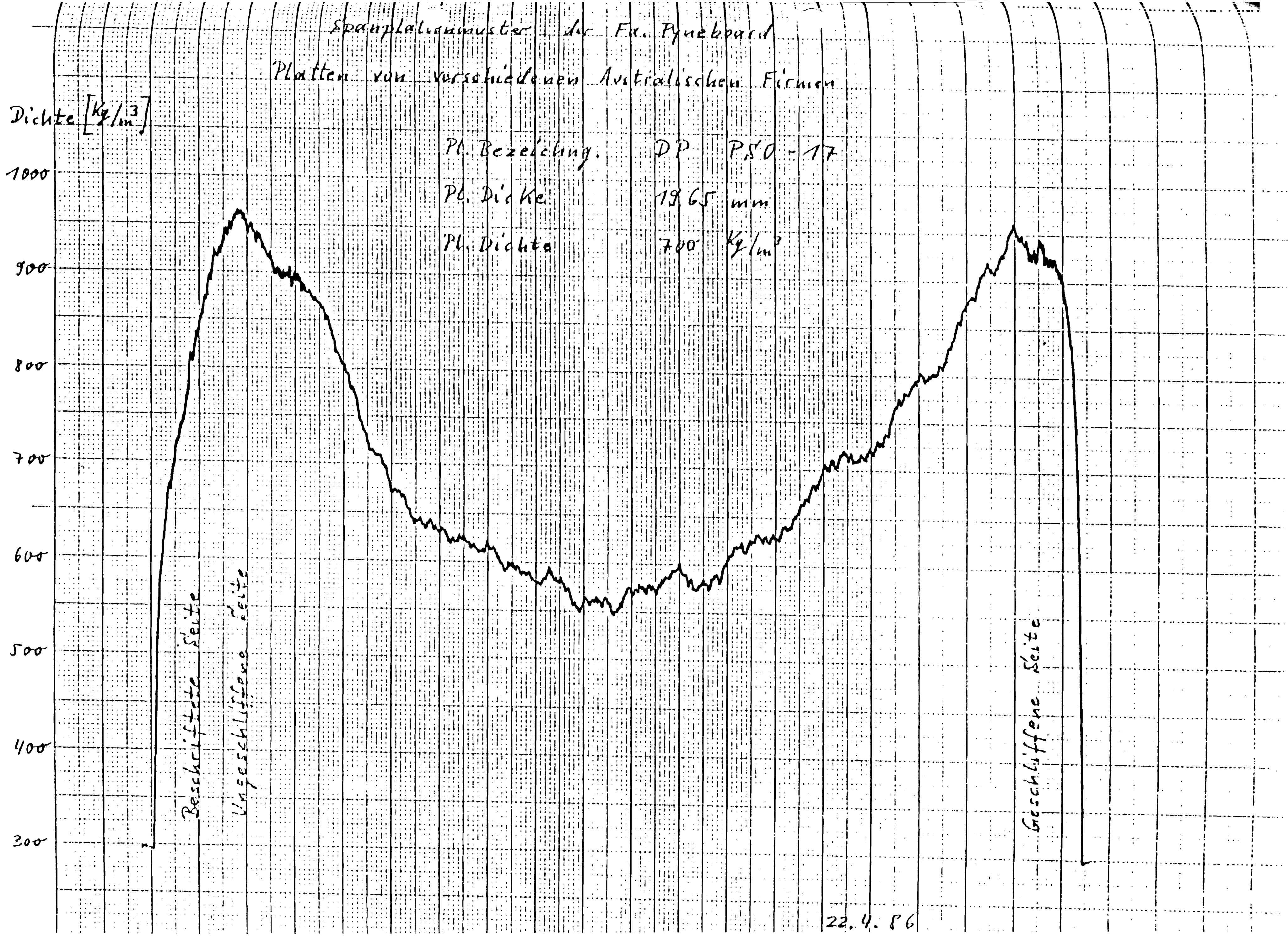
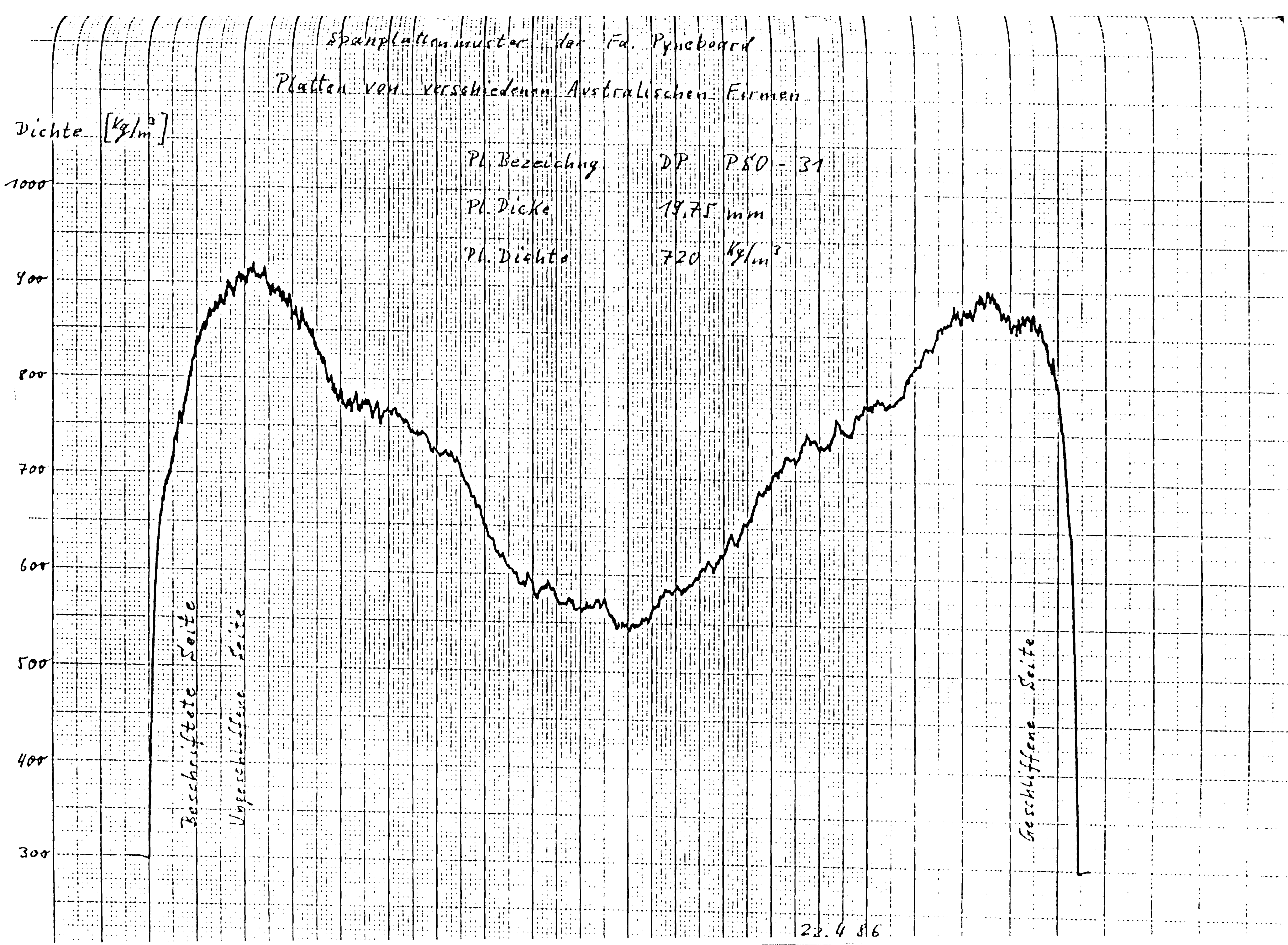
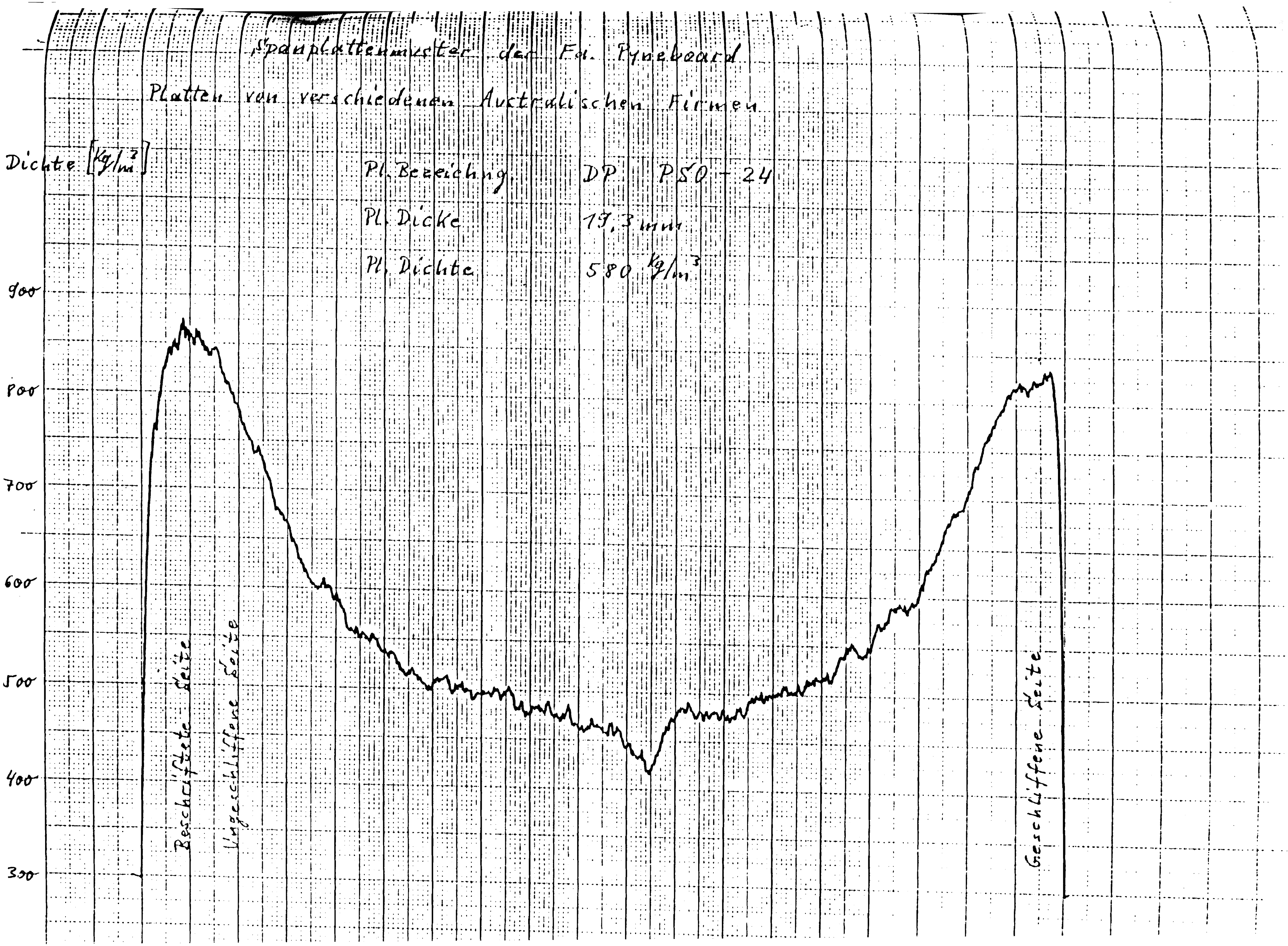


Spanplattenmuster der Fa. Pyneboard
Platten von verschiedenen Australischen Firmen
Dichte [Kg/m³]
Pl. Bezeichnung. DP PSO - 17
Pl. Dicke 19,65 mm
Pl. Dichte 700 Kg/m³
1000
900
800
700
600
500
400
300
Beschliffte Seite
Ungeschliffene Seite
Geschliffene Seite
22. 4. 86



Spanplattenmuster der Fa. Pyneboard
Platten von verschiedenen Australischen Firmen
Dichte [Kg/m³]
Pl. Bezeichng DP P80 - 31
Pl. Dicke 19,75 mm
Pl. Dichte 720 Kg/m³
1000
900
800
700
600
500
400
300
Beschiftete Seite
Ungeschliffene Seite
Geschliffene Seite
22. 4 86


Spanplattenmuster der Fa. Pyneboard
Platten von verschiedenen Australischen Firmen
Dichte [kg/m³]
Pl. Bezeichng. DP PSO - 24
Pl. Dicke 17,3 mm
Pl. Dichte 580 kg/m³
900
800
700
600
500
400
300
Beschriftete Seite
Ungeschliffene Seite
Geschliffene Seite