

TIP 0404-07

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Paper machine drying rate

Scope

This TIP outlines procedures for calculating paper machine drying rates for coated and uncoated papers and provides drying rate curves. The objective of the TIP is to define rate of water removal on a common basis for mills to use to compare a particular machine to past performance and to other machines. The definition of drying rate and its calculation are simple to permit widespread use. These procedures cannot be used for machines with auxiliary drying equipment such as infrared dryers and impingement dryers unless these auxiliary dryers are shut off.

Data points on the curves represent observed performance of existing machines. Lines represent calculated average and two-sigma variation of plotted data.

The calculation does not identify or account for factors that affect drying rate. There are many variables that can affect calculated drying rate. These factors include:

- | | | |
|----------------------------|-------------------------|----------------------|
| • Sheet furnish | • Dryer configuration | • Type of pressing |
| • Syphon design | • Dryer felting | • Amount of pressing |
| • Use of dryer bars | • Dryer surface scale | • Breaker stack |
| • Pocket ventilation | • Hood humidity | |
| • Dryer fabric application | • Reel moisture content | |

Safety precautions

This TIP outlines a calculation procedure. No safety precautions are required.

Definition of drying rate

The drying rate (R_H) as applied to drying on the machine is defined as the amount of water evaporated per hour per unit area of drying surface. Drying surface is defined as the total circumferential length of steam-heated dryers that are in contact with the sheet multiplied by the width of the sheet at the reel. Drying rate is expressed as pounds per hour per square foot in customary units and as kilograms per hour per square meter in SI units, and reported at the average steam temperature.

where:

T_{avg}	=	average saturation steam temperature, °C (°F)
T_i	=	saturation steam temperature, of dryer (i), °C (°F)
N	=	number of steam-heated dryers that contact the sheet

Saturation steam temperatures can be determined from measured dryer steam pressures using common steam tables (1, 2). Abbreviated excerpts from these references are included in this TIP.

Note that a weighted average steam pressure is not necessarily equal to the corresponding weighted average steam temperature. This is because steam pressure and steam temperature are not linearly related. Also note that the temperature of the saturated steam in the dryer is higher than the temperature of the condensate leaving the dryer.

Drying rate for coated papers

Equations 1 and 2 can also be used to compute the drying rate for coated papers. However, entering dryness E must generally be calculated from information on coating weight and moisture, while reel basis weight B can be either used directly or computed from the raw stock basis weight. The equations for these calculations are as follows:

$$B = \frac{B_c(P/100) + W}{(L/100)} \quad (4)$$

$$E = 100 - 100 \left[\frac{B_c(1 - \frac{P}{100}) + W(\frac{100}{C} - 1)}{B_c + \frac{(100W)}{C}} \right] \quad (5)$$

in which the variables are defined as:

B_c	=	basis weight of the sheet entering the coater (wet basis), kg/m ² (lb/ream)
W	=	dry coating weight applied, kg/m ² (lb/ream)
P	=	percent dryness of sheet entering the coater
C	=	percent coating solids in coating solution as applied to the sheet (wet basis).

Equations 4 and 5 can also be used to calculate the drying rate after a size press, where W is the dry weight per ream of the starch picked up and C is the percent starch solids in the size solution.

An example of these equations follows in both customary and SI units:

Customary units

S	=	2000 ft/min
B_c	=	43 lb/ream into coater (includes moisture)
L	=	96% dryness (fiber and coating) leaving the dryer section
P	=	94% dry (wet basis) entering the coater
A	=	3300 ft ² /ream
D	=	5.0 ft diameter
N	=	6 coater dryers
W	=	8 lb of dry coating applied per ream
C	=	60% coating solids

Press. (kPa)	°C	Press. (kPa)	°C	Press. (kPa)	°C	Press. (kPa)	°C
10	45.81	210	121.78	420	145.40	820	171.46
15	53.97	215	122.53	430	146.26	830	171.97
20	60.06	220	123.57	440	147.10	840	172.47
25	64.97	225	124.00	450	147.93	850	172.96
30	69.10	230	124.71	460	148.74	860	173.46
35	72.69	235	125.41	470	149.54	870	173.94
40	75.87	240	126.10	480	150.32	880	174.43
45	78.73	245	126.77	490	151.10	890	174.90
50	81.33	250	127.44	500	151.86	900	175.38
55	83.72	255	128.09	510	152.60	910	175.85
50	85.94	260	128.73	520	153.34	920	176.31
65	88.01	265	129.37	530	154.06	930	176.78
70	89.95	270	129.99	540	154.78	940	177.24
75	91.78	275	130.60	550	155.48	950	177.69
80	93.50	280	131.21	560	156.17	960	178.14
85	95.14	285	131.81	570	156.86	970	178.59
90	96.71	290	132.39	580	157.53	980	179.03
95	98.20	295	132.97	590	158.20	990	179.47
100	99.63	300	133.55	600	158.85	1000	179.91
105	101.00	305	134.11	610	159.50	1020	180.77
110	102.31	310	134.67	620	160.14	1040	181.62
115	103.58	315	135.22	630	160.77	1060	182.46
120	104.80	320	135.76	640	161.39	1080	183.28
125	105.99	325	136.30	650	162.01	1100	184.09
130	107.13	330	136.83	660	162.61	1120	184.89
135	108.24	335	137.35	670	163.21	1140	185.68
140	109.31	340	137.87	680	163.81	1160	186.46
145	110.36	345	138.38	690	164.39	1180	187.23
150	111.37	350	138.88	700	164.97	1200	187.99
155	112.36	355	139.38	710	165.55	1220	188.74
160	133.32	360	139.87	720	166.11	1240	189.48
165	114.26	365	140.36	730	166.67		
170	115.17	370	140.84	740	167.23		
175	116.06	375	141.32	750	167.78		
180	116.93	380	141.79	760	168.32		
185	117.79	385	142.26	770	168.86		
190	118.62	390	142.72	780	169.39		
195	119.43	395	143.18	790	169.91		
200	120.23	400	143.63	800	170.43		
205	121.02	410	144.53	810	170.95		

Table 2. Saturated Steam Temperatures (S. I. Units).

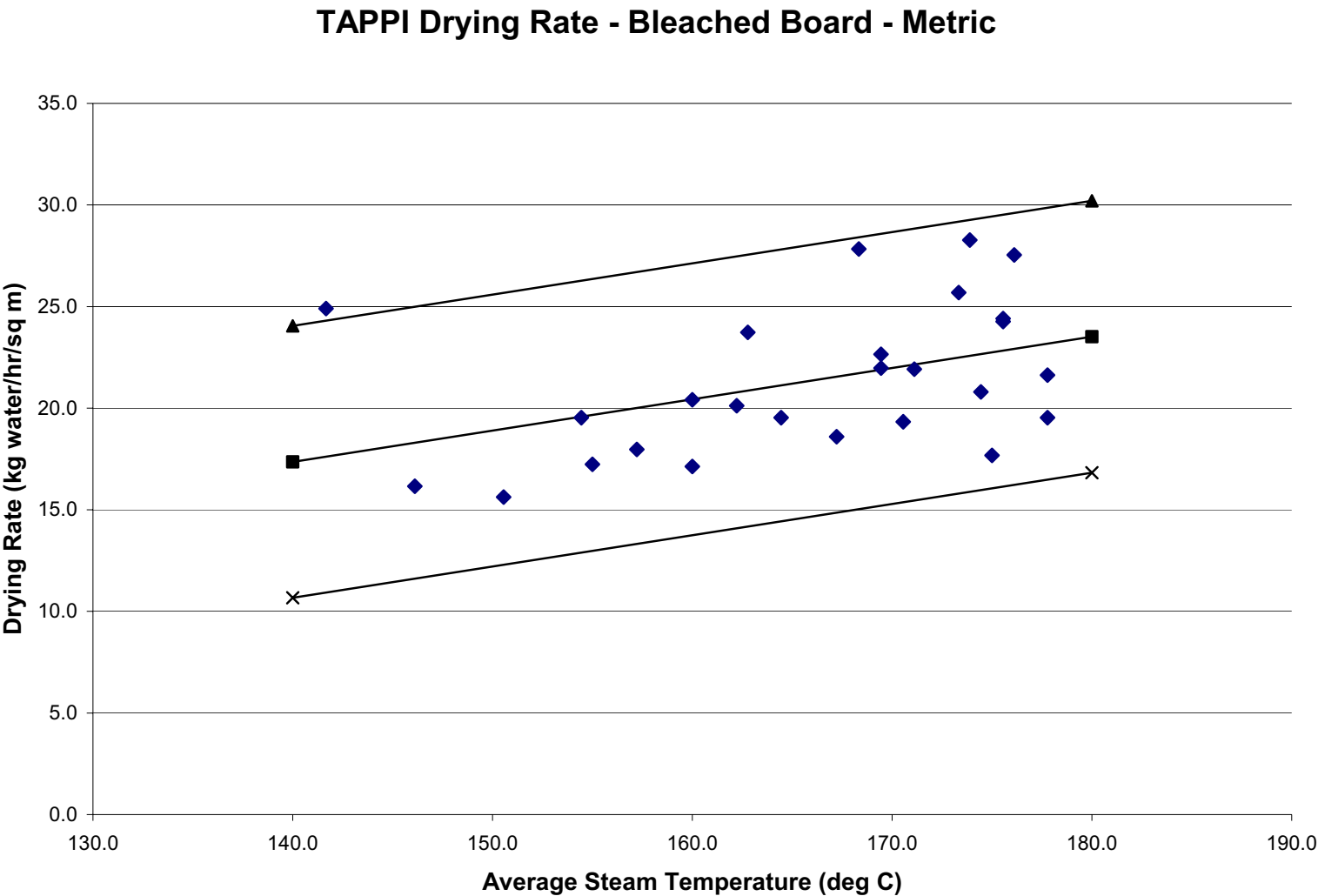


Fig. 4M. Bleached board drying rate curve.

TAPPI Drying Rate - Wood-containing Paper - Metric

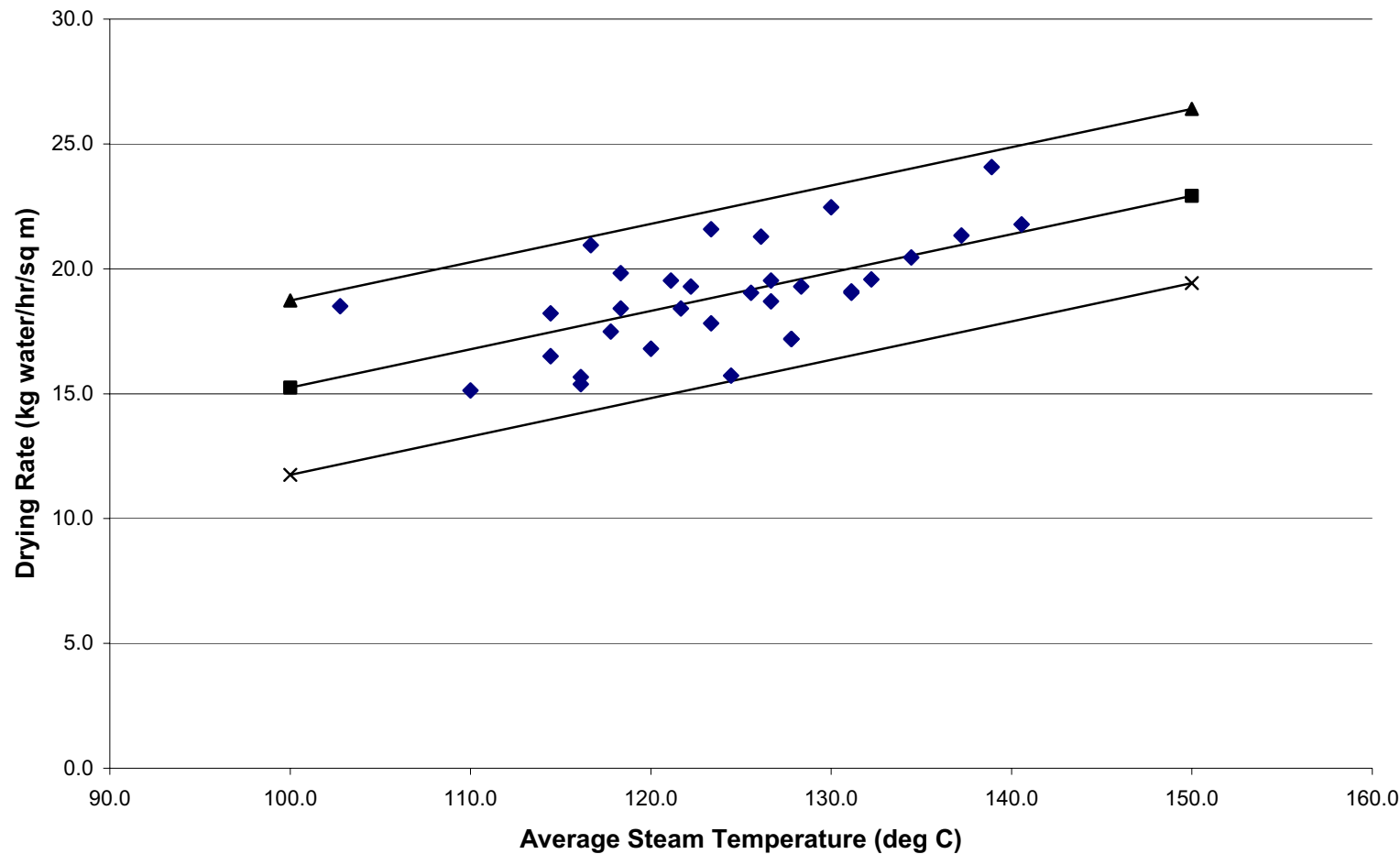


Fig. 7M. Wood-containing paper drying rate curve.

TAPPI Drying Rate - Average Lines - Metric

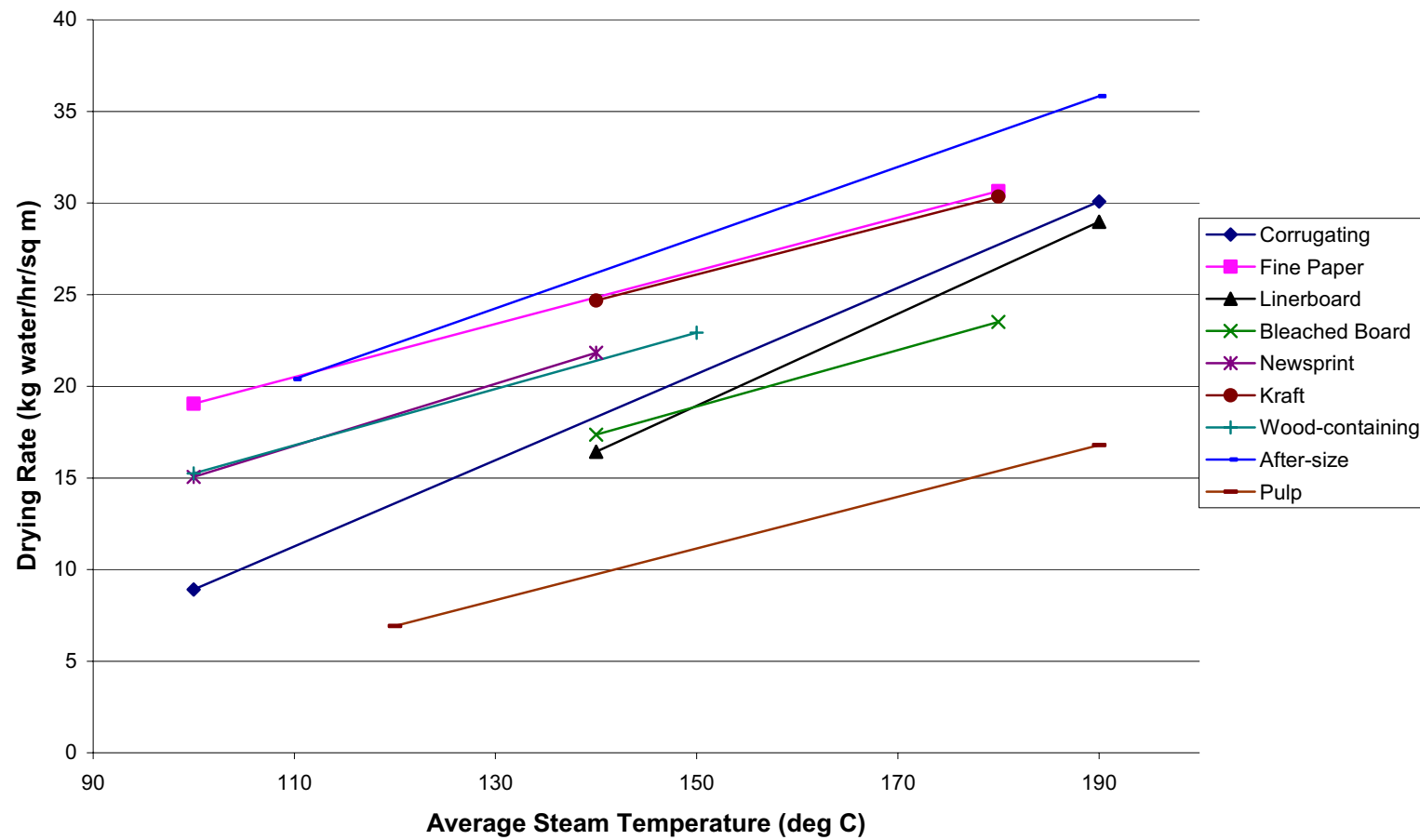


Fig. 10M. Average curves for all machines.