Physical Test Methods Sub-Group

Technical Report

Recommendation of Measurement Area for Air Permeability of Super Slim Cigarette Papers

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1. PARTICIPATING LABORATORIES

Borgwaldt KC, Hamburg, Germany

Cerulean, Milton Keynes, UK

Imperial Tobacco (Reemtsma), Hamburg, Germany

SODIM, Fleury-les-Aubrais, France

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3. BACKGROUND AND INTRODUCTION

CORESTA Recommended Method CRM 40 "Determination of Air Permeability of Materials used as Cigarette Papers, Filter Plug Wrap and Filter Joining Paper including Materials having an Oriented Permeable Zone" (1994) offers a single measurement head size of 20 mm x 10 mm (200 mm^2). ISO 2965:2009 adds a smaller head size of 15 mm x 2 mm (30 mm^2) to enable measurements of paper with bands of different, normally lower, permeability. These head dimensions have been used over many years for air permeability measurements of cigarette papers, including banded papers now used widely in the production of LIP cigarettes.

The PTM Sub-Group of CORESTA was approached to extend the Recommended Method to include a measurement head area suitable for use with super-slim cigarette papers, particularly including a head suitable for the testing of 'spills', i.e. paper samples cut from fabricated cigarettes. Spills taken from super-slim cigarettes might be as little as 15 mm wide and the width available for measurement is less than this due to the seam overlap. In this context it was elected to trial a head of 10 mm x 3 mm to assess its suitability for measurement of super-slim cigarette papers, both in the base paper region and in the band region of LIP papers. Relevant to this assessment was previous work[i,ii] that indicated that the measured air permeability was a function of measurement head area, specifically that there was a contribution to the measured flow deriving from the perimeter length of the head that added to the 'area' flow. For smaller head areas this 'perimeter' flow appeared to be a significant contribution to the total flow and hence that the apparent air permeability of a given sample depended on the head area used to make the measurement.

4. EXPERIMENTAL PROGRAMME

Two samples of paper were selected, both having nominal air permeability around 9 CU (1 CORESTA Unit = 1 cm^3/min of volume flow / cm^2 head area). The air permeability of the papers was measured using three measurement heads:

- 20 mm x 10 mm = 200 mm^2
- 15 mm x 2 mm = 30 mm^2
- 10 mm x 3 mm = 30 mm^2

Three types of commercially available air permeability instruments were available for the measurements, from Borgwaldt KC, Cerulean and SODIM and these laboratories took part together with Imperial Tobacco (Reemtsma), Germany, using a Borgwaldt KC instrument.

The experimental protocol involved making duplicate measurements on both papers using all three measurement heads.

5. EXPERIMENTAL RESULTS

The results are presented in the Table 1. All the individual results are collated, including the air flow expressed as CU and cm^3/min.

Table 1 Results of air permeability measurements

Sample ID	Clamp size	Replicate Number	Lab	Mean AP (CU)	SD AP (CU)	Area (cm^2)	Perimeter (cm)	Flow (cm^3/min)
Sample 1	10 mm x 3 mm	1	BKC	10.61	1.12	0.3	2.6	3.18
Sample 1	10 mm x 3 mm	2	BKC	10.41	1.01	0.3	2.6	3.12
Sample 1	15 mm x 2 mm	1	BKC	12.41	1.19	0.3	3.4	3.72
Sample 1	15 mm x 2 mm	2	BKC	12.47	2.57	0.3	3.4	3.74
Sample 1	10 mm x 20 mm	1	BKC	9.23	0.68	2	6	18.46
Sample 1	10 mm x 20 mm	2	BKC	9.27	0.81	2	6	18.53
Sample 2	10 mm x 3 mm	1	BKC	10.17	1.27	0.3	2.6	3.05
Sample 2	10 mm x 3 mm	2	BKC	9.99	1.24	0.3	2.6	3.00
Sample 2	15 mm x 2 mm	1	BKC	11.46	1.43	0.3	3.4	3.44
Sample 2	15 mm x 2 mm	2	BKC	11.96	1.14	0.3	3.4	3.59
Sample 2	10 mm x 20 mm	1	BKC	8.65	0.56	2	6	17.30
Sample 2	10 mm x 20 mm	2	BKC	8.08	0.25	2	6	16.16
Sample 1	10 mm x 3 mm	1	Cer	13.77	1.43	0.3	2.6	4.13
Sample 1	10 mm x 3 mm	2	Cer	12.83	1.16	0.3	2.6	3.85
Sample 1	15 mm x 2 mm	1	Cer	17.06	2.11	0.3	3.4	5.12
Sample 1	15 mm x 2 mm	2	Cer	14.72	2.34	0.3	3.4	4.42
Sample 1	10 mm x 20 mm	1	Cer	9.73	1.13	2	6	19.46
Sample 1	10 mm x 20 mm	2	Cer	9.91	0.94	2	6	19.83
Sample 2	10 mm x 3 mm	1	Cer	14.16	1.68	0.3	2.6	4.25
Sample 2	10 mm x 3 mm	2	Cer	13.53	1.22	0.3	2.6	4.06
Sample 2	15 mm x 2 mm	1	Cer	16.37	1.32	0.3	3.4	4.91
Sample 2	15 mm x 2 mm	2	Cer	13.94	1.53	0.3	3.4	4.18
Sample 2	10 mm x 20 mm	1	Cer	9.52	0.52	2	6	19.04
Sample 2	10 mm x 20 mm	2	Cer	9.27	0.66	2	6	18.54
Sample 1	10 mm x 3 mm	1	Reem	10.33	0.98	0.3	2.6	3.10
Sample 1	10 mm x 3 mm	2	Reem	11.17	2.19	0.3	2.6	3.35
Sample 1	15 mm x 2 mm	1	Reem	12.86	1.14	0.3	3.4	3.86
Sample 1	15 mm x 2 mm	2	Reem	12.07	1.50	0.3	3.4	3.62
Sample 1	10 mm x 20 mm	1	Reem	10.79	0.97	2	6	21.58
Sample 1	10 mm x 20 mm	2	Reem	10.13	0.41	2	6	20.26
Sample 2	10 mm x 3 mm	1	Reem	10.98	1.38	0.3	2.6	3.29
Sample 2	10 mm x 3 mm	2	Reem	10.30	1.57	0.3	2.6	3.09
Sample 2	15 mm x 2 mm	1	Reem	12.78	1.62	0.3	3.4	3.83
Sample 2	15 mm x 2 mm	2	Reem	13.32	1.58	0.3	3.4	4.00
Sample 2	10 mm x 20 mm	1	Reem	9.20	0.40	2	6	18.40
Sample 2	10 mm x 20 mm	2	Reem	9.06	0.88	2	6	18.12
Sample 1	10 mm x 3 mm	1	SODIM	12.03	2.03	0.3	2.6	3.61
Sample 1	10 mm x 3 mm	2	SODIM	12.54	1.00	0.3	2.6	3.76
Sample 1	15 mm x 2 mm	1	SODIM	13.20	1.01	0.3	3.4	3.96
Sample 1	15 mm x 2 mm	2	SODIM	13.42	1.53	0.3	3.4	4.03
Sample 1	10 mm x 20 mm	1	SODIM	9.48	0.87	2	6	18.95
Sample 1	10 mm x 20 mm	2	SODIM	8.75	0.50	2	6	17.50
Sample 2	10 mm x 3 mm	1	SODIM	12.19	1.54	0.3	2.6	3.66
Sample 2	10 mm x 3 mm	2	SODIM	12.19	1.48	0.3	2.6	3.66
Sample 2	15 mm x 2 mm	1	SODIM	13.83	0.77	0.3	3.4	4.15
Sample 2	15 mm x 2 mm	2	SODIM	14.22	1.94	0.3	3.4	4.26
Sample 2	10 mm x 20 mm	1	SODIM	8.77	0.56	2	6	17.54
Sample 2	10 mm x 20 mm	2	SODIM	8.83	1.07	2	6	17.65

Figure 1 presents a graphical summary of the data.

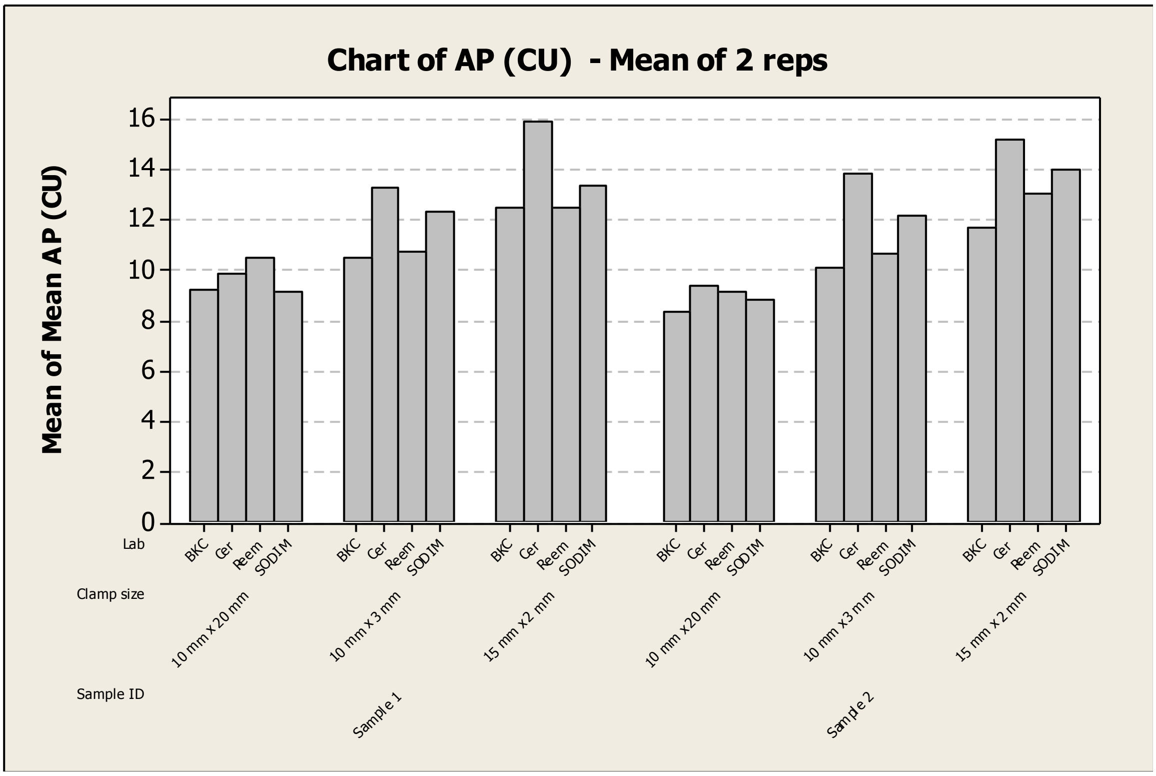

Figure 1 Graphical representation of air permeability results, averaging over the two replicates

It can be seen that, notwithstanding some finer detail, there is a general trend that the measured air permeability decreases in the order; 15 x 2 head > 10 x 3 head > 20 x 10 head. This is highlighted in Figure 2 in a further summarizing of the data to present the average over all the laboratories.

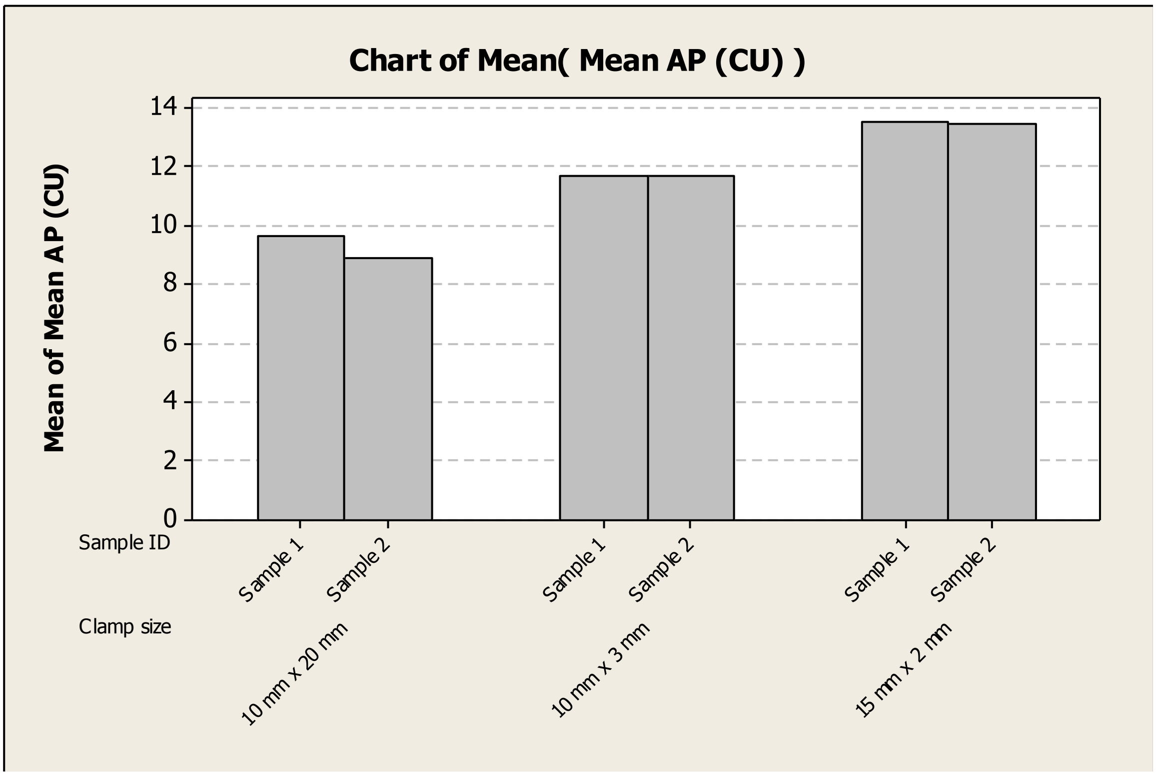

Figure 2 Graphical representation of air permeability results, averaging over all instruments

6. ANALYSIS AND DISCUSSION

From Figure 2 it is clear that any analysis of the results can summarize the data for all the instruments and both the paper types – only the head dimension needs to be treated as a variable. It is also clear that the perimeter of the measurement head does indeed make a significant contribution to the flow, as seen in the comparison of the two smaller heads, which both have the same measurement area.

A regression fit (Minitab 16) to the flow data using the head area and perimeter as predictors (and forcing the fit through zero) yields the following model:

Flow (cm^3/min) = 7.85 Area (cm^2) + 0.480 Perimeter (cm)

```
Predictor          Coef    SE Coef     T       P
No constant
Area (cm2)       7.8478   0.2512    31.24  0.000
Perimeter (cm)  0.48047  0.06969     6.89  0.000
```

Both the area and perimeter terms are seen to be statistically significant. Thus the ‘true’ area-based air permeability of the paper can be taken as 7.85 CU, with each cm of perimeter contributing an additional 0.48 cm^3/min to the total flow. The CU value of this perimeter flow of course depends on the head area.

The model as applied to the summarised measurements is presented in Table 2. The apparent area and perimeter contributions to the flow were calculated from the model, hence the percentages do not add exactly to 100%.

Table 2 Fit of model to actual flow

Head Size	Head area (cm^2)	Head perimeter (cm)	Measured Air Permeability CU (cm/min)	Air Flow (cm^3/min)	Area Contribution	Perimeter Contribution
20 mm x 10 mm	2	6	9.291	18.583	84.5%	15.5%
10 mm x 3 mm	0.3	2.6	11.699	3.510	67.1%	35.6%
15 mm x 2 mm	0.3	3.4	13.506	4.052	58.1%	40.3%

The surprising result is that even for the 20 mm x 10 mm head, the perimeter flow contributes 15% to the total and that this increases to 40% for the 15 mm x 2 mm head.

The model must be treated with some caution because the range of area and perimeter are far from ideal. An evenly covered range of areas and aspect ratios from circular to extended rectangles would be required to ‘independently’ assess the effect of area and perimeter. However such an experiment was beyond the scope of this investigation.

The detailed mechanisms of perimeter flow have been discussed in the referenced papers and no attempt was made either to validate or extend the prior work in this regard.

7. CONCLUSIONS AND RECOMMENDATIONS

It is concluded that a 10 mm x 3 mm measurement head is a viable option for making air permeability measurements but that perimeter flow appears to contribute significantly to the total flow. Thus interpretation of air permeability measurements made using different measurement areas requires care. The mechanisms of perimeter flow have been discussed previously in the referenced articles but significant additional work would be required to gain a full understanding.

Notwithstanding this open technical aspect it is **recommended that:**

A. A 10 mm x 3 mm head is adopted for the measurement of air permeability of super-slim papers.

B. The finding of this study that measured air permeability depends on the dimensions of the head should be incorporated into CRM 40.

C. Users of the method should be recommended to undertake correlation studies when seeking to compare air permeability measurements made using different head sizes.

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[i] CODWISE, W., DUROCHER D. "Techniques for making accurate low permeability measurements on print banded papers using the Borgwaldt A-10" CORESTA Congress 2004, Kyoto, Japan, PTPOST 05

[ii] VINCENT, J., TINDALL, I., "Potential sources of measurement error when measuring the permeability of low ignition propensity (LIP) papers to ISO 2965", CORESTA SSPT 2007, Jeju Island, Korea, SSPTPOST 02