PRIVATE AND CONFIDENTIAL

JLE/CAL/46C

19th September 1968

TEMPERATURE MEASUREMENTS ON CIGARETTES WITH HIGH PACKING DENSITY AND AXIAL CHANNEL

INTRODUCTION

According to U.K. Patent No. 1,086,443 granted to Messrs J.A.E. Bell, J.D. Jones and D.H. Laing, it is declared that, "It is an object of this invention to provide a cigarette wherein the tobacco is more tightly packed than heretofore,....., thereby creating a lower idle temperature. It is an object of the invention to provide a cigarette having an idle temperature of about 530°C and an average maximum temperature of about 665°C,..... much lower than those of a conventional cigarette. By average maximum temperature with the invention, we mean the average temperature of the hottest part of the combustion zone in the densely packed tobacco in the inventive cigarette during a number of puffs". (Column 4, lines 85 - 108).

Cigarettes manufactured by I.T. Co. Canada with packing densities up to 1.3 times normal were submitted to Messrs Bell, Jones and Laing for modification according to their patent. An axial channel was produced in these cigarettes with an 0.06" tungsten probe heated to 430°C. Samples of these modified cigarettes, together with the unmodified control, have been examined at R. & D.E. Temperatures during the puff and during the smoulder immediately before the beginning of the puff were determined. The results obtained to date are discussed in this note; it is not anticipated that the experiments still under way will alter the conclusion, that the claim made by Messrs Bell, Jones and Laing cannot be substantiated.

EXPERIMENTAL DETAILS

Eight samples of cigarettes were received; these consisted of two groups

of cigarette rods with added high and low efficiency acetate filters. Initially it was decided to restrict measurements to the cigarettes with the high efficiency acetate filter as it was anticipated that the filter would have little, if any, effect upon the temperatures of the tobacco rod.

Cigarettes were conditioned (58% R.H., 68°F) and selected on the basis of mean weight and pressure drop. Temperature measurements were carried out using three Pt/13% Rh-Pt thermocouples, in tandem, with 4 mm between adjacent thermocouples. Measurements were made in duplicate with the thermocouples placed on the central axis and at radial distances of 1.5 and 3.0 mm from the central axis. Smoulder temperatures were measured 1 second before the beginning of a puff, and puff temperatures 1.5 second after the beginning of the puff (see R. & D.E. Report Nos. 219-F, 287-F and 331-F).

Visual inspection of cigarettes which had been quartered showed that for most of the cigarettes examined the channel was not on the axis of the cigarette. Examination of the butts of cigarettes used for temperature measurements also showed this effect. (A photograph of sections of a typical cigarette are given in the Appendix.) From this evidence it is concluded that it is unlikely that the centrally placed thermocouples were actually within the channel for many of the determinations.

Cigarettes were smoked on a B-A.T., restricted, smoking engine at one puff per minute, each puff of 35 ml and 2 seconds duration, with increased packing density the puff duration increased slightly. The temperatures measured were plotted against the distance of the thermocouples from the paper burn 4 seconds after the start of the puff and the graphs used to give values for:

1. The mean maximum temperature.
2. The maximum temperature recorded.
3. The distance between 700°C contours.
4. The distance between 400°C contours.
5. The position of hottest part of the coal from paper burn edge.
6. The distance the 200°C, 400°C and 700°C contours moved between the smoulder temperature measurement and puff temperature measurement, i.e. 1 second smoulder plus $1\frac{1}{2}$ second puff (effectively $1\frac{1}{2}$ second puff).
7. The distance between 200°C and 700°C contours at the butt end for both puff and smoulder.

Temperature contours were also plotted to give the general picture of the puff and smoulder temperature profiles. The results are given as an Appendix (Table 1). The most significant effect is the increase in mean maximum temperature with packing density. Plots of these temperatures against packing density are linear, with the exception of the smoulder temperature measured at 3.0 mm from the axis (Figure 1). Temperature measurements on the unmodified cigarettes with different packing densities, confirmed this observation (see Appendix, Table 2, Figure 2) although the increases in puff temperatures were not as large as those measurements for the modified cigarettes.

Only small differences were noted in the "distances between like-contours" and, allowing for the rather inexact nature of these measurements (the paper burn is the reference mark) these differences are probably not significant. From the temperature profiles the volume of the coal at a temperature greater than 700°C is least for the unmodified control cigarette, for both puff and smoulder. The cigarettes with the highest packing density

have a more barrel shaped profile than that of the control and those with intermediate packing densities have more pointed hot zones.

The puff temperature profile for the cigarette with packing density 1 .4 times normal is interesting because, towards the butt end, the lower temperature contours, e.g. 200°C, extend down the axis of the cigarette. This is probably the only case where the thermocouples were actually in the channel and these higher temperatures measured are the result of the hot gases streaming down the channel.

From the smoulder rates of the cigarettes, and the distances between the 200°C and 700°C contours on the axis, it may be concluded that the rate of heating of the tobacco during smoulder decreases by 50% as the packing density increases by 50%. Generally, the rate of heating is inversely proportional to the packing density.

Measurements carried out with a puff frequency of 3 puffs per minute showed that the differences between puff and smoulder temperatures are not very great as, presumably, there is insufficient time between puffs for a steady smoulder state to be reached, (see Appendix, Table 3). Compared to 1 puff per minute, the hot region of the coal (above 400°C) is longer at the higher puff frequency.

Temperature measurements made with a 25 ml puff, taken once per minute, indicate that the combustion temperatures at this puff volume are slightly lower than those obtained with a 35 ml puff (see Appendix, Table 4). Only the unmodified control cigarette and the modified cigarette with the highest packing density were used and the temperatures measured for the latter cigarette were higher, as found for the 35 ml puff.

Thus, it appears that the temperature changes noted in the modified cigarettes are probably attributable to the increase in packing density

and not to the presence of the axial channel. Further, no evidence has been found to support the claims of Messrs Bell, Jones and Laing, as all cigarettes examined with a channel have had higher puff and smoulder temperatures than the unmodified control cigarettes.

APPENDIX

CIGARETTE SPECIFICATIONS

Samples received

Code Number		Packing Density
RL 268		x1
RL 268A	- High F.E. Acetate Filter	x1.3
RL 268B		x1.4
RL 268C		x1.5
RL 268D		x1
RL 268E	- Low F.E. Acetate Filter	x1.3
RL 268F		x1.4
RL 268G		x1.5

Samples RL 268 and RL 268D had no axial channel.

Cigarettes selected to mean weight and pressure drop:

	Weight (g/cig)	Pressure Drop (cm W.G.)
RL 268	1.12-1.16	16.3-17.7
RL 268A	1.36-1.42	14.9-16.1
RL 268B	1.46-1.52	16.3-16.7
RL 268C	1.56-1.62	17.5-19.0

Cigarettes not examined for combustion temperature.

	Mean Weight (g/cig)	Mean Pressure Drop (cm W.G.)
RL 268D	1.16	12.9
RL 268E	1.42	14.1
RL 268F	1.50	12.0
RL 268G	1.60	14.2

Cross sections cut from same cigarette showing the variable position of the channel. This cigarette had been selected for temperature measurements but was not used.

TABLE 1

TEMPERATURE MEASUREMENTS

1 Puff per minute, 35 ml puff

Code No.	Thermocouple	Puff					Smoulder				
		Mean Maximum Temp. (°C)	Maximum Temp. (°C)	Distance Between 700°C Contours (mm)	Distance Between 400°C Contours (mm)	Approximate Distance of Hottest Part of Coal from Paper Burn (mm)	Mean Maximum Temp. (°C)	Maximum Temp. (°C)	Distance Between 700°C Contours (mm)	Distance Between 400°C Contours (mm)	Approximate Distance of Hottest Part of Coal from Paper Burn (mm)
RL 268	1	815	825	6	11	7	760	760	4	9.5	8
	2	790	810	6.5	12	6	710	745	2	10	7
	3	730	730	2	7.5	4	600	620	-	6.5	5
RL 268A	1	830	855	7.5	11.5	8	775	815	6.5	12.5	8
	2	840	865	6	11	5	730	755	3.0	9.5	6
	3	760	825	3.5	9	2	630	645	-	8	5
RL 268B	1	875	1060	9.5	12.5	9	800	815	6.5	11.0	10
	2	795	815	6.5	12	6	735	740	4.5	11.0	7
	3	780	810	2	7	2	560	605	-	6.5	4
RL 268C	1	895	925	6.5	11	7	790	805	4.5	11	8
	2	810	810	7	12	6	750	760	5.0	11	7
	3	770	815	1.5	6.5	2	555	590	-	7	4

	Distance Contour Moves Back On Axis of Cigarette in 1.5 secs			Distance Between 200°C & 700°C Contour (mm)
	200°C (mm)	400°C (mm)	700°C (mm)	
RL 268	1.6	1.7	2.2	4.4
RL 268A	1.3	1.1	2.1	3.6
RL 268B	3.0	1.8	2.1	5.5
RL 268C	0.4	0.8	1.7	3.7

Distance Between 200°C & 700°C Contour On Axis (d) (mm)	Smoulder Rate (mm/min)		Time for Distance (t) (min)	Rate of Heating from 200°C to 700°C (x 100°C per min)
	(1)	(2)*		
5.0	3.94	RL 268D 3.96	1.26	3.98
4.4	3.10	RL 268E 3.02	1.42	3.1
4.5	2.98	RL 268F 2.93	1.51	2.98
5.0	2.71	RL 268G 2.65	1.84	2.72

*Low efficiency acetate filters on cigarette rods

Thermocouple 1 = Central axis
2 = 1.5 mm from axis
3 = 3.0 mm from axis

100457260

TABLE 2

AXIAL TEMPERATURE MEASUREMENTS ON UNMODIFIED CIGARETTES

1 puff per minute, 35 ml puff

Code No.	Puff					Smoulder				
	Mean Maximum Temp. (°C)	Maximum Temp. (°C)	Distance Between 700°C Contours (mm)	Distance Between 400°C Contours (mm)	Approximate Distance of Hottest Part of Coal from Paper Burn (mm)	Mean Maximum Temp. (°C)	Maximum Temp. (°C)	Distance Between 700°C Contours (mm)	Distance Between 400°C Contours (mm)	Approximate Distance of Hottest Part of Coal from Paper Burn (mm)
RL 268	815	825	6	11	7	760	760	4	9.5	8
RL 268A	835	860	6	11	8	790	800	5	11	8
RL 268B	855	855	6	11	8	815	830	5	11	8
RL 268C	840	850	6	11	8	790	800	5	11	7

TABLE 3

TEMPERATURE MEASUREMENTS

3 puffs per minute, 35 ml puff

Code No.	Thermocouple	Puff					Smoulder				
		Mean Maximum Temp. (°C)	Maximum Temp. (°C)	Distance Between 700°C Contours (mm)	Distance Between 400°C Contours (mm)	Approximate distance of Hottest Part of Coal from Paper Burn (mm)	Mean Maximum Temp. (°C)	Maximum Temp. (°C)	Distance Between 700°C Contours (mm)	Distance Between 400°C Contours (mm)	Approximate distance of Hottest Part of Coal from Paper Burn (mm)
RL 268	1	780	815	8.5	14.5	11	790	800	7	13.5	11
	2	760	775	7.5	13.5	8	745	765	5.5	13.5	8
	3	750	750	3.5	12.5	2	650	650	-	10	5
RL2268C	1	825	850	10	14	11	810	825	8.5	14	11
	2	830	845	9.5	15	9.5	800	820	8	15	9
	3a*	650	700	-	6	2	520	540	-	6.5	3
	3b*	450	475	-	5	3					

* Individual results - poor duplicates

Code No	Distance Contour Moves Back on Axis of Cigarette in 1.5 Secs			Distance Between 200°-700°C (mm)
	200°C (mm)	400°C (mm)	700°C (mm)	
RL 268	1.3	1.5	1.8	5.5
RL 268C	1.3	0.7	0.7	4.8

Code No	Distance Between 200°-700°C (mm)	Smoulder Rate (mm/min)*	Time for Distance (min)
RL 268	5.9	3.96	1.49
RL 268C	4.2	2.65	1.59

* Unrealistic to use this smoulder rate as steady smoulder state not achieved at this puffing frequency

100457262

TABLE 4

TEMPERATURE MEASUREMENTS

1 puff per minute, 25 ml puff

Code No.	Thermocouple	Puff					Smoulder				
		Mean Maximum Temp. (°C)	Maximum Temp. (°C)	Distance Between 700°C Contours (mm)	Distance Between 400°C Contours (mm)	Approximate distance of Hottest Part of Coal from Paper Burn (mm)	Mean Maximum Temp. (°C)	Maximum Temp. (°C)	Distance Between 700°C Contours (mm)	Distance Between 400°C Contours (mm)	Approximate Distance of Hottest Part of Coal from Paper Burn (mm)
RL 268	1	790	805	5	11	6	750	750	3	10	6
	2	775	805	6	9	7	735	750	3	9	7
	3	845*	890*	4	8	4	600	675	-	9	8
RL 268C	1	855	860	5	10	8	785	790	4	10	8
	2	855	855	6	10	7	775	775	4	10	7
	3	650	665	-	8	2	615	620	-	7	4

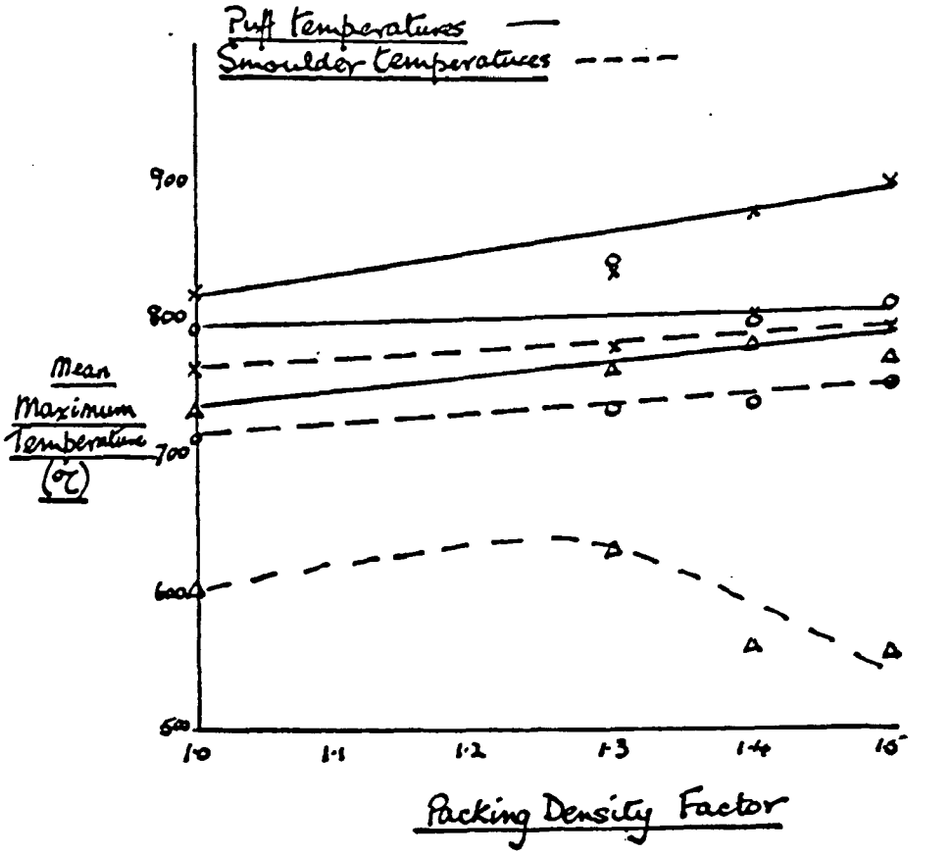
* Unusually high - probably attributable to peripheral hot spots

Fig 1

Variation of Mean Maximum Temperature with Packing Density (modified cigarettes) (1 puff per min)

Thermocouple positions

X – centre (axis)
O – 1·5mm from axis
Δ – 3·0mm from axis



100457264

Fig 2.

Variation of Mean Maximum Temperature with packing Density (unmodified cigarettes) (1 puff per min)