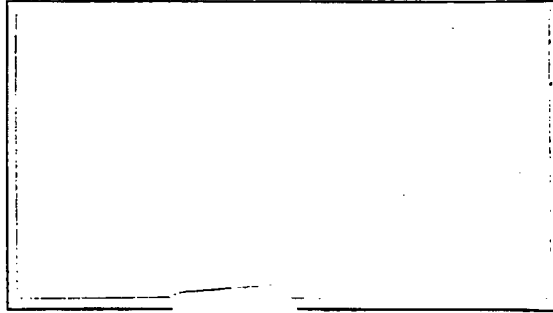


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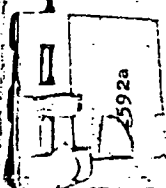


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Research & Development Establishment  
Southampton

RD 837-R

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THE EFFECT OF CHANGED DELIVERIES AT CONSTANT  
PRESSURE DROP ON HUMAN SMOKING PATTERN

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Research & Development Establishment,  
British-American Tobacco Co. Ltd.,  
SOUTHAMPTON.

DC/LMMcG/CAL/46D-6

3rd November, 1971.

THE EFFECT OF CHANGED DELIVERIES AT CONSTANT PRESSURE  
DROP ON HUMAN SMOKING PATTERN

(Report No. RD.837-R)

SUMMARY AND RECOMMENDATIONS

A test has been devised using existing techniques to show whether a panel of smokers would compensate by their puffing and inhaling behaviour for reduced deliveries of TPM and nicotine. The test took the form of a comparison between two cigarettes of similar pressure drop but differing deliveries of TPM and nicotine.

It was found that there is indeed a degree of compensation for the reduced delivery. The panel as a whole took larger puffs from the lower delivery cigarette, inhaled the smoke more deeply and held the smoke in the lungs for a longer time. The six individual panel members compensated for changed delivery in different ways, some by increased volumes, and others by increased numbers of puffs on the lower delivery cigarette. No attempt has been made to quantify the effect of the compensation in terms of smoke deliveries because, in the absence of a smoking machine which will accurately reproduce any given human smoking pattern, it is not possible to take account of differences in puff profile or in the spacing of puffs down the cigarette.

Further investigations are recommended in order to determine the effect on smoking pattern of various changes in cigarette design.

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INTRODUCTION

During recent years the cigarettes in many countries have shown a steady fall in their average smoke deliveries. However most markets continue to offer the consumer a fairly wide choice in this respect. Publication of "tar" and nicotine deliveries has led consumers to assume that switching to a lower delivery brand will of necessity reduce their intake of smoke. It becomes important to know whether this assumption is true. There is in fact some evidence to the contrary. Ashton and Watson (1) found that a group of subjects smoking a low nicotine cigarette took more frequent puffs than a second group smoking a high nicotine cigarette, and that both groups achieved very similar nicotine intakes. Because of the increased puffing frequency the low nicotine cigarette was smoked in a shorter time than the high nicotine cigarette. In a rather similar study involving three cigarettes, two of which were the same as those used by Ashton and Watson, Frith (2) observed the same effect of nicotine delivery on both puffing frequency and the time taken to smoke a cigarette, but did not observe any meaningful effect on puff volume. In addition he found that, during an eight hour period, the higher the nicotine content the smaller was the number of cigarettes smoked.

In the two studies quoted above the different levels of nicotine delivery were achieved largely by means of filters of different efficiency. This meant that the cigarettes differed not only in nicotine delivery but also in TPM delivery and pressure drop. It would be desirable to know the separate effect of each of these three variables on human smoking behaviour, and to investigate the effect of other cigarette

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design features. Equally it would be desirable to extend the observations of human smoking behaviour to include other relevant parameters, such as the spacing of puffs down the cigarette (which influences smoke delivery) and the inhalation/exhalation characteristics (which influence the degree of smoke retention within the respiratory system - see reference 3).

The experiment described in this report is the first of a series aimed at investigating the effect of certain cigarette design variables on human smoking behaviour. It is restricted to the manner in which individual cigarettes are smoked, with no observations on the rate of consumption of cigarettes over a period, but includes the additional behaviour parameters mentioned above. This first experiment compares two cigarettes of similar pressure drop but differing deliveries of TPM and nicotine.

#### EXPERIMENTAL PROCEDURE

The cigarettes designed for this trial were manufactured in R. & D.E. from the flue-cured Virginia tobacco blend used for State Express 555 Filter Kings. The cigarette dimensions and filter constructions are shown below in Table 1.

A panel of six subjects, all of whom were regular smokers, but untrained in the sensory evaluation of cigarettes, was assembled, and monitored while smoking these cigarettes at will.

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TABLE 1  
CIGARETTE DIMENSIONS AND FILTER CONSTRUCTIONS

(Dimensions expressed in mm)

		Cigarette A	Cigarette B
Tobacco rod	Length	69	69
	Circumference	24.75	24.75
Filter tobacco section	Material	-	Paper
	Length	-	15
Filter mouth section	Material	CA 8Y/48,000	CA 15/64,000
	Length	20	5

Both cigarette filters were over-wrapped with printed cork tipping paper, and there were no code or identification marks on either cigarette so that they were indistinguishable to the smokers.

The deliveries of nicotine and TPM, when smoked under standard conditions, are shown below in Table 2.

TABLE 2  
NICOTINE AND TPM DELIVERIES OF THE CIGARETTES WHEN SMOKED BY MACHINE

(TPM and Nicotine delivery expressed in mg)  
(Pressure drop expressed in cm W.G.)

Cigarette	A	B
Tip	20 mm C.A.	15 mm Paper + 5 mm C.A.
Total nicotine delivery	1.68	1.36
TPM delivery	30	24
Pressure drop	14.7	14.2
Mean puff number	10.3	10.2

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The breathing pattern was measured by impedance pneumograph according to the method previously described (4). The puff volume, duration and profile were also measured by the method described in (4). The inter-puff period was determined by measuring the distance between the recordings of puff profile on a continuous trace of the smoking, recorded on an U.V. recorder at the rate of 5 mm/second.

After the attachment of the two electrodes to the chest and an earth reference electrode to one leg for the recording of the breathing pattern, the subject was seated in an arm chair in the controlled environment room. He listened to music of his own choice, at whatever volume he wished. When settled he picked up the cigarette, which was held in the special holder, and lit it himself. The subjects smoked entirely at will and extinguished the cigarette when they had either smoked enough or finished the cigarette. The butt length was then measured.

During the smoking the subject was insulated from all external influences, and could not normally see the operator. A microphone was provided inside the environmental room so that the subject could communicate with the operator if necessary.

The six subjects smoked six examples of brands A and B, but only one cigarette was smoked on any particular day. The experimental design was such that 3 of each brand were smoked in the morning, and 3 in the afternoon. Three of the subjects smoked their six examples of A before B, and three subjects smoked B before A.

#### RESULTS

The averaged results for each subject, and for the entire panel, are shown in Table 3, and the statistical treatment of these results is shown in Table 4. For purposes of statistical evaluation, the results

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of each cigarette smoked by all subjects were fed into a computer (S.I.A. (London) C.D.C.6600) and evaluated by an analysis of variance for factorial design program (version 20-5-64 Health Sciences Computing Facility U.C.L.A.). The significance of the changes shown in Table 4 does not indicate the direction of the change, i.e. increase or decrease. Reference to the unprocessed data (Table 3) shows that all significant changes relating to the cigarettes are increases for the lower delivery cigarette.

In addition to the results in Table 3, an attempt has been made in Table 5 to express the spacing of the puffs with respect to time. The total time for which the cigarette was alight has been divided into three equal periods, designated the beginning third, middle third and end third. The average individual numbers of puffs taken in each of these thirds, together with the total smoke volume taken in each third, are presented in Table 5.

The beginning third of the cigarette includes the lighting puff, which is atypical in that the smoke is not often inhaled, but a puff taken shortly after the lighting puff is inhaled. It must be remembered that, by definition, the beginning third of a cigarette starts with a puff and similarly the end third finishes with a puff, whereas the probability is that the middle third both starts and finishes part way through an inter-puff period; thus in most cases fewer puffs will be taken from the middle third than from either the beginning or the end third even if all puffs are equally spaced with respect to time.

#### DISCUSSION

The results show that there was a highly significant difference between the subjects in all the measured parameters. The differences

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between the cigarettes are shown by significant changes in the puff volume and in all the measured aspects of the breathing pattern.

An increase in puff volume, but not puff duration, means that subjects must have drawn harder on the lower delivery cigarettes, and that the flow rate was greater during puffing. This implies that smokers are willing to work harder to achieve an optimum delivery from a lower delivery cigarette.

The differences in interpuff period were not statistically significant which is consistent with the result that the number of puffs taken was not significantly different.

The fact that the panel compensated for the lower delivery by increasing the depth of inhalation, the depth of exhalation and the total time for which the smoke was held within the body is of particular interest in the light of the finding that more is retained from a puff of smoke that is inhaled deeper, and held within the lungs for longer (3).

Reference to the unprocessed data (Table 3) suggests that individual panel members compensated for the changed deliveries in different ways. This can also be deduced from the statistical interactions. Subjects 3 and 5 took larger puffs from the lower delivery cigarette, inhaled the smoke more deeply and held it in the lungs for a longer time. Subject 4 compensated in a similar manner to subjects 3 and 5, except with regard to the residence time in the lungs. Subject 2, although not increasing his puff volume, took a larger number of puffs from the lower delivery cigarette, inhaled the smoke more deeply and held it in the lungs for a longer time. Subject 6 increased both the number of puffs and the puff volume when smoking the lower delivery cigarette, but did not inhale it quite as deeply and did not hold the smoke for any

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longer in the lungs. Subject 1 showed little compensation for changed delivery and smoked both cigarettes in an apparently similar manner. The results of some subjects tend to reflect the observations of previous investigators (1, 2) with regard to puffing frequency and the time taken to smoke a cigarette. Thus Subjects 2, 5 and 6 took more frequent puffs from the lower delivery cigarette, while Subjects 2 and 5 took less time to smoke this cigarette than to smoke the higher delivery cigarette.

There is no evidence in Table 5 of any dramatic difference between the two cigarettes with regard to the spacing of the puffs. The group average results show that more puffs were taken from the lower delivery cigarette in the first and final thirds, and that the total volume of smoke taken from each of the three sections of this cigarette was larger than from the higher delivery cigarette. Thus the tendency to compensate for the reduced smoke delivery was exhibited throughout the cigarette, and was not confined either to the early puffs or to the later puffs.

It has not been possible to take account of the puff profiles, which could influence the deliveries of TPM and nicotine from puffs of the same volume and duration. It is hoped that the actual intake of smoke components by the smokers can be measured when a system for accurately duplicating the human smoking behaviour is available.

Further trials will be necessary to investigate the effects of other changes in cigarette design, including pressure drop and TPM to nicotine ratio. With the existing panel, who are regular smokers of flue-cured Virginia tobacco cigarettes, it will be impracticable to extend the study to other tobacco types.

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REFERENCES

1. Ashton, H. and Watson, D.W. Br. Med. J. 1970, 3, 679-681.
2. Frith, C.D. Psychopharmacologia, 1971, 19, (2), 188-192.
3. B-A.T. R. & D.E. Report No. RD.824-R, 26.8.71.
4. B-A.T. R. & D.E. Report No. L.316-R, 2.9.69.

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TABLE 3

INDIVIDUAL AND GROUP AVERAGE PUFFING AND INHALING DATA FOR CIGARETTES  
A AND B SMOKE AT WILL

Subject	Cigarette	1	2	3	4	5	6	Group Average
		FB	RE	DI	TI	II	IP	
Number of puffs	A	10.5	12.0	13.5	17.2	17.5	14.8	14.2
	B	10.8	14.5	12.7	16.2	17.3	18.0	14.9
Puff volume (ml)	A	52.0	40.3	28.9	44.0	28.0	48.3	40.2
	B	47.2	40.4	31.1	45.0	40.1	50.5	42.4
Puff duration (sec)	A	2.5	2.0	0.9	1.4	2.9	2.0	2.0
	B	2.2	2.0	1.0	1.6	2.9	1.9	1.9
Interpuff period (sec)	A	40.9	30.6	36.1	21.2	24.2	21.6	29.1
	B	42.5	19.5	39.9	25.9	19.1	17.5	27.4
Inhalation depth (mm deflection)*	A	20.8	9.3	7.9	9.1	12.9	21.7	13.6
	B	15.0	12.6	10.8	13.5	27.6	18.6	16.4
Exhalation depth (mm deflection)*	A	27.1	11.9	11.8	10.4	15.4	27.1	17.2
	B	21.2	14.8	13.0	15.5	34.8	22.9	20.4
Inhalation time (sec)	A	1.3	1.0	0.8	1.2	1.2	1.0	1.1
	B	1.2	1.7	0.9	1.0	2.5	1.1	1.4
Exhalation time (sec)	A	2.1	1.2	1.2	1.2	1.4	1.8	1.5
	B	2.2	1.7	1.3	1.5	1.7	1.6	1.7
Total time alight (sec)	A	414	361	463	367	450	328	397
	B	442	293	477	419	362	333	388
Butt length (mm)	A	33	37	35	29	26	33	32
	B	33	37	35	28	26	35	33

\*mm deflection on the chart recorder, which is approximately proportional to volume.

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TABLE 4

THE STATISTICAL EVALUATION OF PUFFING AND INHALING DATA FOR 6 SUBJECTS SMOKING CIGARETTES A AND B AT WILL

Parameter	Difference between Subjects			Difference between Cigarettes			Interaction between Subjects and Cigarettes		
	Degrees of Freedom	F	Significance	Degrees of Freedom	F	Significance	Degrees of Freedom	F	Significance
Number of puffs	5	19.70	***	1	1.98	N.S.	5	2.20	N.S.
Puff volume	5	13.46	***	1	4.97	*	5	1.75	N.S.
Puff duration	5	66.31	***	1	1.58	N.S.	5	1.03	N.S.
Interpuff period	5	22.23	***	1	<1	N.S.	5	4.45	**
Inhalation depth	5	13.22	***	1	7.46	**	5	4.28	**
Exhalation depth	5	12.51	***	1	6.47	*	5	4.52	**
Inhalation time	5	6.16	***	1	4.53	*	5	2.48	*
Exhalation time	5	5.38	***	1	5.34	*	5	1.02	N.S.
Butt length	5	7.48	***	1	3.06	N.S.	5	<1	N.S.

\*\*\* Significant at 99.9% level  
 \*\* Significant at 99.0% level  
 \* Significant at 95.0% level  
 N.S. = Not significant

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TABLE 5

INDIVIDUAL AND GROUP AVERAGE NUMBERS OF PUFFS AND TOTAL VOLUMES OF SMOKE TAKEN FROM THE BEGINNING, MIDDLE AND END THIRDS OF THE TEST CIGARETTES

Puff volumes expressed in ml

Subject	Cigarette A						Cigarette B					
	Beginning		Middle		End		Beginning		Middle		End	
	Number of Puffs	Total Volume	Number of Puffs	Total Volume	Number of Puffs	Total Volume	Number of Puffs	Total Volume	Number of Puffs	Total Volume	Number of Puffs	Total Volume
1	4.0	214	3.0	152	3.5	179	4.8	228	3.0	139	3.0	142
2	4.8	191	3.7	151	3.5	139	5.7	238	4.2	159	4.7	179
3	5.0	156	3.8	108	4.7	128	4.8	162	3.5	104	4.3	128
4	8.0	359	4.5	206	4.7	188	6.7	314	4.5	197	5.0	211
5	6.5	214	5.5	141	5.5	121	7.0	312	4.5	166	5.8	210
6	6.2	321	3.8	183	4.8	213	7.5	407	5.2	256	5.3	263
Group Average	5.8	242	4.1	157	4.4	161	6.1	277	4.1	170	4.7	189

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