

CONFIDENTIAL

# UK SMOKE CONSTITUENTS STUDY

## Part 3 : Determination of Nitrogen Monoxide Yields in Cigarette Smoke

COMMISSIONED BY :

Tobacco Manufacturers Association

55 Tufton Street

LONDON SW1P 3QL

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*Setting standards  
in analytical science*

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## UK SMOKE CONSTITUENTS TESTING STUDY PROTOCOL

### Determination of Nitrogen Monoxide Yields in Cigarette Smoke

#### 1. Introduction

This work was undertaken by LGC Limited at the request of the Tobacco Manufacturers' Association in accordance with the Study Protocol provided by, and agreed with, the UK Department of Health.

#### 2. Summary

The objective of this study is to determine the yield ratings of selected smoke constituents (Appendix 1) in mainstream cigarette smoke as identified by the United Kingdom Department of Health. The study encompassed 25 brands of cigarettes representing a 58% market share (July 2001) of the UK market. In addition a Kentucky reference cigarette 1R4F has been smoked as part of the study.

This report details the results for Nitrogen Monoxide

#### 3. Samples

25 brands of cigarettes were selected because their design parameters are representative of the brands in the UK market place. The selection criteria include a range of "tar" values, ventilation, paper permeability, circumference, length, tobacco weight, blend and market share. The Kentucky reference cigarettes 1R4F & 1R5F were also included in this part of the study.

2000 cigarettes of each brand were obtained from a single production batch of current specification (November/December 2001), and stored in plastic containers at 4°C. Cigarettes were selected from packets on a random basis for testing.

Cigarettes were conditioned<sup>1</sup> at a temperature\* of  $22 \pm 1^\circ\text{C}$  and  $60 \pm 2\%$  relative humidity\* for a minimum of 48 hours but not exceeding 10 days.

Butt marking was done in accordance with ISO butt length specifications<sup>2</sup>. Filtered cigarettes were smoked to a measured butt length equal to either the tipping paper + 3 mm or filter length + 8 mm whichever was longer. The minimum butt length was 23 mm and this was used for non filter brands. All smoking was conducted in an environment of temperature  $22 \pm 2^\circ\text{C}$  and  $60 \pm 5\%$  relative humidity<sup>1</sup>.

#### 4. Smoking

The cigarettes were smoked on a 20 channel Rotary Borgwaldt smoking machine.

10 cigarettes were sub-sampled from packets chosen on a random basis and smoked to determine the yield of nitrogen monoxide using the method given below (see section 5) Five determinations were performed for each of the 25 brands & 1R4F. In addition the Kentucky Reference cigarette 1R5F was also tested. Brands were randomised and smoked on different

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\* The parameter is slightly more stringent than that specified in ISO

days – the exception being Vogue Superslims which were all smoked on the same day as the smoking machine has to be fitted with a different labyrinth holder for this size of cigarette.

ISO conditions<sup>3</sup> for smoking cigarettes were used. The smoking machine puffing parameters was  $35 \pm 0.2 \text{ cm}^3$  puff volume\* with  $2.0 \pm 0.02$  second puff duration once every  $60.0 \pm 0.5$  seconds.

## 5. Method and Validation

This method is applicable to the quantitative determination of nitrogen monoxide in vapour phase smoke of cigarettes of a range of deliveries. Ten conditioned cigarettes are smoked using a 20 channel rotary smoking machine. The vapour phase of fresh smoke from each puff is analysed using an instrument which measures the chemiluminescence produced by the reaction of nitrogen monoxide, NO, (also known as nitric oxide) with ozone. Immediate analysis of the fresh smoke from each puff is necessary because of the rapid reaction of nitric oxide with other vapour phase constituents.

The full method is given in an Annex to this report.

Before use, the method was validated to show that it was suitable for carrying out the bench mark study. The validation data is given in an Annex to this report.

## 6. Results & Discussion

The results were tabulated for each brand (see Tables). The mean, standard deviation and relative standard deviation were determined for each sets of results.

A summary of the results is included at the beginning (Page 6). Linear least squares regression analysis has been carried out for nitrogen monoxide yield versus NFDPM (Page 7) and nitrogen monoxide yield versus Carbon Monoxide (Page 7) for the twenty five cigarette brands (excluding 1R4F & 1R5F).

In this study there were no repeat analyses (denoted by an “r” at the end of the data). NB Equipment failure (e.g. sampling valve in the analyser stops working) during a smoking run is not counted as a repeat determination because there is no original result.

## 7. Outlier Test

It was agreed as part of the study protocol that Dixon’s outlier test would be performed on each set of results. This has been carried out and where an outlier has been detected then the result has been flagged “95%”. A judgement was then made as to whether to use the original results or recalculate the mean excluding the outlier. The CV values for each analyte across the 25 brands were examined before making this judgement. As a result of this, the original results have been used in the summary table as comparison of the CV values did not confirm that there are true outliers present in the original data.

## 8. Information provided in the Appendices and Annexes

Appendix 1 contains technical opinions and interpretations about the method, validation data and the results.<sup>4</sup>

Appendix 2 lists the specific analytes to be determined in the study.

Appendix 3 contains a brief glossary of selected abbreviations and terms used in this report

Appendix 4 contains a brief description of the cigarettes used in this survey. It also lists the butt lengths determined for each brand of cigarette.

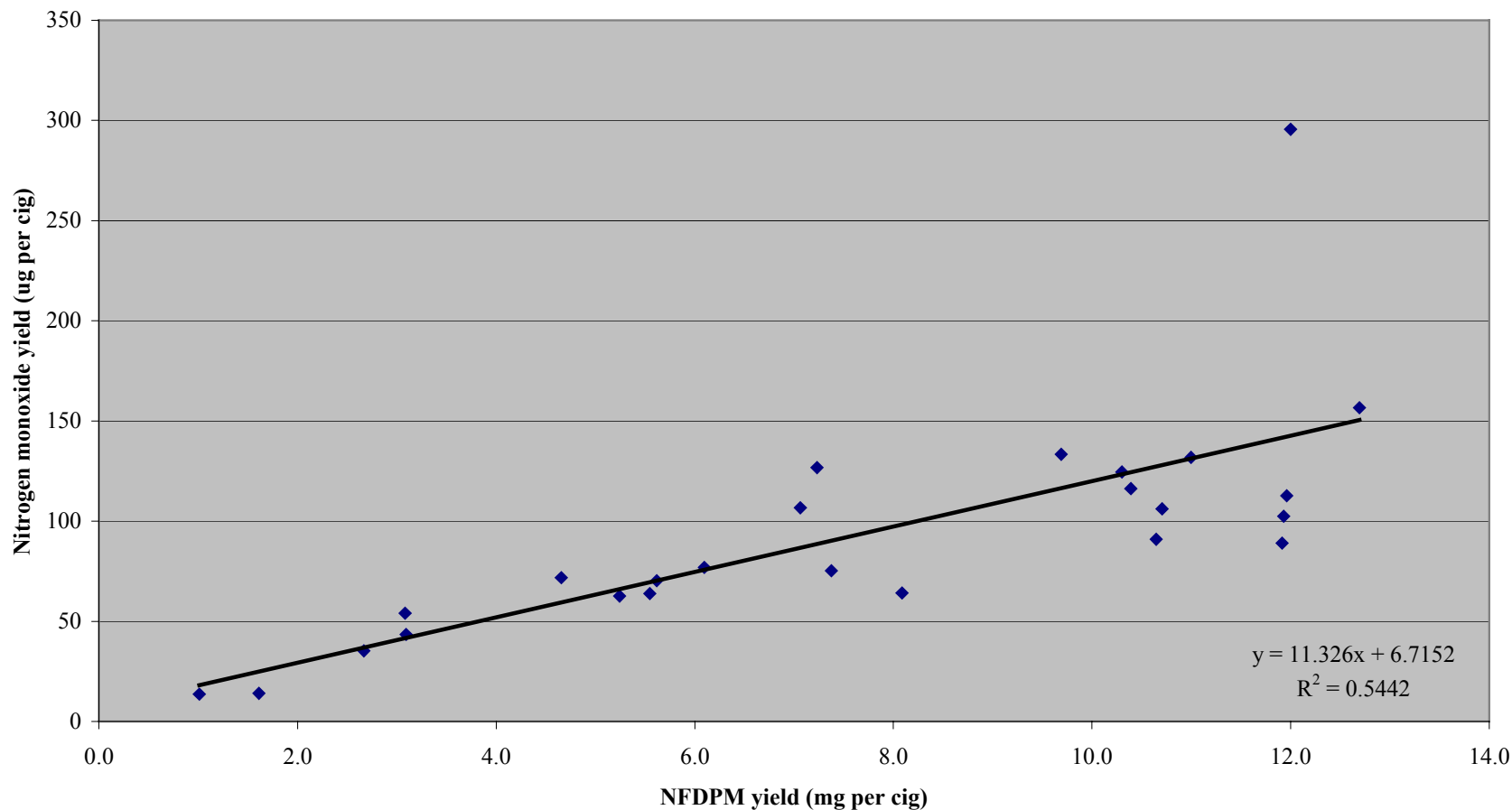
There are two Annexes to this report. One describes the method used to determine nitrogen monoxide yields in cigarette smoke. The other contains a summary of the validation data used to show that the method was suitable for the purposes of the bench mark study.

**Tables****Summary of mean results for 25 cigarette brands plus 1R4F & 1R5F**

<b>Brand</b>	<b>Nitrogen Monoxide</b>	<b>NFDPm</b>	<b>Carbon Monoxide</b>
	<b>ug/cig</b>	<b>mg/cig</b>	<b>mg/cig</b>
<b>1R4F</b>	277	9.06	12.26
<b>1R5F</b>	98.7	1.92	3.36
<b>Benson &amp; Hedges King Size</b>	125	10.30	11.74
<b>Berkely Superkings</b>	133	9.69	11.50
<b>Camel Ultra Lights</b>	43.4	3.09	3.13
<b>Consulate Menthol</b>	107	7.06	8.30
<b>Gitanes Caporal Filter</b>	296	12.00	12.60
<b>Lambert &amp; Butler King Size</b>	102	11.93	13.30
<b>Lambert &amp; Butler Lights King Size</b>	62.6	5.24	6.48
<b>Lambert &amp; Butler Ultra Lights</b>	14.1	1.61	1.49
<b>Marlboro King Size</b>	157	12.69	12.79
<b>Marlboro Lights King Size</b>	76.9	6.10	7.19
<b>Mayfair Lights King Size</b>	127	7.23	8.73
<b>Mayfair Menthol King Size</b>	71.8	4.65	5.95
<b>Red Band Lights King Size</b>	63.9	5.55	6.41
<b>Regal Filter</b>	90.9	10.65	10.92
<b>Regal King Size</b>	113	11.96	13.86
<b>Rothman Royals 120s</b>	116	10.39	9.44
<b>Rothman Royals King Size</b>	132	11.00	10.86
<b>Senior Service</b>	89.0	11.92	7.71
<b>Silk Cut Extra Mild</b>	35.3	2.67	3.16
<b>Silk Cut King Size</b>	70.3	5.62	5.78
<b>Silk Cut Ultra King Size</b>	13.7	1.01	1.20
<b>Superkings</b>	106	10.71	11.41
<b>Superkings Lights</b>	64.1	8.09	7.54
<b>Superkings Ultra Lights</b>	54.1	3.08	3.53
<b>Vogue Superslims</b>	75.3	7.38	6.05

**Regression analysis of nitrogen monoxide versus NFDPM**

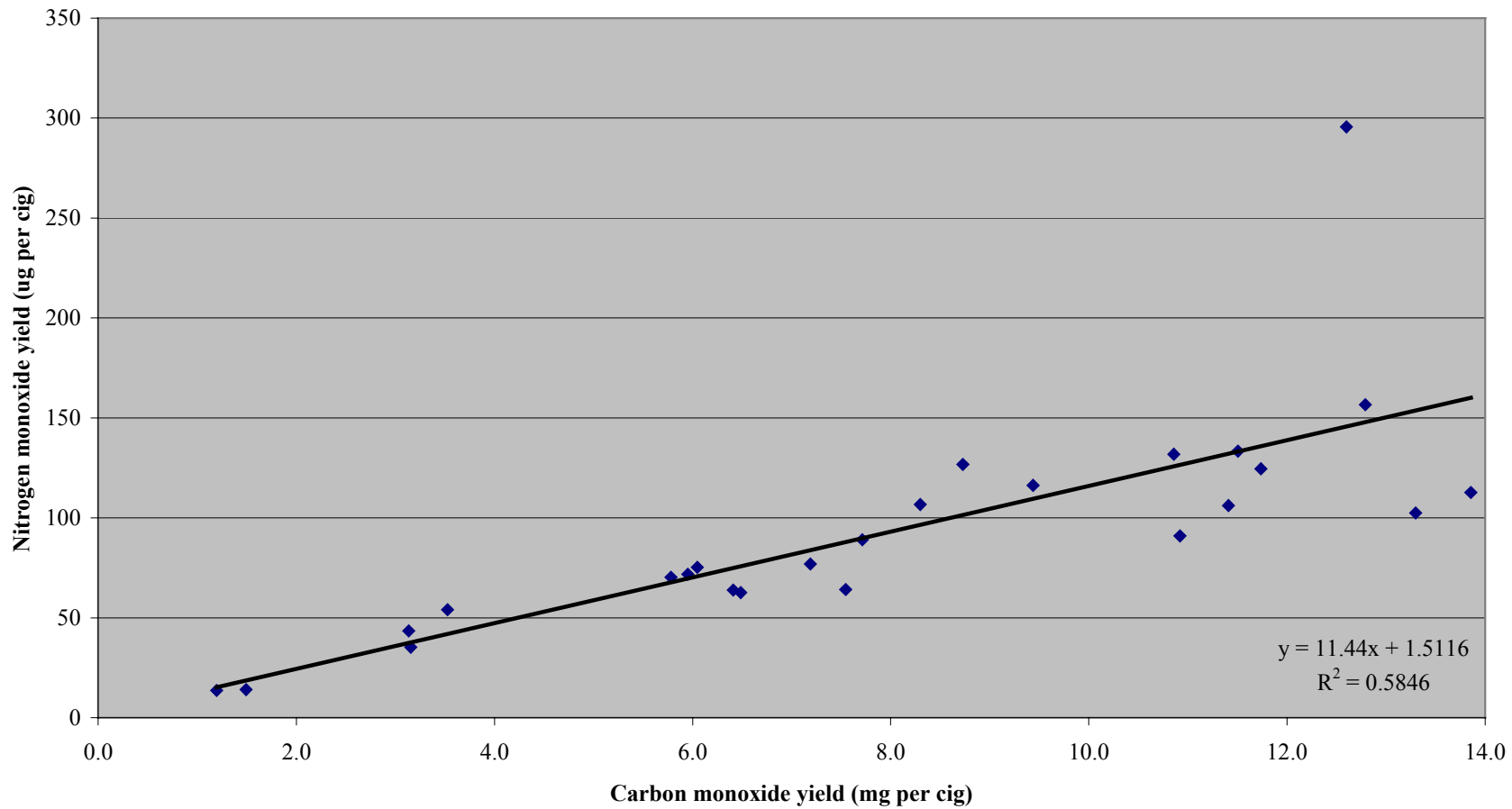
**Regression analysis of nitrogen monoxide versus NFDPM for 25 cigarette brands**



The regression analysis trend line has been calculated on the basis of a linear relationship ( $y = mx + c$ )

**Regression analysis of nitrogen monoxide versus carbon monoxide**

**Regression analysis of nitrogen monoxide versus carbon monoxide for 25 cigarette brands**



The regression analysis trend line has been calculated on the basis of a linear relationship ( $y = mx + c$ )

**1R4F**

<b>Brand</b>	<b>Total number of puffs (10 cigarettes)</b>	<b>NO concentration per puff (volume/volume expressed as ppm)</b>	<b>Nitrogen Monoxide yield (ug per cigarette)</b>
1R4F	81.3	729	260
1R4F	88.8	724	280
1R4F	84.6	765	282
1R4F	91.9	663	264
1R4F	88.7	766	297
<b>Mean (ug/cig)</b>			277
<b>Standard Deviation</b>			14.9
<b>CV (%)</b>			5.4
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			259.9229
			263.883
			280.1896
			282.0479
			296.7364
Statistical test applied			
Dixons low end test			0.107572
Outlier detected at 95%			
Dixons high end test			0.398998
Outlier detected at 95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			277
<b>Standard Deviation</b>			14.9
<b>CV (%)</b>			5.4

**1R5F**

<b>Brand</b>	<b>Total number of puffs (10 cigarettes)</b>	<b>NO concentration per puff (Volume/volume expressed as ppm)</b>	<b>Nitrogen Monoxide yield (ug per cigarette)</b>
1R5F	69.0	327	98.9
1R5F	74.3	295	95.5
1R5F	71.6	308	96.1
1R5F	75.0	298	96.9
1R5F	71.3	342	106
<b>Mean (ug/cig)</b>			98.7
<b>Standard Deviation</b>			4.43
<b>CV (%)</b>			4.5
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			
			95.45771
			96.06151
			96.90147
			98.8649
			106.3
Statistical test applied			
Dixons low end test			
Outlier detected at 95%			
Dixons high end test			
Outlier detected at 95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			98.7
<b>Standard Deviation</b>			4.43
<b>CV (%)</b>			4.5

**Benson & Hedges King Size**

<b>Brand</b>	<b>Total number of puffs (10 cigarettes)</b>	<b>NO concentration per puff (Volume/volume expressed as ppm)</b>	<b>Nitrogen Monoxide yield (ug per cigarette)</b>
Benson & Hedges King Size	84.0	337	124
Benson & Hedges King Size	88.4	297	114
Benson & Hedges King Size	89.9	317	124
Benson & Hedges King Size	90.3	354	137
Benson & Hedges King Size	90.1	316	124
<b>Mean (ug/cig)</b>			125
<b>Standard Deviation</b>			8.05
<b>CV (%)</b>			6.5
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			114.2317
			123.6134
			123.7416
			124.0746
			136.8438
Statistical test applied			
Dixons low end test			0.414896
Outlier detected at 95%			
Dixons high end test			0.564705
Outlier detected at 95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			125
<b>Standard Deviation</b>			8.05
<b>CV (%)</b>			6.5

### Berkely Superkings

Brand	Total number of puffs (10 cigarettes)	NO concentration per puff (Volume/volume expressed as ppm)	Nitrogen Monoxide yield (ug per cigarette)
Berkely Superkings	94.4	314	129
Berkely Superkings	98.2	293	125
Berkely Superkings	95.2	318	131
Berkely Superkings	95.8	331	137
Berkely Superkings	104.8	317	144
<b>Mean (ug/cig)</b>			133
<b>Standard Deviation</b>			7.33
<b>CV (%)</b>			5.5
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			125.1507
			129.4101
			131.4139
			136.7673
			144.1583
Statistical test applied			
Dixons low end test			0.224089
Outlier detected at 95%			
Dixons high end test			0.388843
Outlier detected at 95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			133
<b>Standard Deviation</b>			7.33
<b>CV (%)</b>			5.5

**Camel Ultra Lights**

<b>Brand</b>	<b>Total number of puffs (10 cigarettes)</b>	<b>NO concentration per puff (Volume/volume expressed as ppm)</b>	<b>Nitrogen Monoxide yield (ug per cigarette)</b>
Camel Ultra Lights	88.1	125	47.9
Camel Ultra Lights	82.2	103	36.7
Camel Ultra Lights	77.6	134	45.2
Camel Ultra Lights	86.8	116	43.6
Camel Ultra Lights	93.6	107	43.6
<b>Mean (ug/cig)</b>			43.4
<b>Standard Deviation</b>			4.13
<b>CV (%)</b>			9.5
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			36.69095
			43.55168
			43.56719
			45.20295
			47.87189
Statistical test applied			
Dixons low end test			0.61361
Outlier detected at 95%			
Dixons high end test			0.238705
Outlier detected at 95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			43.4
<b>Standard Deviation</b>			4.13
<b>CV (%)</b>			9.5

**Consulate Menthol**

<b>Brand</b>	<b>Total number of puffs (10 cigarettes)</b>	<b>NO concentration per puff (volume/volume expressed as ppm)</b>	<b>Nitrogen Monoxide yield (ug per cigarette)</b>
Consulate Menthol	82.2	326	116
Consulate Menthol	76.8	307	102
Consulate Menthol	76.4	309	103
Consulate Menthol	79.1	314	107
Consulate Menthol	80.1	301	105
<b>Mean (ug/cig)</b>			107
<b>Standard Deviation</b>			5.72
<b>CV (%)</b>			5.4
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			102.3739
			102.6054
			104.8318
			107.373
			116.2539
Statistical test applied			
Dixons low end test			0.01668
Outlier detected at 95%			
Dixons high end test			0.639831
Outlier detected at 95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			107
<b>Standard Deviation</b>			5.72
<b>CV (%)</b>			5.4

**Gitanes Caporal Filter**

<b>Brand</b>	<b>Total number of puffs (10 cigarettes)</b>	<b>NO concentration per puff (Volume/volume expressed as ppm)</b>	<b>Nitrogen Monoxide yield (ug per cigarette)</b>
Gitanes Caporal Filter	71.8	910	286
Gitanes Caporal Filter	76.5	863	287
Gitanes Caporal Filter	68.3	973	289
Gitanes Caporal Filter	73.3	1046	329
Gitanes Caporal Filter	66.1	994	286
<b>Mean (ug/cig)</b>			296
<b>Standard Deviation</b>			18.7
<b>CV (%)</b>			6.3
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			286.2902
			286.395
			287.4432
			288.7386
			328.9399
Statistical test applied			
Dixons low end test			0.002458
Outlier detected at 95%			
Dixons high end test			0.942593
Outlier detected at 95%			95%
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			287
<b>Standard Deviation</b>			1.14
<b>CV (%)</b>			0.4

**Lambert & Butler King Size**

<b>Brand</b>	<b>Total number of puffs (10 cigarettes)</b>	<b>NO concentration per puff (Volume/volume expressed as ppm)</b>	<b>Nitrogen Monoxide yield (ug per cigarette)</b>
Lambert & Butler King Size	85.2	262	97.5
Lambert & Butler King Size	75.9	280	92.2
Lambert & Butler King Size	78.7	291	99.5
Lambert & Butler King Size	79.5	346	118
Lambert & Butler King Size	83.0	290	105
<b>Mean (ug/cig)</b>			102
<b>Standard Deviation</b>			9.79
<b>CV (%)</b>			9.6
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			92.23959
			97.50405
			99.53033
			104.9289
			117.9469
Statistical test applied			
Dixons low end test			0.204785
Outlier detected at 95%			
Dixons high end test			0.506392
Outlier detected at 95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			102
<b>Standard Deviation</b>			9.79
<b>CV (%)</b>			9.6

**Lambert & Butler Lights King Size**

<b>Brand</b>	<b>Total number of puffs (10 cigarettes)</b>	<b>NO concentration per puff (Volume/volume expressed as ppm)</b>	<b>Nitrogen Monoxide yield (ug per cigarette)</b>
Lambert & Butler Lights King Size	67.8	228	67.1
Lambert & Butler Lights King Size	62.1	220	58.9
Lambert & Butler Lights King Size	68.6	204	60.8
Lambert & Butler Lights King Size	69.5	214	63.8
Lambert & Butler Lights King Size	69.8	205	62.4
<b>Mean (ug/cig)</b>			62.6
<b>Standard Deviation</b>			3.13
<b>CV (%)</b>			5.0
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			58.85541
			60.82611
			62.41078
			63.79699
			67.14041
Statistical test applied			
Dixons low end test			0.237863
Outlier detected at 95%			
Dixons high end test			0.403551
Outlier detected at 95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			62.6
<b>Standard Deviation</b>			3.13
<b>CV (%)</b>			5.0

**Lambert & Butler Ultra Lights**

<b>Brand</b>	<b>Total number of puffs (10 cigarettes)</b>	<b>NO concentration per puff (Volume/volume expressed as ppm)</b>	<b>Nitrogen Monoxide yield (ug per cigarette)</b>
Lambert & Butler Ultra Lights	78.6	33.4	11.5
Lambert & Butler Ultra Lights	72.5	30.6	9.67
Lambert & Butler Ultra Lights	80.4	52.0	18.2
Lambert & Butler Ultra Lights	80.9	48.0	16.7
Lambert & Butler Ultra Lights	80.2	41.2	14.4
<b>Mean (ug/cig)</b>			14.1
<b>Standard Deviation</b>			3.53
<b>CV (%)</b>			25.1
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			9.670119
			11.47577
			14.39566
			16.65537
			18.18042
Statistical test applied			
Dixons low end test			0.212173
Outlier detected at 95%			
Dixons high end test			0.1792
Outlier detected at 95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			14.1
<b>Standard Deviation</b>			3.53
<b>CV (%)</b>			25.1

**Marlboro King Size**

<b>Brand</b>	<b>Total number of puffs (10 cigarettes)</b>	<b>NO concentration per puff (Volume/volume expressed as ppm)</b>	<b>Nitrogen Monoxide yield (ug per cigarette)</b>
Marlboro King Size	90.3	416	163
Marlboro King Size	92.2	356	142
Marlboro King Size	96.9	372	156
Marlboro King Size	97.8	402	170
Marlboro King Size	98.2	356	152
<b>Mean (ug/cig)</b>			157
<b>Standard Deviation</b>			10.8
<b>CV (%)</b>			6.9
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			141.7221
			152.1734
			156.1835
			162.8224
			170.1806
Statistical test applied			
Dixons low end test			0.367247
Outlier detected at 95%			
Dixons high end test			0.258557
Outlier detected at 95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			157
<b>Standard Deviation</b>			10.8
<b>CV (%)</b>			6.9

**Marlboro Lights King Size**

<b>Brand</b>	<b>Total number of puffs (10 cigarettes)</b>	<b>NO concentration per puff (volume/volume expressed as ppm)</b>	<b>Nitrogen Monoxide yield (ug per cigarette)</b>
Marlboro Lights King Size	82.2	226	80.7
Marlboro Lights King Size	75.5	220	71.8
Marlboro Lights King Size	85.0	208	76.7
Marlboro Lights King Size	83.0	217	77.9
Marlboro Lights King Size	87.0	204	77.3
<b>Mean (ug/cig)</b>			76.9
<b>Standard Deviation</b>			3.22
<b>CV (%)</b>			4.2
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			71.81459
			76.73705
			77.28476
			77.87666
			80.68996
Statistical test applied			
Dixons low end test			0.55462
Outlier detected at 95%			
Dixons high end test			0.316979
Outlier detected at 95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			76.9
<b>Standard Deviation</b>			3.22
<b>CV (%)</b>			4.2

### Mayfair Lights King Size

Brand	Total number of puffs (10 cigarettes)	NO concentration per puff (volume/volume expressed as ppm)	Nitrogen Monoxide yield (ug per cigarette)
Mayfair Lights King Size	79.9	342	119
Mayfair Lights King Size	84.5	335	123
Mayfair Lights King Size	81.3	361	128
Mayfair Lights King Size	85.0	371	135
Mayfair Lights King Size	81.2	361	128
<b>Mean (ug/cig)</b>			127
<b>Standard Deviation</b>			5.93
<b>CV (%)</b>			4.7
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			119.3124
			123.3548
			127.5035
			128.0746
			135.199
Statistical test applied			
Dixons low end test			0.254454
Outlier detected at 95%			
Dixons high end test			0.448452
Outlier detected at 95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			127
<b>Standard Deviation</b>			5.93
<b>CV (%)</b>			4.7

**Mayfair Menthol King Size**

<b>Brand</b>	<b>Total number of puffs (10 cigarettes)</b>	<b>NO concentration per puff (volume/volume expressed as ppm)</b>	<b>Nitrogen Monoxide yield (ug per cigarette)</b>
Mayfair Menthol King Size	78.1	181	61.9
Mayfair Menthol King Size	85.1	188	69.9
Mayfair Menthol King Size	74.4	225	72.9
Mayfair Menthol King Size	77.2	251	83.2
Mayfair Menthol King Size	77.7	210	71.3
<b>Mean (ug/cig)</b>			71.8
<b>Standard Deviation</b>			7.63
<b>CV (%)</b>			10.6
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			61.89086
			69.86106
			71.28065
			72.87602
			83.18514
Statistical test applied			
Dixons low end test			0.374288
Outlier detected at 95%			
Dixons high end test			0.484126
Outlier detected at 95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			71.8
<b>Standard Deviation</b>			7.63
<b>CV (%)</b>			10.6

**Red Band Lights King Size**

<b>Brand</b>	<b>Total number of puffs (10 cigarettes)</b>	<b>NO concentration per puff (Volume/volume expressed as ppm)</b>	<b>Nitrogen Monoxide yield (ug per cigarette)</b>
Red Band Lights King Size	89.1	164	63.6
Red Band Lights King Size	82.5	152	54.6
Red Band Lights King Size	89.5	172	67.1
Red Band Lights King Size	91.6	174	68.4
Red Band Lights King Size	92.5	163	65.7
<b>Mean (ug/cig)</b>			63.9
<b>Standard Deviation</b>			5.51
<b>CV (%)</b>			8.6
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			54.55873
			63.6331
			65.67174
			67.11026
			68.43894
Statistical test applied			
Dixons low end test			0.653763
Outlier detected at 95%			
Dixons high end test			0.095725
Outlier detected at 95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			63.9
<b>Standard Deviation</b>			5.51
<b>CV (%)</b>			8.6

**Regal Filter**

<b>Brand</b>	<b>Total number of puffs (10 cigarettes)</b>	<b>NO concentration per puff (Volume/volume expressed as ppm)</b>	<b>Nitrogen Monoxide yield (ug per cigarette)</b>
Regal Filter	70.9	277	85.7
Regal Filter	70.6	288	88.5
Regal Filter	71.9	277	86.5
Regal Filter	73.5	309	97.4
Regal Filter	72.9	303	96.4
<b>Mean (ug/cig)</b>			90.9
<b>Standard Deviation</b>			5.56
<b>CV (%)</b>			6.1
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			85.73312
			86.54714
			88.45688
			96.38747
			97.3815
Statistical test applied			
Dixons low end test			0.069883
Outlier detected at 95%			
Dixons high end test			0.085336
Outlier detected at 95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			90.9
<b>Standard Deviation</b>			5.56
<b>CV (%)</b>			6.1

**Regal King Size**

<b>Brand</b>	<b>Total number of puffs (10 cigarettes)</b>	<b>NO concentration per puff (volume/volume expressed as ppm)</b>	<b>Nitrogen Monoxide yield (ug per cigarette)</b>
Regal King Size	77.8	326	110
Regal King Size	76.6	325	108
Regal King Size	88.0	280	107
Regal King Size	89.7	304	117
Regal King Size	85.5	326	121
<b>Mean (ug/cig)</b>			113
<b>Standard Deviation</b>			6.24
<b>CV (%)</b>			5.5
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			107.2354
			107.731
			110.0708
			116.9842
			121.4123
Statistical test applied			
Dixons low end test			0.034958
Outlier detected at 95%			
Dixons high end test			0.312347
Outlier detected at 95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			113
<b>Standard Deviation</b>			6.24
<b>CV (%)</b>			5.5

**Rothman Royals 120s**

<b>Brand</b>	<b>Total number of puffs (10 cigarettes)</b>	<b>NO concentration per puff (Volume/volume expressed as ppm)</b>	<b>Nitrogen Monoxide yield (ug per cigarette)</b>
Rothman Royals 120s	113.1	262	129
Rothman Royals 120s	116.9	210	107
Rothman Royals 120s	117.9	217	111
Rothman Royals 120s	120.7	226	118
Rothman Royals 120s	125.4	215	117
<b>Mean (ug/cig)</b>			116
<b>Standard Deviation</b>			8.41
<b>CV (%)</b>			7.2
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			106.7926
			110.8648
			117.0027
			117.9159
			128.9455
Statistical test applied			
Dixons low end test			0.183821
Outlier detected at 95%			
Dixons high end test			0.497885
Outlier detected at 95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			116
<b>Standard Deviation</b>			8.41
<b>CV (%)</b>			7.2

**Rothman Royals King Size**

<b>Brand</b>	<b>Total number of puffs (10 cigarettes)</b>	<b>NO concentration per puff (Volume/volume expressed as ppm)</b>	<b>Nitrogen Monoxide yield (ug per cigarette)</b>
Rothman Royals King Size	87.5	291	110
Rothman Royals King Size	87.1	352	134
Rothman Royals King Size	90.2	350	137
Rothman Royals King Size	90.4	358	140
Rothman Royals King Size	89.5	356	138
<b>Mean (ug/cig)</b>			132
<b>Standard Deviation</b>			12.2
<b>CV (%)</b>			9.2
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			110.4747
			133.5295
			136.8886
			138.4498
			139.9421
Statistical test applied			
Dixons low end test			0.782384
Outlier detected at 95%			95%
Dixons high end test			0.050643
Outlier detected at 95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			137
<b>Standard Deviation</b>			2.75
<b>CV (%)</b>			2.00

**Senior Service**

<b>Brand</b>	<b>Total number of puffs (10 cigarettes)</b>	<b>NO concentration per puff (volume/volume expressed as ppm)</b>	<b>Nitrogen Monoxide yield (ug per cigarette)</b>
Senior Service	71.3	266	82.9
Senior Service	70.5	315	96.9
Senior Service	69.0	290	86.9
Senior Service	72.5	281	87.4
Senior Service	69.0	303	91.0
<b>Mean (ug/cig)</b>			89.0
<b>Standard Deviation</b>			5.27
<b>CV (%)</b>			5.9
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			
			82.85773
			86.94883
			87.43581
			90.95229
			96.92224
Statistical test applied			
Dixons low end test			
Outlier detected at 95%			
Dixons high end test			
Outlier detected at 95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			89.0
<b>Standard Deviation</b>			5.27
<b>CV (%)</b>			5.9

**Silk Cut Extra Mild**

<b>Brand</b>	<b>Total number of puffs (10 cigarettes)</b>	<b>NO concentration per puff (volume/volume expressed as ppm)</b>	<b>Nitrogen Monoxide yield (ug per cigarette)</b>
Silk Cut Extra Mild	78.8	115	39.3
Silk Cut Extra Mild	73.2	107	34.1
Silk Cut Extra Mild	77.9	106	35.7
Silk Cut Extra Mild	78.0	97.9	33.0
Silk Cut Extra Mild	76.9	102	34.2
<b>Mean (ug/cig)</b>			35.3
<b>Standard Deviation</b>			2.43
<b>CV (%)</b>			6.9
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			33.02835
			34.07893
			34.24566
			35.69158
			39.26476
Statistical test applied			
Dixons low end test			0.16846
Outlier detected at 95%			
Dixons high end test			0.572953
Outlier detected at 95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			35.3
<b>Standard Deviation</b>			2.43
<b>CV (%)</b>			6.9

**Silk Cut King Size**

<b>Brand</b>	<b>Total number of puffs (10 cigarettes)</b>	<b>NO concentration per puff (Volume/volume expressed as ppm)</b>	<b>Nitrogen Monoxide yield (ug per cigarette)</b>
Silk Cut King Size	89.6	165	64.8
Silk Cut King Size	94.4	159	65.6
Silk Cut King Size	92.7	169	68.3
Silk Cut King Size	96.2	214	88.2
Silk Cut King Size	88.9	167	64.6
<b>Mean (ug/cig)</b>			70.3
<b>Standard Deviation</b>			10.1
<b>CV (%)</b>			14.4
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			
			64.57772
			64.77658
			65.55576
			68.29438
			88.19851
Statistical test applied			
Dixons low end test			
			0.008419
Outlier detected at 95%			
Dixons high end test			
			0.842653
Outlier detected at 95%			
			95%
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			65.8
<b>Standard Deviation</b>			1.71
<b>CV (%)</b>			2.6

**Silk Cut Ultra King Size**

<b>Brand</b>	<b>Total number of puffs (10 cigarettes)</b>	<b>NO concentration per puff (volume/volume expressed as ppm)</b>	<b>Nitrogen Monoxide yield (ug per cigarette)</b>
Silk Cut Ultra King Size	81.1	30.5	10.8
Silk Cut Ultra King Size	84.9	40.2	14.9
Silk Cut Ultra King Size	88.7	29.3	11.3
Silk Cut Ultra King Size	84.7	39.4	14.3
Silk Cut Ultra King Size	81.9	47.4	17.0
<b>Mean (ug/cig)</b>			13.7
<b>Standard Deviation</b>			2.57
<b>CV (%)</b>			18.8
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			10.82305
			11.30365
			14.333
			14.86201
			16.95105
Statistical test applied			
Dixons low end test			0.078427
Outlier detected at 95%			
Dixons high end test			0.340901
Outlier detected at 95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			13.7
<b>Standard Deviation</b>			2.57
<b>CV (%)</b>			18.8

### Superkings

Brand	Total number of puffs (10 cigarettes)	NO concentration per puff (Volume/volume expressed as ppm)	Nitrogen Monoxide yield (ug per cigarette)
Superkings	84.5	274	100
Superkings	82.6	315	112
Superkings	82.3	314	113
Superkings	86.3	284	106
Superkings	86.5	264	99.5
<b>Mean (ug/cig)</b>			106
<b>Standard Deviation</b>			6.24
<b>CV (%)</b>			5.9
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			99.45496
			100.3349
			106.0495
			112.0637
			112.6311
Statistical test applied			
Dixons low end test			0.066782
Outlier detected at 95%			
Dixons high end test			0.043063
Outlier detected at 95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			106
<b>Standard Deviation</b>			6.24
<b>CV (%)</b>			5.9

### Superkings Lights

Brand	Total number of puffs (10 cigarettes)	NO concentration per puff (Volume/volume expressed as ppm)	Nitrogen Monoxide yield (ug per cigarette)
Superkings Lights	81.9	178	63.3
Superkings Lights	88.0	176	66.9
Superkings Lights	88.6	171	65.9
Superkings Lights	91.4	163	64.3
Superkings Lights	89.4	155	60.4
<b>Mean (ug/cig)</b>			64.1
<b>Standard Deviation</b>			2.52
<b>CV (%)</b>			3.9
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			60.36626
			63.34482
			64.28122
			65.90506
			66.85262
Statistical test applied			
Dixons low end test			0.459203
Outlier detected at 95%			
Dixons high end test			0.146085
Outlier detected at 95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			64.1
<b>Standard Deviation</b>			2.52
<b>CV (%)</b>			3.9

### Superkings Ultra Lights

Brand	Total number of puffs (10 cigarettes)	NO concentration per puff (volume/volume expressed as ppm)	Nitrogen Monoxide yield (ug per cigarette)
Superkings Ultra Lights	75.4	170	55.7
Superkings Ultra Lights	69.1	161	47.9
Superkings Ultra Lights	76.2	173	57.3
Superkings Ultra Lights	77.3	170	56.5
Superkings Ultra Lights	77.4	157	52.8
<b>Mean (ug/cig)</b>			54.1
<b>Standard Deviation</b>			3.81
<b>CV (%)</b>			7.0
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			47.94478
			52.84307
			55.69403
			56.53264
			57.28528
Statistical test applied			
Dixons low end test			0.524414
Outlier detected at 95%			
Dixons high end test			0.080579
Outlier detected at 95%			
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			54.1
<b>Standard Deviation</b>			3.81
<b>CV (%)</b>			7.0

**Vogue Superslims**

<b>Brand</b>	<b>Total number of puffs (10 cigarettes)</b>	<b>NO concentration per puff (Volume/volume expressed as ppm)</b>	<b>Nitrogen Monoxide yield (ug per cigarette)</b>
Vogue Superslims	79.1	216	74.0
Vogue Superslims	76.5	249	82.5
Vogue Superslims	78.8	216	73.7
Vogue Superslims	77.8	216	72.7
Vogue Superslims	79.2	214	73.5
<b>Mean (ug/cig)</b>			75.3
<b>Standard Deviation</b>			4.04
<b>CV (%)</b>			5.4
<i>Outlier Test</i>			
Dixons outlier test was applied to the above data			
Data sorted			72.70567
			73.53122
			73.68431
			74.0495
			82.45665
Statistical test applied			
Dixons low end test			0.084663
Outlier detected at 95%			
Dixons high end test			0.862185
Outlier detected at 95%			
			95%
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>			
<b>Summary of Results</b>			
<b>Mean (ug/cig)</b>			73.5
<b>Standard Deviation</b>			0.57
<b>CV (%)</b>			0.8

## Appendix 1: Technical opinions and interpretations

The following notes have been compiled to point up technical issues encountered in developing and validating the method to determine nitrogen monoxide in cigarette smoke.

### Interference

The specificity of the method is important to ensure that the target analyte is being measured rather than the many other chemicals present in cigarette smoke. Previous work<sup>†</sup> has shown that small amounts of interference can arise from two sources, but act in opposite directions. Firstly the presence of carbon monoxide quenches (decreases) the response due to NO and secondly certain alkenes lead to artificial chemiluminescence producing an increased response.<sup>‡</sup>

### Measurement uncertainty

All measurements have an uncertainty associated with them. There are two components in the uncertainty of each result (a) sample (smoking of the cigarette), (b) analysis by the nitrogen monoxide analyser.

There is some evidence that samples containing low concentrations of nitrogen monoxide gave larger uncertainties than “high yield” brands – this would be expected as sample concentrations at the bottom end of the calibration range are close to the intercept which varies from run to run.

### Reproducibility

Nitrogen monoxide concentration in cigarette smoke decreases rapidly with time. Therefore the amount of nitrogen monoxide in cigarette smoke measured by a laboratory will be dependent on the set up of the smoking machine/NO analyser. There was approximately a 6 second delay between smoking and analysis with the set up used in this study.

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<sup>†</sup> P R Houlgate and W H Evans, Artificial chemiluminescence in the determination of nitrogen monoxide in the vapour phase of mainstream cigarette smoke., *Analyst*, 1989, **114**, 71 – 75

<sup>‡</sup> Nitric Oxide yields of cigarettes, Report for DoH, June 1998 (available from [www.doh.gov.uk/scoth](http://www.doh.gov.uk/scoth))

**Appendix 2: Selected smoke constituents for UK study**

<b>Type</b>	<b>Specific analyte(s)</b>
	nicotine free dry particulate matter
	nicotine
	carbon monoxide
	ammonia
	hydrogen cyanide
	nitrogen monoxide
Aromatic amines	1-aminonaphthalene
	2-aminonaphthalene
	3-aminobiphenyl
	4-aminobiphenyl
Aldehydes & Ketones	formaldehyde
	acetaldehyde
	acetone
	acrolein
	propionaldehyde
	crotonaldehyde
	methyl ethyl ketone
	butyraldehyde
Nitrosamines	n-nitrosomicotine (nnn)
	n-nitrosoanatabine (nat)
	n-nitrosanabasine (nab)
	n-nitrososnormicotine ketone (nnk)
Phenols	phenol
	catchechol
	hydroquinone
	resorcinol
	ortho-cresol
	meta-cresol
	para-cresol
Polycyclic aromatic hydrocarbons	benzo[a]pyrene
Semi Volatile Compounds	pyridine
	quinoline
	styrene
Trace Metals	arsenic
	cadmium
	chromium
	lead
	mercury
	nickel
	selenium
Volatile Organic Compounds	benzene
	toluene
	1,3-butadiene
	isoprene
	acrylonitrile

**Appendix 3: Selected abbreviations and terms used in this report**

<b>Term/Definition</b>	<b>Meaning</b>
NO	Nitrogen Monoxide
Channel	The channel of the smoking machine that the cigarette was smoked on
CO	Carbon Monoxide
CO(%v/v)	Percentage volume of carbon monoxide in the total volume of mainstream smoke corrected for any clearing puffs
Overwrap	The wrapper applied to the mouth end of the cigarette
Run	The smoking run that the cigarette was smoked in
TPM	Total Particulate Matter
Yield	The concentration of analyte measured in the smoke (normally per cigarette)
°C	Degree Celsius
ng	Nanogram
µg	Microgram
mg	Milligram
mL	Millilitre
L	Litre
mm	Millimetre
cig <sup>-1</sup>	per cigarette
ppm	Parts per million
v/v (ppm)	Volume/volume expressed in parts per million (sometimes called vpm)

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<sup>1</sup> ISO 3402: 2000 - Tobacco and tobacco products – atmosphere for conditioning and testing

<sup>2</sup> ISO 4387: 2000 - Methods for chemical analysis of tobacco and tobacco products: Determination of total and nicotine- free dry particulate matter using a routine analytical smoking machine

<sup>3</sup> ISO 3308:2000 – Routine analytical cigarette smoking machine: Definitions and standard conditions

<sup>4</sup> NB When evaluating a set of results obtained using a particular method it is important to put the results in context and this is what we have set out to do in this Appendix.

**Appendix 4: Description of brands (sold in the UK - Nov/Dec 2001) used in the benchmark study**

<b>Brand</b>	<b>Length (mm)</b>	<b>Butt length used for the study (mm)</b>	<b>Description</b>
Benson & Hedges King Size	84	28	filter – typical UK blend
Berkeley Superkings	99	33	filter – typical UK blend
Camel Ultra Lights	84	35	filter – typical American blend
Consulate Menthol	84	35	filter – typical UK blend – menthol
Gitanes Caporal Filter	70	23	filter – dark air cured blend
Lambert & Butler King Size	84	30	filter – typical UK blend
Lambert & Butler Lights King Size	84	34 (overwrap + 3 mm)	filter – typical UK blend
Lambert & Butler Ultra Lights	84	34 (overwrap + 3 mm)	filter – typical UK blend
Marlboro King Size	84	29	filter – typical American blend
Marlboro Lights King Size	84	35	filter – typical American blend
Mayfair Lights King Size	84	28	filter – typical UK blend
Mayfair Menthol King Size	84	33	filter – typical UK blend – menthol
Red Band Lights King Size	84	33	filter – typical UK blend
Regal Filter	71	26	filter – typical UK blend
Regal King Size	84	30	filter – typical UK blend
Rothman Royals 120s	120	38	filter – typical UK blend
Rothman Royals King Size	84	30	filter – typical UK blend
Senior Service	69	23	plain - typical UK blend
Silk Cut Extra Mild	84	33	filter – typical UK blend
Silk Cut King Size	84	28	filter – typical UK blend
Silk Cut Ultra King Size	84	33 (overwrap + 3 mm)	filter – typical UK blend
Superkings	99	34	filter – typical UK blend
Superkings Lights	99	33	filter – typical UK blend
Superkings Ultra Lights	99	34	filter – typical UK blend
Vogue Superslims	99	38	filter – typical American blend