

CONFIDENTIAL

UK SMOKE CONSTITUENTS STUDY

Part 6 : Determination of Hydrogen Cyanide Yields in Cigarette Smoke

COMMISSIONED BY :

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Consumer Safety and Tobacco Products Group



*Setting standards
in analytical science*

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UK SMOKE CONSTITUENTS TESTING STUDY PROTOCOL

Determination of Hydrogen Cyanide 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(s) has been smoked as part of the study.

This report details the results for hydrogen cyanide.

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 and 1R5F were 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 conditioned¹ 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 specifications². 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 humidity¹.

4. Smoking

The cigarettes were smoked on a 20 channel Filtrona SM350 smoking machine or a Filtrona SM400 smoking machine.

2 cigarettes were sub-sampled from packets chosen on a random basis and smoked to determine the yield of hydrogen cyanide using the method given below (see section 5) Five determinations were performed for each of the 25 brands, 1R4F and 1R5F. As far as was practicable sub-samples of each brand were smoked on different channels on different smoking runs.

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

ISO conditions³ for smoking cigarettes were used. The smoking machine puffing parameters was $35 \pm 0.2 \text{ cm}^3$ puff volume* with 2.0 ± 0.02 second puff duration once every 60.0 ± 0.5 seconds.

5. Method and Validation

This method is applicable to determination of hydrogen cyanide in mainstream tobacco smoke by UV/Visible Spectroscopy. Two conditioned cigarettes are smoked on a 20 channel linear smoking machine. The mainstream smoke is passed through Cambridge filter holders (with pad) attached to glass manifolds containing silica gel. The hydrogen cyanide is extracted from the filter pad and silica gel into dilute sodium hydroxide solution. The smoke solutions are then treated to a two stage process which complexes the cyanide ions present so that the absorbance might be measured. First, an aliquot of the smoke solution is put into a test tube, buffer solution added followed by chloramine-T to generate cyanogen chloride. Secondly, pyridine/barbituric acid reagent is added to produce a visibly coloured complex. The solutions are then analysed using a UV/visible spectrophotometer.

The full method is given in an Annexe 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 Annexe 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 set of results.

A summary of the results is included at the beginning (Page 6). Linear least squares regression analysis has been carried out for hydrogen cyanide yield versus carbon monoxide (Page 7) and hydrogen cyanide yield versus NFDPM (Page 8) for the twenty five cigarette brands (excluding 1R4F and 1R5F).

The study showed that the reporting limit set was higher than the hydrogen cyanide yields for some low tar brands. To determine the reporting limit, a blank sample solution had been put through the analysis procedure ten times. The mean of the blank plus 5 sample standard deviations gave a concentration of $0.10 \mu\text{g mL}^{-1}$. NB The reporting limit of $< 8 \mu\text{g cig}^{-1}$ was calculated using this limit of quantitation for the blank sample (assuming 150 mL NaOH & 2 cigarettes smoked).

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 Annex

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

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.

The Annex to this report lists the method used to determine the hydrogen cyanide yields in cigarette smoke. It also contains a summary of the validation data used to show that the method was suitable for the purposes of the bench mark study.

¹ ISO 3402: 2000 - Tobacco and tobacco products – atmosphere for conditioning and testing

² 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

³ ISO 3308:2000 – Routine analytical cigarette smoking machine: Definitions and standard conditions

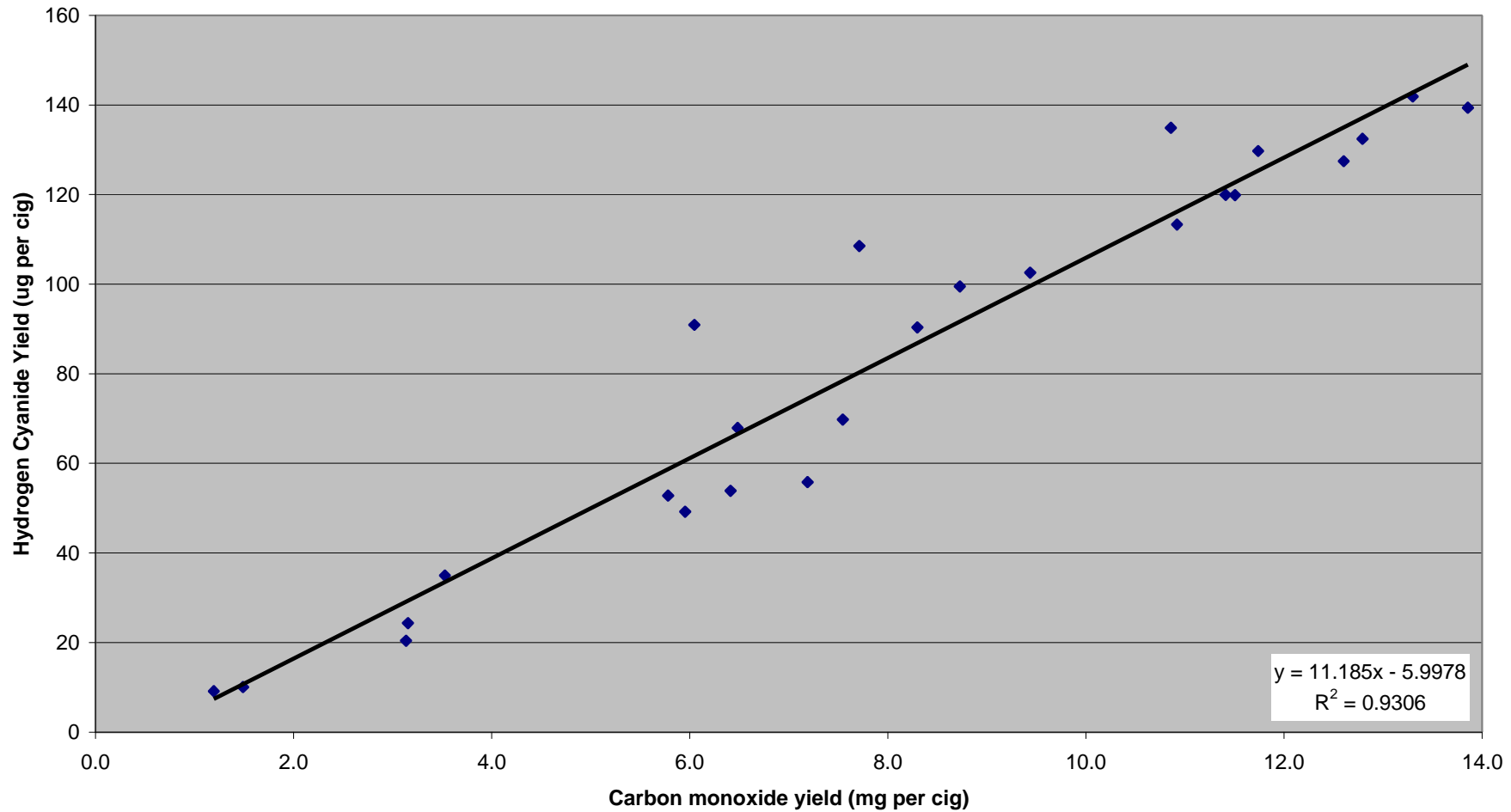
⁴ NB When evaluating a set of results obtained using a particular method it is important to put the results in context and this is what we have set out to do in this Appendix.

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

	Hydrogen Cyanide	NFDPM	Carbon Monoxide
	ug/cig	mg/cig	mg/cig
1R4F	125	9.06	12.26
1R5F	22.8	1.92	3.36
Benson & Hedges King Size	130	10.30	11.74
Berkely Superkings	120	9.69	11.50
Camel Ultra Lights	20.4	3.09	3.13
Consulate Menthol	90.4	7.06	8.30
Gitanes Caporal Filter	127	12.00	12.60
Lambert & Butler King Size	142	11.93	13.30
Lambert & Butler Lights King Size	67.9	5.24	6.48
Lambert & Butler Ultra Lights	10.1	1.61	1.49
Marlboro King Size	132	12.69	12.79
Marlboro Lights King Size	55.8	6.10	7.19
Mayfair Lights King Size	99.5	7.23	8.73
Mayfair Menthol King Size	49.2	4.65	5.95
Red Band Lights King Size	53.8	5.55	6.41
Regal Filter	113	10.65	10.92
Regal King Size	139	11.96	13.86
Rothman Royals 120s	103	10.39	9.44
Rothman Royals King Size	135	11.00	10.86
Senior Service	109	11.92	7.71
Silk Cut Extra Mild	24.3	2.67	3.16
Silk Cut King Size	52.8	5.62	5.78
Silk Cut Ultra King Size	9.1	1.01	1.20
Superkings	120	10.71	11.41
Superkings Lights	69.8	8.09	7.54
Superkings Ultra Lights	34.9	3.08	3.53
Vogue Superslims	90.9	7.38	6.05

Regression analysis of hydrogen cyanide versus carbon monoxide

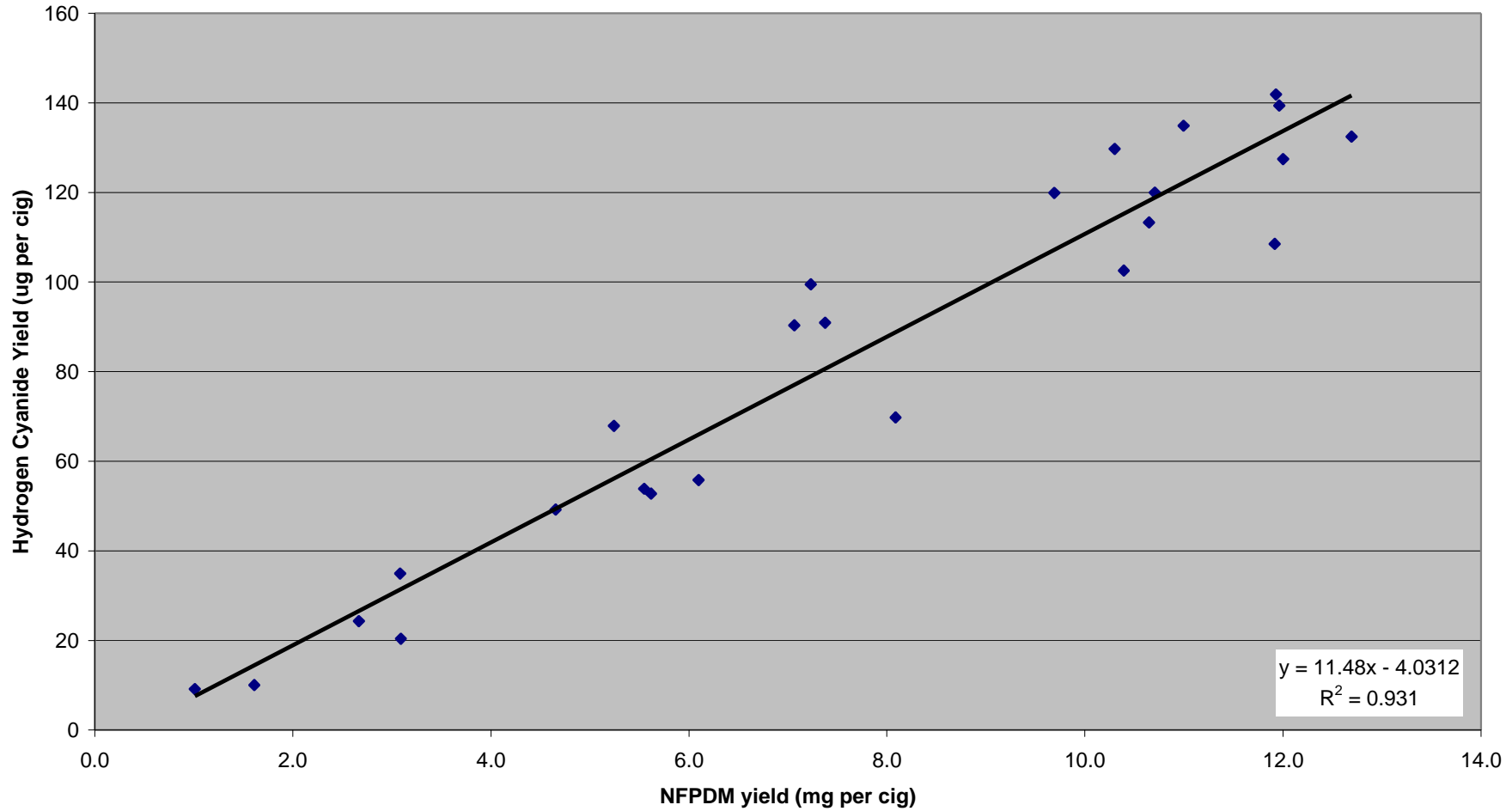
Regression analysis of hydrogen cyanide versus carbon monoxide for 25 cigarette brands



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

Regression analysis of hydrogen cyanide versus NFDPM

Regression analysis of hydrogen cyanide versus NFDPM for 25 cigarette brands



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

1R4F

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
1R4F	308	114
1R4F	605	118
1R4F	214	123
1R4F	511	135
1R4F	101	135
Mean (ug/cig)		125
Standard Deviation		9.88
CV (%)		7.9
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		113.6097729
		117.5505932
		122.9008947
		135.0210231
		135.0317348
Statistical test applied		
Dixons low end test		0.183961688
Outlier detected at 95%		
Dixons high end test		0.000500034
Outlier detected at 95%		
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>		
Summary of Results		
Mean (ug/cig)		125
Standard Deviation		9.88
CV (%)		7.9

1R5F

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
1R5F	318	21.2
1R5F	502	22.4
1R5F	205	23.0
1R5F	111	23.1
1R5F	615	24.1
Mean (ug/cig)		22.8
Standard Deviation		1.07
CV (%)		4.7
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		21.21472815
		22.37306065
		23.02133517
		23.07288017
		24.12770412
Statistical test applied		
Dixons low end test		0.397645745
Outlier detected at 95%		
Dixons high end test		0.362112136
Outlier detected at 95%		
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>		
Summary of Results		
Mean (ug/cig)		22.8
Standard Deviation		1.07
CV (%)		4.7

Benson & Hedges King Size

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Benson & Hedges King Size	505	111
Benson & Hedges King Size	618	128
Benson & Hedges King Size	114	128
Benson & Hedges King Size	208	129
Benson & Hedges King Size	411	153
Mean (ug/cig)		130
Standard Deviation		14.9
CV (%)		11.5
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		110.96614950635
		128.01814375436
		128.18850735809
		128.57880247763
		152.75035260931
Statistical test applied		
Dixons low end test		0.408096672
Outlier detected at 95%		
Dixons high end test		0.578485369
Outlier detected at 95%		
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>		
Summary of Results		
Mean (ug/cig)		130
Standard Deviation		14.9
CV (%)		11.5

Berkely Superkings

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Berkely Superkings	317	113
Berkely Superkings	614	116
Berkely Superkings	501	119
Berkely Superkings	710	125
Berkely Superkings	204	127
Mean (ug/cig)		120
Standard Deviation		5.76
CV (%)		4.8
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		113.0935994
		115.7187718
		119.1643159
		124.8778786
		126.5141087
Statistical test applied		
Dixons low end test		0.195608997
Outlier detected at 95%		
Dixons high end test		0.121920125
Outlier detected at 95%		
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>		
Summary of Results		
Mean (ug/cig)		120
Standard Deviation		5.76
CV (%)		4.8

Camel Ultra Lights

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Camel Ultra Lights	604	16.0
Camel Ultra Lights	213	19.9
Camel Ultra Lights	307	20.4
Camel Ultra Lights	709	22.8
Camel Ultra Lights	420	22.9
Mean (ug/cig)		20.4
Standard Deviation		2.81
CV (%)		13.8
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		16.01535241
		19.92429456
		20.44046800
		22.81926029
		22.90197461
Statistical test applied		
Dixons low end test		0.567613852
Outlier detected at 95%		
Dixons high end test		0.012010869
Outlier detected at 95%		
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>		
Summary of Results		
Mean (ug/cig)		20.4
Standard Deviation		2.81
CV (%)		13.8

Consulate Menthol

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Consulate Menthol	305	76.4
Consulate Menthol	211	88.8
Consulate Menthol	715	91.4
Consulate Menthol	602	93.5
Consulate Menthol	418	102
Mean (ug/cig)		90.4
Standard Deviation		9.16
CV (%)		10.1
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		76.44528562
		88.83344804
		91.38171668
		93.47522680
		101.7101551
Statistical test applied		
Dixons low end test		0.490331541
Outlier detected at 95%		
Dixons high end test		0.325943830
Outlier detected at 95%		
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>		
Summary of Results		
Mean (ug/cig)		90.4
Standard Deviation		9.16
CV (%)		10.1

Gitanes Caporal Filter

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Gitanes Caporal Filter	606	110
Gitanes Caporal Filter	512	123
Gitanes Caporal Filter	215	125
Gitanes Caporal Filter	309	130
Gitanes Caporal Filter	102	149
Mean (ug/cig)		127
Standard Deviation		14.0
CV (%)		11.0
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		110.2233077
		123.1311707
		124.9655884
		130.1273228
		148.6860547
Statistical test applied		
Dixons low end test		0.335593892
Outlier detected at 95%		
Dixons high end test		0.482511868
Outlier detected at 95%		
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>		
Summary of Results		
Mean (ug/cig)		127
Standard Deviation		14.0
CV (%)		11.0

Lambert & Butler King Size

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Lambert & Butler King Size	404	122
Lambert & Butler King Size	107	131
Lambert & Butler King Size	517	132
Lambert & Butler King Size	701	155
Lambert & Butler King Size	220	169
Mean (ug/cig)		142
Standard Deviation		19.5
CV (%)		13.7
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		122.3377997
		131.3419762
		131.5937941
		154.7103978
		169.3565038
Statistical test applied		
Dixons low end test		0.191502013
Outlier detected at 95%		
Dixons high end test		0.311495315
Outlier detected at 95%		
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>		
Summary of Results		
Mean (ug/cig)		142
Standard Deviation		19.5
CV (%)		13.7

Lambert & Butler Lights King Size

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Lambert & Butler Lights King Size	509	50.9
Lambert & Butler Lights King Size	302	64.3
Lambert & Butler Lights King Size	118	69.1
Lambert & Butler Lights King Size	712	77.3
Lambert & Butler Lights King Size	415	77.9
Mean (ug/cig)		67.9
Standard Deviation		11.1
CV (%)		16.3
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		50.93441467
		64.31520991
		69.06096706
		77.25052338
		77.90902680
Statistical test applied		
Dixons low end test		0.496051442
Outlier detected at 95%		
Dixons high end test		0.024411970
Outlier detected at 95%		
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>		
Summary of Results		
Mean (ug/cig)		67.9
Standard Deviation		11.1
CV (%)		16.3

Lambert & Butler Ultra Lights

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Lambert & Butler Ultra Lights	516	<8
Lambert & Butler Ultra Lights	106	8.9
Lambert & Butler Ultra Lights	219	9.3
Lambert & Butler Ultra Lights	610	10.5
Lambert & Butler Ultra Lights	403	11.5
Mean (ug/cig)		10.1
Standard Deviation		1.19
CV (%)		11.9
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		7.563469676
		8.882270498
		9.342739160
		10.51988835
		11.53032440
Statistical test applied		
Dixons low end test		0.332455034
Outlier detected at 95%		
Dixons high end test		0.254719702
Outlier detected at 95%		

If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier

Summary of Results

Mean (ug/cig)	10.1
Standard Deviation	1.19
CV (%)	11.9

Note: One result gave a hydrogen cyanide yield of <8 ug cig-1. However the original hydrogen cyanide results have been used to perform the regression analysis (shown in grey).

Marlboro King Size

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Marlboro King Size	601	121
Marlboro King Size	714	125
Marlboro King Size	304	131
Marlboro King Size	417	140
Marlboro King Size	120	144
Mean (ug/cig)		132
Standard Deviation		9.63
CV (%)		7.3
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		121.2142359
		125.4012561
		131.4177564
		140.3208745
		143.9558514
Statistical test applied		
Dixons low end test		0.184112700
Outlier detected at 95%		
Dixons high end test		0.159838115
Outlier detected at 95%		
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>		
Summary of Results		
Mean (ug/cig)		132
Standard Deviation		9.63
CV (%)		7.3

Marlboro Lights King Size

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Marlboro Lights King Size	313	50.9
Marlboro Lights King Size	110	54.6
Marlboro Lights King Size	520	55.4
Marlboro Lights King Size	704	58.9
Marlboro Lights King Size	407	59.1
Mean (ug/cig)		55.8
Standard Deviation		3.41
CV (%)		6.1
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		50.89470062
		54.60756833
		55.43018336
		58.93230984
		59.13258110
Statistical test applied		
Dixons low end test		0.450706673
Outlier detected at 95%		
Dixons high end test		0.024311018
Outlier detected at 95%		
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>		
Summary of Results		
Mean (ug/cig)		55.8
Standard Deviation		3.41
CV (%)		6.1

Mayfair Lights King Size

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Mayfair Lights King Size	608	96.4
Mayfair Lights King Size	104	96.7
Mayfair Lights King Size	217	97.1
Mayfair Lights King Size	401	98.5
Mayfair Lights King Size	514	109
Mean (ug/cig)		99.5
Standard Deviation		5.30
CV (%)		5.3
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		96.35380321
		96.65381920
		97.09222299
		98.53667137
		108.8504937
Statistical test applied		
Dixons low end test		0.024007636
Outlier detected at 95%		
Dixons high end test		0.825324299
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>		
Summary of Results		
Mean (ug/cig)		97.2
Standard Deviation		0.97
CV (%)		1.0

Mayfair Menthol King Size

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Mayfair Menthol King Size	515	45.9
Mayfair Menthol King Size	402	48.0
Mayfair Menthol King Size	218	49.6
Mayfair Menthol King Size	105	50.7
Mayfair Menthol King Size	609	51.9
Mean (ug/cig)		49.2
Standard Deviation		2.33
CV (%)		4.7
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		45.90973202
		48.02538787
		49.60426703
		50.66573231
		51.86671319
Statistical test applied		
Dixons low end test		0.355155706
Outlier detected at 95%		
Dixons high end test		0.201608978
Outlier detected at 95%		
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>		
Summary of Results		
Mean (ug/cig)		49.2
Standard Deviation		2.33
CV (%)		4.7

Red Band Lights King Size

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Red Band Lights King Size	412	46.4
Red Band Lights King Size	209	50.4
Red Band Lights King Size	619	53.4
Red Band Lights King Size	506	58.3
Red Band Lights King Size	115	60.7
Mean (ug/cig)		53.8
Standard Deviation		5.78
CV (%)		10.7
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		46.43864598
		50.37852719
		53.43684578
		58.33921016
		60.65171689
Statistical test applied		
Dixons low end test		0.277201263
Outlier detected at 95%		
Dixons high end test		0.162702821
Outlier detected at 95%		
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>		
Summary of Results		
Mean (ug/cig)		53.8
Standard Deviation		5.78
CV (%)		10.7

Regal Filter

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Regal Filter	413	102
Regal Filter	116	111
Regal Filter	620	116
Regal Filter	507	117
Regal Filter	210	121
Mean (ug/cig)		113
Standard Deviation		7.30
CV (%)		6.4
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		101.7101551
		111.1072179
		116.2421493
		116.7842031
		120.5781142
Statistical test applied		
Dixons low end test		0.498043415
Outlier detected at 95%		
Dixons high end test		0.201076922
Outlier detected at 95%		
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>		
Summary of Results		
Mean (ug/cig)		113
Standard Deviation		7.30
CV (%)		6.4

Regal King Size

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Regal King Size	508	122
Regal King Size	117	135
Regal King Size	414	138
Regal King Size	301	145
Regal King Size	711	157
Mean (ug/cig)		139
Standard Deviation		13.1
CV (%)		9.4
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		121.5444288
		135.0210231
		137.9407616
		145.3544391
		157.0655967
Statistical test applied		
Dixons low end test		0.379396150
Outlier detected at 95%		
Dixons high end test		0.329695172
Outlier detected at 95%		
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>		
Summary of Results		
Mean (ug/cig)		139
Standard Deviation		13.1
CV (%)		9.4

Rothman Royals 120s

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Rothman Royals 120s	410	91.7
Rothman Royals 120s	613	98.2
Rothman Royals 120s	316	101
Rothman Royals 120s	203	106
Rothman Royals 120s	708	117
Mean (ug/cig)		103
Standard Deviation		9.31
CV (%)		9.1
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		91.66078984
		98.18562456
		100.7054370
		105.8671714
		116.5038381
Statistical test applied		
Dixons low end test		0.262642275
Outlier detected at 95%		
Dixons high end test		0.428154654
Outlier detected at 95%		
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>		
Summary of Results		
Mean (ug/cig)		103
Standard Deviation		9.31
CV (%)		9.1

Rothman Royals King Size

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Rothman Royals King Size	212	131
Rothman Royals King Size	603	131
Rothman Royals King Size	306	131
Rothman Royals King Size	419	135
Rothman Royals King Size	707	146
Mean (ug/cig)		135
Standard Deviation		6.16
CV (%)		4.6
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		131.1596696
		131.4177564
		131.4200977
		134.7672779
		145.5512910
Statistical test applied		
Dixons low end test		0.017933123
Outlier detected at 95%		
Dixons high end test		0.749325797
Outlier detected at 95%	95%	

If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier

Summary of Results

Mean (ug/cig)	132
Standard Deviation	1.72
CV (%)	1.3

Senior Service

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Senior Service	310	93.0
Senior Service	103	103
Senior Service	513	114
Senior Service	216	114
Senior Service	607	118
Mean (ug/cig)		109
Standard Deviation		10.3
CV (%)		9.5
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		92.96283551
		103.4863350
		113.6107193
		114.1259463
		118.3356595
Statistical test applied		
Dixons low end test		0.414754758
Outlier detected at 95%		
Dixons high end test		0.165914253
Outlier detected at 95%		
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>		
Summary of Results		
Mean (ug/cig)		109
Standard Deviation		10.3
CV (%)		9.5

Silk Cut Extra Mild

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Silk Cut Extra Mild	201	18.6
Silk Cut Extra Mild	314	22.0
Silk Cut Extra Mild	408	23.7
Silk Cut Extra Mild	705	24.4
Silk Cut Extra Mild	611	33.0
Mean (ug/cig)		24.3
Standard Deviation		5.34
CV (%)		21.9
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		18.63386098
		21.98898830
		23.69534556
		24.38939288
		33.02512212
Statistical test applied		
Dixons low end test		0.233136435
Outlier detected at 95%		
Dixons high end test		0.600067579
Outlier detected at 95%		
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>		
Summary of Results		
Mean (ug/cig)		24.3
Standard Deviation		5.34
CV (%)		21.9

Silk Cut King Size

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Silk Cut King Size	617	44.5
Silk Cut King Size	113	45.1
Silk Cut King Size	504	54.6
Silk Cut King Size	207	57.1
Silk Cut King Size	320	62.5
Mean (ug/cig)		52.8
Standard Deviation		7.79
CV (%)		14.8
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		44.53942777
		45.14716188
		54.63681241
		57.08878183
		62.50860289
<i>Statistical test applied</i>		
Dixons low end test		0.033820924
Outlier detected at 95%		
Dixons high end test		0.301617688
Outlier detected at 95%		

If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier

Summary of Results

Mean (ug/cig)	52.8
Standard Deviation	7.79
CV (%)	14.8

Note: One result gave a hydrogen cyanide yield of <8 ug cig-1. However the original hydrogen cyanide results have been used to perform the regression analysis (shown in grey).

Silk Cut Ultra King Size

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Silk Cut Ultra King Size	503	>8
Silk Cut Ultra King Size	319	8.3
Silk Cut Ultra King Size	112	8.4
Silk Cut Ultra King Size	206	8.6
Silk Cut Ultra King Size	616	11.3
Mean (ug/cig)		9.1
Standard Deviation		1.45
CV (%)		15.9
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		5.976727786
		8.310392292
		8.356692362
		8.568479009
		11.30495464
Statistical test applied		
Dixons low end test		0.437981447
Outlier detected at 95%		
Dixons high end test		0.513580917
Outlier detected at 95%		
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>		
Summary of Results		
Mean (ug/cig)		9.14
Standard Deviation		1.45
CV (%)		15.9

Superkings

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Superkings	519	110
Superkings	703	112
Superkings	406	120
Superkings	312	129
Superkings	109	129
Mean (ug/cig)		120
Standard Deviation		9.00
CV (%)		7.5
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		109.9083216
		112.0551291
		119.9576869
		128.5788025
		129.2396636
Statistical test applied		
Dixons low end test		0.111053206
Outlier detected at 95%		
Dixons high end test		0.034185994
Outlier detected at 95%		

If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier

Summary of Results

Mean (ug/cig)	120
Standard Deviation	9.00
CV (%)	7.5

Superkings Lights

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Superkings Lights	510	59.1
Superkings Lights	416	66.8
Superkings Lights	303	67.4
Superkings Lights	119	77.5
Superkings Lights	713	78.0
Mean (ug/cig)		69.8
Standard Deviation		7.99
CV (%)		11.4
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		59.13258110
		66.80183357
		67.41225052
		77.47021724
		78.03558967
Statistical test applied		
Dixons low end test		0.405715971
Outlier detected at 95%		
Dixons high end test		0.029909124
Outlier detected at 95%		
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>		
Summary of Results		
Mean (ug/cig)		69.8
Standard Deviation		7.99
CV (%)		11.4

Superkings Ultra Lights

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Superkings Ultra Lights	405	26.9
Superkings Ultra Lights	108	31.7
Superkings Ultra Lights	518	33.7
Superkings Ultra Lights	311	37.0
Superkings Ultra Lights	702	45.3
Mean (ug/cig)		34.9
Standard Deviation		6.87
CV (%)		19.7
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		26.86882934
		31.74491941
		33.74471086
		36.95801789
		44.80111654
Statistical test applied		
Dixons low end test		0.271916796
Outlier detected at 95%		
Dixons high end test		0.437373022
Outlier detected at 95%		
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>		
Summary of Results		
Mean (ug/cig)		34.9
Standard Deviation		6.87
CV (%)		19.7

Vogue Superslims

Brand	Sample Number	Hydrogen Cyanide yield (ug per cigarette)
Vogue Superslims	202	74.9
Vogue Superslims	409	75.3
Vogue Superslims	706	92.4
Vogue Superslims	612	93.7
Vogue Superslims	315	118
Mean (ug/cig)		90.9
Standard Deviation		17.7
CV (%)		19.5
<i>Outlier Test</i>		
Dixons outlier test was applied to the above data		
Data sorted		74.89676531
		75.26445698
		92.42847174
		93.73691556
		118.2553338
Statistical test applied		
Dixons low end test		0.008480254
Outlier detected at 95%		
Dixons high end test		0.565480344
Outlier detected at 95%		
<i>If an outlier is detected then the mean, standard deviation and CV have been recalculated excluding the outlier</i>		
Summary of Results		
Mean (ug/cig)		90.9
Standard Deviation		17.7
CV (%)		19.5

Appendix 1: Technical opinions and interpretations

The following comments are of a technical nature about the method, validation data and results obtained during the study. They are designed to help put the results in context.

Trapping system

An ideal trapping system should be capable of trapping 100% of the analyte(s) under investigation. It should also not significantly effect the way that the cigarette smokes – i.e. cigarette should be smoked to ISO conditions.

Experiments showed that with the trapping system used, the silica gel was very efficient at holding on to the hydrogen cyanide. To ensure that >90% of the hydrogen cyanide was extracted into the sodium hydroxide solution only a small quantity of silica gel was used in the trap (4 g of particle size 2.5 – 6 mm), along with a large volume (150mL) of extraction solution (NaOH).

Method sensitivity and reporting limit

The study showed that the reporting limit set was higher than the hydrogen cyanide yields for some of the results obtained from low tar brands. In our opinion, it was not practicable to have a standard lower than the bottom concentration ($0.32 \mu\text{g mL}^{-1}$) due to its low absorbance (approximately 0.050). It might be practicable to smoke three cigarettes to improve the sensitivity of the method.

Stability

It was found that there was a significant decrease in hydrogen cyanide concentration in the sample solutions after 3 - 4 hours. Therefore, all solutions were analysed within 2 hours of smoking. The coloured complex developed in the test tube is unstable and so should be analysed within 5 –to 15 minutes of the pyridine-barbituric reagent being added.

Measurement uncertainty

All measurements have an uncertainty associated with them. There are three components in the uncertainty of each result (a) sample (smoking of the cigarette), (b) trapping the smoke and (c) the analytical method.

From the results of the study, it would appear that the trapping of the hydrogen cyanide and the analytical technique could both be the cause of significant uncertainty. Two key areas have been identified as: -

1. **Packing of silica gel.** Since only a small quantity of silica gel is used to trap the hydrogen cyanide, it is important that the gel is packed 'securely' to ensure efficient trapping (i.e. no gaps so that the smoke passes through the trap without impacting on the silica gel).
2. **Operator technique.** Several pipetting operations are required for each sample plus a set length of time for the colour to develop. The final solution containing the coloured complex needs to be thoroughly mixed as the colour will tend to settle to the bottom of the test tube on standing. Therefore, a good operator technique is essential. NB Solutions were analysed in small batches to maintain consistency with the timing of adding reagents and subsequent colour development.

Appendix 2: Selected smoke constituents for UK study

Type	Specific analyte(s)
	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-nitrosanonicotine (nnn)
	n-nitrosoanatabine (nat)
	n-nitrosanabasine (nab)
	n-nitrosanormicotine 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

Term/Definition	Meaning
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 ⁻¹	per cigarette
HCN	Hydrogen cyanide
NaOH	Sodium hydroxide

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

Brand	Length (mm)	Butt length used for the study (mm)	Description
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