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the Cigarette Safety Act of 1984"

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APPENDIX A

U.S. DEPARTMENT OF COMMERCE
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"Reevaluation of Experimental Cigarettes used in the Cigarette Safety Act of 1984"

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Introduction

Under P.L. 101-352, the Fire-Safe Cigarette Act of 1990, one of the tasks assigned to NIST was to develop a valid test method for the ignition propensity of cigarettes. In a previous study [A-1], under the Cigarette Safety Act of 1984, 32 experimental cigarettes that vary systematically in five design parameters were extensively studied to determine their ignition propensity on soft furnishings. The evaluation was done with bench-scale mock-ups and on full-scale furniture. Analysis of the test results indicated an agreement between the bench-scale and full-scale tests. Since these experimental cigarettes are well characterized, it is desirable to use these cigarettes in the new study. However, these cigarettes have been stored in freezers since the completion of the first study. To determine if the cigarettes have changed during storage, a reevaluation was undertaken using fabric and padding materials retained from the first study.

Statistical Selection of Cigarettes

The original characterization of these cigarettes involved testing on four substrates, which in turn were composed of combinations of 3 fabrics and two paddings. Due to the limited availability of one of the fabrics (California standard), it was impossible to repeat the entire experimental series using all 32 types of cigarettes on all 4 substrates. There was only enough material available to perform ignition tests for 8 of the 32 cigarettes on all 4 substrates, using 5 replicates for each case.

The selection of 8 cigarettes from the available 32 amounts to choosing exactly a 1/4 fraction of the available cigarette types. In making the selection, we attempted to achieve two objectives:

(1) to choose cigarettes whose ignition propensities evenly span the entire range of ignition rates observed in the previous testing, and

(2) to choose cigarettes in a balanced fashion — so that each of the five design factors that define the cigarette types would be equally represented among the 8 selected cigarettes.

The statistical theory of *fractional factorial* experimental design [A-2] can be used to satisfy the second objective. In particular, a 1/4 fraction of the (full) 2^5 factorial design that defines the 32 cigarettes would consist of 8 cigarettes for which:

- 4 have Burley tobacco, and 4 have Flue-cured;
- 4 have Expanded tobacco, and 4 are Not expanded;
- 4 have paper of Low permeability, and 4 have High permeability;
- 4 have Citrate, and 4 have No citrate; and
- 4 are 21 cm in circumference, and 4 are 25 cm.

In addition, in a fractional factorial experimental design, a second level of balance would be achieved. For example, among the 4 cigarettes with high citrate, 2 would be 21 cm in circumference and 2 would be 25 cm; similarly, the 4 low citrate cigarettes would have 2 at 21 cm and 2 at 25 cm circumference. In an analogous way, each pair of factors would exhibit this kind of balance, with the result that each level of one factor would be combined with each level of the other factor in an equal number of cases.

There are many ways that this kind of fully balanced fractional factorial selection could be made from the 32 cigarette types available. It was initially hoped that one or more of these fractional factorial selections would yield a set of 8 cigarettes that would also satisfy the first objective of uniformly spanning the ignition rates that had been obtained in the previous experiment. Ultimately we found that it was not possible to achieve both of the stated objectives exactly, and so a compromise set of 8 cigarettes was found that was imperfectly, but nearly, balanced and which does exhibit quite uniform coverage of the ignition rates. It was felt that for the purposes of this reevaluation experiment, the need to use cigarettes that uniformly represent the full range of previously observed ignition rates was more important than achieving a perfectly balanced fractional factorial arrangement.

Table A-1 displays the extent to which balance in the above sense was achieved in the final compromise set of cigarettes chosen.

Table A-1. Selection of Cigarettes for Reevaluation Study: Balance on Cigarette Design Factors and Coverage of Levels of Previous Numbers of Ignitions

Cigarette Number	Tobacco Type	Packing Density	Paper Permeability	Citrate	Circumference	Previous Number of Ignitions
106	B	E	L	N	21	1
130	F	E	L	N	25	4
108	B	E	H	N	21	7
129	F	E	L	C	25	10
101	B	N	L	C	21	13
131	F	E	H	C	25	15
103	B	N	H	C	21	17
120	B	N	H	N	25	20
Balance Achieved	5 B 3 F	5 E 3 N	4 L 4 H	4 N 4 C	4 21mm 4 25mm	

Results and Conclusions

The eight statistically-selected cigarettes were tested for their ignition propensity on the same substrates and in the same manner as the previous study. In addition to the storage factor, two other differences were a change in the canopy hood used and the technician who performed the tests.

The results of the testing are shown in Table A-2 below.

Table A-2. Reevaluation of Eight of the Thirty-two Experimental Cigarettes

Cig. Id.	Number of Ignitions									
	CA/CB Unc./flat		SPL/PU Unc./flat		SPL/PU[a] Unc./flat		Denim/PU Crev./cov.		Total	
	Prev.	Now	Prev.	Now	Prev.	Now	Prev.	Now	Prev.	Now
106 BELN21	0	0	1	1	0	0	0	0	1	1
130 FELN25	3	4	1	1	0	2	0	5	4	12
108 BEHN21	3	2	4	3	0	0	0	1	7	6
129 FELC25	5	5	3	5	2	5	0	1	10	16
101 BNLC21	3	4	5	5	5	5	0	5	13	19
131 FEHC25	5	3	5	5	5	5	0	0	15	13
103 BNHC21	5	4	5	5	5	5	2	5	17	19
120 BNHN25	5	5	5	5	5	5	5	5	20	20
Totals	29	27	29	30	22	27	7	22	87	106

Maximum number of ignitions per cigarette is 20, per substrate 40.
CA/CB California test fabric/cotton batting.
SPL/PU 100% cotton Splendor fabric/polyurethane 2045.
Denim/PU 100% cotton Denim fabric/polyurethane 2045.
Unc./flat Uncovered cigarette on a flat mockup.
Crev./cov. Covered cigarette in mockup crevice.
a Cigarette with filter with one half of the tobacco column removed before lighting.

If no real change in ignition propensity occurred, then the numbers of ignitions in the "Previous" and "Now" columns of Table A-2 should be the same, except for statistical fluctuations.

For each of the 8 cigarette types, and for each of the 4 substrates shown in Table A-2, we calculated the difference between the number of ignitions in the current study ("Now"), minus the number of ignitions in the "Previous" study. If these differences represent only statistical fluctuations, then they would form a statistical population centered near zero. The Wilcoxon Signed Rank Test [A-3] was adopted as a formal statistical test procedure to evaluate whether the observed differences indicate a change in ignition propensity or only random noise. This is a non-parametric test procedure that is valid for use with data that do not follow the commonly assumed Gaussian distribution. Validity for non-Gaussian data was an important consideration because the difference data from this experiment clearly exhibit a non-Gaussian pattern of variation.

The results of the Wilcoxon Signed Rank Test are that the observed differences in numbers of ignitions show a statistically significant tendency ($p = 0.04$) toward increased ignitions after the storage period. Inspection of Table A-2 shows that the increased ignitions come almost exclusively from the denim substrate, which suggests the possibility that the statistically significant difference is due entirely to the denim substrate. This is consistent with the observation of Rogers and Hayes [A-4] that unless denim is stored free of finishing materials in the dark and in a temperature controlled environment, it will deteriorate with time.

To evaluate the hypothesis of no change in ignition propensity for the non-denim substrates, the Wilcoxon Signed Rank Test was recomputed using only the other three substrates (CA/CB, SPL/PU, and SPL/PU-half cigarette). In this case, the differences in ignition numbers were not significantly different from zero ($p = 0.47$). That is, the data for the three non-denim substrates are wholly consistent with the hypothesis of no change in ignition propensities of the experimental cigarettes, compared with the previous study.

It was noted that cigarette number 129 showed noticeable increases in the number of ignitions for both of the conditions involving the SPL/PU substrate. This suggests the possibility of a real change in ignition propensity for this particular combination of cigarette and substrate. In pursuing this observation, it is pertinent to note that cigarette 129 showed a relatively small increase in ignitions on the denim substrate both in comparison to its increase for the two SPL/PU substrates and also in comparison to the increases for other cigarettes on the denim substrate. Thus any physical explanation of a change in ignition propensity for cigarette 129 would seem to call for a unique cigarette-substrate interaction on SPL/PU. The reevaluation experiment was designed as an overall test for possible changes in the experimental cigarettes. It was not designed to generate sufficient data to evaluate unique effects for each cigarette and substrate combination. As it happens, the largest single observed difference (2 ignitions in the previous study versus 5 ignitions now) is not significant at the standard 5% level of significance ($p = 0.08$). Here, the significance calculation was obtained using Fisher's Exact Test for a 2×2 contingency table [A-5]. Based on all these considerations, it does not seem profitable to pursue further the observed increase in ignitions for cigarette 129 on SPL/PU.

Summary

Overall, we interpret the results of this study as showing that the ignition propensities of the experimental cigarettes have not changed during storage but that the denim substrate has changed in ignitability.

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References

[A-1] Gann, R.G., Harris, R.H., Krasny, J.F., Levine, R.S., Mitler, H.E., and Ohlemiller, T.J., "The Effect of Cigarette Characteristics on the Ignition of Soft Furnishings," NBS Technical Note 1241, National Institute of Standards and Technology, Gaithersburg, MD, 1988.

[A-2] Box, G.E.P., Hunter, W.G., and Hunter, J. S., *Statistics for Experimenters*, John Wiley and Sons, New York, 1978, Chapter 12.

[A-3] Snedecor, G.W. and Cochran, W.G., *Statistical Methods*, 7th ed., The Iowa State University Press, Ames, Iowa, 1980, pp. 141-143.

[A-4] Rogers, R.E. and Hays, M., "Effect of Storage on Fabrics," *Textile Research*, pp. 22-35, April 1943.

[A-5] Placket, R.L., *The Analysis of Categorical Data*, 2nd ed., Macmillan, New York, 1981, Section 6.3.