# FACTORS AFFECTING STATIC BURNING RATE

By F.E. RESNIK, W.G. HOUCK, W.A. GEISZLER,
and J.E. WICKHAM,
Philip Morris Research Center,
Richmond, Va.

Static burning rate is of interest primarily because it correlates well with the number of puffs obtainable from a cigarette. Two methods are used in measuring static burning rate: weight loss methods and timed distance methods. Experimental data can be expressed as mg consumed per minute to give a mass static burning rate ($SBR_m$), or as mm burned per minute to give a distance static burning rate ($SBR_d$). SBR is affected by three major cigarette parameters: the paper, the tobacco and cigarette construction. SBR increases with increasing paper porosity, with the addition of certain salt additives to the paper or the tobacco, and with increasing Burley content of the tobacco filler. SBR decreases with certain other salt additives on the tobacco, and with increasing Oriental tobacco concentrations in the filler. $SBR_d$ decreases with increasing tobacco rod density while $SBR_m$ remains constant; $SBR_d$ decreases with increasing rod circumference while $SBR_m$ increases.

## INTRODUCTION

Static burning rate, the rate of consumption of a cigarette in a smoldering state, is of interest primarily because of its negative correlation with puff count. Through this correlation (**Fig. 1**), static burning rate becomes a convenient quality control monitor for cigarette production. The static burning rate is also of interest in R&D work for determining the effects of controlled changes in cigarette paper, tobacco, geometry, etc. on cigarette properties.

## EXPERIMENTAL METHODS

Several methods for determing static burning rate have been reported (1-5). The methods can be classified as "weight loss' methods and "timed distance" methods. In weight loss methods, a lit cigarette is held on a balance, in either a horizontal or a vertical position, and the weight loss during a specified time period is determined. One problem presented by this method is that ash weight must be taken into account to express the data as a linear rate of burn. In the timed distance methods, the time to burn a specified length of the cigarette is measured.

Static burning rate may be defined as a mass rate and reported in milligrams per minute as follows:

$$SBR_m = \frac{W}{SBT} \qquad (1)$$

where W is the weight of a 40 mm length tobacco rod and SBT is the time in minutes required to burn a 40 mm section.

In instances where the tobacco rod weight is not measured, the burning rate may be expressed as a function of distance:

$$SBR_d = \frac{L}{SBT} \qquad (2)$$

where L is the length of tobacco rod burned and the data is reported in millimeters per minute.

In this work, the static burning rate was determined by an automated timed distance method performed on equipment much like the Filtrona string cut-off device shown in **Fig. 2.** This device employs two taut pieces of string aligned perpendicularly to the axis of the cigarette and contacting the tobacco rod at two points a known distance apart (usually 40 mm). Each thread, when taut, depresses a microswitch arm which is connected to a timer. When the char line of the burning cigarette burns through the first string, the timer is activated. Similarly, burning through the second string stops the timer and gives the time required to burn the specified distance. The burning was conducted under controlled temperature (75° F), humidity

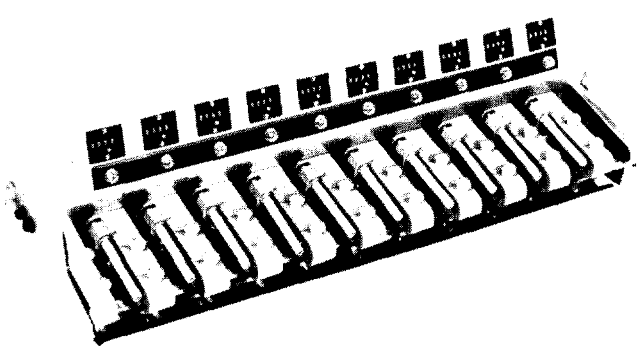

Fig. 2. Filtrona string cut-off device for static burning time measurement.

*Contribution received October 1, 1976. Tob. Sci. XXI: 103-107, 1977.*

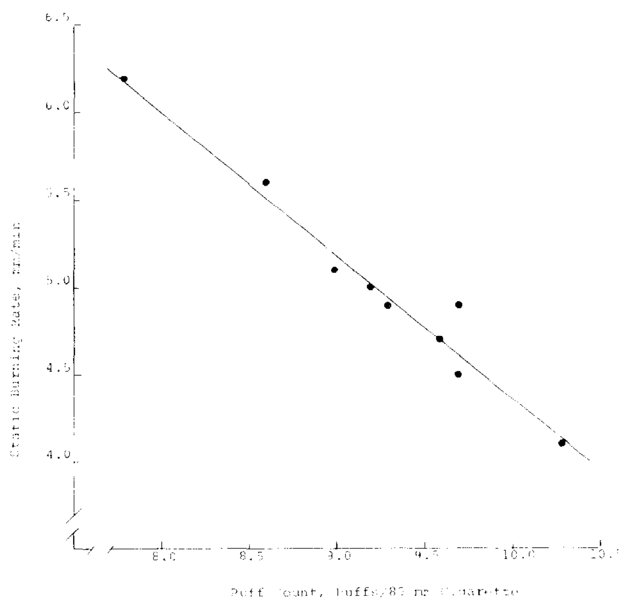

Fig. 1. SBR versus puff count.

(60% RH) and draft conditions. Cigarettes to be tested were weighed and held at the same temperature and humidity for at least 24 hours prior to testing.

Static burning rates reported here are averages for 24 cigarettes and have a relative standard deviation of 6%. All cigarettes were made on conventional cigarette making machines to 25.0 mm circumference and 0.26 g/cc tobacco rod density, except where noted otherwise. Commercial cigarette papers without burn chemicals were treated with additives on our lab-scale size press.

## RESULTS AND DISCUSSION

SBR is affected by three major cigarette parameters: the paper, the tobacco, and cigarette construction.

A. *Paper Variables.* The most important paper variables influencing SBR are the porosity and additives. The burning rate increases as the paper becomes more porous. This is shown in **Fig. 3.** Mechanical or electrical perforations of the paper, which increase the puff count of a cigarette, have little effect on SBR as illustrated in **Table 1** and **Fig. 4 (6).** The higher puff

**Table 1. Effect of perforated paper on SBR[a].**

| Mechanical Perforations (# Of Lines) | Greiner Porosity (sec/50 cc) | Static Burning Rate (mg/min) |
|---|---|---|
| 0 | 12 | 60 |
| 6 | 4 | 59 |
| 11 | 2 | 59 |
| 0 | 35 | 40 |
| 6 | 5 | 39 |
| 0 | 45 | 42 |
| 6 | 5 | 43 |

[A] *Data from Ecusta Paper Div., Olin Corp.*

**Table 2. Effect of citrate salts added to paper on SBR.**

| Type Citrate (2% Anion) | Static Burning Rate (mm/min) | Static Burning Rate (mg/min) |
|---|---|---|
| None | 4.0 | 53 |
| Magnesium | 4.5 | 59 |
| *Citric Acid* | 4.7 | 61 |
| Lithium | 5.2 | 68 |
| Potassium | 5.3 | 69 |
| Sodium | 5.5 | 72 |

**Table 3. Effect of phosphate salts added to paper on SBR.**

| Type Phosphate (1% $PO_4^{\equiv}$) | Static Burning Rate (mm/min) | Static Burning Rate (mg/min) |
|---|---|---|
| None | 4.3 | 57 |
| $NH_4H_2PO_4$ | 4.5 | 60 |
| $(NH_4)_2HPO_4$ | 4.4 | 59 |
| $NaH_2PO_4$ | 4.7 | 62 |
| $KH_2PO_4$ | 4.9 | 65 |
| $Na_3PO_4$ | 5.3 | 70 |
| $K_3PO_4$ | 5.5 | 72 |

**Table 4. Effect of sodium salts added to paper on SBR.**

| Type Na Salt (0.5% Na) | Static Burning Rate (mm/min) | Static Burning Rate (mg/min) |
|---|---|---|
| None | 4.0 | 53 |
| Carbonate | 5.2 | 68 |
| Phosphate | 5.3 | 69 |
| Acetate | 5.3 | 70 |
| Formate | 5.3 | 70 |
| Citrate | 5.5 | 72 |

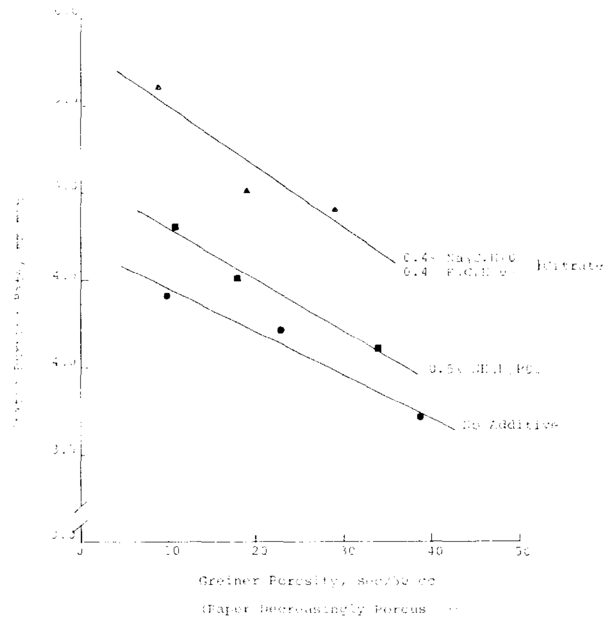


Fig. 3. Effect of inherent paper porosity on SBR.

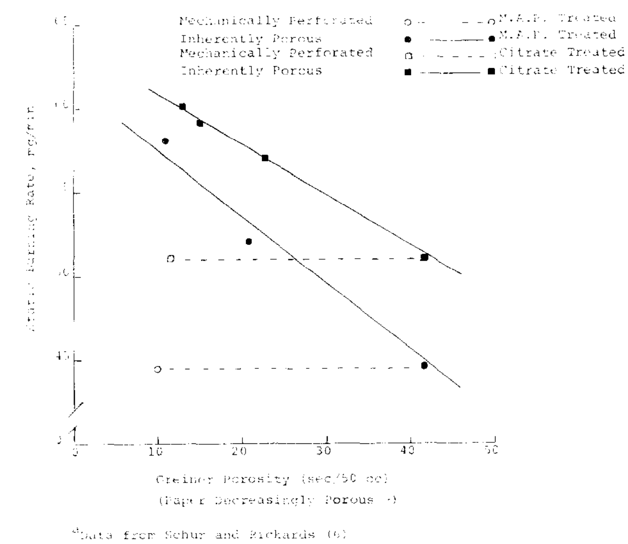


Fig. 4. Effect of mechanical perforations on SBR[a].



Tobacco Science, 1977, 21-30, p. 103-107, ISSN. 0082-4523.pdf

Table 5. Effect of tobacco type on SBR. (equal firmness tobacco rods)

| Tobacco Type | Static Burning Rate (mm/min) | Static Burning Rate (mg/min) |
|---|---|---|
| Turkish | 3.3 | 52 |
| Bright | 5.3 | 69 |
| Burley | 6.2 | 77 |

Table 6. SBR for various humectant combinations of tobacco (equal weight tobacco rods.).

| System | Moisture[1], % | Static Burning Rate (mm/min) | Static Burning Rate (mg/min) |
|---|---|---|---|
| 0.3% Glycerine, 0.2% Propylene Glycol | 11.3 | 4.9 | 61 |
| 1.0% Glycerine, 0.9% Propylene Glycol | 11.5 | 5.1 | 64 |
| 1.4% Glycerine, 1.4% Propylene Glycol | 11.9 | 5.3 | 66 |

[1]Oven volatiles at 100° C for 3 hours.

count observed with perforated papers (compared to non-perforated papers) is a result of less air being drawn into the coal during puffing, thereby decreasing the amount of tobacco rod consumed.

Various chemical compounds can be added to cigarette paper to alter the burning rate of the cigarette. Citrate and phosphate salts are commonly used paper additives. The importance of the type of cation in the salt is demonstrated in **Tables 2** and **3.** Magnesium citrate is a less effective burn promoter than sodium citrate; similarly $NH_4H_2PO_4$ is less effective than $K_3PO_4$. The effect of anion on burning rate is shown in **Table 4** for several Na salts, there being only slight differences among the anions listed. The metallic ion, then, is the key to accelerating burning rate, metals from Group 1A of the Periodic Table being the most effective.

The effect of salt concentration on burning rate is shown in **Fig. 5.** Static burning rate increases with increasing concentration of burn promoters like sodium citrate and phosphate, but with diminishing effectiveness at higher concentrations. This is also shown in data by Jodl (7). Burning rate does not change appreciably with increasing concentrations of $NH_4H_2PO_4$, an additive used mainly for improving ash appearance. Still higher concentrations of such nonpromoting additives may actually retard SBR.

B. *Tobacco Variables.* Tobacco type, cut width, additives, and moisture content are important tobacco variables influencing SBR. In **Table 5**, oriental tobacco is seen to be slow burning, burley is relatively fast burning, while bright lies between the two. The cut width of tobacco has an inverse effect on burning rate as shown in **Fig. 6**, smaller cut widths giving faster burning rates. This is confirmed by data from Flesselles (8).

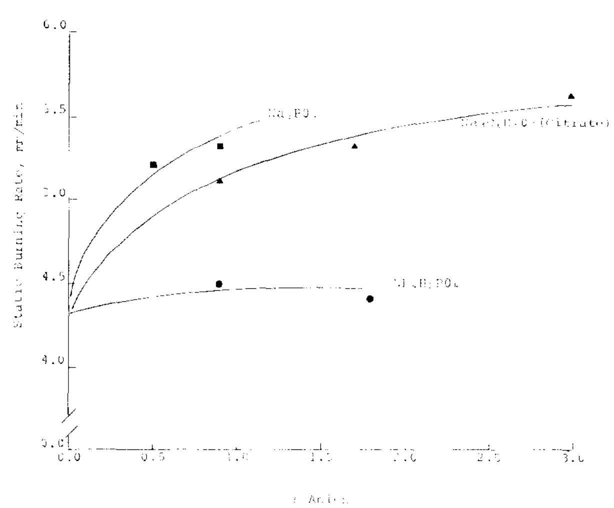

Fig. 5. SBR versus salt concentration on paper.

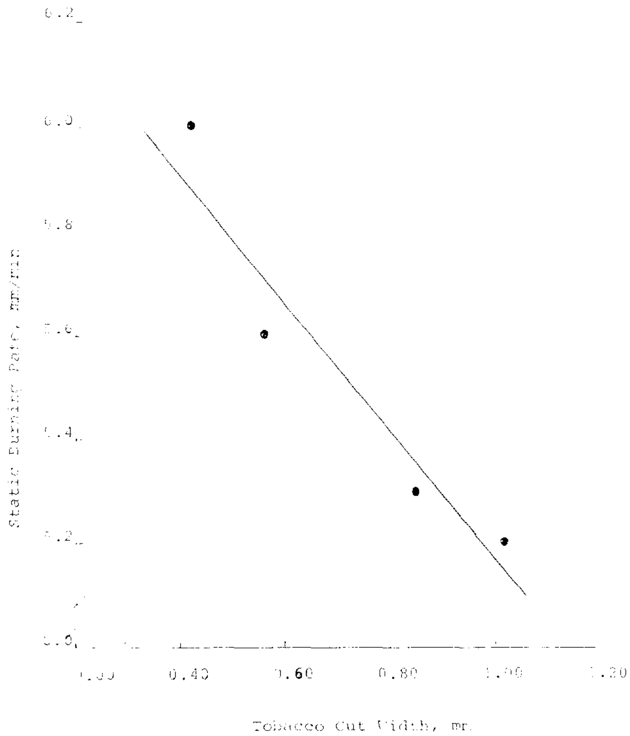

Fig. 6. SBR versus tobacco cut width.

Two classes of additives to tobacco are humectants and salts. Burning rates for several humectant combinations are shown in **Table 6.** Here, increasing amounts of humectants appear to increase SBR slightly. Further testing would have to be done over a wider range of humectant levels to confirm these data. Salts have been shown to both accelerate and retard SBR. Data of Aksu (9) and Pyriki and Philipp (10) are shown in **Tables 7** and **8** to illustrate this. In **Table 7,** magnesium acetate is seen to retard the burning rate very slightly while potassium acetate tends to accelerate it. Table 8 summarizes the effects of various inorganic salts on SBR. Here again the importance of the cation is demonstrated: KC1 increases the SBR, $CaCl_2$ and $MgCl_2$ decrease it. According to Pyriki and Philipp, the retarding effect of these latter two is due to the low melting points of the hydrated salts.

The effect of tobacco moisture content on SBR is shown in

Table 7. Effect of organic salts added to tobacco on SBR.[a]

| Salt Added (2%) | Static Burning Rate (mg/min) |
|---|---|
| None | 43 |
| Magnesium Acetate | 42 |
| Potassium Lactate | 45 |
| Potassium Malate | 45 |
| Potassium Acetate | 46 |

[a]Data from Aksu (9).

Table 8. Effect of inorganic salts added to tobacco on SBR[a].

| Effect On SBR | Salt (2%) |
|---|---|
| 5-10% Increase | KC1, $K_2SO_4$, $K_2CO_3$, $Na_2CO_3$ |
| <5% Change | NaCl, $Na_2HPO_4$, $Na_3PO_4$, $KH_2PO_4$, $K_3PO_4$ |
| 5-10% Decrease | $Na_2SO_4$, $NaH_2PO_4$, $K_2HPO_4$ |
| >10% Decrease | $CaCl_2$, $MgCl_2$, $MgSO_4$ |

[a]Data from Pyriki and Philipp (10).

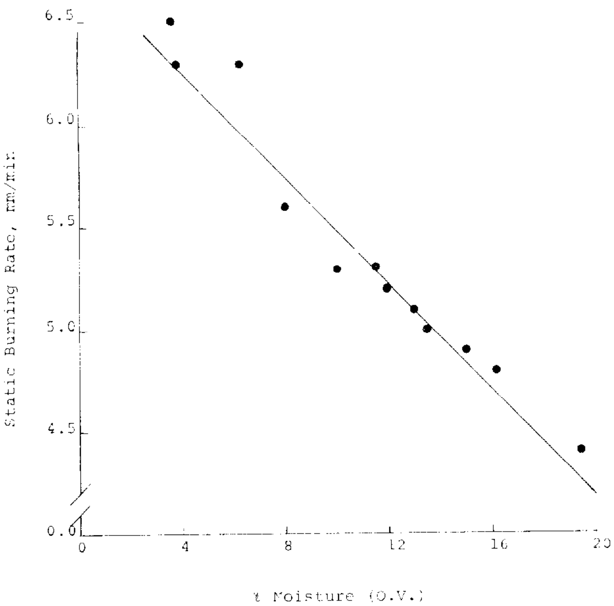


**Fig. 7. SBR versus moisture content of tobacco.**

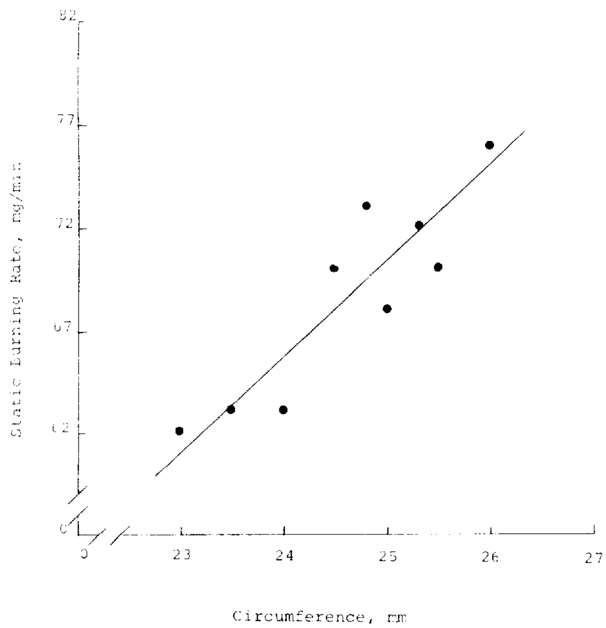


**Fig. 9. $SBR_m$ versus tobacco rod circumference.**

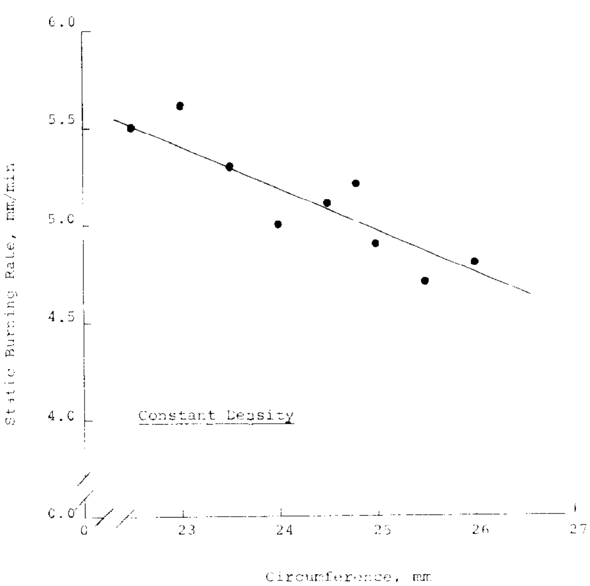


**Fig. 8. $SBR_d$ versus tobacco rod circumference.**

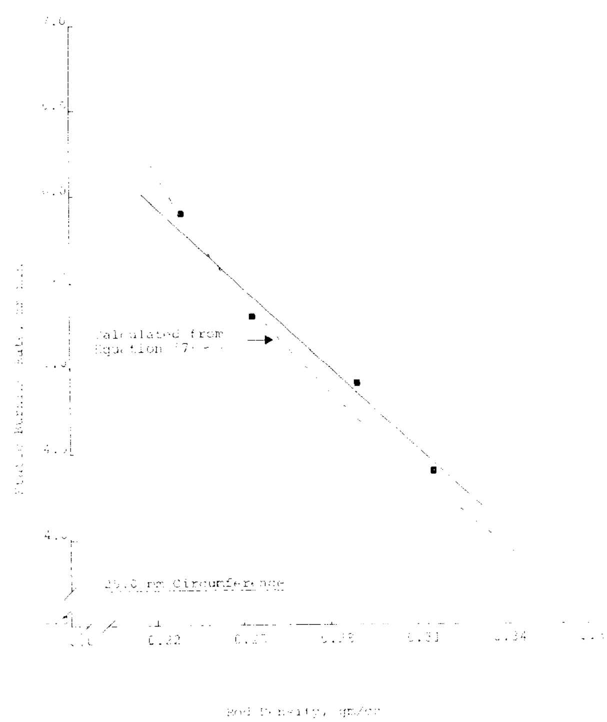

**Fig. 10. $SBR_d$ versus tobacco rod density.**

**Fig. 7.** As would be expected, burning rate decreases with increasing moisture content.

C. *Cigarette Construction.* Both the geometry and the density of the tobacco rod have an effect on SBR. **Fig. 8** shows that increasing rod circumference at constant rod density causes $SBR_d$ to decrease. However, converting the data of **Fig. 8** to $SBR_m$ units, we find that $SBR_m$ increases with increasing circumference (**Fig. 9**). This phenomenon is important in "slim" (22-23mm circumferences) cigarette design where the percentage decrease in puff count caused by decreasing the circumference is not as great as the percentage weight reduction.

In **Fig. 10,** $SBR_d$ is seen to decrease with increasing rod density for a given rod circumference. $SBR_m$, however, is nearly constant with increasing density, as shown in **Fig. 11.** The data of **Fig. 11** can be expressed as

$$SBR_m = K_c \qquad (3)$$

where $K_c$ is a constant for a given circumference. From equations (1) and (2),

$SBR_m$ and $SBR_d$ can be interrelated:

$$SBR_m = \frac{W}{L} \bullet SBR_d \qquad (4)$$

The weight per unit length of tobacco can be expressed as

$$\frac{W}{L} = \frac{C^2\varrho}{4\pi} \qquad (5)$$

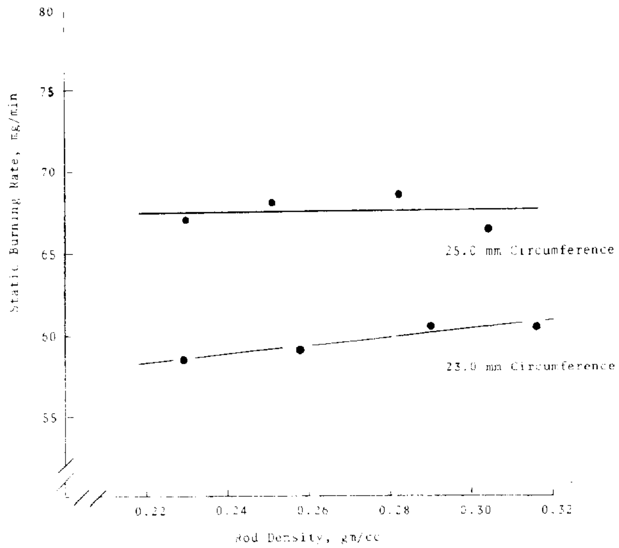


**Fig. 11. $SBR_m$ versus tobacco rod density.**

where $\varrho$ is the tobacco rod density and C is the circumference. Equations (4) and (5) can be combined to give

$$SBR_m = \frac{C^2\varrho}{4\pi} \bullet SBR_d \qquad (6)$$

Substituting equation (3) into equation (6) and rearranging gives

$$SBR_d = \frac{4\pi K_c}{C^2\varrho} \qquad (7)$$

indicating $SBR_d$ for constant circumference is inversely proportional to $\varrho$. Substituting the value of $K_c$ for 25 mm circumference cigarettes from **Fig. 11** into equation (7) gives the relationship between $SBR_d$ and $\varrho$ shown by the broken line in **Fig. 10.** The broken line fits the experimental points reasonably well.

This paper is intended as a survey of the extent to which various cigarette parameters affect the static burning rate. For this reason, the authors have refrained from speculating about the mechanisms by which certain parameters influence the burning.

## LITERATURE CITED

1. Artho, A.J. A method to determine the static burning rate of cigarettes. *Beitr. Tabakforsch.* 3(1):19-24. 1965.

2. Rice, R.L., R.S. Perrier, V.C. Runeckles. A weight loss technique for determining rate of static burn. *Coresta Inform. Bull.* 4779, 1967.

3. Wiley, R.M. and J.C. Holmes. An automation device for determining the static burning rate of cigarettes. **Tob. Sci.** 6:144-145. 1962.

4. Stoop, E. A method for measuring the burning rate of cigarettes. **Beitr. Tabakforsch.** 4 (3):159-160. 1968.

5. Pullman, J.O. and C.H. Keith. A semi-automatic instrument for the measurement of cigarette free-burning rates. **Tob. Sci.** 8:133-135. 1964.

6. Schur, M.O. and J.C. Rickards. The design of low yield cigarettes. **Tob. Sci.** 4:69-77. 1960.

7. Jodl, R. Effect of burning additives of cigarette paper on burning rate of cigarettes. **Beitr. Tabakforsch.** 5(1):22-24. 1969.

8. Flesselles, J. Influence of the cut width of cut tobacco on some physical characteristics of the cigarette. **Tob. Abstr.** 11(1694):478. 1967.

9. Aksu, S. Some organic salts as humectants in cigarettes. **Beitr. Tabakforsch.** 5(1):18-19. 1969.

10. Pyriki, C. and W. Philipp. The influence of various inorganic salts on the burning capacity of fermented tobacco. **Ber. Inst. Tabakforsch.** Dresden 2:94-111. 1955.



Tobacco Science, 1977, 21-30, p. 103-107, ISSN. 0082-4523.pdf