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IMPERIAL TOBACCO LIMITED
RESEARCH & DEVELOPMENT DIVISION
MONTREAL
THE USE OF THE FREIRI SLAVE SMOKER
TO INVESTIGATE CHANGES IN SMOKING BEHAVIOUR
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THE USE OF THE FREIRI SLAVE SMOKER
TO INVESTIGATE CHANGES IN SMOKING BEHAVIOUR:

PART I

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THE USE OF THE FREIRI SLAVE SMOKER
TO INVESTIGATE CHANGES IN SMOKING BEHAVIOUR

PART I

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SUMMARY

Evidence is presented demonstrating the differences between human and standard machine smoking. With a panel of 10 cigarette smokers, human smoking parameters were monitored when smokers changed from their normal cigarette to one of lower nicotine, lower TPM delivery. Pronounced differences in pressure drop hindered nicotine delivery from being maintained. As well, smoking patterns were observed when changes to higher than normal nicotine content cigarettes were encountered. Changes in number, duration and volume of puffs were noted as well as butt length and pressure drop differences. In each case, the smoker adjusted his smoking habits in order to duplicate his normal cigarette nicotine intake. Such compensation suggests that much further analyses is required in order to better appreciate the implications and health factors related to these changes in smoking patterns.

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INTRODUCTION

Since it has been suggested that a change to a lower tar, lower nicotine cigarette could possibly reduce the health hazards of cigarette smoking (1-3), it was decided to assess the real effect on smokers of modifying their normal smoking product.

There have been numerous and various reports recently (on changes in cigarette brands), with regard to modification of smoke rates in order to regulate nicotine intake (4-8). Because of conflicting evidence, differences in human and standard machine smoking * were evaluated. In addition, a study of the effect on smoke yield from the cigarette and smoking patterns was undertaken when changes A) to a lower nicotine, lower TPM delivery cigarette, as a result of higher pressure drop, and B) from lower to higher cigarette nicotine content, were made.

* BAT Bellows Smoking Machine

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A) THE PLAYERS STUDY

Purpose

The purpose of this study was to investigate any changes in smoking behaviour of a series of volunteers when changing from their normal cigarette, Players Filter Regular length, to Du Maurier King Size, a cigarette of slightly less nicotine and total particulate matter delivery but of a considerably higher pressure drop. At the same time, this human smoking data will be compared to standard machine smoking data.

Subjects and Methods

Nine healthy volunteers, 3 women and 6 men of varying age, all members of the ITL staff, took part in this comparative study. All smoked at least 20 Players Filter Regular cigarettes per day. The volunteers were asked to come each day and smoke a cigarette of this brand while being monitored by instrumentation measuring smoking parameters. A time was selected, convenient to each volunteer, when he would normally smoke a cigarette. No restrictions were placed upon the normal routine of smoking except for minimal interference by the instrumentation.

The smoker was monitored by a one-port slave smoking machine, the Freiri Smoker, following the procedure outlined previously (9). Subjects were separated from instrumentation and the technician by a curtain, as well as a two-way mirror. The mirror aided in observing

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any physical actions of the smoker (i.e. smoke lost through seepage from the mouth) during the smoking period. Any inquiries concerning instrumentation were allayed in order that the smoker be as relaxed as during any regular smoking experience. Each volunteer was monitored approximately ten times in order to establish consistent smoking patterns.

It was at this point in the study that each volunteer was given a different cigarette, Du Maurier King Size, and the above study repeated.

One of the limitations is that the volunteers smoked only one cigarette per day of this different brand, and not consistently the same cigarette throughout the entire length of the study.

Observations & Discussion

Smoking parameters of the Loyal Players Filter Regular smoker, as established by the Freiri Slave Smoking machine, are compared in Table 1 to those obtained from standard machine smoking. All human smoking parameters were found to be larger than those obtained from standard machine smoking. The most pronounced increase of 62% in total volume of smoke drawn, results in a 64% increase in nicotine and 58% increase in TPM.

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TABLE I

Players Filter Regular Smoking Parameters

<u>Smoking Parameter</u>	<u>Standard Machine Smoking</u> <u>(Mean Value)</u>	<u>Freiri Slave Smoker (Human)</u> <u>(Mean Value)</u>
Total Time Alight (sec.)	414	460
Puff number	7.9	9.0
Puff Interval (sec.)	60	62
Puff Duration (sec.)	2.0	2.2
Total Puff Volume (ml.)	277	448
Puff Velocity (ml/min.)	1050	1300
Nicotine Delivery (Main Stream Smoke) (mg/cig.)	1.40	2.30
TPM Delivery (Main Stream Smoke) (mg/cig.)	25.3	41.0

From Figure 1, it is illustrated that pressure drop, puff volume and puff duration tend to decrease through the smoking cycle. This is contrary to standard machine smoking where both puff volume and duration remain constant, though pressure drop after an initial rise does decrease through the smoking cycle.

With regard to puff interval, more puffs tend to be taken at the beginning and end of the smoking cycle; this behaviour accounting for the "S" shaped curve of Figure 2.

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Data of two cigarette types employed in this study, obtained under standard machine smoking conditions, are listed in Table II.

TABLE II

Product Data For Cigarettes* Used

<u>Cigarette</u>	<u>Players Filter Reg.</u>	<u>Du Maurier K.S.</u>
Cigarette Length mm.	72	84
Filter Length mm.	11	17
Paper Porosity Greiner/sec.	35	35
Filter Type	C.A.	C.A.
Filter P.D. in. /H ₂ O	1.0	2.0
Total P.D. of cigarette (in. H ₂ O)	3.8	5.4
Nicotine (mainstream smoke) (mg/cigt.)	1.40	1.25
TPM (mainstream smoke) (mg/cigt.)	25.3	23.2
Puff Number	7.9	9.5
Butt Length mm.	30	30

* Cigarettes were conditioned (60% R.H. and 72⁰F) and pressure drop selected.

Conventionally obtained standard smoke yields (from standard smoking machine) indicate that the du Maurier K.S. has 10.7% less nicotine and 8.3% less TPM than the Players Filter Reg. However, this difference becomes significant for human smoke yields. For the loyal Players

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smoker, when smoking Du Maurier, the average observed increases amount to 30.4% and 31.1% for nicotine and TPM respectively. This is seen from Table III.

TABLE III
Human Smoking Parameters Obtained from
the Freiri Slave Smoking Machine

<u>Cigarette</u>	<u>Players Filter Reg.</u>		<u>Du Maurier King Size</u>	
	<u>Mean Value</u>	<u>Range</u>	<u>Mean Value</u>	<u>Range</u>
Total Time Alight (sec.)	460	380-550	490	390-650
Mean Puff Number	9.0	6.0-11.0	9.4	6-15
Puff Interval (sec.)	62	39-104	63	44-108
Puff Duration (sec.)	2.2	1.6-4.5	2.4	1.5-5.0
Puff Volume (ml.)	49.8	31-107	42.6	26-108
Total Puff Volume	448		400	
Puff Velocity* (ml/sec.)	1300	1170-1500	1054	920-1320
Pressure Drop** (in.)	3.8	2.4-5.0	5.9	5.0-11.5
Butt Length (mm)	26	20-38	33	22-48
Nicotine Delivery (mg/cigt.)	2.3	0.9-4.2	1.6	0.6-3.0
TPM Delivery (mg/cigt.)	41.0	14.0-83.0	28.0	10.0-63.0

* Puff velocity is obtained from ratio: volume/time interval for each puff, averaged for all cigarettes smoked.

** Pressure Drop: Maximum during puff.

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By further analysis of Table III, these differences most likely result from the large difference in pressure drop between the two cigarettes. The smoker must apply more effort when smoking the Du Maurier K.S. cigarette in attempting to obtain equivalent Players Filter Reg. smoke yields. This is evidenced in Figure 3 where changes in maximum pressure drop through the smoking cycle are illustrated. The pressure drop for the Du Maurier K.S. cigarette is much higher than anticipated from pressure drop measurements taken during standard machine smoking. Further evidence of reactions to the pressure drop difference is seen in the puff volume and puff duration changes, these being the main contributors to smoke yield. This is illustrated in Figure 4 and 5 respectively. An overall increase of 9.4% in puff duration was noted for the Du Maurier cigarette. However, puff volume of this cigarette was 14.5% below the anticipated Players level. It might be expected that the smoker would normally increase his puff volume in order to obtain more nicotine from this new cigarette, but the increased resistance limits this volume correction.

It should be further noted from Figure 5 that the regular Players smoker makes a final compensation attempt by increasing puff number and increasing significantly the puff duration toward the completion of the Du Maurier cigarette. As well, he takes advantage of 5 of the additional 6 mm. of tobacco present.

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There is no significant difference in average puff interval between the two cigarettes, but in both cases the smoker tends to puff in more rapid succession, with larger volume and for longer duration through the first minutes of smoking. Thus, it can be concluded that the Players Filter Reg. cigarette smoker significantly alters his smoking pattern in order to overcome a lower nicotine and TPM delivery, as a result of this experienced high pressure drop.

B) THE MATINEE STUDY

Purpose

The purpose of this study was to investigate any changes in smoking behaviour of loyal Matinée smokers upon increasing cigarette nicotine content. The slave smoking studies of this cigarette will also be compared to standard machine smoking data. Matinée Regular constitutes a low TPM, low nicotine cigarette of relatively high pressure drop.

Subjects and Method

A group of healthy loyal Matinée Regular smokers, 8 women and 2 men, volunteered to take part in this comparative study. All members of ITL staff, they averaged 20-25 cigarettes per day.

The cigarettes used in this study were Matinée Regular as control, and cigarette types 2N and 3N. These latter two cigarettes were reinforced by addition of nicotine (as citrate salt) to PCL sheet, at the same time attempting to maintain other properties of the control cigarette.

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The same procedure, as outlined in the previous section, was followed in this study. A series of 10 cigarettes of each sample were smoked by each subject, to ensure that definite smoking trends could be established. It should be stressed again at this point, that these studies represented monitoring changes of one new cigarette (i.e., 2N or 3N) per day, and not the overall effect of a completely new regime of nicotine reinforced cigarettes.

Observations & Discussion

A comparison of human versus standard machine smoking parameters of the Matinée Regular cigarette is seen in Table IV. The marked increases of 51% in nicotine delivery and 17% in TPM delivery, as observed for human smoking, result in part from a 12% increase in puff volume*. This is in contrast to a decrease in total smoking time, puff interval and puff duration.

* (However, these high percentage increases may be misleading because of differences in free versus restricted standard machine smoking).

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TABLE IV

Matinée Regular Smoking Parameters

<u>Smoking Parameter</u>	<u>Standard Machine Smoking (Mean Value)</u>	<u>Freiri Slave Smoking (Human) (Mean Value)</u>
Total Time Alight (sec.)	360	298
Puff Number	7.0	8.8
Puff Interval (sec.)	60	37
Puff Duration (sec.)	2.0	1.7
Total Puff Volume (ml.)	245	274
Puff Velocity (ml/min.)	1050	1098
Nicotine Delivery (Mainstream smoke) (mg/cigt.)	0.45	0.68
TPM Delivery (Mainstream smoke) (mg/cigt.)	11.0	12.9

Figure 6 exhibits, as in the previous Players study, a continuous decrease in puff volume, and duration through the smoking cycle though this is not the case for the pressure drop. The puff interval distribution pattern, is also similar to that of the previous study.

These observed differences of human smoking behaviour appear to be dependent on the brand of cigarette smoked. This is further investigated in a series of cigarettes of increasing nicotine delivery, the data for which are given in Table V.

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TABLE V

Product Data for Cigarettes* Used

<u>Cigarette Types</u>	<u>Matinée Control</u>	<u>2N</u>	<u>3N</u>
Code	097	013	402
Length (mm)	72	72	72
Paper Porosity (Greiner/secs)	13	13	13
Filter Type	CA	CA	CA
Filter P.D. in H ₂ O	2.8	2.8	2.8
Total PD	5.5	5.5	5.5
<u>Blend</u>			
PCL % nicotine	1.07	11.64	23.24
% PCL	7.9	7.9	7.8
% CRS	18	19	18
% Total Alkaloids	1.17	1.82	2.67
<u>Smoke</u>			
Butt Length (mm)	30	30	30
Puff Number	7.0	7.1	7.1
TPM mg/cig.	11	12	12
Nicotine mg/cig.	0.45	0.68	0.88
Extr. Nicotine mg/cig.	0.08	0.16	0.22
% Extr. Nicotine	17.2	23.9	25.3
pH of TPM	5.61	6.00	6.10

*All cigarettes were pressure drop selected, and conditioned (60% R.H. and 72°F).

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These cigarettes represent increases of 51% and 96% in nicotine yield (under standard smoking conditions) for the 2N and 3N cigarettes respectively above that of the Matinée control cigarette. These increased nicotine deliveries were accompanied by an unexpected increase in TPM pH.

Data collected from the "Freiri Slave Smoker" is seen in Table VI. No definite trend in puff number is noted for the cigarette changes, but in the highest nicotine cigarette, fewer puffs tended to be taken. It can also be noted from this data, as illustrated in Figure 7, that overall smoking time and puff interval increased with elevated nicotine concentrations. This correlates with a decrease in puff volume and puff duration as illustrated in Figure 8 and Figure 9 respectively. The smoker instinctively reduces his volume of smoke in the case of the nicotine reinforced cigarettes, and furthermore he tends to reproduce his nicotine delivery, 0.88 mg., at the sacrifice of reducing TPM.

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TABLE VI

Human Smoking Parameters Obtained from the
"Freiri" Slave Smoking Machine

<u>Cigarette Type</u>	<u>Matinée Control</u>		<u>2N (013)</u>		<u>3N (402)</u>	
	<u>Mean Value</u>	<u>Range</u>	<u>Mean Value</u>	<u>Range</u>	<u>Mean Value</u>	<u>Range</u>
Total Time Alight (sec.)	298	190-437	328	210-640	342	220-420
Puff Number	8.8	6-14	8.9	6-13	8.0	5-13
Puff Interval (sec.)	37	13-79	41	15-66	49	12-104
Puff Duration (sec.)	1.7	1.2-2.5	1.5	0.9-2.3	1.4	1.0-2.1
Puff Volume (ml)	31.1	25.2-41.7	27.8	15.6-40.5	26.2	18.6-40.0
Total Puff Volume (ml)	274		247		210	
Puff Velocity* (ml/min.)	1098	840-1280	1112	840-1390	1123	900-1400
Pressure Drop** (in. H ₂ O)	5.2	4.7-5.7	4.8	4.3-5.4	4.4	3.8-4.9
Butt Length (mm)	30	21-40	31	23-43	28	22-40
Nicotine Delivery (mg/cig.)	0.68	0.4-1.2	0.88	0.4-1.5	0.88	0.4-1.5
TPM Delivery (Mainstream smoke) (mg/cig.)	12.9	6.1-25.5	10.5	5.5-18.7	8.7	4.6-13.1

* Puff Velocity is obtained from volume/time interval for each puff, averaged for all cigarettes smoked.

** Pressure Drop: Maximum during puff.

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Figure 10 illustrates the changes in pressure drop of the cigarette through the smoking cycle. The pressure drop established for the Matinée control cigarette increases after the lighting puff only to slowly decrease through the smoking cycle. This pattern is not duplicated for the nicotine enriched cigarettes. A distinct separation in pressure drop range within the three cigarettes is observed, establishing that human nicotine requirements may be satisfied with much reduced effort for the cigarettes with more available nicotine. At the same time, there is a marked reduction of TPM (15-20%) in each case for the nicotine enriched cigarettes. However, it cannot be overlooked that the increase in pH, related to the increased nicotine, will probably have induced different subjective effects (impact, taste etc.) upon the smoker, thus contributing also to changes in smoking patterns.

Conclusions

This study illustrates alterations in smoking behaviour of subjects when confronted with other than their preferred cigarettes.

The data obtained in the duplication of human smoking flexibility with the use of the Freiri slave smoker demonstrates a distinct advantage over standard machine smoking data.

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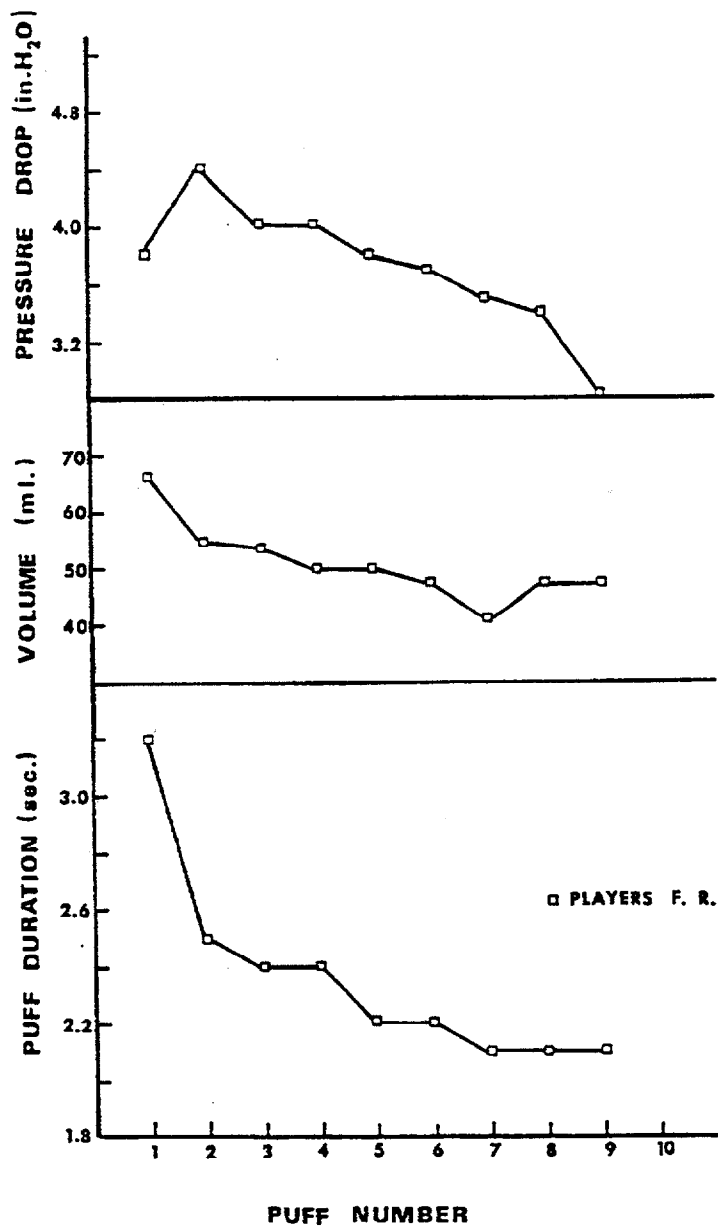
In the Players study, the behavioural changes of subjects, when exposed to a higher pressure drop cigarette yielding lower than preferred nicotine delivery, are studied. These changes are indicated by number, duration and volume of puffs, as well as butt length and pressure drop differences. This cigarette change results in the smoker adjusting to compensate for this lower nicotine delivery, but further analysis of total smoking diet would be required to conclude definitely whether satisfaction is achieved through this change.

In the Matinée comparative study, with excess nicotine availability, the same parameters were monitored. Here the smoking pattern is altered such that the nicotine level plateaus (i.e. nicotine satisfaction maintained) regardless of the excess nicotine present. In each circumstance, it is evident that the smoker adjusts his overall behaviour to compensate for his expectations of this modified smoking experience.

Further studies with regard to the role of TPM in human smoke yields are presently being investigated, as a follow-up of this study.

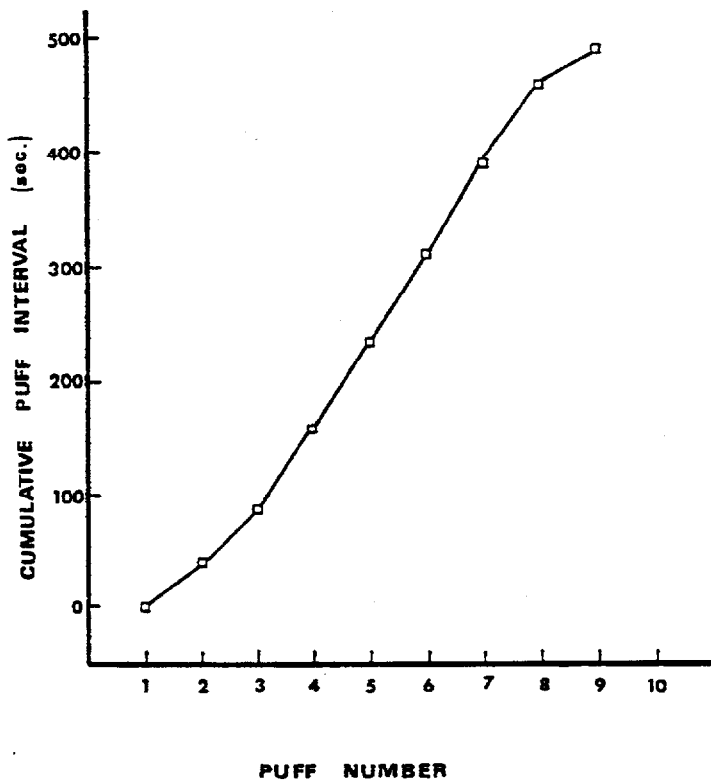
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Figure 1



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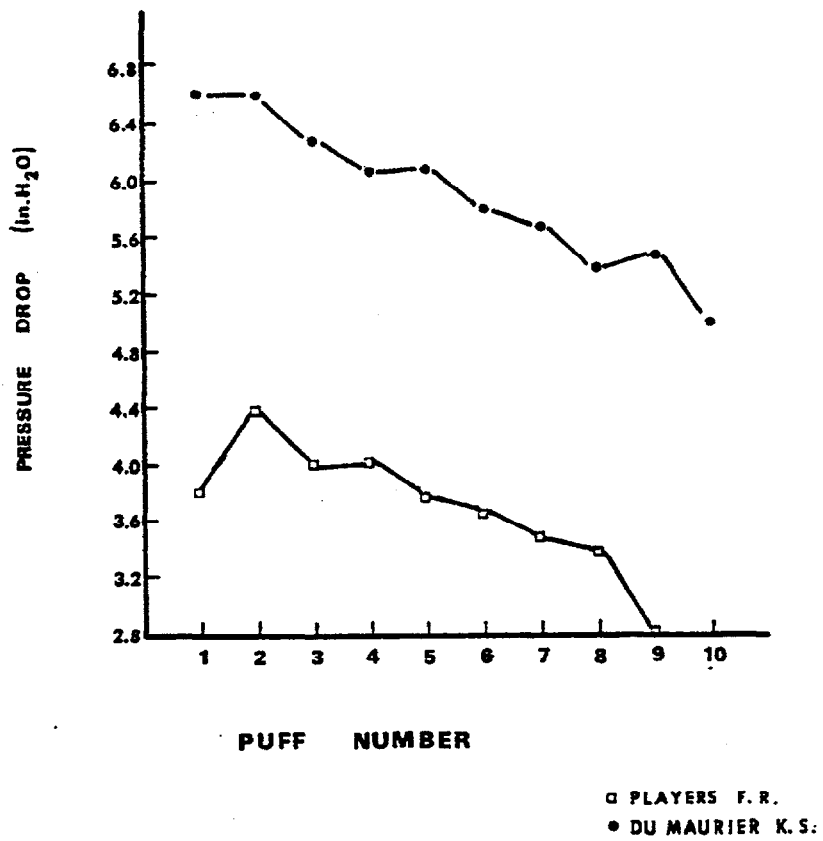
Figure 2



□ PLAYERS F. R.

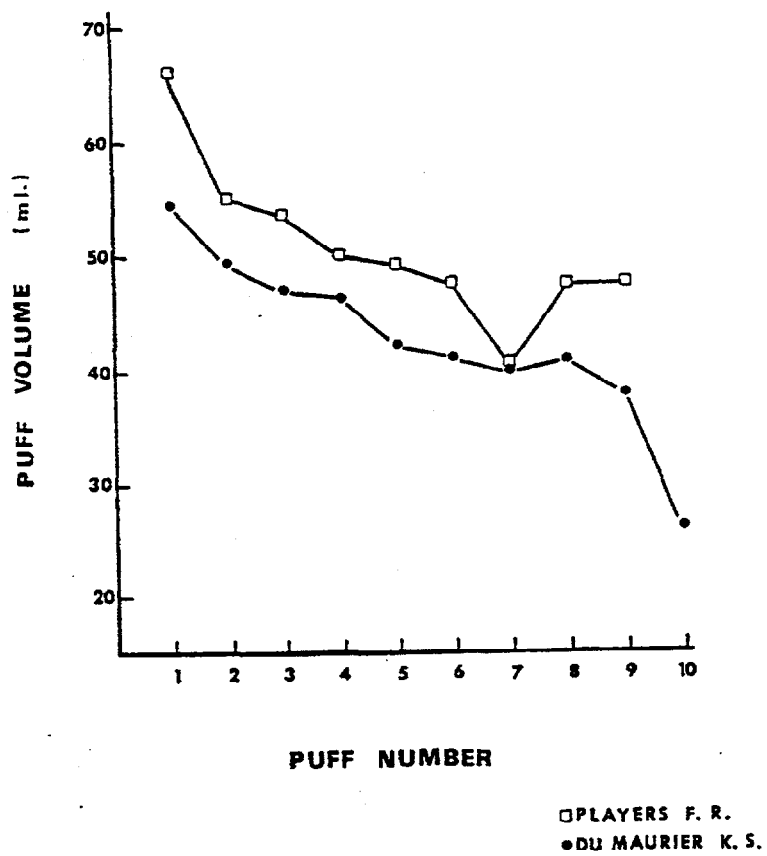
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Figure 3



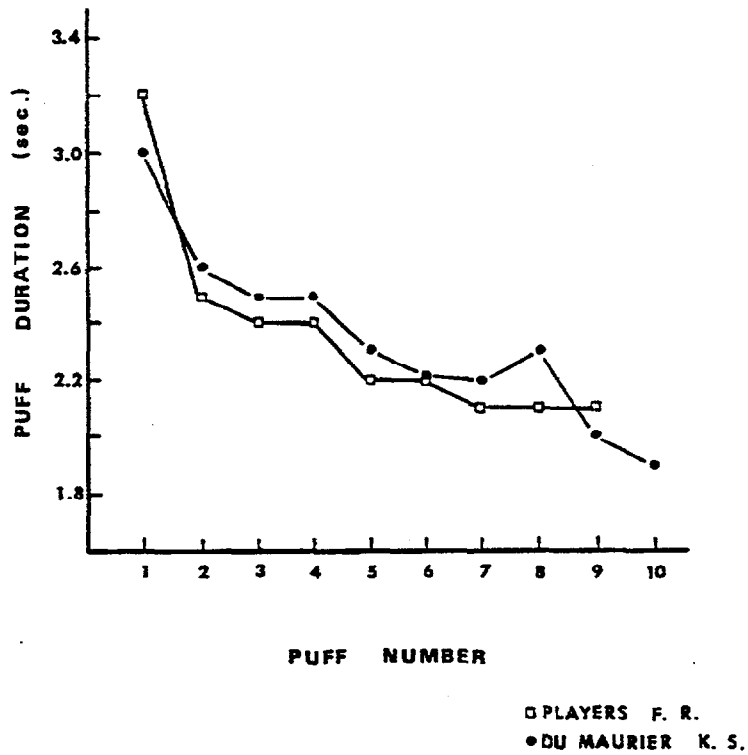
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Figure 4



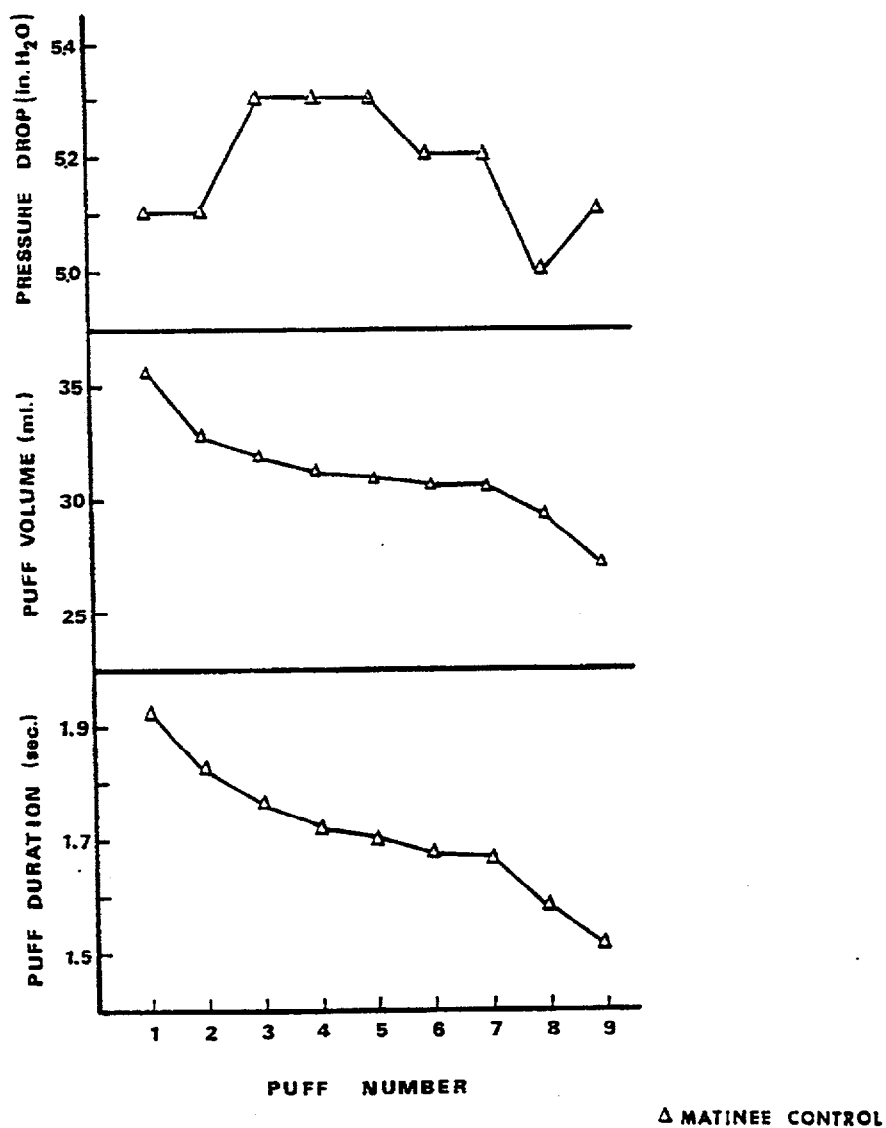
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Figure 5



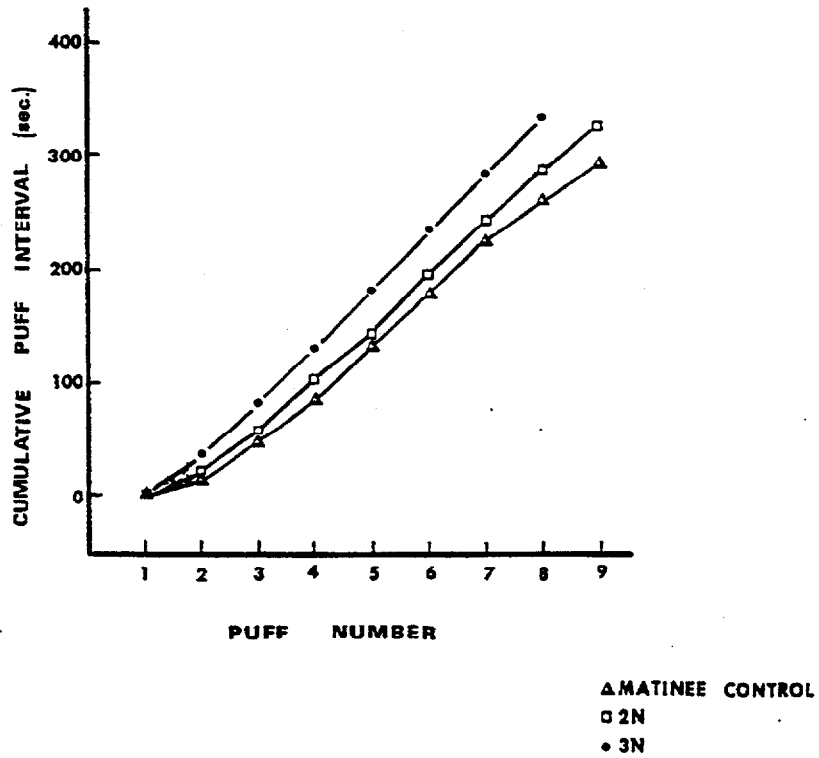
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Figure 6



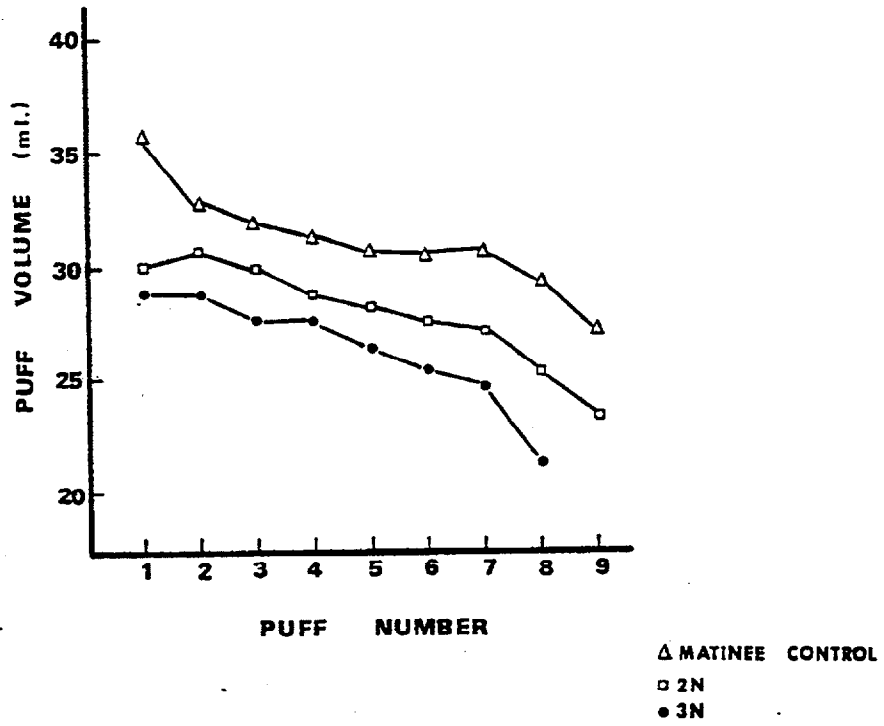
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Figure 7



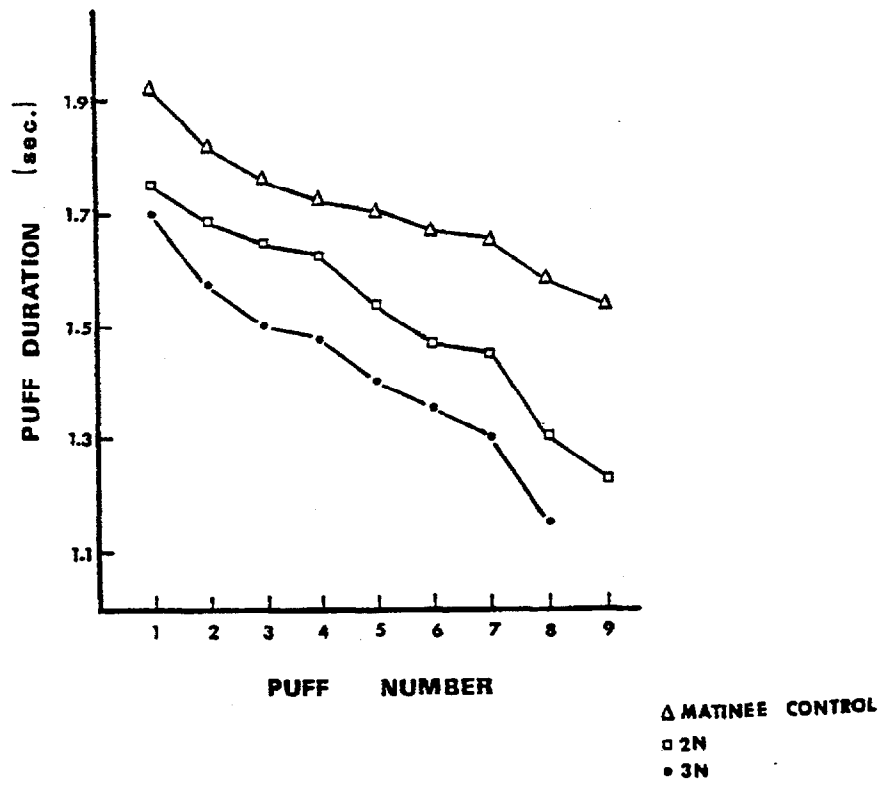
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Figure 8



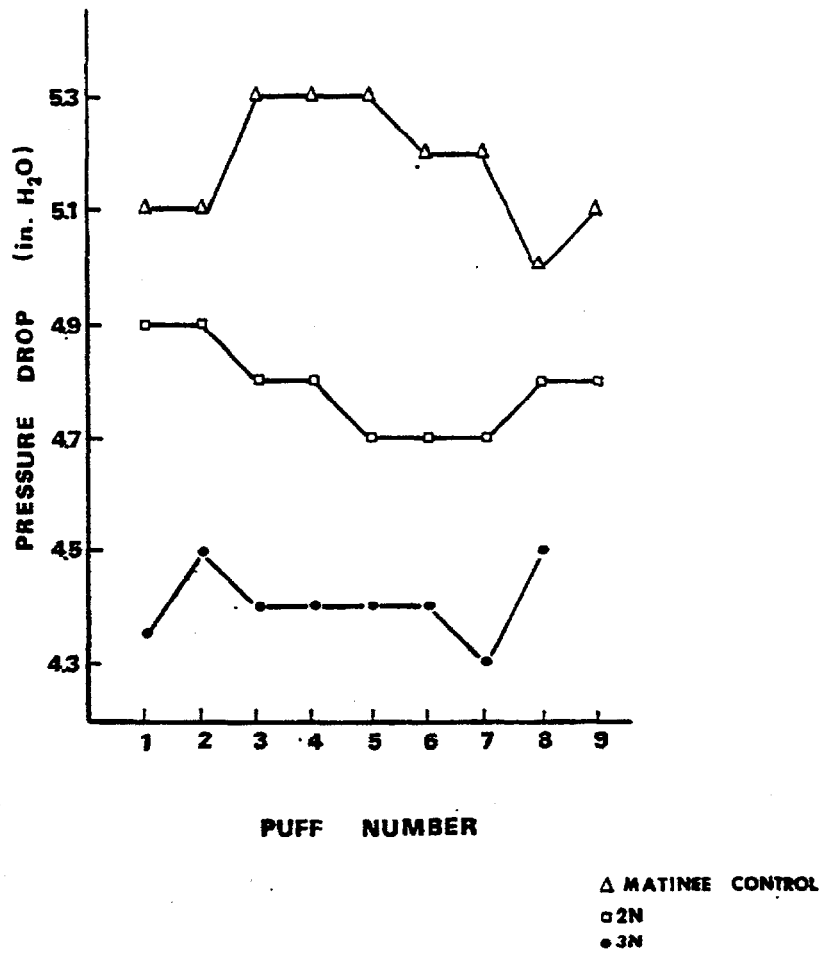
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Figure 9



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Figure 10



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