THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

VARIABILITY OF COMMERCIAL DIAPHRAGMS. PART I. BETWEEN CAVITY VARIANCE

Project 1108-26

Report Seven

A Preliminary Report

to

FOURDRINIER KRAFT BOARD INSTITUTE, INC.

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PART I. BETWEEN CAVITY VARIANCE

SUMMARY

As one phase of the current investigation regarding bursting strength standardization, the Institute and B. F. Perkins and Son, Inc. initiated a study designed to determine the variability in commercially manufactured diaphragms. The diaphragms at present are manufactured in a 25 cavity mold in batches or orders of from 2000 to 10,000 diaphragms. For the initial study it was decided to study the variability between diaphragms in a given order, i.e., the differences between cavity locations in the master die and the differences occurring from start to end of the selected orders. Later studies will evaluate differences between orders.

With the above in mind the 13 odd-numbered diaphragms were selected from the following mold impressions or "heats": 1, 100, 200, 300, 400. The 65 diaphragms were evaluated at the Institute for hardness, thickness, and diaphragm pressure at 3/8-inch.

Among the conclusions reached were the following:

1. All diaphragms gave pressures materially higher than that specified in Rule 41. The over-all average of 37.9 p.s.i.g. was 7.9 p.s.i.g. higher than the upper specification limit of 30 p.s.i.g.

2. The differences in pressure between diaphragms were relatively modest --ranging from about 36 to 40 p.s.i.g. Thus, on the basis of these data, the principal problem is to lower the average level to meet Rule 41 requirements.

3. Statistical analysis of the differences in diaphragm pressure between cavities or heats revealed no significant differences. While the between cavity

differences were not significant, it appeared that diaphragms from certain of the cavities tended to exhibit higher than average thicknesses and pressures. Some improvement in uniformity may be expected, therefore, if thickness can be controlled to closer tolerances.

INTRODUCTION

Because of the importance of the bursting strength tester to the paperboard industry, a subcommittee of the F.K.B.I. was set up to enlist the co-operation of B. F. Perkins and Son, Inc., in diaphragm and tester standardization. As a result, it was decided to pursue a research program at the Institute for the purpose of (a) identifying diaphragm characteristics which govern diaphragm life and contribution and (b) to develop specifications for diaphragms.

Previous reports to the Technical Committee have summarized progress in several phases of the work (1-5). Diaphragms differing in design (tapered center and ribbed styles) were compared in References (1), (2), and (4). In general, the studies indicated that the various designs gave approximately equivalent bursting strength results. In Reference (3) the effect of diaphragm pressure on test readings was re-evaluated and the results indicated that present diaphragm specifications of 23 to 30 p.s.i.g. permit about a 2 p.s.i.g. difference in bursting strength of kraft linerboard.

Arrangements were then made with B. F. Perkins and Son, Inc. to cooperatively determine the variance in diaphragm characteristics of present commercially manufactured diaphragms. At present, diaphragms are manufactured in a 25 cavity (see Fig. 1), mold and apparently are ordered in batches of from 2000 to 10,000--that is, 80 to 400 separate moldings. Therefore, within a given order, diaphragms may differ in their characteristics due to either cavity location or position in the production sequence. Diaphragms from different orders may also be expected to differ in their characteristics; thus, three sources of variances may be identified as follows:

1. Within orders or batches
    (a) between cavities

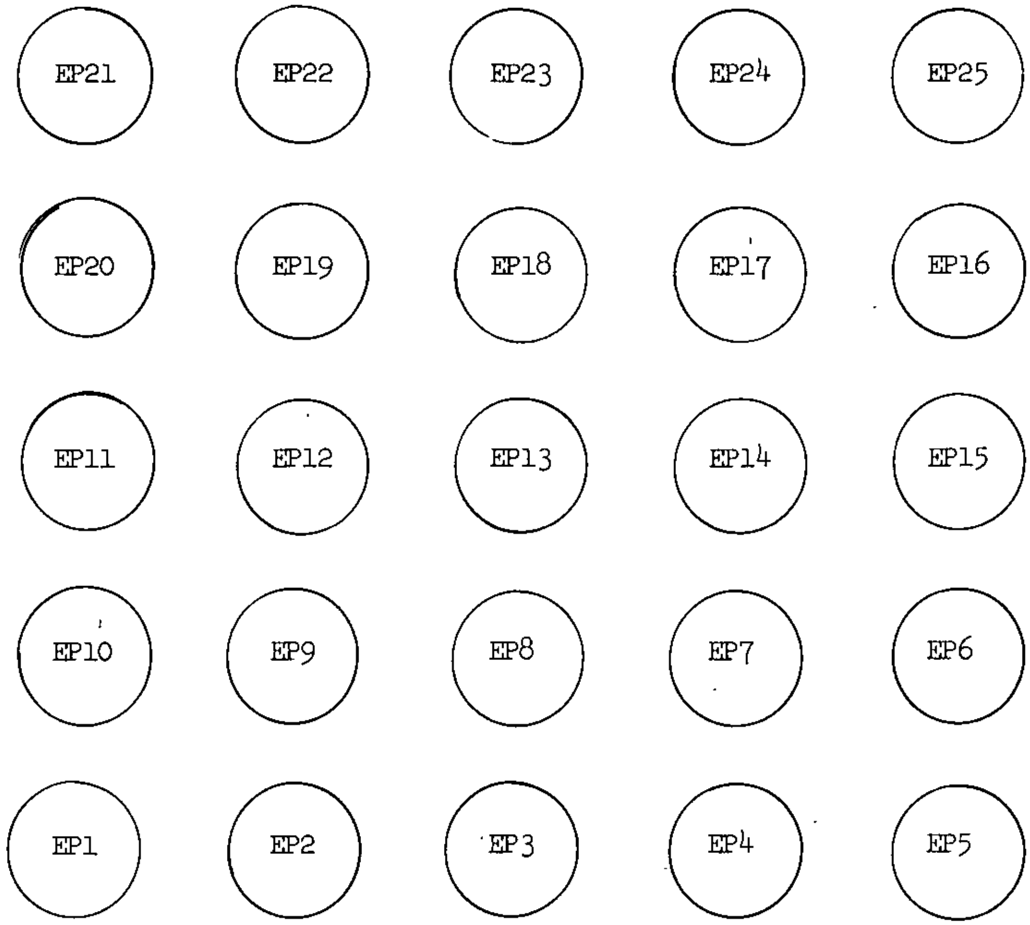

Figure 1. Cavity Position in 25 Cavity Mold

(b) between moldings or "heats"

2. Between orders or batches.

As an initial step, it was decided to sample diaphragms from a single order to determine the relative contribution of cavity location and mold sequence to diaphragm differences. The findings in this step could then guide selection of a suitable sampling procedure to compare diaphragms between orders.

With this in mind, the manufacturer was requested to select and forward to the Institute the 13 odd-numbered diaphragms from the following mold or heat numbers: 1, 100, 200, 300, and 400. These 65 diaphragms were then evaluated at the Institute for thickness, hardness, and diaphragm pressure. The measurements of diaphragm pressure were made using the apparatus to facilitate rapid and reproducible pressure measurements by both Institute and manufacturer (5).

TEST PROCEDURE

The diaphragms were evaluated as follows:

1. Durometer hardness: One determination was made on the center portion and two determinations were made on the rim for each diaphragm.
2. Thickness
   a. Standard caliper--8 ± p.s.i. average pressure. One determination was made in the center portion of each diaphragm.
   b. Modified caliper--100-gram force, 3/8-inch anvil diameter.
      1. Center: 1 test per diaphragm.
      2. Thin portion: 2 tests separated by 180° per diaphragm.
      3. Rim: 1 test per diaphragm.
3. Diaphragm pressure at 3/8 inch
   a. Tester: Model A tester with 60 p.s.i. gage and pressure measuring device.

b. Procedure

1. Install the diaphragm and adjust the diaphragm height in its retracted position so that its upper surface is flush with the lower platen.
2. Distend the diaphragm to approximately 1.8 cm. ten times.
3. Check to determine if the diaphragm in its retracted position is still flush with the lower platen and adjust if necessary.
4. Determine the pressure required to distend the diaphragm to 3/8-inch. Make a total of 5 determinations.
5. For the five diaphragms marked EP25, repeat the above determinations after distending the diaphragm 40 times to 1.8 cm.

DISCUSSION OF RESULTS

The hardness, thickness, and diaphragm pressure measurements are summarized in Tables I through IV. Referring to the tables, it may be noted that, on the average, hardness values in the center ranged from 69.6 for cavity positions 17 and 19 to 70.8 for cavity positions 7 and 25. In general, there appeared to be little or no relationship between hardness and diaphragm pressure as illustrated in Fig. 2.

With regard to central thickness, diaphragms from cavity numbers 3, 13, and 21 generally exhibited higher than average calipers and it may be interesting to note that diaphragms from cavities 3 and 13 exhibited higher than average diaphragm pressures. The relationship between center caliper and diaphragm pressure is graphed in Fig. 2 and tends to indicate that the higher the caliper the higher the pressure. The results suggest, therefore, that improving center thickness uniformity should also increase diaphragm pressure uniformity.

With regard to thickness at the rim and thin section, diaphragms from cavity 13 gave consistently higher thicknesses in both locations. Cavity 21 diaphragms exhibited the lowest thickness in the thin portion and this may help to explain their lower than average diaphragm pressures.

The diaphragm pressure measurements in Table IV indicate that:

(a) All diaphragms gave pressures materially higher than specified in Rule 41. The over-all average of 37.9 p.s.i.g. was 7.9 p.s.i.g. higher than the upper specification limit of 30 p.s.i.g.

(b) The differences in pressure between diaphragms were relatively modest--ranging from 36.1 to 40.0 p.s.i.g. or a spread of about 4 p.s.i.g. Therefore, it appears that the main problem is to lower the diaphragm pressures to bring them within specifications.

TABLE I

DUROMETER HARDNESS VALUES AS A FUNCTION OF CAVITY POSITION AND MOLD SEQUENCE

	Durometer Hardness, units											
	Center						Rim					
	Mold No.						Mold No.					
Cavity No.	1	100	200	300	400	Av.	1	100	200	300	400	Av.
1	69	69	69	72	70	69.8	67	67	70	69	68	68.2
3	69	68	70	72	72	70.2	68	65	68	69	68	67.6
5	71	69	72	70	71	70.6	68	64	69	68	68	67.4
7	71	69	72	70	72	70.8	68	66	70	68	68	68.0
9	68	70	72	72	69	70.2	66	66	69	68	68	67.4
11	68	68	71	70	72	69.8	68	66	70	70	70	68.8
13	70	69	70	72	70	70.2	67	66	70	70	69	68.4
15	71	70	72	72	71	71.2	70	66	70	70	68	68.8
17	69	67	72	70	70	69.6	67	66	68	69	70	68.0
19	69	68	70	70	71	69.6	68	66	68	70	68	68.0
21	69	69	72	70	70	70.0	67	66	70	68	68	67.8
23	71	70	70	73	70	70.6	68	66	68	68	68	67.6
25	71	69	71	72	71	70.8	68	66	70	70	68	68.4
Average	69.7	68.8	71.0	71.2	70.7		67.7	65.8	69.2	69.0	68.4	

TABLE II

THICKNESS OF CENTER PORTION OF DIAPHRAGMS

	Caliper, points (100 g. pressure)						Caliper, points (8 p.s.i.g.)					
	Mold No.						Mold No.					
Cavity No.	1	100	200	300	400	Av.	1	100	200	300	400	Av.
1	96.5	96.6	97.2	96.5	97.4	96.8	94.0	94.0	94.8	94.2	95.0	94.4
3	100.7	100.7	100.9	100.6	100.4	100.7	98.0	97.9	98.2	97.9	97.2	97.8
5	98.8	98.4	98.3	98.3	98.4	98.4	96.0	96.0	95.6	95.5	96.0	95.8
7	98.2	98.5	97.4	97.8	97.8	97.9	95.6	95.6	95.0	95.1	95.3	95.3
9	96.7	96.7	98.9	96.7	96.8	97.2	94.0	94.3	96.2	94.0	94.2	94.5
11	97.8	97.7	97.3	97.3	97.9	97.6	95.3	95.0	94.9	94.9	95.7	95.2
13	102.2	102.3	99.2	99.7	99.0	100.5	99.2	99.5	96.5	97.0	96.2	97.7
15	100.3	100.1	99.9	98.4	100.1	99.8	97.6	97.2	97.2	97.3	97.2	97.3
17	97.9	98.1	98.3	99.1	98.3	98.3	95.2	95.3	95.3	96.3	95.8	95.6
19	100.0	99.2	99.0	99.3	98.7	99.2	97.2	96.3	96.2	96.3	96.1	96.4
21	101.9	101.7	101.7	102.1	102.1	101.9	99.0	99.0	99.0	99.0	99.2	99.0
23	97.8	97.1	97.7	97.7	97.1	97.5	95.0	94.6	94.9	94.9	94.8	94.8
25	97.7	98.2	98.3	98.2	98.6	98.2	95.0	95.2	95.6	95.7	96.0	95.5
Average	99.0	98.9	98.8	98.6	98.7		96.2	96.1	96.1	96.0	96.1	

TABLE III

THICKNESS MEASUREMENTS ON RIM AND THIN SECTION

Caliper, points[a]

	Rim						Thin Section					
	Mold No.						Mold No.					
Cavity No.	1	100	200	300	400	Av.	1	100	200	300	400	Av.
1	61.5	61.2	61.9	61.7	62.5	61.8	35.0	34.8	35.6	35.5	36.2	35.4
3	61.3	61.8	61.7	61.7	61.4	61.6	36.2	36.6	35.7	36.4	36.6	36.3
5	61.6	61.2	61.2	60.8	61.3	61.2	35.8	40.4	35.1	35.2	36.6	36.6
7	62.3	62.6	61.7	62.0	61.9	62.1	36.2	36.2	35.2	36.2	36.4	36.0
9	61.4	60.9	59.9	62.1	62.2	61.3	35.8	35.8	34.5	36.6	36.0	35.7
11	60.5	60.2	61.7	60.3	61.0	60.7	35.6	35.1	36.0	36.5	36.2	35.9
13	66.0	65.8	63.0	64.2	62.7	64.3	40.0	40.0	37.2	39.1	37.2	38.7
15	61.7	60.8	61.2	66.2	63.6	62.7	35.7	34.9	35.1	37.0	35.6	35.7
17	61.8	61.4	61.7	62.5	62.0	61.9	36.0	40.4	35.2	37.6	36.0	37.0
19	62.0	62.3	61.9	62.3	61.2	61.9	35.9	35.9	35.4	37.0	36.1	36.1
21	61.2	60.6	60.4	61.1	61.1	60.9	34.3	35.2	35.1	35.6	35.5	35.1
23	62.7	61.8	62.4	62.2	61.9	62.2	37.2	35.8	36.6	37.6	36.2	36.7
25	60.7	60.8	61.0	61.2	61.6	61.1	34.8	34.8	35.2	36.3	36.8	35.6
Average	61.9	61.6	61.5	62.2	61.9		36.0	36.6	35.5	36.7	36.3	

[a]Using 100-gram load on 3/8-inch diameter anvil.

TABLE IV

DIAPHRAGM PRESSURE AS A FUNCTION OF CAVITY LOCATION
AND MOLD SEQUENCE

	Average Diaphragm Pressure (3/8-in.), p.s.i.g.					
	Mold No.					
Cavity No.	1	100	200	300	400	Av.
1	37.2	36.6	37.8	37.3	38.9	37.6
3	38.0	39.7	37.4	38.4	37.8	38.3
5	37.4	37.8	38.6	38.6	38.6	38.2
7	39.1	37.0	37.7	36.9	37.7	37.7
9	37.8	36.7	38.4	37.3	37.4	37.5
11	37.6	37.6	38.0	38.3	38.3	38.0
13	39.1	39.2	38.6	38.8	38.5	38.8
15	38.7	37.4	37.9	37.1	38.3	37.9
17	37.0	37.5	37.8	40.0	37.0	37.9
19	37.4	36.7	38.4	38.8	38.0	37.9
21	37.9	37.4	37.7	37.5	36.7	37.4
23	37.5	36.1	38.2	37.0	38.0	37.4
25	39.7	37.2	36.9	38.4	38.6	38.2
Average	38.0	37.5	38.0	38.0	38.0	37.9

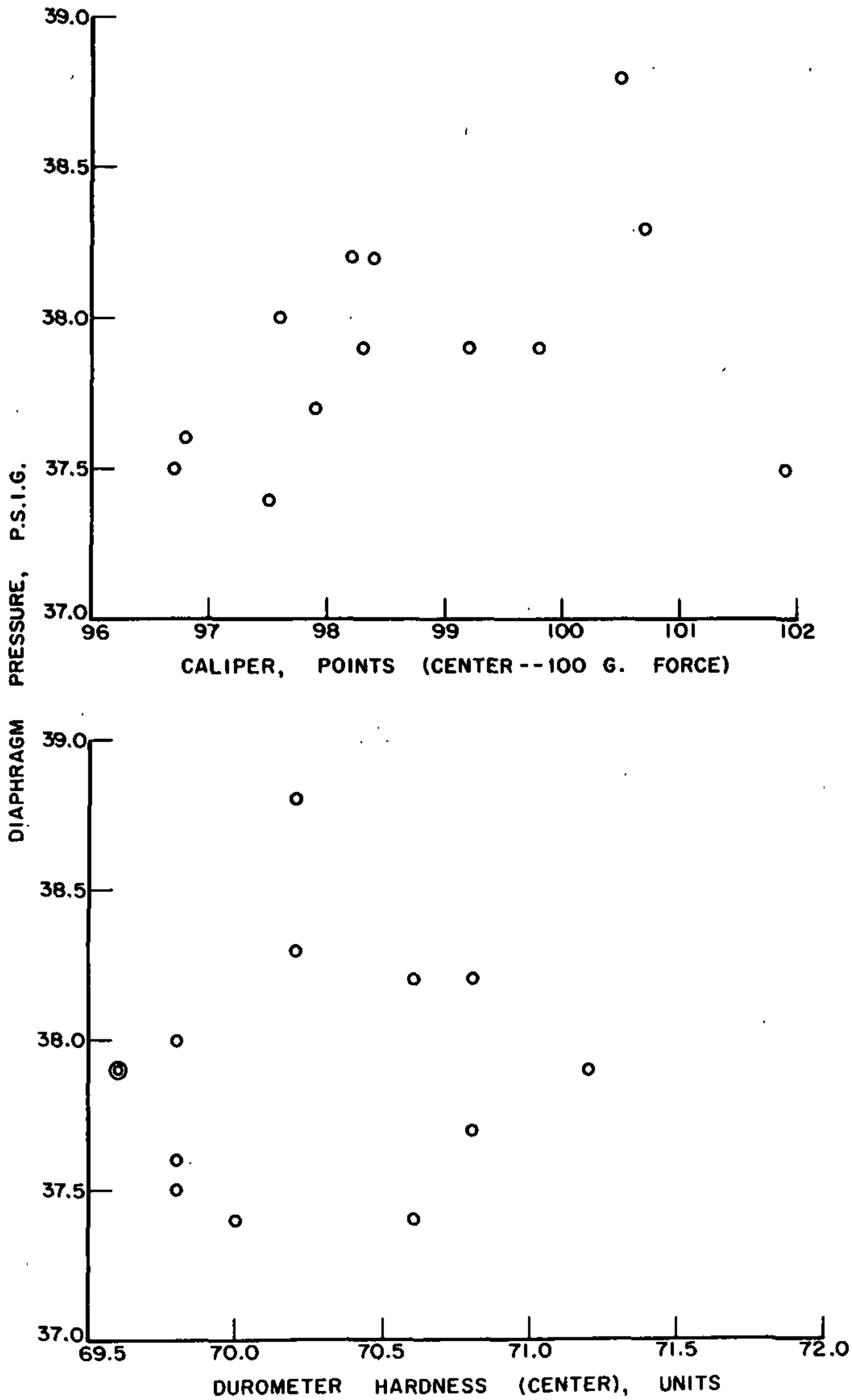

Figure 2. Relationship Between Average Diaphragm Pressure and Center Hardness and Thickness

(c) As noted in Fig. 3, diaphragms from cavity positions 21, 23, 9, 1, and 7 tended to give lower than average pressures and diaphragms from cavities 11, 5, 25, 3, and 13 tended to give higher than normal pressures. Certain of these differences may be related to thickness variations as noted above.

(d) The diaphragm pressures were sensibly constant on the average through the production run.

A two-factor analyses of variance was performed using the results shown in Table IV. The analysis is summarized below:

Source of Variance	Degrees of Freedom	Mean Square	F
Between "heats"	4	0.790	1.30
Between cavities	12	0.902	1.48
Residual	48	0.608	

Neither major effect was significant at the 5% level which is not unexpected in view of the relatively modest differences between cavities and "heats" (production sequence).

The above diaphragm measurements were taken after distending each diaphragm to about 1.8 cm. ten times, as previous work has indicated this is sufficient to stabilize the diaphragm pressures. As a check on this the five diaphragms from cavity 25 were given an additional 40 distentions (giving a total of 50 distentions to 1.8 cm.) and the diaphragm pressures were remeasured. The results obtained are shown in Table V. As may be noted, the results at 10 and 50 distentions were approximately equal.

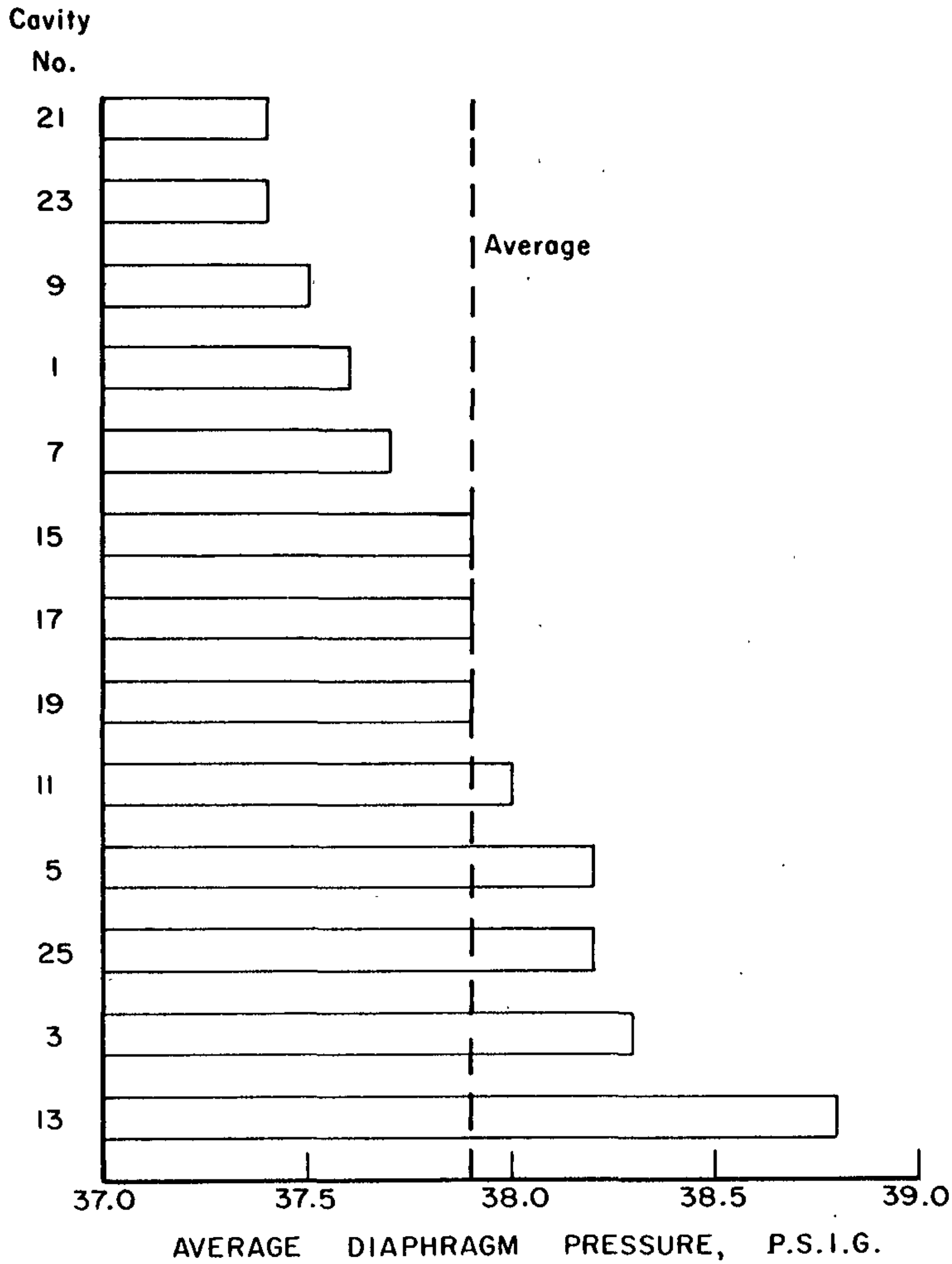

Figure 3. Cavity Ranking with Respect to Diaphragm Pressure

TABLE V

EFFECT OF ADDITIONAL DISTENTIONS ON DIAPHRAGM PRESSURE

Diaphragm No.	Diaphragm Pressure, p.s.i.g. After 10 Distentions	After 50 Distentions
25-1	37.5	37.3
25-100	36.1	36.4
25-200	38.2	37.2
25-300	37.0	37.7
25-400	38.0	37.8
Average	37.4	37.3

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