

ON FILTRATION.

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CONSIDERING that a large percentage of the analyst's working time is spent upon various filtering operations, it is not a little remarkable how ill the conditions are understood which influence the rate at which a fluid passes through a filter. The text-books are generally silent upon the subject, or, when they do give instructions to the student, mostly direct that the filter-paper should be fitted into the funnel as closely as possible. (See, for instance, Fresenius's "Qual. and Quant. Analysis.") In many laboratories where students are instructed, this advice is followed. In others the paper is folded so that the angle formed by the edges of the filter should meet in an angle somewhat larger than 90° . In others, again, various forms of pleating the filters are in use.

If we except the Bunsen Waterpump arrangement—which no doubt allows of the most rapid working, but is not in general favour owing to the transferring of filtrates from one vessel into another which it entails, and the not infrequent breaking of filters in the middle of an analysis which occurs,—for quantitative purposes, smooth filters closely fitted, or loosely laid into the funnel, are employed; for qualitative work, various forms of pleated filters.

It has long ago been observed by Fleitmann ("Zeitsch. f. Anal. Chem.," xiv., p. 77) that in many cases a double filter filters more rapidly than a single one, because it presents a thicker passage for the filtrate to escape. With a similar intention, Ebermayr ("Chem. Centralbl.," 3, f. x., 176) recommends to lay under the filter a small piece of muslin into the funnel. Hempel ("Zeitsch. f. Anal. Chem.," xiv., p. 308) etches, with hydrofluoric acid, a few channels into the funnels used in connection with a Bunsen pump, whilst De Mollins ("Zeitsch. Anal. Chem.," xix., p. 334) uses a perforated cone placed into a funnel. A similar arrangement has recently been patented in England by Nickels.

When a filter-paper of sufficient coherency is placed tightly into a funnel in the manner directed by Fresenius, and the rate of filtration ascertained, and the paper, when empty, is then cautiously lifted so that a glass rod may be placed between it and the funnel, the velocity of filtration is in all cases much increased. It is evident that by placing the paper close to the walls of the funnel the fluid which is capable of passing through the

pores of the paper cannot find an exit with sufficient rapidity to allow of the total filtering capacity of the paper being brought into play. The smoother the funnel and the more nearly its angle approaches 60° , the more complete the fit and the greater the blockage. The old-fashioned fluted funnels were no doubt constructed to counteract this blockage, but in the case of the thin filter-paper now generally in use, this object is not attained, the fluting being too shallow to prevent the paper, expanded as it is by the moistening, from clinging closely to the funnel and barring the flow of the filtrate.

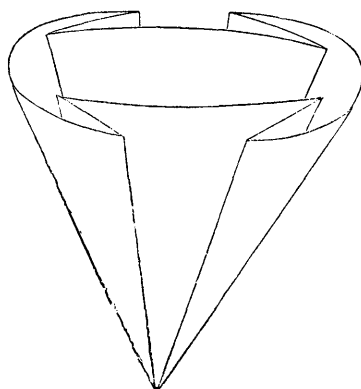
We therefore got some funnels made which have a number, generally four, high ridges running straight on the inner surface from the edge of the funnel for some distance into the shaft. It is impossible for the filter-paper, however thin, to adapt itself to the sides and to obstruct the flow of the filtrate, whilst at the same time sufficient support is given to the paper to enable it to bear the heaviest precipitates without risk of breakage.

The following table gives the time, in seconds, required for filtering 250 c.c. of cold water. In all cases the filters were kept full of water during the duration of the experiment. For the purpose of strict comparison, we attempted to use one and the same piece of filter-paper for the different modes of filtration, but we found that even pure water gradually blocks up or contracts the pores of the paper, each succeeding $\frac{1}{4}$ litre requiring a somewhat longer time than the preceding one, as will be seen from the following set of figures, which represent such successive times:—

217, 245, 267, 282, 292, 295, 296 seconds.

For each experiment, therefore, a new piece of paper was taken, all from the same bundle, and four separate sets of trials were made to equalise as much as possible differences in thickness and porosity. All papers were of the same size.

Column 1 shows the kind of filter-paper used; 2, the rate of filtration in the case of the old smooth funnel with narrow shaft, the paper laid closely into the funnel, and the shaft kept full of water; 3, filtration through smooth funnel, with shaft cut short, the paper being folded so as not to fit well; 4, new funnel with four high ridges, paper dropped in anyhow; 5, old fluted funnel, no particular care taken to fit the paper; 6, pleated paper for qualitative analysis; 7, paper pleated in the following manner, and shown in the figure:—Fold the paper across the centre as usual, open it, and fold it again at right angles; press the parts between the diameters thus indicated inward to the middle; the paper when looked at from the top now forms a four-pointed star. Press it flat; the outer edges now meet at an angle of 90° . Double back each pair of edges, so that they meet in the middle, and open the filter as shown in the figure.



1 Paper.	2 Smooth ; Shaft full.	3 Folded larger than 90°.	4 New Funnel.	5 Old Fluted Funnel.	6 Pleated Paper.	7 Richmond's Pleat.
Best Swedish, Thin	682	592	95	854	56	70
	200	548	95	1290	70	73
	480	138	97	600	61	69
	218	85	74	115	84	60
Average	395	341	90	715	68	68
English, Thin	328	137	51	152	52	75
	306	135	60	90	45	83
	156	79	49	217	80	91
	181	287	65	152	48	55
Average	285	160	56	153	61	76
Schleicher and	563	840	160	338	98	120
Schüll (590),	450	160	145	543	100	200
washed with	545	180	192	582	90	155
H.Fl.	750	250	162	508	188	150
Average	577	357	165	492	119	156
Schleicher and Schüll (597), very Thick	1070	415	262	295	192	155
	700	368	350	288	210	172
	612	1125	332	420	180	175
	1160	280	322	488	202	160
Average	886	547	317	373	198	150
Schleicher and Schüll (597), Thick	548	517	188	132	85	92
	412	182	212	455	88	100
	388	252	168	188	135	145
	430	252	160	507	80	92
Average	445	301	182	321	97	107

It is seen that, with all classes of filter-paper examined, the worst plan which can be adopted is to fit a filter closely into the funnel. The paper does not get a chance to work, and the loss of time is very great, the greater the thinner the paper. When the filter is folded so that it lies loosely in the funnel, excellent results are frequently obtained, but these are somewhat erratic, especially with thin papers, because the paper is apt to slip closely into the funnel when fully weighted with water. In all cases the velocity in Class 3 was the greater, the greater the angle at which the fold was made.

The new ridged funnel gave the best and most concordant results. It disposes of any chances due to imperfect folding or fitting of the paper ; it allows more freely than any of the other methods the passage of the fluid into the stem, and this far more certainly than the old fluted funnel, which, indeed, with thin paper gives very bad results.

Paper folded in pleats in the usual manner filters, especially in the case of very thick paper, faster than smooth filters are capable of doing, but the long, uneven

edge renders washing so difficult that they cannot well be used for exact quantitative work.

The folding used in the tests stated in Column 7 is intended to obviate this difficulty as far as possible, and to provide a pleated filter with a smooth edge. It will be seen that its filtration velocity equals that of ordinary pleated paper.

The funnels with deep ridges, described in this paper, have been made by, and may be obtained from Messrs. Townson and Mercer, 87, Bishopsgate Street, at a price differing but very little from that of ordinary smooth funnels.
