Economy in Filter Area for Standard Liquor Filtration

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For many years the plate and frame filter has been practically the only type of filter used for standard liquor filtration in the beet sugar plant. In recent years, there have been several types of filters introduced for this purpose. Each has certain advantages and possibly some disadvantages. It appears that some of the basic concepts previously generally accepted, should be scrutinized in the light of the new equipment available. In other words, previously accepted rules may not apply to the more recent types of filters.

The action of diatomite in aiding filtration is well established and has been discussed in many articles. In spite of this, one of the first considerations concerning replacement equipment is rate of filtration.

A filter's function is that of furnishing a supporting medium for the deposit of a mixture of diatomite, slimes and other insoluble impurities in the liquor as the liquor passes through. The cake thus formed is the factor regulating the rate at which the liquid can be filtered.

Any equipment that furnishes such a medium, properly supported to provide free flow of the liquor after it passes through the cake, should have the same filtering capacity per square foot of filtering area.

Offhand, one might deduce that regardless of type of filter, equal total area is required. However, economic considerations indicate this is not true.

In the May 1941 issue of "Sugar," Robert D. Kent, then of The Dicalite Company, discussed the optimum filteraid for standard liquor. He stated the correct amount of filteraid is that which will just about but not quite fill the cake space in a press as the maximum pressure is reached at the end of the cycle The optimum amount of filteraid can be established for a given standard liquor by experimental means. A quick method of determining this and adjusting the filteraid feed accordingly might result in considerable saving and would justify some work. For discussion here the optimum filteraid is assumed.

Brix, carbonation and other conditions under plant control, affect filtration considerably. The optimum conditions as far as these are concerned are quite well known by the operators, chemists, and engineers.

The data used for plotting the rate curves, etc., was obtained by actual bomb filter tests on standard liquor in a mill under average conditions. In this case, it was 66 brix at a temperature of 90° C.

Figure 1 is a log log plot of accumulated volume vs. time at 10 lbs. per sq. in. constant pressure. The basic formula for volume vs. time at constant pressure is $V = K\Theta^n$. Volume being a function of time at an exponent power, a straight line is obtained. This is true when sufficient filteraid is used to prevent compression of cake.

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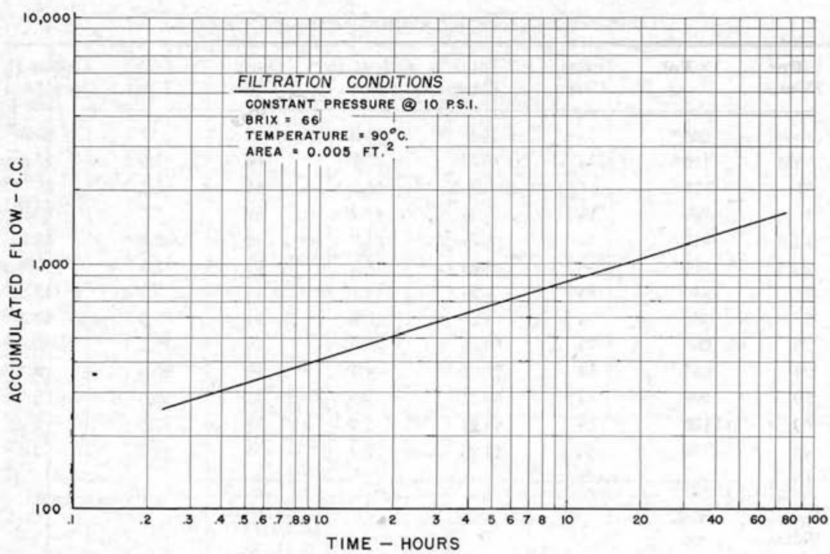

Figure 1.—A log log plot of accumulated volume vs. time at 10 lbs. per sq. in. constant pressure.

This plot can be used for predicting plant flow on a given plant liquor and filteraid dosage. For example, if the average flow per square foot of filtering area is desired for a 10-hour cycle, the line at 600 minutes will show that the total flow for the filter disc used is 850 cc. To convert the cc per .005 sq. ft. (which was the area of the disc) to gallons per sq. ft., multiply by the factor .0528. This will give 44.9 total gallons filtered per sq. ft. or an average of 4.49 gal. per sq. ft./hr. at 10 lbs. constant pressure. To convert this to a constant flow at the plant maximum presure of 50 lbs. per sq. in., multiply one over the square root of two times the square root of the different pressures, or $4.49 \times \frac{1}{\sqrt{2}} \sqrt{\frac{50}{50}} = 7.09$. This means with sufficient filteraid, if the filters were set to run 7.09 gallons per sq. ft./hr., the maximum pressure of 50 lbs. per sq. in. would be obtained in 10 hours. This was the method used to calculate the data used for Figure 3.

For the sake of pointing out the tremendous drop in flow rate with time (conversely this could be the equivalent increase in pressure with time at constant flow), instantaneous rates vs. time were plotted. To do this we differentiated the formula $V = K\Theta^n$ was with respect to time to get $\frac{dV}{d\Theta} = Kn\Theta^{(n-1)}$. Then, of course, values for Θ were assumed and the equivalent rates were calculated as shown in Figure 2.

If a filter could be operated on very short cycles, the total filter area required would thus be very small. The shortest time duration of a cycle that can be tolerated is dependent on the cleaning time and other economic considerations. Clarity considerations might also eliminate extremely short cycles.

Table 1.—Data Used for Plotting Curves on Figure 3

Opr. Time	Vol. cc.	Down Time	Total Time	Gal/sq. ft. per hr.	Down Time	Total Time	Gal/sq. ft. per hr.
¼	265	¼	½	44.2	½	¾	29.5
½	330	¼	¾	36.7	½	1.0	27.6
¾	375	¼	1.0	31.3	½	1.25	25.0
1	410	¼	1.25	27.4	½	1.5	22.8
1.5	460	¼	1.75	21.9	½	2.0	19.2
2	510	¼	2.25	18.9	½	2.5	17.0
3	580	¼	3.25	14.9	½	3.5	13.8
5	680	¼	5.25	10.8	½	5.5	10.3
10	850	¼	10.25	6.9	½	10.5	6.8
20	1050	¼	20.25	4.3	½	20.5	4.3
30	1200	¼	30.35	3.3	½	30.5	3.3
40	1320	¼	40.25	2.7	½	40.5	2.7
48	1400	¼	48.25	2.4	½	48.5	2.4
Opr. Time	**Vol. cc.**						
¼	265	¾	1.0	22.1	1	1.25	17.7
½	330	¾	1.25	22.0	1	1.5	18.4
¾	375	¾	1.5	20.9	1	1.75	17.9
1	410	¾	1.75	19.6	1	2.0	17.1
1.5	460	¾	2.25	17.1	1	2.5	15.4
2	510	¾	2.75	15.5	1	3.0	14.2
3	580	¾	3.75	12.9	1	4.0	12.1
5	680	¾	5.75	9.9	1	6.0	9.5
10	850	¾	10.75	6.6	1	11.0	6.5
20	1050	¾	20.75	4.2	1	21.0	4.2
30	1200	¾	30.75	3.3	1	31.0	3.2
40	1320	¾	40.75	2.7	1	41.0	2.7
48	1400	¾	48.75	2.4	1	49.0	2.4
Opr. Time	**Vol. cc.**						
¼	265	1.5	1.75	12.6	2	2.25	9.8
½	330	1.5	2.0	13.8	2	2.5	11.0
¾	375	1.5	2.25	13.9	2	2.75	11.4
1	410	1.5	2.5	13.7	2	3.0	11.4
1.5	460	1.5	3.0	12.8	2	3.5	11.0
2	510	1.5	3.5	12.2	2	4.0	10.6
3	580	1.5	4.5	10.8	2	5.0	9.7
5	680	1.5	6.5	8.7	2	7.0	8.1
10	850	1.5	11.5	6.2	2	12.0	5.9
20	1050	1.5	21.5	4.1	2	22.0	4.0
30	1200	1.5	31.5	3.2	2	32.0	3.1
40	1320	1.5	41.5	2.7	2	42.0	2.6
48	1400	1.5	49.5	2.4	2	50.0	2.3

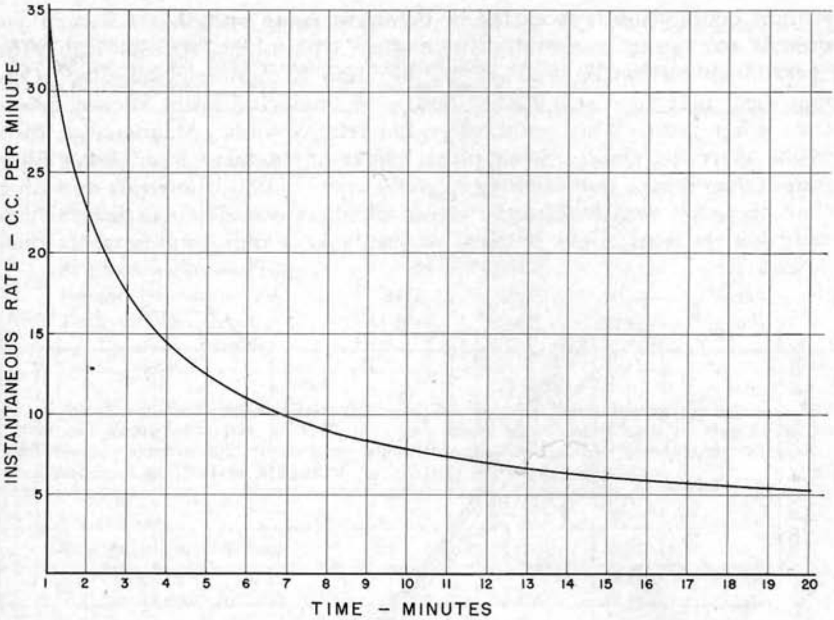

Figure 2.—Equivalent rates calculated with assumed values of Θ.

Figure 1 was used to develop the data for Figure 3 and was calculated as per the example cited. Figure 3 shows plots of gallons filtered per sq. ft./hr. at 50 lbs. maximum pressure using constant flow versus the length of cycle. In this case, however, the length of cycle refers to the operating cycle plus the down-time. For example, the rate of flow is the total gallonage filtered during the operating time divided by the operating time plus the down-time. Table 1 shows the data used in plotting the curves on Figure 3. It will be noticed the curves converge. This is due to the fact that on the longer cycles the loss of flow because of down-time becomes quite small in relation to the total flow. These curves were plotted on semi-log paper merely for convenience.

It was previously pointed out by use of the curve on Figure 2, that very high rates of filtration can be obtained on short cycles. Figure 3 also shows this. Actually, it can be shown mathematically that if enough filteraid is used to get a theoretically perfect cycle, the maximum output of a filter is obtained when the operating time is equal to the down-time.

When considering economy, labor costs for cleaning, and filter cloth costs are more favorable with long cycles since more total liquor is filtered per each cleaning and dressing. On the other hand, depreciation cost would be lowest if the maximum output per filter or short cycles were maintained. It was felt it might be interesting to try to find the balance where lowest total cost is obtained.

In the following, it is not intended to compare the economy of one type filter vs. another. This would result in erroneous conclusions. If a given type appears to be the most economical, it is possible this type might require double filtration to insure necessary safety and thus result in an over-all cost quite comparable to another type which appears higher in operational cost but on which single filtration is considered sufficient. Certain sugar beet areas may have a history of producing easier filtering juices than other areas. This could affect the relative costs. Maintenance costs might affect the choice. Some plants might afford more room for a filter station than others, thus favoring a certain type. Finally, the yearly operating time of a mill would affect the choice of filters considerably, since a high capital investment might be hard to justify in a mill running short campaigns.

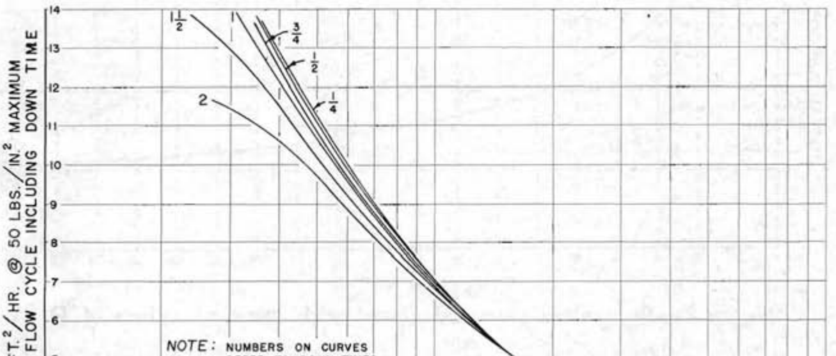

Figure 3.—Plots of gallons of filtered per sq. ft./hr. at 50 lbs. maximum pressure using constant flow vs. the length of cycle.

The tables that follow are merely examples of how an engineer, after selecting a filter that will do the best job for his particular plant, might determine the most economical filter area and the most economical operation of the filter he selects.

Table 2 refers to a type of filter that can be cleaned and put back on the line in 15 minutes. The type of filter that might permit this would be an internal sluicing filter. The most economical area based on the assumed costs appears to be at 1200 square feet or two 600 sq. ft. filters for the assumed plant flow of 12,000 gallons per hour. Table 3 is based on the same type with an assumed cleaning time of one-half hour and indicates best economy between 1200 and 1800 sq. ft. total area.

It might be of interest to explain how the costs in the table were calculated. The required over-all rate per sq. ft. for the given plant flow

Table 2.—Internal sluicing type filter, ¼ hr. cleaning time, for 12,000 gal. standard liquor per hour, labor cost at $1.75 per man hour, approximate precoat cost at $43.00 per 100 lbs. asbestos fibre precoating material using 10 lbs. per precoat per filter, approximate cost of filter at $15,000.00 for the 600 sq. ft. size.

No. of filters	1	2	3	4
Rate gal. per sq. ft. per hr.	20	10	6.67	5.0
Cycle length hrs.	2.1	5.9	10.7	16.3
Volume per cycle per filter	25,200	35,400	42,816	48,900
Labor cost cents per gal.	.00174	.00124	.00102	.00089
Replacement cost cents per gal.	.00278	.00556	.00833	.01111
Precoat cost cents per gal.	.01731	.01215	.01004	.00879
Total cost cents per gal.	.02183	.01895	.01939	.02079

Table 3.—Internal sluicing type filter, ½ hr. cleaning time, for 12,000 gal. standard liquor per hour, labor cost at $1.75 per man hour, approximate precoat cost at $43.00 per 100 lbs. asbestos fibre precoating material using 10 lbs. per precoat per filter, approximate cost of filter at $15,000.00 for the 600 sq. ft. size.

No. of filters	1	2	3	4
Rate gal. per sq. ft. per hr.	20	10	6.67	5.0
Cycle length hrs.	1.9	5.8	10.6	16.3
Volume per cycle per filter	22,800	34,800	42,420	48,900
Labor cost cents per gal.	.00384	.00251	.00206	.00179
Replacement cost cents per gal.	.00278	.00556	.00833	.01111
Precoat cost cents per gal.	.01886	.01235	.01014	.00879
Total cost cents per gal.	.02548	.02042	.02053	.02169

was first determined for an assumed number of filters. The required total cycle was then obtained from Figure 3. The volume per cycle can then be calculated. The labor and cloth costs per gallon are then obtained. The replacement or depreciation costs are based on the number of filters assumed handling the given plant flow 100 days per year for 20 years

Table 4 is for the hand-sluicing types that might be cleaned in one-half hour and indicates four filters of 600 sq. ft. each or a total of 2400 sq. ft. as the cheapest. Table 5 is the same as 4 assuming ¾ hour per cleaning.

Table 4.—Hand sluicing type filter, 1/2 hr. cleaning time for 12,000 gal. standard liquor per hr. labor cost at $1.75 per man hour, approximate cloth cost using Nylon at $5.40 per yard (used 40 cycles), approximate cost of filter $14,000 for the 600 sq. ft. size.

No. of filters	2	3	4	6
Rate gal. per sq. ft. per hr.	10	6.67	5.0	3.33
Cycle length hrs.	5.8	10.6	16.3	29.7
Volume per cycle per filter	34,800	42,420	48,900	59,340
Labor cost cents per gal.	.00251	.00206	.00179	.00147
Replacement cost cents per gal.	.00486	.00729	.00972	.01458
Cloth cost cents per gal.	.02586	.02122	.01840	.01517
Total cost cents per gal.	.03323	.03057	.02991	.03122

Table 5.—Hand sluicing type filter, ¾ hr. cleaning time for 12,000 gal. standard liquor per hr. Labor cost at $1.75 per man hour, approximate cloth cost using Nylon at $5.40 per yard (used 40 cycles), approximate cost of filter $14,000 for the 600 sq. ft. size.

No. of filters	2	3	4	6
Rate gal. per sq. ft. per hr.	10	6.67	5.0	3.33
Cycle length hrs.	5.6	10.4	16.3	29.7
Volume per cycle per filter	33,600	41,620	48,900	59,340
Labor cost cents per gal.	.00390	.00315	.00268	.00221
Replacement cost cents per gal.	.00486	.00729	.00972	.01458
Cloth cost cents per gal.	.02679	.02162	.01840	.01517
Total cost cents per gal.	.03555	.03206	.03080	.03196

Tables 6 and 7 are based on a horizontal leaf type filter and indicate fifteen 142 sq. ft. filters if they can be cleaned in ¾ hour or 1 hour.

Table 6.—Horizontal leaf type filter, ¾ hr. cleaning time, for 12,000 gal. standard liquor per hr., labor cost at $1.75 per man hour, approximate cloth cost using Nylon at $5.40 per yard (used 40 cycles), approximate cost of filter $6,000 for the 142.3 sq. ft. size.

No. of filters	10	15	20	25
Rate gal. per sq. ft. per hr.	8.43	5.62	4.22	3.37
Cycle length hrs.	7.4	13.6	21.0	29.0
Volume per cycle per filter	8,877	10,876	12,611	13,907
Labor cost cents per gal.	.01476	.01204	.01039	.00942
Replacement cost cents per gal.	.01042	.01562	.02083	.02604
Cloth cost cents per gal.	.02405	.01963	.01693	.01535
Total cost cents per gal.	.04923	.04729	.04815	.05081

Table 7.—Horizontal leaf type filter, 1 hr. cleaning time, for 12,000 gal. standard liquor per hr., labor cost at $1.75 per man hour, approximate cloth cost using Nylon at $5.40 per yard (used 40 cycles), approximate cost of filter $6,000 for the 142.3 sq. ft. size.

No. of filters	10	15	20	25
Rate gal. per sq. ft. per hr.	8.43	5.62	4.22	3.37
Cycle length hrs.	7.2	13.6	21.0	29.0
Volume per cycle per filter	8,637	10,876	12,611	13,907
Labor cost cents per gal.	.02026	.01609	.01388	.01258
Replacement cost cents per gal.	.01042	.01562	.02083	.02604
Cloth cost cents per gal.	.02471	.01963	.01693	.01535
Total cost cents per gal.	.05539	.05134	.05164	.05397

Tables 8 and 9 consider the plate and frame. Both seem to indicate around 6,000 sq. ft. for best economy.

In traveling among and talking with operating personnel, the general feeling with regard to plate and frame filters is the longer the cycle, the better the operating efficiency. With an established filter station as is the case with the majority of the mills, this is probably true.

Table 8.—Plate and frame type filter, 1½ hr. cleaning time (2 men) for 12,000 gal. standard liquor per hr., labor cost at $1.75 per man hour, approximate cloth cost using cotton (used ave. 6.5 times) at $1.00 per sq. yd., approximate cost of 600 sq. ft. filter is $4,200.00.

No. of filters	6	8	10	12
Rate gal. per sq. ft. per hr.	3.33	2.5	2.0	1.67
Cycle length hrs.	29.7	45.0	61.0	74.0
Volume per cycle per filter	59,340	67,500	73,200	74,150
Labor cost cents per gal.	.00885	.00778	.00717	.00708
Replacement cost cents per gal.	.00438	.00583	.00729	.00875
Cloth cost cents per gal.	.01710	.01504	.01387	.01369
Total cost cents per gal.	.03033	.02866	.02833	.02952

Table 9.—Plate and frame type filter, 2-hr. cleaning time (2 men) for 12,000 gal. standard liquor per hr., labor cost at $1.75 per man hour, approximate cloth cost using cotton (used ave. 6.5 times) at $1.00 per sq. yd. approximate cost of 600 sq, ft. filter is $4,200.00.

No. of filters	6	8	10	12
Rate gal. per sq. ft. per hr.	3.33	2.5	2.0	1.67
Cycle length hrs.	29.7	45.0	61.0	74.0
Volume per cycle per filter	59,340	67,500	73,200	74,150
Labor cost cents per gal.	.01180	.01037	.00956	.00944
Replacement cost cents per gal.	.00438	.00583	.00729	.00875
Cloth cost cents per gal.	.01710	.01504	.01387	.01369
Total cost cents per gal.	.03328	.03124	.03072	.03188

Speaking of the optimum cycle length in Table 9, a 61-hour cycle is quite a long one. The possibility of the plate and frame filter having a cake space to accommodate such a cycle and whether the liquid velocities within the frame are sufficient to suspend filteraid was of concern. On the basis of .7 lbs. filteraid per ton of beets, a press with one and one-half inch frames should accommodate a 60-hour cycle In addition, the calculated velocity seems to be sufficient to suspend the filteraid.