THE JOURNAL OF THE American Oil Chemists' Society

Volume 32 JANUARY, 1955 No. 1

Continuous Countercurrent Vacuum Bleaching

W. A. SINGLETON and C. E. McMICHAEL, Votator Division, The Girdler Company, a Division of National Cylinder Gas Company, Louisville, Kentucky

TO review bleaching practice it may be stated that by far the most nearly universally used means of bleaching vegetable oils is the use of adsorbents, such as fuller's earth, the acid-activated earths, and activated carbon. It is with adsorbent bleaching that this paper will deal.

The oldest method of bleaching is practiced in open, steam-heated kettles equipped with mechanical agitators. The oil is heated to, or near, bleaching temperature, the required amount of adsorbent is added, the mixture is agitated for a period of about 20 minutes while being maintained at the desired temperature, and the material is pumped through a filter to remove the earth. This method is still in use in many plants throughout the country. A typical batch atmospheric bleaching system is illustrated in Figure 1.

As pointed out by King and Wharton (1), an equilibrium exists between two factors favorable and two unfavorable in respect to color reduction. Of these four factors, three are related to oxidation, two of which, oxidative increase in color and oxidative stabilization against adsorption, are unfavorable. King and Wharton show that lower colors invariably result when oxygen is excluded from the process.

A large number of the more recent installations of bleaching apparatus are designed to operate under vacuum, thus taking advantage of the beneficial effect of oxygen exclusion. The operation of batch vacuum-bleaching kettles is similar to that of atmospheric kettles, except that the vessel and agitator are designed to expose as much oil as possible to the surface and consequently provide efficient deaeration. The oil is usually cooled either before filtration or at the discharge of a closed delivery filter to prevent exposure of hot oil to the atmosphere. A typical batch vacuum-bleaching system is illustrated in Figure 2.

As would be expected, an important advance in bleaching technology has been the development of continuous processing systems. There have been several such processes proposed. Probably the one which has been in commercial operation for the longest time is that of King *et al.* (2). This process involves con-

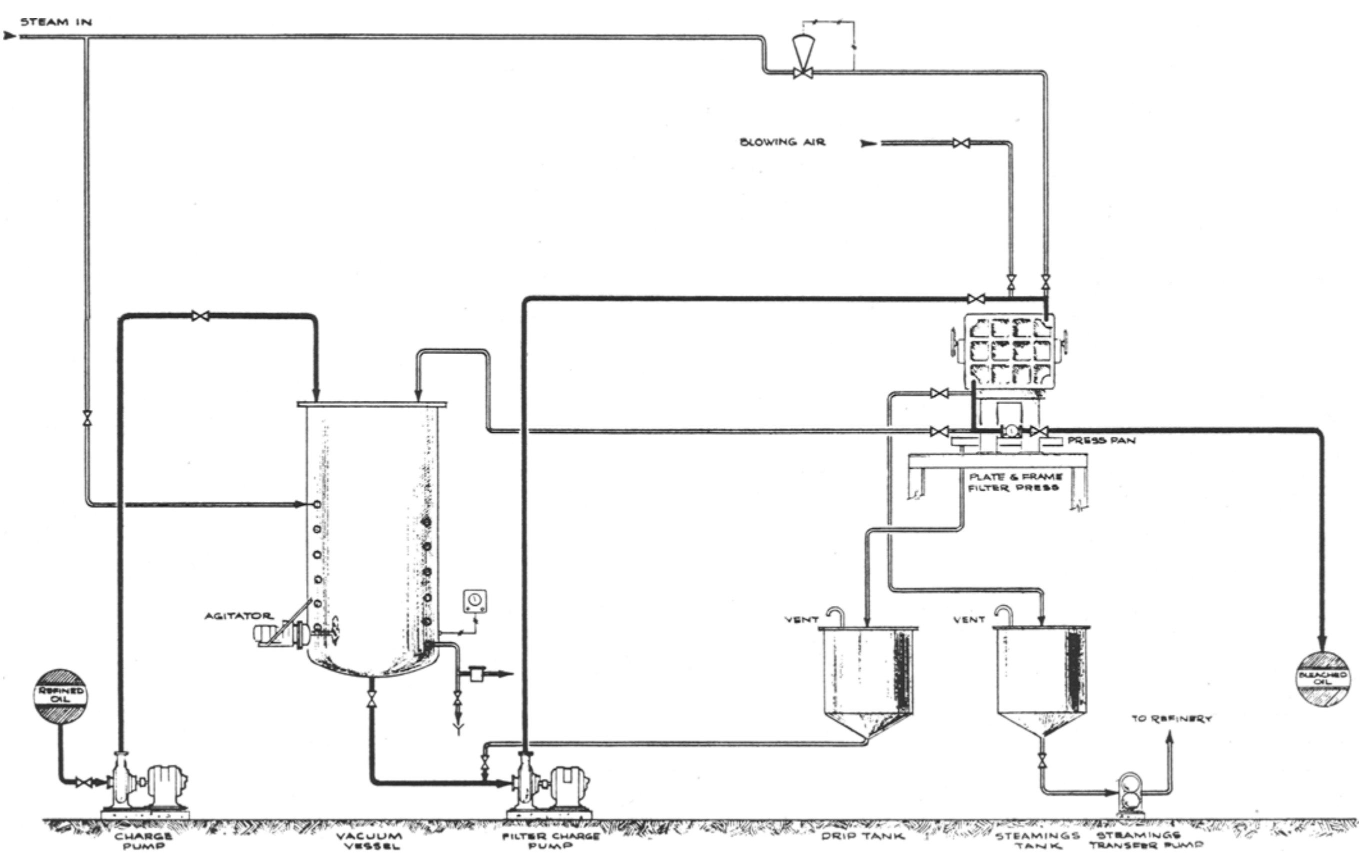

FIG. 1. Batch open kettle-bleaching system.

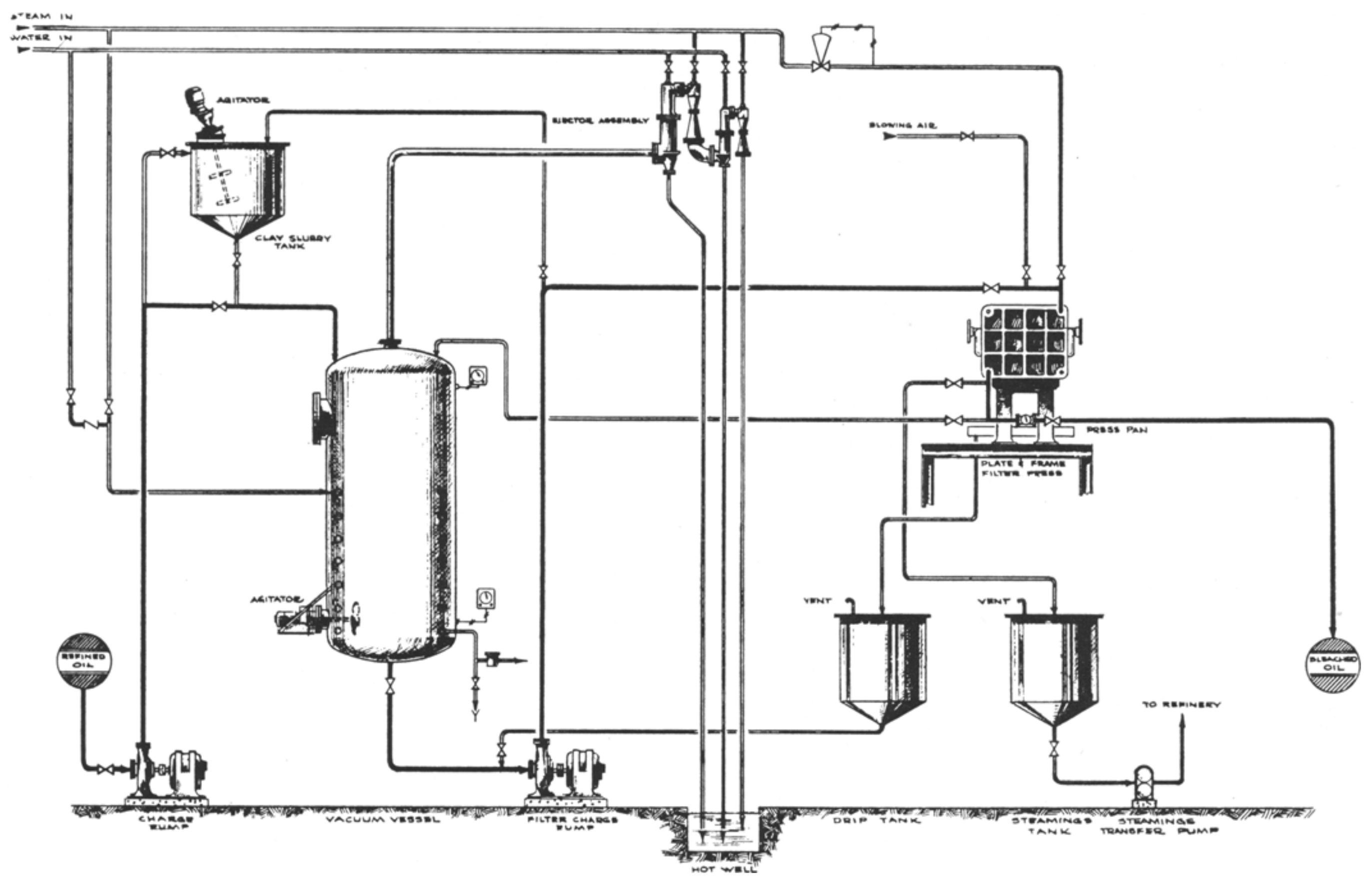

FIG. 2. Batch vacuum-bleaching system.

tinuously mixing the adsorbent with the oil from storage and spraying this slurry into the upper portion of an evacuated, two-compartment tower. This serves to flash off air and free moisture. The slurry is then pumped through a heat exchanger, where it is brought up to the desired bleaching temperature and sprayed into the lower section of the tower. The second spraying serves to release the "bound" moisture introduced with the earth. After a short residence time in the lower section, the slurry is pumped out through two closed delivery filter presses in series for earth removal, thence through a water-cooled heat exchanger to storage.

A newer development which is believed to be a major improvement over the other processes described is the Votator continuous countercurrent vacuum-bleaching plant. A schematic flow diagram is given in Figure 3. This system employs countercurrent contacting of oil and adsorbent clay. The adsorbent which has reached equilibrium with respect to color adsorbing power with the effluent oil still has bleaching power for the darker unbleached oil, and this residual bleaching power is therefore utilized in the countercurrent system.

In operation the oil to be bleached, which should be at a temperature of about 130°F., is picked up by the charge pump (1) and sprayed into the bottom section of the process vessel (2), which is held at an absolute pressure of about 1.5 in. of mercury. This spraying of the oil into a vacuum vessel is an efficient way of removing small amounts of water, dissolved and occluded air, and other gases usually contained in refined oil. A small amount of sparging steam is introduced into this section to assist in the removal of water and gases. The rate of flow of oil is controlled by a flow controller on the charge pump discharge and controls the production rate of the system.

The deaerated and dehydrated oil is then passed through an economizer (3), steam heater (4), through a filter press (5) which contains partially spent bleaching material, and through a back pressure valve (6) into the top section of the process vessel (7). A predetermined level of oil is maintained in the bottom, or deaerating, section of the process vessel by means of a suitable level controller actuating a control valve on the discharge side of the first-stage filter pump.

A side stream of bleached, effluent oil (8) (about 10% of the throughput) is continuously returned to the clay slurry tank (9), measured through a flowmeter, and used for slurrying the clay used for the final bleaching step. The clay is metered into the slurry by means of a calibrated feeder (10) so that any desired clay dosage can be used. This clay slurry (usually about 25% clay) is continuously drawn by vacuum through a spray nozzle (11) into the top section of the process vessel (7). The spraying action here removes from the slurry the air and water which has been introduced by the clay. A small amount of sparging steam is introduced in this section to provide thorough agitation and to assist in removing air and moisture from the slurry introduced in this top section. A steam coil is provided in this section to maintain the oil at bleaching temperature. The oil and earth are withdrawn from this section by the second-stage filter pump (12) and passed through a second filter (13) for clay removal, thence through the economizer (3), and after-cooler (14), and to bleached oil storage. When this filter has been filled with clay, valves are manipulated to make it the first-stage filter; a clean filter is employed as the second-stage filter, and the one which has been the first-stage filter is removed from service and may be blown, steamed, and cleaned to be used for a second-stage filter later. Thus one filter is out of service at all times, being cleaned or ready for service, and there is no interruption to the process.

The clay dosage is accurate and can be varied instantly without stopping the process. The operation is automatic and requires only attention time plus filter cleaning time. Feedstocks can be changed without fear of contamination, and with a minimum of down time. All vessels can be pumped clean and the heat exchangers and presses blown free of oil and drained.

The advantages of this system are:

a) economy of operation,
b) improvement in oil quality,
c) significant reduction in space requirements,
d) automatic design features which make the system simple to operate,
e) cleanliness of plant,
f) particular effectiveness in bleaching excessively dark oils,
g) tentative approval of M.I.D. of B.A.I. for alternatively processing animal and vegetable oils without intermediate cleaning, and
h) other merits of any continuous process.

With the assistance of others we set about some time ago to develop and compile data, based on both pilot plant and commercial plant tests, to measure a) the advantages of batch vacuum-bleaching over open kettle-bleaching and b) the advantages of the Votator continuous countercurrent vacuum-bleaching method over the conventional batch vacuum system. Our findings indicate that a bleached oil of superior quality can be produced at lower cost by the Votator system than by any batch method. The economic considerations will be presented first.

Economic Evaluation

There are several factors which affect the economy of any processing plant. The most important are a) operating costs, b) space requirements, and c) initial investment.

Operating Costs. A tabulation of the results of comparative performance tests by open kettle-bleaching, batch vacuum-bleaching, and the Votator continuous method is given in Table I.

It will be noted that the batch vacuum-bleaching method requires approximately 16% less bleaching agent to reduce the color of a given oil to a given level than does the atmospheric method. As a consequence of the utilization of the residual bleaching power of the partially spent earth, approximately 10% less adsorbent is required to reduce the color of a given oil to a given level, by continuous countercurrent system than by the batch vacuum-bleaching system. Particular attention is invited to the comparative ease with which excessively dark oils are bleached by the continuous countercurrent method.

Since the amount of adsorbent required to bleach a given oil to a given level is reduced, it follows that the gross amount of oil retained in spent adsorbent is also reduced. It is well known among the processors of edible fats and oils that the principal saving resulting from reduced adsorbent dosage is in reduced oil losses rather than in the cost of adsorbent. This reduction in oil loss becomes even more important

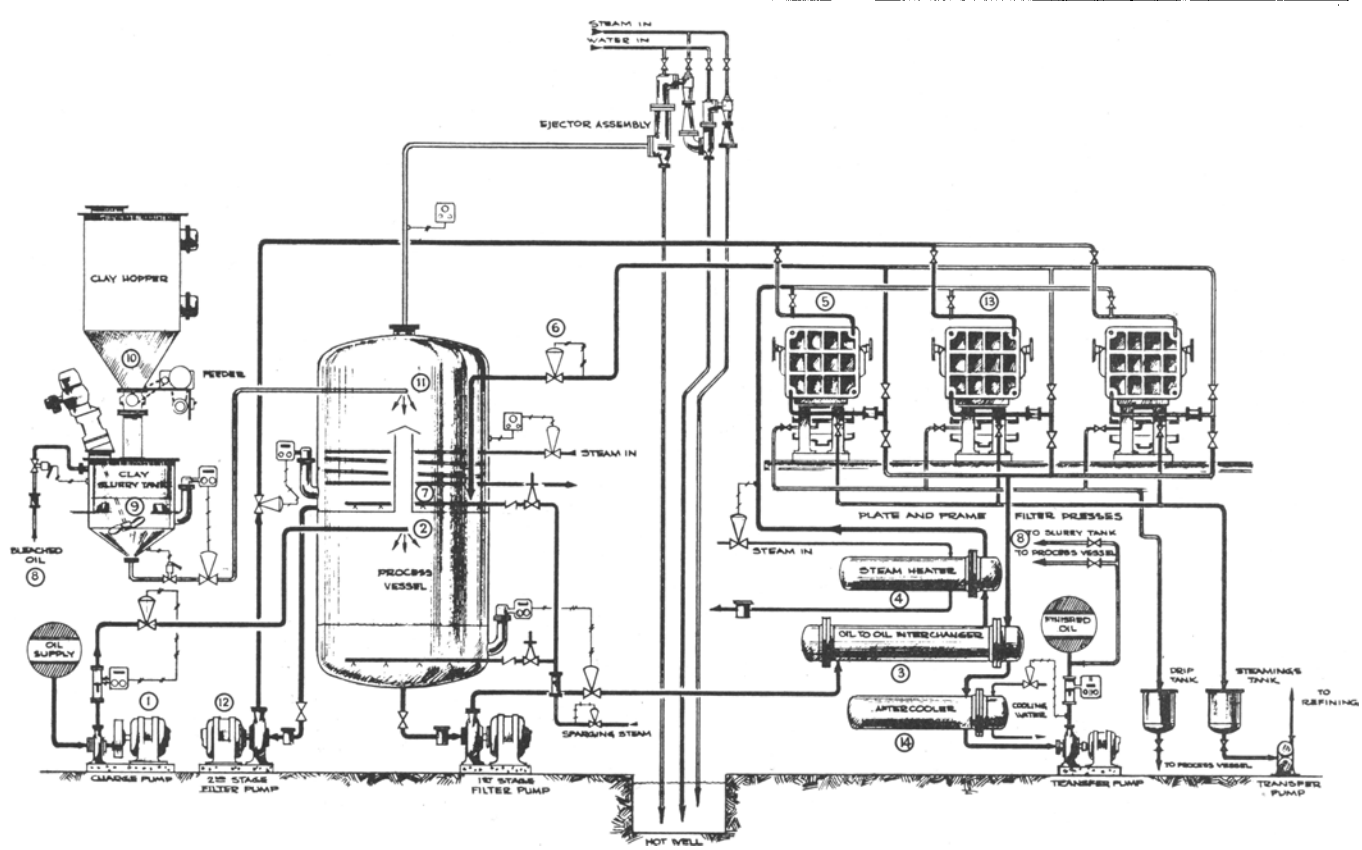

FIG. 3. Votator continuous countercurrent vacuum-bleaching system.

TABLE I
Results of Comparative Bleaching Tests (Bleaching Efficiency)

Kind of oil	Bleaching method	Adsorbent		Colors Lovibond red	
		Type	Dosage %	Initial	Final
SBO	Batch open kettle	Neutral	1.25	10.5	5.0
	Continuous counter-current vacuum		0.675		3.5
SBO	Batch open kettle	Acid activated	1.0	23.0	5.5
	Batch vacuum		0.5		6.4
	Continuous counter-current vacuum		0.5		4.6
SBO	Batch open kettle	Acid activated	1.0	11.5	2.8
	Batch vacuum		1.0		2.1
	Continuous counter-current vacuum		0.8		1.9
CSO	Batch open kettle	Neutral	1.0	8.0	3.5
	Batch vacuum		1.0		3.1
	Continuous counter-current vacuum		1.0		2.8
CSO	Batch open kettle	Neutral	2.0	8.2	2.4
	Batch open kettle		1.0		3.3
	Batch vacuum		1.0		2.5
	Continuous counter-current vacuum		1.0		2.3
CSO	Batch open kettle	Neutral	2.0	7.3	2.1
	Batch vacuum		1.5		2.1
	Continuous counter-current vacuum		1.0		2.1
CSO	Batch open kettle	Acid activated	2.0	12.3	4.6
	Batch vacuum		2.0		4.1
	Continuous counter-current vacuum		1.5		2.6
CSO	Batch open kettle	Acid activated	3.0	11.3	4.4
	Batch vacuum		2.0		4.0
	Continuous counter-current vacuum		1.3		3.7

when using acid-treated adsorbents which retain approximately 6% by weight more oil than do neutral adsorbents. Also of importance are reductions in press cleaning labor, cloth wear, handling, and storage, which result from smaller adsorbent dosages.

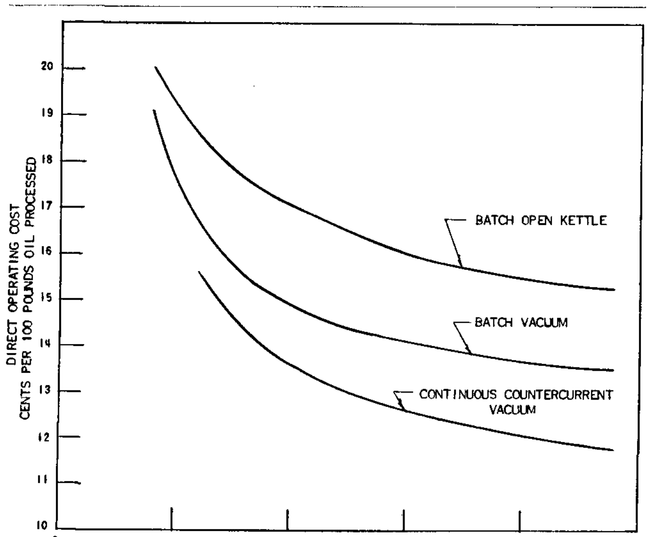

FIG. 4. Bleaching direct operating costs.

Figure 4 shows graphically the relationship between the direct operating costs of batch open kettle-, batch vacuum-, and continuous countercurrent vacuum-bleaching plants. For this plot, reasonable values were assumed for the unit costs of oil, adsorbent, labor, and utilities. The exact figures, of course, will vary from plant to plant and from time to time, but the comparison will hold approximately true when these costs are calculated for a specific instance. The factors taken into consideration in calculating these costs include labor, utilities, cost of adsorbent, cost of oil, and repairs and maintenance, but do not include any fixed charges such as taxes, insurance, amortization, etc., which vary widely from plant to plant.

From Figure 4 it is apparent that, at any capacity, an appreciable savings in operating cost will result from the continuous countercurrent system. In general, the saving will amount to about \$0.03 per hundred pounds of oil processed over batch open kettle-bleaching, and about \$0.02 per hundred pounds of oil processed over batch vacuum-bleaching. The savings increase as the production capacity increases, making the process even more attractive for larger producers. This decrease in operating cost with increased capacity is largely due to the fact that with the automatic features incorporated in the process, a plant of extremely large size can be operated with little more labor than is required for a single batch kettle.

Space Requirements. Since the capacity of batch systems can be increased only by installing duplicate units, the floor space required increases very rapidly with increased capacity.

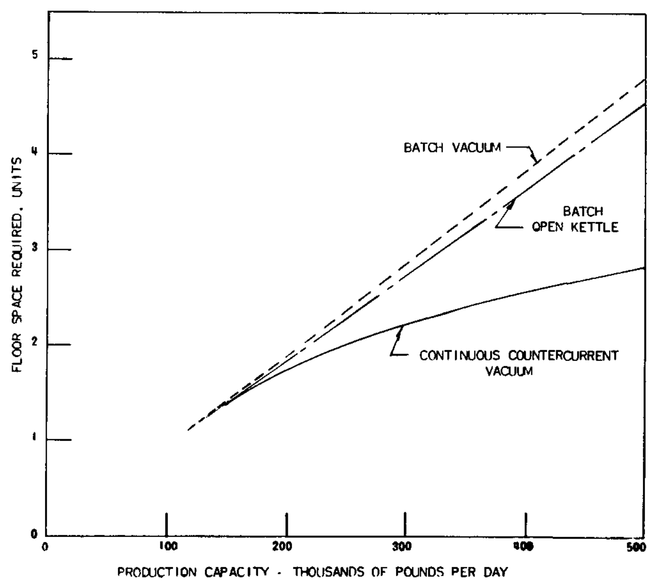

FIG. 5. Bleaching floor space requirements.

Figure 5 shows the relative floor space requirements of batch open kettle-, batch vacuum-, and continuous countercurrent vacuum-bleaching plants of various sizes. In this figure no absolute values are are given on the floor space ordinate since the actual amount of space required depends to a large extent upon local conditions. With the countercurrent system, savings in floor space are generally possible over equivalent batch bleaching capacity at production requirements of 10,000 pounds per hour or more. At a production capacity of 20,000 pounds per hour the space requirement for a continuous countercurrent vacuum-bleaching system is roughly 75% of that for the batch system. This item can be extremely significant in increasing the capacity of already overcrowded plants or in new construction.

Initial Investment. A comparison of the initial investment, again expressed in units, for batch open kettle-, batch vacuum-, and continuous countercurrent vacuum-bleaching plants of various sizes is given in Figure 6. This comparison indicates that the investment for continuous countercurrent vacuum-bleaching apparatus is considerably greater than for either of the batch methods at production capacities of less than 10 tank cars per day. In the lower capacity ranges the difference is quite large. However, considering the savings in operating cost (neglecting floor space), it can be proven that even at the low production rate of 2 tank cars per day, replacement of batch open kettle-bleaching apparatus with the continuous countercurrent vacuum system will result in an operating saving which will retire the entire investment in less than four years, or that the choice of the continuous countercurrent vacuum system over batch open kettle-bleaching for a new installation of this capacity will pay off the difference in investment in a period of two years. At a capacity of 15,000 pounds per hour (6 tank cars per day) the operating savings over batch vacuum-bleaching will retire the entire investment in slightly over five years, or pay off the difference in about one and one-third years. At this same capacity, savings over batch open kettle-bleaching will retire the entire investment in about two and one-third years or pay off the difference in investment in about 250 days. Figure 7 is a plot of the time required for the Votator system's operating savings as compared to batch systems to retire the entire equipment investment of plants of various capacities. Figure 8 shows the time required for these savings to pay off the difference in investment between the Votator system and the two batch systems. Thus it is apparent that the continuous countercurrent vacuum-bleaching system definitely should not be ruled out economically even in the small plants where the investment per unit of capacity is quite high compared with batch apparatus.

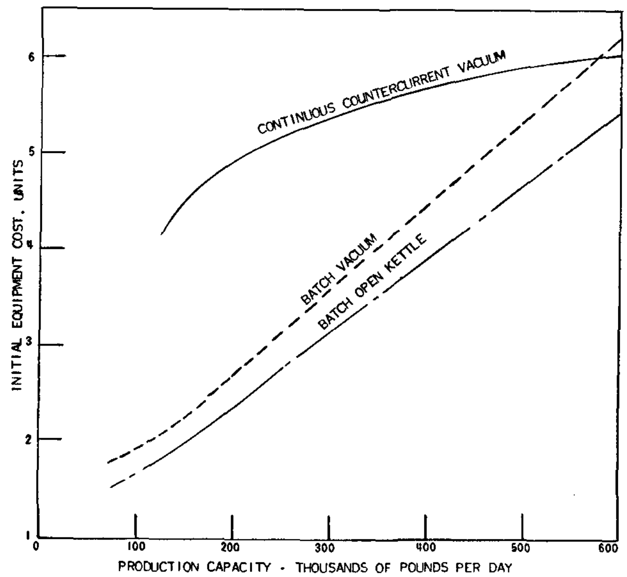

FIG. 6. Bleaching investment costs.

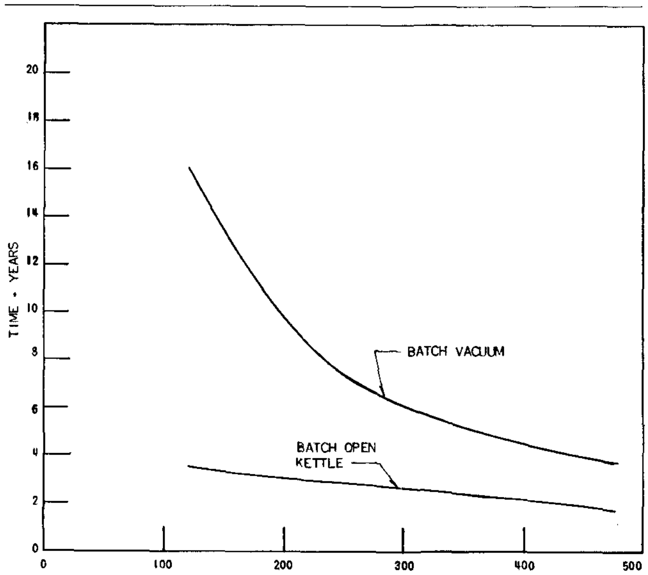

FIG. 7. Time for operating savings over batch bleaching methods to retire entire investment of continuous countercurrent plant.

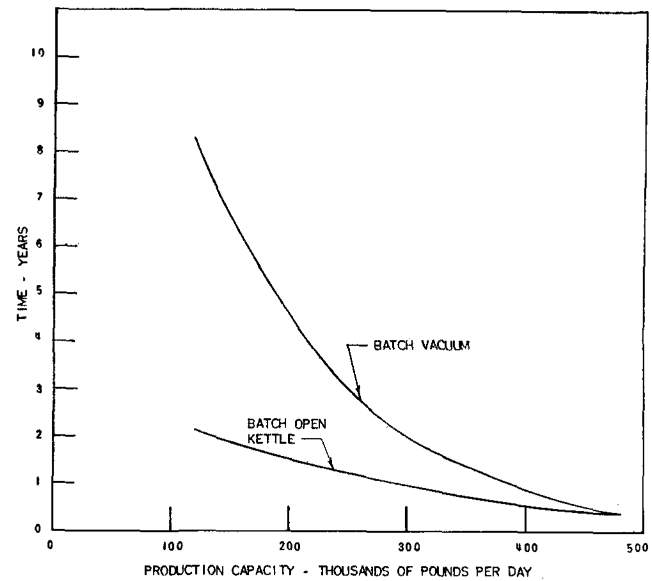

FIG. 8. Time for operating savings to retire cost differential between continuous countercurrent and batch bleaching systems.

Qualitative Evaluation

The data in Table II give some of the qualitative results of comparative bleaching tests under batch open kettle and continuous countercurrent vacuum conditions.

It is an established fact that the free fatty acid content of a refined oil frequently increases during the bleaching operation. This can be attributed to hydrolysis of soap or neutral oil. In the absence of moisture no hydrolysis can take place. Thus if both the oil to be bleached and the adsorbent are thoroughly dehydrated before raising the oil to bleaching temperature, a marked decrease in the amount of hydrolysis can be expected. It is also recognized that the use of adsorbent earths with a low pH value accelerates this tendency toward free fatty acid rise.

Examination of Table II shows that there is seldom a significant increase in the FFA content in oils bleached by the continuous countercurrent vacuum method, and quite frequently there is a significant decrease. This decrease is probably due to absorption of the fatty acids. This holds true for bleaching with earths of low pH as well as neutral earths. Since to-

TABLE II
Results of Comparative Bleaching Tests (Oil Quality)

Kind of oil	Bleaching method	Type of adsorbent	Percent FFA		Peroxide value of bleached oil	AOM stability (hours)
			Initial	Final		
SBO	Batch open kettle	Acid activated	0.12	0.15		9
	Batch vacuum			0.19		11
	Continuous countercurrent vacuum			0.14		14
SBO	Batch open kettle	Neutral	0.09	0.08	23.6	19
	Continuous countercurrent vacuum			0.07	2.8	21
CSO	Batch open kettle	Neutral	0.04	0.05		12
	Batch vacuum			0.05		14
	Continuous countercurrent vacuum			0.05		17
CSO	Batch open kettle	Neutral	0.04	0.04		11
	Batch vacuum			0.04		12
	Continuous countercurrent vacuum			0.04		13
CSO	Batch open kettle	Acid activated	0.07	0.07	10.4	12
	Batch vacuum			0.07	5.0	14
	Continuous countercurrent vacuum			0.08	0.2	16
CSO	Batch open kettle	Neutral	0.06	0.08		8
	Batch vacuum			0.08		7
	Continuous countercurrent vacuum			0.04		12
SBO	Continuous countercurrent vacuum	Neutral	0.04	0.035		
		Acid activated		0.03		
CSO	Batch open kettle	Neutral	0.07	0.04	3.6	13
	Continuous countercurrent vacuum			0.03	0.3	15
	Batch open kettle	Acid activated	0.07	0.10	0.4	14
	Continuous countercurrent vacuum			0.06	0.1	16

day's market demands the production of low color, low FFA bleached oils, it is of primary importance that the more efficient acid-activated earths which give a much greater color reduction per unit weight of adsorbent can be used without the increase in FFA content which usually attends the use of these earths.

The stability of vacuum-bleached oils has been shown previously (1) to be greater than that of open kettle bleached oils. This also is shown by the data in Table II, which indicate that the stability of a continuous countercurrent vacuum-bleached oil is about 10% to 20% greater than that of the same oil bleached comparatively in atmospheric kettles. Also notable is the fact that the peroxide value of the continuous countercurrent vacuum-bleached oils average about 15% of that of the open kettle-bleached oils.

These effects are due, of course, to the efficient exclusion of air from the oil and adsorbent at elevated temperatures. Since oxidation is effectively prevented, the tendency of the earth to adsorb products of oxidation results in an extremely low peroxide value in the bleached oil. Although the peroxide value is not necessarily an indication of the actual stability of the oil (3), it is certainly not without meaning in two portions of the same oil bleached with the same earth under different conditions.

There has proven to be little difference in the color stability of vacuum-bleached and atmospheric-bleached oils. An illustrative set of data from pilot plant operations is given in Table III. Qualified flavor panels have reported a marked advantage in flavor stability for vacuum-bleached oils over open kettle-bleached oils. These results indicate that the oil from a vacuum-bleaching process is superior in many respects to the same oil bleached in atmospheric kettles, and that this oil can be produced using less adsorbent by countercurrent contacting of oil and adsorbent.

TABLE III
Results of Comparative Bleaching Tests (Color Revision)
Bleaching Light Cottonseed Oil

Method	Clay (%)	Bleached color (Lovibond red)	Color after 24 hrs. at 212°F. (Lovibond red)
Batch open kettle	2.0	2.4	2.1
Batch open kettle	1.0	3.3	3.0
Batch vacuum	1.0	2.5	2.3
Continuous countercurrent vacuum	1.0	2.6	2.3
Continuous countercurrent vacuum	1.0	2.4	2.1
Continuous countercurrent vacuum	1.0	2.3	2.0

Summary

The Votator continuous countercurrent vacuum bleaching system has been described and compared with older methods of bleaching. Data have been presented, comparing the performance of batch open kettle-, batch vacuum-, and continuous countercurrent vacuum-bleaching systems. These data indicate that the vacuum methods of bleaching result in a superior quality bleached oil with the use of less adsorbent. They also prove the value of countercurrent contacting of oil and adsorbent as practiced in the Votator system.

The economic aspects of bleaching have been discussed, proving that the continuous countercurrent vacuum-bleaching system, due to its automatic operation, compactness, and savings in adsorbent operates at a considerably lower cost than either batch method. Data have been offered to show the qualitative advantages of vacuum-bleached oils over atmospheric-bleached oils.

REFERENCES

1. King, R. R., and Wharton, F. W., J. Am. Oil Chemists' Soc., *26*, 201-207 (1949).
2. King, R. R., Pack, S. E., and Wharton, F. W., (to Mrs. Tuckers' Foods Inc.) U. S. Pat. 2,428,082 (1947).
3. Hassler, J. W., and Hagberg, R. A., Oil & Soap, *15*, 115-120 (1938).

ADDITIONAL REFERENCES

Bailey, A. E., "Industrial Oil and Fat Products," 2nd Ed., Interscience Publishers, New York (1951).
Bailey, A. E., (to the Girdler Company) U. S. Patent 2,618,644 (1952).
Baldwin, A. R., J. of Am. Oil Chemists' Soc., *26*, 610-614 (1949).
Hassler, J. W., and Hagberg, R. A., Oil and Soap, *16*, 188-191 (1939).
King, R. R., and Wharton, F. W., J. Am. Oil Chemists' Soc., *26*, 389-392 (1949).
Langston, R. B., and Rich, A. D., Oil and Soap, *23*, 182-184 (1946).
Robinson, A. A., (to Standard Brands Inc.) U. S. Patent 2,483,710 (1949).
Schwitzer, M. K., "Continuous Processing of Fats," Leonard Hill Ltd., London (1951).
Stout, L. E., Chamberlin, D. F., and McKelvey, J. M., J. Am. Oil Chemists' Soc., *26*, 120-126 (1949).

[Received October 29, 1953]