Energy Saving Techniques in Continuous Degumming and Refining

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ABSTRACT

Energy requirements for individual operations in the continuous caustic soda refining process are discussed. The electrical power requirements for the process are determined basically by the throughput rate which fixes centrifuge motor sizes. The electrical power requirements are not subject to significant reduction without a basic change in the process. However, the steam usage may be reduced by as much as 75% by proper heat-recovery methods. The selection of process streams for most effective heat recovery is discussed.

INTRODUCTION

Of the several available methods for chemical refining of vegetable oils, the conventional continuous caustic soda process is the most widely used in North America. This process is practiced on both degummed and nondegummed oils. Although it is true that small installations may use batch refining or that a high volume plant may occasionally batch refine special, small lots of oil, the continuous caustic soda process is the process most generally used.

There are other continuous processes that are available, including the soda ash process, modified soda ash process, caustic soda-soda ash process and the Zenith process which is being used in Europe. For this discussion, the energy consumption of existing systems and possible future energy savings will be limited to the continuous caustic soda system. Continuous processing systems offer the advantages of constant utility loads once steady state conditions have been established. Heat interchange is normally more efficient in continuous systems than in batch or semi-continuous systems.

This paper will assume that crude soybean oil is being degummed and refined by the continuous caustic soda process. By picking a single, specific oil, average losses at each step of the process may be assigned and the costs of utilities for each individual step in the process can be related to a unit weight of incoming crude oil. Since the subject under discussion is energy conservation, using a single oil as a basis does not detract from the presentation but it does allow the energy uses at each stage of the process to be added.

It has been estimated that about 1/3 of the soybean oil produced in the U.S.A. must be degummed to satisfy the need for lecithin (1). The author knows of 3 major oil refiners in the U.S.A. who degum soybean oil and market various lecithin products. There also are producers of degummed soybean oil who degum the extracted soybean oil at the mill and add the gums back to the meal entering the desolventizer. However, most of the soybean oil which is produced is eventually refined without first being degummed. Quite obviously, the highest energy consumption takes place with a separate degumming operation. A separate centrifuge must be used just for degumming when, on the other hand, the combined degumming and refining could be carried out in one step in the primary centrifuge.

Before beginning a discussion of utilities requirements for the degumming – refining precess, it is necessary to establish the operating conditions for each step in the processing.

DEGUMMING

Conditions for batch continuous degumming are 2% water, 1 hr mixing and 160 F (67 C) and for continuous degumming are 2% water, 10-15 min residence and 160 F (67 C). If lecithin is being produced, the oil normally will be degummed with ca. 2% water. There are numerous references in the literature which indicate that phosphoric acid degumming causes darkening of the lecithin (2). If the gums are to be added back to the meal in a desolventizer – toaster, the oil may be degummed either with water or a phosphoric acid solution.

Most major refiners of soybean oil who produce lecithin degum continuously using in-line mixers. However, oils may be degummed continuously by adding water to the oil in one of 2 day tanks and by alternating day tanks as a continuous feed to the degumming centrifuges. In either case, the oil is heated to ca. 160 F (67 C) and the heat required is to raise the oil temperature from ca. 90-160 F (32-67 C) (3).

This operation will remove very effectively the alpha lipoids which are readily water hydratable when the oil is centrifuged (4). The oil from the degumming centrifuge is cooled to 90-100 F (32-37 C) before entering a surge tank which acts as a feed tank for the refining operation.

The heat requirement in degumming, as previously stated, is in heating the oil to 160 F (67 C). The main source of power consumption is in operating the degumming centrifuge. The total power required for the pump and mixer motors is relatively small compared to the horsepower required for the degumming centrifuge.

REFINING

The degummed soybean oil which has been cooled to 90-100 F (32-37 C) is pumped from the feed tank and mixed with the required amount of lye before being pumped through a high shear mixer. The required amount of lye is calculated from the equation:

$$\frac{(\%\ \text{FFA} \times 0.142 + \%\ \text{excess})\ 100}{\%\ \text{NaOH in caustic}}$$

The percentage of excess caustic for degummed soybean oil is usually 0.10-0.12% (5) and the caustic used for refining soybean oil is 14-18° Be'. The oil at 90 F (32 C) and caustic is kept mixed for 5-10 min in the in-line mixers before being heated to 165 F (73 C) and centrifuged (6).

Refining may be done with or without phosphoric acid pretreatment. The action of the caustic on the oil will cause the beta lipoids to be hydrated and will reduce the metallic ion content of the oil. However, there is ample evidence in the literature that phosphoric acid pretreatment even on oil which has been water degummed will cause further lowering of the metallic ion content than can be accomplished with caustic alone (7). There is also considerable evidence to indicate that the beta lipoids or nonhydratable phosphatides in the crude oil are related directly to both the processing during the extraction and bean condition before extraction (8,9,10).

The steam requirement for refining is in heating the oil-caustic mixture from 90-165 F (32-73 C). Since ca. 2% loss is incurred in degumming and ca. 1½% caustic is added at the start of refining, the total weight through the refining operation is almost the same as the weight of the crude oil put into the degumming operation. The power requirements for refining (through separation in the primary centrifuge) are almost the same as for degumming since the major power usage is in the centrifugal separator. The difference in power usage in degumming and in refining crude oil (through separation in the primary centrifuge) is in the number of mixers required in the refining operation. Refining requires ca. 0.1 KW/ 1000 lbs. of oil processed more than degumming.

WATER WASHING

The oil from the refining operation should contain less than 500 ppm soap – generally ca. 300 ppm (11). This oil is mixed with ca. 10-15% soft water, heated to 185 F (84 C) and centrifuged. After a single water wash, the oil should contain less than 50 ppm soap. The major heating requirement is in heating the water from ambient temperature to 185 F (84 C) since the oil is already at a temperature of ca. 165 F (73 C). As with degumming and refining, the major electrical power requirement is for the operation of the water-washing centrifuge.

VACUUM DRYING

The oil from the water-washing centrifuge at 180-185 F (82-84 C) is sent directly to a vacuum dryer maintained at a pressure of ca. 25 mm of mercury. The oil leaving the dryer has ca. 0.1% moisture. The steam requirements for vacuum drying are for the vacuum jet. The power requirements are minimal, being only those required to operate the dryer discharge pump.

ACIDULATION

The soapstock from the primary centrifuge is mixed with sulfuric acid and boiled if the acidulation operation is conducted batchwise (12). If acidulation is conducted continuously the mixture of soapstock and acid is heated to ca. 190-195 F (87-89 C). Since the soapstock is at a temperature of ca. 175 F (79 C) the heating requirements are modest. The electrical requirements for centrifugation of the acidulated fatty acids in a continuous system is relatively small because the mass of the fatty acids is small compared to the total weight of the oil being refined.

ENERGY CONSUMPTION

Having defined the process parameters, a block flow diagram (Fig. 1) can be used to indicate the individual steps in degumming and refining crude oil. There are 5 separate places where heat must be added. The 2 largest areas where steam is consumed are in heating the crude oil to degumming temperatures and in heating the cooled degummed oil to refining temperatures. In each case, ca. 35 lb of steam per 1000 lb of crude oil is required. About 10 lb of steam/ 1000 lb of crude oil is required to heat the oil and wash water before water washing. The remaining steam is used to heat the soapstock and acid to acidulation temperatures and ca. 2.0 lb of steam per 1000 lb of oil is necessary for the vacuum jet or the dryer.

Most of the electrical power is consumed in operating the centrifuges. A single refining or degumming centrifuge may require a 50 HP motor. A substantial reduction in the electrical energy would mean that the power requirements for operating the centrifuges would have to be reduced. This is not possible, at least with present technology, so potential energy savings must arise from steam savings.

In assessing the possibility of steam savings, it is apparent that at no place in the degumming–refining–water washing operation is the oil heated above 185 F. It also is apparent that the oil is alternately heated to ca. 160-175 F. and cooled to 90-100 F. The possible means of obtaining heat are to use the heat contained in the hot degummed oil stream to heat the incoming oil partially while concurrently cooling the degummed oil and/or to find another process in the plant which can supply heat.

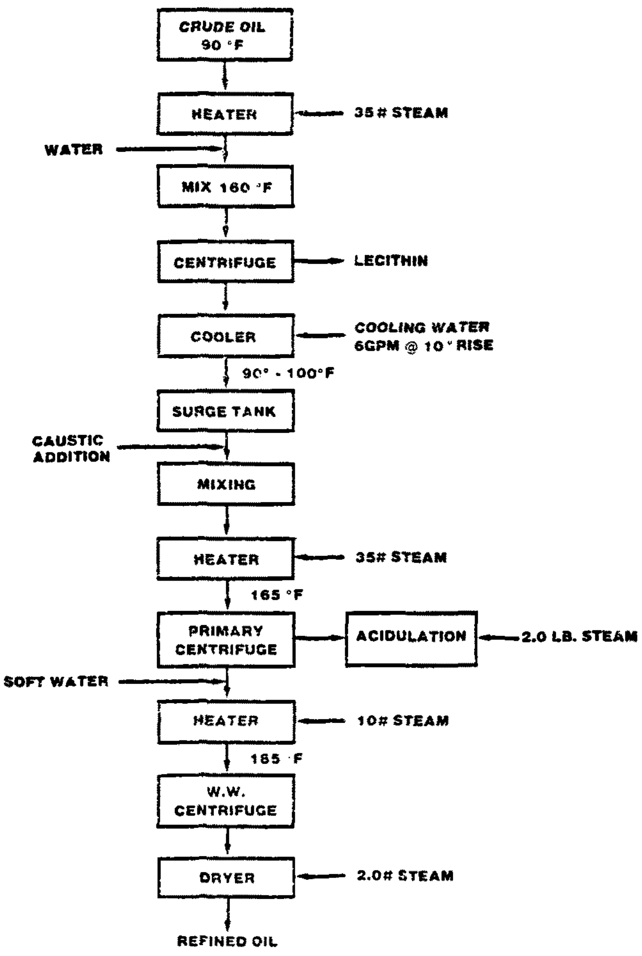

FIG. 1. Caustic refining with degumming, no heat recovery (per 1000 lb oil).

SOURCES OF HEAT

The degummed oil at 160 F is cooled to ca. 90-100 F before refining. The heat contained in the degummed oil is enough to provide ca. 60% of the heat required to heat the crude oil to degumming temperatures.

Other possible sources of heat are from hydrogenated oil, deodorized oil and bleached oil. Most hydrogenation plants are batch-operated and the hydrogenation and deodorization departments often are remote from the refining department. The most logical alternate source of heat is the bleached oil. In established plants, the bleaching department often is located near the refining department and most new plants have a continuous refining and bleaching system. The bleached oil will exit from the filters at ca. 210-220 F and should be cooled immediately if it is not nitrogen-protected. Therefore, bleached oil makes an excellent source of heat to heat the oil in the refining process.

In Figure 2, a system is shown in which the degummed oil is used to partially preheat the incoming crude oil; bleached oil is used to heat the oil before separation in the primary centrifuges. In such a system, the steam usage is reduced by 75% (from 84 lb/1000 lb oil to 21 lb/1000 lb

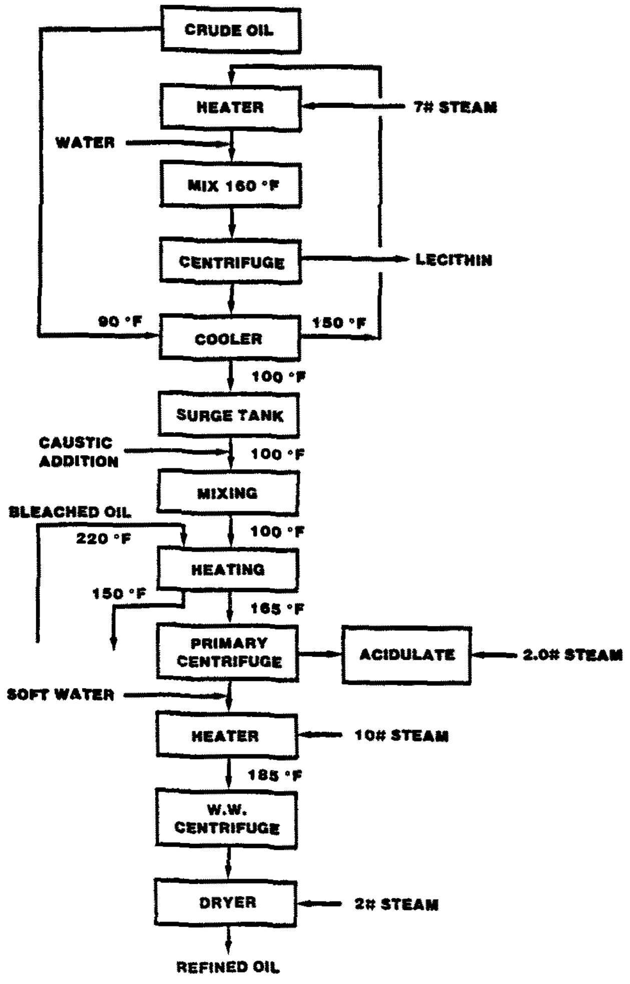

FIG. 2. Caustic refining with degumming, with heat recovery (per 1000 lb oil).

TABLE I

Utilities Summary (1000 # Crude Oil)

	No heat recovery steam/electric	Heat recovery steam/electric
Degum	35/1.1	7/1.1
Refine	35/1.2	0/1.2
Water wash	10/1.1	10/1.1
Vacuum dry	2/0.1	2/0.1
Acidolate	2/0.5	2/0.5
	84/4.0	21/4.0

TABLE II

Utilities Cost (steam $7.5/1000 lb.), (electricity $0.06/kwh), (30,000 lb/hr)

	No heat recovery	Heat recovery
Steam	$150,000	$37,500
Electricity	57,000	57,000
	187,000	94,500

oil). Total energy requirements with and without heat recovery are all shown in Table I. Total utilities costs based on steam costing $7.50/1000 lb and electricity costing $0.06/kwh based on a throughput rate of 30000 lb/hr are shown in Table II.

It should be noted that additional heat exchangers are not required to conserve the energy. The same number of heat exchangers are used but in some cases they would be larger. For example, using bleached oil at 220 F to heat the oil to refining temperatures would require a larger heat exchanger than using steam to heat the oil. However, with the potential steam savings, the capital investment for larger heat exchangers could be justified readily. These steam savings are in addition to savings of cooling water which is accomplished when the degummed oil is cooled by the crude oil stream rather than using cooling water for this purpose.

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REFERENCES

1. Handbook of Soy Oil Processing and Utilization, edited by D.R. Erickson, E.H. Pryde, O.L. Brekke, T.L. Mounts, and R.A. Falb, published jointly by the American Soybean Association, St. Louis, MO and American Oil Chemists' Society, Champaign, IL, 1980, p. 72.
2. Brekke, O.L., Ibid, p. 75.
3. Carr, R.A., JAOCS 53:348 (1976).
4. Wiedermann, L.H., Ibid. 58:162 (1981).
5. Wiedermann, L.H., Ibid. 58:162 (1981).
6. Wiedermann, L.H., Ibid. 58:162 (1981).
7. List, G.R., T.L. Mounts, and A.J. Heakin , Ibid 55:280 (1978).
8. Kock, M. Lurgi Technical Bulletin, 36 DGF-Vortragstagung, Kiel 8-11, September 1980.
9. Robertson, J.A., JAOCS, 50:443 (1973).
10. List, G.R., C.D. Evans, K. Warner, R.F. Beal, W.F. Kwalek, L.T. Black, and K.J. Moulton, Ibid. 54:8 (1977).
11. Carr, R.A. Ibid. 53:351 (1976).
12. Woerfel, J.B., Ibid. 55-188 (1981).

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