Oil-Solids Separation in Edible Oil Processing

E.G. LATONDRESS, Davy McKee Corporation, 10 South Riverside Plaza, Chicago, IL 90909

ABSTRACT

Sedimentation, centrifugation and filtration are the methods used in the edible oil industry to separate oils and solids. In many instances, the choice of separation method is based more on economics than technical reasons because more than one method of separation accomplishes the desired end result. Increasing manufacturing costs have brought about the development of automated filtration systems so that only one operator is needed for a battery of filters. Centrifuges are being used in applications formerly reserved only for filters and new processes have been developed that make former batch separation processes continuous. These developments have had the goal of maintaining separating efficiencies while reducing costs and increasing sanitation.

INTRODUCTION

From the time that crude oil is expressed from the bean or oilseed until the finished oil is packaged, the oil passes through a clarification or filtration step in almost every part of the processing sequence. Even finished oils are subjected to a final filtration before being chilled and packaged or before being loaded into tank cars and trucks.

The three generally used methods of separating solids from oils are sedimentation, centrifugation and filtration. A fourth method of separating solids from oils, electrofiltration, which will be discussed later, has been tested but has not yet found acceptance in the industry. These three methods of separation find the following applications.

APPLICATIONS

Sedimentation Applications

Standing sedimentation has largely been replaced by centrifugation for refining operations, but some small refiners still practise batch refining and sedimentation for separation of the soapstock and washwater. Sedimentation is practised in crude oil clarification through the use of screening tanks. A typical screening tank schematic is shown in Figure 1 (1). In this type of separation, the crude oil extracted from the screw presses enters a quiet zone in the tank. The tank is baffled to reduce currents and turbulence.

The foots which settle out of the crude oil are collected by buckets or paddles mounted on a drag chain conveyor which lifts the foots out of the oil and across a screen installed in the top of the tank, allowing the free oil to drain from the foots. The foots eventually drop into a conveyor to be repressed. The product oil is pumped out of the tank from a point opposite the inlet for further clarification.

Centrifugation Applications

Hydroclones are commonly used to separate fines from the miscella in solvent extracted oils, and centrifuges recently have been applied to clarify screw pressed oils further after sedimentation in a screenings tank. This process will be discussed in detail later.

Centrifuges are being used in the winterization of brush-hydrogenated soybean oil. The centrifuges used in this application are basket-type centrifuges. When the holding capacity of the basket is reached, the stearine is mechanically removed so the operation is cyclical rather than continuous (2). The stearine obtained from the centrifuges contains little oil but the power and maintenance costs are high and the process is being used only by a limited number of soybean oil processors.

A relatively new process utilizing centrifuges has been developed using water and a wetting agent (sodium lauryl sulfate) and an electrolyte (magnesium sulfate) in the dewaxing and winterization of oils. This process will also be described later.

Filtration Applications

Filters of various types are used in crude oil clarification after primary clarification in a screenings tank. The use of filters in bleach clay and catalyst removal, in removal of

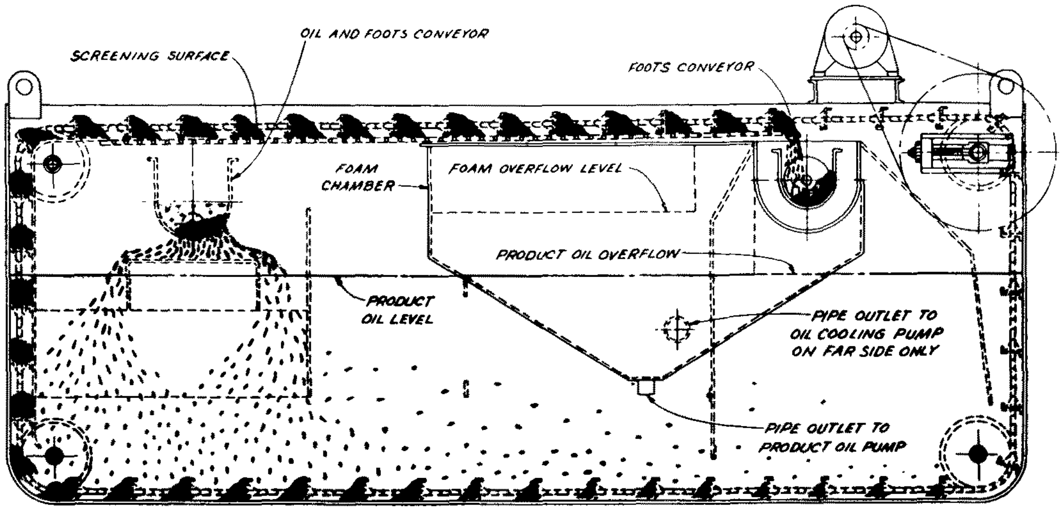

FIG. 1, Screenings tank.

stearines and waxes and in polishing oils before packaging or before loading into bulk shippers is well known. It will be one of the purposes of this paper to show how the standard filters have been changed and also to show the new types of filters that have been developed. While a great deal of progress has been made in all phases of oil-solids separation, the greatest number of changes have been made in filtration applications because filters are more widely used than any other single oil-solid separation method and also because not too long ago filtration was manually controlled.

EVALUATING SEPARATION METHODS

The preceding discussion was presented only to show that the methods of removing solids from oils are very interchangeable. In many cases, one separation method will produce as satisfactory a product as another. The choice of a separation method as well as the equipment to be used once a method is chosen requires a careful examination of the costs of capital, labor and utilities as well as area and maintenance requirements. The changes that have been made in oil-solids separation techniques have been made to make the processes more economically attractive as well as to improve sanitary conditions. The subsequent discussion is intended to depict the oil-solid separation techniques currently in use in various edible oil operations as well as to indicate new techniques that have been and are being developed.

Briefly, the point is that in many cases one separation technique will work as well as another from a technical or product quality standpoint. Economic considerations then determine the equipment to be used.

Crude Oil Clarification

Oil from a screenings tank needs further clarification to complete removal of the fines from the oil. Pressure leaf filters have found wide acceptance in this application. This type of filter offers a satisfactory solution but not an ideal one because:

- The very fine foots which pass the screenings tank form a filter cake which is compressible and tends to blind the screens. Because the cake is so compressible, the filtration rate decreases fairly rapidly as the cake builds up on the leaves.
- The use of filter aids to maintain cake porosity, and yield higher filtration rates adds to the operating cost and also increases the ash content of the filter cake and finished meal.
- Dual filters are needed to maintain filtration capability while one filter is being cleaned. The filter systems then require relatively large areas, especially when plant production volumes require several filters to be on stream at one time.

To overcome these difficulties, decanter centrifuges are being used. These are horizontal bowl centrifuges equipped with a helical screw conveyor. As the solids deposit on the horizontal bowl, the screw conveyor carries them to a discharge outlet.

These centrifuges provide oil with excellent clarity. Labor requirements are minimal, throughput rates are high and no filter aid is required. However, the initial capital investment is very high when compared to pressure leaf filters and power costs also are very high compared to that required for filtration. While I have no data on the maintenance costs for these centrifuges in this application, maintenance costs for centrifuges normally would be higher than for filters.

Winterizing

The removal of stearines from oils during the winterization process has always posed serious problems. Stearine cakes are relatively dense and nonporous and as a result filtration rates decrease rapidly as the cake thickness increases. The viscosity of the cold oil contributes to poor filtration rates and also makes it difficult to reduce the oil content of the cake.

Recessed plate and frame and pressure leaf filters have been used in winterization since these filters have the cake holding capacity that the process requires. Obviously, when 15% or more of the feed is removed in the form of stearine, substantial solid retention capacity is needed.

A new type plate and frame or recessed plate filter contains a series of diaphragms which can be hydraulically expanded mechanically to compress the cake and reduce the oil content of the cake after the filtration cycle is complete and the frames are full of stearine, as illustrated in Figure 2 (3).

This type of filter has been successfully used on all types of salad oil stearines. The filtration rates are the same as for plate and frame presses but the oil content of the stearine is greatly reduced. The cake is dry enough that the presses can be automatically opened and vibrated to be cleaned.

The filtration of soybean oil stearine is much less difficult than cottonseed oil stearine. Rotary vacuum filters (which are already widely used in solvent fractionation of palm oil) have been used successfully in this application. Since the stearine is removed with each revolution of the drum, cake thickness does not build up to the point where it retards filtration rates. Results reportedly achieved with one type of rotary vacuum filter shown in Figure 3 (4) operated at 7.2 C (45 F) and with hourly feed rates of 1000-1500 lb/ft^2/hr gave yields of 1000 lb of oil and 350-500 lb of cake. The cake had an iodine value (IV) of 95-97; the oil had a cold test of 9-19 hr.

I have been told that the hydrogenated oil used to obtain these data was obtained from normal plant production at the plant of a major US refiner of soy oil. From this it is presumed that the oil was hydrogenated to about 110 IV. The high yield of stearine and very low IV of the stearine are difficult to reconcile. The normal winterization loss of 15-20% would yield a stearine with ca. 103 IV. When the stearine has an IV well below 100, one would expect the loss to be correspondingly lower due to the lower oil content. However, the IV of the stearine is not a point to be belabored. The important point is the high filter feed rate which the manufacturer is willing to guarantee. This type filter has become very popular in soybean oil winterization.

To the best of my knowledge, the rotary vacuum type filter has not been used for the winterization of cottonseed oil, nor has it been used for the dewaxing of any type of oil.

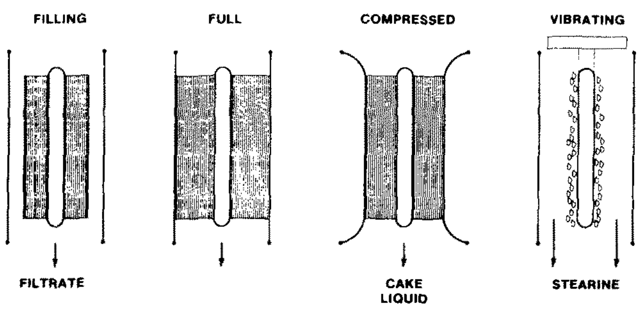

FIG. 2. Diaphragm filter.

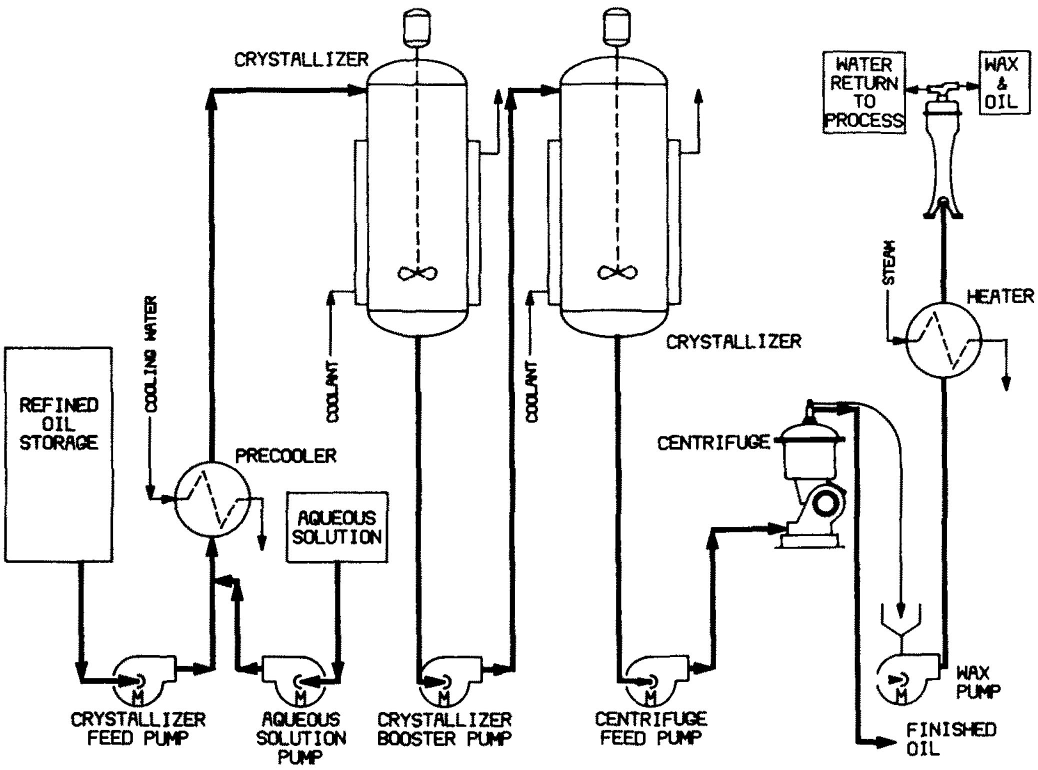

FIG. 3. Dewaxing process.

Dewaxing

The normal dewaxing procedure involves either batch or continuous chilling of the oil and then continuously filtering the oil. A body feed approximately equal to the wax content of the oil is used to prevent blinding of the filter leaves. Without a body feed, the waxes slime over and blind the screens almost immediately. Both pressure leaf and plate and frame presses have been used in this application.

A new process has been developed for dewaxing oils. This process, illustrated in Figure 3 (5) utilizes a wetting agent and centrifuges. An aqueous solution containing a wetting agent is metered into the oil stream which is precooled in a heat exchanger before entering the crystallizers. The aqueous solution is then centrifuged out of the oil and carries with it the waxes. This aqueous/wax mixture is then passed through a heat exchanger and recentrifuged to recover the wetting agent from the waxes.

This process is the same basic process originally developed for the fractionation of palm oil. The same process also may be used to winterize oils other than palm oil. The process is relatively new for continuous dewaxing of oils, but has been in use for some time in palm oil fractionation.

Bleach Clay-Catalyst Removal

Traditionally, either plate and frame filters or pressure leaf filters have been used for bleach clay or catalyst removal. The sequence of change in usage was approximately as follows: plate and frame, pressure leaf, self-cleaning – closed, and automated filters.

Pressure leaf filters began to replace plate and frame presses for several reasons. One of the major reasons was that these filters were easier to clean than the plate and frame presses, and labor costs were less. All of the presses were manually cleaned. The leaves on the pressure leaf filters were much lighter weight than the plates on the plate and frame presses.

The capability of automating filter cycles was available long before the filters were used in the edible oil industry in the USA. Even then, the first so-called automated filters really were only automated from the standpoint that an operator could control all of the functions from a panelboard and he had to start and stop each operation with a push-button. The impetus for complete automation, of course, was the increase in labor costs. As labor costs increased, industry found it economically feasible to automate completely with turbidimeters, flow controllers, safety overriders should an operation not be completed on schedule, filter openers, vibrators, etc. Present filtration systems allow control of one or a battery of filters by a programmable controller. Whatever flexibility of operation is required can be instrumented into the system and controlled by the controller.

It is not the purpose of this paper to discuss the hardware and instrumentation that accomplishes the automation in filtration operations. However, at about the same time that automation in filtration operations began to increase, the first self-cleaning-automated-closed filters were marketed.

The first of this type of filter to be marketed was a horizontal plate, bottom discharge filter. A horizontal plate system was used in the filter with filtration occurring at the top of each plate. Since the cake then built up on the top of the plates, gravity assisted in keeping the cake in place whenever the heel was being filtered or when the cake was being blown with gas to reduce its oil content (6).

The precoating and filtration cycles were conventional. The operator made a visual determination of when clarity of the filtrate was achieved and directed the flow of filtrate to the proper place. All other operations were automatic. When the pressure drop across the leaves reached a predetermined level, the filtration cycle was stopped and the heel was filtered. The solids were discharged from the filter in one of two ways: (a) slurry discharge, where the filtrate was backflushed through the filter while the leaves were slowly rotated; or (b) dry discharge, where the filter leaves were rotated to throw the filter cake off the leaves into the tank body. Using turbidimeters, the entire operating sequence could have been automated and one individual could operate a battery of these filters.

Many of these units were sold for edible oil operations. These units currently are manufactured and marketed by more than one manufacturer. The advantages of the unit are rather obvious. The throughput rate is high and typical for this type filter, little labor is required and the cleanliness is outstanding. The filter does have two disadvantages. The leaves tend to blind despite the backflushing and it is time consuming and expensive to open the unit and repair it when maintenance is required.

The latest type of self-cleaning closed filter is a vertical plate dry discharge filter, as in Figure 4 (7). The filter contains vertical leaves mounted between stationary brushes. The brushes remove the cake from the leaves and also clean the leaves when the filter is full of oil in a fully automated cycle. Figures 5 and 6 are an actual cross-section of the open filter and show how the brushes are mounted between the leaves of the filter.

This filter is precoated and the filtration cycle continued until a predetermined pressure drop across the leaves is achieved. At this time filtration is stopped and the filter body is drained. The press is blown with air or nitrogen to remove excess oil from the cake. To discharge the cake, the leaves begin to rotate and the cake is brushed from the filter leaves by the stationary brushes. An auger in the bottom of the filter conveys the sludge from the filter.

To clean the leaves, the filter body is refilled with oil to be filtered and the leaves again rotated slowly (2-5 rpm).

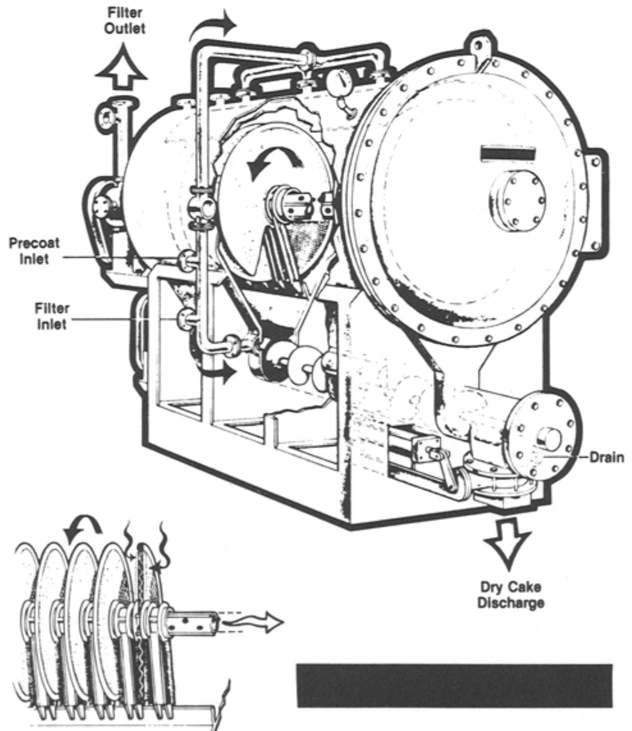

FIG. 4. Self-cleaning filter.

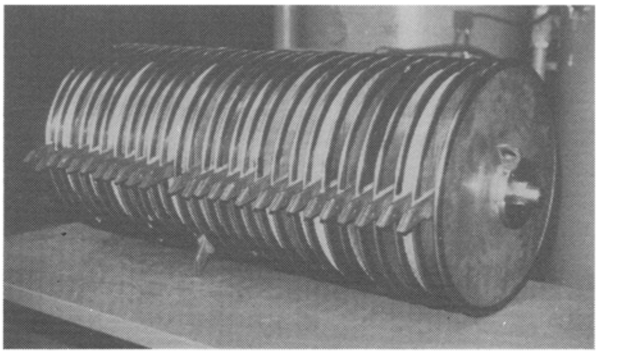

FIG. 5. Self-cleaning filter.

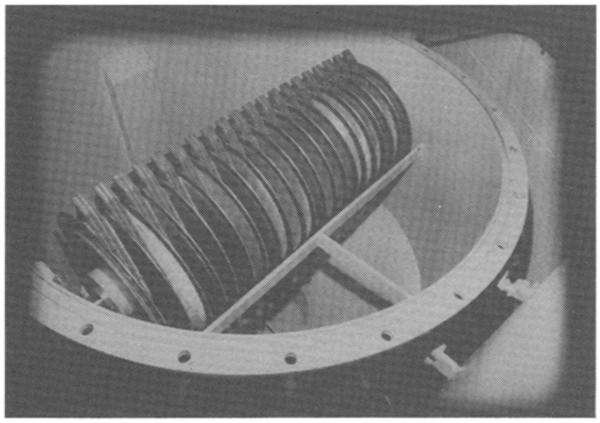

FIG. 6. Self-cleaning filter.

This cleaning period normally lasts 5-10 min which is said to prevent blinding and sliming of the filter septum. The filter is again ready for precoating.

Except for the actual filtration cycle which is stopped when a predetermined filter pressure is reached, all of the operations are timed. The time for each operation is set on an electrical control console and may be varied as individual operations require. This type of filter has the advantages of cleanliness and closed operation. I know of one installation where this type filter has been installed. No data are available on oil content of the cake or maintenance costs. The filtration rates should be about the same as for a pressure leaf filter of the same area since, during the filtration cycle, the unit actually operates as a pressure leaf filter. One operator should be able to operate a battery of these filters from a console. The cost of the units is somewhat higher than a pressure leaf filter of the same filtration capacity.

Hydrogenation

Hydrogenation black presses traditionally have been of the plate and frame or pressure leaf variety. A new filter introduced and tested as a catalyst filter is the electrofilter. The process flow diagram for this type of filter is shown in Figure 7 (8).

The electrofilter is an electrical filter in which the interelectrode space is packed with a matrix for trapping particles by means of an electric field. In theory, the electrofilter

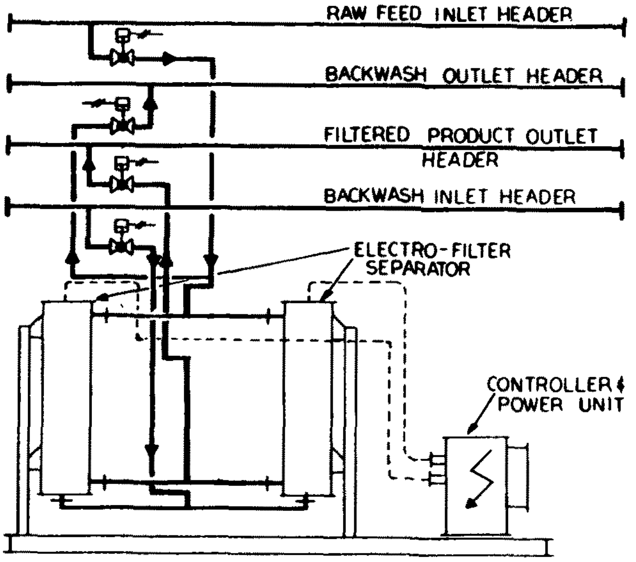

FIG. 7. Electrofiltration.

should remove all suspended particles in the oil or fat being processed independent of particle size or flow rate. In theory, the filtrate clarity should be better than achievable with a normal filter since there would be absolute removal of all particles.

To recover the nickel catalyst from the filter, the power is turned off the unit and the filter backflushed with a small amount of oil. Recovering the catalyst in slurry form does not present a real problem if this type of system accomodates a catalyst reuse program. In addition to the absolute particle removable, a further advantage of the filter is its extremely small size.

I know of one plant where such a filter was installed and tested. The filter is no longer in use. Apparently in normal plant operation it was very difficult to retrieve the catalyst, and traces of moisture upset the system in addition to some other operating problems. While this type of filter is used extensively in the petrochemical industry, some problems apparently need to be resolved before it can be applied to the edible oil industry.

Oil Polishing

Horizontal plate filters have long been used as polishing filters for deodorized oils. These filters are well adapted to this service, since oil clarity is excellent and the amount of solids to be removed from the oil is small. The disadvantages to this type of filter are the labor required to dress the filter and the space required.

In oil polishing applications, small cartridge or bag filters have been introduced. These can be automated so that at a predetermined pressure drop across the filter, the inlet and outlet valves will switch to a second unit and a warning light or alarm can sound to notify the operator to replace the bag in the first unit. Filter bags are rated according to nominal and absolute retention of particle size. The filters themselves are inexpensive, require little space and the replacement filter bags are relatively inexpensive.

We have a client building a new plant to replace an old one. In one process in this plant, he currently uses a horizontal plate filter to clarify vegetable oil. The character of the feed to the filter is such that without a combination of filter aids, the filter blinds quickly and filtration rates drop off rapidly. The volume of oil being filtered is small and handling several filter aids for a small quantity of oil was a nuisance. The client had been told that a self-cleaning centrifuge would solve this problem. We also knew it would solve the problem but we felt a better solution was a pair of bag filters operated in parallel.

The system we designed utilizes parallel bag filters with a pressure differential indicator switch so that when a predetermined pressure differential is reached, the feed and discharge switch to the second filter. An alarm sounds and a light on a panel board indicates which filter needs a bag replacement. The cost of replacement bags and the filters is so much less than the cost of buying and installing a centrifuge that this system was easily justified.

ACKNOWLEDGMENTS

In addition to those companies (listed in the references) who have supplied information for this paper, the author acknowledges assistance of The Duriron Co., Industrial Filter and Pump Manufacturing Co., French Oil Mill and Machinery Co., and the Pennwalt Corp., (Sharples Division), all of whom provided information used in preparing this paper.

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