CHAPTER XII

WAX PLANTS

Chillers—Refrigeration—Filter presses—Wax sweating—
Oven design—Wax filtering and treating—Packing—Exam-
ple of equipment calculations—Notes on building fea-
tures.

The wax-bearing distillate from the crude is the basis for
the manufacture of paraffine wax and the valuable neutral lubri-
cating oils discussed in previous chapters. The removal of the
wax, with its subsequent treatment, is carried on in wax plants.
The wax distillate from the crude distillation is usually unfit for
direct introduction to the wax plant. This is because the wax
content is in an amorphous rather than a crystalline state. In
this condition, it would gum up the wax presses and otherwise
give trouble. It is found that by re-running the crude distillate

![Fig. 96](image)


in fire stills and curtailing the use of open steam sufficiently to
allow the temperatures in the still to rise slightly above the
cracking or decomposing point, the contained wax is altered to
crystalline form.
The first step in the removal of the wax is to chill the wax distillate. The chilling temperature is a few degrees below the desired cold test of the neutral oil. Obviously, if the distillate is chilled to a certain temperature, and all crystalline wax then removed therefrom, the pressed oil, or oil from which the wax is removed, will no longer congeal or "chill" upon cooling, until the temperature drops below that at which the wax removal was accomplished. It is here, therefore, that the cold tests of many of our lubricating stocks are controlled.

In the United States, two types of chilling machine are used. The double pipe "chiller," shown in Fig. 97, is very popular. This machine consists of a number of 6 inch pipes in series, each jacketed by an outer 8 inch pipe. Inside of the 6 inch pipe is a screw conveyor driven by chain sprockets on an extension of the shaft at one end. This conveyor is necessary to force the congealed wax along with the oil. The cooling medium is circulated between the two pipes.

The capacity of chillers depends upon the initial temperature of the distillate. For ordinary conditions, one section of double pipe chiller will reduce the temperature of 30 barrels of distillate from 90° to 15° F. in 24 hours.

Double pipe chillers may be assembled in any number of sections up to twelve. Less than four sections per chiller are,
however, rarely used, since one small press would require at least this number. The exchanging surface per section of the Carbondale machine, Fig. 97, is 53 square feet. The rate of heat transfer between the oil and the cooling medium for this type of machine is \( \rho = 4 \) to 5 B.t.u.\(^1\) At this rate, one section will chill twenty-five barrels of distillate from 90° to 15° F. per 24 hours. This figure will allow for the "foots oil" recirculated.

**Fig. 98**

Double pipe chillers showing insulation.

Chillers should be carefully insulated. Room insulation in this case is not so efficient as insulating the machine itself. An inexpensive and efficient method is to build a box of matched lumber enclosing all but the end fittings of the machine. This box should then be filled with ground cork. Fig. 98 shows a system using light sheet metal instead of wood.

\(^1\) \( \rho = \) heat transferred per square foot per 1° F. of mean temperature difference between the two mediums per hour.
In discussing chillers it is well to consider the power required to drive the screw conveyors. The drive is through a worm gear which greatly reduces the speed. Under normal conditions, individual motors of 3 H.P. will be satisfactory but 5 H.P. motors are customary to allow some leeway. Often, however, the pressure will mount and the load will exceed 5 H.P. with consequent blowing of fuses and possible "freezing" of the chiller before a new start can be made. For this reason, the writer favors the group drive for chillers. Five or less on a shaft are satisfactory. If a 25 H.P. motor is arranged to drive five machines in this manner and the load goes up on one or two machines, there is plenty of reserve power available. It is extremely unlikely that all five will give trouble at once. The group drive has the added advantage of lower first cost.

Fig. 99

Fahl double pipe chiller.

The Fahl chiller, Fig. 99, is another type of double pipe machine. The advantages claimed for it are compactness and
the elimination of abrupt changes in the direction of the oil current. This machine is also self-supporting.

Fig. 100 illustrates the Gray double shell type chiller. It resembles a gigantic ice cream freezer with power driven paddles so arranged that when revolved the resistance of the oil forces the blades firmly against the shell. Hence the deposition of chilled paraffine on the shell is avoided, and the insulating effect of such a deposition overcome. The cooling medium (brine) is circulated between the two shells, the transfer of heat from the oil to the brine being through the inner shell. The
manufacturers of this apparatus recommend it for all temperatures down to 15° Fahrenheit. Below 15° the chilled paraffine wax has a tendency to adhere to the paddles, which increases the resistance and power requirement. Favorable features of the machine are its simplicity and large capacity per square foot of floor space. One Gray chiller is rated at 400 barrels (42 gal.) from 90° to 18° F. per day.

A new type of Gray chiller which embodies the above features but which may be operated at lower temperatures is il-
Absorption refrigerating machine with double pipe rectifier, absorber and condenser.

Fig. 102
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illustrated by Fig. 101. The vertical shells, while smaller than those described in the preceding paragraph, are similar in general design.

The absorption type of refrigerating system shown in Figs. 102 and 103, is in almost universal use for this kind of service at the present time. This system runs on exhaust steam at 3 lb. pressure or above. With the exception of the pumps, there are no moving parts, and the apparatus is very reliable. Refrigerating machines are rated on their ice making capacity in net tons per day. For ordinary wax plant design without unusual requirements such as the extra capacity for producing special stocks of extremely low cold tests, one-eighth of a ton refrigerating capacity is sufficient per barrel of wax distillate throughput per day.

Approximately 30 pounds of exhaust steam at from 3 lbs. to 15 lbs. pressure are required per ton of refrigeration per hour. The water consumption should also be considered. Four gallons per minute per ton of refrigeration should be allowed. The steam pressure on the generator will depend on the water temperature. Three pounds for water at 60° F. and 15 pounds for water at 75° F. represent the two extremes usually encountered in practice. Intermediate values may be interpolated.

A short discussion of the calculations involved in refrigeration practice is here offered.

The unit of refrigeration is the heat required to melt one ton (2,000 lbs.) of ice, or, conversely, the quantity of heat which must be abstracted in order to freeze one ton of water. In practice, this quantity is taken at 288,000 B.t.u. A 1-ton refrigerating machine has the capacity for one ton of refrigeration per 24 hours.

The amount of refrigeration required to chill a substance from one temperature to another is expressed by the following formula:

\[ T = \frac{W S (t_1 - t_2)}{288,000} \]

where:
- \( T \) = Refrigeration, tons.
- \( W \) = Weight of substance, tons.
- \( S \) = Specific heat of substance, B.t.u. per lb.
- \( t_1 \) = Initial temperature, °F.
- \( t_2 \) = Final temperature, °F.
FIG. 103

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\[ W = \text{weight of substance, lbs.} \]
\[ S = \text{specific heat of substance.} \]
\[ t_1 = \text{initial temperature.} \]
\[ t_2 = \text{final temperature.} \]

If \( W \) denotes lbs. per day, \( T \) is the rated tonnage of the machine. If \( W \) = lbs. per \( h \) hours, the weight of substance chilled per day is \( 24 \frac{W}{h} \) and the rated tonnage of the machine is

\[
\frac{24}{h} T = \frac{WS (t_1 - t_2)}{12,000h}
\]

One gallon degree is the heat required to change the temperature of one gallon of brine 1° F. per minute. In B.t.u., this quantity may be expressed as 8.35 \( gs \), where \( g = \) specific gravity of the brine and \( s = \) specific heat. Brine tables are available giving Baumé readings and specific gravities along with the specific heat and per cent. of salt or calcium chloride. The gallon degrees per ton of refrigeration is given by the formula:

\[
G_t = \frac{34,491}{gs}.
\]

Knowing the quantity of brine circulated per minute and the drop in temperature through the brine cooler, the refrigeration rate per day is given by the formula:

\[
\text{Tonnage rating} = \frac{1440 V(t_1 - t_2)}{G_t} = 0.042 gsV(t_1 - t_2)
\]

\( V = \text{quantity of brine, gal. per min.} \)

Where good water is obtainable, double pipe absorbers, rectifiers and condensers are recommended. Besides giving high efficiency, they may be placed under cover where they will receive attention. On the other hand, if there are scale forming ingredients in the water, a shell and tube absorber with atmospheric rectifiers and condensers placed on the roof is considered better practice. Shell and tube brine coolers are most commonly used.
Calcium chloride brine is usually employed for the chilling medium. The usual brine temperature is 0° F. Centrifugal or triplex brine pumps, power driven, are recommended. After passing through the oil chillers, the brine should return to a well-insulated brine tank, from which it is again pumped through the brine coolers and to the chillers in a closed circuit. Efficient flow meters and thermometers on the brine system will permit a constant check to be kept on the refrigeration. Where oils of extremely low cold test are desired, the ammonia from the absorption machine condensers may be expanded directly into a double pipe chiller. This direct chilling of the oil replaces the chilling of the brine in the brine cooler.

Since wax distillate has a high cold test, or in other words, chills rapidly at moderate temperatures, it has to be kept around 90° F. to be handled successfully with pumps. At this temperature, a considerable heat may be removed by water alone, and sometimes a chiller of the Gray type is reserved for this use. Again the pressed oil returning from the presses is, in the case of a single pressing, around 16° to 18° F. This oil is usually en route to distillation or treating apparatus and hence may well absorb heat from the wax distillate on the way to the presses.
A chiller of either type may be used for this purpose. Both of these steps will reduce the amount of refrigeration. Fig. 104 shows a chilling system using both the pressed oil and brine.

After chilling, the wax distillate is pumped through a filter press, Figs. 105, 106 and 111. The filter press consists of a series of steel plates with perforated plates riveted thereto. In the center of each plate is a circular opening. A 12-ounce canvas blanket is drawn through this opening so as to lie against both sides of the perforated plates and is secured around the circumference of the assembly. Fig. 107 shows, in detail, a plate made up ready for the press. Spacing rings of two types are used between adjacent plates. Fig. 107 shows the separate type of spacing ring. The rings are ½ inch in thickness and are placed...
on the frame between each two press plates. Some companies prefer to have the rings attached to the press plates themselves. Fig. 108 is an assembly of this kind. The advantage is said to be in the reduction of the time required for dumping the press due to the fact that both ring and plate are moved by one operation. Contrary arguments discount the time saving element and hold that the "cake" will fall more freely with separate rings. The wear on the canvas blankets is more severe with the attached rings, and the first cost and repair expense are greater. For these reasons most companies favor the separate type of ring. The diameter of plates is usually made 27 inches or 48 inches, the latter being the more common in present use.

The capacity of filter press plates depends on the amount of wax present in the wax distillate. For a high wax content of 20 per cent., two 48 inch plates should be allowed for each barrel of wax distillate pressed per day. For a wax content of 10 per cent., one 48 inch plate per barrel will suffice. These figures allow sufficient leeway to take care of the foots oil later extracted from the wax and returned for pressing.

Fig. 107
Filter press plate.

The press plates are hung by the lugs from the side rod of the press frame. By using inverted lugs on every third
fourth plate the tendency of the press to buckle under pressure, forcing the plates near the center off the side rods, is overcome. Press frames are manufactured to accommodate any number of plates up to 500. When new, ten plates will occupy one foot of space between the platens. After some use, a few more may be added. As usually furnished, the plate space is from 30 to 40 feet. In this connection it should be noted that the larger presses will require more time to fill up and hence afford fewer cycles in a given period. Since it is more economical in investment to install four 500 plate presses than five 400 plate presses, the larger presses are recommended. Sufficient presses should be installed to provide one which is always ready for filtering and to take care of special stocks if such are manufactured.

Fig. 108

Filter press plate assembled. Spacing rings attached.

After the plates are on the frame they are pressed together by the hydraulic ram, and the tension bolts are drawn tight. The press is then ready for filtering. The cold wax distillate from the chillers is forced through the annular opening formed though the center by the openings in the closely packed plates.
The course of the oil through the plates is shown in Fig. 109. The crystalline wax is retained between the canvas blanket. As this wax space gradually fills up, the pressure is allowed to mount to the practical limit, usually about 350 pounds per square inch, and the press is then ready for dumping. A usual arrangement where there is more than one press is to place a relief valve on the line so that the wax distillate will automatically pass to the next press. While the wax is accumulating, the oil is dripping into a trough and being conveyed to the “drip” tanks, usually arranged so that each press has its own receptacle. Fig. 110 is a cross section of a 48 inch press showing the pressed oil trough in position.

To dump the press, the trough is rolled to one side by a lever mechanism, thus uncovering the wax conveyor directly beneath. The nuts or keys on the tension rods are then removed and the ram is reversed, moving the front platen back. Two men, one on either side of the press, slide the plates one after the other through the space made by drawing back the platen, and re-
move the wax cake from the blankets with spuds, the broken cake falling on the spiral conveyor which carries it to the wax "dump" tank. This tank is usually at the opposite end of the press from the drip tank for pressed oil. The wax is melted by steam coils in the dump tank and may then be pumped to storage.

The wax as taken from the presses is yellow, soft and crumbly, and contains a large amount of oil. It is called "slack wax," and is now ready for further treatment to yield the various grades of commercial paraffine wax.

The building housing the refrigerating, chilling and pressing apparatus and auxiliaries should receive special attention.

The usual arrangement is shown in Fig. 112. Future extensions may be easily added. One modification of this arrangement places the chillers on a second floor directly over the presses. The oil outlets of the chillers should, of course, be
above the inlet to the presses. A pipe gallery, two stories in height, between the refrigerating room and the two story press and chiller section will be of service for the concentration of the piping between the two sets of apparatus. Fig. 113 illustrates this design. Buildings constructed of reinforced concrete, or of brick and steel with reinforced concrete floors, are recommended. The press rooms should be thoroughly insulated. One system uses two layers of 1 inch cork boards, breaking joints between layers. Nailing strips to receive this insulation should be left in walls and ceilings. Wire mesh and Portland cement plaster are applied over the boards. Sil-O-Cel brick for press room walls and partitions has also been used with success. These bricks have considerable structural strength and may be laid up in a partition 8 inches thick in the ordinary way. Plastering over wire mesh applied to the brick is necessary to lend sufficient stiffness to the wall. All press room doors should be of the "refrigerating" type, as used in cold storage work. Presses should be placed with the ram end toward an outside wall and, if possible, with a door opposite each press to facilitate the removal of the ram.

Steam pumps are to be recommended for wax plant service. The absorption refrigerating system and the heating of the tanks will utilize all the exhaust
General arrangement of wax plant.
steam. Since the exhaust steam requirements minimize the effect of high steam consumption, full advantage may be taken of the low first cost and reliability of steam pumps. Power pumps, engine driven, have proven economical, but in this case the power load is not large enough to furnish sufficient exhaust steam.

![Diagram](image)

**Fig. 113**  
Section through chiller and press rooms showing pipe gallery.

In the writer's opinion, all principal operations, including packing and shipping, should be housed in one building. Such an arrangement results in short pipe lines, low installation costs, and efficient management. The building shown in Fig. 112 houses all the steps of wax manufacture except sweating and treating. Some refiners prefer to have a separate building in which to filter, barrel and mould their wax.

Every precaution should be taken to conserve refrigeration. All brine pipes and cold oil lines should be insulated with best quality cork covering; and the brine coolers, absorber and generator should be properly lagged. These important points are often neglected.
As before stated, the wax contains a large amount of oil. This oil is removed by chilling the wax to a solid mass and then gradually raising the temperature. This process is based on the theory that, in the solid state, the wax crystals still have innumerable interstices and voids in which the oil is contained. As the temperature is gradually raised, the resultant expansion opens these cells so that the entrained oil may drain away. The process is called "sweating."

The apparatus used for this purpose usually consists of a series of shallow steel pans set in a bank several units high and enclosed in a room of good insulating properties. Installations vary as to size and details.

The pans in use by some of the older and smaller refineries are 8 by 20 feet in plan, and about 8 inches deep at the ends, sloping to a depth of 14 inches at the center. They are usually assembled in stacks, eight high, and with one or two stacks in a room or "oven." A rack made of light angle or tee iron is laid in the pan and carefully levelled. A galvanized iron wire mesh of 1 inch squares is then stretched across the rack and over this a brass wire cloth of 50 meshes per inch is securely fastened. A coil for cooling the wax is laid over this screen. Water is turned into the pans to a depth sufficient to just cover the screen, and the hot wax is then pumped in to a depth of 5 or 6 inches. This is about the maximum possible cake thickness if there is to be a uniform temperature throughout the cake. By pumping cold water through the coils, the wax is chilled below its melting point, and becomes a solid cake. The oven is then tightly closed, the water withdrawn from the pans, and by the use of steam coils along the walls the temperature is raised. The oil sweats out of the wax, drains through the screens, and by outlets at the low center of the pans, is led to storage. This oil is known as "foot oil." Two cuts are usually made, the first being straight foots oil, and the second a mixture of oil and wax in about the same proportion as that of slack on the pans. The second cut is usually introduced directly into slack wax and re-sweated. The process is continued at a certain temperature until
The oil is thoroughly sweated out. The remaining wax is known as “scale wax.” This remaining solid wax will have a melting point approximately at the temperature at which “sweated,” since all the portion melting at that temperature is removed by the process and is carried away by the foots oil. It is here, therefore, that the melting points of the waxes are controlled. The scale remaining on the screen is then melted by turning steam through the coils and is drained from the bottom of the pan to a rundown tank for further treatment.

Crude scale wax on the first sweating has a melting point which may be varied from 105° to 120° F., and has many commercial uses. If “refined” waxes of higher melting points are desired, further sweating is necessary. When running to refined waxes, the first sweating to crude scale is usually at a melting point between 105° and 109° F. This scale is then resweated for a scale of higher melting point called “resweated scale.” The cuts in this case will carry a much higher wax content than those of the slack wax sweating. The resweated scale is again sweated and the residual will be the highest melting point wax desired. The two cuts are also resweated and will give residuals of somewhat lower melting points. Innumerable combinations of resweating are possible, with a wide range of products as to melting point and degree of dryness or oil content. When resweating, the cycles are shorter on account of the lessened quantity of oil remaining to be sweated out in the succeeding steps. A safe rule in figuring oven capacity is to provide for all the slack for a scale wax of about 109° melting point, and then to add 80 per cent. to take care of all resweating for refined waxes if this further step is desired.

Fig. 114 shows the arrangement of a sweating oven of the type described. The building is constructed to give thorough ventilation when cooling down and proper insulation when sweating.

Each stack of 8 pans of above specifications will hold 4,000 gallons of slack wax. The time required from charge to charge, and the capacity of slack wax sweated per day under average
weather conditions and with average equipment, would be as follows:

<table>
<thead>
<tr>
<th>Melting Point, °F</th>
<th>Time, Hrs</th>
<th>Gallons per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>105</td>
<td>35</td>
<td>2,740</td>
</tr>
<tr>
<td>115</td>
<td>42</td>
<td>2,280</td>
</tr>
<tr>
<td>120</td>
<td>45</td>
<td>2,140</td>
</tr>
<tr>
<td>125</td>
<td>49</td>
<td>1,960</td>
</tr>
</tbody>
</table>

**Section A. Elevation Double Oven.**

**Fig. 114**

Oven arrangement for double bench of sweat pans.

The above capacities are based on the assumption that the slack contains about 50 per cent. of foots oil. If a very dry cake is obtained from the presses, better time and greater capacities are attainable. For quick cooling and melting down, 0.04 square feet of external pipe area should be allowed for the pan coils per gallon of charging capacity. The side wall coils should have from 0.06 to 0.07 square feet of external surface per gallon charged.

While following similar lines, modern practice in large re-
fineries has progressed considerably. Oven capacities are much greater. Pans are in use from 50 to 60 feet long and 10 feet wide. One result of larger pans, designed pitching from both

ends to the center, was poor drainage. To overcome this difficulty, pans have been designed with the bottom in the shape of a series of inverted pyramids. Oven capacities have also been increased by placing more pans in the stack. The charging capacity of a 10 by 50 foot pan is about 1,400 gallons. A 10 by 60 foot pan will contain 1,670 gallons. Oven capacities range from 12,000 to 20,000 gallons. Fig. 116 shows a modern 50 foot pan. An assembly 8 pans high is illustrated in Fig. 117.

The costly and troublesome wire gauze screen has been replaced to a large extent by inexpensive perforated metal plates. No. 14 B.W.G. sheet steel, perforated with ⅛ inch round holes on ⅛ inch centers will give satisfaction.

For sweating purposes hot water, circulated through the coils in the pan, has replaced the use of steam in the side coils of the oven. This system provides much better heat regulation and applies the heat where most effective, directly in the wax cake. The water temperature is not sufficiently high to melt the wax crystals, as would be the case if steam were turned into the coils.
For hot water circulation, a pump capacity of about 20 gallons per minute per 1,000 gallons charged into the ovens is satisfactory. The temperature of the water may be regulated automatically by introducing live or exhaust steam into a tank containing the circulating water. As shown in Fig. 119, a regulator, controlled by the temperature of the water in the tank, actuates a diaphragm valve on the steam inlet. Each oven should be equipped with its own pump, tank and regulator. For smooth operation the tank capacity should be about three times the capacity of the pump in gallons per minute.

In a closed system of water circulation it is very difficult to determine which coils are functioning correctly. For this reason, it is recommended that each coil discharge separately into an overflow trough placed above the top pan and arranged to drain back to the tank for recirculation.

Steam coils along the sides of the ovens are advisable for
two reasons. In the first place, in order to prevent the foots oil from chilling in the run down line, the oven temperature should be maintained about the same as that of the sweating cake. Furthermore, the coils are needed to assist in melting

Fig. 117
Assembly of wax sweating pans showing piping.
down the wax after sweating. Obviously, they need not be as large as those required in a system having no hot water circulation. About half the previous figure will suffice. The addition
of an open steam spray under the screen is a valuable aid in melting down.

With hot water circulation, unrestricted outlets, and better ovens, the time cycle has been materially reduced from the figures given for the older type of sweaters. Since the heating surface is proportioned to the charge, the size of batch has very little influence on the number of hours per cycle. In modern practice, with well designed ovens, sweating to scale of 105° M.P. (melting point) requires only 30 hours per cycle. Some companies report as low as 24 hours. For scale of 120° M.P., about 36 hours will be required. In the case of the scale wax of 105° M.P., the 30 hour period is divided as follows:

<table>
<thead>
<tr>
<th></th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charging</td>
<td>2</td>
</tr>
<tr>
<td>Cooling</td>
<td>11</td>
</tr>
<tr>
<td>Sweating</td>
<td>15</td>
</tr>
<tr>
<td>Melting down</td>
<td>2</td>
</tr>
</tbody>
</table>

For the higher M.P. residual, the extra time is principally in sweating, with a slight increase in time for melting down.

Oven design has changed materially. As originally designed, two stacks were usually placed in a solid brick building with large door openings at either end. In order to increase ventilation when cooling, these doors and the louvres of the roof monitor were opened. The doors also served to allow one pan to be withdrawn for repairs without interfering with others. The rundown tanks were usually buried outside, and the pumps were located in an adjacent building.

With hot water sweating, space for the circulating pumps and tanks was required. This factor, together with the desirability of housing the rundown tanks and transfer pumps, has led to the form of oven arrangement shown in Fig. 120, which is popular today. Troubles due to warping and sagging of the wooden doors covering the end openings, have led some companies to adopt large rolling steel shutters. The ease of operation and reliability of the steel shutters are said to compensate for their lower insulating properties. Steel shutters for this
purpose should be of the type made from a single sheet of corrugated metal. The joints of the interlocking type will quickly rust out on account of moisture coming from the inside of the oven.

One prominent company finds repairs requiring the withdrawal of a pan to be so infrequent that it has eliminated large doors on ovens. In order to obtain the required ventilation while cooling, this concern uses a cold air blast which is released directly over both ends of each layer of molten wax. This blast is produced by a large motor driven fan. In comparison with other modern ovens, this installation shows approximately 15 per cent. better time results. The increased capacity per oven apparently warrants the additional first and operating costs.

The foots oil obtained from the wax, as above described, may take one of three courses. It may be returned to the stills wherein the wax distillate is re-run, or returned to the re-run wax distillate, or resweated and then returned to the process by one of the two previous methods. In all cases, it eventually finds its way back to the chillers and presses, where the wax extraction starts.

In resweating foots oil, since the sweated product is “slack wax” of similar characteristics to the slack from the presses, much thicker cakes can be treated. This product is more porous and crumbly and allows the oil to percolate to a greater distance. Tank sweaters have been used with success. Rectangular boxes holding 20,000 gallons, packed with coils for water circulation, and shell and tube apparatus with water circulated through the
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tubes, have also been used. Pans similar to those for wax, but deeper and with multiple coil layers, are successful. Yields of from 15 to 40 per cent. of slack wax may be taken from foots oil, depending upon the melting points at which the original sweating was done. Obviously, the higher the temperature of the first sweating, the higher the wax content in the foots oil. On account of the comparatively low temperatures (from 90° to 100° F.) at which foots oil is sweated, the work can be done in about one half the time taken for slack sweating.

The scale or refined waxes are sometimes chemically treated in an agitator, usually used for this especial purpose. It is necessary to keep the temperature well above the melting point. For this reason, a tile or hollow brick jacket around the agitator is advisable. Steam coils between the jacket, and closed steam coils in the agitator cone, are used. The treating temperatures are from 150° to 175°. A weak soda solution is all that is usually required. After treating with the soda solution, the batch is washed with hot water and is blown dry with air. The temperature is maintained during the drying. From 7 to 9 hours are usually required for this step, the agitator capacity depending on the daily requirements. No special features of agitator design are necessary except the steep pitch of the cone. This should not be less than 45 deg. As no acids are ordinarily used, a lead lining is not necessary.

With or without treating, it is necessary to filter the wax to obtain a clean white product. Fullers' earth is usually used. The filter bed need not be so deep as that for lubricants. From 6 feet for Pennsylvania wax to 10 feet for some of the North Texas and Louisiana waxes is sufficient. The rate of filtration is also high, six barrels per day per square foot of filter bed area is not uncommon. The yields per ton of clay will vary with the character of the crude from which the wax has been extracted. From 225 to 275 barrels per ton of clay have been reported for Pennsylvania waxes and as low as 100 barrels for the Texas and Louisiana products. The clay usually used has been regenerated 7 or 8 times in lubricating service and may be dis-
carded after one filtration of wax. Except for the fact that the wax filters may be more shallow in relation to their diameter, the design of the filters follows that of those for lubricating oils, as described in Chapter XIII. In order to avoid excessive pumping (a difficult matter with a material which must be kept hot), it is considered good practice to locate the wax filters in the wax plant.

Some refiners prefer the use of bone black for wax filtration, although the newer installations are usually operated on fullers' earth. The use of bone black requires a special furnace for its regeneration. If a filter house for lubricants is not included in the refinery, this is perhaps warranted. Excellent colors and good yields are reported from operations with bone black. It is usually regenerated many times. When fullers' earth from the lubricating filters is no longer suitable for use, or is "spent," it may still be used for wax and afterward discarded. This accounts for the popularity of the fullers' earth method, since practically the only cost involved is the labor of moving the fullers' earth to the wax filters.

After filtration, the wax is ready for packing. Bulk scale wax shipments are usually made in light wooden barrels. The barrels need not be absolutely water tight. Fig. 121 shows a machine that prepares the wax for barreling. A hollow cast iron cylinder 8 or 10 feet long revolves above a pan of the wax, which is kept in a liquid state by a steam or hot water coil in the pan. The cylinder is placed horizontally, so that only a small portion of its circumference is submerged in the wax. Cold water is circulated through stuffing boxes on either end. As the cylinder revolves, a thin film of the hot wax congeals on the surface and is scraped off by a knife held against the cylinder by weights or springs. This thin film of partially chilled wax is quite elastic, and is deflected through a chute into the barrel below. A man tamps it solid as it falls. In some cases the machine is placed on the floor over the packing room and a packing machine similar to those used for packing bran is installed underneath on the packing room floor.
The refined waxes are often moulded into cakes. The hot wax was originally poured into moulds and allowed to cool. Shrinkage caused uneven cakes. The Gray moulding press, Fig. 122, overcomes this difficulty. The operation of this machine is not unlike that of a filter press. Moulds and cooling plates are placed alternately on the frame and "set up" by the ram. The sides of the moulds and frames extend 3 inches above the tops so that an excess of wax may remain above and in communication with each mould. An arrangement is provided to keep this excess wax hot so that it may flow into the moulds to make up for the shrinkage. After the moulds are filled, cold water is circulated through the cooling plates. The wax will chill in from 2 to 3 hours, depending on the melting point. The platen is then drawn back, and by moving the cooling plates along the rods, the wax cakes may be removed.

In order to illustrate the principles of wax plant design, a hypothetical case will be assumed and the requirements worked out in detail. Let it be assumed that a refinery has available 1,200 barrels of good wax distillate per day; and that laboratory or practical tests show that when this is pressed for an 18° cold test oil there is a slack wax yield of 15 per cent.
Fig. 123 shows the process to be followed. Only one grade of scale wax is desired, of about 109° M.P. The losses are not shown, as they amount to only 1 or 1\(\frac{1}{2}\) per cent. at each step and would not influence the selection of equipment.

![Image of a machine](image)

**FIG. 122**

Gray moulding machine for wax cakes.

The capacity figures for refrigeration, chillers and presses all include an allowance for the returned foots oil. In this case, therefore,

\[
\text{Refrigeration} = \frac{1,200}{8} = 150 \text{ tons},
\]

\[
\text{Chillers} = \frac{1,200}{25} = 48 \text{ sections}.
\]

Four 12-section machines will do. Two press plates per barrel per day at 20 per cent. wax content and one at 10 per cent. wax content are required. At 15 per cent. wax content, 1.5 plates will suffice.

\[
\text{Plates} = 1,200 \times 1.5 = 1,800.
\]

The required capacity might be obtained, therefore, by using
presses of 300, 360, or 450 plates in groups of six, five, and four, respectively. Since five or six presses would be more expensive to install and would require more frequent dumping, four 450-plate presses will be selected.

The daily oven requirements are for 251 barrels or 12,500 gallons. A 10 × 50 foot pan will charge 1,400 gallons. For 109° M.P. wax, 32 hours should be allowed per cycle. The daily pan capacity will be, therefore,

\[
1,400 \times \frac{24}{32} = 1,050 \text{ gallons.}
\]

The number of pans required will be

\[
\frac{12,550}{1,050} = 12.
\]

Two ovens of 6 pans each, with sufficient headroom to allow for two additional future pans in each oven, will be satisfactory. In addition, a fooots oil sweater of the tank type charging
4,300 gallons will be required, or an oven of about 6 additional pans similar to the wax pans may be used.

For treating the wax, one batch per day, an agitator of 125 barrels' capacity will be required. To allow for occasional interruptions of treating and for future growth it would be advisable to increase the agitator capacity to about 250 barrels.

The required filter area is

\[
\frac{120}{6} = 20 \text{ sq. ft.}
\]

A filter tank 5 feet in diameter by 10 feet deep will do this work. To allow for washing the filter and replacing the clay, this equipment should be installed in duplicate.

Auxiliary equipment will consist of tanks, pumps, packing equipment, and miscellaneous smaller items. Since all the stocks shown on the diagram are intermediate except the finished wax, from 7 to 10 days' tank storage capacity should suffice for each. In the case of finished wax, tankage for 60 days' storage should be provided. Three 2,500 barrel tanks are recommended. The selection of three small tanks instead of one or two larger ones is made to provide for the production of more than one grade of the finished wax if such a policy should eventually be found desirable.
CHAPTER XIII
FILTERING


Filtering or percolation through fullers' earth is one of the usual means of improving the color of petroleum products. There is much controversy as to the relation between color and value in lubricating oils. Except as an indication of the possibility of the presence of unsaturated compounds, which are liable to break down under heat and release free carbon, color bears no apparent close relation to the quality of a lubricant. Moreover, this indication is by no means infallible. Trade demands are often responsible for efforts toward improving the color of a lubricant which would nevertheless be satisfactory with a lower color standard. Most lubricating oils are, therefore, subjected to filtration through fullers' earth, the so-called "filter clay." Extensive beds of this material are located in Florida and in one or two of our Western states. It is crushed and screened to size and shipped to the refineries in bulk or in burlap bags.

The size of the clay particles depends upon individual preference. Clay passing through a sieve of 40 meshes per lineal inch but retained on a 60-mesh sieve (known as "40–60 clay") is extensively used. Excellent results are reported with 60–90 clay, although with oils of high viscosity, the rate of filtration is slow. For such oils, 30–60 or 40–60 clay is generally preferred. Since the fine clays require greater head to produce a steady flow they are not well adapted to gravity feed filters. In general, it appears that the finer the clay, the higher is its efficiency as a decolorizing agent. The degree of fineness is limited by practical mechanical difficulties. Clay pulverized to a dust is very effi-
cient and filters adapted to the use of such material are in process of development.

The action which takes place in a filter is the subject of much discussion. According to some authorities, the action is chemical, while in the opinion of others it is entirely physical. It is probably both chemical and physical. Chemical reaction is often indicated by a material increase in temperature between the ingoing and the outgoing oil at the start of the run. After a time there is no further apparent increase and beyond this point the action is probably physical.¹

Filter clay, as received from the mines, contains upward of 5 per cent. moisture, which must be removed prior to use. This is accomplished in kilns of various types. The complete removal of moisture is necessary for satisfactory results in the filters. A

¹ For a theoretical discussion of decolorization by filtering, see Bacon and Hamor, American Petroleum Industry, p. 614.
cubic foot of raw or "green" clay of 30-60 mesh has an average weight of about 35 lbs. After a preliminary "burning" to remove the moisture, the weight becomes 33 lbs. per cubic foot, indicating a moisture content when received from the mines of 6 per cent.

Some clays are found to have a more active decolorizing effect on certain oils, if the water of constitution is also removed. Mr. T. T. Gray reports the average loss in weight of 12 samples of 60-90 clay when burned in laboratory apparatus at a dull red heat as 13.2 per cent. From 5 to 6 per cent. of loss is due to contained moisture, the balance being the water of constitution.

The vertical type of filter is generally used. A canvas blanket over a perforated drainage plate is provided to hold the clay, the oil passing on through the outlet. Manholes for charging and discharging the clay and the necessary pipe connections are provided. Fig. 124 shows a small filter. Construction details for a larger unit are shown in Fig. 125. The
pressures employed in filtering are low. In order to provide sufficient strength for blowing out with air pressure and for steaming, filters should be designed, however, for a pressure of from 40 to 50 pounds per square inch.

The filtering rate and corresponding capacity vary with the stock and the fineness of the earth. In general, the greater the amount of color to be removed, the greater is the amount of clay necessary. The filtering rate may be expressed in terms of the quantity of oil per square foot of sectional area of the filter per unit of time. The following rates are typical:

<table>
<thead>
<tr>
<th></th>
<th>Bbls per Sq Ft per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder stocks</td>
<td>0.6</td>
</tr>
<tr>
<td>South Texas lubricants</td>
<td>0.7</td>
</tr>
<tr>
<td>Pressed neutral oils</td>
<td>0.8</td>
</tr>
<tr>
<td>Wax</td>
<td>4 to 6</td>
</tr>
</tbody>
</table>

The rate of flow of a given filter depends, therefore, upon the diameter. The depth must be sufficient to provide a suitable length of contact between the oil and the clay, and for most oils should be about 15 feet. For wax a depth of 5 or 6 feet is sufficient. Another factor enters into the question of depth. Increasing the depth provides greater clay charging capacity, and, consequently, lengthens the possible run before the filter must be dumped and recharged. The increased length of run will result in greater throughput per annum. There is a practical limit of about 30 feet to the depth, above which limit channeling of the oil is liable to occur. As a guide in the selection of filters, the following table is offered:

**Table 45. Filter Capacities**

<table>
<thead>
<tr>
<th>Diameter, Feet</th>
<th>Depth, Feet</th>
<th>Charging Capacity, Tons of Clay</th>
<th>Rate of Flow, Gallons per Minute</th>
<th>Average Throughput, Barrels per Day (Averaged over the year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>6</td>
<td>15</td>
<td>7</td>
<td>0.50</td>
<td>0.58</td>
</tr>
<tr>
<td>8</td>
<td>20</td>
<td>17</td>
<td>0.88</td>
<td>1.03</td>
</tr>
<tr>
<td>8</td>
<td>25</td>
<td>21</td>
<td>0.88</td>
<td>1.03</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
<td>25</td>
<td>1.38</td>
<td>1.61</td>
</tr>
<tr>
<td>10</td>
<td>25</td>
<td>32</td>
<td>1.38</td>
<td>1.61</td>
</tr>
<tr>
<td>10</td>
<td>30</td>
<td>38</td>
<td>1.38</td>
<td>1.61</td>
</tr>
</tbody>
</table>
FILTERING

In the above table, the rates of flow and daily averaged throughput take into account the yields for the various products, as follows:

I. Cylinder stocks.
II. Paraffine oils.
III. Neutral oils.

Since the greater the yield obtained, the lower is the percentage of idle time, the yields directly affect the possible throughput. The clay charging capacities are based on "fresh" earth, that is, earth which has been dried to remove the water content but which has not been previously used for filtering. Clay which has been used and subsequently burned or regenerated for further use is heavier than the fresh earth, so that the capacity in tons with burned clay is greater than the tabular value. This increase in weight will be further discussed in connection with the subject of regeneration of the earth.

No fixed standards for yields per ton of clay can be established. The yields will vary with different stocks and also with different grades of the same stock, depending upon the previous handling and the desired color reduction. The quality of the clay also has its influence. Fresh clay is best adapted to the manufacture of light colored oils, while for a lesser decolorizing effect a good yield may be obtained with clay regenerated one or more times. Seven or eight burnings is about the present limit for lubricants, after which the clay may be used for wax or sometimes for refined oils. It is customary to classify the clay by numbers indicating successive regenerations. Thus "number one" clay has been burned once, besides the original dehydration, "number two" clay twice, and so on.

Another system which has the advantage of giving a symbol for the clay at each separate stage of its life, is as follows:

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>New clay</td>
</tr>
<tr>
<td>½</td>
<td>New clay dehydrated</td>
</tr>
<tr>
<td>1</td>
<td>New clay dehydrated and used once</td>
</tr>
<tr>
<td>1 ½</td>
<td>Above after regeneration</td>
</tr>
<tr>
<td>2</td>
<td>Above again used</td>
</tr>
<tr>
<td>2 ½</td>
<td>Above after regeneration</td>
</tr>
<tr>
<td></td>
<td>Etc.</td>
</tr>
</tbody>
</table>
Typical yields with different qualities of clay are as follows:

**Table 46. Filter Clay Yields**

<table>
<thead>
<tr>
<th>Stock</th>
<th>Color No</th>
<th>Yield, Barrels per Ton of Clay</th>
<th>Clay No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light spindle</td>
<td>1</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Medium spindle</td>
<td>2½</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Dark spindle</td>
<td>3</td>
<td>8–10</td>
<td>5</td>
</tr>
<tr>
<td>Light red oils</td>
<td>5</td>
<td>12–15</td>
<td>1</td>
</tr>
<tr>
<td>Dark red oils</td>
<td>6</td>
<td>19–21</td>
<td>2 and 3</td>
</tr>
<tr>
<td>Cylinder stocks</td>
<td>—</td>
<td>7–10</td>
<td>1</td>
</tr>
<tr>
<td>Wax</td>
<td>—</td>
<td>20–30</td>
<td>7 and 8</td>
</tr>
</tbody>
</table>

Colors numbered according to National Petroleum Association standard.

While these yields are subject to great variation, depending on the original color of the stock and the final color desired, they are fairly representative for these classes of stock. In the table of filter capacities, the oils are grouped under three classifications, and the figures are based upon average conditions. The figures may be used with safety, since every installation will have several filters, so that the retarded operation of one unit will usually be balanced by better results obtained from others.

Filters may be operated with gravity or pressure feed. The latter is preferred in modern practice. The operation of a pressure feed filter is usually as follows: After the filter has been charged with clay, oil is pumped in under a pressure of 5 or 6 pounds per square inch until the oil “shows through.” The time required for this operation will depend upon the viscosity of the stock, the shape of the filter and the fineness of the clay. The pressure may then be increased to 15 pounds per square inch and the filter will settle down to a steady rate of flow. The oil first through or “off” will show color well above that desired. As the filtration continues, the filtrate gradually becomes darker until the blended filtrate finally reaches the color standard established.

It is often possible to continue the operation of the filter after the stock originally desired is off, by segregating further filtrates for use in blending other products. Since it decreases idle equipment time and thus provides for a greater average throughput,
this method is always desirable. The possible length of run will be determined by the rate of flow, the filter charging capacity in tons of clay, and the yield of stock obtainable from the clay. This may be approximated from the tabular data given above.

After the run is finished, air pressure may be applied to assist in draining the filter. Even with the use of air, the drainage will take several hours. In order to abstract the coloring matter from the clay, light naphtha is then pumped through the filters. From 6 to 7 barrels are required per ton of earth. Steam is introduced to displace the naphtha, leaving only the heavier tarry bodies which are intimately absorbed by the clay. The steaming process usually requires from 15 to 18 hours. The amount of steam necessary varies. Some refiners report as high as 900 pounds per ton of clay, but 500 pounds per ton is generally sufficient. From 30 to 55 pounds per ton per hour may be used in calculating steam mains. The clay tonnage of the maximum number of filters to be steamed at one time can be readily estimated.

![Filter plant of the Vacuum Oil Co. at Paulsboro, N. J. Burner house at left, concrete clay bins center and filter house at right.](image)

The steam and naphtha vapors leaving the filter should be condensed in suitable surface or jet condensers and passed through a trap where the naphtha may be continuously reclaimed from the water and returned to the wash tank. After
several washings, the naphtha is re-run, leaving in the still a dark stock which may be utilized for various products.

After steaming, the filter is dumped, inspected, closed and recharged. In large filter houses with conveying systems this step is of short duration. For filters up to 20 or 25 tons’ capacity, it is practical to install conveyors large enough to handle the entire charge or discharge in one hour. For larger sizes, the cost of a conveying system sufficiently large to handle the clay in one hour should be balanced against the cost of idle time.

Idle time is usually a large item in filter plant operation. As an example of a filter cycle, the operation of a 25 ton filter operating on a neutral oil will be considered in detail.

The filtrates and yields from one ton of clay are:

<table>
<thead>
<tr>
<th></th>
<th>lbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light spindle</td>
<td>4</td>
</tr>
<tr>
<td>Medium spindle</td>
<td>6</td>
</tr>
</tbody>
</table>

The periods required for each step in the process are:

<table>
<thead>
<tr>
<th></th>
<th>hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fill and show through</td>
<td>18</td>
</tr>
<tr>
<td>Light spindle filtrate</td>
<td>40</td>
</tr>
<tr>
<td>Dark spindle filtrate</td>
<td>60</td>
</tr>
<tr>
<td>Drain with air</td>
<td>25</td>
</tr>
<tr>
<td>Wash and steam</td>
<td>32</td>
</tr>
<tr>
<td>Dump, inspect and charge</td>
<td>4</td>
</tr>
<tr>
<td>Total cycle</td>
<td>179</td>
</tr>
</tbody>
</table>

Idle time, per cent.,

$$\frac{79}{179} = 44.1.$$  

Since the time actually consumed in filtering depends upon the yield of filtrate from the clay, it is obvious that with such oils as cylinder stocks, a shorter cycle will result. For instance, an oil from which one ton of clay yields only three barrels will go off color in about thirty hours and no further filtration will be provided without recharging. Since the periods for the other steps will be about the same, the cycle will approximate 109 hours, and the idle time will amount to 72 per cent.
Oils of high viscosity, particularly cylinder stocks, are usually filtered in a solution of naphtha. Various ratios of naphtha to stock are reported. In most cases, the stock is from 30 to 40 per cent. of the combined total. The mixing of the stock and naphtha may be accomplished by introducing the discharge from each pump into a mixing header connected to the battery of filters. The two pumps may then be regulated to give the desired ratio. For cylinder stocks which are subsequently to be cold settled, filtering in solution entails practically no extra expense, since, in any case, the stock would be diluted with naphtha prior to settling. The naphtha is usually removed from the oil after filtering by steam distillation.

The conventional arrangement of large filter houses is shown in Fig. 127. The service piping is illustrated in detail in Fig.
128. An arrangement suitable for a small filter plant is shown in Fig. 129.

![Diagram of filter plant](image)

**Fig. 128**

Service piping for filters.

Filtration temperatures will vary greatly. Certain oils must be handled quite hot, while with others, equally good results are obtained at normal temperatures. Ample steam coil radiating surface should be provided in the filter compartments in all cases where the requirements are doubtful. In general, cylinder stocks require the highest temperature and the temperatures for other oils vary somewhat according to viscosity.

Mention has heretofore been made of the regeneration of the spent earth from the filters. The process is one of burning the tarry coloring matter out of the pores of the clay at a temperature sufficient to accomplish this result but not high enough to disintegrate the clay. Pyrometers are essential to maintain the correct temperatures. Average temperatures from 600° to 750° F. are found satisfactory. The allowable maximum is about
Arrangement of small filter house.
950° F. Above 950°, the clay becomes vitrified and its decolorizing power is decreased. G. G. Brockway states that an overburn of 300° F. will reduce filtering capacity 30 per cent.

![Modern filter plant.](fig. 130)

The two general types of apparatus now in use for regenerating the clay are the vertical gravity oven and the rotary kiln. The Brockway New Century (U. S. patent 978625) and the Kuebler (U. S. patent 919598), shown in Figs. 131 and 132, are types representative of the vertical gravity oven. The advantages claimed for this type of oven are small floor space, a minimum number of moving parts, low first cost and small maintenance expense. The fuel consumption in the New Century dryer is said to be from 6 to 10 gallons of fuel oil per ton of clay. The capacity of the New Century furnace illustrated is 24 tons of clay per 24 hours. That of the Kuebler is 10 tons per 24 hours. These capacities are for clay previously used in the filters. When drying green clay, somewhat greater throughputs may be expected.

The rotary kiln is preferred by some refiners. Fig. 133 shows a kiln manufactured by the Bonnot Company. A steel shell lined with refractory material is mounted on rollers and revolved by a train of gears. The kiln is inclined, the clay entering at the rear or high end and discharging from the cylinder through the bottom of the movable housing, placed at the low or front end.
Burners are introduced through the housing, the products of combustion leaving the kiln through the rear stationary housing and stack.

Fig. 131
New Century dryer.

After leaving the kiln, the clay must be cooled to approximately 130° to 150° F. for safe and convenient handling. A rotary cooler is placed beneath the kiln with draft supplied by a separate stack. The general arrangement is shown in Fig. 134
Fig. 132

Kuebler clay burner.
FILTERING

The standard sizes manufactured by this company are as follows:

<table>
<thead>
<tr>
<th>Diameter, Ft.</th>
<th>Length, Ft.</th>
<th>Capacity, Tons per Hr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>40</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>40</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>40</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>60</td>
<td>4</td>
</tr>
</tbody>
</table>

Few refiners operate kilns of this type at such high capacities. Present practice is usually limited to about 25 per cent. of the above ratings when burning clay from the filters and 40 per cent. when dehydrating green earth, although rates of 40 per cent. and 60 per cent. are occasionally reported.

The fuel consumption of rotary kilns is from 10 to 12 gallons of fuel oil (38° B.) per ton of clay burned. As in the case of the vertical gravity furnaces, gas or oil fuel is best adapted to this service. Mechanical or air atomizing oil burners are recommended. Little success is reported with steam atomizing burners.

The clay burning capacity required for filter plants depends upon several factors. In general, one ton per hour per 300 tons of clay charging capacity will suffice. This figure will allow sufficient excess capacity for the dehydration of the green clay. It applies only to plants operating on an average line of products resulting from the natural yields of the crude, such as neutrals, red oils and a moderate proportion of cylinder stocks, and when using filters of from 25 to 30 tons' capacity. When filtering a larger proportion of cylinder stocks or oils of similar character,
or where the yields per ton of clay are below average, or the filters are small, resulting in short cycles, the clay burning capacity should be increased to one ton per hour per 200 tons of filter charging capacity.

As previously stated, the clay will increase in weight with successive burnings. Reports on 30–60 mesh clay are as follows:

- **Table 48. Effect on Weight of Burning 30–60 Clay**

<table>
<thead>
<tr>
<th>Clay Type</th>
<th>Lbs. per Cu. Ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green clay</td>
<td>35</td>
</tr>
<tr>
<td>Fresh dehydrated clay</td>
<td>33</td>
</tr>
<tr>
<td>No. 1 clay</td>
<td>35</td>
</tr>
<tr>
<td>No. 2 clay</td>
<td>36</td>
</tr>
<tr>
<td>No. 3 clay</td>
<td>33</td>
</tr>
<tr>
<td>No. 4 clay</td>
<td>39</td>
</tr>
<tr>
<td>No. 5 clay</td>
<td>40</td>
</tr>
<tr>
<td>No. 6 clay</td>
<td>40</td>
</tr>
</tbody>
</table>

After the fifth or sixth burning, no further increase in weight becomes apparent.

It is the custom of some refiners to use clay over and over, successively, adding make-ups of fresh clay to each charge. The larger filter plants, however, with many filters in operation on various stocks, segregate the clays in separate bins according to the number of times they have been burned. The clay is usually discarded after seven or eight burnings.

If it is desired to segregate the clay, two bins should be provided for each grade, one for the dry burned clay ready for the filters, the other for the wet clay from the filters. In addition, one or more bins each for the fresh clay and the green clay should be provided. It is poor economy to reduce the number of bins and rely on feeding a filter from a kiln or vice versa. The slow burning rate will result in excessive idle filter time, with consequent extensive outlay for additional equipment. Assuming that the clay is discarded after seven burnings, a minimum of 16 bins is required. If they are of a uniform size, one additional bin each for green and fresh clay is advisable to furnish extra storage capacity for these grades, making a total of 18 bins. The individual bin capacity should be slightly in excess of the charging capacity of one filter. If large extensions are
probable, a capacity for each bin, slightly greater than the combined charging capacities of two filters, is good policy. If first cost is of vital importance, however, future filter installations may be provided for by the construction of additional bins as required.

A rule for bin capacities which has been used with success is as follows:

New clay, one large bin.
New burned clay, two bins.
Unburned clay from filters, two bins for each retort.
Burned clay, ready for filters, two bins for each retort.
Spent clay, one bin.

For example, a plant with two retorts should have a large new clay storage bin and eleven smaller bins. In order to avoid delays, this arrangement will require closer attention from the plant operator than that previously described.

(Courtesy Hammond Iron Works.)

Fig. 135
Filters being erected.

Clay bins have been successfully constructed of both steel and reinforced concrete. The design follows conventional practice. The weights of the clay are given above. The angle of
repose for burned clay may be taken at 35 degrees. The minimum inclination for chutes and spouts should be 40 degrees from the horizontal. An inclination of 45 degrees is preferable.

As previously mentioned, presupposing a reasonable first cost, the conveying system should be designed to transfer clay to and from the filters in the least possible time. The rate of transfer from kilns to storage is closely established. In the selection of conveying and elevating apparatus, a few practical considerations, the outgrowth of experience, are of interest. Since filter clay is abrasive, elevator buckets mounted on chains moving over sprockets are not satisfactory. Buckets riveted to 6-ply stitched and oiled canvas belting running over pulleys give good results. Troughed conveyor belts are recommended, although some refiners prefer the flat type. Higher capacities for a given investment are possible with the former. Stitched and oiled 4-ply canvas belts are well adapted for the conveyor use.
CHAPTER XIV

COLD SETTLING

Object of process—Application—Types of settling apparatus—Details of process—Cooling required—Capacities—Typical results—The centrifugal process.

Residual cylinder stocks contain a considerable quantity of wax which has not been removed with the wax distillate cut. Since the residual stock has been run with every effort to avoid cracking, the wax is in an amorphous state. The cold test of such residual stocks varies from 20° F. or less up to 50° or 60° F. After decolorization by filtration or other means, the cold test often rises to 80° or 100° F. on account of the removal of the asphaltic bodies which reduce the congealing tendencies of the amorphous wax.

The viscous cylinder stocks may be compounded with neutral and other mineral oils into many grades of lubricants, such as automobile oils. It is necessary to remove the asphaltic bodies, however, and the resulting high cold test is objectionable. In order to produce these "bright stocks" with satisfactory cold tests, the process known as cold settling is adopted.

In the early days of refining, the storage of paraffine base crude oils during cold winter weather often resulted in a separation of the amorphous wax. Upon the distillation of the crude oil from which the wax had settled, the resulting cylinder stocks were found to have an improved cold test and a consequent higher value. This fact led to experiments in producing similar results artificially. The modern process of cold settling is the outcome.

Two types of settling apparatus, the box type and the tank settler, are now in use. The box type is the older systm. In this apparatus, the cylinder stock, in solution as later discussed, is placed in rectangular tanks, in rooms provided with refrigerating coils. The temperature is maintained at 0° F. This
system apparently attempts to reproduce the conditions whereby the oils were naturally settled during winter storage. It requires expensive building construction and excess refrigerating capacity, and is slow of operation.

These objections have led to the tank type of apparatus which is in general use today. A standard vertical cylindrical tank is used. The depth of the tank is from 80 to 85 per cent. of the diameter, and the capacity from 10,000 to 80,000 gallons. Coils for circulating the cooling medium are provided in horizontal layers at the top. Suitable insulation protected by brick or tile jackets is essential. Efficient sampling devices at close intervals from the bottom of the tank half way to the top are necessary to enable the operator to differentiate between the settled stocks and the petrolatum (the amorphous wax) and to arrange his draw-offs accordingly. The outlets for bright stock should be so arranged that the contents of the tank may be drawn from the different strata. A tank charging 500 barrels is shown in Fig. 136. In place of various outlet pipes, some refiners use an adjustable suction pipe inside of the tank provided with a level indicator on the outside. This suction pipe carries a spider which draws the oil from several points. Close separation and a minimum disturbance of the contents are provided by this arrangement.

The coils are placed as near the roof as possible. Brine is used for chilling. The brine temperature is usually from 10° to 20° F. Coils of relatively small diameter, from 1½ inch to 2 inches, are better than an equal amount of surface with larger pipe. Twenty-five square feet of surface per one thousand gallons of charging capacity is satisfactory. The coils may be supported on structural framing within the tank, or suspended from the roof. Since columns and struts in the body of the tank are liable to disturb the quiet, uniform action desired, roof suspension for the coils or I-beam supports of clear span are preferred.

Theoretically, the refrigeration required per 1,000 gallons of stock and naphtha is approximately 1.1 tons for the complete
cycle. The refrigeration will vary with different proportions of naphtha and stock and with the yield of petrolatum. The latter will depend upon the desired cold test of the stock. From

1.8 to 2.0 tons of refrigeration per 1,000 gallons will cover such variations as well as the heat losses, if satisfactory insulation is applied. Ordinarily, for multiple unit plants, a refrigerating capacity of three quarters of a ton per day per 1,000 gallons of total charging capacity (cylinder stock and naphtha) will suffice.
COLD SETTLING

The operation is usually conducted as follows. Best results are obtained if the stock and naphtha are charged into the tanks at a temperature of from 90° to 100° F. This temperature may be obtained by a steam heated double pipe or shell and tube interchanger on the charging line. After charging, the settling tank is gradually cooled down, the petrolatum settling and accumulating at the bottom. At the start, water may be used in the coils. Where a battery of several settlers is in use, further economy of refrigeration is sometimes gained by pumping the cold settled oil from a tank being emptied through an auxiliary set of coils in a tank being cooled down.

When the oil is cooled to 8° or 10° F., the refrigeration is stopped and the mass is allowed to settle for 24 hours. The stock is then pumped off through the upper suction lines or the movable suction pipe which is adjusted above the petrolatum level as determined by the sample cocks. At this point some refiners remove a second portion of stock lying between that ad-

![Image](image-url)

**FIG. 137**

Cold settling tanks of Tiona Refining Company at Clarendon, Pa.

judged as standard and the petrolatum. This stock is termed "half-settled," and is introduced into the settling apparatus with the next batch. After drawing off the stock the bottoms are pumped off as petrolatum. The naphtha in each fraction is removed by steam distillation in the usual way, the bottoms
from the stills being the "bright cylinder stocks" and petrola-
tum. The bright stocks are then ready for compounding into
various cylinder and motor oils. The petrolatum, after decolori-
zation and treatment, is the basis of the various petroleum jellies
and ointments.

The time for a cycle of a cold settling tank is from 4 to 6
days. Since a high cold test will not require so much time as a
lower test, the desired cold test of the bright stock will influence
the time. For a given unsettled stock, the lower the cold test
desired, the greater will be the yield of petrolatum.

For cylinder stocks made from Pennsylvania crude oil typical
results from the cold settling process are as follows:

<table>
<thead>
<tr>
<th>Table 49. Tests and Yields. Cold Settling</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
</tr>
<tr>
<td>Cold test of charge, °F. ................. 80</td>
</tr>
<tr>
<td>Yield of bright stock, per cent. .......... 85</td>
</tr>
<tr>
<td>Cold test of bright stock, °F. ........... 50</td>
</tr>
<tr>
<td>Yield of petrolatum, per cent. ........... 15</td>
</tr>
<tr>
<td>Melting point of petrolatum, °F. ......... 115-117</td>
</tr>
</tbody>
</table>

The operation of cold settling as above described is not as
simple as the description indicates. Since the gravity of the
mixture of bright stock and naphtha is very nearly the same
as that of the mixture of petrolatum and naphtha, any disturb-
ance to the mass during settling is liable to throw the batch
"off." As it is necessary to start the settling at the relatively
high temperatures, before mentioned, of 90° to 100° F., it is
obvious that considerable trouble may result if the mixture is
disturbed and then has to be reprocessed.

Recent adaptations of the centrifuge to the manufacture of
bright stocks have attracted considerable attention. The ad-
vantages claimed for the centrifuge method are continuous op-
eration, lower cold test for the bright stock, better yield of
bright stock and a higher quality of petrolatum.

Fig. 138 shows the Sharples process. The mixture of 60
per cent. naphtha and 40 per cent. cylinder stock is heated, as
in settlers of the tank type, to 100° F., and is then cooled in the
chilling tanks to minus 10° F., over a period of 48 hours. From
Diagram of Sharples process for the manufacture of bright stocks.
the chilling tanks, the stock passes to the primary centrifuges. In order to effect the continuous discharge of the wax (petrolatum) from the centrifuge, a carrier liquid heavier than either stock or petrolatum is necessary, which will form a layer on the periphery of the rotor. Brine or water is used for this purpose.

Fig. 139

Installation of Sharples centrifuges.

The wax free oil, and a mixture of petrolatum and brine or water, are then discharged continuously from two distinct outlets. After passing through heat exchangers to conserve refrigeration the cold wax free cylinder stock is carried to storage and the naphtha is subsequently removed by distillation as in the tank type settlers. The petrolatum and brine are heated by steam, the wax rising to the surface and flowing to storage. This wax, however, must be further dehydrated and this is done in a second-
ary centrifuge at a temperature of 150° F. After the second centrifuging, the mixture is reduced to reclaim the naphtha, the residual being commercial petrolatum.

The commercial units manufactured by the Sharples Specialty Company will process 55 barrels of combined naphtha and

FIG. 140

De Laval centrifuge for manufacture of bright stock.

stock per day. From green stocks adapted to the previously described methods of settling, yields of from 85 to 95 per cent. of bright stock are reported with a pour test of from 15° to 30° F. The Sharples units operate at 17,000 r.p.m., requiring a power input of 1 K.W. per hour each. Four tons of refrigeration-
tion per 24 hours are necessary for each unit. Fig. 139 shows a commercial installation of this process.

The De Laval Separator Company's apparatus is shown in Fig. 140. It differs from the Sharples system principally in the elimination of the carrier liquid. The bright stock and petrolatum are therefore ready for steam distillation as received from the separators, without further centrifuging.
CHAPTER XV

COMPOUNDING


Compounding is the term usually applied to the process of mixing together two or more petroleum stocks in the manufacture of lubricants. Animal or vegetable oils are also frequently added. The mixing of naphthas, burning oils and fuel oils to meet various specifications is termed blending. Blending is a simple operation requiring no elaborate equipment, and is often accomplished on a small scale in the shipping or barreling tanks.

Lubricants, however, demand more attention. They are compounded to meet specifications for gravity, viscosity, cold test and color, and for special uses. The various formulas for lubricants are innumerable and beyond the scope of this volume.

In order to meet gravity specifications, oils may be mixed in direct proportion by weight. Flash and fire tests will remain nearer that of the portion having the lowest tests. High cold and pour tests may be reduced by mixing with oils of lower test, but not, by any means, in direct proportion. No rules of general application have been evolved on this subject. The nature of the stocks obtained from different crudes has considerable influence upon results.

Compounding is practiced principally in order to meet viscosity specifications. The viscosity of a mixture cannot be calculated by the law of direct proportions. It is lower than that shown by proportional calculations. For instance, it might be assumed that the viscosity of a mixture of 50 per cent. of 100 viscosity oil and 50 per cent. of 200 viscosity oil would be 150. The actual viscosity will be about 137. Considerable study has been spent on this subject and formulas and charts are available from which the percentages of oils of various viscosities
required to produce a mixture meeting the viscosity specifications may be determined.¹

Various oils other than mineral oils are used to meet certain conditions. Cylinder oil, for instance, compounded with from 5 to 7 per cent. of tallow, adheres more closely to the metal surfaces and produces a greater lubricating effect than the mineral oil alone. Other animal oils, such as neats-foot, lard, sperm and fish oils are sometimes used. Linseed, rape, cotton seed, and castor oil are the vegetable oils commonly used in compounding.

![Diagram](image)

**FIG. 141**

Steam bottom compound tank.

Since vegetable oils decompose at comparatively low temperatures, they have but limited application. Their viscosities may be increased by air blowing. In handling vegetable oils, measures should be taken to prevent spontaneous combustion.

The plant required for compounding oils consists of tanks for the process, steam for heating, air for agitation, and the necessary transfer pumps and pipe lines. The size of batches

¹ For a thorough résumé of the work of various investigators, see Hamor and Padgett, “The Examination of Petroleum,” pp. 354–373.
varies widely, depending upon the refinery capacity and the quantity of the various stocks produced. Compounding tanks from 100 to 1,000 barrels are in use. They are of two general types, the steam bottom type, shown in Fig. 141, and those with heater coils. Heater coils should be so designed that no steam can escape into the batch of oil. Various methods directed at

Fig. 142

Section of compound and barrel house.

the elimination of couplings or fittings inside of the tank have been used to attain this result. Welded spiral coils and box coils with each run passing through stuffing boxes on the shell of the tank and with return bends outside have been used.

A small compounding plant is shown in Fig. 142. In this case, the barrels are filled directly from the compounding tanks. This practice is quite common.

Greases are compounds of mineral oil stocks and animal fats, with soap. Compounding of this nature is done on a relatively small scale. Comparatively high temperatures are employed and mechanical stirring is usually adopted. A standard grease kettle is shown in Fig. 143.

After compounding, the various products are ready for shipment. Barrelling may be accomplished directly from the compounding tanks or the oils may be transferred to barrelling tanks.

Barrels as received from the barrel factory need no further attention than painting and stenciling. Oil barrels are used many times, however, and the returned "seconds" require careful preparation prior to refilling.
The barrels are first steamed, bung down, over drains. They are then partially filled with a weak caustic solution and rotated. The rotating is sometimes done by machine. See Fig. 144. The barrels should be allowed to drain for twenty minutes, and are then thoroughly dried by a hot air blast.

(Courtesy M. W. Kellogg Co.)

Fig. 143

Steam jacketed grease kettle

The usual heater consists of a series of steam pipes in a closed chamber, through which the air is drawn by a fan. The advisable air temperature is from 200° to 250° F. Less air is required at the higher temperature. Reports on the quantity of air used vary from 5 to 32 cubic feet per minute per barrel. Two air changes per barrel per minute or about 13 cubic feet
of fan capacity per barrel per minute is recommended. From 4 to 6 ounces of air pressure at the fan are customary.

Fig. 144

After the hot blast, the seconds are ready for coopering. The irregularity of this work makes it largely a matter of manual labor. Minor repairs are made, such as plugging, caulking and occasionally replacing a stave. From 16 to 20 barrels can usually be recoopered by one man in an eight hour day. Sufficient space should be reserved for this work to handle 25 per cent. of the seconds. Hoop driving capacity must be provided for the total number of barrels required. The machine used for this work, described in Chapter XIX will set up the hoops on from 65 to 70 barrels per hour.

The barrels are then ready for the gluing and draining operations. The glue coat is usually quickly set by means of a cold air blast. To conserve space, the barrels may be stacked two high as shown in Fig. 218, care being taken to preserve aisle space for handling. From four to eight hours are required for setting the glue, depending upon atmospheric condi-
tions. The air and fan requirements are about the same as those for the hot blast. A typical arrangement for preparing 1,000 barrels per day is shown in Fig. 145.

![Diagram of barrel preparation plant](image)

**SECTION A-A.**

**Fig. 145**

Plant for preparation of wood barrels.

The barrels are now ready for painting. If the number of barrels is large, the circumferential surface may well be painted by machine. The barrels are placed between two platens and the mechanism is lowered so that the shells dip into a bath of paint. They are then revolved rapidly against the brushes, raised from the paint bath, and are conveyed to a point where the heads are painted by hand.

Filling may best be accomplished by gravity through automatic fillers of the type shown in Fig. 146. The filler shuts off
the oil when the barrel is filled. The arrangement of the filling floor will vary according to the requirements. Fig. 147 is a typical arrangement. The number of separate brands to be barrelled is a large factor. Lubricants are often barrelled from the compounding tanks, as shown in Fig. 142. The various brands are numerous and the quantity of each is usually small. The most economical layout provides for filling the barrels in rows; placing, filling and rolling them to cars or storage in successive steps. The principal consideration is to avoid any crossing or backward movement of the barrels.

The storage space reserved for full barrels is influenced by numerous factors, such as the number and volume of orders and the available shipping facilities. Requirements for different plants are widely variant. A minimum covered storage space sufficient for two days' output of filled barrels is recommended. This storage capacity will allow uninterrupted operation if shipments are held up for a day.

Can filling is usually accomplished in the department devoted to the manufacture of cases and cans. If cans and boxes are purchased, the filling may be advantageously done adjacent to the space reserved for barrel filling. Can filling may be accomplished automatically by the machine shown in Fig. 148. This machine fills 12 five gallon cans simultaneously and has a possible output of 600 cans per hour. Three men and a boy are required to operate the apparatus. After filling, the cans are packed two in a case and the loaded cases are removed by means of conveyors or hand trucks, depending upon the volume of production.

Filling stations are usually one story in height. Fireproof construction is preferable. Since there is a fire risk in the in-
terior as well as from the exterior of a filling station, exposed steel work is a source of danger. Wood block floors are recom-
mended. Under the rolling action of heavy barrels concrete floors

are subject to excessive wear and chipping. Moreover, the roughness of a concrete surface is liable to mar the appearance of the painted barrels. Floor loads are moderate. For a single tier of filled barrels, one high, 125 pounds per square foot should be allowed when they are placed on end, and 100 pounds per square foot when they are placed on the bilge. In filling station

Fig. 147

Barrel-filling house, Union Petroleum Co. at Marcus Hook, Pa.
work, barrels are rarely piled. This practice is more liable to be encountered in warehouses and will be discussed hereafter. When placed on the bilge, 900 square feet should be provided per hundred barrels. When placed on the end, 800 square feet will suffice. In both cases, the above figures allow for the necessary aisle space.

Warehouses for the storage of full barrels require consideration. The following remarks are applicable whether the warehouse is located at the refinery or at a distant point. Economical arrangements for handling the barrels are of primary importance. Several different brands will usually be stored, which, for convenience in inventorying and shipping, should be segregated. Barrels may be tiered two high on the bilge or on end but the labor cost is high. Modern warehouses employ barrel racks, three or four barrels high, as shown in Fig. 149, and use machines for raising and turning the barrels. The Revolvator, shown in Fig. 150, is an apparatus for doing this work.

For a warehouse with racks, 16 foot bays are recommended. The windows should be arranged to light the aisles between the racks. Multi-story warehouses are satisfactory when provided
Any combination of width, length and height may be made

Barrel racks 3½-9.00 in
Channels
Barrel stop

Fig. 149

Barrel racks.
with an efficient barrel elevator system. Where land values are not excessively high, however, one story construction is considered more economical.

**Fig. 150**

Machine for raising, lowering and stacking oil barrels.

**Table 50. Floor Loads and Space Allowances for Warehouses.**

<table>
<thead>
<tr>
<th>Tiers</th>
<th>Bilge or End Arrangement</th>
<th>Floor Load, Lbs. per Sq. Ft.</th>
<th>Space Required, Including Aisles, Sq. Ft. per 100 Bbls.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without racks</td>
<td>2</td>
<td>bilge</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>end</td>
<td>250</td>
</tr>
<tr>
<td>With racks</td>
<td>3</td>
<td>—</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>—</td>
<td>350</td>
</tr>
</tbody>
</table>
Barrels awaiting shipment, Vacuum Oil Company, Bayonne, N. J.

Minimum carload requirements for filled oil barrels are about as follows:

**TABLE 51**

<table>
<thead>
<tr>
<th>Length of Car</th>
<th>Loading Weight</th>
<th>Number of:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Wood Barrels</td>
</tr>
<tr>
<td>Under 36 ft. 6 in.</td>
<td>26,000</td>
<td>59</td>
</tr>
<tr>
<td>36 ft. 6 in. to 37 ft. 6 in.</td>
<td>26,780</td>
<td>61</td>
</tr>
<tr>
<td>37 ft. 6 in. to 38 ft. 6 in.</td>
<td>27,560</td>
<td>62</td>
</tr>
<tr>
<td>38 ft. 6 in. to 39 ft. 6 in.</td>
<td>28,340</td>
<td>64</td>
</tr>
<tr>
<td>39 ft. 6 in. to 40 ft. 6 in.</td>
<td>29,120</td>
<td>66</td>
</tr>
<tr>
<td>40 ft. 6 in. to 41 ft. 6 in.</td>
<td>30,420</td>
<td>69</td>
</tr>
<tr>
<td>41 ft. 6 in. to 42 ft. 6 in.</td>
<td>31,720</td>
<td>72</td>
</tr>
<tr>
<td>42 ft. 6 in. to 46 ft. 6 in.</td>
<td>36,920</td>
<td>83</td>
</tr>
<tr>
<td>46 ft. 6 in. to 50 ft. 6 in.</td>
<td>42,120</td>
<td>95</td>
</tr>
<tr>
<td>50 ft. 6 in.</td>
<td>52,000</td>
<td>117</td>
</tr>
</tbody>
</table>