## VALVES - TYPES, SERVICE AND USE

<table>
<thead>
<tr>
<th>Service Pressure</th>
<th>Description and Uses</th>
<th>Sizes</th>
</tr>
</thead>
<tbody>
<tr>
<td>125#</td>
<td>Nordstrom Cocks, flanged. Used on gas, oil and lye lines at low temperatures.</td>
<td>2&quot; to 10&quot;</td>
</tr>
<tr>
<td>125#</td>
<td>Nordstrom Cocks, threaded. Used on gas, oil and lye lines at low temperatures.</td>
<td>1/2&quot; to 2&quot;</td>
</tr>
<tr>
<td>950#</td>
<td>Nordstrom Cocks, flanged. Used on oil and gas lines at medium temperatures.</td>
<td>2&quot; to 8&quot;</td>
</tr>
<tr>
<td></td>
<td>Safety Valves, Malleable steel and brass. Used as a safety measure on pumps and sealed vessels.</td>
<td>1/2&quot; to 4&quot;</td>
</tr>
<tr>
<td></td>
<td>Check Valves, Brass, steel and cast iron. Used on steaming out lines, injection and gland sealing lines. Its duty is to prevent any fluid leaking back due to back pressure should the pump or steam line fail.</td>
<td>1/2&quot; to 8&quot;</td>
</tr>
</tbody>
</table>
The importance of cleanliness in all piping work must be emphasized. A large amount of pipe is laid in ditches where clay, gravel, etc. is bound to get into threads and on the face of flanges. Tight pipe joints cannot be obtained unless threads are properly cleaned and the face of the flanges scraped and wiped thoroughly clean before the joints are made. Threads, couplings, flanges, gaskets and even bolts should be cleaned before assembling.

Adequate support of all piping is also essential; otherwise threaded joints will be "sprung", resulting in damaged threads and fittings and subsequent leakage at the joints.

Manifolds: Construction and Application

Manifolds are arrangements of piping, fittings, and valves to allow the transfer of liquids and gases to and from various locations by the use of only one pump. Their purpose is to centralize and save valves and fittings, conserve space and simplify pumpings.

Manifolds are usually constructed of flanged or welded fittings, the latter being much cheaper and greater insurance against leaks. The welded construction saves bolts, flanges and gaskets. The manifolds used are known as Bayway Manifolds (vertical or horizontal) and any number of lines can be connected to one manifold, but only two at one time can be used; one as a suction line and one as a discharge line. There are two headers on every manifold; one discharge and one suction. The discharge of the pump is connected to the top or side of the discharge header. The suction header is connected to the suction of the pump. The diagrams on this page illustrate two types of Bayway manifolds.
Gaskets

A gasket is material which is inserted between metal faces to insure tight joints and thus prevent leakage between the metal faces. A full gasket is one which completely covers the face of the flange. Holes are made in the gasket to match the bolt holes in the flange. A ring gasket is one which fits inside the bolt circle and covers that part of the flange face which is between the bolt holes and the pipe. Ring gaskets are also used in tongue and groove joints, in which case they fit the groove.

Gaskets are made of various materials, such as paper, asbestos sheet, fibre board, aluminum, rubber and steel. In some cases gaskets of a soft material, such as asbestos sheet, are encased in metal. These gaskets are used from 500°F. to 650°F. at pressures up to 300 pounds per square inch and from 650°F. to 850°F. at pressures up to 150 pounds per square inch. A very tough sheet asbestos fibre board gasket material, known as "Durabla" is most commonly used throughout the refinery. It can be used as gasket material on all oil, steam and gas lines up to temperatures of 650°F. and pressures of 150 pounds per square inch. Steel ring gaskets are used on all 600, 900 and 1500 pounds per square inch fittings and for fairly high temperature service. Ordinary rubber is used in some cases for sulphuric acid and is, of course, very satisfactory for water line flange gaskets, but cannot be used on any oil line. Some of the synthetic rubbers are less affected by oil than natural rubber and will, in the future, no doubt be used for special purposes in oil refining work. Heavy paper gaskets are quite serviceable on very low pressure and temperature work.

Bolts

Standard bolts with square heads are used for bolting up most pipe work. A hexagon nut is used with this bolt to permit easier positioning of wrenches while tightening up the joints.

Stud bolts, fitted with hexagon nuts on both ends, are used extensively for all high pressure work. This follows from the fact that stud bolts and nuts are made of a special high tensile strength steel, which will resist more strain than will ordinary bolts.

Steel washers are used to provide a flat turning base for nuts when necessary.

The proper choice of a bolt, with the correct length for a particular job, is important. Bolts should be long enough to allow the nut to be screwed on completely, yet should not extend too far through the nut. Long bolt ends sticking through the nuts not only give the joint a poor appearance, but also give rise to difficulties when the bolt has to be removed, because the exposed threads often become clogged with rust or dry paint.

Tools

Various tools are used in pipe fitting, but in general only a small assortment is required. Most of these are illustrated on page 12. The most common tools are Trimo or Stillson pipe wrenches for the smaller sizes of pipe, and Key tongs or Chain tongs for the larger sizes. The Trimo and Stillson wrenches are adjustable for certain sizes of pipe and have hardened steel corrugated jaw pieces. These wrenches are built so that the corrugated jaw pieces grip the pipe as pressure is applied to the handle. Key tongs have two solid jaws, which are made to fit a particular size of pipe. They are not adjustable.
TOOLS

PIPE WRENCH

MONKEY WRENCH

SPANNER

BOX WRENCH

KEY TONGS
Hardened steel keys are inserted in the jaws of these tongs, and the powerful leverage which can be exerted by closing the handles and pulling, causes these keys to grip the pipe and turn it as motion is applied. Chain tongs have a single hardened steel corrugated jaw piece. The chain which is attached to the handle of the wrench on one side of the jaw piece must be taken around the pipe, pulled up tight and hooked into a forked holder shaped especially for the chain links. As the turning motion is applied to the handle, the chain tightens causing the corrugated jaw to firmly grip the pipe.

The smaller tools consist of spanners, monkey wrenches, box wrenches, scrapers, etc. The spanners are made of hardened steel with straight or offset handles. This type of wrench has a jaw opening to fit the size of nut for which it was made and is not adjustable. Scrapers are very necessary for cleaning faces of flanges. A wire brush is used to clean threads. Monkey wrenches have adjustable square jaws.

Each tool is designed for a certain specific purpose. In this regard a few general rules apply. Use the proper sized tool for the job. Do not use a Stillson or Trimo wrench on nuts, for the corners of the nuts will become rounded, rendering the nut useless. Spanners or monkey wrenches are to be used for this purpose. Do not use hammers on the adjustable jaw type wrenches to help loosen nuts. All tools should be kept in proper condition.

**PUMPS**

Most of the materials processed in a petroleum refinery are liquids. Consequently, a large number of many different types of pumps are used in the refinery to move these liquids from one piece of processing equipment to another.

A pumping unit may be divided into two mechanical parts; the power end and the pump end. The power end supplies the motivating power to the pump, and the pump end transmits this energy to the liquid being pumped.

The Power Ends of Pump Units

The driving power may be supplied to pumps from many different sources. Steam engines, steam turbines, internal combustion engines and electric motors are the ones most commonly used in the refinery.

Steam Engines

A steam engine is one in which steam at high pressure and high heat content is admitted into a cylinder, where the steam expands, pushing back the piston against the atmospheric pressure and work load, and is then allowed to escape at lower pressure and heat content. The energy lost by the steam is given up to the piston, which in turn uses this energy to do useful work.

In a simple steam engine this expansion of the steam takes place in one cylinder, or in several cylinders in parallel, and the expanded steam is allowed to escape to the atmosphere; whereas in a compound steam engine there are two or more cylinders in series and the exhaust steam from the first cylinder further expands in the second cylinder, thereby giving up more of its energy. Only after the steam has left the last cylinder in the series is it allowed to escape to the atmosphere.

Practically all modern steam engines are double acting; that is, the steam is admitted and exhausted alternately from each end of the cylinder and drives the piston on both forward and backward strokes.
The energy imparted to the piston of a steam engine may be used to set up a rotary motion in a flywheel by means of a crankshaft; or the simple reciprocating motion of the piston may be transmitted directly to the piston of a pump or compressor.

The admission of steam to the cylinder and the escape of the exhaust from it is controlled by a valve mechanism operated by a connecting rod from a crosshead, eccentric or crank-pin of the engine. Various steam control valves are used such as D Slide Valve, Balanced Slide Valve, Piston Valve and the Corliss Engine Valve.

The D slide valve is illustrated below. In the first three types of steam control valves, one valve piece controls both admission and exhaust; in the Corliss engine separate skeleton cylindrical valves control admission and exhaust. The speed of the engines using the first three kinds of valves is controlled by throttling the steam being admitted to the steam chest; in the Corliss engine the speed is controlled by direct action of the governor on the valve gear mechanism.

![Diagram of steam engine cylinder and D-slide valve]

**Steam Engine Cylinder and D-Slide Valve**

**Steam Turbines**

The steam turbine is another mechanical device for converting the energy of steam into rotary mechanical motion. In the most common type, steam issues at high velocity from a nozzle which directs the steam jet against a series of blades mounted radially on a disc or rotor, which is in turn attached to a shaft.

The impulse of the steam and the kinetic energy of the expanding steam is imparted to the blades, thereby making the rotor capable of doing useful mechanical work. The number of nozzles used and the size of the unit is dependent on the power required. The speed at which the rotor revolves is controlled by a governor, which regulates the amount of steam entering the nozzle or nozzles.
Turbines are used extensively as standby sources of power to replace electric motors should they become inoperative due to failure of the electric power supply. This is especially important as a safety measure in cases where the pump run by an electric motor is absolutely necessary for safe operation of refinery processing units. If a turbine is used as a standby, its steam shutoff valve is controlled by an electrical device known as a solenoid. While current is supplied to the electric motor, this current passes through the solenoid, keeping the steam valve closed, but if the power fails the solenoid becomes inactive and the steam valve opens automatically, starting the turbine which continues to drive the pump.

STEAM TURBINE

Electric Motors

Electric motors are generally used to operate rotary pumps. This source of power is cheaper than steam power, despite the fact that a steam turbine is required as a standby in case of electric power failure.

Internal Combustion Engines

The internal combustion engine or gas engine is used chiefly in the refinery as a source of power to drive reciprocating pumps operating at high pressures, where the size of electric motor and turbine standby would be too cumbersome. The modern trend is, however, towards the use of motor drives and steam turbines in such services. Gas engines drive the pumps which force the feed stock through the cracking coils at #2 plant.

The Pump Ends of Pump Units

Reciprocating Pumps

The reciprocating pump is the oldest and probably best known form of pump. In it the delivery of liquid is effected by the displacement of a piston or plunger moving in a forward and backward reciprocating motion.
The flow of liquid is intermittent, due to reversal in the movement of the piston. Diagram below illustrates one type of reciprocating pump. Reciprocating pumps are roughly classified by the number of liquid cylinders on a single drive mechanism, the action of the liquid cylinder, the type of valves used in the pump, and by the motivating power used to drive the pump.

**HORIZONTAL STEAM PISTON PUMP**

A "Simplex" pump is one having only one cylinder for each single drive mechanism. A "duplex" pump has two cylinders and a "triplex" pump has three cylinders, all on a single drive mechanism. In the duplex pump the pistons or plungers are controlled by the valve mechanism, so that they are always travelling in the opposite direction, hence tending to make the flow of fluid more uniform.

The liquid cylinder can be single acting, in which case the liquid is taken in and discharged from one end only; or the liquid cylinder can be double acting, in which case the liquid is taken in and discharged from both ends of the cylinder. Thus each forward and backward stroke of the piston or plunger is a delivery stroke. Double acting pumps, of course, will give more uniform delivery than that from single acting pumps.

Briefly, the operating mechanism of a reciprocating pump is as follows: The inflow and outflow of the liquid being pumped is controlled by valves, which are actuated by pressure differences created as the piston or plunger moves forward or backward. The valves controlling the inflow are called suction valves and those controlling the outflow are called discharge valves. When the piston or plunger moves from one end of the cylinder to the other, it causes a partial vacuum on one side and a positive pressure on the other side. The partial vacuum causes the suction valve to open and admit liquid, to be discharged on the back stroke. The pressure built up on the opposite side closes the suction valve at that end and, when this pressure exceeds that on the discharge valve, the discharge valve opens allowing the liquid to be pushed out through the discharge port.

The most common types of valves used in suction and discharge valve assemblies are Spring or Disc Valves, Hinge Valves, Block Valve, Pot or Wing Valves and Ball Valves.
The spring valve assembly consists of a valve seat, valve disc, valve spring and valve stem. These parts are assembled within the main pump casting on a machined surface known as the valve deck. There may be several valve assemblies on the single valve deck, depending upon the size of the valve and upon the pumping capacity of the pump.

Efficient operation of the spring valve assembly depends upon the condition of the valve seat and valve disc, the tension on the spring and the amount of lift the disc has. Lift is the distance a valve can raise from its seat due to the pump suction or pressure. The valve lift is controlled by the spring and length of valve stem. This type of valve assembly is very commonly used in pumps handling cold or moderately hot liquids with moderate viscosities at discharge pressures up to 200 pounds per square inch.

The hinge valve assembly is somewhat similar to that of the spring valve, with the exception that it operates like a hinge from the valve deck. This type of valve has not as good a seating surface as the spring valve, but the hinge arrangement restricts the opening through the valve seat less. It is most commonly used in pumps handling solid asphalt after it has been heated to a liquid state.

The block valve is usually a solid, machined, rectangular piece of metal seated on a valve deck with guides in the body of the pump to keep the valve directly over its seat. The valve's lift is governed by the clearance between the valve and the overhead casting of the pump body. It is difficult to keep the valve seats smooth if a corrosive liquid is being pumped and it is difficult to repair the seats, since they are cast as part of the main body of the pump. This type of valve is used in pumps handling hot heavy liquids.

The pot valve gets its name from the shape of the recess in the pump casting in which the valve operates, in that it resembles a pot with a bolted flange on the top. The valve seat is some distance down from the top of the pot. The valve generally has a convex surface to fit in this seat and is guided by the upper section of the pot. The valve stem is located in the centre of the upper surface of the valve. The valve lift is determined by the clearance of the stem under the flange covering the top section of the pot.

The wing valve is similar except in that its guides are on the underside of the valve. Access to these valves is easy. The seats are renewable and there is no spring to lose its tension due to heat. Both of these types of valve assemblies are used in pumps handling hot liquids at working pressures of 300 pounds per square inch.

The ball valve is a smooth metal ball moving in a cylindrical well with the valve seat at the bottom of the well. The escape ports are located in the walls of the well. The valve lift is determined by the length of this cylinder. This type of valve gives excellent service in pumps handling hot liquids against pressures in excess of 500 pounds per square inch.

Centrifugal Pumps

A centrifugal pump consists of an impeller or rotor, which is mounted on a drive shaft and which rotates in a casing provided with suction and discharge ports. The impeller is essentially a series of curved vanes spaced evenly apart and extending radially from a central hub. The casing is cast in two sections to facilitate assembly and future inspection. The shaft is usually mounted on journal or anti-friction bearings and the housing for these bearings may be cast as part of the rotor casing, or as independent stands. Stuffing boxes are used to seal
the clearance between the casing and the shaft. A centrifugal pump may be
designed to operate in either a horizontal or vertical position; that is, the
main shaft may be either parallel to the floor or perpendicular to it. An il-
lustration of one type of centrifugal pump is shown below.

![Diagram of a centrifugal pump]

**TWO-STAGE CENTRIFUGAL PUMP**

In the centrifugal pump, the rotating impeller imparts energy to
the liquid, throwing it by centrifugal force towards the casing. The cir-
cumference of the casing is a spiral shaped channel and the liquid moving
along this spiral channel acquires a velocity head from the energy imparted
to it by the impeller vanes. The head developed by the pump depends on
the radius of the impeller and on the speed at which it is rotating.

Centrifugal pumps are roughly classified by the type of impeller
used and by the number of impellers in a single pump. The impeller is de-
scribed as open impeller, closed impeller or screw impeller. The open impeller
merely consists of a group of evenly-spaced radial curved vanes, whereas the
closed impeller has side walls attached to the vanes. These side walls ex-
tend from the suction opening in the centre to the tips of the vanes. The
screw impeller resembles the propeller of a ship. The closed impeller is
the most common type used in refinery service. It gives a direct radial flow
of liquid.

Several impellers may be used in one centrifugal pump. If only one
impeller is used, the pump is termed single stage. A pump having two or
more impellers in series is called a multi-stage centrifugal pump. In such
cases the discharge from the first impeller passes into the suction of the
next impeller in series with it. Thus higher heads can be developed without
increasing the size of the impeller or the speed at which it rotates beyond
practical limits.

Centrifugal pumps find a wide range of application in refinery ser-
vice. They can be designed to pump various amounts of water and petroleum
products at widely different temperatures and pressures. Centrifugal pumps
will deliver a steady flow of liquid free from the pulsations found when reciprocating pumps are used. They have not a good suction lift, however. They must be primed on starting and during operating the pumps must have their casings filled with liquid at all times, otherwise they will cease to operate.

Rotary Positive-displacement Pumps

This type of pump operates on the same general principles as a reciprocating pump, but here the displacement of the liquid is effected by a rotary motion, rather than a reciprocating motion. The rotary gear pump falls into this class. It consists of two closely meshed gears rotating on mounted shafts in a casing. These meshing gears or rotors revolve in opposite directions, drawing the liquid up between them and discharging it on the other side. The meshing of the gears seals the pump against backflow. The diagram shown below illustrates this action.

Numerous designs are in use utilizing many different types of gears, figure-of-eight impellers and screws. This type of pump is self-priming and no pump valves are necessary. They may be designed for a wide range of capacities and pressures, but it is essential that the liquid being pumped be free from grit and abrasive material, otherwise the rotors are subject to excessive wear, which destroys the close meshing and snug fitting within the casing necessary for their operation.

Pump Starting

Steam Engines:

Before starting steam engines, which drive pumps, all drain cocks on the steam cylinder must be closed. They are normally left open when the pump is not in operation. The condensed steam which accumulates in the live steam and exhaust steam lines before the shutoff valve and exhaust valve should be drained through the drain valves provided. The same preliminary precautions should be taken before opening the main steam valve. Care must be taken that the exhaust steam valve is opened before the main steam valve.
Section 7

Reciprocating Pumps

Valves in the suction and discharge lines of the pump should be opened. Then the steam valve on the power end of the unit may be opened slowly. If the pistons do not move, it is possible that have stopped at dead centre, in which case they must be moved off centre by means of a bar so as to permit the admission of steam past the steam cylinder valve. The pump should then be brought up slowly to normal pumping speed; usually 40 to 50 cycles per minute. If the pump "pounds" excessively, this pounding may be due to several causes; the pump operating too fast, the suction lines not being large enough, insufficient suction capacity, or the piston rings or liquid cylinders not being in proper working order.

All reciprocating pumps should be provided with a relief valve large enough to take care of the full pump capacity. This valve should be installed between the pump and any block valves on the suction or discharge lines. Thus it will relieve the pressure should the discharge valve be shut accidentally while the pump is operating.

Centrifugal Pumps

Before starting the prime mover (electric motor, steam, etc.), the suction valve on the centrifugal pump should be opened and the discharge valve closed. If the pump has a suction lift, i.e., must lift liquid from a level lower than the pump, it will be necessary to fill the casing with liquid before starting the pump, and to keep it filled while starting so as to drive out any air or vapor in the casing. Pet cocks are provided on the top of the casing through which the air can escape. This process is called "priming." The pump may be primed by an auxiliary pump or syphon.

The valve in the discharge line from the centrifugal pump should not be opened until the pump is rotating at full speed. If the pump is primed and the discharge valve open, pumping would start as soon as the electric motor is turned on. This would cause too heavy a load on the motor while it is getting up to speed and would probably burn out the fuses. Consequently, the discharge valve of the primed pump is kept closed until the motor is up to speed. Under this condition, the impeller of the pump simply turns in the liquid in the pump and little work is done. Since little work is done, no overload is put on the electric motor.

The opposite procedure must be done in the case of any gear pump. If the discharge valve is closed, liquid will be pumped against the valve from the moment the pump starts, building up higher and higher pressures, until something gives under the strain. This follows because gear pumps are positive displacement pumps. They cannot rotate in the liquid, as can a centrifugal pump.

Packing

Packing is material used to prevent the escape of steam, liquid, etc., between metal surfaces.

If surfaces are bolted together to make a tight joint, a flat sheet packing is used, similar to gaskets. The packing employed would depend upon the pressure, temperature, chemical properties, etc. of the fluid coming in contact with it. The most common type of sheet packing used in oil refinery service is made from asbestos. This packing is purchased in sheet form in various thicknesses from 1/64" to 1/8". When bolting together relatively smooth sur-
faces, such as those found on the split casing of a centrifugal pump, a gasket 1/64" or 1/32" thick is used. Between roughly machined surfaces, however, a thicker gasket is preferable. It should be remembered that gaskets are usually held in place against the service pressure only by the bearing of the bolted surfaces, so that the thinner the gasket, the better the joint.

A packing with a square cross section is used to prevent leakage around moving parts, such as piston rods or valve stems, where they enter the cylinder casing on both steam and pump ends. This may be procured in coil form or ring form in various sizes to fit the stuffing boxes. Many types of packing are required for the liquid ends of pumps because of the many different fluids encountered in oil processing. The composition of each type of packing is governed by the nature of the liquid being pumped and by the range of temperatures and pressures encountered. Packing for the steam ends of pumps usually has an asbestos base.

Over a period of years, manufacturers of packing, aided by the practical knowledge of the oil industry, have developed numerous styles of packing to meet various requirements. As a guide to the general types of packing required for various services, the list shown below has been prepared. This list, however, does not confine packing to the particular brands named.

When new equipment is installed an endeavour is made to have it packed with the proper packing. However, if the process operators notice undue leaking at the glands, scoring of the rods, or overheating of the parts moving through the packing, action should be taken immediately to ascertain the cause of the trouble. Perhaps the packing installed was not suitable for that particular service. Even today there is room for improvement in packing materials to take care of the wide varieties of uses to which they are put.
## PACKINGS AND THEIR USES

<table>
<thead>
<tr>
<th>Pump Service</th>
<th>Max. Temp. of Packing Op.</th>
<th>Packing used on Reciprocating Rods or Plungers</th>
<th>Packing for Rotary Shafts</th>
<th>Packing for Pistons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acids, strong &amp; weak, or acid sludge</td>
<td>200</td>
<td>Garlock 95, 94 or 230 Kurlite. Anchor 888</td>
<td>Anchor 888 Garlock 230</td>
<td>3 rings of acid-resisting bronze</td>
</tr>
<tr>
<td>Air</td>
<td>450</td>
<td>Metallic packing with one ring of Garlock 777 at front. Anchor 317</td>
<td>Anchor 317</td>
<td>Cast iron rings.</td>
</tr>
<tr>
<td>Alkalis, caustic soda, etc.</td>
<td>450</td>
<td>Alternate rings of rubber and asbestos. Garlock 94</td>
<td>Anchor 5757 Anchor 317</td>
<td>3 cast iron rings</td>
</tr>
<tr>
<td>Ammonia</td>
<td>250</td>
<td>Anchor or Kurlite packings</td>
<td></td>
<td>Cast iron rings.</td>
</tr>
<tr>
<td>Asphalt</td>
<td></td>
<td>Multi V. Preformed or Anchor 5757</td>
<td></td>
<td>Cast iron rings.</td>
</tr>
<tr>
<td>Brine</td>
<td>110</td>
<td>Garlock 95 ring packing Anchor 380</td>
<td>Anchor 317</td>
<td>Brass rings or Anchor 334</td>
</tr>
<tr>
<td>Foam Solution</td>
<td>110</td>
<td>Anchor 380 or Garlock 777 on sodium bicarbonate end Garlock 94 (rubber centre) on aluminum sulphate end.</td>
<td>Anchor 380</td>
<td>Brass 3 rings.</td>
</tr>
<tr>
<td>Gas</td>
<td>450</td>
<td>Anchor or Kurlite</td>
<td></td>
<td>Garlock 150 Cast iron rings, with alternate rings of square flax.</td>
</tr>
<tr>
<td>Gasoline</td>
<td>250</td>
<td>Anchor 318, or Garlock 94 with 2 rings of Garlock 777 at each end with lubricating oil dropping on the stainless steel rods.</td>
<td>Anchor 318</td>
<td>Cast iron rings. Kurlite</td>
</tr>
<tr>
<td>Oils, crude, heating and fuel oils</td>
<td>250</td>
<td>Anchor 318, Garlock 233</td>
<td></td>
<td>Anchor 318 3 cast iron rings Kurlite preformed</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>Anchor 5757</td>
<td></td>
<td>Anchor 5757 Anchor Carbonite</td>
</tr>
<tr>
<td></td>
<td>800</td>
<td>Snyder #23 John Crane style 100 with alternate rings of style 300.</td>
<td></td>
<td>Duremetallic None D-110</td>
</tr>
<tr>
<td>Steam</td>
<td>550</td>
<td>Anchor 210, Garlock 150</td>
<td></td>
<td>Carbon rings Cast iron rings</td>
</tr>
<tr>
<td>Fresh and salt water</td>
<td>110</td>
<td>Garlock 777, Anchor 380</td>
<td>Anchor 318, Garlock 262</td>
<td>Kurlite</td>
</tr>
</tbody>
</table>
Maintenance

Normally a specially trained maintenance crew takes care of repair work on pumps and other equipment, but it is essential that the operator remember that the proper care of equipment when it is in his charge, whether it be in use or idle, is the best kind of maintenance. The point that preventative maintenance is far more efficient than repair maintenance cannot be stressed too much. When repair work is required on a piece of equipment, that particular piece is out of service, and if it is a vital link in the operation of a unit, it is quite possible the whole unit will have to drop out of service.

In the operation of all pumps and other equipment with moving parts, there is nothing more important than proper lubrication. Proper lubrication is the use of the right oil in proper quantities. The right oil to use for each specific service is that recommended by the maintenance engineer. He bases his recommendations on exhaustive studies made by the manufacturers of lubricating oils and greases, and if their advice is not adhered to the need for costly repairs may result.

The purpose of lubricating oil and grease is to provide a liquid film between metallic surfaces, which rub against each other. The film of oil keeps the metallic surfaces separated and reduces friction by substituting "fluid friction" for "solid friction."

The lubrication of the steam valve and cylinder in a steam engine is very important. It really has a dual purpose; that of forming a film for reducing friction and that of sealing the clearance between the piston and cylinder to prevent steam blowing by.

The lubricating oil for the steam valve and the cylinder is introduced into the steam line just before the steam enters the steam chest. The proper method of introducing the oil is shown by comparing the right and wrong methods in the diagram on page 24. The Hydrostatic Lubricator and the Mechanical Lubricator are the two main types of lubricators used for supplying oil to steam engines.

As shown on the same page, the hydrostatic lubricator is connected in two places to the vertical leg of the steam line feeding the steam engine. The lubricator is filled with oil. Steam coming through the condensing bulb is condensed into water which is conducted to the bottom of the lubricator through a tube. The oil being lighter than water floats on top. The bent tube is connected to the oil drop regulating valve, which in turn opens into the sight feed glass. This sight feed glass is then connected at its top through a valve to the lower connection on the steam line.

Steam enters the body of the lubricator from two directions when the valves in the upper and lower lines connecting the lubricator to the steam line are open. The pressures would equalize except for the fact that steam is condensed in the condensing bulb and in the pipe above. The additional hydrostatic head due to the water drives the oil through the lower connection to the steam line. The rate of flow of the oil is controlled by an oil drop regulating valve. The oil forms in large drops at the valve nozzle and the drops rise up through the water passing into the steam line.

The above principle may be applied to a battery of steam engines operating from a central lubricating system, each unit having an independent connection to the central oil supply.
LUBRICATORS

Wrong

Right

Method of Introducing Oil into a Steam Line

Hydrostatic Lubricator

Mechanical Lubricator

Oil Ring Lubrication
The mechanical force-feed lubricator provides an efficient and satisfactory method of lubrication. There are several commercial designs available. One type is illustrated.

A typical type of mechanical lubricator consists of a small reservoir for oil, fitted with a plunger pump mechanism which derives its motion from cams or levers connected by means of a ratchet and parallel rod to the cross-head or some other moving part of the pump. There may be one or more small plungers in each lubricator, each of which deliver oil by means of a small pipe or tube to any point where lubrication is desired. The quantity of oil delivered by each plunger is varied by adjusting the plunger stroke.

The speed at which the lubricator works is dependent upon the speed of the moving part of the machine which drives the plungers. This is particularly advantageous on pumps that are working under automatic control and consequently work at constantly varying rates.

Another form of lubrication is that found in the oil ring bearing. The diagram illustrates such a bearing. This type of lubrication is quite common on rotating shafts where a frictionless ball race or roller bearing is used. The bearing is usually encased in a housing, the lower section of which forms a small oil reservoir. Rings running free over the bearing have their lower portion running in the oil, and as they rotate carry the oil up to the bearing.
CRUDE PROCESSING

Crude processing is essentially one of fractional distillation, followed by chemical or physical treatment, redistillation and blending to produce marketable products. Depending on the refining equipment available, the type of crude oil, and the demands of the market, a petroleum refinery is one of the following types:

(a) Topping
(b) Topping and Cracking
(c) Topping, Cracking, Lubricating Oil and Asphalt
(d) Complete

Topping

Topping involves only the removal of white products (chiefly gasoline and kerosene) from the crude by distillation, leaving a residual product (reduced crude) usually marketed as Fuel Oil. This operation is practised at the Fort Norman refinery.

Topping and Cracking

This involves topping crude petroleum for the removal of white products, and either cracking of the reduced crude (reduced crude cracking) or further distillation of the reduced crude to yield clean distillate stocks, which are cracked (gas oil cracking). Both these operations are practised at the Calgary, Regina, Montreal and Halifax refineries.

Topping, Cracking, Lubricating Oil, Asphalt

This involves topping the crude for removal of white products, followed by vacuum or steam distillation of the reduced crude for the production of lubricating oil distillates and asphalt. This operation is generally carried out on low cold test crude petroleums (Colombian, Gulf Coast Texas, Peruvian), which produce relatively wax free lubricating oil distillates. This operation is practised at the Loco refinery.

Complete

A complete refinery involves all the above operations, as well as processing of wax bearing crudes (Canadian Crude from Petrolia; Mid-Continent and Illinois Crudes from the United States) for the production of high grade lubricating oils and paraffin wax. Also associated with a complete refinery is the manufacture of all grades of greases and compounded oils.

CRUDE PROCESSING AT SARNIA REFINERY

Crude petroleum is received at Sarnia by pipe line from the United States and Petrolia and during the summer months by tanker from the United States. Also, low cold test lubricating oil distillates are received by tanker from the Montreal refinery.
The following constitute the raw materials processed at the Sarnia refinery:

1. **Mid-Continent Crude**.
2. **Illinois Crude (Louden, Roland, Devonian)**.
3. **Canadian Crude from Petrolia**.
4. **Low Cold Test Lubricating Oil Distillates from Montreal** (Webster and Colombian).

Mid-Continent crude is usually processed for a maximum yield of the water white fraction and the lubricating oil distillates. It is customary to augment the supply of Mid-Continent crude by including Illinois crude (Louden) in the ratio of one part Louden to one part Mid-Continent.

Louden crude is primarily run for aviation base stock, gas oils (cracking feed stocks) and coke.

Canadian crude is processed primarily for the production of high quality cylinder stock.

Low cold test lubricating oil distillates from Montreal are further processed at Sarnia for the production of industrial and automotive low cold test lubricating oils.

In the discussion that follows it should be appreciated that there are many modifications in crude processing at Sarnia, depending upon market requirements.

The usual processing for each type of crude petroleum or distillate is shown in the chart opposite.

**Processing Mid-Continent or Mid-Continent-Louden Mixture on Continuous Crude Shell Stills Nos. 17-23.**

This battery of stills consists of 5 stills (Nos. 17-21) fitted with bubble towers and vapor heat exchangers, and 2 stills (Nos. 22 & 23) fitted with vapor heat exchangers only. The Continuous Crude Shell Still Battery is shown diagramatically on the next page.

All of the crude shell stills are fitted with internal flues in order to pick up more heat from the products of combustion obtained from the gas or oil burnt underneath the still. From each still with an attached tower a vapor line runs from the top of the still to a point near the bottom of the tower. A runback line from the bottom of the tower permits liquid to flow back to the still. On the top of the bubble tower there is a partial condenser to provide reflux back to the tower. Cold crude petroleum pumped through tubes in the partial condenser cools the vapors passing on the outside. Some condensation of the vapors is effected, which is returned to the tower as a liquid known as "hot reflux". In all the stills open steam is used in the bottoms to (1) strip or drive out the lighter fractions, (2) agitate the contents of the still, thus preventing deposition of salt or coke, and (3) to reduce the partial pressure to enable the distillation to proceed at a lower temperature.
The crude is preheated by passing through the vapor heat exchanger, then through the partial condenser on top of the bubble tower of #17 still. From here it flows in the same way through the vapor heat exchangers and partial condensers of Nos. 18, 19 and 20 stills. It then flows through the partial condenser on #21 still into an expansion drum, where some of the gases released from the crude by heat are vented. From here it passes through the heat exchangers on #22 and/or #23 stills. After passing through these exchangers the crude petroleum, which is heated to a temperature of approximately 300°F, enters a Crude Flash Tower, where a light naphtha fraction is distilled overhead. This light naphtha contains large quantities of gaseous hydrocarbons, which due to their high vapor pressure must be removed in order to give a product with a reasonable vapor pressure. These gaseous products, which consist of propane and lighter, are removed in a depropanizing tower (Depropanizer). The overhead from this Depropanizer goes into the wet gas line to the Gas Absorption Plant, where traces of liquid carried by the gas products are recovered. The bottoms from the Depropanizer are delivered to the Cold Lye Wash Plant (C.L.W. #5).

The crude petroleum, which has had its light naphtha removed in the Crude Flash Tower, is pumped into the bubble tower of #17 crude still. The bottoms of this bubble tower run back into #17 still through the run back line. The oil in #17 still is held at a temperature of approximately 410°F, and vapors from this still pass up the vapor line into the bubble tower. The top temperature of this bubble tower is held at approximately 235°F. A light naphtha fraction, similar to that obtained overhead from the Crude Flash Tower, is taken overhead. The bottoms from #17 still are delivered into the bubble tower of #18 still by a process known as "steam lifting". Oil is drawn from the bottom of #17 still through a line in which a steam jet is placed. This steam jet forces or lifts the oil into the bubble tower of #18 still.

Heavy naphtha taken overhead from #18 still is diverted to cracking coil stock. The combined overheads from #19 and #20 stills, depending on the operating conditions, may be water white or stove distillate. Both require further treatment. The overhead from #21 still, which is a light gas oil, is either pumped to cracking coil stock or after further treatment used as furnace fuel oil or highspeed diesel fuel.

Crude shell stills, Nos. 22 and 23, are not fitted with bubble towers. The vapor line from these stills goes into a heat exchanger. Here partial condensation of the heavier portions of the vapor takes place, giving a liquid known as heavy gas oil, which goes to cracking coil stock instead of flowing back as reflux. The uncondensed portion from the heat exchangers is cooled in an ordinary water box condenser, or condensing worm, to light gas oil, which is also used as cracking coil stock.

The bottoms or residue from #22 (or #23) still is reduced crude and normally has a viscosity of 95 to 210°F. S.U. These bottoms normally amount to 40% of the crude charged and are delivered to the Vacuum Flash Oils for further processing, or can be worked up into 190 steam refined cylinder oil. It is important that the temperatures on Nos. 22 and 23 stills be maintained as low as possible, in order to minimize decomposition or cracking of the valuable lubricating oil fractions that make up the greater part of the bottoms. Still #22 and #23 are used either alternately or in parallel.
Processing Louden Crude on the Kellogg Combination Topping and Coking Unit.

Louden crude is processed in the Kellogg combination Topping and Coking Unit. This unit is characteristic of the most modern method of processing crude. Five separate operations are carried out in this unit.

1. Distillation of crude into component straight run (S.R.) fractions.
2. Redistillation of the lighter fractions.
3. Mild cracking of the reduced crude.
5. Continuous production of coke.

In contrast to the Crude Shell Still Battery, where the Flash Tower and seven stills separate seven fractions, the Kellogg unit, while processing approximately 25% more crude, produces the same fractions plus three cracked fractions, all of which are more closely cut in three towers. In addition it continuously produces coke. This unit is shown diagramatically on pages 8 and 9.

Topping Section.

Crude is preheated in an elaborate system of heat exchangers and then heated in a pipe still furnace called the Topping Furnace, to about 735°F. From the furnace the heated crude is flashed into the Crude Bubble Tower. A naphtha fraction from this bubble tower is taken overhead, which is condensed and then re-distilled in the Rerun Tower. The bottom product from the Rerun Tower is heavy naphtha, which is used for cracking coil stock. The overhead from the Rerun Tower, like the light naphtha from the Flash Tower of the continuous Crude Shell Still Battery is depropanized, and the depopropanized naphtha delivered to the Cold Lye Wash Plant (C.L.W. #5) to be treated for aviation base stock.

An upper side stream is withdrawn from the Crude Bubble Tower and delivered to a stripping tower or "stripper", where steam strips out low boiling components. The stripped product, which is water white or stove distillate, is delivered to the Refinery Agitators for finishing.

The middle side stream from the Crude Bubble Tower, after being stripped with steam, is a light gas oil which is used either as furnace fuel oil or highspeed diesel oil. It may also be delivered to cracking coil stock. When this light gas oil as produced on the Kellogg Unit is to be used for furnace fuel oil, part of the kerosene fraction is added to meet distillation requirements. This product does not require further chemical treatment, as does furnace fuel oil from the crude shell still battery. A lower side stream, which is heavy gas oil, is also removed from the Crude Bubble Tower. This is pumped directly to cracking coil stock.

Coking Section.

The reduced crude leaving the bottom of the Crude Bubble Tower passes to the coking section, where it is heated in the Reduced Crude Preheater under mild cracking conditions and passes into the Coker Bubble Tower. A small amount of cracked naphtha, known as coke still naphtha (C.S. Naphtha) is taken overhead and delivered to No. 2 Plant, where it joins the cracking coil pressure distillate stream for further processing into cracked gasoline.
An upper side stream is removed from the Coker Bubble Tower known as coke still light gas oil, which goes to cracking coil stock. Likewise a lower side stream is removed, known as coke still heavy gas oil, which also goes to cracking coil stock.

The bottoms from the Coker Bubble Tower form the Coke Furnace charge. These are heated in the coke furnace and discharged into one of three Coking Drums. The vaporous overhead from the Coking Drums goes back to the Coker Bubble Tower. When one of the Coking Drums (capacity 120 tons) is filled with coke, the charge is swung to another Coking Drum. The coke is cut out of the drums by means of high pressure water jets. The coke so removed is crushed and then carried by water to a large conical separator (Hydro-bin) where the water is separated from the coke. When coke is the final product from crude, the operation is known as "running to coke".

The major products produced by this operation are white products and by mild cracking a large yield of gas oils suitable for cracking coil stock. This is in contrast to the operation on the Crude Still Battery where every effort is made to avoid cracking, so as to obtain a high yield of valuable viscous lubricating oil fractions. It is to be understood, however, that the topping side of the Kellogg unit may be run to produce reduced crude suitable for charging to the Vacuum Flash Coils by bypassing the coking side.

Processing Canadian Crude for Cylinder Stock

Canadian Crude is batted in a still, usually one of the stills in 9-12 Battery, also called the Rerun Battery. This battery is also used for rerunning batches of Long Time Burning Oil, wash oil, light lubricating oils, etc. The batch operation on Canadian crude is carried on until the bottoms in the still have a viscosity of approximately 65 at 210°F. S.U. All the overhead from this batch distillation, including naphtha, water white and light gas oil fractions, are pumped directly to cracking coil stock, since they do not yield high quality products due to their high sulphur content. When the bottoms have reached the above viscosity, they are pumped to the Paraffin Agitators for further treatment.

Processing Reduced Crude at the Vacuum Flash Coils

Reduced crude, usually from the continuous Crude Shell Still Battery, is subjected to vacuum distillation in the Vacuum Flash Coil, which consists of two units. The purpose of this distillation under reduced pressure is to separate the lubricating oil fractions from the small percentage of asphalt normally found in Mid-Continent crude oil. This separation must be done under vacuum in order to lower the boiling point of the lubricating oil distillate as far as possible below cracking temperature. These lubricating oil distillates have high boiling points at atmospheric pressure. If distillation was carried out at atmospheric pressure, decomposition or cracking would occur. Cracking would produce low-boiling, non-viscous products, which would be unsuitable as lubricating oils.

The reduced crude is heated to a temperature of 800°F in a pipe still and discharged into a bubble tower. This tower is maintained under a vacuum by means of radojets (also called ejectors). Three side streams are withdrawn from this tower, having the following viscosity specifications and names (when running Mid-Continent-Lowden reduced crude).
Topping Section - Sarnia Topping and Coking Unit

(Kellogg)

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Diagram with labels:
- Condenser
- Crude Bubble Tower
- Cooler
- Condenser
- Pump
- Strippers
- Light Stove Oil or Xerosex
- Reduced Crude to Heater
- Heavy Naptha
- Deprapurized Gasoline
- Deprapurized Gas Main

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Heat Crude

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Page 8.
Stream | Viscosity | Name
---|---|---
Upper Side Stream | 160/170 @ 100°F. S.U. | 160/170 Paraffin Distillate
Middle Side Stream | 77/82 @ 210°F. S.U. | 77/82 Paraffin Distillate
Lower Side Stream | 180/190 @ 210°F. S.U. | 180/190 Paraffin Distillate

A heavy gas oil fraction, known as 50/100 Paraffin Distillate, is taken overhead, condensed, and used as a diesel fuel or a non-viscous lubricating oil. The bottoms from the vacuum flash tower are called "pitch". Pitch has a softening point of 85 to 110°F.

Superheated steam is blown into the residue in the bottom of the vacuum tower (pitch) in order to strip out all lubricating oil fractions, and to assist in the distillation by lowering the partial pressure of the oil vapors. It is important in the operation of these vacuum units that temperatures be maintained as low as possible in order to avoid cracking. The lubricating oil distillates are delivered to treating plants for further refining. The pitch from the bottom of the vacuum tower is usually delivered to the Asphalt Plant. A diagram of the Vacuum Flash Coils is shown on page 11.

CRACKING

The cracking process, by breaking down large hydrocarbon molecules into smaller ones, was developed as a means of increasing the yield of gasoline per barrel of crude petroleum. This is accomplished by heating cracking coil stock to high temperatures. Cracking will be covered in more detail in Section 9.

Thermal cracking, as formerly practised at this refinery, involved heating the oil to temperatures of 880 to 925°F., under pressure of the order of 1000 pounds per square inch. This yielded relatively low octane number cracked gasoline. To increase the octane number of the cracked gasoline, Normal Suspensoid cracking was developed at Sarnia. In this operation, the oil is heated to temperature of 1030 to 1050°F., under a pressure of 500 pounds. Due to the presence of a catalytic clay introduced with the feed stock and the higher operating temperatures, a higher octane number gasoline is produced.

Since the hydrocarbons required for the production of synthetic rubber polymers are constituents of the "cracked gases", one of the products of cracking, the Super-Suspensoid cracking process was developed at Sarnia to yield a maximum quantity of these gases. This process involves heating the oil in the presence of the catalytic clay to temperatures of about 1070°F. Light and heavy gas oils mixed with naphtha are used as a charge stock for this process. It is important that this stock be free of tarry matter (low C.C.R.) which, at these high temperatures, would cause coke to be laid down in the coils despite the scouring action of the catalytic clay. The quantity of cracked gases required for the synthetic rubber program are such that it is also necessary to crack naphthas and re-crack cracked naphthas. This process is known as "reforming" and is carried out at temperatures of 1000 to 1115°F. and approximately 375 lbs. pressure.

The products from the cracking operation are cracked gases, pressure distillate, cracked gas oil and craking coil tar. The cracked gases will be delivered to the rubber processing units. More cracked gases, and some light liquid hydrocarbons (light ends) will be separated from pressure distillate and also delivered to the rubber processing units. The remainder of the pressure distillate is cracked naphtha, a component of motor gasoline.
The cracked gas oil is utilized without further treatment as a fuel oil, known as Star fuel. The cracking coil tar which contains the spent clay catalyst, is filtered in the Tar Filter Plant, and then delivered to bunker fuel tankage or delivered to the Asphalt Plant. The catalyst used in Super-Suspensoid cracking is usually clay from the Contact Filter Plant, where it has been used for decolorizing lubricating oils. After use as a catalytic clay in the Super-Suspensoid cracking process, the spent clay is at present discarded.

DEBUTANIZATION, STABILIZATION & GAS ABSORPTION PLANT

The D.S.A. Plant is concerned with the recovery and control of light hydrocarbons. It consists of two fractional distillation towers, known as the Debutanizer and Stabilizer, and the Gas Absorption Plant. The charge to the Debutanizer consists of pressure distillate from the Cracking Coils and coke still naphtha from the Kellogg Combination Topping and Coking Unit. This charge is heated and passed into the Debutanizer where the gaseous and light liquid hydrocarbons are removed overhead and cracked naphtha is taken from the bottom. This cracked naphtha, freed of the gaseous and light liquid hydrocarbons, is delivered to the Gold Lye Wash Plant #3. Since it has a low vapor pressure, it can be safely stored without danger of high evaporation losses.

The overhead from the Debutanizer passes through a condenser and then into the Stabilizer feed drum. The condensed portion is then refractionated in the Stabilizer. The bottoms from the Stabilizer, known as stabilizer bottoms, or light ends, are lye-treated and delivered to refrigerated storage. The gases overhead from the Stabilizer go to the refinery gas line.

The uncondensed gases from the Stabilizer feed drum and the gases from the pressure distillate drums at the Cracking Coils (High Line Gas) form the charge stock to the High Pressure Absorber of the Gas Absorption Plant. Low pressure gases from No. 1 Plant evolved during the distillation of crude enter the Low Pressure Absorber, the second of the Gas Absorption Plant units. These units recover any light ends in the gases by absorbing them in a light oil known as the "menstruum". The light ends absorbed by the menstruum (fat oil) are recovered by distillation and delivered to the Stabilizer. The menstruum freed of light ends (lean oil) is used to recover more light ends. The dry gases enter the refinery gas line. The diagram on page 13 shows the essential features of a gas absorption unit.

Future Modification of the D.S. & A. Plant

When the refinery is operated to produce hydrocarbons as feed materials for the production of synthetic rubber polymers, the operation of the D.S. & A. Plant will be changed considerably. The Debutanizer will fractionate pressure distillate from the Cracking Coils into cracked naphtha and an overhead stream consisting essentially of pentanes and lighter, which will go directly to the Light Ends Recovery Unit of the Polymer Corporation. When so used, the Debutanizer will be known as a "Distillate Splitter". Since high line gas from the Cracking Coils will also go directly to the Light Ends Recovery Units, the Gas Absorption Plant will process only low pressure gases, which will be essentially those gases produced at No. 1 Plant. With this arrangement there will be no need for the Stabilizer.
ASPHALT PLANT

Pitch bottoms from the Vacuum Flash Coils and cracking coil tar from the Cracking Coils, when it is available, are delivered to the Asphalt Plant for processing into the various grades of solid and liquid asphalts.

The Vacuum Flash Coil pitch and the cracking coil tar are steam reduced in a vacuum flash coil at the Asphalt Plant. Steam reduction refers to heating pitch in a pipe coil, discharging it into a tower held under reduced pressure, and blowing or stripping the product with steam to remove some of the oily constituents. Oxidized asphalts are produced by heating the pitch to approximately 450°F and blowing air through the pitch. This air-blowing raises the softening point to any desired level. The softer grades of solid asphalt are usually sold on the basis of the penetration test, there being a definite relationship between softening point and penetration for pitch from a given crude petroleum.

Liquid asphalts are produced by adding a volatile solvent to solid asphalt, the volatility of the solvent used being dependent upon the rate of setting up or curing desired. For example, M.C. (medium cure) liquid asphalts are made by dissolving 100 - 120 penetration steam reduced Mid-Continent - Louden flash coil pitch in cracked naphtha (debutanizer bottoms); R.C. (rapid cure) liquid asphalts are produced by blending 160 - 170 penetration oxidized Mid-Continent - Louden flash coil pitch with light naphtha (rerum debutanizer bottoms).
FINISHING WHITE PRODUCTS

The white products (aviation gasoline, specialty solvents, straight run and cracked naphthas, water white and stove distillate) require treatment to improve their odour, remove corrosive sulphur compounds and improve their burning characteristics.

Sulphur chemically combined in more or less complex compounds is present in all fractions produced by crude distillation and by cracking. In some fractions a small amount of sulphur is not harmful depending on the use to which the product will be put. However, sulphur compounds are always potentially dangerous corrosive agents and the lighter ones always have a foul odour. The lighter sulphur containing compounds, hydrogen sulphide and light mercaptans, are removed from white products by washing them with a straight lye solution in a continuous process. When the lye solution loses 55% of its ability to remove sulphur compounds (55% spent) it is withdrawn from the treating system and discarded. Heavier products are lye washed in cone bottomed tanks (agitators) where the lye and oil are mixed by air jets. Treating in an agitator is a batch operation.

Aviation base stocks and naphthas for naphtha specialties are continuously treated with lead lye solution (Doctor solution) to remove hydrogen sulphide and to convert heavy mercaptans (c.q. octyl mercapton) which are not affected by straight lye solution to odourless disulphides (c.q. octyl disulphide). Elemental sulphur must be added continuously (sulphurized oil) in the process to complete this conversion.

Sulphur compounds are removed in serious treaters throughout the refinery. The principles of a continuous treater for white products is shown in the diagram on page 15. This diagram shows the essentials of Cold Lye Wash Plant #5 at No. 1 plant.

Aviation Base Stock

Aviation Base stock from the depropanizer at the Kellogg Combination Topping and Coking unit is lead-lye treated in the Cold Lye Wash Plant (C.L.W. #5). Since disulphides have an adverse effect on the octane number of leaded aviation gasoline, they must be removed by re-running. This is carried out by re-running lead-lye treated aviation base stock in Nos. 35 to 38 Rerun Stills. Here temperatures are maintained so that the higher boiling disulphides are concentrated in the bottoms. The overhead is finished Aviation Base Stock. This overhead product will meet vapor pressure specifications, since it was depopropanized in the Kellogg unit depropanizer. Aviation base stock is produced normally from Louden crude, since the aviation base from Mid-Continent crude is low in octane number. Satisfactory aviation base stocks can also be produced from Roland and Devonian crudes.

Specialty Solvents

Under this heading are included such products as Dry Cleaners' Naphtha, Varnish Makers' and Painters' Solvent, Rubber Solvent and Solvent Naphtha. These must be narrow cut naphthas and possess little or no odor. A selected naphtha cut is taken from the Crude Shell Stills or the Kellogg unit. These are lead-lye treated (C.L.W.#5) to convert mercaptans into sweet-smelling disulphides and then rerun in the Column Steam Still to produce various solvents with definite boiling ranges. As an aid to the Marketing Department, these solvents (called Iosols) are
Section 8.

**CONTINUOUS STRAIGHT LYE TREATMENT**

- LEAF MIXERS
- PUMP
- UNTREATED STRAIGHT LYE NAPHTHA
- RECYCLED LYE SOLUTION
- TREATED NAPHTHA TO SEWER
- 550° SPENT LYE TO SEWER
- NAPHTHA
- LYE SOLUTION
- GAUGE

**CONTINUOUS LEAD LYE TREATMENT**

- LEAF MIXERS
- HEATER
- SULPHURIZED NAPHTHA
- RECYCLED LEAD LYE SOLUTION
- TREATED NAPHTHA TO COLUMNS STEAM STILL

**CONTINUOUS LEAD LYE TREATMENT AND WATER WASH**

- LEAF MIXERS
- SULPHUR DRUM
- UNTREATED AVIATION BASE STOCK
- TREATED AVIATION BASE STOCK BACK TO BAYON 7/16""}

**SIMPLIFIED FLOW DIAGRAM OF COLD LYE WASH PLANT**

Page 15.
given a number, which indicates their boiling range; thus, Iosol 1028 refers to a specialty solvent having a boiling range of 100 - 280°F.

The Column Steam Still unit consists of two towers, the primary tower, and the secondary tower, both of which operate under pressure or vacuum. These are shown in the diagram on page 17. About 7 pound pressure absolute is used when light naphtha is distilled. Vacuum (28" mercury) is used with heavy naphthas. Heat for distillation is supplied by preheaters using steam as the heating medium. Open steam is used in the secondary tower. Steam distillation is used in the production of specialty naphthas since (1) it permits accurate control of temperatures, thus allowing narrow cut fractions to be produced; (2) it reduces fire hazard present when handling light naphtha products; (3) there is no local overheating as in a direct fired still, which would decompose some of the sulphur compounds and give rise to what is commonly known as distillation odour in the finished product.

Straight Run and Cracked Naphthas.

Straight run naphtha produced at the Continuous Crude Shell Stills and the crude side of the Kellogg Combination Topping and Coking Unit is lye washed for removal of hydrogen sulphide and light mercaptans in the Cold Lye Wash Plant (C.L.W.#5). This lye-washing is followed by a water wash to remove traces of caustic soda and the product delivered to straight run naphtha storage.

Pressure distillate, which consists for the most part of cracked naphtha and coke still naphtha from the Kellogg unit, are processed in the Debutanization, Stabilization and Gas Absorption Plant at Plant No. 2, as described previously.

The debutanizer bottoms (cracked naphtha) which is the pressure distillate with gases and light ends (light liquid hydrocarbons) removed, are lye washed in the Cold Lye Wash Plant #3, water washed and an inhibitor added to prevent gum formation. It is then delivered to cracked naphtha storage. The overhead from the Debutanizer enters the Stabilizer where the light ends are separated from the gaseous hydrocarbons. These light ends are lye washed at the D.S. & A. Plant for mercaptan removal and pumped to refrigerated storage.

Water White and Stove Distillate

Water White and Stove Distillates are treated in a batch process at the Refinery Agitators. Both these stocks are sweetened by treatment with lead-lye, followed by water washing. The difference between water white distillate and stove distillate is mainly one of distillation range, the latter having an end-point of approximately 530°F, whereas water white has an end-point of 490°F.

When it is desired to produce Long Time Burning Oil, the water white distillate is treated in the Refinery Agitators with sulphuric acid, followed by lye washing to remove traces of acid. This treated distillate is rerun in one of the 9 - 12 batch Rerun Stills. A heart cut is taken and lead-lye treated in the Refinery Agitators. This procedure produces a superior illuminating oil for light-house and railway lamps.
Simplified Flow Diagram
of
Column Steam Stills

Legend:

- Vapour
- Liquid
- Steam

SABRIA REFINERY
MARCH 1959
TREATING GAS OILS

Furnace Fuel Oil

Furnace Fuel Oil which is a light gas oil produced at the Kellogg Unit, requires no treatment other than air blowing to dry it. Furnace fuel oil produced at the Continuous Crude Shell Stills must be lye washed in the Refinery Agitators to remove hydrogen sulphide, after which it is water washed and blown dry with air. Furnace fuel oil is also used as a highspeed diesel oil.

It will be recalled that when producing furnace fuel oil, part of the kerosene fraction is included in the light gas oil stream from the Kellogg unit, to modify the distillation range. All other gas oil streams produced at the Kellogg and Continuous Crude Shell Still Battery receive no chemical treatment since they form cracking coil stock.

PROCESSING LUBRICATING OILS

When charging reduced Mid-Continent - Louden crude to the Vacuum Flash Coil, four paraffin distillates are removed, which are:

<table>
<thead>
<tr>
<th>VISCOSITY</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>50/100 at 100°F. S.U.</td>
<td>50/100 Paraffin Distillate (Overhead gas oil)</td>
</tr>
<tr>
<td>160/170 at 100°F. S.U.</td>
<td>160/170 Paraffin Distillate</td>
</tr>
<tr>
<td>77/82 at 210°F. S.U.</td>
<td>77/82 Paraffin Distillate</td>
</tr>
<tr>
<td>180/190 at 210°F. S.U.</td>
<td>180/190 Paraffin Distillate</td>
</tr>
</tbody>
</table>

These distillates are processed for the production of either industrial lubricating oils or automotive and aviation oils. For the production of industrial lubricating oils, each distillate is dewaxed, acid treated and clay treated. For motor and aviation oils, each distillate is phenol treated, dewaxed and clay treated. The various treating steps to which the untreated lube distilled from Mid-Continent - Louden Crude may be subjected are shown in the chart on page 19.

Five lubricating oil distillates from Colombian or Webster crudes are received from Montreal. These five distillates have the following viscosity ranges:

<table>
<thead>
<tr>
<th>VISCOSITY</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>58/60 at 100°F. S.U.</td>
<td>58/60 Low Cold Test Distillate</td>
</tr>
<tr>
<td>125/140 at 100°F. S.U.</td>
<td>125/140 Low Cold Test Distillate</td>
</tr>
<tr>
<td>50/52 at 210°F. S.U.</td>
<td>Low Cold Test Distillate 50/52</td>
</tr>
<tr>
<td>80/85 at 210°F. S.U.</td>
<td>Low Cold Test Distillate 80/85</td>
</tr>
<tr>
<td>160/170 at 210°F. S.U.</td>
<td>Low Cold Test Distillate 160/170</td>
</tr>
</tbody>
</table>

These distillates are called low cold test distillates since they are relatively wax free and do not require dewaxing, with the possible exception of the heaviest distillate. As in the case of the paraffin distillates, industrial lubricating oils are manufactured from the Colombian - Webster
distillates by acid treating, followed by clay treating. Automotive and aviation oils are produced from these distillates by phenol treating followed by clay treating. The various treating procedures to which the untreated lube distillates may be subjected, are shown on page 20.

The processes used at Sarnia in the finishing of lube oil distillates into marketable products are as follows:

Solvent Extraction (Phenol Treating)
Acid Treating
Dewaxing
Clay Treating
Lye Treating
Re Running

Solvent Extraction – Phenol Treating

Phenol treating is a continuous solvent extraction process whereby undesirable constituents are removed from the lube oil distillates. These undesirable constituents consist of unstable compounds, which break down under the influence of heat to form sludge and carbon in motors. These also consist of compounds that have a poor temperature viscosity relationship (V.I.) causing the lubricating oil to thicken at low temperatures and thin out at high temperatures. These undesirable constituents are dissolved out of the lubricating oil distillates by phenol. As there is no chemical action between the phenol and these undesirable constituents the phenol may be recovered by distillation and used again in the process.

The lubricating oil distillates and the phenol are contacted in a counter-current treating tower. The desirable portion, with a small amount of phenol dissolved in it (known as raffinate) comes off the top of the treating tower. The undesirable constituents dissolved in phenol comes off the bottom with the "spent phenol". The process requires definite ratios of phenol to untreated oil and specific temperatures.

The raffinate has its phenol content removed (dephenolized) by distillation in a pipe still and a bubble tower. This unit is known as the Dephenolizing Unit. The phenol is taken from the top of the bubble tower. The bottoms, which constitutes the dephenolized lubricating oil, is known as treated oil. Similarly, the phenol is recovered from the spent phenol by distillation in another pipe still and bubble tower, the Phenol Recovery Unit. The phenol is taken overhead and the bottoms product known as "extract" is used as a heavy fuel oil. Colombian – Webster distillates are treated in the Phenol Plant under different conditions of temperature and ratio of phenol, but the phenol recovery process is always the same. Yields of treated oil from phenol treated Mid-Continent – Louden paraffin distillates and Colombian – Webster low cold test distillates range from 50 to 80% of the untreated oil charged.

The essentials of the Sarnia Phenol plant are shown in the diagram on Page 22. This diagram is very much simpler than the actual plant.

It is interesting to note that the Sarnia Phenol Treating Plant was one of the first commercial selective solvent Treating Plants for lubricating oils in the world, and was developed by the Imperial Oil.
SIMPLIFIED FLOW DIAGRAM
OF
PHENOL PLANT
Acid Treating.

Sulphuric acid also removes some of the undesirable constituents from lubricating oil distillates chiefly by chemical reaction. However sulphuric acid has little effect on those constituents which have a poor viscosity temperature relationship. The treatment with sulphuric acid is secured out in the Paraffin Agitators, where the acid is added to the oil and mixed by blowing with air. After a period of time, which varies according to the different stocks, the air is shut off and a product known as "acid sludge" settles to the bottom. This sludge is the product of chemical reaction between the acid and some of the undesirable constituents. This acid sludge is drawn from the bottom of the agitator and any unreacted sulphuric acid is recovered. The acid treated oil is then delivered to the Clay Treating Plant.

Dewaxing.

Paraffin distillates contain wax, which must be removed in order that the lubricating oil will flow at low temperature. At Sarnia this wax removal is accomplished by two processes -

1. Solvent Dewaxing (for any waxy distillate).
2. Centrifuge Dewaxing (essentially for cylinder stocks only).

In the process of solvent dewaxing, the paraffin distillate is first mixed with a solvent, known as Ketone, (a mixture of methyl butyl ketone and methyl propyl ketone). The paraffin distillate and the solvent are then cooled at definite rates down to temperatures between 300°F. and 0°F. At these temperatures the lubricating oil remains in solution, while the wax precipitates out. The wax is then separated by filtration in rotary filters. The solvent can then be recovered from the dewaxing oil by fractional distillation in a pipe still and bubble tower and used again. Likewise, the solvent accompanying the wax is recovered in a pipe still and bubble tower and used again in the process. This solvent dewaxing process was developed by Imperial Oil Limited. The plant is shown diagrammatically on page 24.

In the centrifuge dewaxing process the raw lube stock is mixed with light naphtha, the mixture being chilled down to approximately -10°F., where the wax separates out. The mixture of wax, naphtha, and lubricating oil is passed through a centrifuge machine. The wax being heavier, is separated much in the same way as cream is separated from milk in a cream separator. The naphtha in the dewaxed oil from the centrifuge is removed by batch distillation in Nos. 9-12 Rerun stills. The naphtha in the wax is also removed by distillation in these stills.

The wax obtained by centrifuging 190 steam refined cylinder stock is a mixture of oil and non-crystalline wax known as dark petrolatum.

Clay Treating

Phenol treated dewaxed paraffin distillates are contacted with clay to improve their color, remove traces of acid, improve their stability and improve their resistance to emulsification. Clay treating similarly improves phenol treated low cold test Colombian and Webster distillates. Sulphuric acid treated paraffin distillates and Colombian-Webster low cold test distillates are clay contacted in order to improve their color and to remove the last traces of sulphuric acid and acid sludges.
SIMPLIFIED FLOW DIAGRAM OF DEWAXING PLANT
In the Clay Contact Plant a lubricating oil distillate is mixed with a laboratory determined quantity of activated or natural clay (activated clay such as Super-filtrol and natural clay such as Attapulgus) and then heated in a pipe coil to temperatures of the order of 300 to 450°F., depending on the viscosity and flash point of the lubricating oil distillate. The hot oil-clay mixture is filtered to remove the clay and the impurities removed by the clay. The oil goes to finished oil tankage and the spent clay is delivered to the cracking coils as catalyst for the Super-Suspenosoid cracking process.

Lye Treating

Certain lubricating oil distillates are lye washed to remove acidic compounds, thus improving their resistance to oxidation. The lye washing is done in the Paraffin and Refinery Agitators.

Rerunning

In many cases where lubricating oil distillates have been lye treated, they are rerun in contact with lye in order to separate a heart cut, thus eliminating undesirable low boiling point unstable components. This rerunning operation is usually done in Nos. 1 - 6 Vacuum Shell Stills.

EFFECTS OF REFINING OPERATIONS ON LUBRICATING DISTILLATES

The characteristic common to raw lube distillates from any crude petroleum is a poor resistance to oxidation as indicated by sludging. In addition to this general characteristic, raw lube distillates from naphthenic base crudes (Colombian & Webster) are characterized by a relatively low pour point. The viscosity index, gravity and flash for a given viscosity are also low. On the contrary, lube distillates from paraffinic base crudes (Mid-Continent) have a high pour point and relatively high viscosity index, gravity and flash for a given viscosity. The chief quality deficiencies are the low viscosity index of naphthenic base distillates, the high pour point of paraffinic base distillates and the poor resistance to oxidation characteristic of both.

The natural low viscosity index of a naphthenic oil is readily improved by phenol treating. By this procedure the high natural viscosity index of a paraffin oil can be equalled by a naphthenic oil. Furthermore, during this refining step, it is found that the stability towards oxidation of a naphthenic oil is often improved beyond the natural stability of the paraffinic oil. It will be realized, of course, that phenol treating can also be applied to a dewaxed paraffinic oil, which then places the paraffinic oil much ahead of the solvent treated naphthenic oil, so far as viscosity index and stability towards oxidation are concerned.

Effect of Phenol Treating on Naphthenic and Paraffinic Base Distillates:

<table>
<thead>
<tr>
<th></th>
<th>Naphthenic</th>
<th>Paraffinic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raw Stock</td>
<td>Treated</td>
</tr>
<tr>
<td>Viscosity Index</td>
<td>36</td>
<td>76</td>
</tr>
<tr>
<td>Slight Oxidation mg. sludge/24 hours</td>
<td>96</td>
<td>6</td>
</tr>
</tbody>
</table>
The high pour point of paraffinic crudes is corrected by dewaxing. This step causes practically no change in any of the other characteristics. Generally speaking, dewaxing is not carried out to such an extent as to obtain a pour point equal to that of naphthenic crudes, having in mind oils of similar viscosity. The reason for this is that, technically, these extremely low pour points are difficult to obtain and, further, in a case of extreme dewaxing, viscosity index is sacrificed. Where a pour point lower than that readily obtained by dewaxing is desired, recourse may be had to Paraflow, which is an additive that lowers the natural pour point of an oil.

Effect of Solvent Dewaxing and Paraflow on Paraffinic Base Distillates:

<table>
<thead>
<tr>
<th></th>
<th>Raw Stock</th>
<th>Dewaxed</th>
<th>Dewaxed plus Paraflow</th>
<th>Naphthenic Raw Stock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pour Pt. °F</td>
<td>-90</td>
<td>-25</td>
<td>-10</td>
<td>-5</td>
</tr>
</tbody>
</table>

PRODUCTION OF CYLINDER OILS

Cylinder Oil from Canadian Crude

Reduced Canadian Crude from Nos. 9 - 12 Rerun Stills is treated in the Paraffin Agitators with sulphuric acid to remove asphaltic material, and then clay treated. The clay treated product is steam reduced (distilled with open steam) in the 9 - 12 Rerun stills to give a bottoms product having a viscosity of 190/195 at 210°F. S.U., which is finished cylinder stock.

190 Steam Refined from Mid-Continent - Louden Crude

Reduced Mid-Continent - Louden crude from Nos. 17-23 stills is acid treated in the Paraffin Agitators to remove asphalt, and then clay treated. This oil is then dewaxed in the Centrifuge Plant and steam reduced to give a high viscosity bottoms product, known as 190 Steam Refined stock. This stock has a viscosity of 190/200 at 210°F. S.U.

WAX PROCESSING

When the paraffin distillates produced at the Vacuum Flash Coils are dewaxed, each of these yield a wax product. Slack wax is obtained from 160/170 Paraflin Distillate, which, after sweating and treatment with Fullers Earth (clay treating), yields a white crystalline product known as Refined Wax.

Sweating is a process in which wax is solidified in shallow pans in a room over which accurate control of the temperature can be maintained. As the temperature of the room slowly rises, oil is separated from the wax, yielding a relatively oil-free wax. The separated oil is known as Foot's Oil, which is sent to cracking coil stock.

Phenol treated Paraffin Distillate, 77/82, when dewaxed yields less crystalline wax, which on lye washing and clay treating is known as Pale Raw Wax.

Paraffin Distillate 180/190 on dewaxing yields a product known as Dark Raw Wax, which is a less crystalline product than the Pale Raw Wax. This receives no further treatment.
BLENDING

Although many of the products described so far are finished products, they may also be combined in definite proportions to form other finished products with different specifications. Non-petroleum products are also added to finished stocks to give them special properties. These operations are called blending.

Aviation Gasoline.

Aviation Base Stock is blended with varying amounts of ethyl fluid to produce finished aviation gasolines up to 87 octane number. In order to produce higher octane number aviation gasolines, it is necessary to add a high octane number synthetic blending agent, such as alkylate or cumene. The latter is manufactured at Sarnia.

Motor Gasoline.

Treated cracked naphtha, treated straight run naphtha and Light Ends are stored separately to minimize evaporation loss and to enable the refinery to produce a tailor-made product, depending on the season and the quality required by the market. Straight run and cracked naphthas are blended and the volatility and vapor pressure adjusted by adding varying percentages of Light Ends (Stabilizer Bottoms). Ethyl fluid is then added to increase the octane number to the desired level.

Fuel Oils.

Industrial fuel oils of varying compositions, according to market demands, are produced by blending cracking coil tar and gas oils. Bunker "C" Fuel is also prepared by blending cracking coil tar and Vacuum Flash Coil pitch with gas oils to adjust the viscosity.

Lubricating Oil.

A full line of Aviation, Automotive, Industrial and Special Lubricating Oils are prepared by blending the finished stocks shown on pages 19 and 20. From a relatively small number of finished lubricating oil base stocks a large number of finished lubricating oils, to meet many different specifications and uses, can be blended as required. This blending is done in the Marvelube pump-house and in the Barrel Filling Plant.

OIL COMPOUNDING

There are many types of machinery that require special lubricants, where unusual conditions of pressure and temperature are experienced. Thus sulphur, lead soap, etc. are added to lubricating oils to increase their load bearing properties. Degras and acidless tallow are added to cylinder oils to improve their operation under wet steam conditions. Soaps are added to lubricating oils to give a product known as Soluble Cutting Oil, which can be emulsified with water. Non-emulsifiable cutting oils are made by the addition of sulphur to the oil. The addition of non-petroleum products to lubricating oils is carried out in the Compounding Plant.
GREASE PLANT

Grease is manufactured to supply lubricants in a solid form. Greases are solid or semi-solid combinations of petroleum oil and soap or a mixture of soaps with or without fillers. The soap is made from fats such as beef tallow, fleshing grease, mutton tallow or a fatty acid such as cottonseed or animal fatty acid, and an alkali such as caustic soda or lime. In addition to sodium and calcium soaps, aluminum soaps are also used.

The soap is made by cooking the fat and caustic soda or lime under pressure for a period of time at temperatures in the neighbourhood of 300°F. This process is known as "saponification". The soap is then dropped into a grease kettle and is stirred into lubricating oil of the desired viscosity. The characteristics of the finished grease will depend upon the relative amounts of oil and soap, and the strict control of the free alkali, acid and water content.
CRACKING

The term "cracking" is used to denote the decomposition by heat of high boiling, high molecular weight hydrocarbons into lower boiling, lower molecular weight hydrocarbons. The original purpose of cracking was to increase the supply of motor gasoline; today cracking not only produces motor and aviation gasoline but the hydrocarbons required in the production of aviation blending agents, many different chemicals and synthetic rubber polymers. Furthermore, cracking is an important means of adjusting the yields of the various products of petroleum to meet the everchanging demands of the market. Cracking operations at Sarnia will produce cracked naphtha for motor gasoline and hydrocarbons for the production of synthetic rubber polymers.

Some idea of the importance of cracking may be obtained from the fact that in the United States the production of cracked gasoline in 1914 was only 6% of the total gasoline produced. Today, more than 50% of the gasoline used is produced by the cracking process. The enormous increase in gasoline consumption during the past 25 years (over 5,000,000,000 barrels now used in the United States each year) forced the oil industry to look for a new method of meeting this increased demand. Thus, the well known phenomenon of cracking a heavy high-boiling liquid to produce a light low-boiling liquid by the proper application of heat was utilized in the production of gasoline. If the cracking process had not been developed and utilized, the demand for gasoline would necessitate double the production of crude petroleum over that now required. This would have resulted in an over-production of reduced crude and other products.

Brief History of Cracking

Cracking is almost as old as the petroleum industry itself. The first cracking in the petroleum industry happened accidentally about 1864. As the story goes, a still runner had distilled all of the kerosine from the charge in his still and then visited a nearby saloon while the heavy oils were coming over. His visit at the saloon lasted many hours during which time his still got hotter and developed pressure. On his return he was amazed to find the overhead product to be a light kerosine-like product not at all like the heavy oil he expected. Investigation showed the excess heat and pressure had caused the heavy oil to decompose into a lighter oil.

The cracking operation accidentally discovered was widely used by refiners to increase the production of kerosine. By distillation under pressures of 30 to 40 lbs. per sq. in. heavy oils which contained no kerosine fraction could be made to yield up to 60% of a product that could be sold as kerosine.

The first commercial cracking process for the production of gasoline was introduced in 1912. This process, known as the Burton Process, was a batch operation in which about 200 barrels of gas oil was heated to 750°F. under 75 to 95 lbs. per sq. in. pressure in heavy rivetted shell stills. A batch would be distilled in 48 hours producing about 100 barrels of distillate of 48 - 52° A.P.I. gravity. A battery of Burton stills were built about 1914 at Sarnia - the first units on the #2 plant site.
The diagram below shows in a qualitative manner the formation of the various products as the feed stock moves through a cracking coil. The change in the amount and kind of the products is due to the decomposition and polymerization reactions going on in the feed stock as it passes through the coil.

Coking is one of the most objectionable features of all cracking processes. This coke settles out on the inside of the furnace tubes and since it is a poor conductor of heat causes the temperature of the walls of the tubes to rise. This coke will gradually build up until it will completely plug the tube, thus forcing a shutdown of the unit.

Although gasoline and light gases are the most common light products from the cracking system other oils having boiling ranges intermediate between gas oil and tar are produced. These intermediate products produced in the cracking system are kept within the system until they are decomposed. This intermediate material is called recycle stock and in the case of the Tube and Tank process, for example, is continuously recycled back to the furnace until finally decomposed into gasoline and tar or coke.

There are two general types of reactions which take place in the cracking system; first, primary reactions which involve decomposition of large molecules into smaller ones; and second, secondary reactions by which active or olefinic molecules polymerize to form heavy tarry materials. These products of polymerization may again be decomposed into smaller molecules. The primary cracking reaction may be illustrated as follows:

\[
\begin{align*}
\text{Butane} & \quad \text{Methane} & \quad \text{Propylene} \\
\text{CH}_3-\text{CH}_2-\text{CH}_2-\text{CH}_3 & \quad \text{CH}_4 & \quad \text{CH}_3-\text{CH} = \text{CH}_2 \\
\text{CH}_3-\text{CH}_2-\text{CH}_2-\text{CH}_3 & \quad \text{Ethane} & \quad \text{Ethylene} \\
\text{Butane} & \quad \text{CH}_3-\text{CH}_3 & \quad \text{CH}_2 = \text{CH}_2
\end{align*}
\]
Section 9

After the Burton process was introduced many forms of equipment were built whereby oils could be heated under pressure. In 1925 a process known as the Tube and Tank Process, developed by the Standard Oil Company of New Jersey was installed at Sarnia. In this process the cracking stock was heated by passage through tubes (the cracking coil) arranged within a furnace. The heated stock then entered a reaction chamber called a soaker where cracking reactions continued. From the soaker the cracked stock entered a tar separator where the "cracking coil tar" settled out. The rest of the cracked stock entered distillation towers where the cracked naphtha and cracked fuel oils were fractionated out. Cracking Coils #3 and 4 at #2 Plant were the original Tube and Tank installations here. These coils operated at a pressure of 350 lbs. per sq. in. and temperatures up to 800°F. In 1929 and 1930 Cracking Coils #5, 6, 7 and 8, all Tube and Tank installations, were built. These could operate at 1000 lbs. pressure per sq. in. and at temperatures up to 900°F.

Since 1937 experimental work here has developed a catalytic cracking process which is now used in Cracking coils #5, 6, 7 and 8. The catalyst not only exerts a directive effect on the cracking reactions but continuously occurs the cracking coils free of coke thus permitting temperatures of almost 1100°F. to be used. This process when used for the production of a maximum amount of cracked naphtha is known as Suspensosaid cracking. When cracked gases are the desired product, higher temperatures are used and the process is called Super Suspensoaid cracking. This is the process that will produce the hydrocarbons required for the production of synthetic rubber polymers.

Cracking Reactions

In the distillation of crude petroleum, two or more fractions are separated by means of the difference in boiling ranges of these fractions. If crude petroleum is distilled and the vapours removed fast enough to keep the pressure at atmospheric, substantially no cracking or decomposition will take place, providing the temperature is below 700°F. The products of distillation obtained under these conditions may be blended together again to form a mixture which will be the same as the original crude petroleum. Distillation, therefore, involves no chemical change, but only a physical separation based on the boiling points of the various fractions. When temperatures of 700°F. are exceeded decomposition of the hydrocarbons in the crude occurs. In this case, blending of the products of distillation would form a mixture different from the original crude petroleum. Decomposition has taken place and this is a chemical change.

Cracking is a process in which many chemical reactions take place at the same time yielding many different hydrocarbons. In general the majority of the reactions cause large molecules to be broken down into smaller molecules, many of which are olefins. Some of the olefins however, recombine (polymerize) into molecules larger than those in the original feed stock. Many of these large molecules are re-cracked and then combined again. Many repetitions of this process, during each one of which the molecule loses hydrogen atoms, finally causes the formation of a molecule that is very large, very complex in its structure and with very few hydrogen atoms. Such molecules make up the tar and coke formed during cracking. Consequently, the products of cracking are:
1. Gaseous (cracked gases) and low-boiling liquid compounds (cracked naphtha) relatively rich in hydrogen atoms.
2. Liquid products of higher molecular weight (cracked gas oil or Star fuel) tar and coke possessing a low content of hydrogen atoms.
the same quantities on cracking as a similar fraction from another type of crude petroleum. It is customary to evaluate cracking stocks from different types of crude petroleum by means of their aniline points; thus, the higher the aniline point the more paraffinic is the fraction and the more easily it will decompose by cracking.

Temperature is the most important factor affecting the cracking reaction and its velocity. At 1100°F, the velocity of decomposition is approximately doubled for every 38 degrees rise in temperature. In general, the longer the time of heating the greater the decomposition. As cracking starts, the primary decomposition reaction takes place, which is the formation of a low-boiling point saturated hydrocarbon and a low-boiling unsaturated or olefinic hydrocarbon. As the time is increased, the concentration of active unsaturated material increases and secondary reactions take place with the polymerization of the olefinic hydrocarbon. These secondary reactions use up some of the material that has been formed during the primary reaction, so that the yield of gasoline decreases. Generally speaking, time is interchangeable with temperature is roughly the same as a short time at high temperature. High temperature and short times of reaction favour the production of unsaturated hydrocarbons, whereas long times at lower temperature would tend to allow these active unsaturated fractions to polymerize. Various devices have been used to increase the time, such as lengthening the heating coil, or the introduction of soaking drums. The increase in time by these means gives higher conversions of the feed into gasoline.

In the Tube and Tank process, the charge stock is heated to the cracking temperature in a heating coil in as short a time as possible and discharged into an unfired soaking drum, where the reaction is allowed to proceed. Another method of increasing or decreasing the time of reaction is by varying the feed rate, or raising or lowering the pressure. Diluents may be added during the heating process, such as steam or inert gas, which so dilute the mixture that each hydrocarbon fraction is at a high temperature for a very short time. The use of diluents is not practised in cracking operations carried out at Sarnia.

As stated above, increasing the pressure on a given cracking system tends to crowd the molecules into a smaller space and thus increases the time during which the soil is held at the cracking temperature. Thus, providing that the same charging rate is maintained, it will take longer for individual hydrocarbons at the higher pressure to travel through the unit, than it would if they were under lower pressure. High pressure also favours polymerization of unsaturated hydrocarbons. From the equation noted above, two volumes of ethylene shrink to one volume of butylene when they are polymerized. It is a general rule in chemical reactions that an increase in pressure tends to favour reactions that would reduce that pressure. Thus, in this case, two volumes of ethylene combine to form one volume of butylene and this reaction would be aided by an increase of pressure.

Feed stocks for a cracking process are usually segregated on the basis of their gravity, aniline point, distillation range and carbon residue. As stated above, heavy stocks decompose more readily than lighter ones and it is often advantageous to crack these stocks separately under conditions suitable for each. Different types of crudes give feed stocks that vary in their characteristics due to the percentage of the different types of hydrocarbons present. In some cases it is possible to segregate these fractions from different types of crude petroleum and adjust the cracking conditions to give maximum yields of desired produced for each individual type of stock.