overhead is removed to the High Pressure Gas Absorption Plant by a line from the top of the drum into which the debutanizer overhead discharges. The drum is the Stabilizer Feed Drum. The stabilizer fractionates this feed to remove the remaining gases overhead, while the bottoms contain light ends (chiefly C₄ and C₅ cuts), which are used to give volatility to motor gasoline. These bottoms are stored in refrigerated tankage and are usually known as "Stabilizer Bottoms." A flow plan of a typical stabilizer is shown on Page 6.

8. Depropanizer

A depropanizer is a bubble tower designed to remove propane, ethane and methane from its feed. By this definition the stabilizer is also a depropanizer; but at Sarnia the term "depropanizer" is reserved for the two towers, which perform this function at the Kellogg unit and the 17-23 stills. These towers have certain distinguishing characteristics:

1. The feed goes in on the top plate, so no reflux is required.

2. The overhead goes off as a gas, and is piped eventually to the Low Pressure Gas Absorption Plant.

3. Because the overhead is a gas and no condenser is used, the tower operates under a lower pressure than is required by the stabilizer, i.e., about 50 p.s.i. instead of 200 p.s.i.

4. The cut is not as sharp as it is in the stabilizer; that is, the overhead contains appreciable amounts of C₄ and C₅ cuts. These are recovered in the Gas Absorption Plant.

9. Solvent Recovery Towers

Solvent extraction systems recover the solvents used by distillation in standard bubble towers under either vacuum or atmospheric pressure. At Sarnia there are two such systems, the ketone process at the dewaxing plant, and the phenol process for lube treating. The mixed ketones are recovered from the slack wax and from the oil filtrate by heating in pipe stills and flashing into bubble towers. Each stream passes through two sections of the tower, one under vacuum, the other at atmospheric pressure.

In the phenol plant, phenol is recovered from both the spent phenol and the raffinate in conventional bubble towers with pipe still reboilers and tubular condensers.

10. Distillation Auxiliaries

Reboilers

A reboiler is any equipment in which liquid drawn from the bottom of the tower is vaporized and returned to the tower below the bottom tray. For high-boiling materials the reboiler is a small pipe still; for low-boiling material the reboiler is identical with the tube and shell exchanger illustrated, except that steam condenses in the tubes, while liquid enters the shell side at the bottom and vapor leaves at the top. At the Kellogg unit, the reboilers for the rerun tower and the depropanizer are heated by hot streams from other parts of the unit.
HEAT EXCHANGERS

TANK AND TUBE TYPE

TANK AND TUBE TYPE WITH TUBE PASSAGES

SHELL AND TUBE TYPE WITH TUBE PASSAGES

COLD LIQUID INLET

HOT LIQUID INLET

HOT LIQUID OUTLET

COLD LIQUID OUTLET

360°F.

150°F.

125°F.
Condensers

A condenser removes heat from a vapor, and so converts it to liquid. Condensers are classified as total condensers or partial condensers, depending on whether the vapor is completely or partly condensed. The oldest type of condenser is the tube and tank condenser, which consists of a series of pipe coils immersed in a tank of water. This is called a condenser box and the coils, a condensing worm. This type has a large water consumption, and thus a low efficiency. To increase the efficiency, the amount of surface per length of pipe may be increased by using a ribbed construction. The so-called Sterling sections used in refineries are examples of this ribbed construction.

Shell and tube type condensers, like the one illustrated, are now frequently used despite their high first cost because they are compact, accessible for repairs, convenient to clean, very efficient and require a minimum of space. In this type of condenser, vapor is directed by means of baffles around a nest of tubes through which water or cold oil flows. The water at the same time enters the bottom series of tubes and leaves through the top series. The number of series of tubes through which the water flows are called passes. Due to the high velocity of the water through the tubes, heat transfer rates are high and the inside surface of the tube is kept clean by the swirling action of the water. Cleaning tubular condensers is simple because the whole tube bundle may be removed from the shell.

In operation, the correct amount of water to be used in condensers of this type is dependent on two factors - the required outlet temperature of the condensate, and the outlet temperature of the water. At Sarnia the water outlet temperature is usually set at a maximum of 120°F, since above this temperature scale will deposit on the tubes. This scale is known as temporary or carbonate hardness. The outlet temperature of the condensate is governed largely by the product in question; e.g., light volatile products must be cooled to relatively low temperatures to prevent excessive evaporation losses.

Coolers

Tube and tank and shell and tube equipment, when used to cool an oil stream to a safe temperature, is called a cooler. Coolers follow condensers in the arrangement of the overhead equipment of a distillation unit. Water must continue to flow through shell and tube condensers and coolers while they are in use. If water fails to flow, the relatively small amount of water in the tubes is soon changed to steam with consequent development of high pressures. Oil vapors do not condense when water failure occurs with consequent danger of fire when the vapors leave the unit uncondensed. Failure of the water supply to tube and tank condensers is not so serious due to the large volume of water in the tank.

Exchangers

Heat exchangers are devices for transferring heat from hot streams to cold oil streams. They thus serve as condensers and coolers, using cold oil instead of water as the cooling substance. In any distillation process, heat is added to the feed and later removed from the distillation products. If the hot product streams can be made to give up part of their heat to the cold feed streams, both fuel and water consumption will be reduced. To effect this saving, heat exchangers are very widely used in refineries.

Modern heat exchangers are nearly all of the tube and shell type with floating heads on the tubes (see illustration) to allow for the unequal expansion
caused by liquids at different temperatures. The liquid to be heated is usually passed through the tubes, while the liquid to be cooled is taken through the baffled shell. If one of the liquids is likely to deposit solids it is passed through the tubes instead of the shell. The high velocity in the tubes will help keep the solids in suspension.

Exchangers may be either liquid exchangers or vapor exchangers, depending on whether the material being cooled is liquid or vapor. If the vapor is cooled and partly condensed, the apparatus is called a partial condenser. Exchangers become dirty from corrosive products in the vapors or deposits from the liquids, and they must be periodically cleaned. Salt deposits are usually flushed out with hot water; scale may be removed by dipping the whole bundle in dilute acids or alkalis. When starting up units, or putting exchangers into service, it is essential that hot liquids be turned into cold exchangers very slowly. If the hot liquid is suddenly admitted to a cold exchanger, the sudden expansion of the tubes will loosen them from the tube sheets and gaskets will leak. It is a usual practice to warm up all equipment slowly by circulating gas oil, which is gradually heated.

It should be noted that liquid heat exchangers, vapor heat exchangers, partial condensers, total condensers, reboilers and coolers of the shell and tube construction are essentially alike.

Steam Lifts

In the 17-23 Continuous Crude Shell Still Battery, oil is withdrawn from the bottom of each shell still and fed into the bubble tower on the next still. Instead of using a pump to lift the oil, the drawoff line for the still bottoms is bent into a U-shape, and steam is injected into the outlet side near the bottom of the U. Since a mixture of steam and oil weighs less than oil alone, the column of oil on the inlet side of the U will lift a longer column of oil and steam up the outlet side to a higher level. At this level the oil-steam mixture spills into the bubble tower on the next still. Since the lifting action depends on the density in the two sides of the U, oil can be lifted only short distances by this means.

Steam Jet Ejectors

A stream of gas or liquid leaving a nozzle at high velocity is called a jet. A jet has the property of dragging the air near the nozzle into the stream. This can be observed in still air by letting tobacco smoke drift near the nozzle of a garden hose. If the velocity of the water leaving the nozzle is great enough, the movement of the smoke will show the flow of air into the jet. This is the principle whereby air is removed from vacuum distillation units.

The evacuating apparatus for distillation units is known as an ejector or a jet pump. The jets in the ejector are formed by high pressure steam, passing through nozzles. Ejectors in which the nozzles are arranged in a radial pattern are sometimes called radojets. An ejector is essentially a specially-shaped large pipe, into one end of which one or more steam jets discharge. Near this end a second pipe connects the ejector with the distillation unit. Air and gases are sucked up this pipe by the action of the jets and discharged out of the ejector with the steam. The exhaust steam may be blown into the atmosphere or condensed. If higher vacuum is needed, two or more ejectors are placed in series with condensers between them.
The diagram shows a single ejector with three nozzles.

**MULTIPLE NOZZLE EJECTOR.**

**Barometric Leg Condensers**

In vacuum distillation, the overhead vapors and steam from the tower are condensed, and only the uncondensed gases (chiefly air) go to the steam ejector. The condensed water and oil are separated in a drum, and the water is removed to the sewer. However, the separating drum, like the rest of the equipment, is under vacuum created by the diminution of volume that takes place when the steam and oil vapors condense to liquids, and by the steam jet ejectors. Since there is an atmospheric pressure of about 14.7 pounds per square inch absolute outside the drum, the water cannot flow out. To remedy this, a vertical pipe 30 feet or more in length connects the water outlet to a well below, which drains to the sewers. Water from the drum fills this pipe to a depth such that the weight of the water in the pipe is exactly equal to the atmospheric pressure. If more water enters the pipe, the weight of water is then greater than atmospheric pressure and the excess water flows into the well. In this way, the water that accumulates in the drum is removed.

The pipe in which the column of water balances the atmospheric pressure is the barometric leg. The height of the column of water varies with the atmospheric pressure and with the vacuum maintained in the distillation unit. At sea level, under the standard atmospheric pressure of 14.7 pounds per square inch absolute and perfect vacuum, the water column would be 33.93 feet.
II - ABSORPTION

Gas produced by refining operations is made up chiefly as follows:

Crude Distillation

(Kellogg Crude Tower, 17-23 Battery)

- C₁ cut - Methane
- C₂ cut - Ethane

Cracking Operations

(Kellogg Coking Section, #2 Plant Cracking Coils)

- C₁ cut - Methane
- C₂ cut - Ethylene
Section 5

C₃ cut - Propane  

C₄ cut - Isobutane  
   n-Butane

C₅ cut - Isopentane  
   Pentane

C₃ cut - Propylene  
   Propane

C₄ cut - Isobutylene  
   Isobutane  
   n-Butylenes  
   n-Butane

C₅ cut - Isopentylene  
   Isopentane  
   n-Pentylene  
   n-Pentane

The C₅ cut is present in small amounts, as vaporized liquid. Some C₆ cut may also be present.

The C₄, C₅ and C₆ cuts in the gas mixture are valuable, since they give needed volatility (increased vapor pressure) to motor gasoline, and by their high octane number, increase the octane number of motor gasoline. Consequently, these valuable fractions must be recovered. They are recovered in Gas Absorbers.

1. Absorbers

   The molecules in each of the above cuts have different powers of attracting other molecules. Thus, at any given temperature, the different cuts have, for example, different degrees of solubility in an oil. The more carbon atoms in a molecule, the more soluble it is in the oil. Butane, for example, has a greater tendency to remain in the oil than propane. By mixing the gas mixture with an oil, the larger molecules (C₄, C₅ and C₆ cuts) tend to remain in the oil, while the smaller molecules (C₁, C₂ and C₃ cuts) tend to stay out of the oil. Consequently, the desired C₄, C₅ and C₆ cuts can, for the most part, be separated from the C₁, C₂ and C₃ cuts. This is the principle on which Gas Absorbers are based.

   The Gas Absorber (see diagrams Section 8 and Page 14) is a bubble tower, into the top of which the absorption oil (menoolum or lean oil) is passed. As it flows from tray to tray down the tower, the gas mixture which enters the bottom of the tower, bubbles through the oil on its way to the top. The gases leaving the top (dry gas) are essentially a mixture of only C₁, C₂ and C₃ cuts. The absorption oil with the dissolved C₄, C₅ and C₆ cuts (called rich or fat oil) leaves the bottom of the tower to enter a distillation tower called a stripper, where the C₄, C₅ and C₆ cuts are distilled out.

2. Strippers

   Strippers used in conjunction with gas absorbers are bubble towers, with the usual arrangement of trays and caps, and are operated in the usual manner. Steam is usually added to aid in the distillation.

The Absorption Plant at Sarnia has two absorbers, each with its own stripper still. Both absorbers are 3½ feet in diameter, 58 feet high and have 23 trays. One absorber, the Low Pressure Absorber, operates at 30 pounds per square inch gauge and at 80°F. The High Pressure Absorber operates at 75 pounds per square inch gauge and also at 80°F. The two strippers, called the Low Pressure Still and the High Pressure Still, have 18 trays. The overhead from both stills combine to form the absorption gasoline stream that is
refractionated in the stabilizer. The bottoms from the stills is lean absorption oil, which is recycled to the absorbers.

III - TREATING

1. Lye Wash Plants

Equipment used in the lye wash and naphtha treating plants consists of Leaver mixers and settlers. A Leaver mixer is a large pipe containing sections of smaller perforated pipes, known as bullets, as shown in the illustration below. The turbulence created by the passage of naphtha and treating solution through these small holes mixes the two intimately. After being mixed, they pass to the settlers, which are horizontal drums in which the lead lye or lye solution settles out and can be drawn from the bottom, while the sweetened naphtha is drawn from the top. The treating solution is recirculated, while the naphtha is washed with water in another Leaver mixer and settler.
Sarnia treats straight run naphtha, aviation base stocks, and specialty naphthas in Continuous Lye Wash Plant No. 5. This is illustrated in Section 8. Debutanized cracked naphtha is treated in Continuous Lye Wash Plant No. 3.

2. Refinery Agitators

Kerosene and Longtime Burning Oil are sweetened in batch agitators called Refinery Agitators, which are vertical, cylindrical tanks with conical bottoms and low domed roofs equipped with explosion hatches, which fly open and close again if an explosive mixture of vapor and air should ignite. The treating agent, either sulphuric acid, caustic soda or lead lye, is mixed with the light oil by blowing air into the cone. When the treating is complete the air is shut off, and the material separates into two layers, which are drawn off separately. Since acid treating takes place, the agitator is lead lined, because the dilute acid solution formed in the subsequent water wash is very corrosive. A typical agitator is shown on Page 16.
3. Paraffin Agitators

Lubricating Oils are treated in the Paraffin Agitators, which resemble the refinery agitators, except that they have globe-shaped roofs. A low roof (and consequently small vapor space) is not necessary for paraffin agitators because there is not the same explosion hazard in handling lubes that there is in handling light oils. Paraffin agitators for acid washing do not have linings, since they handle only concentrated acid, which does not attack steel. The acid treated stocks are not washed with water. Traces of acid left in the oil are usually neutralized by clay treating. In special instances, the lube oils are lye washed to remove traces of organic acid.
4. Phenol Tower Treaters

Lubricating oil is treated with phenol in a counter current treating system. Formerly a series of mixers and settling drums was used, but now the treating is done in two towers fitted with special baffle plates and perforated downspouts. A view of two of these plates is shown in the accompanying diagram. Phenol passes onto one plate through the perforations in the side downspouts, flows across the solid plate and down the central downspout. The central downspout has perforated sides and is blocked by a solid plate halfway down, so the phenol passes through the perforations in fine streams and descends to the plate below. The oil is injected into the lower part of the tower and passes up through the downspouts and baffles, mixing with the phenol at every baffle. The

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**Diagram Description:**

- **TREATED OIL**
- **PHENOL SPRAYS**
- **WIR**
- **CIL**
- **OIL SPRAY**
- **PHENOLIC WATER SPRAYS**
- **PHENOL SPRAYS**
- **DOWNSPOUT**
- **WIR EDGE**

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Section 5

treated oil separates from the phenol at the top of the tower and is drawn off, while the spent phenol containing the undesirable extracted matter passes out of the tower bottom and is recovered.

5. Clay Contactors

Lubes and refined waxes are treated with special active clays (Filtrol, Attapulgus or Fuller's Earth) to improve the colour, remove off-odour compounds, and neutralize excess acids.

Acid treated oils are mixed with laboratory determined quantities of Attapulgus or Filtrol in a mixing tank. The mixture is pumped through a pipe still, where it is heated to about 450°F. and into a flash drum, where moisture flashes off. From the flash drum the oil and clay pass to the rotary filters, which will be described in section VII.

Phenol treated lubes are treated with Filtrol clay chiefly to improve the colour, and are filtered on rotary filters of the Oliver type. Formerly Sweetland filter presses and Shriver presses were used to remove the clay, but the precoat Olivars are more efficient.

Refined waxes are treated in steam-jacketed, air-agitated agitators similar to the Refinery and Paraffin Agitators. The clay is settled and drawn off, while the decolorized wax is filtered through two small plate and frame presses to remove the small amount of suspended clay. Attapulgus and Filtrol are used for the pale raw wax, but only Fuller's Earth is used for the refined wax.

IV - DEWAXING

1. Centrifuge Dewaxing

Stocks containing non-crystalline waxes (chiefly cylinder stock) are dewaxed by the centrifuge method. Cylinder stock is mixed with about 65% its volume of naphtha and chilled slowly in tanks to about 10°F., and then chilled in rapid-chilling tanks to a predetermined temperature between -10°F. and -30°F. The wax settles out as a dark, muddy jelly, which cannot be filtered because it plugs the filter cloths. The mixture of oil, naphtha and non-crystalline wax (slurry) is fed into a super-centrifuge of the type illustrated, consisting essentially of a narrow tapered cylinder revolving at 17,000 to 19,000 r.p.m. The wax is heavier than the diluted oil, so it is thrown to the outside of the bowl, while the oil-naphtha mixture is drawn continuously from the centre of the bowl at the top. The amorphous wax flows under the high pressure exerted on it and discharges continuously from a lower point in the bowl.

2. Solvent Dewaxing

The flow diagram for the process is shown in Section 8. The following equipment is required in the operation.

When the waxy lubricating stock is first mixed with the solvent ketone, both wax and oil are dissolved in the ketone. By cooling, a temperature is reached at which the wax crystallizes out as a solid, while the oil remains in solution in the ketone. The rate of cooling is important, since rapid cooling causes many small wax crystals, which tend to plug the filter cloths, while
slow cooling forms large easily filtered crystals. By a controlled rate of chilling and filtering operation can be obtained.

**Chillers**

Chilling is carried out by passing the keytone-waxy oil mixture through a pipe (6") which is centered within a larger pipe (8"). The cooling medium passes in the space between the inner and outer pipes. Since the wax crystals that form will settle out on the pipe, they must be continuously scraped from the pipe by means of longitudinal blades caused to rotate by a driven shaft through the pipe centre. A chiller will consist of a dozen or so such double pipes about 30 feet long arranged in a connected series. The shafts of the scrapers, which protrude from the end of the chiller, are all driven by a single chain drive.

Two chillers, Carbondale and York, are used in the Sarnia Dewaxing Plant. Controlled chilling is accomplished by means of cold dewaxed oil from the filters passing through the first chiller. In the second chiller, the "shock" chiller, cooling is caused by evaporation of liquified amonia.
Sweaters

The slack wax recovered from the Dewaxing Plant contains from 5 to 20% oil, most of which must be removed to produce a refined wax. Although this operation is not carried out in the Solvent Dewaxing Plant itself, it is described at this point, since it is closely associated with the dewaxing process.

The operation is carried out in sweating pans, as shown in the illustration. The sweating pans are shallow trays about 10 feet wide and 40 feet long dished slightly toward the centre to allow draining. A bank of eight pans arranged one above another are enclosed in a room with steam coils on the walls. In each pan is a horizontal 50 mesh screen and above each pan is a coil of pipe through which cold water or steam may be circulated.

Cold water is flowed into the pans to the level of the screens. Molten wax is then flowed on top of the water, which causes the wax to solidify. The water is then drained off and the wax remains on the screen. The steam is then passed through the coils on the walls and the temperature of the room slowly raised. As the temperature rises, the oil sweats from the wax and drips into the pan from which it is drained as foets' oil. When sufficient oil has sweated out (as determined by the gravity and melting point of the wax), the wax is melted by steam passing through the coil above each pan and the wax run to tankage. Only wax derived from 160/170 Paraffin Distillate is sweated; waxes from the higher viscosity pipe still streams can not be sweated.

Wax Presses

Refined wax in the 133 to 136°F. A.M.P. range is cast into blocks in large, horizontal, hydraulic presses, through which water is circulated to hasten the solidification of the wax.

Parowax (A.M.P. 123 to 126°F) is pressed into smaller blocks in a similar press.

V - ASPHALT MANUFACTURE

Asphalt is produced from two refinery streams (1) from cracking coil tar, which is a liquid at ordinary temperatures, and which must be flashed to produce asphalt, and (2) from vacuum flash coil pitch, which can be used directly, or which may be oxidized to raise the softening point.

1. Flash Coil

The flash coil for production of asphalt from cracking coil tar is a simple piece of equipment consisting of a pipe still, which discharges into a flash drum kept under vacuum by steam jet ejectors. The hydrocarbon vapor formed in the flash drum is condensed and returned to cracking coil stock. The operation is similar to lubricating oil distillation with the following simplifications:

(a) Elaborate fractionation is not necessary, so no plates are required; instead, a simple flash drum is used.

(b) Higher temperatures can be maintained without damaging the asphalt. Lubes cannot be heated over about 700°F, while asphalts are often heated to 780°F.
2. Asphalt Oxidizers

To obtain asphalt with higher softening point and lower penetration, flash coil pitch is oxidized. It is heated to about 450°F. and discharged into a vertical tank where air is blown through it. Cooling coils in the body of the tank circulate oil from a cooler to keep the temperature down to about 500°F. The air and products of oxidation are conducted from the top of the drum and cooled in a water spray. The asphalt is blown for 5 to 10 hours, depending on the product required, and is then pumped out of the oxidizer.

3. Flash Corrector

Some cracking coil tar is used directly as bunker fuel oil. For this purpose, it must have a minimum flash point of 150°F. To make the tar meet this requirement, it is pumped from the cracking coils at about 400°F. into a drum maintained under vacuum. The most volatile material flashes off, leaving a satisfactory bunker fuel as residue. Note that this flash correction occurs at much lower temperature than flashing to asphalt.

VI - CRACKING

1. Cracking Coils

Cracking coils are pipe still furnaces designed to allow the oil to heat to 900°F. to 1100°F. and to hold it at that temperature for the necessary time. Because the temperatures and pressures in cracking coil furnaces are
high, special materials are used in their construction.

The first tubes in the furnace are extra strong, mild steel tubes, but the last ones in the radiation section may be at temperatures above 1000°F., at which temperatures mild steel may fail, so alloy tubes, usually chromium-nickel steels, are used for these high temperature locations. High pressures used in cracking coils necessitate extra strong or double extra strong pipe.

The fire brick which lines the furnace must also be of different type if oil temperatures over 1000°F. are encountered. At lower temperatures the brick walls will support themselves, but at higher temperatures they are weakened until they are no longer safe. Then each brick is specially shaped, so it can be hung from a steel bar. The convection section is at a lower temperature, so ordinary walls are satisfactory. The roof bricks of both sections are hung from steel work.

2. Soaking Drums

In older (thermal) cracking processes, the hot oil from the cracking coil was discharged into soaking drums, where the cracking was completed. These soakers are forged steel cylinders, 35 feet high, 6 feet in diameter, with walls 5 inches thick to enable them to withstand the pressure. Soaking drums are not used at Sarnia refinery in suspensoid cracking operations. The soakers on the 3 and 4 cracking coils are now used as catalyst towers for production of cumene. For this service, they are filled with a catalyst of phosphoric acid supported on kieselguhr.

VII - FILTERS

1. Rotary Vacuum Filters

The slurry of oil, ketone and wax from the chillers at the dewaxing plant is filtered by four large Oliver filters. The Oliver continuous rotary vacuum filter consists essentially of a large drum, 8 feet in diameter, 14 feet long covered with the filter medium (canvas in this case) and mounted on bearings so it can be rotated slowly. The drum is divided into segments by partitions running from the centre to the canvas. Each segment has one or more small pipes connecting to central headers, which, in turn, open onto the surface of a large disc (about 30" in diameter) mounted on the end of the rotating shaft outside the bearing. Bearing against this disc is another disc which does not rotate. The stationary disc has elongated openings or ports, which connect with the piping system to the various filtrate tanks and vacuum pumps. These ports are opposite the header openings on the rotating disc, so as the drum revolves each filter segment is, in turn, connected to the different lines that connect the filter to the rest of the plant. The whole drum dips into a tank containing the feed slurry. The drum and feed tank of the dewaxing plant filters are housed in an air-tight casing to prevent loss of the volatile solvent. The illustration shows an Oliver filter without a filter case.

The filter operates as follows:

(a) As each segment dips below the slurry surface, it is connected by the rotating valve mechanism just described to a filtrate tank and a vacuum pump. Thus a vacuum is formed in the segment dipping into the feed. The suction due to the vacuum draws the oil and ketone through the canvas into the segment, while the wax adheres to the canvas outside the segment. The filtrate (ketone and oil) drawn into the segment is caused by the vacuum to leave the filter through the ports in the valve mechanism to the filtrate tank.
(b) When the segment with its layer of wax rises out of the slurry, sprays of ketone wash most of the remaining oil out of the wax cake. At this stage, different ports on the valve connect with the proper header, and the wash ketone is drawn off to separate tanks.

(c) During the next part of the revolution, gas is sucked through the wax cake to displace as much ketone as possible from the cake.

(d) In the final part of the revolution, still other ports are connected, and gas is blown through the canvas from inside the segment to loosen the wax cake. Finally, a long scraper blade which almost rests against the face of the drum, lifts the wax from the canvas and dumps it into a trough, where a screw conveyor carries it away.

(e) The drum at this point has made one complete revolution, and the segment under discussion is ready to begin the above cycle of operations over again.

2. Rotary Pressure Filters

Clay is filtered from lubricating oil, at the Clay Contract Plant in rotary pressure filters of the Oliver type. Clay is also filtered from C.C. tar at the Tar Filter Plant by similar filters. The operation of the pressure filters is like that of the vacuum filters, with the following differences:

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(a) Pressure is applied to the feed to force it through the filter medium, instead of having vacuum draw the feed through. A larger pressure differential can be obtained by this method. To maintain the pressure, the whole filter is enclosed.

(b) The filter medium is not canvas, but fine metal screen, which withstands high temperatures better. To remove the finest particles of clay, a "precoat" layer of diatomaceous earth (celite) is applied to the surface of the screen. Thus the actual filter is not the screen, but the porous layer on the screen. Not only does the precoat remove the suspended matter more completely, but also it speeds up the filter operation. The outer surface of the precoat must be continuously removed, as it plugs up with fine particles, and slows down the operation. This is done by a knife edge which shaves off a thin layer of precoat on each revolution of the drum.

(c) Since the rotating drum is covered with a layer of precoat material, air blow cannot be used as in vacuum filters to dislodge the filter cake, since this would remove the precoat as well.

VIII - REFINERY SEPARATORS

All drains in the refinery lead to rectangular cement boxes known as separators or traps. Here any oil in the water separates and is drawn off to be reprocessed, the water being run into the river. It is important that this water discharged to the river be free of oil, otherwise it would seriously pollute the river.
 UTILITIES

The subject of utilities usually covers the following items as applied to oil refineries: Steam, Water, Electricity, Air and Fuel. Utilities are usually accepted as being present without a great deal of thought being paid to them in everyday operation of the plant. However, utilities and their costs have a definite effect on the size and types of equipment employed in an oil refinery and on the economy of refining operations. Under modern conditions, the cost of utilities will represent a substantial amount of the total manufacturing costs. To maintain satisfactory operation close control of operating costs is necessary and this in turn means close control of utilities.

In studies made at the Sarnia Refinery, as little as 10% reduction in fuel and steam on individual refining units has shown a substantial decrease in operating costs.

STEAM

Steam is an invisible water vapour. When steam is released to the air it becomes a white cloud due to partial condensation to water. At 212°F. and 14.7 lbs./sq. in. absolute, 1 cu. ft. of water produces 1676 cu. ft. of steam, or 1 lb. of water produces 26.82 cu. ft. steam.

When water at 212°F. is converted to steam at 212°F. and 14.7 lbs./sq. in. absolute, 970 B.T.U.'s of heat are absorbed, and a similar amount of heat is released when one lb. of steam is condensed at 212°F. and 14.7 lbs./sq. in. absolute. This is called "latent heat of evaporation". It follows from this that 1 cu. ft. of water at 212°F. will require 62.5 x 970 = 60,600 B.T.U.'s to convert it to steam, and this will occupy 1676 cu. ft. This same amount of heat is given up when this amount of steam is condensed. When a steam meter records a certain number of pounds of steam per hour (e.g. 7,000 lbs./hr.) this means the meter has measured a volume of steam that, if it were all condensed, would weigh 7,000 lbs. If the steam in the main were at 212°F. and 14.7 pounds absolute then the actual volume that would pass through the meter would be 26.82 x 7,000 = 187,740 cu. ft. However, the steam is at a considerable pressure so that its actual volume would be considerably less than this.

Uses

Steam is used in the refinery for driving pumps and turbines. It is also used for steam stripping, steam heated reboilers and heating of buildings. On occasion, steam may be used for smothering fires in furnace headers, tank roofs and other enclosed places. The air in the area is displaced by the steam and the fire thus ceases due to lack of oxygen that is necessary to support combustion.

The steam coming from pumps is called exhaust steam, that is the steam is at a lower pressure and temperature after performing work on the pumps. This steam can be used for tank heating, building heating and preheating the feed water to the boilers in the boiler houses.

Generation

There are three boiler houses in the Sarnia Refinery as follows:

(a) #1 Boiler House, situated at #1 plant has a total of 18 boilers with a total rated boiler horse power of 5218. These 18 boilers consist of 10 horizontal return tube boilers and eight sectional water tube boilers.
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All 18 boilers are connected to a common steam header. However #17 and #18 boilers can be connected to the high pressure steam mains.

There are several units in both plants that use high pressure steam due to its higher temperature and there is only one boiler at one time in each plant in this service.

(b) #2 Boiler House which is also situated at plant #1 has three horizontal return tube boilers with a total boiler horse power of 555.

(c) #3 Boiler House situated in plant #2 has four water tube boilers and four horizontal return tube boilers. These eight boilers have a total boiler horse power of 2068.

A boiler horse power is the equivalent of the evaporation of 34.5 lbs. of water/hour with feed water at 212°F. This is usually taken as the evaporation on 10 sq. ft. heating surface. Thus a boiler horse power may be stated as the evaporation of 34.5 lbs. of water/hour on 10 sq. ft. of heating surface. Thus if a boiler is operating at its rated capacity, it is evaporating 34.5 lbs. of water on each 10 sq. ft. of its heating surface and if operating at an overload or overrate capacity it is evaporating more than 34.5 lbs./hr of each 10 sq. ft. of heating surface.

Thus 200% overrate would be 69.0 lbs./hr./10 sq. ft.

Feed water for the boilers in both plants is drawn from the plant service water mains during normal operations. In case of an emergency, connections are provided to the Sarnia city water mains. Feed water from the St. Clair River is pumped through a sand filter and then through zeolite water softeners. This treatment removes temporary or carbonate hardness, thus preventing scale from depositing on the walls or tubes of the boilers. The scale is similar to that found in tea kettles.

After treatment the boiler feed water is deaerated (removal of dissolved air) by heating the feed water to its boiling point. This is done by direct contact with process exhaust steam which is returned to the boiler house from the operating units of the plant. By means of this heating, air is driven from the feed water, passed through a condenser and then vented to the atmosphere. The purpose of the condenser is to condense any steam in the air. The condensate falls back into the heater. From the deaerating heater, the feed water passes through economizers which are essentially heat exchangers. The feed water is preheated in the economizer by the hot gases of combustion passing up the stacks.

For the generation of steam in the boiler house, a relatively large number of fuels are used which may be divided into the following groups:

(a) Gas - 1700 B.T.U./cu. ft. - produced from refinery units.

(b) 1. Bunker fuel - commercial fuel oil 6,260,000 BTU/bbl.

2. Acid Sludge - heavy sludge from acid treating 4,030,000 BTU/bbl.

Acid Oil - light sludge from acid treating 5,440,000 BTU/bbl.

3. Phenol Extract from phenol plant. 6,742,000 BTU/bbl.

4. Non-Commercial waxes - high M.P. waxes 6,062,000 BTU/bbl.

5. Slops - from bottoms of slop tanks 6,100,000 BTU/bbl.
6. Line washings from washing oil lines 6,260,000 BTU-bbl.

(c) Solid Fuels.

1. Coal—purchased.

2. Pit Mix—coal, coke breeze, and separator deposits.

It is apparent that a number of the fuels burned in the boiler house constitute non-commercial fuels. The most economical way to dispose of them is to burn them in the boiler house and generate steam. Since a record of fuel costs is kept considerable book-keeping is necessary due to the wide range and quality of the fuels burned in the boiler house.

The average fuel efficiency in Sarnia boiler houses is approximately 70%. This means that the theoretical amount of heat required to produce the number of pounds of steam measured is 70% of the total heat input to the furnace. Calorific values (B.T.U. per pound or per barrel or per cubic foot) must be obtained frequently as a check on the heating values of the fuels since they are not uniform.

Boiler Operation

A definite rotation of shutting down, cleaning, and inspection of the boilers is necessary for maximum efficiency and safety. Under heavy winter loads, the boilers run at 200% overload or better for considerable periods of time.

A system of continuous blowdown is used on each boiler. This means that a small portion of the water from the bottom of the boiler is drawn off to remove any sediments such as mud or rust that has been deposited. These lines are rather small (1/2") In addition to the continuous blowdown, each boiler is blown each day for 1/2 to 1 minute through a main blow down line (2"). This removes any sediment that did not get out the small line.

The heat from the water in the continuous blow down is recovered by giving it up to the feed water in a heat exchanger. This continuous blowdown amounts to approximately 3% of the water fed to the boilers.

The daily blow down may have to be more frequent if the river water is noticeably turbid or if the boiler is operating under heavy load. If this is not done frothing and foaming will result giving false levels and this in turn will make the regulator open and close rapidly instead of letting the water in at a uniform rate. No. 1 and No. 2 Boiler Houses are not equipped to superheat steam but the four Kidwell boilers in No. 3 Boiler House give about 30°F. of superheat. The steam leaving the boiler houses in the steam mains generally has 2 to 3% water and is produced at a pressure of 120 to 125 lbs.

The steam is metered to the various processing units and the steam costs per unit are calculated accordingly. The high pressure steam systems in both plants are used where steam of a higher temperature and pressure than the normal steam are needed. The whole system cannot be operated at these pressures due to the fact that some of the older boilers do not meet safety specifications for operation at pressures over 125 lbs. per sq. in.

Under winter loads, steam production at Sarnia refinery is roughly 420,000 lbs./hour. This is the equivalent to converting into steam 42,000 Imperial gallons or 1200 barrels of river water per hour.
Section 6

WATER

Oil Refineries are usually located near adequate source of cooling water and in this respect Sarnia Refinery is fortunate. The total water pump capacity at Sarnia Refinery is 69,160,000 Imperial gallons per day. This quantity is never obtained due to the inadequacy of the water line system. Under summer conditions when the river water temperature rises to 70°F., 37,000,000 Imperial gallons per day is the maximum load. During winter months this quantity is appreciably less. Service water is not metered at the various units, and constitutes the least expensive of all utilities. Nevertheless, its use should be restricted in order that the existing facilities such as pumps and lines as well as sewers and separators are not over taxed. The water pump house also supplies water for the fire fighting system. At various points in the plant there are fire pumps that take suction on the service water line and discharge into the fire water line to boost up the pressure. It is important to point out that no changes in the settings of the valves on the water system should be made without the approval of the Fire Marshal or shift foreman or operating foremen. If some of the wrong valves are moved it is possible to cut off the water supply to a whole section of the refinery. The average pumping efficiency is 75-80%. This is the theoretical kilowatt hours necessary compared to the actual kilowatt hours used is 75-80%. Most of the pumps are electric motor driven. No. 1 plant has steam stand-by pumps.

No spare pumps are provided at #2 plant but the water systems in each plant are connected by two lines in case of failure of the pumps at No. 2 plant.
ELECTRICITY

Electricity is a most useful but at the same time a most dangerous source of power in the refinery. When controlled as it is in the operation of motors, heating units, lighting systems, recording instruments, automatic controls, etc., electricity is a most convenient source of energy. When uncontrolled it is exceedingly dangerous. Lightning is a form of uncontrolled electricity. However, there are less obvious forms of uncontrolled electricity that are equally dangerous. Electricity is generated simply by the flow of liquid through a pipe, by a belt running over a pulley, and even by dry air flowing over metal. If the pipe or other object is insulated the large amount of electricity that accumulates will discharge through the body of a person touching it. Many electrical shocks have been received by persons in the refinery by this means. These shocks are fortunately harmless to a person but if a spark is formed during the discharge and an explosive mixture of petroleum vapour is present, a disastrous explosion and fire can result. Improper use of electrical equipment or repairs to electrical equipment by those unskilled in such work can lead, not only to dangerous sparks, but to fatal electrical shocks. Consequently, electricity in general is something to be avoided by all except the members of the refinery electrical department.

Static and Current Electricity

Static electricity does not flow. This is the type that accumulates on insulated bodies as described above. The amount of static electricity that accumulates on any insulated body is measured by its "potential". The units of potential are called "volts". The greater the accumulation of static electricity, the greater its potential or the greater is the number of volts. High potential static electricity may be likened to a liquid under high pressure held in check by a valve. Discharge of the electricity is equivalent to opening the valve with a consequent rush of liquid and loss in pressure.

Since the actions which cause static electricity are going on all the time, means must be taken to prevent the accumulation of static electricity in dangerous amounts. This is done by connecting all pieces of equipment by metal wire, strips or pipe to the earth or as it is usually called, by "grounding" the equipment. The provision of a metal path for static electricity to flow into the earth is called "bonding". All equipment must be bonded at all times and care must be taken that the bonding is not harmed.

Electricity in motion is called current electricity. If the electricity flows in one direction like water through a garden hose, it is called direct current electricity. Direct current cannot be transported over long distances. Consequently use is generally made of alternating current which can be transported for hundreds of miles. Alternating current changes its direction of flow many times per second. The number of reversals per second is expressed in cycles. In Ontario, the usual electric current is a 25 cycle alternating current. Higher frequency currents such as 60 cycle are finding more favour particularly in the United States. Equipment designed for 60 cycle current cannot as a rule be used where 25 cycle current only is available.

Current electricity may be at any potential just as liquid flowing in a pipe can be at any pressure. As in the case of static electricity the potential is measured in volts. The current in home lighting systems is at 110 volts. In the refinery voltages up to 26,000 volts are available.

The amount of current flowing in a line is measured in "amperes". Just as variable amounts of liquid can flow through a pipe so variable amounts of
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of electricity can flow through a wire.

If electricity is used up in a light bulb, heating element, motor, etc. the rate with which it is used up is measured in "watts". Watts are obtained by multiplying the current amperes by the current voltage. A 300 watt bulb, for example, on a 110 volt circuit must use approximately 2.7 amperes of current. The number of watts used in an hour is known as the number of watt-hours and the number of watts used in a thousand hours is known as the kilowatt-hour or K.W.H. This is the unit by which electricity is purchased from the electric power supplier. The Sarnia refinery purchases about 77,000 K.W.H. a day from the Ontario Hydro Commission.

Electricity and Magnetic Effects

When an alternating current is passed through wire arranged in a coil, the coil acts as if it were a magnet. This is one of the chief ways in which electricity is used. By arranging many such coils in circle, and controlling the flow of current through them the magnetic effects produced causes an internal part to rotate. This is the basic idea of an electric motor. Many automatic control mechanisms as solenoids, operate by means of the magnetic effects produced by an alternating current in a coil of wire. For example, a special valve on a steam line to a stand-by turbine connected to an electric motor operated pump may be kept closed by the magnetic pull due to an alternating current flowing through the coil in a solenoid. If the current fails, the magnetic effect stops allowing the valve to open. The turbine then starts and operates the pump which would otherwise stop functioning due to the current failure.

Hazards in the Use of Electricity

A hazard may be defined as a condition that endangers life or property. The following notes will serve as a guide in avoiding hazardous conditions.

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1. All electric wires should be considered dangerous. Care should be taken to prevent any object being handled from touching electric wires.

2. In starting electric motors handle all switches according to instructions. Stand in a safe position.

3. Do not change light bulbs when switches are on.

4. Replace burned out fuses with the correct size. Never use tinfoil, coins, in place of fuses.

5. Never use an extension cord that is not in good condition.

Causes of Motor Failure

1. Continued overload resulting in overheating will burn insulation and winding of motor. Motor casing should be no hotter than the hand can stand.

2. Dirt in a motor will cause short circuits.

3. Water in a motor will destroy the insulation on the windings and will cause short circuits.

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Causes of Motor Failure (continued)

4. Use of too large capacity fuses may permit overload on motor.

5. Lack of proper lubrication will cause bearing wear.

AIR

Compressed air is supplied to all parts of #1 and #2 plants. The air systems between the two plants are connected. The air compressors used are electric motor driven, and are two stage compressors with water cooling of the air between stages. The total horsepower for the motor driven compressors is 1025. There are two steam driven stand-by compressors in plant #1 and one steam stand-by in #2 plant. Outside of settling drums and drain pots in the lines, no attempt is made to dry the air. Compressed air is used in a large number of the automatic controls and instruments throughout the refinery as well as tube cleaning, operating mechanical tools and in the laboratories. Furnace Fuel Oil is dried in #2 plant by heating with a steam coil and blowing with air. The Refinery and Paraffine Agitators and Compound Plant use air agitation but these plants have their own low pressure air compressors.

Air is used also in revivifying the spent lead-lye treating solutions. The quantities of air must be estimated as no metering facilities are provided at the individual units.

It is important that the air compressors be kept in good mechanical condition as poor efficiency of the compressors raises the cost of supplying compressed air.

FUEL

Gas and Fuel Oil are the two fuels used at most of the processing units. These fuels are carefully controlled to give steady firing conditions. These two fuels are metered and these constitute one of the major operating costs. Most of the non-commercial fuels are burned in the boiler houses.

There is considerable bookkeeping entailed in recording all these costs and this work involves the Production Control, the Instrument Department and the Cost & Yield Department.
UTILITIES

The subject of utilities usually covers the following items as applied to oil refineries: Steam, Water, Electricity, Air and Fuel. Utilities are usually accepted as being present without a great deal of thought being paid to them in everyday operation of the plant. However, utilities and their costs have a definite effect on the size and types of equipment employed in an oil refinery and on the economy of refining operations. Under modern conditions, the cost of utilities will represent a substantial amount of the total manufacturing costs. To maintain satisfactory operation close control of operating costs is necessary and this in turn means close control of utilities.

In studies made at the Sarnia Refinery, as little as 10% reduction in fuel and steam on individual refining units has shown a substantial decrease in operating costs.

STEAM

Steam is an invisible water vapour. When steam is released to the air it becomes a white cloud due to partial condensation to water. At 212°F and 14.7 lbs./sq. in. absolute, 1 cu. ft. of water produces 1876 cu. ft. of steam, or 1 lb. of water produces 26.32 cu. ft. steam.

When water at 212°F is converted to steam at 212°F and 14.7 lbs./sq. in. absolute, 970 B.T.U.'s of heat are absorbed, and a similar amount of heat is released when one lb. of steam is condensed at 212°F and 14.7 lbs./sq. in. absolute. This is called "latent heat of evaporation". It follows from this that 1 cu. ft. of water at 212°F will require $62.5 \times 970 = 60,600$ B.T.U.'s to convert it to steam, and this will occupy 1876 cu.ft. This same amount of heat is given up when this amount of steam is condensed. When a steam meter records a certain number of pounds of steam per hour (e.g. 7,000 lbs./hr.) this means the meter has measured a volume of steam that, if it were all condensed, would weigh 7,000 lbs. If the steam in the main were at 212°F and 14.7 pounds absolute then the actual volume that would pass through the meter would be $26.82 \times 7,000 = 187,740$ cu. ft. However, the steam is at a considerable pressure so that its actual volume would be considerably less than this.

Uses

Steam is used in the refinery for driving pumps and turbines. It is also used for steam stripping, steam heated reboilers and heating of buildings. On occasion, steam may be used for smothering fires in furnace headers, tank roofs and other enclosed places. The air in the area is displaced by the steam and the fire thus ceases due to lack of oxygen that is necessary to support combustion.

The steam coming from pumps is called exhaust steam, that is the steam is at a lower pressure and temperature after performing work on the pumps. This steam can be used for tank heating, building heating and preheating the feed water to the boilers in the boiler houses.

Generation

There are three boiler houses in the Sarnia Refinery as follows:

(a) #1 Boiler House, situated at #1 plant has a total of 18 boilers with a total rated boiler horse power of 5218. These 18 boilers consist of 10 horizontal return tube boilers and eight sectional water tube boilers.
All 18 boilers are connected to a common steam header. However #17 and
#18 boilers can be connected to the high pressure steam mains.

There are several units in both plants that use high pressure steam due
to its higher temperature and there is only one boiler at one time in each plant in
this service.

(b) #2 Boiler House which is also situated at plant #1 has three horizontal
return tube boilers with a total boiler horse power of 555.

(c) #3 Boiler House situated in plant #2 has four water tube boilers and
four horizontal return tube boilers. These eight boilers have a total
boiler horse power of 2068.

A boiler horse power is the equivalent of the evaporation of 34.5 lbs. of
water/hour with feed water at 212°F. This is usually taken as the evaporation on
10 sq. ft. heating surface. Thus a boiler horse power may be stated as the evapora-
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is operating at its rated capacity, it is evaporating 34.5 lbs. of water on each 10
sq. ft. of its heating surface and if operating at an overload or overrate capacity
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Thus 200% overrate would be 69.0 lbs./hr/10 sq. ft.

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the walls or tubes of the boilers. The scale is similar to that found in tea kettles.

After treatment the boiler feed water is deaerated (removal of dissolved
air) by heating the feed water to its boiling point. This is done by direct contact
with process exhaust steam which is returned to the boiler house from the operating
units of the plant. By means of this heating, air is driven from the feed water,
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hot gases of combustion passing up the stacks.

For the generation of steam in the boiler house, a relatively large number
of fuels are used which may be divided into the following groups:

(a) Gas - 1700 B.T.U./cu. ft. - produced from refinery units.

(b) 1. Bunker fuel - commercial fuel oil 6,260,000 BTU/bbl.
    2. Acid Sludge - heavy sludge from acid treating 4,080,000 BTU/bbl.
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    3. Phenol Extract from phenol plant. 6,742,000 BTU/bbl.
    4. Non-Commercial waxes - high M.P. waxes 6,062,000 BTU/bbl.
    5. Slops - from bottoms of slop tanks 6,100,000 BTU/bbl.
6. Line washings from washing oil lines 6,260,000 BTU-bbl.

(c) Solid Fuels.

1. Coal - purchased.

2. Pit Mix - coal, coke breeze, and separator deposits.

It is apparent that a number of the fuels burned in the boiler house constitute non-commercial fuels. The most economical way to dispose of them is to burn them in the boiler house and generate steam. Since a record of fuel costs is kept considerable book-keeping is necessary due to the wide range and quality of the fuels burned in the boiler house.

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Boiler Operation

A definite rotation of shutting down, cleaning, and inspection of the boilers is necessary for maximum efficiency and safety. Under heavy winter loads, the boilers run at 200% overload or better for considerable periods of time.

A system of continuous blowdown is used on each boiler. This means that a small portion of the water from the bottom of the boiler is drawn off to remove any sediments such as mud or rust that has been deposited. These lines are rather small (1/2"). In addition to the continuous blowdown, each boiler is blown each day for 1/2 to 1 minute through a main blow down line (2"). This removes any sediment that did not get out the small line.

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The steam is metered to the various processing units and the steam costs per unit are calculated accordingly. The high pressure steam systems in both plants are used where steam of a higher temperature and pressure than the normal steam are needed. The whole system cannot be operated at these pressures due to the fact that some of the older boilers do not meet safety specifications for operation at pressures over 125 lbs. per sq. in.

Under winter loads, steam production at Sarnia refinery is roughly 420,000 lbs./hour. This is the equivalent to converting into steam 42,000 Imperial gallons or 1200 barrels of river water per hour.
Section 6

WATER

Oil Refineries are usually located near adequate source of cooling water and in this respect Sarnia Refinery is fortunate. The total water pump capacity at Sarnia Refinery is 69,160,000 Imperial gallons per day. This quantity is never obtained due to the inadequacy of the water line system. Under summer conditions when the river water temperature rises to 70°F., 37,000,000 Imperial gallons per day is the maximum load. During winter months this quantity is appreciably less. Service water is not metered at the various units, and constitutes the least expensive of all utilities. Nevertheless, its use should be restricted in order that the existing facilities such as pumps and lines as well as sewers and separators are not over taxed. The water pump house also supplies water for the fire fighting system. At various points in the plant there are fire pumps that take suction on the service water line and discharge into the fire water line to boost up the pressure. It is important to point out that no changes in the settings of the valves on the water system should be made without the approval of the Fire Marshal or shift foreman or operating foremen. If some of the wrong valves are moved it is possible to cut off the water supply to a whole section of the refinery. The average pumping efficiency is 75-80%. This is the theoretical kilowatt hours necessary compared to the actual kilowatt hours used is 75-80%. Most of the pumps are electric motor driven. No. 1 plant has steam stand-by pumps.

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Causes of Motor Failure (continued)

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AIR

Compressed air is supplied to all parts of #1 and #2 plants. The air systems between the two plants are connected. The air compressors used are electric motor driven, and are two stage compressors with water cooling of the air between stages. The total horsepower for the motor driven compressors is 1025. There are two steam driven stand-by compressors in plant #1 and one steam stand-by in #2 plant. Outside of settling drums and drain pots in the lines, no attempt is made to dry the air. Compressed air is used in a large number of the automatic controls and instruments throughout the refinery as well as tube cleaning, operating mechanical tools and in the laboratories. Furnace Fuel Oil is dried in #2 plant by heating with a steam coil and blowing with air. The Refinery and Paraffine Agitators and Compound Plant use air agitation but these plants have their own low pressure air compressors.

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STEAM

Steam is an invisible water vapour. When steam is released to the air it becomes a white cloud due to partial condensation to water. At 212°F. and 14.7 lbs./sq. in. absolute, 1 cu. ft. of water produces 1676 cu. ft. of steam, or 1 lb. of water produces 26.82 cu. ft. steam.

When water at 212°F. is converted to steam at 212°F. and 14.7 lbs./sq. in. absolute, 970 B.T.U.'s of heat are absorbed, and a similar amount of heat is released when one lb. of steam is condensed at 212°F. and 14.7 lbs./sq. in. absolute. This is called "latent heat of evaporation". It follows from this that 1 cu. ft. of water at 212°F. will require 62.5 x 970 = 60,600 B.T.U.'s to convert it to steam, and this will occupy 1676 cu.ft. This same amount of heat is given up when this amount of steam is condensed. When a steam meter records a certain number of pounds of steam per hour (e.g. 7,000 lbs./hr.) this means the meter has measured a volume of steam that, if it were all condensed, would weigh 7,000 lbs. If the steam in the main were at 212°F. and 14.7 pounds absolute then the actual volume that would pass through the meter would be 26.82 x 7,000 = 187,740 cu. ft. However, the steam is at a considerable pressure so that its actual volume would be considerably less than this.

Uses

Steam is used in the refinery for driving pumps and turbines. It is also used for steam stripping, steam heated reboilers and heating of buildings. On occasion, steam may be used for smothering fires in furnace headers, tank roofs and other enclosed places. The air in the area is displaced by the steam and the fire thus ceases due to lack of oxygen that is necessary to support combustion.

The steam coming from pumps is called exhaust steam, that is the steam is at a lower pressure and temperature after performing work on the pumps. This steam can be used for tank heating, building heating and preheating the feed water to the boilers in the boiler houses.

Generation

There are three boiler houses in the Sarnia Refinery as follows:

(a) #1 Boiler House, situated at #1 plant has a total of 18 boilers with a total rated boiler horse power of 5218. These 18 boilers consist of 10 horizontal return tube boilers and eight sectional water tube boilers.
Section 6

All 18 boilers are connected to a common steam header. However #17 and #18 boilers can be connected to the high pressure steam mains.

There are several units in both plants that use high pressure steam due to its higher temperature and there is only one boiler at one time in each plant in this service.

(b) #2 Boiler House which is also situated at plant #1 has three horizontal return tube boilers with a total boiler horse power of 555.

(c) #3 Boiler House situated in plant #2 has four water tube boilers and four horizontal return tube boilers. These eight boilers have a total boiler horse power of 2068.

A boiler horse power is the equivalent of the evaporation of 34.5 lbs. of water/hour with feed water at 212°F. This is usually taken as the evaporation on 10 sq. ft. heating surface. Thus a boiler horse power may be stated as the evaporation of 34.5 lbs. of water/hour on 10 sq. ft. of heating surface. Thus if a boiler is operating at its rated capacity, it is evaporating 34.5 lbs. of water on each 10 sq. ft. of its heating surface and if operating at an overload or overrate capacity it is evaporating more than 34.5 lbs./hr of each 10 sq. ft. of heating surface.

Thus 200% overrate would be 69.0 lbs./hr./10 sq. ft.

Feed water for the boilers in both plants is drawn from the plant service water mains during normal operations. In case of an emergency, connections are provided to the Sarnia city water mains. Feed water from the St. Clair River is pumped through a sand filter and then through zeolite water softeners. This treatment removes temporary or carbonate hardness, thus preventing scale from depositing on the walls or tubes of the boilers. The scale is similar to that found in tea kettles.

After treatment the boiler feed water is deaerated (removal of dissolved air) by heating the feed water to its boiling point. This is done by direct contact with process exhaust steam which is returned to the boiler house from the operating units of the plant. By means of this heating, air is driven from the feed water, passed through a condenser and then vented to the atmosphere. The purpose of the condenser is to condense any steam in the air. The condensate falls back into the heater. From the deaerating heater, the feed water passes through economizers which are essentially heat exchangers. The feed water is preheated in the economizer by the hot gases of combustion passing up the stacks.

For the generation of steam in the boiler house, a relatively large number of fuels are used which may be divided into the following groups:

(a) Gas – 1700 B.T.U./cu. ft. – produced from refinery units.

(b) 1. Bunker fuel – commercial fuel oil 6,260,000 BTU/bbl.

2. Acid Sludge – heavy sludge from acid treating 4,080,000 BTU/bbl.

   Acid Oil – light sludge from acid treating 5,440,000 BTU/bbl.

3. Phenol Extract from phenol plant. 6,742,000 BTU/bbl.


5. Slops – from bottoms of slop tanks 6,100,000 BTU/bbl.
6. Line washings from washing oil lines 6,260,000 BTU-bbl.

(c) Solid Fuels.


2. Pit Mix – coal, coke breeze, and separator deposits.

It is apparent that a number of the fuels burned in the boiler house constitute non-commercial fuels. The most economical way to dispose of them is to burn them in the boiler house and generate steam. Since a record of fuel costs is kept considerable book-keeping is necessary due to the wide range and quality of the fuels burned in the boiler house.

The average fuel efficiency in Sarnia boiler houses is approximately 70%. This means that the theoretical amount of heat required to produce the number of pounds of steam measured is 70% of the total heat input to the furnace. Calorific values (B.T.U. per pound or per barrel or per cubic foot) must be obtained frequently as a check on the heating values of the fuels since they are not uniform.

Boiler Operation

A definite rotation of shutting down, cleaning, and inspection of the boilers is necessary for maximum efficiency and safety. Under heavy winter loads, the boilers run at 200% overload or better for considerable periods of time.

A system of continuous blowdown is used on each boiler. This means that a small portion of the water from the bottom of the boiler is drawn off to remove any sediments such as mud or rust that has been deposited. These lines are rather small (1/2""). In addition to the continuous blowdown, each boiler is blown each day for 1/2 to 1 minute through a main blow down line (2"). This removes any sediment that did not get out the small line.

The heat from the water in the continuous blow down is recovered by giving it up to the feed water in a heat exchanger. This continuous blowdown amounts to approximately 3% of the water fed to the boilers.

The daily blow down may have to be more frequent if the river water is noticeably turbid or if the boiler is operating under heavy load. If this is not done frothing and foaming will result giving false levels and this in turn will make the regulator open and close rapidly instead of letting the water in at a uniform rate. No. 1 and No. 2 Boiler Houses are not equipped to superheat steam but the four Kidwell boilers in No. 3 Boiler House give about 30°F. of superheat. The steam leaving the boiler houses in the steam mains generally has 2 to 3% water and is produced at a pressure of 120 to 125 lbs.

The steam is metered to the various processing units and the steam costs per unit are calculated accordingly. The high pressure steam systems in both plants are used where steam of a higher temperature and pressure than the normal steam are needed. The whole system cannot be operated at these pressures due to the fact that some of the older boilers do not meet safety specifications for operation at pressures over 125 lbs. per sq. in.

Under winter loads, steam production at Sarnia refinery is roughly 420,000 lbs./hour. This is the equivalent to converting into steam 42,000 Imperial gallons or 1200 barrels of river water per hour.
WATER

Oil Refineries are usually located near adequate source of cooling water and in this respect Sarnia Refinery is fortunate. The total water pump capacity at Sarnia Refinery is 69,160,000 Imperial gallons per day. This quantity is never obtained due to the inadequacy of the water line system. Under summer conditions when the river water temperature rises to 70°F, 37,000,000 Imperial gallons per day is the maximum load. During winter months this quantity is appreciably less. Service water is not metered at the various units, and constitutes the least expensive of all utilities. Nevertheless, its use should be restricted in order that the existing facilities such as pumps and lines as well as sewers and separators are not over taxed. The water pumphouse also supplies water for the fire fighting system. At various points in the plant there are fire pumps that take suction on the service water line and discharge into the fire water line to boost up the pressure. It is important to point out that no changes in the settings of the valves on the water system should be made without the approval of the Fire Marshal or shift foreman or operating foremen. If some of the wrong valves are moved it is possible to cut off the water supply to a whole section of the refinery. The average pumping efficiency is 75-80%. This is the theoretical kilowatt hours necessary compared to the actual kilowatt hours used is 75-80%. Most of the pumps are electric motor driven. No. 1 plant has steam stand-by pumps.

No spare pumps are provided at #2 plant but the water systems in each plant are connected by two lines in case of failure of the pumps at No. 2 plant.
ELECTRICITY

Electricity is a most useful but at the same time a most dangerous source of power in the refinery. When controlled as it is in the operation of motors, heating units, lighting systems, recording instruments, automatic controls, etc., electricity is a most convenient source of energy. When uncontrolled it is exceedingly dangerous. Lightning is a form of uncontrolled electricity. However, there are less obvious forms of uncontrolled electricity that are equally dangerous. Electricity is generated simply by the flow of liquid through a pipe, by a belt running over a pulley, and even by dry air flowing over metal. If the pipe or other object is insulated the large amount of electricity that accumulates will discharge through the body of a person touching it. Many electrical shocks have been received by persons in the refinery by this means. These shocks are fortunately harmless to a person but if a spark is formed during the discharge and an explosive mixture of petroleum vapour is present, a disastrous explosion and fire can result. Improper use of electrical equipment or repairs to electrical equipment by those unskilled in such work can lead, not only to dangerous sparks, but to fatal electrical shocks. Consequently, electricity in general is something to be avoided by all except the members of the refinery electrical department.

Static and Current Electricity

Static electricity does not flow. This is the type that accumulates on insulated bodies as described above. The amount of static electricity that accumulates on any insulated body is measured by its "potential". The units of potential are called "volts". The greater the accumulation of static electricity, the greater its potential or the greater is the number of volts. High potential static electricity may be likened to a liquid under high pressure held in check by a valve. Discharge of the electricity is equivalent to opening the valve with a consequent rush of liquid and loss in pressure.

Since the actions which cause static electricity are going on all the time, means must be taken to prevent the accumulation of static electricity in dangerous amounts. This is done by connecting all pieces of equipment by metal wire, strips or pipe to the earth or as it is usually called, by "grounding" the equipment. The provision of a metal path for static electricity to flow into the earth is called "bonding". All equipment must be bonded at all times and care must be taken that the bonding is not harmed.

Electricity in motion is called current electricity. If the electricity flows in one direction like water through a garden hose, it is called direct current electricity. Direct current cannot be transported over long distances. Consequently use is generally made of alternating current which can be transported for hundreds of miles. Alternating current changes its direction of flow many times per second. The number of reversals per second is expressed in cycles. In Ontario, the usual electric current is a 25 cycle alternating current. Higher frequency currents such as 60 cycle are finding more favour particularly in the United States. Equipment designed for 60 cycle current cannot as a rule be used where 25 cycle current only is available.

Current electricity may be at any potential just as liquid flowing in a pipe can be at any pressure. As in the case of static electricity the potential is measured in volts. The current in home lighting systems is at 110 volts. In the refinery voltages up to 26,000 volts are available.

The amount of current flowing in a line is measured in "amperes". Just as variable amounts of liquid can flow through a pipe so variable amounts of
Section 6

of electricity can flow through a wire.

If electricity is used up in a light bulb, heating element, motor, etc., the rate with which it is used up is measured in "watts". Watts are obtained by multiplying the current amperes by the current voltage. A 300 watt bulb, for example, on a 110 volt circuit must use approximately 2.7 amperes of current. The number of watts used in an hour is known as the number of watt-hours and the number of watts used in a thousand hours is known as the kilowatt-hour or K.W.H. This is the unit by which electricity is purchased from the electric power supplier. The Sarnia refinery purchases about 77,000 K.W.H. a day from the Ontario Hydro Commission.

Electricity and Magnetic Effects

When an alternating current is passed through wire arranged in a coil, the coil acts as if it were a magnet. This is one of the chief ways in which electricity is used. By arranging many such coils in circle, and controlling the flow of current through them the magnetic effects produced causes an internal part to rotate. This is the basic idea of an electric motor. Many automatic control mechanisms such as solenoids, operate by means of the magnetic effects produced by an alternating current in a coil of wire. For example, a special valve on a steam line to a stand-by turbine connected to an electric motor operated pump may be kept closed by the magnetic pull due to an alternating current flowing through the coil in a solenoid. If the current fails, the magnetic effect stops allowing the valve to open. The turbine then starts and operates the pump which would otherwise stop functioning due to the current failure.

Hazards in the Use of Electricity

A hazard may be defined as a condition that endangers life or property. The following notes will serve as a guide in avoiding hazardous conditions.

Personal Protection

1. All electric wires should be considered dangerous. Care should be taken to prevent any object being handled from touching electric wires.

2. In starting electric motors handle all switches according to instructions. Stand in a safe position.

3. Do not change light bulbs when switches are on.

4. Replace burned out fuses with the correct size. Never use tinfoil, coins, in place of fuses.

5. Never use an extension cord that is not in good condition.

Causes of Motor Failure

1. Continued overload resulting in overheating will burn insulation and winding of motor. Motor casing should be no hotter than the hand can stand.

2. Dirt in a motor will cause short circuits.

3. Water in a motor will destroy the insulation on the windings and will cause short circuits.
Causes of Motor Failure (continued)

4. Use of too large capacity fuses may permit overload on motor.

5. Lack of proper lubrication will cause bearing wear.

AIR

Compressed air is supplied to all parts of #1 and #2 plants. The air systems between the two plants are connected. The air compressors used are electric motor driven, and are two stage compressors with water cooling of the air between stages. The total horsepower for the motor driven compressors is 1025. There are two steam driven stand-by compressors in plant #1 and one steam stand-by in #2 plant. Outside of settling drums and drain pots in the lines, no attempt is made to dry the air. Compressed air is used in a large number of the automatic controls and instruments throughout the refinery as well as tube cleaning, operating mechanical tools and in the laboratories. Furnace Fuel Oil is dried in #2 plant by heating with a steam coil and blowing with air. The Refinery and Paraffine Agitators and Compound Plant use air agitation but these plants have their own low pressure air compressors.

Air is used also in revivifying the spent lead-lye treating solutions. The quantities of air must be estimated as no metering facilities are provided at the individual units.

It is important that the air compressors be kept in good mechanical condition as poor efficiency of the compressors raises the cost of supplying compressed air.

FUEL

Gas and Fuel Oil are the two fuels used at most of the processing units. These fuels are carefully controlled to give steady firing conditions. These two fuels are metered and these constitute one of the major operating costs. Most of the non-commercial fuels are burned in the boiler houses.

There is considerable bookkeeping entailed in recording all these costs and this work involves the Production Control, the Instrument Department and the Cost & Yield Department.
PIPING, PUMPS AND ACCESSORIES

Petroleum refining requires the movement of large volumes of fluid materials through many processing units. Consequently, piping, pumps and related equipment constitute an important part of every processing unit. The terms describing the many items concerned in the movement of liquids and gases should be familiar to all refinery operators. This section presents a general account of the more important pumps, pipes and their fittings.

REFINERY PIPING

Piping comprises one of the largest single items of process equipment in a petroleum refinery. The initial costs involved are high and the function of the piping system is extremely important in refinery operation. It follows that the maintenance of the piping system is important and hence requires the services of a considerable proportion of the skilled mechanics in any petroleum refinery.

Steel Line Pipe

Steel pipes are classified by the diameter of their cross sections and by the thickness of the walls. In all sizes up to 12 inches the pipe is known by the inside diameter. The wall thickness of the pipe is governed by the pressure to which the inside of the pipe will be subjected. In order of increasing wall thickness the pipes are described as standard pipe, extra strong pipe and double extra strong pipe. It should be remembered that in any pipe of a given nominal diameter the thickness of the wall is increased at the expense of the inside diameter of the pipe. For example, a 6 inch pipe has an outside diameter of 6.625 inches whether the wall thickness is standard, extra strong or double extra strong. The inside diameters have consequently been reduced from 6.65 inches for standard pipe to 5.761 inches for extra strong and to 4.897 inches for double extra strong. The outside diameter has been kept constant, so that the diameter of the threaded section will be constant.

Standard steel line pipe is the most common type used in the refinery. It can be purchased with plain bevelled ends to be joined by welding, or with threaded ends to be joined by couplings. Up to the present, most work has been done using threaded pipe, but in the future the tendency will be to weld whenever possible. Thus most pipe will be purchased with plain bevelled ends. This bevelled pipe can, of course, be threaded when necessary.

As mentioned before, the diameter of the threaded section is fixed for a given size of pipe. The diameter of the threaded section decreases towards the end of the pipe in a standard taper of 3/4 inch per foot of length. The tapered thread insures a tight joint. If, however, the diameter of the threads is smaller than that specified, or if the pipe is threaded too far so that a portion of the thread at the end of the pipe has no taper, then a "slack thread" will result and the threaded joints will not be tight.

Pipe Fittings

Pipe fittings are specially designed parts, each with its own particular function, used to join lengths of pipe or to close the end of a pipe. Some of the common pipe fittings are shown on page 2. Their construction indicates their use.
PIPE FITTINGS

Bushing  Reducer  Plug  Cap

Close Nipple  Long Nipple  Short Nipple

Swaged Nipple  Bull Plug

90° Elbow  45° Elbow  90° Street Elbow

Tee  Cross  Return Bend

Coupling  Reducer
Pipe fittings are made of cast iron or steel and can be obtained in various wall thicknesses to meet the various demands of temperature and pressure. The threading in all of the various types, however, is standard. Illustrations and descriptions of other common fittings are shown below.

![Diagram of Companion Flange]

**COMPANION FLANGE**

![Diagram of Flanged Union]

**FLANGED UNION**

![Diagram of Nut Union]

**NUT UNION**

Companion Flanges:

A companion flange is a fitting that can be screwed or welded to straight pipe and used to join the pipe to flanged valves or other fittings. When two companion flanges join two pipes together a flanged union results. A companion flange is fastened to a similar fitting by means of bolts through holes in the flange. The companion flange must have the same drilling, bolt circle, etc., as the flanged fitting to which it is bolted. As a general rule both flanges should be of the same material, that is, steel to steel, or cast iron to cast iron. When it is desired to shut off a pipe line at a companion flange, a solid plate drilled to fit the bolt holes of the companion flange is bolted in place. This is called a blind flange.

When flanges are screwed on threaded pipe, they should be "full threaded"; that is, no threads in the flange should be visible when the flange is completely on and the end of the pipe itself should be just a little back of the flange face. If the threading machines are kept in good order and uniform flanges are received from the manufacturers, there will be no trouble experienced in properly setting flanges. If, however, a "slack thread" is cut,
the pipe may run through and beyond the flange face before it will tighten up. In such cases a part of the threaded section must be cut from the end of the pipe, or a pipe with tighter thread used.

Flanged Unions: These connect pipe ends where a coupling cannot be used because the pipe cannot be rotated. A flanged union consists of two companion flanges. In the case of welded piping, flanged unions may be installed to permit temporary parting of the lines for inspection or cleaning. If a pipe line develops a leak at a coupling, the usual procedure is to split the coupling with an air or hand operated steel chisel, remove the defective part and join up the free ends of the pipes by means of a bolted flanged union. When the bolts are removed each half of the union can be screwed on to the open ends of the pipes and be used to re-join the two pipe ends due to the presence of right hand threads in both ends of the coupling. There are right and left hand threaded nipples for just such work as this, but they are used only in sizes up to 2" in steam and hot water heating systems.

Nut Unions: This type of union requires no bolts. Its three parts consist of two end pieces which are threaded inside to screw on the pipe for which they are made, and a centre piece which is machined to fit a shoulder joint on the end piece and threaded to fit the outside threading on the other end piece. Gaskets are used in some unions of this type, while others have ground joint facings. Closure of the joint in both cases is accomplished by right hand turning of the centre part of the union. The "Dart" union is probably one of the best known of the type with ground joint facings.

The data on page 5 gives information on the size, type and service for which various companion flanges and unions are used.
## FLANGES AND UNIONS

### Companion Flanges, Standard Cast Iron

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<tr>
<th>Pipe Size x Flange Diameter</th>
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### Companion Flanges – Light Steel Series #15

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### Companion Flanges – Heavy Cast Iron

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<tr>
<th>Pipe Size x Flange Diameter</th>
<th>Used for low pressure and medium temperature, next to tanks, main steam lines, asphalt manifolds, etc., fits cast iron body bronze mounted valves and heavy cast iron flanged fittings.</th>
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### Companion Flanges – Heavy Steel Series #30

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### Flange Unions – Light Malleable Iron

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### Flange Unions – Heavy Malleable Iron

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VALVES

Gate Valve

Globe Valve

Plug Valve
Valves

Valves and cocks of all types are used for shutting off pipe lines or to govern the flow of fluids through the lines. They are made of various materials such as brass, steel or cast iron and have different wall thicknesses, depending on the pressures to which they are subjected. Both threaded and flanged types are used. Several common types of valves are illustrated on page 6. The data on pages 8 and 9 give some information on size, type and service for which various common valves are used.
<table>
<thead>
<tr>
<th>Service Pressure</th>
<th>Description and Uses</th>
<th>Sizes</th>
</tr>
</thead>
<tbody>
<tr>
<td>125#</td>
<td>All Iron Gate Valve, flanged ends. Valve has all iron seats, discs and stem, is used on lines carrying acids.</td>
<td>2&quot; to 10&quot;</td>
</tr>
<tr>
<td>250#</td>
<td>All Iron Wedge type, flanged.</td>
<td>2&quot; to 10&quot;</td>
</tr>
<tr>
<td>125#</td>
<td>Iron Body Bronze Mounted Double Disc - Gate Valve, flanged. General low pressure valve used on air, water, steam, cold oil lines, manifolds, etc.</td>
<td>2&quot; to 12&quot;</td>
</tr>
<tr>
<td>125#</td>
<td>Hydrant Valve, Split Wedge, tapered seat, threaded. Used on hydrants one end threaded, One end furnished with hose coupling and cap.</td>
<td>2½&quot;</td>
</tr>
<tr>
<td>250#</td>
<td>Iron Body Bronze Mounted - Geared - Gate Valve, flanged. Used next to tanks with gears attached for extension rods to fire wall.</td>
<td>3&quot; to 12&quot;</td>
</tr>
<tr>
<td>125#</td>
<td>Cast Steel Body - Stainless steel trim 45X, flanged. Used on low pressure and temperatures up to 750⁰F.</td>
<td>2&quot; to 10&quot;</td>
</tr>
<tr>
<td>250#</td>
<td>Cast Steel Body - Stainless steel trim 57X, flanged. Used on high pressure and high temperature.</td>
<td>2&quot; to 10&quot;</td>
</tr>
<tr>
<td>250#</td>
<td>Iron Body Bronze Mounted Double Disc - Gate Valve, flanged. Used on medium pressure and low temperature.</td>
<td>3&quot; to 12&quot;</td>
</tr>
<tr>
<td>125#</td>
<td>Globe Valve, Brass body, threaded. Used on general low pressure lines (water and exhaust steam).</td>
<td>1/8&quot; to 3&quot;</td>
</tr>
<tr>
<td>125#</td>
<td>Globe Valve, Throttle brass body, threaded. Used on steam lines at pump.</td>
<td>1/2&quot; to 2&quot;</td>
</tr>
<tr>
<td>125#</td>
<td>Gate Valve, Brass body, threaded. Used on general low pressure lines (water, air and oil).</td>
<td>3/8&quot; to 2&quot;</td>
</tr>
<tr>
<td>600#</td>
<td>Globe Valve, all steel plug stem, threaded. Used on low pressure side of cracking coils for steaming out connections, gauge lines and drips, etc.</td>
<td>3/8&quot; to 2&quot;</td>
</tr>
<tr>
<td>1350#</td>
<td>Globe Valve, all steel, plug stem, threaded. Used on high pressure side of cracking coils for clay lines, gauge lines and drips.</td>
<td>3/8&quot; to 3/4&quot;</td>
</tr>
</tbody>
</table>