THE TREND OF THE REFINING INDUSTRY

AND

APPLICATION OF TECHNICAL KNOWLEDGE IN

DESIGN AND CONSTRUCTION

A thesis submitted to the faculties of
The School of Engineering and the Graduate School
The University of Kansas

For

THE DEGREE OF MECHANICAL ENGINEER

By

WILLIAM L. MATHEWS

1930
The purpose of this paper is to condense, in short, an outline of the petroleum industry showing the transition periods and growth to the present day. Emphasis will be placed upon refinery practice of the past decade, and more especially for the past three years. A typical refinery problem will be solved in detail explanation.

The writer has been active in "Petroleum" in all of its phases from the location of a well site to the marketing of the refined products, for the past twelve years. It has been his privilege to work in most of the departments of the Petroleum industry, finding them all filled with many interesting details. Experience has been acquired from the outdoor life of the oil scout, geologist, casing crew, tool dresser, tool pusher, and experimental work in rotary drilling. He mentions these contacts as forerunners, showing how they tie in and connect with his past five years' experience, during which time he has been with the Standard Oil Company, (Ind) engaged in refinery construction, supervision and design.

It is hoped that the information given herein will prove of some benefit to the reader, by showing how and where technical knowledge can be applied in refinery engineering practice.
# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preface</td>
<td>1</td>
</tr>
<tr>
<td>Table of Contents</td>
<td>1 A</td>
</tr>
<tr>
<td>List of Illustrations</td>
<td>1 B</td>
</tr>
<tr>
<td>History of Petroleum Production and Refining</td>
<td>2</td>
</tr>
<tr>
<td>Growth in Petroleum Refining</td>
<td>7</td>
</tr>
<tr>
<td>Refinery Methods</td>
<td>10</td>
</tr>
<tr>
<td>Tower Stills</td>
<td>11</td>
</tr>
<tr>
<td>Continuous Stills</td>
<td>13</td>
</tr>
<tr>
<td>Pipe Stills</td>
<td>15</td>
</tr>
<tr>
<td>Burton Stills</td>
<td>16</td>
</tr>
<tr>
<td>Holmes-Manley Stills</td>
<td>19</td>
</tr>
<tr>
<td>Cross Stills</td>
<td>19</td>
</tr>
<tr>
<td>Dubbs Stills</td>
<td>20</td>
</tr>
<tr>
<td>Trend of Plant Operations</td>
<td>21</td>
</tr>
<tr>
<td>Steam and Electricity</td>
<td>21</td>
</tr>
<tr>
<td>Air</td>
<td>23</td>
</tr>
<tr>
<td>Fuels</td>
<td>23</td>
</tr>
<tr>
<td>Water</td>
<td>25</td>
</tr>
<tr>
<td>Power</td>
<td>27</td>
</tr>
<tr>
<td>Instruments and Controllers</td>
<td>29</td>
</tr>
<tr>
<td>Heat Reclamation</td>
<td>30</td>
</tr>
<tr>
<td>The Design of a Flash Bubble Tower and Accessories</td>
<td>32</td>
</tr>
<tr>
<td>Flash Bubble Tower</td>
<td>33</td>
</tr>
<tr>
<td>Vapor line</td>
<td>34</td>
</tr>
<tr>
<td>Condenser Coil</td>
<td>35</td>
</tr>
<tr>
<td>Cooler</td>
<td>36</td>
</tr>
<tr>
<td>Explanation of Curves</td>
<td>38</td>
</tr>
</tbody>
</table>
Description of Equipment

Flash Bubble Tower
Pipe Work
Walks and Stairs

Conclusion

Bibliography
### LIST OF ILLUSTRATIONS

<table>
<thead>
<tr>
<th>Figure No.</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 A - Flow Sheet for Tower Still</td>
<td>11 A</td>
</tr>
<tr>
<td>1 B - Flow Sheet for Continuous Still</td>
<td>13 A</td>
</tr>
<tr>
<td>1 C - Flow Sheet for Pipe Still</td>
<td>15 A</td>
</tr>
<tr>
<td>2 A - Flow Sheet for Burton Still</td>
<td>16 A</td>
</tr>
<tr>
<td>2-B - Flow Sheet for Holmes-Manley Still</td>
<td>18 A</td>
</tr>
<tr>
<td>2-C - Flow Sheet for Cross Still</td>
<td>19 A</td>
</tr>
<tr>
<td>2 D - Flow Sheet for Dubbs Still</td>
<td>20 A</td>
</tr>
<tr>
<td>3 - Curve on Heating Film Coefficient</td>
<td>38 A</td>
</tr>
<tr>
<td>4 - Curve on Heating Film Coefficient</td>
<td>38 B</td>
</tr>
<tr>
<td>5 - Curve on Cooling Film Coefficient</td>
<td>38 C</td>
</tr>
<tr>
<td>6 - Specific Heat Curves</td>
<td>38 D</td>
</tr>
<tr>
<td>7 - Properties of Hydro-carbons</td>
<td>38 E</td>
</tr>
<tr>
<td>Heat of Vaporization</td>
<td></td>
</tr>
<tr>
<td>8 - 50% Boiling Point Curves</td>
<td>38 F</td>
</tr>
</tbody>
</table>
Prior to the discovery of the first oil well by Colonel Drake, near Oil City, Pennsylvania, in 1859, most of the oils for lubricating and illuminating purposes were procured by the destructive distillation of coal, and also from whale oil and vegetable oils. Lubricating and illuminating oils were treated with sulphuric acid in a crude refining process, by Tower, in the British Isles sixty years before the discovery of Colonel Drake's well. The treating of petroleum, being one of the most essential phases to produce marketable products, had been tried and perfected by 1859. This fact practically eliminated the problem of treating petroleum products, and left the refiner the problem of fractionation. Fractionation of component parts of a liquid dates to the French in the brewing industry, so that really the discovery of the first oil well gave a new material for the separation of the component parts and the treating of these into a marketable product. The most widely used illuminant prior to the discovery of petroleum in commercial quantities was procured from the destructive distillation of coal, and was known as "coal oil".

There were in the United States, before 1859, fifty three refineries processing "coal oil". This fact readily shows that methods for producing commercial illuminants and lubricants were not new to the industrial world of that time. One of the first products produced from petroleum was medicinal oil incidental to the salt industry. It so happened that a Thomas Kier, manufacturer of salt from salt water wells near Tarentum, Pennsylvania, discovered that after the salt water wells
had produced for a certain length of time, a peculiar and annoying oil collected with the water. This first oil was extracted from the salt water and sold as Seneca Medicinal oil and was supposed to have curing qualities unknown to the medical world at that time. The market for this medicinal oil was not very profitable and therefore other markets were sought.

At that time there was a demand for substitutes to replace animal and vegetable oils. In 1859 there were used in the United States

- 500,000 barrels (31 1/2 gal. barrels) of whale oil
- 300,000 barrels of lard oil, and
- 500,000 barrels of tallow.

This market naturally increased up to the time of the discovery of petroleum in commercial quantities and it was natural to experiment with petroleum for a possible substitute.

Thomas Kier, being one of the pioneers in the manufacture of illuminating oil from coal, profited from his past experience and developed the first petroleum refining unit. Samuel Kier, a son of Thomas, produced a burning oil by distillation in a small cast-iron still. However, this first still was stolen while being transferred to a new location, and he immediately fabricated a new wrought iron still of five barrel capacity, and continued in his experimental work. He noticed that his burning oil produced a very offensive odor and smoke. His first attempts yielded a substance little superior to the crude itself, and he found that double distillation of the crude gave better results. Along with this double distillation he made a few slight changes in the burning lamp used at that time, and succeeded in producing a marketable illuminating distillate. By producing this illuminant was born the embryo refiner's still, which consisted of a kettle fitted with a cover and a worm for condensing.
In 1859, the year of the discovery well, there were produced two thousand barrels of petroleum valued at $16.00 per barrel, with a total value of $32,000.00. At that time the quantity produced represented thirty-three per cent of the world's production. Over a period of sixty-five years from that time there has been produced 8,735,800,000 barrels of crude oil, sixty-two per cent of this representing United States production. Evidently the race between production and consumption of petroleum is of such a nature that the consumption will ultimately overtake production. Many attempts have been made to theorize as to the exact quantity of potential petroleum, and as to the depletion of reservoirs of oil and prospective oil lands, but in 1930 it is very evident that much is unknown as to the potential possibilities.

Early refinery practice was influenced by the demand for illuminants and lubricants, and in the attempt to make those products, gasoline was produced. The value of gasoline at that time was not known so that in order to dispose of the useless product, it was burned; or, against government orders, turned into streams and rivers. The infant refinery consisted of a liquid-containing vessel in which the petroleum was placed. A fire was built under the kettle to vaporize the petroleum, which passed into a condenser in the vapor form. The vessel was generally a cylindrical shell with flat top and bottom, containing no stays. This vessel was generally supported upon a fire box, used as the combustion chamber. Ice was used on the condenser outlet, in an attempt to save some of the more volatile gases. This attempted saving was, no doubt, lost later through evaporation.

The expansion of refinery practices and production began with the advent of the internal combustion engine. Today, practically all of the products from the refinery are for use in internal combustion
engines and for the lubrication of other machinery.

Due to the low cost of petroleum, after considerable production had been procured, very little consideration was given the economics of refinery production. The ultimate idea was to produce salable products, regardless of how efficient the method. At that time the added value of the finished product was high enough to disregard engineering economics, as is now considered in most industrial plants. As the consumption of gasoline and lubricants increased, the production necessarily was increased, but not in step with the consumption. The increased consumption naturally led to experiments, patents and processes which would produce more of the demanded products. This need caused a transition from the conventional shell type stills operating under atmospheric pressure, to stills operating under high pressure and temperatures. This new process, or the cracking process, may be said to date from an accidental discovery at Newark, N. J. in the year 1861. This was in an experimental state, and consisted essentially of heating oils to such a temperature that the heavier molecules decomposed into lighter molecules with the ultimate production of lower boiling point mixtures, known as gasoline. However, the year 1861 does not indicate the commercial use of the cracking process, and it was not thoroughly patented as a commercial advantage until 1912 by Dr. W. M. Burton.

The Burton patent covers practically all methods for cracking fuel oils and gas oils. However, there have been issued many patents on cracking processes which the patent office does not consider an infringement, but from which have arisen many law-suits in the Supreme Courts of the United States.
In the so-called "skimming plants" where only the lighter hydro-carbons are extracted from the virgin petroleum, approximately forty-three per cent is removed in the form of gasoline and kerosene, the balance being gas oil and fuel oil. The increased production of these lighter hydro-carbons due to the cracking process, amounts to thirty-eight per cent or a total production of eighty-one per cent of kerosene and lighter from one hundred per cent crude.

Modern methods for refining petroleum products have been in use for only a short time. By modern methods it is meant that engineering skill and design have reduced the size of equipment for quantity production, and also reduced the man-hours necessary to produce a gallon of gasoline by efficient operating methods.

The facilities in the United States for manufacturing finished products from crude oil for the year 1930 was approximately four million barrels per day from four hundred and seventy nine plants. Table Number One indicates the growth of facilities from 1914 to 1930.
<table>
<thead>
<tr>
<th>Year</th>
<th>Total Number of Refineries</th>
<th>Total Crude capacity bbls. daily</th>
<th>Number of operating refineries</th>
<th>Capacity refineries bbls. daily</th>
<th>Number refineries with cracking process bbls. daily</th>
</tr>
</thead>
<tbody>
<tr>
<td>1914</td>
<td>176</td>
<td>1,166,155</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1918</td>
<td>267</td>
<td>1,295,115</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1919</td>
<td>289</td>
<td>1,530,565</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1920</td>
<td>373</td>
<td>1,886,800</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1921</td>
<td>425</td>
<td>2,164,050</td>
<td>325</td>
<td>1,854,590</td>
<td></td>
</tr>
<tr>
<td>1922</td>
<td>479</td>
<td>3,046,790</td>
<td>362</td>
<td>2,549,490</td>
<td></td>
</tr>
<tr>
<td>1924</td>
<td>574</td>
<td>3,033,682</td>
<td>385</td>
<td>2,680,052</td>
<td>(1)</td>
</tr>
<tr>
<td>1925</td>
<td>584</td>
<td>3,069,340</td>
<td>356</td>
<td>2,770,340</td>
<td>150</td>
</tr>
<tr>
<td>1926</td>
<td>515</td>
<td>3,224,307</td>
<td>328</td>
<td>2,964,427</td>
<td>159</td>
</tr>
<tr>
<td>1927</td>
<td>466</td>
<td>3,426,330</td>
<td>315</td>
<td>3,116,930</td>
<td>148</td>
</tr>
<tr>
<td>1928</td>
<td>456</td>
<td>3,719,550</td>
<td>341</td>
<td>3,454,250</td>
<td>170</td>
</tr>
<tr>
<td>1929</td>
<td>463</td>
<td>3,972,460</td>
<td>362</td>
<td>3,721,560</td>
<td>186</td>
</tr>
<tr>
<td>1930</td>
<td>479</td>
<td>3,972,460</td>
<td>362</td>
<td>3,721,560</td>
<td>186</td>
</tr>
</tbody>
</table>
The 1930 cracking capacity can be divided into the following processes:

<table>
<thead>
<tr>
<th>Process</th>
<th>Capacity (bbls. per day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burton</td>
<td>225,000</td>
</tr>
<tr>
<td>Dubbs</td>
<td>210,000</td>
</tr>
<tr>
<td>Holmes-Manley</td>
<td>230,000</td>
</tr>
<tr>
<td>Cross</td>
<td>300,000</td>
</tr>
<tr>
<td>Tank &amp; Tube</td>
<td>480,000</td>
</tr>
<tr>
<td>Jenkins</td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td></td>
</tr>
<tr>
<td>Shell</td>
<td></td>
</tr>
<tr>
<td>Richmond</td>
<td></td>
</tr>
<tr>
<td>Fleming</td>
<td></td>
</tr>
<tr>
<td>Lewis</td>
<td></td>
</tr>
<tr>
<td>Isom</td>
<td></td>
</tr>
<tr>
<td>Gyro</td>
<td></td>
</tr>
<tr>
<td>Balance including</td>
<td>260,000</td>
</tr>
</tbody>
</table>

**TOTAL...1,705,000**

Following is a gasoline yield record for the years from 1918 to 1929 inclusive:

<table>
<thead>
<tr>
<th>Year</th>
<th>Per cent gasoline to crude refined</th>
</tr>
</thead>
<tbody>
<tr>
<td>1918</td>
<td>26.1</td>
</tr>
<tr>
<td>1919</td>
<td>26.1</td>
</tr>
<tr>
<td>1920</td>
<td>26.8</td>
</tr>
<tr>
<td>1921</td>
<td>27.7</td>
</tr>
<tr>
<td>1922</td>
<td>29.5</td>
</tr>
<tr>
<td>1923</td>
<td>31.0</td>
</tr>
<tr>
<td>1924</td>
<td>33.1</td>
</tr>
<tr>
<td>1925</td>
<td>35.1</td>
</tr>
<tr>
<td>1926</td>
<td>38.5</td>
</tr>
<tr>
<td>1927</td>
<td>39.9</td>
</tr>
<tr>
<td>1928</td>
<td>41.3</td>
</tr>
<tr>
<td>1929</td>
<td>44.0</td>
</tr>
</tbody>
</table>
This increase in gasoline production per unit of crude refined very emphatically shows the effect of cracking processes upon production.

All gasoline produced can be divided into three classes:

- Straight run: 55%
- Cracked: 33%
- Natural gasoline: 12%

100%
REFINERY METHODS

The more antiquated methods used in refining petroleum are of a batched process while modern methods are tending more in the direction of continuous operations. The continuous process has an advantage over the batched process for the reason that more actual hours per year are consumed in producing gasoline or other products. Batched distillation consists mainly of charging a vessel with a given quantity of petroleum, lighting the fires and continuing the batched distillation until the desired residue appears. The residue is then pumped out of the vessel, the vessel cleaned and a new cycle begun. This cycle generally consumes approximately thirty-six to forty-eight hours. Modern methods are to heat oil in tubular typed stills continuously, resulting in a smaller quantity of the inflammable liquid under treatment and producing marketable products at less expense.

Fundamentally most all refinery distillation processes are the same, the object in all cases being to take the raw material in the form of crude oil and separate the oil into products that are marketable. The methods by which this can be done naturally vary, as do the methods of farming, fishing or mining. Several of the more important distillation methods used in the refining of crude oil are outlined as follows:

1. Crude Stills.
   (a) Tower.
   (b) Continuous.
   (c) Pipe.

2. Pressure Stills
   (a) Burton.
   (b) Holmes-Manley.
   (c) Cross.
   (d) Dubbs
Tower stills receive their name from the design of a partial condensation tower through which vapors pass. The heavier hydrocarbons are condensed by coming into direct contact with steel tubes running vertically through the towers. The original method for securing partial condensation was derived from an uncovered vapor line sloping up and away from the still. The vapors in passing from the still upward through the vapor line came in contact with the cool surface of steel which condensed the heavier hydro-carbons and the liquid formed ran back into the still for re-distillation.

The type of tower stills herein described have three vertical atmospheric partial condensation units. Referring to the flow sheet, figure (la) for tower stills, sometimes called coke stills, a batch charge of about eight hundred barrels of crude oil is placed within the fourteen feet diameter times forty feet-no inches cylindrical shells. The cylindrical shell is in a horizontal position, approximately ten feet above the ground line. The distillation begins after the fires have been started and the first vapor being condensed passes through all three towers, through the condenser coil, and to the receiving house. Along with this light hydro-carbon, or light gasoline, some water is carried, which passes through the towers and goes to the water draw-off traps. If the crude being distilled is 36° Bé Mid-Continental, the gasoline cut is taken from the initial, or the over-point, down to and including a stream gravity of 45° Bé. From 45° Bé down to 42° Bé, a water white oil cut is taken. From 42° Bé to 30° Bé, a pressing distillate cut, or pressure still charging stock is taken. From 30° Bé to 26° Bé, a heavy paraffin distillate, or pressure still charging stock, is extracted.
Fig. 1a
FLOW SHEET FOR TOWER STILL
OR COKE STILL
CRUDE TOPPING

Air-Cooled Towers
Air flows up through
tubes condensing
vapors inside of
Shell.

Batch for suction
for pumping out
still.

800 Bbl.
Charg.

85° Bc.
Batch Charging
Crude
Line.

56° Bc.

To Wax
Pot
20° Bc
to
50° Bc.

Heavy
Fuel
Dist.
24° Bc
to
50° Bc.

L.P.
Dist.
49° Bc
over
40° Bc.

Wax
White
Oil
over
60° Bc.

Gasoline
45° Bc.
the pressure still charging stock has been discontinued, the hydro-carbons are of such a nature that they will not pass through the first tower; therefore they are directed to a wax pot. After the wax has been extracted, the balance of the batch charge goes to coke and gas.
Continuous stills generally consist of a series of cylindrical shells supported upon brick and steel settings, enclosed around the bottom to form a fire box. Referring to the flow sheet (1b), for continuous stills, it is seen that a much more efficient fuel consuming unit exists than in the tower still. The cylindrical shells are fourteen feet diameter times fourteen feet-no inches. The crude is fed through a heat exchange system and the heat picked up is sufficient to vaporize approximately thirty per cent of the ten thousand barrels fed. Note that the flow of cold feed is counter-current to the flow of hot gases and liquids. The crude first passes through a coil at the middle of the flash tower which extracts heat from the lightest product being produced by the battery. It then passes through coils in the top of all the towers, thence through a tar heat exchanger coil. After picking up the available heat through the tar heat exchanger, it is dumped into the bottom of the flash tower. That part of the crude which is vaporized, due to the heat pick up through the exchange system, passes up through the flash tower bubble trays and is fractionated to the point where a gasoline of 700 Btu, is recovered. That part of the crude which is dumped into the bottom of the flash tower which does not vaporize flows by gravity to the feed still under which a fire is burning. More heat is added to the unvaporized crude, which vaporizes a portion in the feed still and passes up through the bubble tower on that still. A 560 Btu gasoline is extracted from the feed still. The crude then flows to each one of the remaining stills in series, and cuts are extracted as shown on the flow sheet. From the last still is continuously pumped tar of
Flow Sheet for Continuous Stills.
Crude Topping.
approximately 18° Bé. This tar is either run to coke or 80-90 molten asphalt. Side streams are extracted from the flash tower, these being stripped of the lighter hydro-carbons, by steam, to give the desired initial boiling points.
Pipe stills running virgin crude have essentially the same type of heat exchange equipment as a continuous battery of crude shell stills. By noting the flow sheet (1c) on the crude pipe still, it is very evident that the design of the equipment is more efficient from an engineering standpoint. The equipment is more compact, requiring less valuable space, is more efficient from a thermal standpoint, losing less heat by radiation, and has a much higher furnace efficiency.

The main advantage of a pipe still is that a smaller quantity of inflammable liquid is processed as compared to the shell type still; also, the furnace design is much more efficient. From the flow sheet on the crude pipe still, it is seen that the fractionating equipment consists of one bubble tower having more trays than in the continuous shell type battery. From the bubble tower is extracted light gasoline, heavy gasoline, water white oil, light gas oil, paraffin distillate, slop, lubricating distillate, heavy gas oil and tar, which is run to either coke or asphalt.
The Burton process, being one of the first commercial cracking methods, has to date produced more cracked gasoline than any other cracking process. The original Burton design consisted of a cylindrical shell mounted upon a steel and concrete setting, the lower part being bricked in so as to form a combustion chamber for supplying heat to the oil for distillation and cracking. The vaporized oil passed through a vapor line to a condenser coil. This was later modified by adding an aerial condenser which gave a small amount of fractional condensation. Later changes in the design added tubes in the fire box so that the oil to be heated was broken up into many small streams, also, bubble towers were added through which the vapors were fractionated. The Burton process originally was a batch process being charged with approximately twelve thousand gallons. The fires were started and as the temperature increased, the water vaporized first and was condensed, this being drawn off through water traps. The heat was continually applied until vaporization of the oil took place up to a point where the vapor pressure of the oil produced from ninety to one-hundred pounds gauge pressure at a temperature of approximately 750°F. Under these conditions temperature and pressure, the batch charge was distilled or vaporized down to a predetermined per cent of the original charge. The process was then discontinued, the fires pulled, and the pressure dropped to a point where the residue could be pumped out by the pump-out pump. The stills were then cooled and cleaned ready for a new batch. This cycle generally required thirty-six to forty-eight hours. Noting the flow sheet for batch type Burton stills, it is evident that the pressure on the stills
Fig. 2a
FLOW SHEET FOR BURTON CRACKING STILL
is controlled by throttling the unsaturated or non-condensable gases produced so that a constant back pressure is maintained on the stills. These non-condensable gases are either passed through an absorption plant or burned directly under the stills as fuel.

Yields on batch type Burton stills are approximately fifty per cent pressure distillate based upon pressure still charged stock fed. A later design has converted the batch type Burton stills into a continuous process which yields larger quantities than the original. Although several of the larger oil companies have converted their batch type Burton stills into the continuous type, it is very evident from engineering economics that the newer patented processes are much more economical from a yield and fuel standpoint.
The Holmes-Manley process is very similar to the Burton process in that the pressure is controlled by throttling the non-condensable gases. This throttling takes place after condensation of the pressure distillate vapors. The heating and fractionating equipment has been redesigned to give higher thermal and distillation efficiencies. The oil is heated in a tubular type furnace and passes to vertical soaking drums where it vaporizes and passes through a fractionating column, or bubble tower, for the separation of the pressure distillate desired. The soaking drums, or vertical stills, are designed for four hundred pounds working pressure and 850° F. working temperature. The pressure distillate from which gasoline is obtained by rerunning after treating, amounts to forty per cent based upon a charging stock of sixty-five per cent virgin gas oil and thirty-five per cent recycle stock. The Holmes-Manley process is today one of the most reliable of the cracking units, giving very satisfactory yields, low fuel cost, reliable safety, with minimum amount of maintenance.
FLOW SHEET FOR HOLMES-MANLEY CRACKING STILL
The Cross cracking unit, figure (2c), consists of a tubular type heating element enclosed in a brick and steel setting. The pressure still charging stock passes through a heat exchange system as in other designs, picking up the waste heat where it is dumped into the mixing tank. From the mixing tank the oil is fed by hot oil pumps through the heating element where the pressure is raised to eight hundred pounds and the temperature to 850°F. The back pressure is held on the horizontal soaking drum by a throttle valve which expands the oil to forty pounds pressure into a flash drum. The heavier hydro-carbons drop out as fuel oil and the vapors pass into a fractionating column where the pressure distillate is separated, giving a gasoline of correct end point to be rerun for color. The Cross process gives higher yields, lower fuel costs, good thermal efficiencies, and reliable safety.
Fig. 2c.
FLOW SHEET FOR CROSS CRACKING STILL.
2-(d) DUBBS PRESSURE STILLS

The Dubbs process, figure (2d), was patented a little later than the Burton process. There has been much litigation between the two patentees in the past years. The Dubbs process controls the back pressure on the still in exactly the same way as does the Burton process. The Dubbs process has better thermal efficiencies and reclaims heat by direct liquid to liquid contact, through a continuous feed. Note that the Dubbs process has a tar plant similar to the Holmes-Manley unit. Although the continuous Burton process has not been published to date, it is very evident that several features incorporated therein are similar to the Dubbs-Holmes-Manley and Cross.
TREND OF PLANT OPERATIONS

Steam and Electricity

The most noticeable advance made in present refinery methods is the conservation of fuel. Fuel expenditures amount to fifty per cent of the total manufacturing cost in petroleum refining. Any attempt to save even one or two per cent in fuel cost is not looked upon lightly, and most of those refineries realizing the keen competition of the present day are revamping or making obsolete their present boiler houses and power and light plants, and are installing more modern equipment. Where boiler house efficiencies were running sixty to sixty-five per cent new design gives as high as seventy-five to eighty per cent. This is obtained by new boiler furnace design, adding economizers, air-preheaters and water cooled walls, along with more efficient firing methods.

Heat balances of past years for a steam and power system in a refinery were open to much criticism by the management, but the trend is toward an automatic balance between steam produced and steam consumed with no intentional loss.

Refineries are electrifying most of their existing prime movers on such machines as compressors, pumps, fans, blowers, and mechanical devices. Electricity in a refinery is generally classed as a by-product. The charge for electrical energy is based upon the heat loss through the prime mover, turbine or reciprocating engine. The process work is carried on most generally with five to ten pound exhaust steam from the power plant turbines, pumps and engines, and the plant auxiliary steam consuming equipment. Most generally no condensing equipment is used, the generated steam having a cycle through the turbo-generator to the process.
equipment where it is condensed after doing useful work in stripping
and heating petroleum products.

Higher pressures, four hundred to six hundred pounds per square
inch, are being used along with the existing low pressure equipment,
(125 pounds). The advantage of the high pressure equipment is to gen-
erate electricity with the four hundred to six hundred pound steam, ex-
tracting the exhaust at one hundred twenty-five pounds to drive plant aux-
iliary equipment and making up the deficiency with the hundred and twenty
five pound equipment. The five to ten pound exhaust steam from the
plant auxiliary equipment is used in process work with no heat of the
steam being lost in condenser water until after it has been used to
produce stripping and fractionating action. Naturally the larger per-
centage of the heat in the steam is liberated in the process work where
the latent heat of vaporization is absorbed. Therefore, the process
work carries the highest steam charge, and the electrical energy produced
carries practically no charge. This is one method being used by re-
fineries to obtain a more economical heat balance. Other methods con-
sist in using low pressure condensing turbo-generators to consume the
excess of five to ten pounds steam produced by plant auxiliary equipment.
Other problems are solved by using mixed pressure and bleeder type
turbines in the electrical generating plant. Some of the plants natur-
ally cannot be satisfied with any of these methods and resort to the
purchase of electrical energy from district central stations. In doing
so they electrify a majority of their equipment and produce from the
plant steam prime movers a deficiency of five to ten pound steam for
process work. The remaining steam necessary for process work is ob-
tained by reducing valves and de-superheaters.
On the electrical end of the balance power factors are being raised by synchronous motor installations on the larger charging pumps, compressors and blowers, thus increasing the available generating capacity and reducing the I R losses in the generator and the distribution system. Particular attention is being paid to steam line sizes and insulations in plant distribution.

Air

The production of air in refinery process work is not so important today as in the days of batch agitators when a considerable amount of compressed air was needed for blowing or agitating the gasolines and distillates being treated. The present treating procedure is to treat continuously through a closed system using mechanical mixers in series with the system flow. Compressed air is most generally used at about one hundred and twenty pound per square inch guage. Most air compressors are of the two stage inter and after cooler type. Air is used in construction work, driving pneumatic hammers, rivet busters, air motors for hoisting, blowing out lines and freeing them of asphaltic materials that would plug the lines if not removed when pumping ceases. Asphalt oxidation requires considerable amount of compressed air.

Fuels

More particular attention is paid to the type of fuel used in the refinery today than ever before in the history of the industry. This condition is brought about by the continued excellent market for fuel oil, especially in the railroad and water transportation systems.
It is surprising that a majority of the refineries, not close to large gas producing areas, use coal as a fuel. It is the practice to conserve the petroleum products for sale to the demanding market. When gas is available as an economic fuel it is used most advantageously, being easy to fire, clean, requiring less labor and being more easily transported than coal.

Refineries practice very rigid economy in fuel conservation where possible. All waste products are burned as fuel in a refinery, including acid sludge which is the worn out acid used in treating the gasolines and distillates, and acid coke from acid reclaiming plants. Bad batches of asphalt, road oil emulsions and coke are used as fuel in the conservation program.

Furnace designs on distillation equipment are approaching the most modern boiler practice, so that fuels are economically consumed today where a few years ago the object was to produce gasoline, burning the fuel with no thought of economy, the main purpose being to produce heat, regardless of the resulting economy of fuel consumption. In the refinery, plant gas production presents a problem of dual fuels. The gas reclaimed from the processing equipment is burned as fuel. Often the gasoline content has been removed in the gas absorption plant. A fireman is called upon to use two fuels, such as plant gas and road oil, and must know the firing characteristics so as to obtain economic combustion. The present trend is to have the operating departments so organized that periodic combustion tests are made, showing flue gas analysis and over all efficiency. In these tests the proper damper arrangements are determined for the maximum efficiency, and marked so
that the fireman can reset dampers when changing fuels. The economic combustion of refinery fuels has been increasing during the past five years, caused by more concentrated effort of the combustion department and the operating departments. Savings have been made by increased CO₂ or more complete combustion, tighter furnace settings, better refractory materials, and more efficient insulations.

Water

The water problems in refinery practice are just as important as fuel. Water is used in steam production, condensing and cooling purposes on process equipment, sanitary purposes, washing gasolines and distillates after treating processes to remove acids and caustic solutions, cooling distillation equipment coming down for periodic cleaning and for fire fighting. Clean water with very little suspended matter, organic matter and corrosive and scale forming salts does not present a major problem. This can be exemplified by the refinery in the proximity of the great lakes.

Refineries in the middle west especially, if water is supplied from the Missouri river, are confronted continually by a very serious problem of suspended matter, corrosive and scale forming salts. A record of the suspended matter and salt constituents in Missouri river water is given showing the high content of suspended matter, solids, corrosive and scale forming salts.
RAW MISSOURI RIVER WATER

<table>
<thead>
<tr>
<th>Component</th>
<th>Concentration (g/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Solids</td>
<td>0.4448 g/l</td>
</tr>
<tr>
<td>SiO₂</td>
<td>0.0216 g/l</td>
</tr>
<tr>
<td>CaO (as CaSO₄, CaCl₂)</td>
<td>0.0145 g/l</td>
</tr>
<tr>
<td>CaO (as CaCO₃)</td>
<td>0.0755 g/l</td>
</tr>
<tr>
<td>MgO (as MgSO₄, MgCl₂)</td>
<td>0.0234 g/l</td>
</tr>
<tr>
<td>MgO (as MgCO₃)</td>
<td>0.0158 g/l</td>
</tr>
<tr>
<td>Fe₂O₃ &amp; Al₂O₃</td>
<td>0.0017 g/l</td>
</tr>
<tr>
<td>SO₃</td>
<td>0.1222 g/l</td>
</tr>
<tr>
<td>Cl</td>
<td>0.0255 g/l</td>
</tr>
</tbody>
</table>

Alkalinity — 100 cc. sample

- Phenolphthalein
  - 0.00 cc H/10 H₂SO₄
- Methyl Orange
  - 3.20 cc H/10 H₂SO₄
- Hydrogen ion concentration PH
  - 7.37
The water is most generally distributed in cast iron mains due to outside and inside corrosion. Great Lake refineries carry their water in steel pipe and have done so for the past twenty-five to thirty years. Missouri river water and acid soil conditions will completely destroy steel boiler maker pipe 1/4" thick in from five to eight years. Cast-iron pipe can generally be considered good for fifty years' service, which shows the economy of using cast-iron instead of steel.

The suspended matter deposits in condenser boxes and must be removed by periodical washings. A mud collecting space must be provided in all condensing and cooling equipment of the open box and worm coil types. Strainers and filters must be provided for the enclosed tubular type condensers and coolers. More condensing and cooling surface must be provided when using Missouri river water than for water free from scale forming salts and suspended solids. The salts and mud form an insulation on the surface of the tubes, or pipe, thereby making condensing and cooling more difficult, and therefore increasing the water consumption. The desired method for providing clear water free from suspended matter is a central settling basin and filter for the elimination of the solids. The lime and soda treatment is used on the boiler feed water for the removal of the scale forming and corrosive salts.

Power

Considerable was mentioned on power under steam and electricity but more detailed description will be given herein. In the boiler house and power station prime movers are of several types. The main generating units are most generally of the impulse or reaction types. Preference is generally given to the impulse type as the requirements are
not so severe as in modern central stations where steam must be expanded to a twenty-eight or twenty-nine inch vacuum. Steam most generally leaves the main electrical generating equipment at one-hundred and twenty-five pounds or five to ten pounds depending upon the type of heat balance used. Therefore the need for the advantage of the reaction turbine in the lower stages is not so imperative as in the high vacuum units. Boiler feed, treated water pumps are generally steam turbine drive of the impulse design. Motor driven centrifugal pumps are sometimes used, the argument being for cheap electrical energy from the power station which is considered as a bi-product incidental to processing. This cannot be very easily justified, especially when exhaust steam is used for pre-heating boiler-fed water as in most central stations. Auxiliary pumps are either motor driven centrifugal or small and large reciprocating duplex double acting pumps equipped with common slide steam valves, providing no cut off. The pumps take steam during the complete stroke, making this type of steam valve an uneconomic regulator of steam consumption. However, in refinery practice, as has been mentioned, heat extracted from the steam for power purposes is a bi-product, as the latent heat, or the greatest cost of the steam is used in processing. This secondary use of the steam is the only justification for using such a crude type of steam valve.

Plant pumping equipment is either motor driven centrifugal motor power reciprocating, or steam driven reciprocating. Light distillate can be pumped successfully with centrifugal pumps, providing ample head is present on the suction side to prevent flashing of the distillate and vapor binding of the pump. The trend is to pump all
hot distillates with motor driven centrifugal pumps of special design, having deep water-cooled stuffing boxes and water-cooled out-board bearings, equipped with either the Marine or Kingsbury type thrust bearings. All pump parts are cast steel, steel and special high temperature alloys. Heavier products, such as asphalt, road oils, sludge acid and all very viscous fluids, are most generally pumped with the rotary, screw, or cam typed motor driven pumps. Compressors and blowers are either steel reciprocating, motor power reciprocating, or motor and steam turbine driven centrifugal, depending upon the service, availability of floor space, economy and desired dependability. The trend of pumping design in refinery work is to provide a dual service for the important equipment; such as the charging pumps to a five thousand or ten thousand barrel crude unit. This type of equipment is normally a motor driven centrifugal pump, and for emergency cases, a standby steam turbine driven centrifugal pump of the same design.

Instruments and Controllers.

The trend in refinery design and practice is to control as far as possible fuels, temperatures, flow of liquids and gases, and liquid levels by automatic equipment. This method insures constancy of operation which is of vital importance to the successful production of petroleum products.

Composite controllers are used for controlling flash temperatures and outlet temperatures of heated oils. Liquid and gas flows are controlled by temperatures, liquid level floats, and ratio controllers. The tendency is to equip new and old equipment with complete temperature
and pressure recording and controlling mechanisms. The story of operating characteristics is transferred to the higher authorities for economy and yield production figures, and also to record errors or accidents on the records.

Heat Reclamation

The pioneer refineries were more interested in producing a marketable product than in efficient operation. This is most generally the case when any new industry is born. Today the trend is to produce higher yields of gasoline, and lubricants of superior quality at higher efficiencies and at less cost. This procedure is as necessary for the successful operation of a refinery as it is for central power stations, sugar, steel, textile, and the numerous other industries tending toward higher efficiencies due to marketing competition.

Refineries can increase yields of products by new processes invented and patented. A most outstanding example for increased yields is a new patented hydrogenation process owned by the Standard Oil Company of New Jersey. The claim is made by this patent that nearly one hundred per cent gasoline or any desired marketable product can be procured for every gallon of crude oil treated. This sounds like an impossible Utopia for the patentees, but without doubt it is practical to the extent that millions of dollars are being expended for the construction of such plants. The exact process is not definitely known but it is a known fact in refinery circles that petroleum is composed of organic matter formed by the union of carbon and hydrogen in varying quantities. During the distillation of petroleum after the complete extraction of the natural gasoline content, there is a tendency to form fixed carbon, which, if united with the proper proportions of hydrogen, would yield gasoline.
This patented process of hydrogenation, no doubt, injects free hydrogen into the vapor at very high temperatures and high pressure before the fixed carbon starts to form. The distillation is continued until a recovery of one hundred per cent gasoline or other products is realized. This process will be watched with much interest by the refinery world. No doubt, if the process is successful, probable disaster awaits the majority of existing patentees of other processes. The trend in refinery practice is to increase thermal efficiency by the conservation of heat. This is accomplished by heat exchanger systems through which the cold liquid to be heated flows concurrent to the exit products. By this method many dollars are being saved every year, as before, the heat went up the stack or was lost in condensing and cooling water.
THE DESIGN OF A FLASH BUBBLE TOWER AND
ACCESSORIES FOR A CONTINUOUS CRUDE BATTERY.

In the operation of a battery of shell type crude skimming
stills, it is sometimes desirable to fractionate more exactly the crude,
thereby yielding a larger per centage of finished products. It is pro-
posed to go through the design and description for part of the equipment
involved in such an operation.

Eight 14' x 40' shell stills of the return tubular type are
equipped with a bubble tower for fractionating, the overhead stocks
which at present yields the following cuts, or stocks:

1. Flash tower export gasoline 66° BÉ.
2. One still light gasoline 58° BÉ.
3. Two stills heavy gasoline 49° BÉ.
4. One still water white oil 42° BÉ.
5. One still gas oil 36° BÉ.
6. Two stills paraffin distillate 30° BÉ.
7. One still standby for paraffin distillate.

It is desired to increase the crude feed from ten thousand to fifteen
thousand barrels per day, and, in doing so, to produce a light gasoline
with a possible substitute of aviation gasoline. Also the equipment
must produce varnish makers and painters naphtha, oleum spirits, and
heavy naphtha. The existing equipment is to be retained with the
exception of the flash tower producing export gasoline. A new flash
bubble tower will be designed to yield from the fifteen thousand barrels
per day the following cuts:

13% light naphtha.
33° V H & P.
8% Oleum spirits.
6% Heavy naphtha.
66% bottoms to 8 shell stills for the produc-
of heavy naphtha, water white oil, gas oil, paraffin distillate and resi-
due for coke.
Flash Bubble Tower

The first assumption that it is necessary to make in the design will be based upon standard refinery knowledge. To produce a gasoline cut an empirical rule has been established during the last few years, that there are required eight bubble trays of a particular design, and to produce the side stream cut there are required four additional trays. Therefore to produce the above cuts, there will be required eight trays for the light naphtha, four for the VM & P, four for the Oleum Spirits and four for the heavy naphtha, making a total of twenty trays.

The diameter of the tower will be determined by assuming as conservative practice a vapor velocity through the cross sectional area of the tower of one foot per second. Upon this assumption the diameter of the tower necessary will be as follows:
Feed = 15,000 bbls. / 24 hrs.

50 gallon bbls = 15,000 x 50 = 31,200 gal. / hr.

Steam used to produce Oleum Spirits and V. M. & P. = .7# / gal. from actual test, or

8% of 31,200 = 2,500 gal. / hr.

Plus 8% of 31,200 = 2,500 gal. / hr.

Total = 5,000 gal. / hr.

5000 x .7 = 3,500 # steam / hr. at 2# press and 250° F., or
cu. ft. / sec. steam = $\frac{3500 \times 359}{18 \times 3600}$ = cu. ft. at std. conditions.

$18 = \text{mol wt.}$

$359 = \text{vol. of 1# mol at std. conditions}$

Applying temperature and pressure corrections =

$\frac{3,500 \times 359 \times (460 + 250) \times 14.7}{18 \times 3600} = 24.8 \text{ cu. ft. / sec.}$

Temperature at point in tower determining size = 250° F.

25% vaporization will determine maximum tower diameter or solving

for quantity of oil vapor per sec. = 64° B. = 6.025 # / gal. / mol wt = 110

31,200 x .25 x 6.025 x 359 x (460 + 250) x 14.7 = 54.5 cu. ft. / sec.

Total oil and steam vapor = 54.5

$\frac{24.8}{79.3} = \text{cu. ft. / sec.}$

Say 80 cu. ft. / sec. $a = q = 80.0 = 80 \text{ sq. ft. or a/0 ft. diameter}$

tower is ample.

Vapor line to condenser coil:

20% overhead with 1:1 Reflux ratio, (Reflux ratio is ratio of distillate
pumped back to distillate made) or 40% overhead, with steam at 24.8

$\frac{675}{710} = 23.6 \text{ cu. ft. / sec.}$

Top tower temperature = 215° F.
Total oil vapor volume = \( \frac{31,200 \times .4 \times 6,025 \times 359 \times (460 \times 215) \times 14.7}{110 \times 3600 \times 492 \times 16.7} \)

82 cu. ft. / sec.

Total vapor = 82.0

\[ \frac{25.6}{105.6} \text{ cu. ft. / sec} = \]

Allowable vapor line velocity = 50 ft / sec.

\[ a = \frac{q}{v} = 2.11 \text{ sq. ft.} \]

Use a 20 inch diameter vapor line.

---

**Condenser coil for Vapors**

Heat to be dissipated = Steam - 3500 #/ hr at 2 # and 215° F. top of tower temperature;

Oil - 31,200 x .4 x 6,025 = 75,172 # / hr at 215° F.

To be condensed and cooled to 95° F. by water in at 80° F. exit temperature of water allowed 125° F.

Steam: Although temperature is close to condensation of steam, there will be no condensation due to partial pressure of oil.

Latent heat:

967 B.T. U. per pound.

967 x 3500 = 3,384,500 B.T.U. per hour

Sensible heat:

\[ \text{Temp. drop} = 215 - 95 = 120° F. \]

3500 x 1 x 120 = 420,000 " " "

Oil:

Latent heat:

135 B.T.U. per pound

135 x 75,172 = 10,149,200 " " "

Sensible heat:

\[ \text{Temp. drop} = 120° F \ sp.h. = .56 \text{ B.T. U. per pound} \]

75,172 x 120 x .56 = 5,051,500 Total 19,004,200 B.T. U. per hour
Mean temperature difference water and oil =

\[
\begin{array}{ccc}
\text{95} & \text{oil} & 215 \\
\text{-20} & \text{water} & 125 \\
\text{15} & & 90
\end{array}
\]

\[
\text{m.t.d.} = \frac{90 - 15}{\log 2 \frac{90}{15}} = \frac{75}{1.8} = 42^\circ \text{F.}
\]

Transfer coefficient for condensing and cooling gasoline with steam equals 35 B.T. U. per square foot of surface, per hour, per degree mean temperature difference.

Square feet needed = \( \frac{12,004.200}{35 \times 42} = 12,330 \) sq. feet.

**Cooler for Oleum Spirits**

The cooler is to be of the enclosed tubular type, steel shell and one inch steel tubes.

To cool 9% of feed or 8% of 31,200 = 2500 gphr. from 340° F. to 87.5° F

\[
s_p h = 0.57 \quad \text{Temp. diff} = 252.5^\circ \text{F.}
\]

B.T. U. / hr. to dissipate = \( 6.563 \times 2,500 \times 0.57 \times 252.5 = 2,560,000 \) B.T.U. / hr.

Water inlet temp. = 76° F.

Water outlet temp. = 100° F.

Mean temp. diff = \( \frac{(340 - 100) - (87.5 - 76)}{\log e \left( \frac{340 - 100}{87.5 - 76} \right)} = 76^\circ \text{F.} \)

Water needed = \( \frac{2,560,000}{1 \times 24 \times 60 \times 6.3} = 198 \) gpm = \( \frac{198}{75 \times 60} = 0.44 \) cu ft. / sec

Water velocity around tubes.

Assume tube sheet 36" dia. with 61-1" tube per pass, 8 passes through cooler.
Area water way = 7 \times 17 = 119 \text{ sq. inches.}

0. D. area tube per pass = 51 \times 0.7854 = 40.

Net area = 119 - 40 = 79 \cdot \frac{124}{55} = \frac{55\text{ sq. ft.}}{\text{pass.}}

Water flow, at 0.44 cu. ft. / sec = V = \frac{44}{55} = 0.8 \text{ ft. / sec.}

Cooler to have 1" 0. D. - # 14 ga. steel tubes

0.844 \text{ " I. D. area = } \frac{55 \text{ sq. inches.}}{55}

Tubes 9,625 ft. long area tubes per pass = \frac{51 \times 0.5595}{0.44} = 198 \text{ sq. ft. / pass.}

Oil at rate of 2500 gph = \frac{2500}{3600 \times 7.5} = 0.925 \text{ cu. ft. / sec.}

V = 0.925 = 0.46 \text{ ft. / sec. oil velocity.}

Over all coefficient \(K = \frac{1}{K_1 + \frac{1}{K_2} + \frac{1}{K_3}}\)

\(K_1 = \) water film coefficient = 380

\(K_2 = \) oil film coefficient = 35.2

\(K_3 = \) tube coefficient = 3850.

\(K_1 = 450 V^2 = 450 \times 0.875 = 380 \text{ B.T. U. / hr. / sq. ft. / deg.}

\(K_2 = K (\frac{\nu \cdot D V}{Z} \times \phi \cdot CZ) = \frac{0.79}{0.844} \text{ K for oil}

\(0.844 = \text{dia. tube.}

23 = \text{mass velocity}

6 = \text{viscosity}

.57 = \text{specific heat.}

Mass velocity = 6.563 \times 7.5 = 49.2 \text{ # / cu. ft.}^3

\(49.2 \times 0.466 = 23\)

\(CZ = \frac{0.87 \times 6}{0.079} = 4.24 \text{ from chart} = \phi = 1.75

\(\frac{DV}{Z} = \frac{0.844 \times 23}{6} = 32.4 = \phi = 215\)

\(K_2 = \frac{0.79 (1.75 \times 215)}{0.844} = 35.2 \text{ B.T.U. / hr. / sq. ft. / deg.}

\(K_3 = \frac{25 \times 0.078}{12} = 3850 \text{ Steel = 25 B.T. U. / sq. ft/ deg / ft. thickness.}

\)Over all \(K = \frac{1}{380} + \frac{1}{35.2} + \frac{1}{3850} = 32.2 \text{ B.T. U. / hr. / sq. ft/ deg.}
Coolers for the V M & P and heavy naphtha, are designed by the same method.

Explanation of Curves

Figures #3, #4, & #5.

The curves are used for determining the film coefficient for inside flow in pipes.

\[ h = \text{film coefficient} \]
\[ c = \text{specific heat} \]
\[ s = \text{viscosity in centipoises absolute} \]
\[ \text{= kinematic times specific gravity} \]
\[ d = \text{Diameter of pipe in inches or four times the shape factor} \]
\[ \text{in case of flow around several tubes inside of a larger} \]
\[ \text{tube. This is four times the hydraulic radius in inches.} \]
\[ \text{The hydraulic radius of a conduit flowing full is} \frac{D}{4} \]
\[ \text{the shape factor and} 4 \times \frac{D}{4} = D \text{as state and applies to all} \]
\[ \text{combinations.} \]

\[ V = \text{mass velocity} = \text{linear velocity times density in pounds} \]
\[ \text{per cu. ft.} \]

\[ k = \text{heat of conductivity of fluid in B.T. U. / sq. ft. / deg} \]
\[ \text{temperature difference per foot of thickness.} \]

From above date solve the expressions:

\[ \frac{CZ}{K} = ? \quad \text{and} \quad \frac{DV}{Z} = ? \]

Then from figure #3 determine the value of \( \frac{CZ}{K} \), and from figure #4 the value of \( \frac{DV}{Z} \) for heating runs and from figure #5 for cooling runs; then from Boussinesq equation

\[ \frac{hd}{K} = c \frac{DV}{Z} \times c \frac{CZ}{K} , \text{or} \]

\[ h = K \left\{ \frac{DV}{Z} \times c \frac{CZ}{K} \right\} \frac{1}{D} \]
Properties of Hydrocarbons.

Heat of Vaporization
vs
Boiling Points (760 mm)

Calculated by Hildebrand's Method.

Fig. 7
Properties of Hydrocarbons

50% Boiling Points

50% Boiling Points of Petroleum Oils

Fig. #8
Figure #6

Specific heats of Hydro-carbons

Use this curve by taking mean of temperatures, that is the specific heat of a 30° Bé oil from 100° F to 300° F would be the same as for a 30° Bé oil at \( \frac{100 + 300}{2} = \frac{400}{2} - 200° F \) or .526.

Figure #7

Heat of Vaporization

From figure #6 find 50% boiling point for oil desired, then on #7 using the 50% point from #6 read on #7 curve the heat of vaporization.

Figure #8

50% Boiling Points

Use gravity of oil to find the 50% point from the curve, either the molecular weight or heat of vaporization can be found from #7 curve.
DESCRIPTION OF EQUIPMENT

Flash Bubble Tower

The flash bubble tower consists of a three-fourths inch steel cylindrical shell ten feet in diameter and sixty feet long. The shell is supported by steel lugs at the bottom of the tower, resting upon a steel supporting structure built up from H columns, bracing and I beams. The top of the tower is ninety feet above the base of the steel supporting structure. The tower is equipped with twenty bubble trays spaced two feet apart, a tubular type heat exchanger, a float gauge in the bottom for liquid level indications, and a thermo-couple at the top for temperature control. The temperature is held constant so as to produce a pre-determined hydro-carbon by pumping back to the top of the tower a portion of the overhead gasoline. This is accomplished automatically and does not require manual operation.

The tower is lagged or covered with three inch thick Banner Rock Wool and a number twenty-two gauge galvanized iron jacket. Rock Wool is a spun mineral insulation. The supporting steel is covered and insulated to protect from possible fire which would heat the beams and drop the tower if they were not so protected.

Pipe Work

All pipe work inter-connecting with the existing lines is made of standard steel pipe. All nipples welded into pressure and temperature vessels are extra heavy steel pipe. Extra heavy steel pipe is used in this case to provide for corrosion. Due to low temperatures in the flash bubble tower, extra heavy cast iron valves are
used with malleable iron fittings. All of the lines except the cold crude line are covered with one inch thick asbestos pipe covering and a number twenty-six gauge galvanised iron jacket. One outstanding feature in the construction of the flash bubble tower and inter-connecting pipe work was that no shut down was necessary for the installation of the new equipment. A very great fire hazard was present at all times during the construction period, but due to very careful construction supervision no trouble was encountered.

Walks and Stairs

The flash bubble tower was equipped at every tray level with a man-hole, and it was necessary to provide stairs and platforms to groups of these levels. A design was used, which is not exactly conventional in structural steel design. All members were welded, a few bolts being used in splices. The stair wells and walk supporting members were fabricated independently of the flash bubble tower. This was done to allow for expansion and contraction of the bubble tower. One-fourth inch steel plate was used for walks and platforms and one and one-fourth inch standard steel pipe for hand railing.
CONCLUSION

In the design and construction of refinery equipment there is a well known axiom, "Make everything plenty big". This applies especially to the design of supporting members.

In designing a steel structure such as an office building, designers are not so conservative. In fact some work on the ragged edge of allowable working stresses. In refinery design a very large factor of safety is used, due to two outstanding dangers. Fire must be considered a dangerous hazard, also the possible addition of future equipment must be considered in design work. The changes in refinery equipment are so rapid that most generally equipment is called upon to do double duty, and if not so designed the additional overload cannot be carried. Some designers use as low as twelve thousand to fifteen thousand pounds per square inch allowable fibre stress in bending for supporting structure design. Pumps and motors are generally specified ten to twenty-five per cent over capacity and in some cases as high as fifty per cent. Lines, towers, condensers, and coolers all carry factors of safety from one to two times the theoretical size. The determination should be based upon local plant experience and refinery engineering practice common to the industry.
The writer realizes that statements have been made and terms used which do not carry a complete explanation. This condition can thoroughly be appreciated when note is made of the fact that large industrial concerns engaged in competitive industries do not permit, the broadcasting of their internal machinery. It has been the writer's purpose to stay, if possible, within these limits and yet present some interesting facts and conditions in the petroleum refining industry.

**********
BIBLIOGRAPHY

Facts on History of Petroleum Industry: -
from "American Refining Industry by Bell.
"Oil and Gas Journal"1930 Refinery Issue.

Refinery Methods:--
from Actual Practice and Cross Petroleum Handbook.

Curves:--
from Data Accessible to Writer.