# THE MANUFACTURE OF NATURAL GASOLENE

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By

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# THE MANUFACTURE OF NATURAL GASOLINE

Vocational Training Courses
Petroleum Industry Series

By

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FOREWORD

This course, The Manufacture of Natural Gasoline, is the fifth in the special instructional group of the Vocational Education Courses, Petroleum Industry Series, as set up and developed by the joint educational committee of the American Petroleum Institute, Production Division, and the Departments of Industrial Education of Texas and Oklahoma. It is the intent of the above named groups that this book be used as a text in the regularly organized evening school classes in the petroleum industry. However, it will prove profitable to those who cannot attend evening school classes as a home study course. In states where texts are not used in evening school classes, this book may be used as reference material.

The author, Paul J. Phillips, has had some ten years experience in the manufacture of natural gasoline, and, also, has taught evening school classes in the production division of the petroleum industry during the past five years. He is technically trained, and being very sympathetic with the gasoline plant operators, is thoroughly qualified to produce this text in a usable manner.

To make sure that the information provided is exact and up-to-date, it was checked thoroughly by the following committee:

Rex Morgan, Manufacturing Engineer, Gasoline Division, Phillips Petroleum Company, Oklahoma City District

E. K. Anderson, General Superintendent, Gasoline Division, Skelly Oil Company

H. W. Harts, General Superintendent, Warren Petroleum Company

Not only did they thoroughly check each unit, but also supplied much needed information.

This text was validated for use in the Production Division of the Petroleum Industry at a regular meeting of the Topical Committee on Vocational Training, Division of Production, American Petroleum Institute, September 16, 1938.

Due to the fact that the text is to be used in so many different localities and under different conditions, only general functions and general equipment could be dealt with. It is the intention of the editor, however, that instructors use this material as basis and make definite applications to the type of operations and equipment at hand. Due to this fact, the greatest possible value can be obtained only through class discussions and under the direction of a competent instructor.

As with all other courses in the Petroleum Industry Series, the editor and author will welcome any and all criticism and corrections, and will make use of same in future editions.

W. Fred Heisler

## PREFACE

The manufacture of natural gasoline requires experience and training in many different kinds of jobs as does any modern industry. Each workman has a portion of these jobs to perform and, consequently, has a need for applied information on his job. It was with this thought in mind that this book was compiled. In addition, it is essential that these workmen get a picture of the other operations being carried on previous to and following their own jobs and thus have a better understanding of the whole industry and be better able to perform their own work.

The informational material is general, so far as possible, due to continual changes and improvements. The latest and best practices were intended to be included but already certain improvements have been called to our attention and in the class discussion these improvements and changes should be brought up.

Credit and thanks for permission to use material and illustrations herein contained is hereby gratefully extended to the following publications, manufacturers and individuals:

Publications:

Natural Gasoline, Oberfell and Alden

Handbook of Butane and Propane Gases, Westcott

Handbook of Butane and Propane Gases, Western Gas

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Cooper-Bessemer Corporation
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P. J. Phillips

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DIVISION ONE



DIVISION TWO

D I V I S I O N  O N E

UNIT I

# NATURAL GASOLINE MANUFACTURE

1. Discovery:

The discovery of natural gasoline as a utility came about as numerous others have, because it was a nuisance existing in a place not designed to carry liquids, and something needed to be done to be rid of it. The place was in the casinghead gas line leading to the engine or boiler where the gas was used as fuel. In the winter months this liquid would collect in this line and interfere with the fuel service. The liquid was found to be gasoline and from the place found, near the casing head, it got its first name and is still called "casinghead" gasoline to a certain extent. Since the gasoline now is extracted in a plant designed for this purpose a name more suitable, both from the point of recovery and origin, was chosen, and now it is known generally as "natural gasoline".

2. Development:

To get rid of this liquid which included some water and caused complete freezing off of the line in freezing weather, a tank or joint of large pipe was connected in the line as shown in Fig. 1. This tank caught the "drip", and the tank itself was called a "drip" tank which soon was contracted to "drip", and it is so known today.

In some oil fields as drips were installed it became evident that the volume of gasoline was enough to be of importance, and this caused someone to think of a way to save it. At first barrels were used, the drip gasoline being collected and marketed in the barrels. This happened in 1903 in West Virginia. Soon vacuum pumps were installed which increased the casinghead gasoline production. Following that, compression plants were installed and started what is today, 35 years later, an industry that makes nearly eleven million gallons of natural gasoline per day.

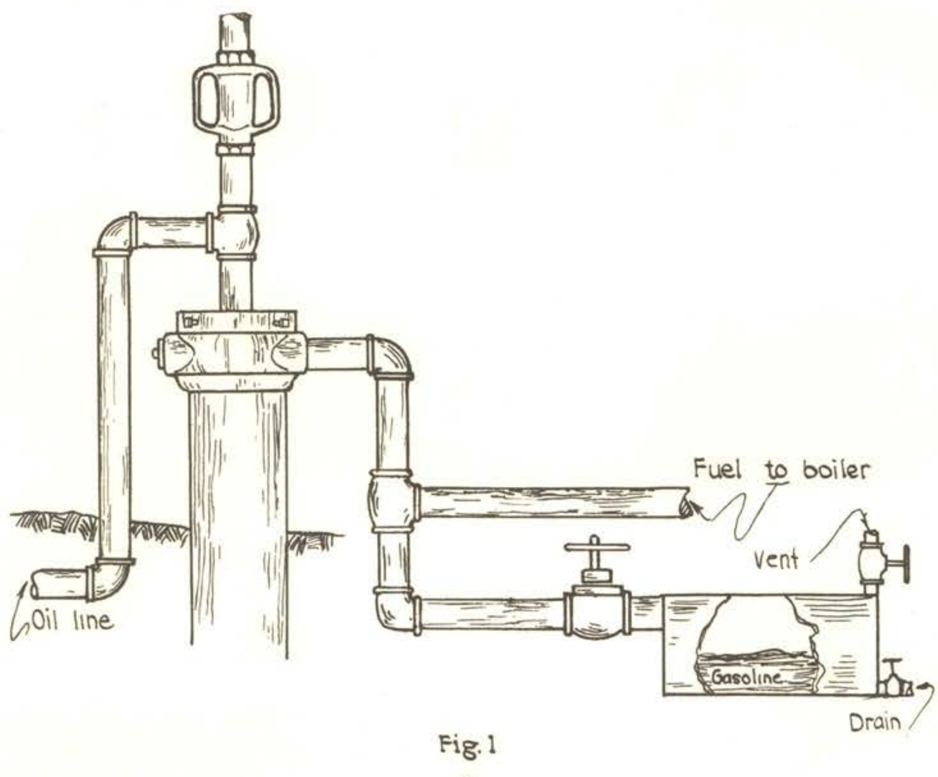



Fig. 1

3. Utilization:

In 1903, there was a ready market for the comparatively few gallons collected from the drips. As the industry grew, the demand for its products increased due to the invention and manufacture of the automobile. The demand increased with the increased manufacture of automobiles. There were a few short periods of time before 1912 in which the demand for the product fell off and producers under contract to hold a vacuum on leases were forced to dispose of their product as best they could, even to the extent of burning some of it.

This first drip product was about a 70 gravity product and was suitable for fuel as fuel then was used. Later the compression plants made a much higher gravity product that was not so suitable, but due to the demand price anything that was capturable in liquid form was salable.

At present most of the filling station automobile fuels contain some percentage of natural gasoline. A recent method of testing a fuel by its octane rating did not hamper the manufacture of the product to any large extent as it has a fairly high rating. This does not prevent its continued use in blending with the refinery products.

4. By-Products:

By-products or products developed and utilized along with natural gasoline at first would not seem to be of any consequence. It would seem that natural gasoline is a product and there is nothing else. However, those who have worked in and are acquainted with the industry know of the great amount of waste that has resulted in stabilizing gasoline to its present day requirements. For instance, a gross production may be reduced 30 per cent by volume when stabilized. The 30 per cent generally was burned at a flambeau or torch riser.

Today this stabilizer gas is utilized as a charge stock into various types of fractionators and stills to make liquefied gas for fuel, industrial solvents, polymer gasoline, and other synthetic products.

What to do with excess residue has been a problem that is being solved by sales to gas distributors and to carbon black plants.

5. Present Day Industry:

There are approximately 700 plants with a daily capacity of near eleven million gallons of natural gasoline operating at the time this text is written. This number of plants is a decrease of 30 per cent, but the production volume is the same. This indicates larger pools, better efficiency, and tendency towards uniting pools or sectioning of producing areas to eliminate duplicate gathering systems.

The geographic location of these plants and their daily capacity is shown in the following table, Fig. 2:

The production of the individual plants is shipped by tank car, pipe line, truck, and tankers to the various refineries in this country and to foreign countries. The sales and transportation of this product is a large business within itself.

At present natural gasoline is made to specifications and sold on the basis of these specifications as will be shown later. This advancement was a result of the demand for improved products and a saving was made by stabilizing the gasoline at the plant rather than shipping the raw product and thus assures a better price.

This equipment in the plants is greatly improved. The process of extraction used in new plant installations is nearly all of the absorption type, whereas in the first years of development only the compression method was used. Greater efficiency has practically eliminated the use of the charcoal recovery system. Manufacturers and producers both have sought improved methods and machinery. The improvement is almost spectacular, but there remains a great opportunity for every one connected with the natural gasoline industry for further improvements. In many cases both field men and plant men gain recognition for suggestions and are given the opportunity for their improvements to be shown and used. The industry's organization, The Natural Gasoline Association of America, signifies its attitude in this matter by giving part of its yearly program over to a "Kinks" section in which any person connected with the industry may show his ideas, and awards are made for the most useful kinks offered.

| NATURAL GASOLINE PLANT CAPACITY BY THE STATES-1938 | NO. PLANTS | DAILY CAPACITY (GAL.) |
|---|---|---|
| Arkansas | 9 | 92,660 |
| California | 105 | 3,106,805 |
| Colorado | 1 | 6,000 |
| Illinois | 28 | 17,300 |
| Kansas | 18 | 338,270 |
| Kentucky | 3 | 35,500 |
| Louisiana | 30 | 532,720 |
| Michigan | 3 | 19,500 |
| Montana | 1 | 16,000 |
| New Mexico | 6 | 208,000 |
| Ohio | 11 | 48,600 |
| Oklahoma | 138 | 2,162,610 |
| Pennsylvania | 92 | 91,030 |
| Texas | 144 | 3,735,250 |
| West Virginia | 84 | 364,962 |
| Wyoming | 7 | 113,300 |
| TOTAL | 680 | 10,888,507 |

Fig. 2

Individual companies with suggestion award systems give their men the same opportunity to improve their knowledge of their job as well as improve the operation.

Competition in the industry as well as the small margin of profit in prices makes it highly essential that operation be accomplished as efficiently as possible. The operation in turn is directly up to the men. With the new equipment, new processes and knowledge required to operate, the responsibility to study and prepare themselves to meet the continued change, is upon the men. A general knowledge of the whole operation such as is being attempted in this book will be essential in coordinating or timing one particular operation with another that follows or precedes it.

UNIT II

## NATURE AND CHARACTERISTICS OF NATURAL GAS

### 1. General Description:

Natural gas in the industry is described as "wet" and "dry". Wet gas contains more or less gasoline in vapor form, and dry gas, as the name indicates, contains no commercial quantities of gasoline. Wet gas, admitted to the gasoline manufacturing plant, is described as "rich" or "lean" referring to the degree of saturation. The wet gas contains a comparatively heavy saturation of gasoline vapor, ranging from 0.5 to 6 gallons per thousand cubic feet of gas, and in some cases, 10 or more G. P. M. A lean gas is one carrying a comparatively small volume of gasoline -- 0.1 to 0.5 G. P. M.

The origin of natural gas is a study in itself of interest primarily to the geologist. For those who are interested in a more detailed discussion a number of books are available, particularly one of this same vocational training series, "Natural Gas".

Its presence today is associated generally with the production of oil. Most of the gas fields were discovered by those seeking oil. When a well is drilled, production may be found to be: gas only, oil and gas, or oil only. Generally the character of the gas from these three kinds of wells is as follows: in the fields producing gas only, the gas itself is dry or lean, and when produced with oil, the gas is wet.

It is reasonable to expect these characteristics. Let us compare them with the conditions of the atmosphere in wet rainy weather and dry weather. In the rainy weather the air is saturated with water vapor and the humidity is high. Water from streams and lakes and on the ground vaporizes and fills the air with this vapor. When the ground is dry, contacting air can have very little water vapor in it. In the oil well, gas that has been in contact with oil carries some of its vapor which is gasoline. In the gas well where there is no oil from which to take gasoline vapors, the gas is dry. Even in dry weather there is still a small moisture content in the air, and, likewise, in some gas pools although oil is not present in recoverable quantities, the vapors of gasoline are present in small quantities, and the gas is "lean".

As stated in the beginning, these conditions exist generally. Some gas wells are wet or have a good content of gasoline vapor and some oil wells produce gas with the G. P. M. so low it does not pay to run it through a gasoline plant. The gas from each producing field has certain characteristics of this sort that determine its use.

Variation of other properties also exist in different fields and producing strata. The reference is to the percentage of lighter and heavier hydrocarbons, and the presence of foreign gases. These will be taken up in more detail.

### 2. Gaseous vs. Liquid State:

The wet gas received, then, has gasoline in it in the form of vapor, and the whole process of manufacture is based on turning all the gasoline vapors into liquid form. It can be compared to making water out of water vapor to steam to a certain extent. In the case of steam we have only to cool the steam to condense it into water. With gasoline in natural gas there is only a comparatively small percentage of the total volume of gas which is gasoline vapor, whereas steam is practically all water vapor, and the process of condensing the gasoline is not so simple. The different gasoline constituents have different condensation temperatures and pressures at which they may be made liquid. To liquefy the vapors of gasoline in natural gas as we would water vapor into water the pressure has to be increased considerably above atmospheric as the number of constituents or different kinds of gasoline present in natural gasoline will not exist at atmospheric pressure as a liquid. They start boiling at ordinary temperatures and pressures as will be shown later. When the pressure is increased and the gases are cooled, much the same as cooling steam, the gasoline condenses. A study of the different constituents called hydrocarbons gives a better understanding of the problem of gasoline vapor condensation or recovery.

3. <u>Properties of Hydrocarbons</u>:

A hydrocarbon is a compound containing hydrogen and carbon, as the name indicates. The particular hydrocarbon compounds of interest in the industry are called the "paraffin" series. There is a peculiar mathematical relation between the hydrogen atoms and the carbon atoms in this series. For each carbon atom present there are two hydrogen atoms plus two more regardless of the number of carbon atoms. This is best illustrated by the formula of the different compounds we are studying:

PARAFFIN SERIES

General Formula = $C_nH_{2n+2}$, where "n" is the number of atoms.

```
                                             H
                                             |
Methane + CH4 or 1C and 2H + 2H, or H -  C - H
                                             |
                                             H
                                             H   H
                                             |   |
Ethane + C2H4 or 2C and 4H + 2H, or H -  C - C - H
                                             |   |
                                             H   H
```

4. <u>Dry Gas</u> - - <u>Methane and Ethane</u>:

Natural gas is mostly made up of methane and a small portion of ethane. It is interesting to note from the standpoint of combustion of fuel that high hydrogen content gases are the most combustible. The formula for these two gases given above shows methane as having four parts hydrogen to one part carbon as against ethane's ratio of 3 to 1. Hence, methane, the largest constituent of natural gas, is the better fuel from the standpoint of combustion, even though it contains less value.

5. <u>Wet Gas</u> - - <u>Propane</u>, <u>Butane</u>, <u>and Heavier to Octane</u>:

Natural gas that has heavier hydrocarbons present in vapor form is generally spoken of as having some gasoline content, or is wet or lean gas. As the formula for these hydrocarbons shows an increased number of carbon and hydrogen molecules in the atom, likewise they are heavier in actual weight as the following table, Fig. 3, shows in the specific gravity column:

| NAME | SYMBOL | SP. GR. AIR - 1.0 | B.T.U. PER CU. FT. | TEMP. (F) TO LIQUEFY AT. ATMOS. PR. | CU. FT. OF VAPOR/GAL. |
|---|---|---|---|---|---|
| METHANE | $CH_4$ | .554 | 1008 | -265 | 80.6 |
| ETHANE | $C_2H_6$ | 1.038 | 1763 | -135 | 46.7 |
| PROPANE | $C_3H_8$ | 1.523 | 2519 | - 44 | 38.2 |
| BUTANE | $C_4H_{10}$ | 2.004 | 3274 | 30.9 | 31.6 |
| ISO BUTANE | $C_4H_{10}$ | 2.004 | 3274 | 10.7 | 32.5 |
| PENTANE | $C_5H_{12}$ | 2.491 | 4029 | 97 | 27.3 |
| HEXANE | $C_6H_{14}$ | 2.975 | 4784 | 156 | 24.2 |
| HEPTANE | $C_7H_{16}$ | 3.495 | 5540 | 208 | 21.6 |
| OCTANE | $C_8H_{18}$ | 3.944 | 6295 | 259 | 19.5 |

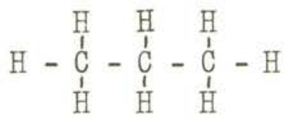
Fig. 3

The amounts of hydrocarbons present in natural gas decrease quite rapidly when we get above butane, and since everything heavier than butane is desirable, these heavier fractions are usually lumped together and designated as "pentane and heavier" or "pentane plus." Octane is perhaps the highest hydrocarbon present in natural gas, at least to any appreciable extent, and often it may be absent.

The compounds, propane and butane, are on the border line between liquids and gases. That is, they are gases under normal conditions, but they are readily condensible to liquid under proper conditions of temperature and pressure.

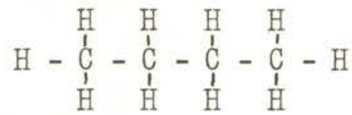
It is this property that renders these compounds particularly valuable as fuels. They may be transported, stored, and handled with the convenience of a liquid. On the other hand, it is possible to distribute them locally and to burn them with all the convenience which is characteristic of a fuel gas.

Propane is similar to ethane in chemical behavior. It is represented by the formula, Fig. 3, $C_3H_8$ or:

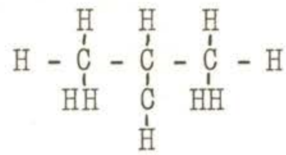


It will be noted in this table that there is another compound called isobutane. Iso is a contraction of the word isomer. Normal butane and isobutane are heavier and more readily liquefied than propane. Their chemical behavior resembles that of propane or ethane. Each of the butanes contains the atomic combination indicated by the formula $C_4H_{10}$. The difference between the two compounds lies in their atomic arrangement. This is shown in the following structural formulae:

Normal Butane



Isobutane



Isobutane has a higher vapor pressure at any given temperature, and therefore, a lower boiling point than normal butane. It is similar to normal butane in other respects.

With some explanation of the relations existing between the columns in the table, Fig. 3, the general picture of what is meant by hydrocarbons and their properties will be made clear.

The first column, <u>Name</u>, is the term in use in the industry to designate a particular compound much the same way as we speak of other materials in every day living such as water, molasses, vinegar, etc.

The second column, <u>Symbol</u>, indicates the chemical elements in each molecule of gas, using letters for the element (C for carbon, H for Hydrogen), and the numeral indicates the number of atoms of the element in each molecule of the compound. If no number appears following a letter such as C in the symbol for methane, $CH_4$, then (through custom) it is understood the number is one.

The third column, <u>Specific Gravity</u>, is the weight of the gas compared to air. Methane is approximately half the weight of air, ethane nearly the same, and the rest heavier. The statement was made above regarding the increase in the weight as the ratio of the C and H numbers increases.

The fourth column, <u>BTU Per Cubic Foot</u>, is the number of heat units obtained from the gas when burned with necessary amount of oxygen. We note again here that as the ratio of carbon to hydrogen atoms increases in the molecule that the heat value increases. It is well to note also that this is BTU per cubic foot of vapor and is not per pound or per gallon, and that the heat values in the latter cases do not increase in the same proportion.

The fifth column, <u>Temperature Necessary to Liquefy at Atmospheric Pressures</u>, gives the temperature in the Fahrenheit scale, at which these different gases liquefy. Normal butane liquefies at 34°F. Above 34° (at atmospheric pressure) it will exist as a gas. The question arises, how is it kept in liquid form? The pressure under which it is held is the explanation. In a vessel and under pressure the temperature may be raised above 34°F. without its passing back into vapor form. For example, at 55 pounds gauge pressure the liquefying temperature is approximately 120°F. The vapor pressure of normal butane at 100°F. is 51 lbs. absolute and of isobutane 72 lbs. absolute showing pressures required to hold it in the liquefied state. More information concerning this action will be given under Fractionation.

The sixth column, Cubic Feet of Vapor Per Gallon, gives the number of cubic feet (at 60°F.) that one gallon of the substance would occupy as a vapor or gas. Thus, one gallon of pentane vaporized will make 27.3 cubic feet of gas. The value of knowing these figures is apparent when you wish to balance the volume of gas coming into the plant against the volume of residue gas. Each gallon of liquid taken from the gas represents so many cubic feet and to make the residue volume balance the plant intake volume, it is necessary to add the number of gallons production times the cubic feet per gallon. The number used for cubic feet per gallon is around 35 depending on the percentages of propane, butane, etc., present in the raw gasoline taken from the gas.

6. Sour Gas and Sweet Gas:

The statement was made that natural gas consists principally of methane and ethane. Other gases also exist in small quantities of greater or less degree. Of these other gases hydrogen sulphide ($H_2S$) is the one that concerns the natural gasoline plants the most. The quantities of the other gases present in areas where the gas is stripped of its gasoline has been found negligible.

Hydrogen sulphide has an objectionable odor--that of rotten eggs--is poisonous, corrosive, and yields injurious compounds when burned. Its presence in the gas causes sulphur compounds to appear in the gasoline extracted. It is difficult to treat out these compounds in large quantities and hydrogen sulphide in the original gas causes large quantities to appear.

Natural gas containing hydrogen sulphide is called "sour" gas and without it, "sweet" gas. The terms sour and sweet were used originally in reference to the odor of the gas. The term as applied to gasoline does not apply always, as the odor will not differentiate between sweet and sour gas. The Doctor Test is used which is explained more thoroughly under Treating to determine its presence. The presence of $H_2S$ is now tested for by means of the corrosive test. This test is made by immersing a strip of copper in the gasoline sample according to A. S. T. M. method No. D130-30. Any discoloration of the copper shows a presence of $H_2S$ and means the gasoline will have to be treated to remove same.

7. Gasoline Content:

Some reference has already been made to the gallons per thousand cubic feet or G. P. M. This means there is in the wet gas, gasoline in vapor form and if one thousand cubic feet of gas is processed and stripped of these vapors, so many gallons of gasoline would be obtained. In actual practice, to obtain the G. P. M. of a sample of gas a fraction of 1000 cubic feet is treated and the same fraction applied to the gasoline obtained. For instance 10 cubic feet might be used for a sample and .02 of a gallon obtained. To get the gallons for 1000 cubic feet: $.02 \times \frac{1000}{10}$ or 2 G. P. M. is the gasoline content of the gas. More detail of this is given later in the unit on The Test Car.

## UNIT III

## NATURAL GASOLINE AND BY-PRODUCTS

1. Nature of Natural Gasoline:

Raw natural gasoline is highly volatile or as sometimes expressed "wild", containing both the fractions later composing the finished gasoline, and those surplus fractions which may be utilized as by-products or from which by-products may be made. It is unstable, that is, it will vaporize back to a gaseous form at atmospheric pressure. Referring to the table, Fig. 3, an explanation of this fact will be found in the column marked Temperature at Which the Different Gases Liquefy. It will be found that the first three, methane, ethane, and propane, liquefy at temperatures below zero, and butane at 34°F. Natural gasoline as it is condensed in the plant contains practically no methane or ethane, but consists of propane, butane, and heavier. It may be expected then that raw gasoline containing propane and butane would tend to vaporize at atmospheric pressure and temperatures, and that is the case. Especially is this true at summer temperatures.

By stabilizing, these lighter hydrocarbons, or "wild ends" as they are termed by the refinery chemist, are separated from the heavier and the product is more stable. Even after stabilizing and blending for motor fuel purposes, gasoline by its nature is still unstable and vaporizes to a certain extent.

2. Use as a Motor Fuel:

After being stabilized, natural gasoline is shipped to the refineries and blended with the gasolines distilled from crude oil and marketed as motor fuel. Approximately 20 per cent of marketable motor fuel is natural gasoline. Some manufacturers stabilize the natural to fuel specification, and it is used without blending as a motor fuel.

3. Liquefied Gases and Their Uses:

Propane and a part or all of the butane are separated from the heavier hydrocarbons by stabilization. Not being marketable as natural gasoline in the earlier days, it was wasted. However, this loss seemed unreasonable and research has brought out ways and means of utilizing it.

In the early 1900's a German, Blau by name, advanced the use of "bottled gas" or liquid gas with his bottled product "Blaugas". This gas was made by condensing gasoline vapors off gasoline storage. The expense of bottles, distribution, and the quality of the early product prevented its becoming so popular. Repeated attempts were made to perfect the use of such a liquefied gas, but not until 1926 when natural gasoline production had become so great, was it taken up by the natural gasoline producers as a means of utilizing their waste stabilizer vapors. Bottle containers were improved, regulators were constructed that would function and permission was obtained to build and use a tank car, Fig. 4, in which to ship the liquefied gases. The liquefied gases today consist of propane, butane, or a mixture.

The use of these gases is established already in a number of ways and is increasing continually. Small towns isolated from natural gas distributing systems have installed their own local distributing systems and supply the gas from tank car shipments of the liquefied gas. In some instances old artificial (coal gas) systems have been augmented or switched over completely to liquefied gas use.

4. Bottled Gas:

In small quantities commercial propane is marketed in bottles and liquefied butane in tank cars. The bottles are similar in appearance to oxygen bottles used for welding purposes. The gas is used for individual home consumption with suitable regulators. This brings to the homes a clean, convenient fuel otherwise not available.

In industry commercial butane is used in furnaces, forges, and other metallurgical heat treating operations. Undoubtedly its use in this field will increase continually as new places are discovered for this kind of fuel.

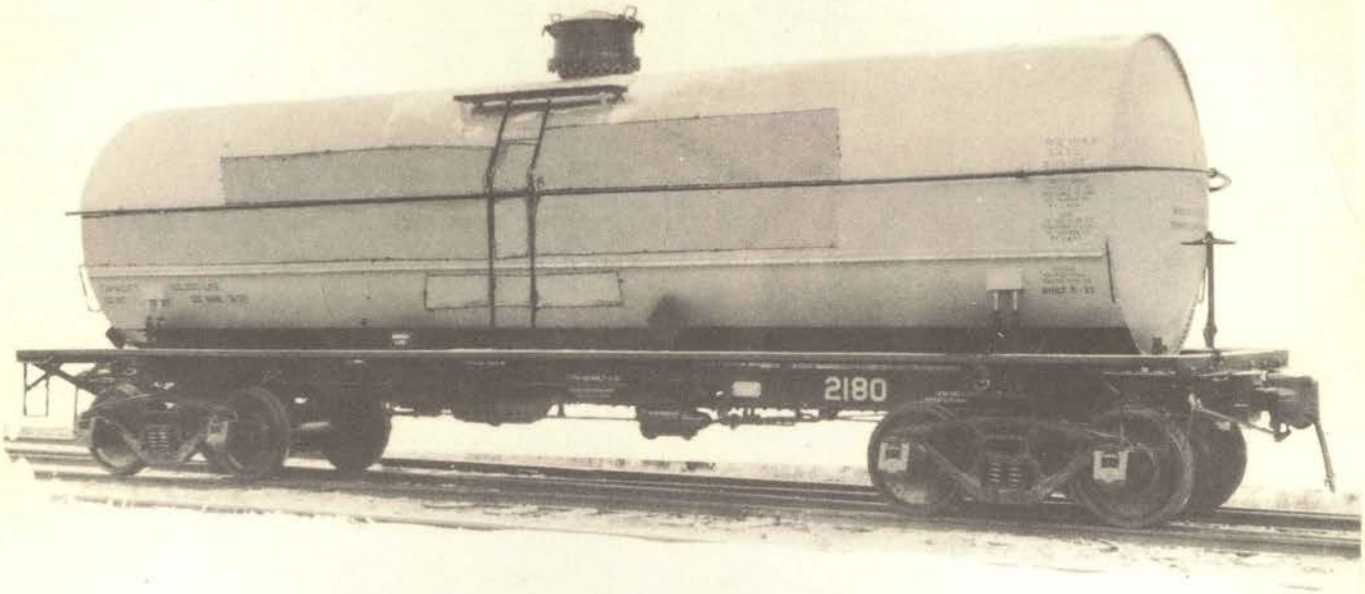


Fig. 4

Quoting from the Bureau of Mines Minerals Yearbook, 1938, concerning the use of liquefied petroleum gases: "The sharp upward trend in sales of liquefied petroleum gases was continued in 1937, when 141,505,000 gallons were distributed. This quantity was 33 per cent higher than the 1936 total and dwarfs the 1927 total of only 1,091,000 gallons".

MARKETED PRODUCTION OF LIQUEFIED PETROLEUM GASES IN U. S.
1927-37 (in thousands of gallons)

| YEAR | QUANTITY | YEAR | QUANTITY |
|---|---|---|---|
| 1927 | 1,091 | 1932 | 34,115 |
| 1928 | 4,523 | 1933 | 38,931 |
| 1929 | 9,931 | 1934 | 56,427 |
| 1930 | 18,017 | 1935 | 76,855 |
| 1931 | 28,770 | 1936 | 106,652 |
| | | 1937 | 141,505 |

5. Polymerization:

Through the many present-day means of advertising this word has come into common usage although only a year or two old. Polymerization concerns the natural gasoline industry in that it creates a use for stabilizer waste butane and lighter gas as a charging stock in the manufacture of "polymer" gasoline. Polymer gasoline is a highly desirable motor fuel. When natural gasoline plant stabilizer vapors are used then polymer gasoline becomes a by-product of the natural gasoline industry.

What is polymerization? In a few words and with the help of the hydrocarbon table, Fig. 3, it means that butane, which has too high a vapor pressure for motor fuel use, has its molecular combination of $C_4H_{10}$ broken apart and reunited into the heavier combinations of hydrocarbons which are fuel gasolines of suitable vapor pressures. The breaking apart is accomplished in stills or vessels under high pressure and at a high temperature, the reuniting is, also, done under pressure and at a high temperature. In one process the reuniting is done in the presence of material which causes the gas to reform into the heavier hydrocarbons instead of reverting back to butane. The material used is called a catalyst and this term is used by the chemist in describing any material that causes a change from the normal in a chemical reaction in its presence. The catalyst itself is not affected by being present during this chemical reaction.

Polmerization plants are being built at this time, where a large enough volume of charge stock is available and for a long enough period of time. A three-way combination of refinery, natural gasoline plant, and polymer unit is becoming popular as all products are utilized. The butane and lighter fractions from the gasoline unit goes to the polymer unit, the polymer unit has an intermediate product that is charged or run to the cracking still of the refinery and some of the gases from the still are charged back to the polymer unit.

6. Other Products:

Other types of stills have been perfected and still others in process of perfection which will utilize the waste gases to make various products. Industrial solvents, snythetic products, and C. P. (chemically pure) laboratory products are some of the materials obtained from these processes.

## UNIT IV

## GASOLINE RECOVERY

1. Gasoline Content and Recovery:

The term used in expressing content--gallons per thousand cubic feet, or G. P. M.--has already been explained. The volume of gas with which the industry is concerned is expressed in cubic feet. However, the number of figures it requires to write out one million cubic feet, that is, a one and six zeros, becomes bunglesome and time using, so the unit used has been changed to thousands of cubic feet or M cubic feet. The Roman numeral M means 1000 and instead of writing 1,000,000 cubic feet, we write 1,000 M cubic feet.

In the natural gasoline industry a thousand cubic feet of gas gets no interest until it shows a gasoline content, then the experts begin checking on the number M cubic feet that are available and multiplying it by the content to see if the total recovery is appreciable.

2. Prospects of Recovery:

As soon as a producing well is brought in with gas and oil present the volume of gas and its content are learned. The well may have from 50 M to 10 or 15 million cubic feet of gas, with a gasoline content ranging from 0 to 5 G. P. M. If this well is not close to a gasoline plant, if the content is two gallons per thousand, and there is 1½ million feet of gas, (that would make 1,500 times 2 or 3,000 gallons of gasoline per day) it would appear that this would be a good place for the location of a gasoline plant. There are other factors, however, that must be taken into consideration which follow:

a. Proration of the oil production will cut the volume to as much as one-tenth or less of the open flow.

b. Back pressure on the well due to a pinched flow will decrease the content because under more pressure less of the volatile gasoline hydrocarbons will come out of the oil into the gas.

c. Characteristics of the oil sand from which the production comes and which may be had from similar wells will tell whether the gas volume and content will hold up for a sufficient length of time to pay out a plant investment.

d. General oil situation will control the rapidity of the development of surrounding wells.

e. The presence of $H_2S$ which has been discussed.

f. The volume of gas available has to be enough to furnish fuel for the field and plant after gasoline extractions. This problem is more acute in plants in old fields where the volume is low and content high giving a profitable production but not enough fuel. In the newer developed fields such as in East Texas, the problem is to distribute the production hours of the wells over the 24 hours of the day so that a fairly even volume will be coming to the plant all the time. This not only solves the fuel problem for all concerned but permits the plant engines and distillation equipment to be operated efficiently.

As the above factors are changing continually some comment is due. Proration means that enough wells will have to be producing even while prorated to give enough volume to pay for installing a plant. Back pressure will decrease on the wells as the sand pressure decreases and this generally means an increase in G. P. M. The general oil and fuel market prices will influence spending the amount required. All these factors and those that follow are taken into account when the building of a gasoline plant is in prospect.

3. Plant Location:

There is one condition in particular upon which the location of the plant will depend. It should be near the center of the producing wells from and to which gathering and residue lines must be laid. This is not always possible as the construction of a plant may and usually does start before a field is completely developed. If the field develops off in one or two directions away from the plant builders estimate, then he must go to the extra expense of laying gathering lines in those directions.

Other conditions controlling plant location are: accessibility, nearness to railroad or pipeline facilities, rights-of-way, and water supply.

For accessibility, roads must be provided for transportation of equipment and to get in and out later. Our modern truck and tractor equipment has relieved this situation as compared to the old horse-drawn equipment, and it has been found cheaper to build serviceable roads than to mire through raw country.

The plant site proper and right-of-way for necessary roads and pipe lines generally are provided before construction starts. This has been a source of a great deal of expense and requires a reasonable and diplomatic approach to land owners to prevent hold-ups and unfavorable feeling among the local farmers and residents. Contrary to the belief that prevails in some sections, that oil companies are going to run over, damage and ruin land, and not pay for it whereever they can, it is found that companies today are willing to assume their full responsibility of paying damages and making repairs to fences, etc., when laying pipe lines.

A water supply that is soft (non-scale forming) easy to get to and of sufficient volume for all requirements is the gasoline plant man's delight. Say "bad water" and a groan rises from the depths. Boilers, coolers, engines, condensers, all will have an increased maintenance and operation expense. It is seldom that a plant must be located near a water supply, but it is essential that a supply be available within reasonable pumping distance. The treatment and uses of water in the plant will be taken up in more detail in the second division of this study.

4. Life of a Recovery Plant:

The term "recovery plant" is used to distinguish it from the main line plant. The source of gases treated makes the difference in classification. The recovery plant gets its gas from oil wells near which it is located and the main line plant treats gas in a natural gas trunk line, and the plant may be located 50 or 100 miles from the producing field.

The life of the recovery plant may be stated simply as the length of time there is enough gas in the immediate area of the plant to pay to operate it. To say that a plant will operate 10 years is anybody's guess. However, as hinted at before, a reasonable length of time has to be expected before anyone will chance the investment. The length of the plant's life is estimated in various ways. The most common and reliable one is a comparison with other producing fields in the same sand or strata. For instance, the deeper sands like the Wilcox, generally have a longer time of production of both gas and oil than the shallower sands like Booch or Caney.

Many times plants have been built and put into operation only to be shut down in a few months because of the rapid drop of the gas volume. The minimum life on which a plant can be installed and pay out is near five years. This is only a generality as conditions and prices may vary this considerably. The estimated life of a plant has been increased by the practice of proration and especially so in fields where repressuring is practiced.

5. Main or Transmission Line Plants:

The discovery of vast reservoirs of natural gas in certain areas has lead to the construction of pipe lines from these areas to large cities and to areas of large population. The size of these lines ranges from 6 to 24 inches in diameter. The volume carried in some of the lines runs as high as 100 million cubic feet per day. The gas is carried through the lines at high pressures, 300 to 400 pounds. At intervals along the line, gas compressor stations boost this pressure and keep the gas moving. With the high volume of gas passing a small gasoline content per M cubic feet makes it profitable to treat the gas and remove the gasoline. For instance, 0.1 G. P. M. in 50 million feet would be 0.1 times 50,000 or 5,000 gallons per day. In treating these lean gases a great deal of butane is made and generally is fractionated out and sold as such. As the main line is a more permanent installation so the operation of the gasoline plant can be calculated to last longer. As long as the volume transmitted stays up the gasoline plant will pay off.

The removal of gasoline from the natural gas improves the gas as a fuel as the heavier constituents of the gas do not burn so freely. It, also, improves the problem of transmission, eliminating the necessity of blowing so many drips to remove fluid collecting in cold weather.

6. Disposal of Products:

It is necessary that the shipping of the product does not cause too much expense, hence a short loading line, the line from plant to loading rack, is ideal and in some instances has influenced the location of the plant. Long loading lines require constant attention, repairing leaks due to corrosion or line tapping by foreign parties. These leaks have caused a great loss. The presence of a buyer's natural gasoline transmission pipe line within reasonable distance sometimes solves the problem of disposal of the gasoline. It eliminates the building of a spur and loading rack.

A third method of gasoline disposal is by tank truck. This has been found feasible where railroad and pipeline facilities are not available and the refinery location is not too many miles for the truck haul.

The disposal of residue gas is an important item of income if sales are available. This is discussed under Residue Disposal.

UNIT V

THE GAS CYCLE

1. The Gathering System:

The gas cycle is the path the gas takes from the well or trap through the piping to the plant and the residue disposal. Beginning at the well, the source of the gas as far as the gasoline plant is concerned, the gas enters the gasoline plant lines. The well lines on each lease join and the gas goes through a meter. Then, it leaves the lease through a lateral into the main line, and the main line runs to the plant. The sizes of all the lines are controlled by the volume of gas available and the pressure at which it is to be carried. If the pressure allowed is high, then smaller lines may be used. Too, consideration must be given for flush production. Flush production means that when wells are first

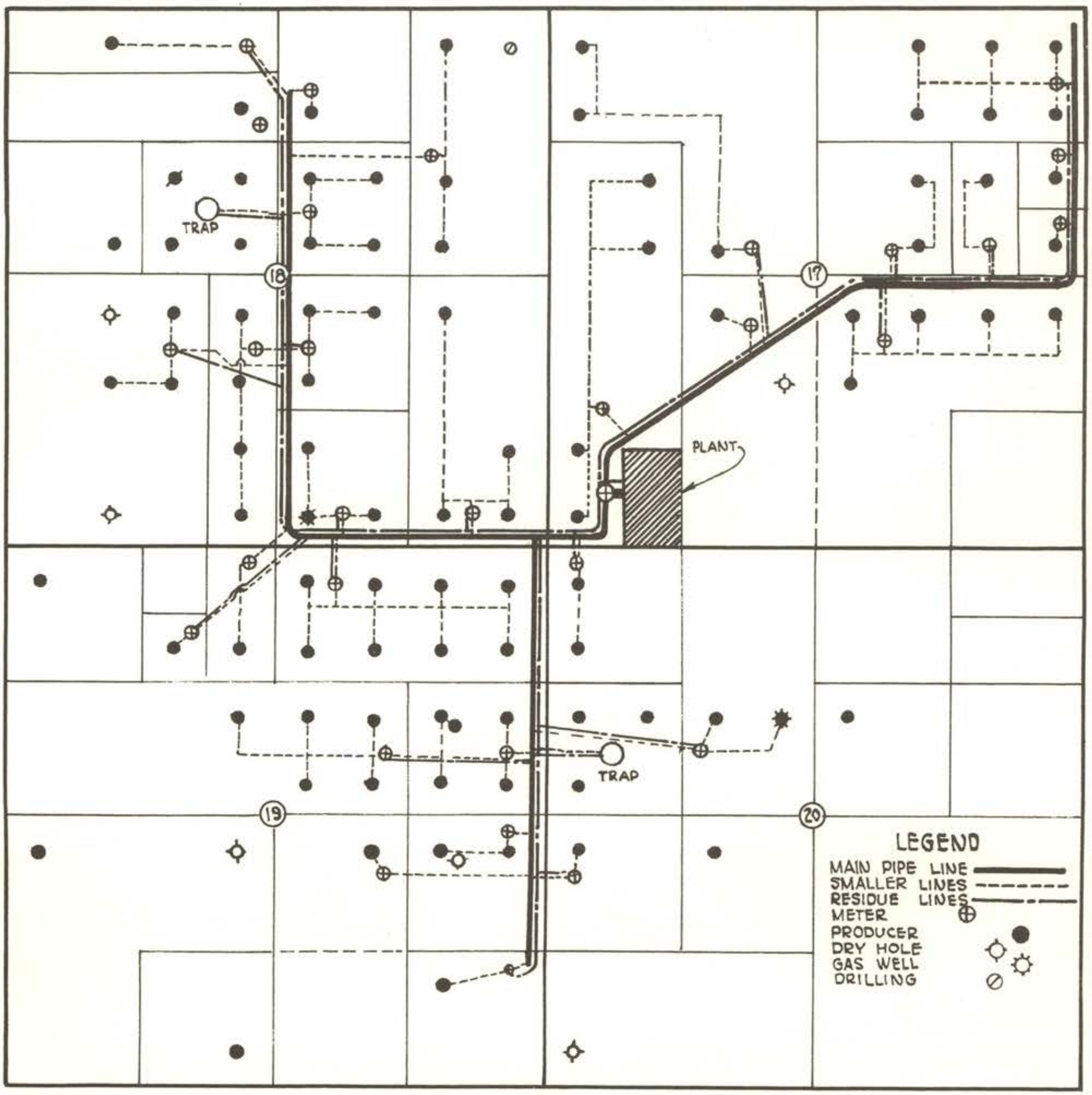



Fig. 5

brought in, the gas volume generally is high and drops off rapidly then lines are laid to carry that lower steady volume. Wells prorated and produced through a choke likewise would not require line capacity of open flow.

A portion of such a gas gathering system is shown in the preceding sketch, Fig. 5. The details of the gathering system will be discussed in a following unit.

By contract it is required that the gasoline plant return residue gas to the lease for fuel. To do this, residue lines are laid back to the leases. The most convenient and economical way to do this is to lay the main residue line along with the main vacuum line and laterals laid to the lease. The residue line is shown on the map dotted to distinguish it from the vacuum line.

2. Gas Intake:

Near the plant the main line from the leases is called the gas intake. The reason for this is obvious when we consider that at this point all incoming gas is ready to start through a series of vessels and equipment, and all starts through at one place.

3. Scrubbers:

Gas is likely to contain oil, water, foreign particles of rust, etc. None of these are wanted as they will do damage to the compressors and ruin the absorber oil. To eliminate this fluid and foreign matter, the gas is "scrubbed" by passing from the intake through scrubber tanks. These tanks are of various design. The sketch, Fig. 6, shows a typical scrubber tank. Sometimes baffling material such as tin cans or small tile is placed in the bottom quarter of the tank to help separate and scrub the gas. Note that the top and bottom of the tanks are convex and concave. Either of these types of construction will withstand both vacuum and pressure better. To give an idea of this pressure at 10" vacuum, it means there is approximately five pounds (2" mercury = 1 lb. pressure) to the square inch atmospheric pressure. The top area is 2867 square inches, and this times 5 makes 14,335 lbs. pressing in on the top and on the bottom areas. Larger scrubbers have to be reinforced internally to withstand vacuum. If the tanks were of flat construction it is easy to imagine what would happen.

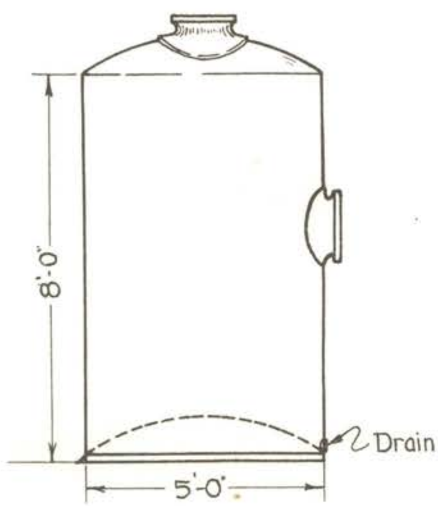



Fig 6

Other scrubbers are of different sizes and arrangements to suit the fluid or dust problem involved. Two installations are shown in Fig. 7.

4. Intake Headers:

From the top of the scrubber tanks the gas passes into the intake header. The term header is used to describe any line which is comparatively short and has a number of connections serving a battery of similar units. In this case the intake header is located along one side of the engine compressor room and

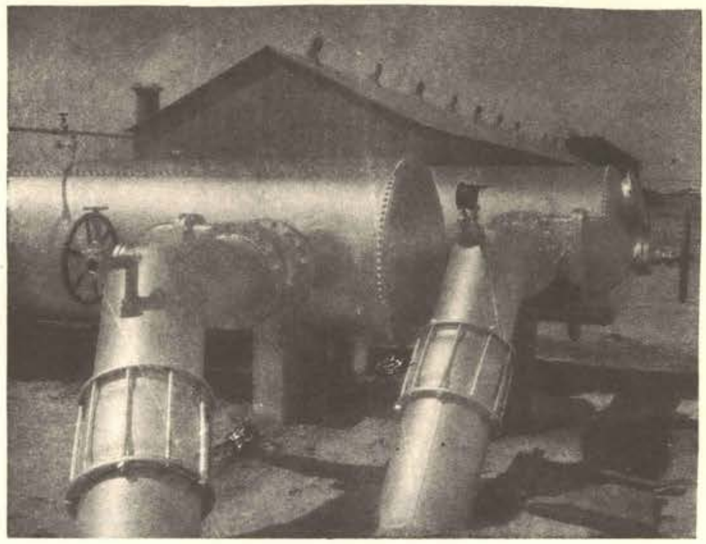
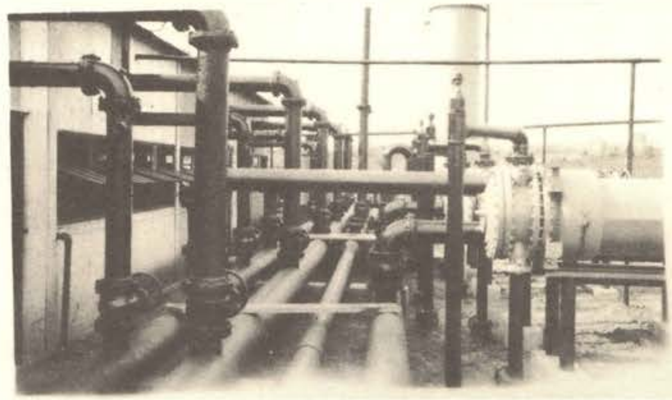


Fig. 7

has connections to the intake of each compressor. Fig. 8 shows an assembly of headers in a gasoline plant.

5. <u>Compressors</u>:

The compressors are the gas pumps. They could be compared to a water.pump set on the bank of a pond where the water is drawn into the intake of the pump and discharged through piping to a dwelling or tank where it is used. The compressor intake draws the gas from the gathering system and wells and discharges it through the plant. In each case a volume is to be moved and the pump or compressor supplies the moving energy. Liquid is not compressible, that is, its volume does not change under the pressure of the piston, and gas is compressible, therefore, pumping gas presents a different problem from pumping liquids. In order to distinguish between the two types of pump used, the name "compressor" is used in pumping gases and the name "pump" for liquids.



Plant Gas Headers. Left to Right, Compressor discharge, Intake, Residue (from absorber), and Gas cooler discharge (absorber intake). Note pop relief valves above discharge valve (between compressor and valve).

Fig.8

The tire pump is a common compressor of simple construction. It uses a small check valve for the discharge valve, and the leather plunger acts as intake. Fig. 9 is a cross section of a tire pump showing the intake and discharge valves and direction of the flow of the "gas" or air as it is in this case. Gas compressors in the plant operate on the same principle, the only difference being that they usually are double-acting meaning that gas is drawn in and compressed on both sides of the piston. Fig. 10 is a cross-section of a typical double-acting compressor. The intake is on top and the discharge at the bottom. Piping from the intake header connects at the intake of this type cylinder. From the discharge it is piped to a discharge header.

Fig. 11 is a sketch of a piping system to give an idea of a piping layout, and showing the names of the different sections with their relation one to the other.

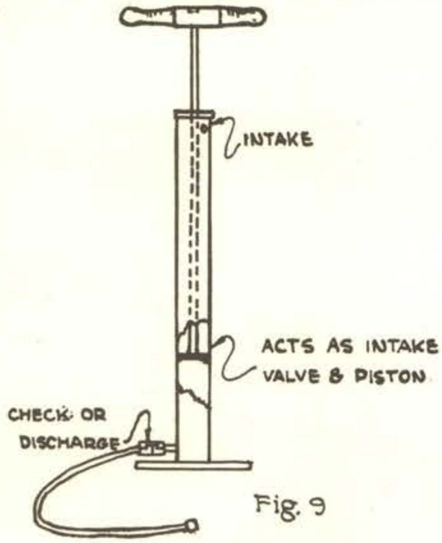


Fig. 9

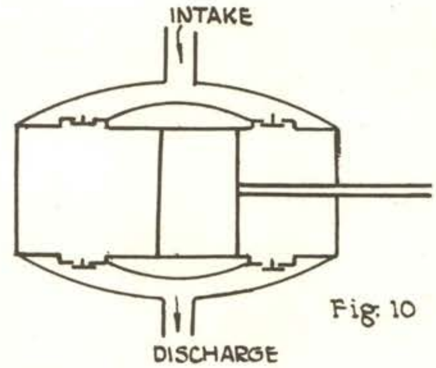


Fig. 10

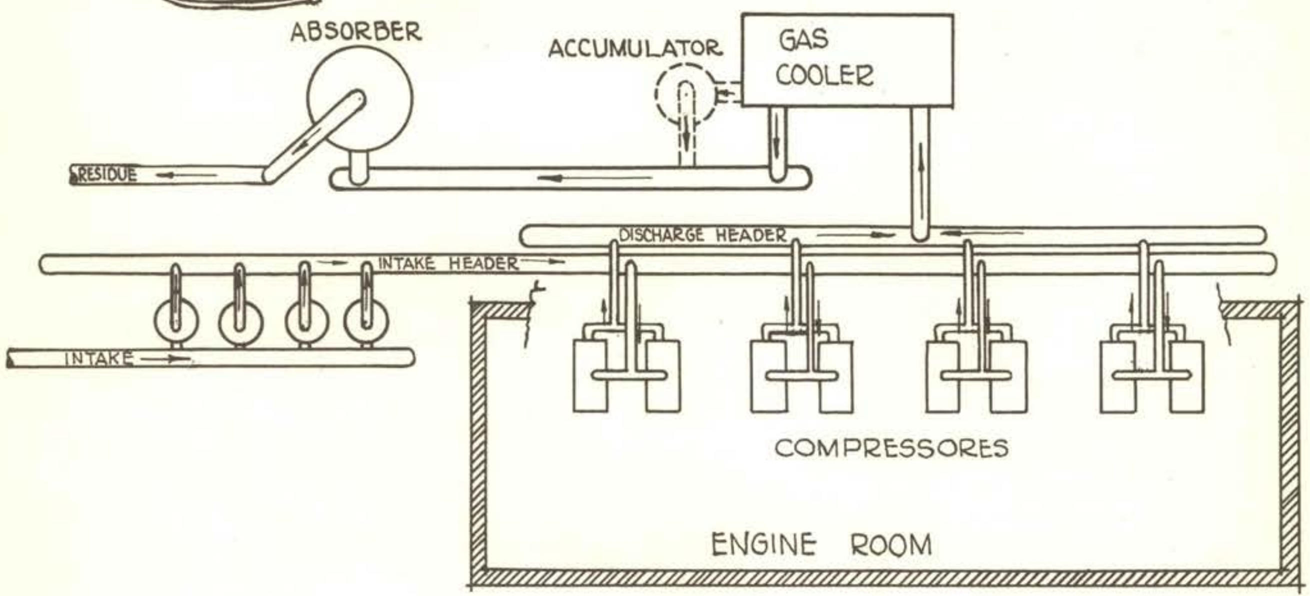


Fig. 11

6. Gas Cooling:

When gases are compressed they become heated. The cause of this heating will be discussed in a following unit. It is necessary to cool the gas to get efficient absorption of the gasoline vapors in the absorber. To accomplish the cooling, two types of coolers are used: the open and closed.

Fig. 12 shows the closed type cooler. As the parted joint section shows, there are a large number of small diameter tubes within the shell. Connections and baffles are so arranged that water passes one direction through half the tubes and back through the other half; gas passes one direction in one-half the shell and around the tubes and back the other direction in the other half. The gas flows through the cooler in an opposite direction to the water flow, and is called counter-flow or counter-current. In this process the heat from the gas in the shell is taken up by the water in the tubes and the gas is cooled.

The open type cooler, Fig. 13, is mounted in a cooling tower where water

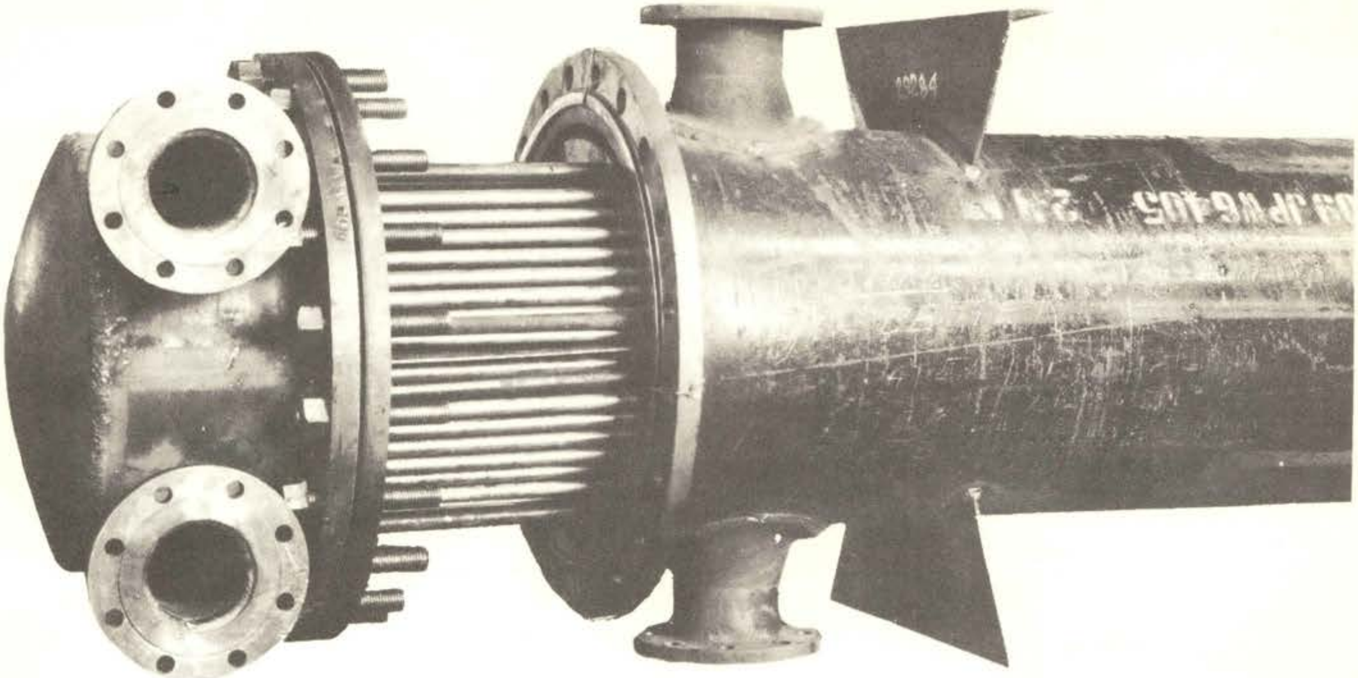


Fig. 12

sprays over all the tubes. Gas passing through the tubes is cooled. This type of cooler is constructed with baffles or partitions in the heads, so that the gas flow may be down one side and back the other. This is in gas cooling. In oil cooling, it goes back and forth again and again as described according to its construction as single pass, 2 pass, 3 pass, etc.

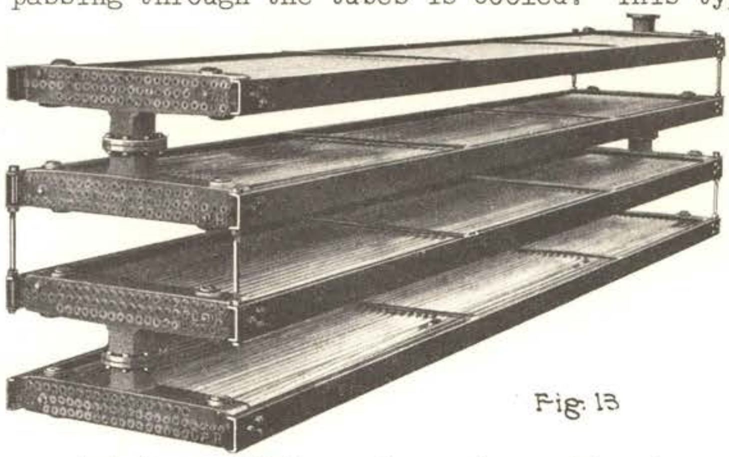


Fig. 13

7. Accumulators:

At this point in the gas cycle where the gas is compressed and cooled, some of the gasoline is condensed, the amount depending upon a number of conditions which will be discussed later. If the volume of gasoline is small, no provision is made and the gasoline goes on into the absorber with the gas. To remove the gasoline, the gas is passed through an accumulator tank, Fig. 14. The fluid drops to the bottom of the tank, the water is drained at the lower connection, and gasoline drawn off at the upper of the two small connections.

The gas then entering the absorber has lost part of its load of gasoline which lightens the job of the absorption oil and the distillation process.

8. Gasoline Extraction:

Extraction is accomplished by one or more of three methods; absorption, compression, and charcoal. The gas cycle through the plant is practically the same for all methods up to the point where it leaves the coolers. In the absorption method the gas continues through the absorber where the gasoline is extracted, then on out as residue as shown in the flow sheet, Fig. 11.

In the compression method, the gas from the coolers is piped back to the compressor rooms to high pressure compressors then to a second set of coolers. In a second set of coolers the gasoline vapors, at high pressure, condense and the gasoline is drawn off through accumulator tanks. From these accumulators the gas goes out as residue, thus completing the gas cycle in the compression extraction method.

In the charcoal method, the charcoal absorber can be installed in place of the oil absorber and the gas cycle is much the same. Each of these methods will be discussed in detail in following units.

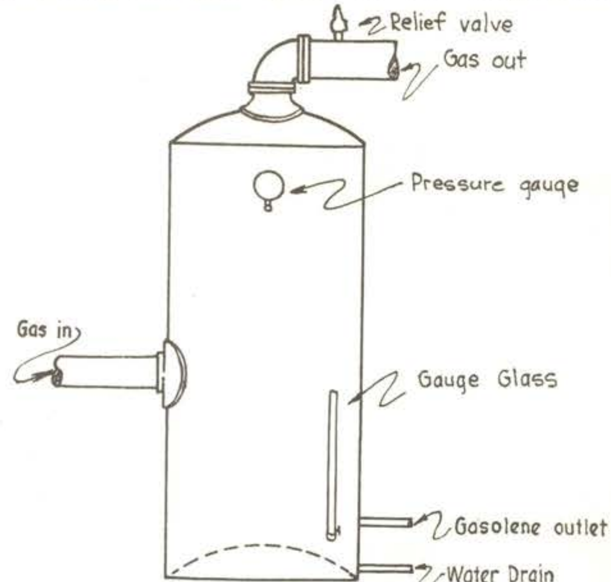


Fig 14

9. Residue Gas Disposal:

Only a small portion of the incoming volume of gas to the plant is removed by gasoline extraction and at first glance it would appear that there is a big volume of good fuel gas available and no place to use it. However, the first places of importance to which this fuel must go are: the producers on the leases and the gasoline plant itself and they require no small amount. If there is a large number of pumping wells, their fuel requirements may run two million or more feet per day. In the plant, one 200 h.p. engine compressor will require approximately 50 M cubic feet per day, and the boilers will require from 50 to 100 M cubic feet per day each.

These field and plant fuel requirements may not use all the residue gas. The excess gas is available for sale as a by-product. Local gas distributing companies may use the gas or if a main gas transmission line is near it may be piped to it. If the field is still being drilled, which is not unusual, then fuel for the drilling rigs is furnished from this excess residue gas. This excess gas is used also for repressuring, gas lifts, and power. Every effort is made to utilize any excess rather than waste it.

The carbon black industry is a common market for residue today. Carbon black is used largely in the manufacture of automobile tires as well as for inks, paints, etc. Carbon black is formed by the incomplete combustion of natural gas. It is referred to commonly as soot when it is formed on the bottom of cooking vessels caused by a poorly regulated gas flame.

10. Well Pressure Operation:

The production of oil and gas from some fields is accomplished by holding enough back pressure on the oil and gas separators to force the gas through the gathering system and absorbers. This method eliminates the use of compressors and coolers and thus simplifies the construction of a gasoline plant. In Fig. 11 all equipment up to the absorber would be eliminated except the scrubbers.

## UNIT VI

## EXTRACTION BY COMPRESSION

1. Mechanical Principles:

The mechanical principle of extracting gasoline from gas is based on the principle attaining the pressure and temperatures at which the gasoline hydrocarbons will liquefy. In the table, Fig. 3, we learned that at atmospheric pressures, certain temperatures are required above which the hydrocarbon existed as a gas and below that point existed as a liquid, this under closed vessel conditions. By increasing the pressure on the gases the liquefying temperature is greatly lowered, and by cooling the highly compressed gases, the liquefying temperature at the high pressure is reached, and the gasoline molecules are condensed. Chapter 13 Elementary Science Applied to the Petroleum Industry explains this action fully. The pressure at which most of the gasoline molecules are condensed is 250 lbs., consequently, that pressure is used commonly. The lower the gas the higher the pressure is that is necessary for efficient extraction.

2. Gas Flow:

The mechanical means of obtaining this pressure has been described partially in a preceding unit. Low stage, large compressor cylinders from 16" to 20" in diameter are used to bring the gas in from the field and discharge it through coolers at pressure varying from 20 lbs. to 50 lbs. From these coolers, called intermediate coolers, the gas goes to the high stage compressors, 5 to 9 inches diameter, and is discharged through high pressure or the high stage coolers. Condensation takes place here and the outlet of the coolers is into the gasoline accumulators. Fig. 15 shows the path of the gas through a compression plant, and Fig. 16 shows the high and low pressure cylinder installation on an engine compressor.

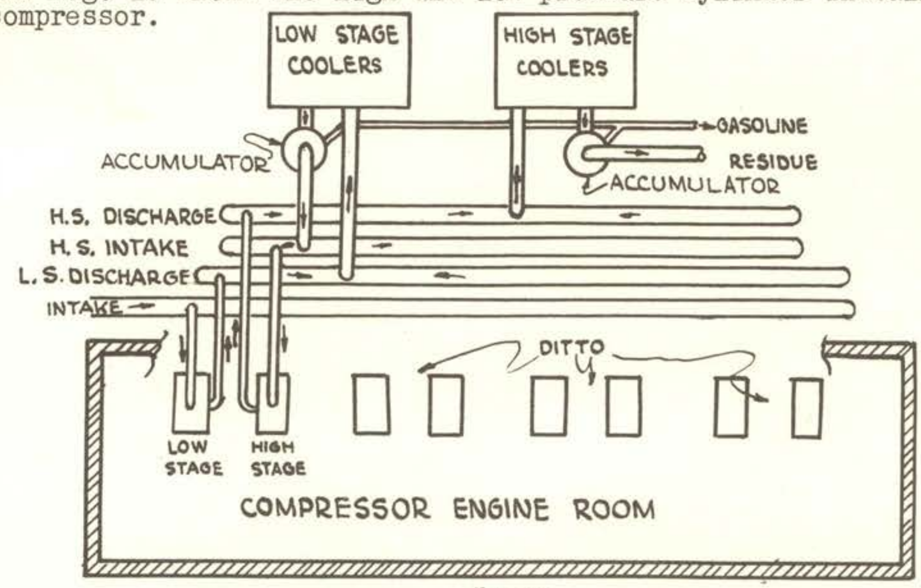



Fig. 15

3. Safety Practices at High Pressure:

As the oil, gas, and natural gasoline industry has progressed, the need for higher pressures in different phases have become more common. Although the plants are swinging over to the absorption process nearly every plant boosts the gas pressure high for sales or for some other purpose. It has been found that men accustomed to working with lower pressures do not give the regard necessary for safe handling of higher pressures. The following general safety precautions are recommended:

1. Pop relief valves on all high pressure equipment should be tested at regular intervals.

2. The correct method of opening and closing valves on the high stage compressors should be understood by all operators who manipulate them.

3. A regular check at stated intervals should be made on the H. S. discharge temperature and a knowledge of normal temperature ranges that should exist.

4. Pressure gauges should be checked at regular intervals and between times if there is cause to believe they are off.

5. Operator should avoid standing in front of compressor cylinders and valves.

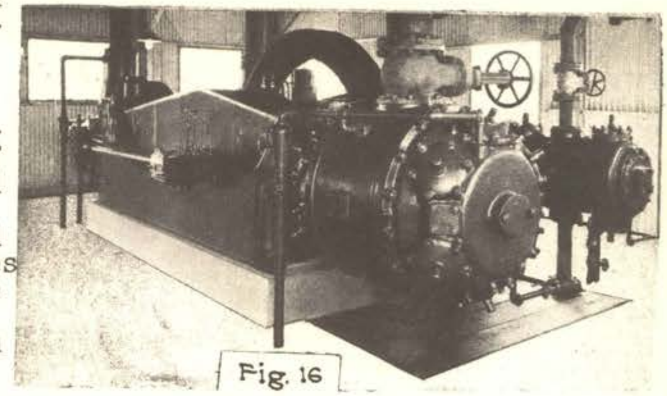


Fig. 16

6. Air content of incoming gas should be checked at regular intervals and between times if indicated. An indication of sudden increased air content such as engines spitting or increased temperature at discharge is the immediate signal to lower the discharge pressure until the condition is remedied.

7. No extraordinary strain is to be placed on high pressure piping or equipment with pipe wrenches, hammers, or other devices.

8. All high pressure valves should be operated occasionally, especially where some corrosion takes place to see that they are in working order for an emergency.

9. Repairing of leaks to be done with extreme caution and only by experienced persons.

10. Especial care should be taken in preventing the maintenance of pressures higher than that prescribed for a cylinder, tank, or any pressure vessel.

11. Avoid the practice of having a gate valve between the pressure vessel and the pop relief valve.

12. When making a pop relief valve installation, it is important that the valve be of sufficient capacity to handle the maximum volume of a cylinder at a safe pressure, and in case of a tank or pressure vessel it should be of sufficient size to carry all vapors from a single or multi-valve installation without excessive back pressure.

13. Where relief valves might pop at a point close to a fire or boiler house, the vapors should be piped away to a safe place. This vapor line should be of sufficient size to carry all vapors from a single or multi-valve installation without excessive back pressure.

14. Do not allow welding near a pop valve discharge.

15. Most gasoline plants have relatively low pressure gasoline treating tanks through which gasoline is pumped or pressured from a potentially high pressure source. Be sure that these tanks are equipped with adequate relief valves as well as automatic pump cut-offs.

More could be added and each plant has its own specific hazards that should be noted and called to attention of all concerned.

4. <u>Recovery Efficiency</u>:

The recovery efficiency or the total amount of vapors condensed by the compression method is not as great as those recovered by the absorption method. This is especially true in treatment of lean gas. The recovery efficiency of a plant is found by testing the residue gas for any condensable vapors left in it. However, there are exceptions to this first statement and it may be misleading.

The exception exists where the gas being treated has a small percentage of the lighter fractions, propane and butane, and the average compression temperatures and pressures recover as much of the condensable gasolines as the absorption process. Recent refrigeration installation, however, has improved the compression plant recovery to equal that of absorption. Where these lighter fractions are of a greater volume the compression method is not as efficient in recovery, due to the fact that the pressure and temperature required cannot be attained consistently. To make the compression method recover all would cost too much in the way of additional compression and cooling equipment.

The statement may be misleading because the efficiency of recovery of all condensable vapors is not the same as efficiency of recovery of just the vapors desired. If it is not possible to utilize these lighter ends at a plant then its efficiency is comparable to the absorption method. On the other hand, if a molecule wrecking and rebuilding apparatus such as the polymer system or propane and butane handling equipment is nearby, then these lighter hydrocarbons are valuable and the absorption process would be the more efficient.

There is another viewpoint of comparison in efficiency if the cost of equipment of the two methods is considered. The detailed study of such a comparison is beyond the scope of this book. A few general statements are of interest: A large volume of gas can be treated with less investment by the absorption process. To treat gas by the compression process requires approximately twice the engine horsepower in raising it from 10" vacuum to 250 lbs. pressure that is required in the absorption process of raising it from 10" vacuum to 25 lbs. pressure. Idle equipment from shut-down plants such as engines and distillation units will also influence the type of installations.

5. Operating Difficulties:

Compression plant operating difficulties are: corrosion, regulation, freezing at accumulators, compressor lubrication, and cooling of gases.

Corrosion takes place under any conditions. It is slowed down on external surfaces by preventative coatings. On the inside of piping, fittings, and vessels it is slow due to lack of oxygen. However, certain impurities in natural gas, hydrogen sulphide, in particular, has a highly corrosive action on metal and brass. This corrosive action is speeded up under pressure and heat. Thus, in the high pressure side of the compression plant there exists a good set-up for corrosion to take place.

High pressure piping, coolers, and accumulators have a comparatively short life where the gas has any corrosive action. The replacement of parts always is expensive not only in the cost of new equipment but quite often, loss of production due to shut down while repairs are made. Corrosion, also, is a partial cause of the other difficulties.

Regulation has been found difficult due to varying loads of gas coming into the plant, and regulators not functioning or not being of the right capacity to handle the volume. This difficulty has been largely overcome by the better type metal seats and by choosing regulators that are neither too large nor too small.

A regulator not functioning is not necessarily a fault of the regulator. Expansion of high pressure gas to a lower causes a lowering of the temperature and it may go low enough to freeze any moisture. In this case, ice forms between the disc and seat of the regulator valve and it ceases to function. This has been remedied by steam jacketing the valve or the incoming gas line. Fig. 17 shows a steam jacketed valve, home made from an empty carbide drum. The drum is split longitudinally with tin snips and cut out to fit around the gas line and upper part of the regulator. This is one of many devices used to keep regulators from freezing. It is more or less a temporary remedy, and copper tubing coiled around the valve body and insulated is a better installation.

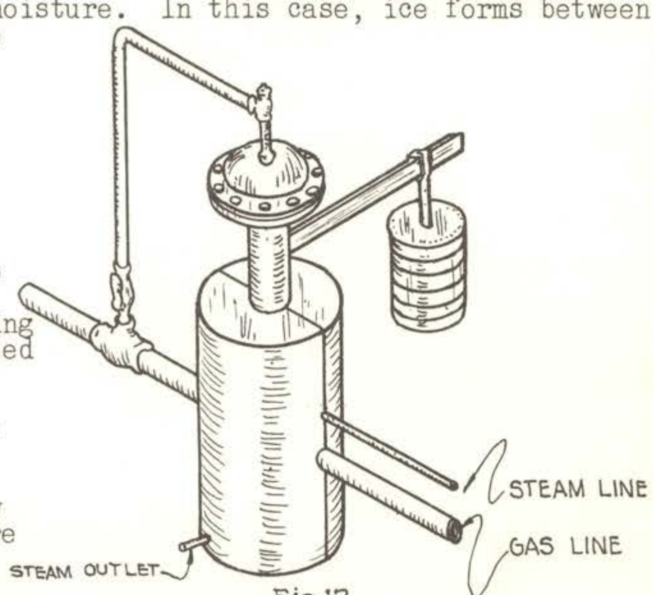


Fig 17

Freezing at the accumulator gasoline out-let valve and the run down line to storage has been a source of a great deal of trouble, especially during the winter months. The expansion of the raw gasoline from 250 lbs. to a tank pressure of 25 lbs. takes up lots of heat with the result that from the valve to storage and sometimes the storage tank, all the pipe is covered with frost. If there is any moisture inside the line it becomes ice immediately.

The remedy for this freezing in summer is to shut off the accumulator outlet temporarily and allow atmospheric temperatures to thaw the line. In winter, the line may be steamed. Either of these may not be satisfactory as the accumulator may fill before the line is open and gasoline wasted. The installation of two run down lines is good practice, then one may be used while the other is cleared. Lubrication becomes more difficult as higher pressures are encountered in any piston-cylinder combination. In the Diesel engine this particular problem was solved by forced feed. The same method is used in compressor lubrication with the additional problem of keeping the oil from off-coloring the gasoline. This has been solved in some instances by the use of castor oil or the special lubricants made from cocoanut oil. The use of special lubricants requires a two-compartment force feed lubricator or a separate high pressure sight feed system. Fig. 18 shows one such sight feed arrangement in use for a number of compressors.

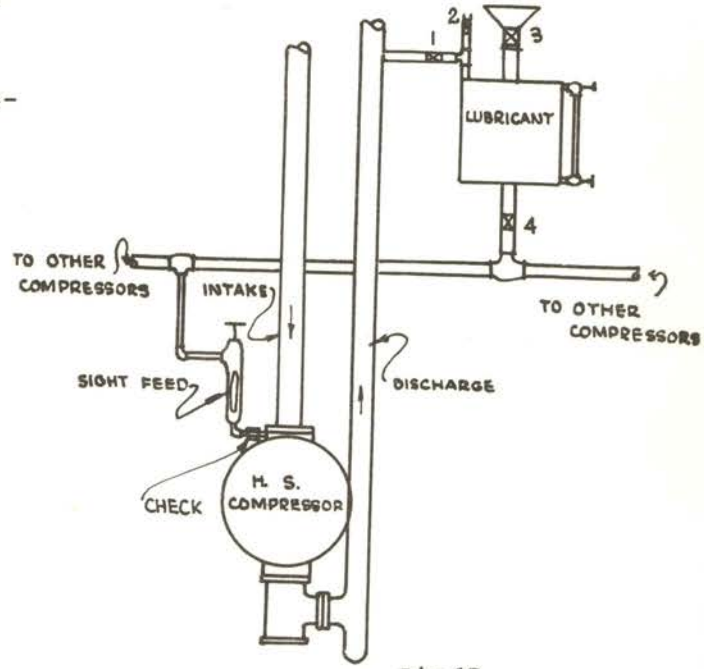


Fig. 18

The cooling of the gases for condensation of the gasoline is no difficulty in the winter months. In the summer when atmospheric temperatures are high the gas is brought down to near the water temperatures only. The water temperature, on certain days when evaporation does not take place freely, a fact to be discussed later, runs high and gross production reflects a drop. A cooler water temperature can be had by installing power driven fans for forced draft.

A gas expander cylinder unit has been used to further cool the gases. In this method the compressed gas is expanded through a closed type cooler counter current to the gases to be cooled. The cooling gas medium is then recycled through the expander cylinder. Propane and butane are excellent gases for this type system and are used as refrigerants for cooling in other than compression plants.

It is an interesting feature of most gasoline plants that the cooling or refrigerating effect of expanding these gases or liquids which also are available at the reflux condenser of the stabilizer, is utilized to make ice. All that is necessary is the brine tank, insulated box, pipe coil in brine and the cans to hold water which is frozen. An equal mixture of mineral seal and gasoline may be used as a cooling medium instead of brine. Compressed air which usually is available is used to circulate the brine. Neither the amount of gas nor air used for this purpose is appreciable and ice is a premium in isolated plants. These small ice plants furnish the laboratory and quite often the camp homes. Fig. 19 is a sketch of one plant's small box for making ice.

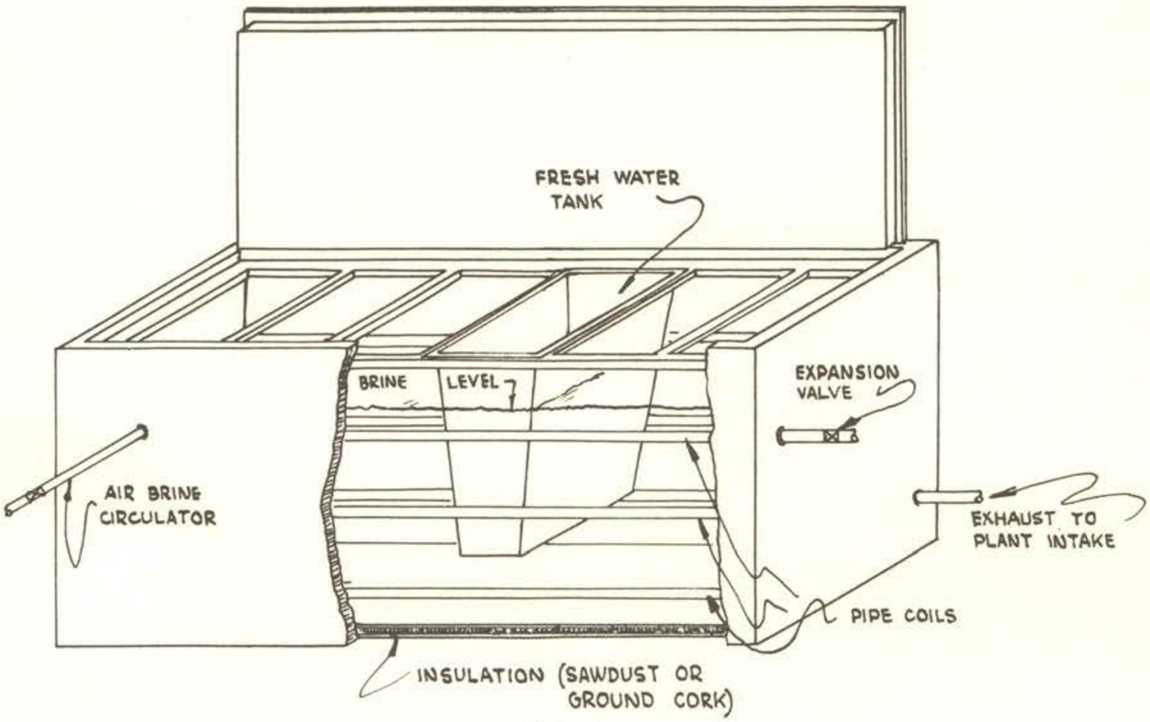

FRESH WATER
TANK
BRINE LEVEL
EXPANSION
VALVE
AIR BRINE
CIRCULATOR
EXHAUST TO
PLANT INTAKE
PIPE COILS
INSULATION (SAWDUST OR
GROUND CORK)

Fig. 19

## UNIT VII

## EXTRACTION BY CHARCOAL ADSORPTION

1. Mechanics of Process:

The name adsorption has a significance in the mechanics of this process. Adsorption means collecting or condensing on the surface. Adsorption means collecting or gathering by intermingling of the molecules which happens in the oil adsorption process. Activated charcoal has a liking for gasoline molecules that causes them to adhere to the charcoal and to condense on its surface. Charcoal is porous so that a great deal of surface is exposed in the many small holes running through it and thus gives it a large capacity to condense gasoline.

There are three operations in the extraction of gasoline from the gas in the charcoal method. First, the "green", untreated, gas is passed through a bed of activated charcoal which adsorbs the gasoline. This bed of charcoal is in a vessel commonly called an absorber, actually an adsorber. When the charcoal has adsorbed all the gasoline it can without letting any pass on through the adsorber, the green gas is switched to another charcoal bed in a second adsorber.

The length of time required to load the charcoal is made by checking the temperature rise of the bed caused by the giving off of heat of condensation. The bed will continue to adsorb efficiently some time after the maximum rise in temperature is attained. This time may be checked by calculation, but, in general, it is done by experimenting until the point of efficiency is found both from a view point of loading the charcoal and not losing any condensible vapors by passing on through the adsorber.

Second, after the gas is shut out of the loaded bed of charcoal steam is turned into the adsorber. The steam evaporates the gasoline and the vapors are piped out to condensing coolers. There may be two coolers in a series; the first at a higher temperature which "knocks down" or condenses most of the water vapor from the steam; the second at a lower temperature that condenses the gasoline vapors; or one condenser may condense all vapors.

Third, the steam is cut out of the charcoal bed after all gasoline vapors are driven out and the bed is allowed to cool, or be cooled by residue gas for another charge of green gas. As these three operations of adsorbing, steaming, and cooling have been described, it is easy to understand that in order to continuously treat gas, it is necessary to have three adsorbers, one for each of the three operations. Fig. 20 is a diagrammatic layout of a charcoal adsorbing

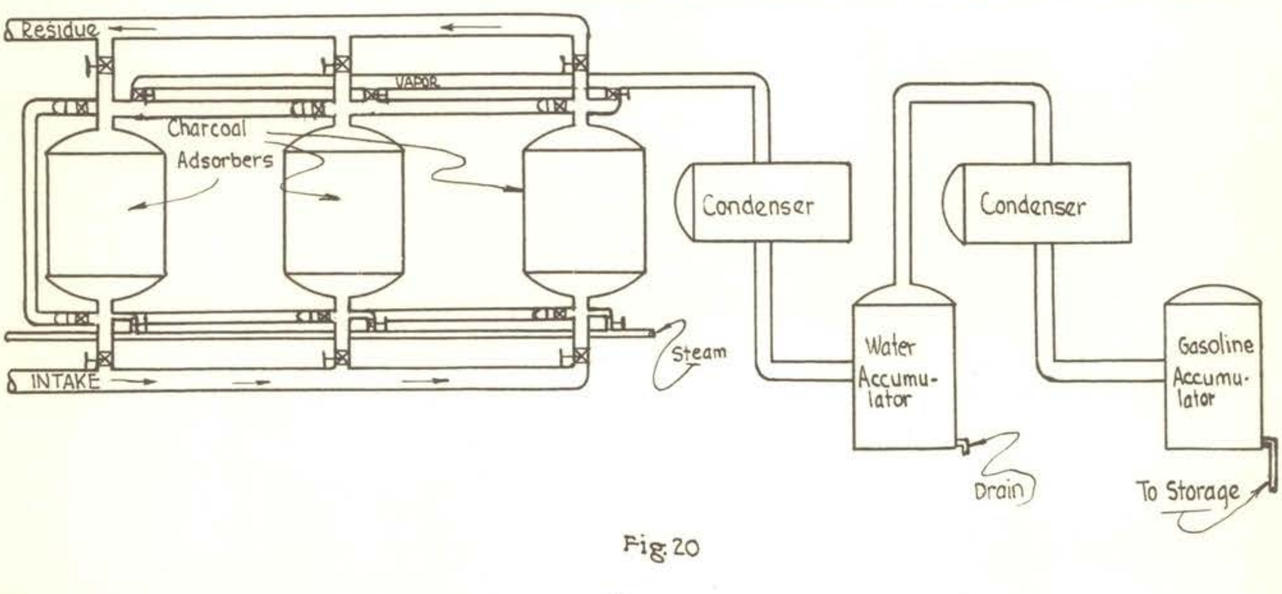



Fig. 20

system. The position of the valves is thus: In the first adsorber the inlet valve is open, residue valve is open in loop back to bottom header, steam vapor line valves are closed, and gasoline is being adsorbed. In the next adsorber, both gas valves are closed and the steam and vapor line valves are open, the gasoline is being evaporated to the condenser. The third adsorber is cooled by circulating the residue gas from the adsorber doing the treating, through it, and out the upper residue header.

The activated charcoal used in this process is very expensive and this is one of the reasons for discontinuing use of the charcoal system. The charcoal is made from cocoanut shells and is the best type found for this purpose. It is broken up and screened to $\frac{1}{8}$ inch to $\frac{3}{16}$ inch in size. It is used extensively now to test lean gases in small laboratory adsorbers.

At one time it appeared that the charcoal process would become as much used as oil adsorption and compression, but, due to the increased efficiency of the adsorption system as against the expense of charcoal and the fact that charcoal did not recover so much of the lighter hydrocarbons, propane and butane which are utilized today, very few charcoal adsorption plants are operating now.

UNIT VIII

EXTRACTION BY OIL ABSORPTION

1. Mechanics of the Process:

Fig. 11 shows the path of the gas through the absorption type plant. The oil circulated in the absorber takes the gasoline from the gas bubbling through it and coming from the absorber is called "rich" oil as against "lean" when it went in. The gasoline has been taken from the natural gas but it is now in the absorbing oil and is separated from it by distillation.

2. Oil Flow:

Fig. 21 shows a simple oil flow chart. Many details are omitted which are taken up later. The oil or absorbing medium is a continuous cycle. From the absorbers with gasoline, to still, and from still to absorbers to pick up another load.

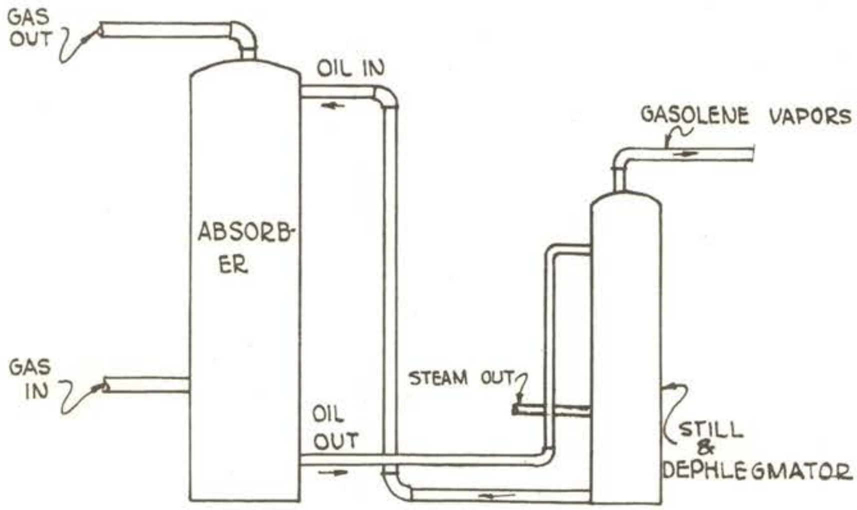



Fig. 21

3. Distillation and Condensation:

The process of distillation in the gasoline plant is similar to that in a refinery, except it is much simplified. In the refinery, crude distillation is done to recover many different products, gasoline, kerosene, naphtha, etc. In the gasoline plant we have an oil which is kerosene or Mineral Seal, a cut between kerosene and naphtha, that has absorbed gasoline. By controlling the still temperatures only the gasoline is evaporated or distilled off and the oil continues through and out the bottom of the still to be used over again in the absorber as lean oil.

The gasoline vapors are taken off the top of the still through a condenser which condenses the vapors and the gasoline flows by gravity into an accumulator tank and from there to storage or to the stabilizer.

4. Recovery Efficiency:

The efficiency of the absorption system for present day plant products has been found to be better than that of the compression plant. Also, from residue analysis it has been found to clean the gas of its condensable hydrocarbons. This efficiency is partly accounted for by the ease with which a margin of safety can be had by circulating slightly more oil than individual tests indicate would clean the gas.

This feature also takes care of any variations of the incoming gas content without loss. For instance, a certain lease or well which has particularly rich gas is only produced part time. If the oil circulation is kept up above maximum requirements of the incoming gas content then there is little chance for loss of production by its not being absorbed. The oil circulation required may vary from 1 gallon per thousand cubic feet of gas treated on lean gas and high pressure to 100 G. P. M. cubic feet of gas at low pressures. The average at 40 pounds pressure is 40 gallons per thousand cubic feet.

The recovery of the lighter ends is particularly desirable and is accomplished by the absorption method, where these lighter ends are being utilized for one of the by-products mentioned as polymer charge stock, carbon black stock, or propane and butane bottling material.

A complete description in more detail is given in Division Two since the majority of new plants built now are of this type.

5. Comparison of Location and Number of Plants and Methods of Manufacture:

The three methods of manufacture of natural gasoline have a great deal more significance if we know where and how much they are used. It has not been the intention to promote or boost either method in this book and if such an impression has been gained from the study herein, it was not so intended.

The best information and data available is from the U. S. Bureau of Mines Minerals Yearbook, 1938:

"Production by Processes--Although production of natural gasoline by the absorption method showed the largest increase in 1936, the compression and charcoal processes continued to gain in relative importance. This was surprising, as straight compression and charcoal plants were thought obsolete as far back as 10 or 15 years ago."

*Natural gasoline produced in the United States in 1936,[1] by States and by methods of manufacture*

| State | Number of plants operating | | | Production (thousands of gallons) | | |
|---|---|---|---|---|---|---|
| | Compression | Absorption[2] | Charcoal | Compression | Absorption[2] | Charcoal |
| ARKANSAS | 1 | 7 | | 1,337 | 10,620 | |
| CALIFORNIA | 3 | 84 | | 2,593 | 590,823 | |
| COLORADO | 1 | 1 | | 186 | 265 | |
| ILLINOIS | 48 | | | 2,337 | | |
| KANSAS | 6 | 12 | | 2,214 | 35,561 | |
| KENTUCKY | 2 | 3 | 1 | 23 | 5,424 | 562 |
| LOUISIANA | 4 | 25 | | 3,580 | 69,107 | |
| MICHIGAN | 1 | 1 | | 379 | 1,636 | |
| MONTANA | | 1 | | | 2,071 | |
| NEW MEXICO | | 4 | | | 28,921 | |
| NEW YORK | 1 | | | 22 | | |
| OHIO | 4 | 7 | 1 | 42 | 5,920 | 1,029 |
| OKLAHOMA | 45 | 107 | | 53,829 | 364,762 | |
| PENNSYLVANIA | 89 | 15 | 1 | 3,088 | 10,956 | 228 |
| TEXAS | 24 | 110 | | 103,523 | 417,024 | |
| WEST VIRGINIA | 53 | 21 | 7 | 11,693 | 25,267 | 7,429 |
| WYOMING | 4 | 6 | | 28,347 | 5,547 | |
| TOTAL, 1936 | 286 | 404 | 10 | 213,188 | 1,573,904 | 9,248 |
| 1935 | 312 | 393 | 10 | 180,953 | 1,463,123 | 7,910 |

1 Figures for 1937 not yet available

2 Includes combination of absorption process with compression and charcoal processes

Fig. 22

6. A New Refrigeration Method:

This method involves freeing of gas of its water content, then cooling by means of propane refrigeration to such a temperature that at the existing pressure the natural gasoline is liquefied. The resulting condensed liquid is then stabilized in the conventional manner. The process not only effectively recovers the gasoline from the natural gas, but it also removes the water from the gas at the same time. While the application of this principle to the natural gasoline industry is new, it has been in successful operation for several years in the recovery of feed for polymerization plants. The principle of propane refrigeration has also been used extensively in the processing of lubricating oil.

The incoming gas from the well separators, after being scrubbed to remove entrained liquid, is cooled to a temperature slightly above freezing. The gas is then dried by passing it through a suitable dehydrating material to prevent freezing at lower temperatures, and is further cooled by propane refrigeration to the required low temperature. The resulting uncondensed gas is then separated out and the liquid is pumped to a conventional stabilizer, where the undesirable constituents are removed and the gasoline of desired vapor pressure is piped to storage. This product is now a stabilized gasoline ready to be blended to produce a commercial gasoline.

It will be seen from the above description that the plant consists principally of heat exchangers, drums, compressors, a stabilizer, a cooling tower and boilers - - all equipment of high salvage value. Fig. 23 is a view of the process area of this type plant.

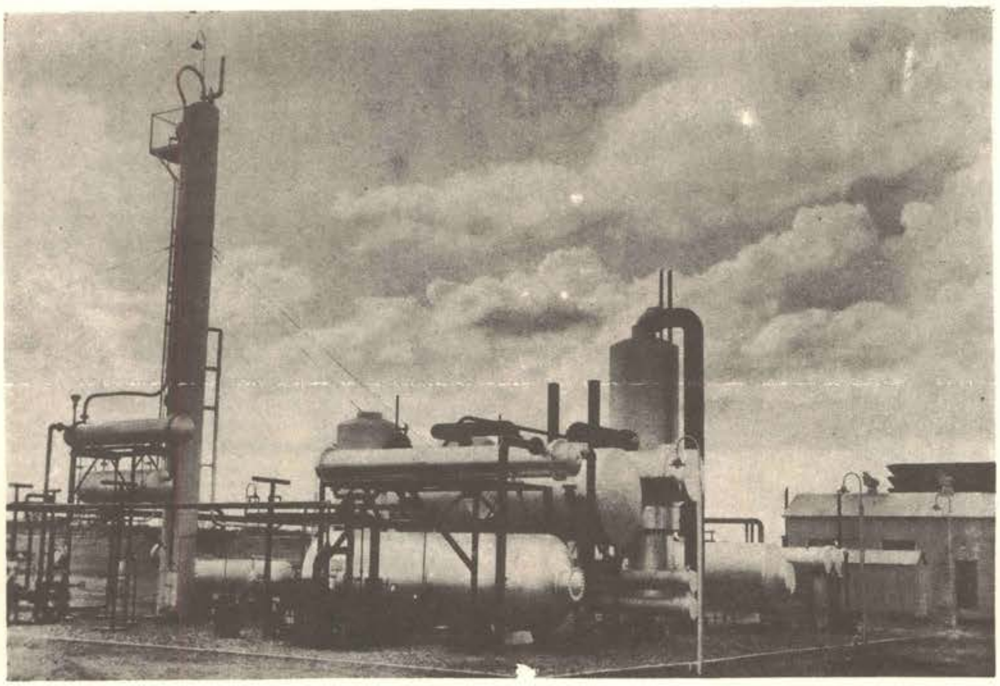


Fig. 23

UNIT IX

NATURAL GASOLINE'S PLACE IN THE PETROLEUM INDUSTRY

Originally the oil business was operated as one unit, but as each phase became larger it was found best to operate each division as a separate unit with men and operators specialized in those divisions. The petroleum industry still remains one big family as each division is dependent on one or more of the other divisions. Thus, we find that natural gasoline, even though it is the youngest of the divisions, has taken an important place.

1. Relation to Natural Gas Division:

The contact between natural gasoline and the natural gas group is in residue sales. This has been referred to, and it has been a point of good operation to serve the gas distribution division with satisfaction to both parties. Continuous delivery at the required pressures and the absence of air in the gas are two requirements essential in this relationship.

The pressure required is high generally compared to the usual gasoline plant pressures and requires high stage compressors to boost it. This generally is done by compressors in the gasoline plant's engine rooms.

Air in the residue gas is due to leaks in a gathering system carrying a vacuum.

2. Relation to Drilling Division:

A similar relationship exists here as with the natural gas except that gas for drilling purposes generally is supplied at plant pressure, eliminating the boosting. As mentioned before the drilling usually continues for some time after the gasoline plant's installation and if the gas volume is sufficient, then practically all the fuel used for drilling comes from the gasoline plant's residue. Whether this is a sale or not depends on whether the oil producer has gas producing wells tied into the gasoline plant. If he has, then the amount of residue due back to his lease according to his contract (see contract residue curves) may be sufficient for his drilling operations. There are variations of this arrangement depending on the drilling contract and who furnishes the fuel.

In case the gasoline plant's water supply is adequate, quite often the water is furnished for drilling operations.

3. Relation to the Production Division:

The closest contact with any of the divisions is with the production. The gasoline plant is dependent on production for its gas, and it is highly essential that cooperation exists between the two.

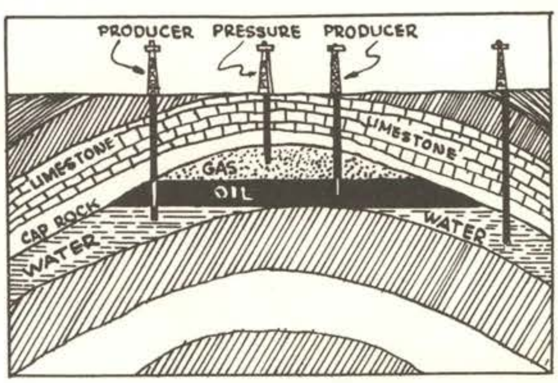


Fig. 24

Repressuring is the process of returning the excess gas to the oil sand, thus keeping up the pressure or repressuring the sand where the pressure has been lowered by oil being produced by natural flow and resultant loss of gas. Natural flow is where the oil is lifted by the gas pressure in the producing sand. The purpose of repressuring is four-fold. First, the gas is not wasted. Second, the wells will continue to flow naturally for a much longer period before having to be put on the pump. Third, the ultimate recovery of oil is greatly increased. Fourth, the life of the gasoline plant is greatly increased.

This ultimate increase in recovery is explained by Fig. 24 showing the location of gas, oil, and water in an oil well. This is a natural relationship as water is heaviest, oil is next, and gas above the oil. As the well is produced water tends to raise the oil level and the gas carries the oil out with it. In repressuring a separate well is drilled into the gas area to return the gas. This gas goes out through the pores of the sand forcing or holding the oil level downward and towards the oil well. If repressuring is not done a certain portion of the oil remains in the sand and is never recovered.

The practice of repressuring is comparatively recent and is rapidly being taken up due to the increased recovery. The gasoline plant operation is directly in the cycle of repressuring, the gas being treated before being returned. The repressuring equipment in some cases is being operated by the gasoline division.

Gas lift is the process of lifting the oil from the well by pumping gas down the tubing and on coming up through the casing lifts the oil with it or the gas may be pumped down the casing. There are variations of this arrangement. The principle of gas lift can best be explained by considering a simple experiment. If, in Fig. 25, the tube be partly filled with soapy water, "a", and a glass tube be inserted to the bottom of the tube, then if air pressure be applied to the tube, the flow of air into the liquid will create air bubbles that, being lighter than the liquid, will rise to the top of the liquid. If the flow be continued, the filmy bubbles will rise to the top of the tube and overflow it as at "c". This action will continue until the entire amount of liquid has been discharged over the top of the tube.

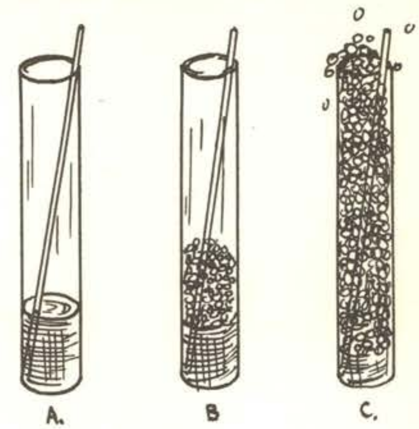


Fig. 25

In like manner, when a well ceases to flow naturally, the well becomes partially filled with dead oil, that is, oil from which the gas has escaped, Fig. 26. If a string of tubing be installed and gas be forced into the liquid through the tubing, the bubbles of released gas move up through the dead oil, thus, enlivening it. As they move upward, the gas expands forming larger bubbles and consequently a lighter, filmy fluid. If the stream of gas be continued, the filmy fluid will eventually reach the top of the casing and the well will flow practically the same as it did naturally.

Again here we have the gasoline plant in the picture furnishing the high pressure residue to flow the wells and treating the gas that lifts the oil. The cycle of gas travel is shown in Fig. 27. The gasoline plant is required to lift the oil and two jobs are done in this compression operation, namely,

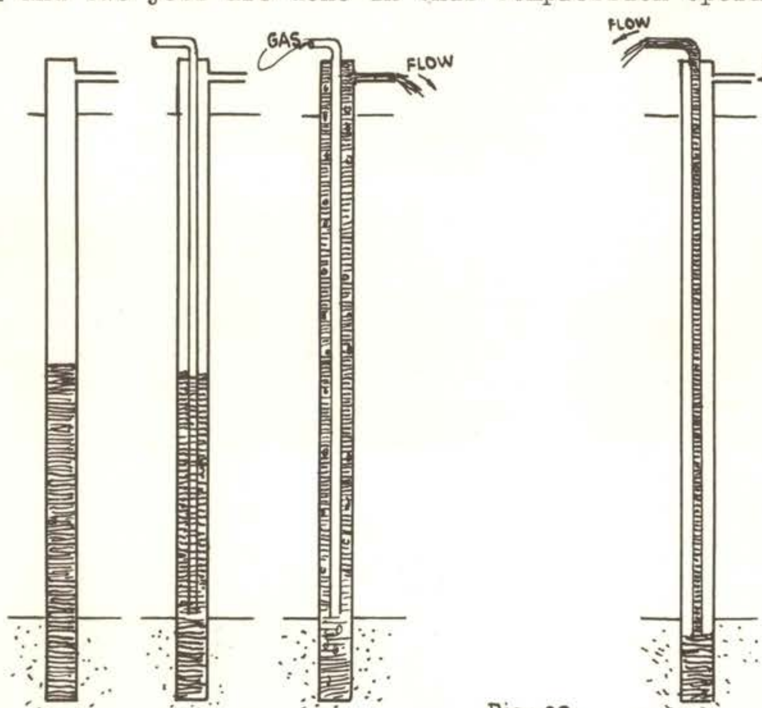


Fig. 26

gasoline extraction and high pressure for oil lifting.

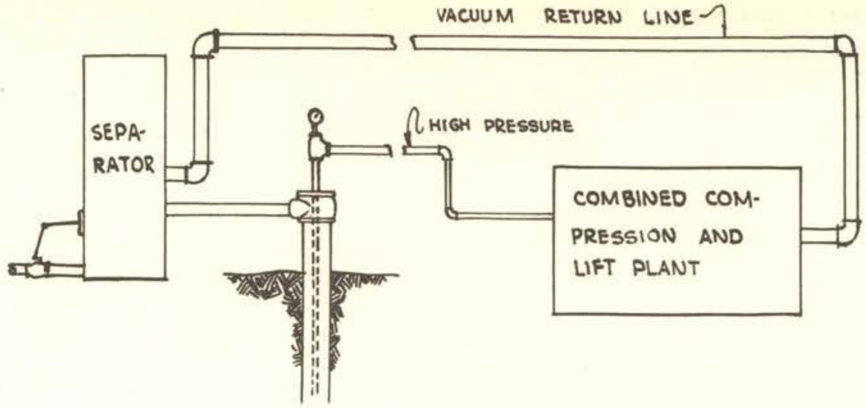



Fig. 27

The closest cooperation between production and the plant is required here in switching wells and adjusting pressures as required. Gas lifting operations have become limited since proration has come into effect. Proration has helped to keep the natural gas pressure up and by the time the wells will not flow they are ready to go on the pump rather than use the gas lift.

The regulation of pressure at the casinghead of a well or at the trap is one the producer is particularly interested in and it is the responsibility of the gasoline plant operation to carry on the producers equipment such pressures as are requested. In some fields a high vacuum is carried on the casinghead and all producers in the area want the same vacuum so as to balance any pressures on the oil sand of offsetting wells. In other fields no vacuum is permitted on the well and it is essential that regulators be kept in good working order to maintain atmospheric or near it as requested. This is discussed further under regulation.

Trap or separator pressures vary with the desires and location of the separators. If the separator oil will not gravity to storage then it will be necessary to set the regulator to hold sufficient back pressure in the separator to force the oil to storage. When the oil will gravity out it is customary to carry high pressures without disturbing oil production. This trap pressure is near 350 lbs. in one field where repressuring is practiced.

4. Relation to Pipe Line Division:

Pipe lines as referred to here are those carrying crude or natural gasoline. Gas lines were referred to under Natural Gas. Pipe lines are now being built and have been used for a number of years, to transport neutral gasoline and fuel gasoline and, of course, oil pipe lines are nearly as old as the industry. Plants disposing of their product by the pipe line then are in direct contact with that division.

Gasoline is pumped in with the crude oil production by a number of producers. In this case, the refinery recovers and fractionates all the products that are generally manufactured at the gasoline plant. This generally is done where the gasoline plant refinery and pipe line are all in the same company.

The gasoline pipe line takes gasoline from any plant checking on the volumes by tank gauges or meters.

5. Relation to Refinery Division:

The refinery receives all natural gasoline, except that stabilized to fuel qualifications which is a small percentage of the total. The refinery requires natural gasoline to blend with the gasolines made from crude oil. Crude oil varies in its gasoline content and kind of gasoline requiring more or less natural to blend with it. In winter months a lighter or high vapor pressure product is made and in summer a lower product. To meet all these conditions certain specifications have been set up. These specifications are taken up later. The gasoline is sold to refineries on these specifications, and it is necessary that the product meet them.

The relationship here then is a seller-to-buyer between the gasoline plant and refinery, and it is the responsibility of the gasoline plant to make the product specified.

The liquefied gases, propane and butane are being used extensively in refineries in new cracking and polymerization processes.

## D I V I S I O N  T W O

### UNIT I

### MECHANICS OF GASES

There are certain laws of gases which must be considered. The term, law, commonly means some rule of conduct that has been prescribed by some individual or a group of individuals telling what must or must not be done. In the case of nature, laws are established ways of doing things that always have been thus. They are natural events and have always occurred the same way, and we can depend upon the scientific fact that materials will always obey these laws. Thus, there are scientific laws of gases that must be known and realized in order to thoroughly understand the mechanics of gases as they are dealt with in the manufacture of natural gasoline.

1. Definitions:

Terms that were learned in Elementary Science may be stated here as they apply to the natural gas industry. It is important to know just how these terms are defined in this connection so that we may really understand the scientific laws of the industry.

Work is the overcoming of resistance to motion. No work is done unless motion is produced. Gas molecules are constantly at work because they are overcoming resistances to keep moving.

Energy is the capability of a body for doing work, or the capacity for work. The amount of work actually done depends upon the energy of the body doing the work. A gas engine may be doing a certain amount of work. If it is capable of using more gas for fuel and thus doing more work it is capable of just that much more energy. Molecules of gas may be moving at a certain rate and thus produce a certain pressure, but if an increase in temperature will cause them to move twice as rapidly, then their energy and resulting work is doubled.

Mass is the quantity of matter in a body. As has been taught, mass is considered the same as weight, although this is true only at sea level. Mass is always the same, but weight varies with altitude, and also with position on the earth with regard to the poles and equator. At the equator the weight is less due to the increased centrifugal force of the earth's motion.

The rate of doing work is the relation between the amount of work done and the time in which it is done. It is calculated as foot-pounds per minute, or as horse power, a total of 33,300 foot-pounds per minute.

Applying these definitions to natural gas, if a molecule of gas consists of matter it has mass. Then, if this molecule is in motion it has energy, that is, it is capable of striking a blow or producing work. Gas molecules may be further endowed with energy by added pressure or temperature. This process, as is evident, will require work and consequent expending of energy. In the study of pressure and measurement of gases and compression and temperature to liquefy gases, it is important to have an idea of the relation between the molecule and its energy.

If a pound weight be suspended in the air it is capable of doing work but is not doing it. This energy is known as potential, or stored up energy. If the weight be released it will do its work. While in motion it has kinetic, or action energy. It is evident that the force with which it strikes and the resulting work will be determined, not so much by the potential energy of the weight, as by the kinetic energy. This same principle applies to gas molecules. The pressure resulting from work by molecules in motion depends upon the kinetic energy of these molecules.

Velocity is the rate of speed of a material in motion and is measured in feet per second. Gas molecules, being substance, have velocity while in motion, and, being always in motion except at absolute zero, their velocity is an important factor in determining work done and resulting pressure and required work to slow down their velocity.

2. Relation of Energy to Mass and Velocity:

The energy of a body in motion and the consequent work done is determined by two factors, the mass of that body and the velocity. It is reasonable that a two pound weight will fall twice as hard as a one pound weight. Just so the actual weight or mass of the molecules of gas determine their kinetic energy.

Likewise, the energy of a moving body depends upon its rate of travel or velocity. A car moving 70 miles per hour presents a far greater degree of kinetic energy than one moving at 40 miles per hour. Just so, a molecule of gas will have its energy increased by an increase in velocity, and vice versa.

A definite formula for measuring energy has been devised and will be stated here. As to how it was devised is a matter of deeper mathematics. The formula is:

Energy = $\frac{1}{2}$ the mass of an object times the square of its velocity.

$$E = \frac{1}{2} MV^2$$

Stated in words, this formula means that the work which a moving body can do or the force of the blow which it can strike is equal to one-half the product of the mass and the square of the velocity.

3. Relation of Pressure to Velocity:

If the kinetic energy of a body in motion is determined partly by the velocity of that body, then the force with which it would strike would be determined to a great extent by that velocity. Gas molecules are in constant motion. Their velocity is determined by several causes. The direction of these molecules is in straight lines unless changed by some other force. They are constantly bombarding the walls of their container with a force depending upon their velocity. This bombarding force is pressure; therefore, gas pressure is directly in proportion to the velocity of the gas.

Now that we know in a general way something of the scientific facts regarding the action of gas, we can better understand certain definite laws peculiar to gases that have been set up and named for the ones who discovered and announced them.

4. Avogadro's Law:

The law of Avogadro is that at constant pressure and temperature, the number of molecules in a given volume is always the same, no matter what the nature of the gas may be. Thus, a cubic foot of hydrogen, oxygen, methane, or any other gas contains the same number of molecules as long as the temperature and pressure are the same. This is known to be a fact and helps to understand the other laws, which otherwise would have to be accepted as facts without explanation.

5. Boyle's or Marriotte's Law:

This law is a statement of the fact that the volume of any given weight of gas at constant temperature is inversely proportional to the absolute pressure. That means that the volume decreases in just about the same proportion as the absolute pressure increases. Thus, in Fig. 28, if two cubic feet of gas be confined in a compressor at one atmosphere of pressure and this pressure be increased to two atmospheres, the volume, if the temperature is not increased, will be one-half the volume as before, or one cubic foot. Again, if the pressure be increased to four atmospheres the volume will be one-fourth, or one-half cubic foot. In reverse order, if the gas be confined at four atmospheres pressure, Fig. 29, and that pressure be reduced to two, the volume of the gas will be doubled. Likewise, if the pressure be reduced to one atmosphere, the volume will be four times the original.

Every operator knows that gas cannot be compressed without raising its temperature. Since a unit mass of gas contains just the same number of molecules whether it be in a large volume or compressed to a small volume, it is evident that the compression will cause the molecules to move closer together and move more rapidly, thus causing greater temperature. Unless this extra heat can be carried away as the gas is compressed, the principle of Boyle's law cannot apply efficiently. If the compressing motion is slow enough that the temperature can be held the same the theory is true. Otherwise the temperature must be considered, and this will be done later in this discussion.

In the case of a compressor, the excess heat of compression is partly removed by the water circulation around the compression chambers, but this cooling effect is not sufficient to make the law perfectly applicable. It is meant only to cool the cylinder walls sufficiently to keep the lubrication in the cylinder from decomposing.

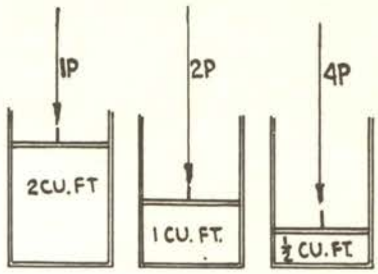



Fig. 28

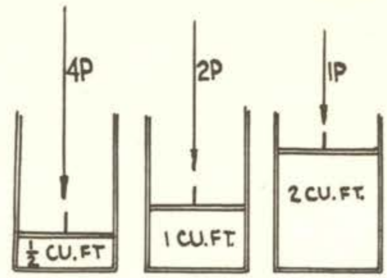



Fig. 29

6. <u>Charles' Law</u>:

Charles' law has to do with the relation of the volume of gas to its temperature. It says that the volume varies directly with the absolute temperature, if the pressure remains constant. The molecular theory back of this law has been discussed, and, realizing that it is a proportion, it is very evident that only absolute temperature can be used. Fig. 30 explains the process. If a unit of gas be placed under one atmosphere of pressure at a given temperature and the temperature be doubled the volume of gas will be doubled, provided that the pressure be kept at one atmosphere. By increasing the temperature four times the original, the volume will be increased four times, etc. It must be remembered that when pressure and temperature are spoken of, it means "absolute".

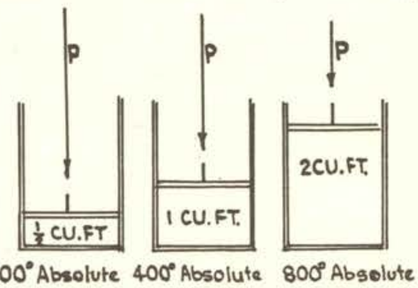



Fig. 30

Reversing the process, if the container be cooled so as to reduce the temperature of the gas, keeping the pressure the same, the volume will be reduced accordingly. This law is definitely important to the natural gas industry operator in controlling volume due to increased temperature and at the same time maintain a constant pressure. It is absolutely necessary to maintain certain constant pressures for transportation and for utilization of gas, consequently the relation of volume to temperature is an important factor. In very cold weather when it is so necessary to maintain a constant pressure at the point of use, the lowering of temperature due to weather conditions make it necessary to increase the volume proportionately.

It is important at this point to notice the difference in measurement due to the use of absolute temperature. Using the ordinary Fahrenheit temperature scale, if a cubic foot of gas be raised from 60° to 120°, according to the law the volume would be increased from one to two cubic feet. Using absolute temperature, the final reading would be 60 + 460 or 520° and when raised 60° it would be 60 + 60 + 460 or 580°. Then the one cubic foot volume of gas would be increased to 580 ÷ 520 or 1.11 cubic feet.

Set up in proportion form:

$$V_2 : V_1 :: 120 + 460 : 60 + 460$$

or

$$V_2 : V_1 :: 580 : 520$$

Since $V_1$ is one cubic foot: $\frac{V_2}{1} = \frac{580}{520}$ and $V_2 = 1.11$

This shows a surprisingly small increase in volume for what seems like a large increase in temperature. However, the increase in absolute temperature has been small and the increase in volume is likewise small.

7. Relation Between Absolute Temperature and Absolute Pressure:

If the absolute temperature of a gas is doubled, its energy is doubled and, therefore, if its volume remains constant, the pressure must be doubled. Stated as a proportion:

$$P_2 : P_1 :: T_2 : T_1$$

assuming of course that both pressure and temperature are absolute. It is evident then that absolute pressure varies directly with absolute temperature.

8. Effect on Volume of Change of Both Pressure and Temperature:

Reviewing Boyle's law, we find that the volume of gas is inversely proportional to the pressure if the temperature remains the same. Then Charles' law says that the volume is directly proportional to the temperature if the pressure remains the same. Now, what effect upon the volume would result from a change of both pressure and temperature? Since both absolute pressure and absolute temperature are concerned, it is reasonable to think that if a volume of gas be changed both in pressure and temperature the new volume would be a combination of the two. Thus, the new volume will be the result of multiplying the old volume by the inverse ratio of the old and the new absolute pressures and this product by the direct ratio of the old and the new absolute temperatures. As an example, if ten cubic feet of gas be raised from forty pounds gauge pressure to sixty pounds gauge pressure, and from 70° to 120°F, the new volume would be found thus:

40 lbs. gauge pressure = 54.4 lbs. absolute

60 lbs. gauge pressure = 74.4 lbs. absolute

Inverse ratio of new pressure to old is $\frac{54.4}{74.4}$

70°F = 530° Absolute

120°F = 580° Absolute

Direct ratio of new temperature to old is $\frac{580}{530}$

Now multiply the old volume by the inverse ratio of pressure and the direct ratio of the temperatures:

$$10 \times \frac{54.4}{74.4} \times \frac{580}{530} = 8.0018$$

Therefore, the new volume would be 8.0018 cubic feet.

From this combination of laws we can compute the volume of any given amount of gas under any condition, if we know the volume occupied under certain conditions. For example: if we know that a certain number of thousands of cubic feet are metered at a city gate at a pressure of 300 pounds per square inch and know that the pressure on the distributing mains is four pounds and at the point of consumption is four ounces, and if we know the different temperatures, we can figure how much gas is being distributed through the mains and what amounts will be metered to the consumer.

9. Compressor Operation:

Most gas compressors are of conventional type or similar construction. Fig. 31 is a picture showing the cylinder, piston, and valves of a double-acting compressor. Fig. 32 shows a section and exterior view of another double-acting cylinder and it will be noticed that there are two intake and two discharge valves at each end of the cylinder, making eight valves in all. This number of valves is necessary in the larger diameter low pressure cylinders in order to get free passage of gas at low pressures.

The valves themselves are removable individually and are of easy access. Fig. 33 shows two types of these valves. In operation bad or leaking valves generally are located by the excessive heat on its cover or by the sound.

Valve maintenance is low on low pressures and higher on higher pressures. This is reasonable as there is more heat and pressure to withstand. A number of spare valves usually are available and as the bad ones are removed a repaired one is installed. The bad valve is then over-hauled for use again.

The sketches above show the water jacket which is built into the shell of the cylinder and cylinder heads. If clean soft water is used and enough water and pumping equipment is used, the cooling water system and jacket requires little maintenance.

There is a by-pass valve between the intake and discharge of the cylinder. This may be built into the cylinder jacket with the valve handle outside as shown in Fig. 32 or the whole by-pass piping may be outside. The purpose of the by-pass valve is to safely operate the compressor in loading and unloading it. Without a by-pass valve too much pressure would build up on the discharge. The operation of the power end of the engine compressor is taken up in the text "Care and Operation of Internal Combustion Engines." The general rules of loading and unloading a compressor follow:

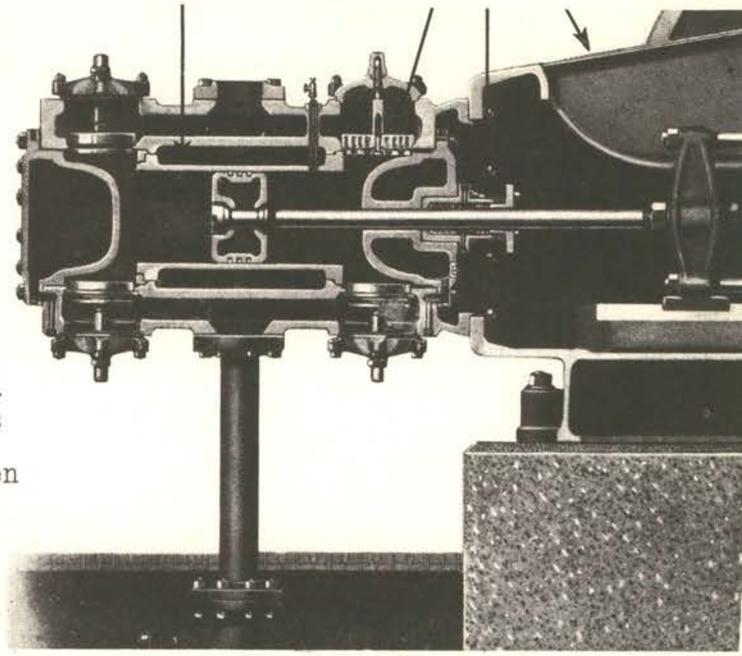
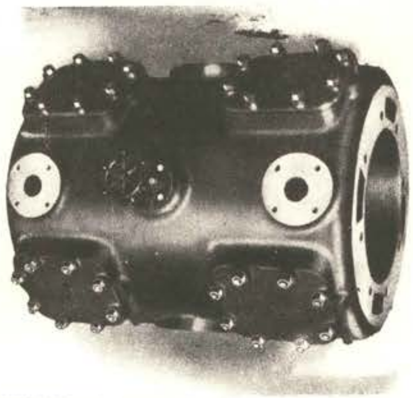


Fig. 31



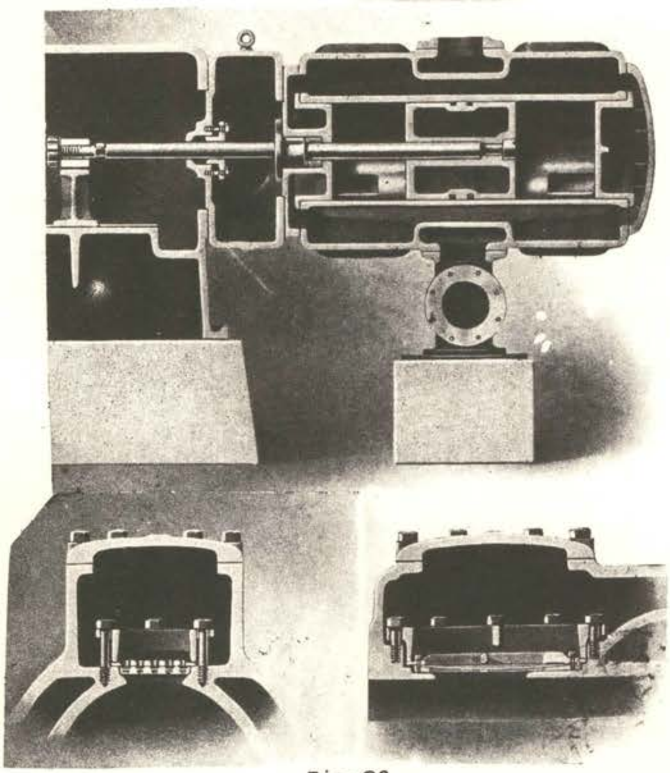


Fig. 32

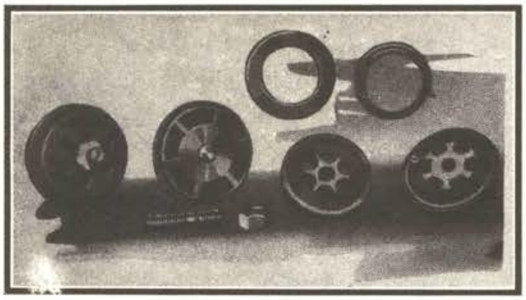
LOADING: (Assume engine is running and that compressor discharge and intake valves are closed, and by-pass open.)

1. Open discharge valve.
2. Close by-pass.
3. Open intake slowly so as not to load engine too rapidly.

UNLOADING:

1. Close the intake valve.
2. Open the by-pass valve.
3. Close the discharge valve.

This is the safe and required procedure of handling the valves on the compressor. A discussion of the results of any other procedure will quickly bring out the reasons for the above procedure. It is very essential that the operator know these procedures of the engine compressor he operates. A full discussion of compressors would take too much space in this text but is covered in another text called Compressors.



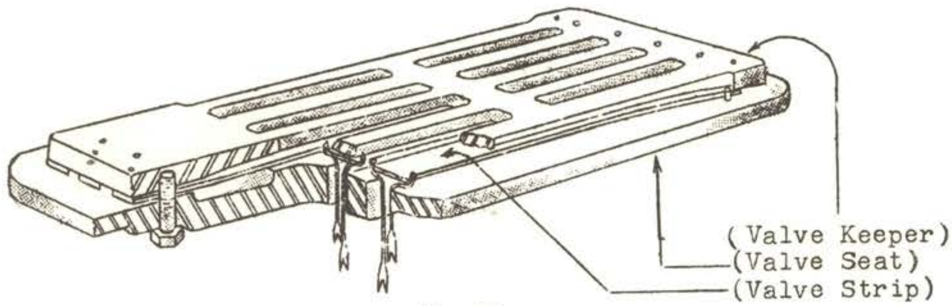



Fig. 33

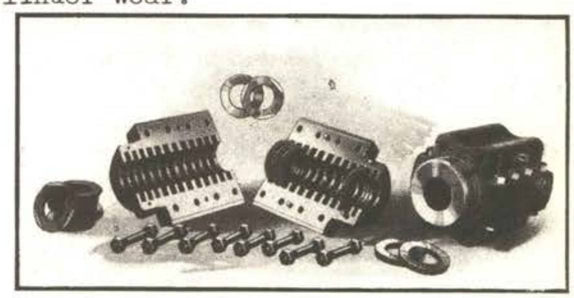
Hard water will cause scale to form in the jacket, this means periodic cleaning in order to get the cooling required. Scale is removed from the jackets by acid or some scale removing compound. Dirty water may leave a silt deposit in the cylinder water jacket. Periodic removal of head and cleaning out with hose clears this.

Piston and ring maintenance at the lower pressures and higher pressures follows the same curve as valves. When properly lubricated and well aligned, maintenance is at a minimum. A composition ring of bakelite material has been used successfully eliminating a great deal of cylinder wear.

Cylinders become worn and have to be rebored to a larger diameter and an oversize piston used or are bored and relined, using standard piston size. The latter method of repair has the advantage of keeping all pistons and cylinders the same size, for replacement.

Piston rods wear and sometimes become scored. Smoothing the rod with a file or returning on a lathe, is done if wear is not too great, otherwise, rod replacement is required. Well-adjusted packing and proper lubrication is the best thing for long lived rods. Soft packing is used on lower pressure rods and metallic ring packing on both high and low pressure rods. Fig. 34 shows packing and glands.

Recommended pipe installation of the compressor discharge is given in Fig. 35. It is self-explanatory. Other installations and allowances left for expansions can be discussed.



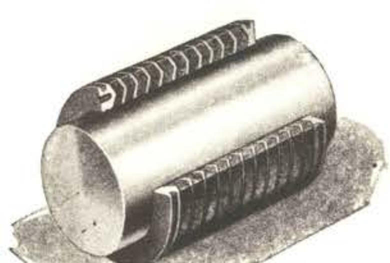
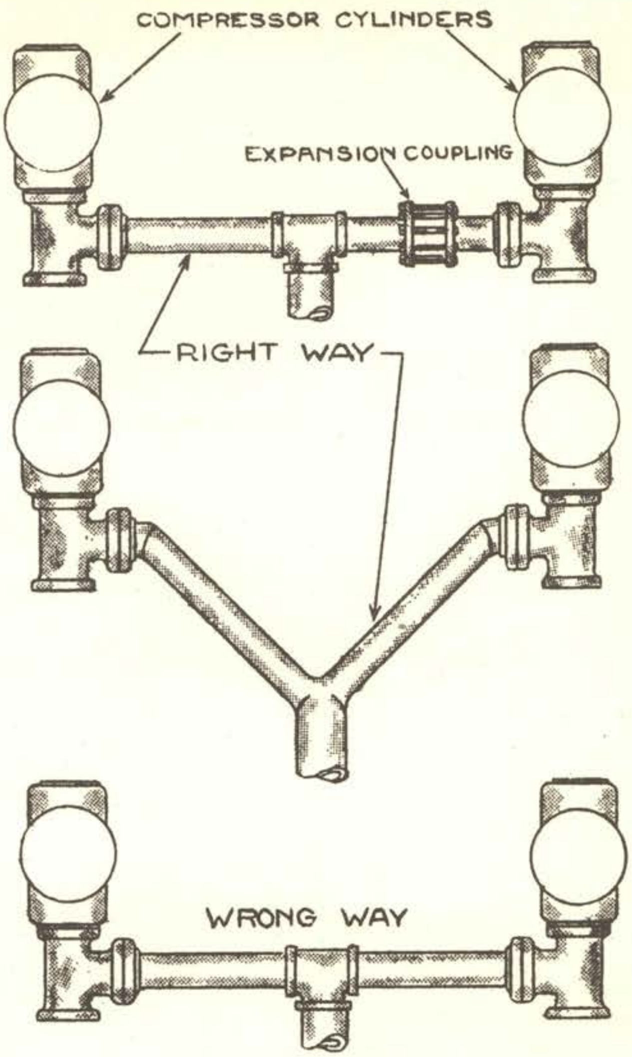


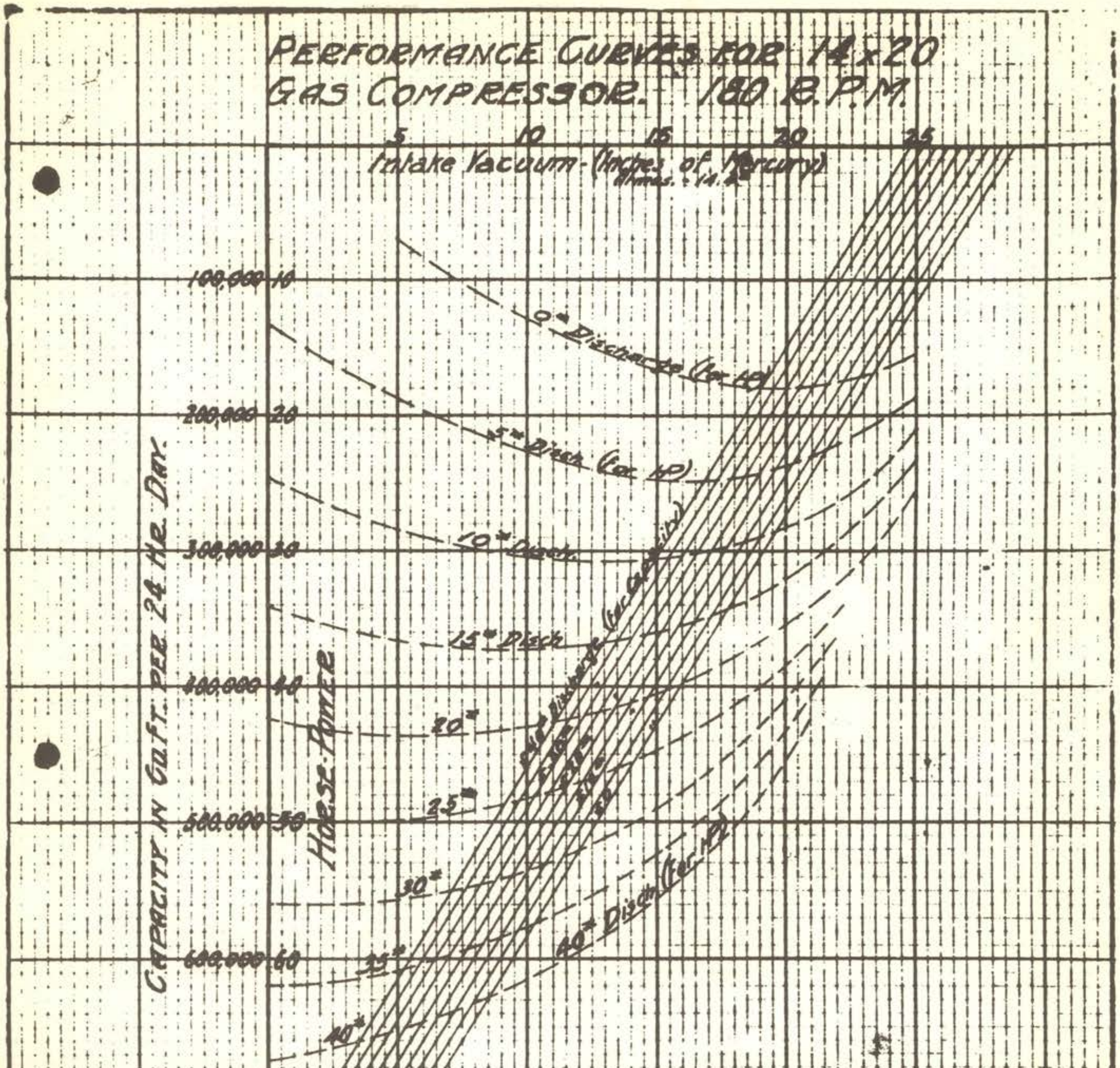
Fig. 34

The amount of gas a cylinder will handle can be calculated but as there are so many variables, for each cylinder, the best source to find this information is to use the engine manufacturers' chart. This will give the amount the cylinder will handle at rated speed with the working limit ranges of both intake and discharge pressures. Some will also give the horse power required. Fig. 36 is such a chart.




COMPRESSOR CYLINDER PIPING

Fig. 35




| Diam - Stroke | Multiplier | Diam - Stroke | Multiplier |
|---|---|---|---|
| 14 x 20 | 1. | 12 x 18 | 0.6992 |
| 15 - | 1.1505 | 13 x - | 0.7763 |
| 16 - | 1.3106 | 14 - | 0.9017 |
| 17 - | 1.4819 | 15 - | 1.0380 |
| 18 - | 1.6000 | 16 - | 1.1822 |
| 19 - | 1.8557 | 17 - | 1.3359 |
| 20 - | 2.0586 | 18 - | 1.5007 |
| 22 - | 2.4928 | 19 - | 1.6719 |
| 24 - | 2.9714 | 20 - | 1.8542 |
| 26 x 20 | 3.4801 | 22 x 18 | 2.2472 |

Use these Multipliers for determining capacity and Horse Power of cylinders other than 14" x 20".

Fig. 36

UNIT II

GATHERING SYSTEM

1. Construction:

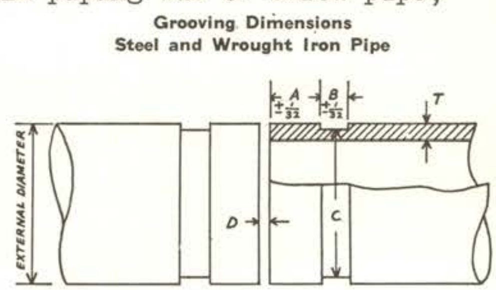
The sketch of the gathering system in the fore part of this book, Fig. 5, is generally called by the draftsman, a straight line pipe drawing or map meaning that one line represents the pipe. A figure above the line is the size pipe and the length of the particular section line either follows the size numeral or is placed below the line. These maps are usually made twice, the first time on a map showing the well locations and the locations and lengths of lines are estimated as closely as possible. This is done to order in the pipe and fittings necessary.

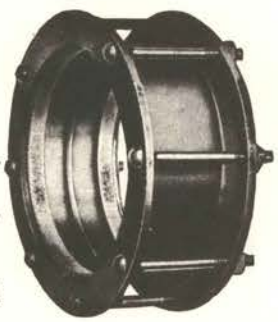
The second map is made after the installation of the lines and the pipe and location is measured. The first and second maps do not come out the same, because between the time of estimating and installation roads and buildings may be built causing detours. Separator locations may be changed or installed at a place other than estimated or new wells may have been drilled in. This last may even change the size of pipe used in the estimate. This last map is for the purpose of record, so that the amount of pipe and fittings and their location can be checked by map reference.

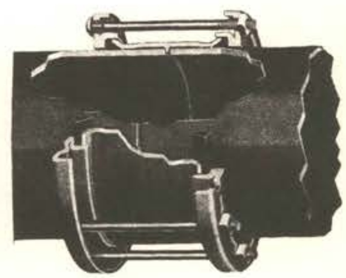
The pipe used for gathering systems of gasoline plants need not be of the high pressure type and for this reason either light weight pipe or second hand pipe that is not suitable for high pressure service is used. This is not always the case as some plants operate on high well pressure and good pipe is necessary there.

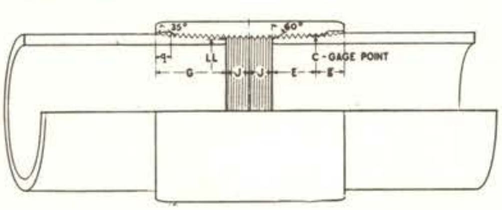
Second hand or used pipe then constitutes a large portion of the gasoline plant's gathering systems, and as such quite often has to be machined for connecting together. Originally practically all field piping was of screw pipe, that is, the ends were threaded and collars used to join them such as is seen in most any plumbing system. However, as the pipe was laid and taken up numerous times, the threads wore and the time and labor required, especially on 6" and larger, became expensive and improved methods of connecting were used. All types of these connectors and couplings are used in the natural gasoline plant's lines. The following pictures in Fig. 37 show some of the different types of couplings used.

Just as the use and convenience of both electric and acetylene welding have become so popular in all lines of metal work so it has also in pipe work and not a few lines are welded completely, thus eliminating use of couplings. All connections, turns, and other







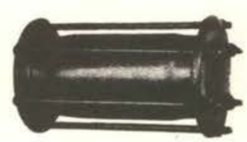



Fig. 37

joints are made by welding thus eliminating more fittings.

The pipe line is designated by the type coupling used such as welded, screwed (collars), Dresser coupled, victaulic, etc. The coupling that allows some flexibility in the pipe and especially welding is found convenient in rough ground, around buildings, roads, and other obstructions.

If new pipe is used light weight pipe of from 30 to 40 foot lengths is popular. One make of a spiral welded construction is especially light, reducing handling and laying costs. Fig. 38 is a vacuum and residue line showing couplings and light weight pipe.

Fig. 38

Fig. 39

Most gathering systems are more or less of a temporary nature, meaning that the field and supply of gas will eventually play out or smaller lines may be laid and the installation is made on that basis. A large portion of the lines are laid above ground. Of course, in cultivated fields, at road crossings, and similar places the lines are buried. Referring again to maps of lines quite often the initials AG and BG follows the pipe size and length data, meaning above ground and below ground.

The problem of crossing creeks and low places is solved by bridging rather than burying. If buried it makes a low place in the line on which it is difficult to install a drip and keep it in operation. Also, a line above water is easier to get to for maintenance. A typical crossing is shown in Fig. 39.

A drip connection is left in the line at all low places, that is where it crosses a gully, dips under a road or the low places in fairly level ground. The connection may be a tee installed in the line with the out-let turned down. The following sketches, Fig. 40, show these two types of drip connections left. The places showing need of drips after the line is in operation is where they are installed. This installation of drip connections when the line is laid, eliminates taking the line out of service later to make the connections.

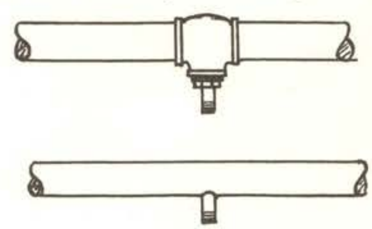


Fig. 40

Fig. 41 shows a popular installation of vertical drips for low and high pressures respectively.

The fittings used, valves, tees, ells, etc., are of standard weight unless the gathering system is from a high pressure gas field in which case heavy or extra heavy fittings suiting the pressure are used. Standard fittings ordinarily are manufactured to withstand 125 lbs., heavy, 200 lbs., extra-heavy, etc. All fittings are stamped for the working pressure they are built to operate under. Some are stamped "250 lbs. W.P. 500 T." Meaning 250 lbs. for working pressure and the fittings have been tested to 500 lbs. The markings are shown on the fittings in Fig. 42.

It is good practice to observe and know the meaning of these markings or fittings. It may prevent a serious accident in case a low pressure fitting is installed on a high pressure line or it may mean a large saving in investment by

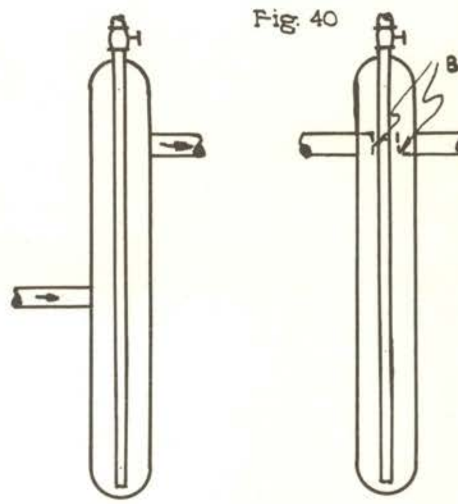



Fig. 41

installing low pressure fittings where they may be used instead of high pressure; the H.P. fittings might be put in through ignorance or sent to the field by mistake.

The following specifications are used generally by manufacturers. The A. P. I. standardization committee is attempting to standardize all oil field fittings and no doubt all fittings will soon be manufactured to their recommendation.

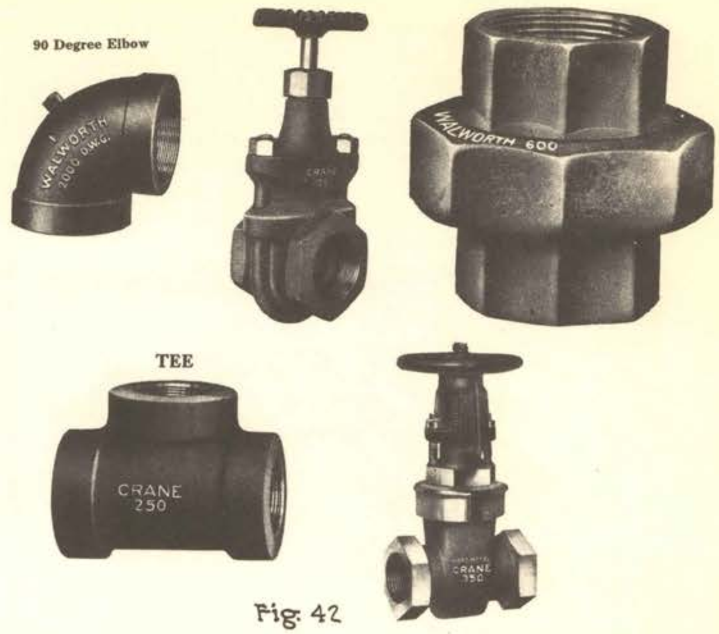



Fig. 42

| SIZE OF FITTING | MATERIAL | PRESSURE | CLASSIFICATION |
|---|---|---|---|
| 2" and under | Bronze and iron | 125 - 150 | Standard |
| 2" and smaller | Bronze | 200 | Heavy |
| 2" and larger | 1BBM | 125 WSP | Standard |
| 2" and larger | 1BBM | 175 | Heavy |
| 2" and smaller | Bronze | 250-300WSP | Extra Heavy |
| 2" and larger | 1BBM | 250 | Extra Heavy |
| | | Either by Pressure or by some manufacturers' series | |
| All Sizes | Steel | 150 | 15 |
| | | 300 | 30 |
| | | 400 | 40 |
| | | 600 | 60 |
| | | 900 | 90 |
| | | 1350 | 135 |
| | | 1500 | 150 |

Some common abbreviations and their meanings follow:

1BBM - Iron body bronze mounted
WSP - Working steam pressure
OWG - Oil-water-gas
St. - Standard
Hy. - Heavy
EH - Extra Heavy
OS&Y - Outside stem and yoke
RS - Rising stem
NRS - Non-rising stem
FE - Flanged ends
Se or SE - Screwed ends
LE - Lead ends
CI - Cast Iron
M or Mal. - Malleable

With few exceptions every man that has worked in the natural gasoline industry has "pipe lined" at some time. The pipe line gang and the pipe liner as an individual represent some of the essential cogs in the oil industry without which it could not exist. A lot of the romance and stories of accomplishment of oil runs back to the pipe line. There is reason for this because every man in the pipe line gang, the collar pounder, the stabber, the jack and tong men and the gang pusher gets a thrill from every joint laid and a bigger thrill when a line is completed. It also means back-breaking work in wet or dry, hot or cold weather.

It is a place where the coordinative efforts of a group show results. They look out for the other fellow not to drop tongs, pry poles, or pipe on his feet. They heave together on a joint so as not to strain one man's back. They swing their tools with care not to strike another. Each man does his part on every joint laid without waste or haste and at the end of a day's work, the job accomplished records itself in each man's mind as one in which he has shared in making the world's wheels go around.

2. The Flow of Gas in Pipes:

The flow of gas through a pipe depends upon a pressure differential, that is, it will flow only when a higher pressure point and a lower pressure outlet are maintained, and then the flow is from the higher to the lower point. This situation exists at the gas burner in the kitchen range and it also exists at the well bottom, consequently, it must exist all along the entire transportation system if gas is to flow.

As has been stated, the flow of gas through a pipe is determined by the velocity of the stream, and velocity depends for its energizing force upon pressure. Flow pressure is determined by initial or potential pressure and diminishes along the line in proportion to the resistance offered by the line. Thus, to produce a certain flow velocity, the gas must be put into the line at a definite pressure and that pressure must be maintained as nearly as possible, else the velocity of the stream will be diminished accordingly. It is worth while then to note some of the factors that must be considered as the cause of the decrease in pressure. Some of these factors concern the pipe, while others concern the gas itself. Those that concern the pipe are:

a. Inside surface of the pipe
b. Length of the pipe
c. Diameter of the pipe

Those factors that concern the gas are:

a. The specific gravity of the gas
b. The viscosity of the gas

The inside surface of the pipe determines the amount of friction upon the stream of gas. It is impossible to think of a surface so rough that it would afford exceedingly high friction. Consequently, it is best to secure the smoothest possible on the inside of the pipe and it is so specified by standards for the manufacturers.

If pressure is lost due to friction on the pipe it is reasonable to think that the longer the pipe the greater the friction drop. As shown in Fig. 43, the gas nearest the pipe is slowed down first and the inner part of the stream moves on. As it expands and moves out through the pipe, the process is repeated until, theoretically, the pressure is lost. However, the velocity of the inner stream will increase as it passes into a larger space, and the volume will increase with the decrease in pressure.

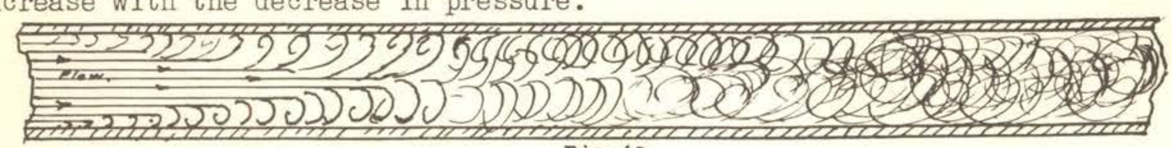



Fig. 43

The volume of a pipe is determined by the square of its diameter, so far as size is concerned. An 8-inch pipe will carry four times as much as a 4-inch pipe, considering the diameters only. However, if gas be flowed through the two at the same initial pressure, the 4-inch line will offer more resistance to its flow than the 8-inch. The reason is that the friction is determined by the amount of surface contacted and the 4-inch pipe will offer 4 x 3.1416 or 12.5664 inches of circumference of pipe while the 8-inch line will offer 8 x 3.1416 or 25.1328 inches of circumference surface. Thus, the 4-inch line pipe offers twice as much resistance to its flow as the 8-inch, all other things being equal. It has been found by engineers that the friction offered by the walls of a pipe varies inversely with the cube root of the diameter of the pipe. Then, the above case might be stated that the ratio of the friction of the 4-inch pipe to the 8-inch pipe would be

$$\frac{\sqrt[3]{8}}{\sqrt[3]{4}}$$

This will hold fairly well for pipes more than 7 inches in diameter. It is evident that the specific gravity or weight of the gas will have some effect upon its movement through the pipe. It has been found that the lighter the gas the sooner it will seek the point of less pressure, and this principle prevails in the pipe line. However, this factor is more or less technical and of no serious consequence.

Viscosity is resistance to flow. Consequently, even with gas, the thinner the gas the easier it will flow. The difference in flowing casing-head gas and fuel gas shows this factor. Like gravity, however, it is of no serious consequence being rather technical.

Temperature and friction are the two important factors in flowing gas. Because of the expansion of gas due to temperature, it is impossible to flow as much gas through a hot line as through a cold one, while on the other hand, when pressure is an important factor, added temperature is an asset. With the addition of compressors to the pipe line system, it is desirable to keep the lines cool so that more gas per line capacity can be flowed through them.

3. Conditions Modifying Flow:

After a line has been built, several conditions may develop that will modify the flow of gas. One common hindrance is the collection of liquids in the line. Water, oil or even gasoline may collect in the low places of the line, and even though they do not entirely fill the line, will impede the flow in proportion to the cross section area of pipe they fill. Drips are installed to trap liquids, but at that, due to condensation and several other causes, the liquids occur. If the liquid fills the entire cross-section of the pipe, the gas must either blow it on through or bubble through the liquid. Traps as have been shown are provided to catch any liquid in the line, but they are not always effective.

As has been stated, dust is produced with gas in some cases, and if not trapped, will settle in the low places. The presence of water in the settling place tends to settle the dust and to cause it to cake up there forming a real obstruction. Some dust is also produced by corrosion and is blown loose by the scrubbing motion of the gas. Even scales are sometimes deposited in the pipe by this process. Even though dust traps, or scrubbers are installed, the driving, scouring motion of the dust will cut valves, meter settings, orifice plates, and other fittings. The wearing of the upstream side of the orifice plate or collection of dust upon it interferes with accurate measurements.

Corrosion, other than producing dust and scales, tends to lesson the internal diameter of the pipe. This is noticeable only in smaller sizes of pipe as it cuts the flow in a greater proportion than in larger sizes. The greatest hindrance to flow caused by corrosion is the increased friction and consequent reduction of pressure. This has been explained. Corrosion in pipe is caused by the action of moisture and other chemicals present in the gas upon the metal of the pipe. This action is especially rapid if oxygen in any form exists in the gas being carried in the line.

Just as the weight of gas in a flow string of a well is a determining factor, so it is in a line where the inlet and outlet are on different elevations. If the outlet is higher than the inlet, the flow will be impeded according to the weight of a column of gas the height of the difference in elevations. If the outlet is lower than the inlet, the flow will be increased in the same proportion. This factor is scarcely ever important except where the difference is very great.

4. Capacities of Pipe Lines to Carry Gas:

To have in his mind, so he can call the information when needed as to how much gas a certain size line of a known length would carry at the pressure allowed would make a gasoline plant man feel that he had learned one of the essentials of the business. The field man who has installed and watched the flow of gas through lines by reading the meters can estimate fairly closely. However, more accurate information is desired and the many variable conditions make it necessary to do some calculating in order to get suitable answers.

The problem of pipe capacity that presents itself in the plant gathering system is: the size of pipe to be laid for main line, laterals, lease main, and line to individual well.

Assume that ten million cubic feet of gas are already available in a field and an estimated ten million will come in with new wells. The amount of back pressure in this field allowed on the separators is six pounds. Assume that engine capacity will be installed to handle the volume at zero lbs. or atmosphere intake. The length of main line that will carry most of the 20 million feet of gas is one mile. Then, the problem here is what size of pipe is required to carry 20 million feet of gas one mile with intake pressure six pounds and discharge zero pounds. Referring to the chart, Fig. 44, we find the formula

$$D^{8/3} = Q/870\left(\frac{L}{P^2 - p^2}\right)^{\frac{1}{2}}$$

Substituting values:

$P = 14.4 + 6 = 20.4$

$p = 14.4$

$L = 1$

$Q = 20,000,000$

The equation becomes:

$$D^{8/3} = \frac{20,000,000}{870}\left(\frac{1}{20.4^2 - 14.4^2}\right)^{\frac{1}{2}} = 23,000\left(\frac{1}{416 - 207}\right)^{\frac{1}{2}}$$

$$= 23,000 \times .0691$$

$$= 1590$$

Going down the last column in the table for $D^{8/3}$, we find the closest value is 1461 and this value is for 16" pipe in the first column.

As this is a popular size pipe in all probability the main line will be laid of this size pipe. The laterals and lease lines may be figured in similar manner.

The above problem was solved assuming the specific gravity of the gas was .6. Rich gas runs higher than this and the correction indicated possibly should be made. Assuming the gravity of the gas was 1.0 then

$$870\sqrt{\frac{.6}{G}} \text{ or } 870\sqrt{\frac{.6}{1}} \text{ or } 870 \times .775 = 675$$

Substituting 675 for 780 in the original equation $D^{8/3}$ comes out 1780. In the column for $D^{8/3}$ we find 1780 lies halfway between the values for 16" and 18" pipe.

# CAPACITY OF GAS PIPE LINES

The Weymouth formula for the flow of gas in a pipe line is as follows:

$$Q = 870\, D^{\frac{8}{3}} \left[ \frac{P^2 - p^2}{L} \right]^{\frac{1}{2}}$$

*Where—*

*$Q$ = Cubic feet of free gas per 24 hours at 14.4 absolute pressure and 60° F.*
*$P$ = Initial pressure, lb. per sq. in. absolute*
*$p$ = Terminal pressure, lb. per sq. in. absolute*
*$D$ = Inside diameter of pipe in inches*
*$L$ = Length of pipe in miles*

*The constant in the formula is based on gas of specific gravity of .6. For gas of other specific gravity the constant becomes* $870 \sqrt{\frac{.6}{G}}$ *where G is the new specific gravity.*

*For solving for other factors than the capacity the formula becomes:*

*For the line diameter—*

$$D^{\frac{8}{3}} = \frac{Q}{870} \left[ \frac{L}{P^2 - p^2} \right]^{\frac{1}{2}}$$

*For the terminal pressure—absolute—*

$$p = \left[ P^2 - \left( \frac{Q}{870\, D^{\frac{8}{3}}} \right)^2 L \right]^{\frac{1}{2}}$$

*For the initial pressure—absolute—*

$$P = \left[ \left( \frac{Q}{870\, D^{\frac{8}{3}}} \right)^2 L + p^2 \right]^{\frac{1}{2}}$$

*For the length—*

$$L = \left( \frac{870\, D^{\frac{8}{3}}}{Q} \right)^2 (P^2 - p^2)$$

Following is a tabulation of the values of $D^{\frac{8}{3}}$ for various pipe diameters and thicknesses.

| Nominal Diameter | Actual Outside Diameter | Thickness of Pipe | D Actual Inside Diameter | $D^{\frac{8}{3}}$ |
|---|---|---|---|---|
| 3 | 3.5 | .215 | 3.07 | 20 |
| 3½ | 4.0 | .225 | 3.55 | 29.4 |
| 4 | 4.5 | .235 | 4.03 | 41.2 |
| 4½ | 5.0 | .245 | 4.51 | 55.5 |
| 5 | 5.56 | .275 | 5.05 | 75 |
| 6 | 6.62 | .275 | 6.07 | 122 |
| 8 | 8.62 | .320 | 7.98 | 254 |
| 10 | 10.75 | .365 | 10.02 | 466 |
| 12 | 12.75 | .375 | 12.0 | 755 |
| 14 | 14 | .3125 | 13.375 | 1000 |
| 14 | 14 | .375 | 13.25 | 983 |
| 16 | 16 | .3125 | 15.375 | 1461 |
| 16 | 16 | .375 | 15.25 | 1430 |
| 18 | 18 | .3125 | 17.375 | 2025 |
| 18 | 18 | .375 | 17.25 | 1987 |
| 20 | 20 | .3125 | 19.375 | 2708 |
| 20 | 20 | .375 | 19.25 | 2661 |
| 22 | 22 | .3125 | 21.375 | 3519 |
| 22 | 22 | .375 | 21.25 | 3465 |
| 24 | 24 | .341 | 23.318 | 4439 |
| 24 | 24 | .409 | 23.182 | 4341 |
| 26 | 26 | .370 | 25.26 | 5556 |
| 26 | 26 | .443 | 25.114 | 5404 |
| 28 | 28 | .398 | 27.204 | 6693 |
| 28 | 28 | .477 | 27.046 | 6588 |
| 30 | 30 | .427 | 29.146 | 8041 |
| 30 | 30 | .512 | 28.976 | 7920 |

Fig. 44

The choice then to be safe would be the 18" pipe. However, another factor enters in; 18" pipe is not in common use for pipe lines, the increase in size to the next commonly manufactured pipe is 4" rather than 2". And 16", 20", 24", 30" are the common sizes. Then, if 18" is not available and the cost of the larger sizes would seem out of line to carry the extra gas that a 16" might not handle, the original estimate of the amount of gas which the line was to carry would be referred to, and since 10 million of the 20 million was estimated as possibly coming in, then again it is seen that 16" would still be a reasonable bet to install.

In the chart, Fig. 44, it will be noted that the formula is rearranged so that one can solve for pressure at either end of the line or for the length of line.

5. Gas Measurement:

Gas is a commodity in the form of fuel that is bought and sold. It could be weighed up and sold but the cost and inconvenience eliminates that method except when liquefied. The measuring device used is a meter and is installed in the gas line. It registers the volume, rather than the weight, of gas passing. In homes the gas used is bought by volume in thousands of cubic feet which are registered on individual meters. Likewise in the oil field each lease is selling to the gasoline plant the gas produced and it is necessary for the volume to be measured by an individual meter on that lease.

It is customary then as shown on the gathering system map to have all the gas from one lease to pass through one meter. The metering process is not the same on these meters as the house meter. The house meter measures by actual displacement as do many other meters. In the field, however, the orifice meter is used.

The reason for the use of the orifice meter is its flexibility of capacity and pressure range. By simply changing the orifice plate, practically any capacity of the line can be measured. If the pressure changes, the pressure spring in the meter may be changed. Thus a complete range of volumes and pressures can be measured by the orifice meter. The displacement meters have a number of dis-

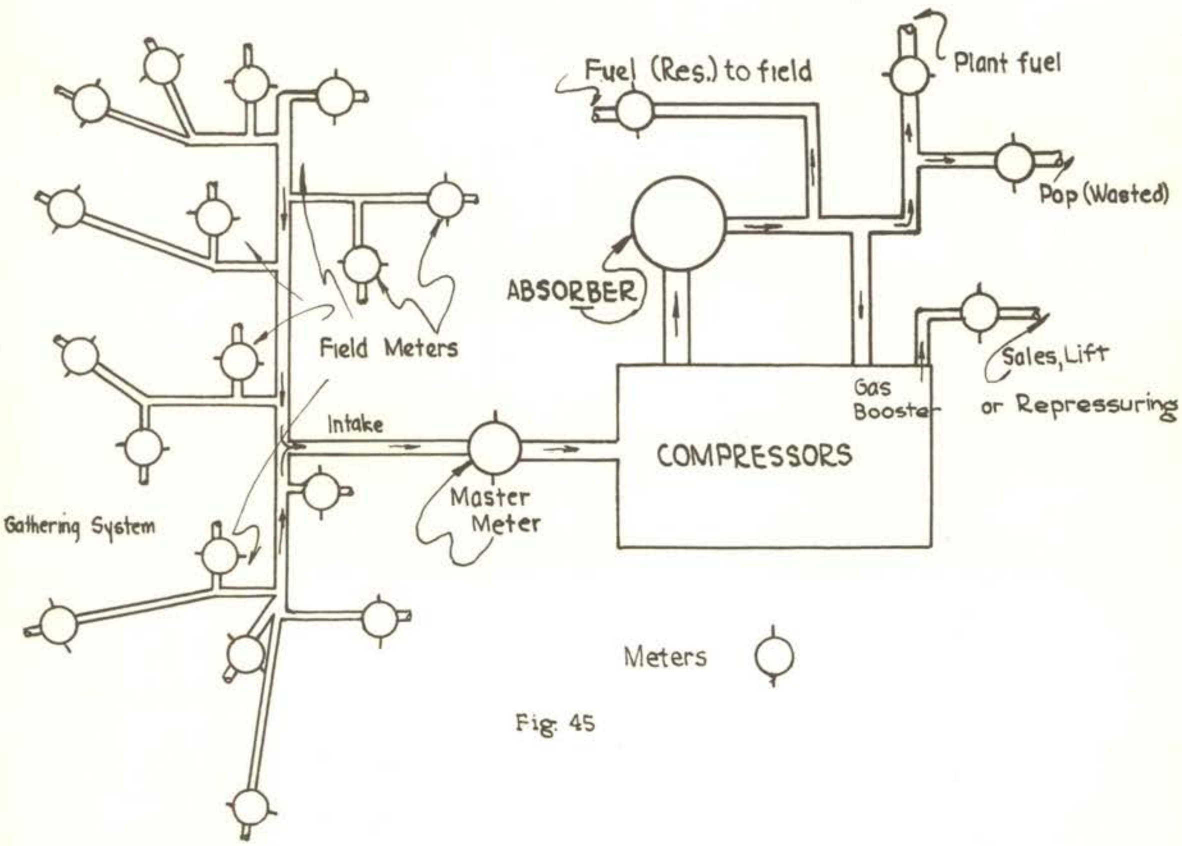



Fig. 45

advantages for this use. (1) The capacity as to volume and pressure of each meter is limited. (2) The wet gas deteriorates the "leather" or diaphrams. (3) They are a great deal more expensive for higher volumes and pressures.

Not only is metering required on gas purchase but also in the plant to check on the circulation in absorbers, residue and sales. Fig. 45 shows the places of measurement to know what has been bought and where it goes. All gas purchases are made at the field meters and the volume added up should check the master meter at the plant intake. This check reading indicates leaks in the gathering system between the field meters and the plant. If there is pressure on the gathering system, the master meter registers less gas when there is leakage than the sum of the field meter volumes and shows the loss. If a vacuum is on the gathering system, then the master meter registers more gas than the field meters and the difference is air entering the lines through leaks.

After the gas passes the intake meter, it goes to the compressors, coolers, and absorbers, then meters measure the disposal. When there is more than one absorber, meters are installed on each absorber to see that the gas is evenly distributed in passing through the absorbers. In this case, sometimes, the intake or master meter is omitted and the volume registered coming from the absorbers is used to check the field meters by adding in the volume taken out by gasoline extraction as mentioned previously.

The residue gas after leaving the absorber may go to a number of places as indicated on the sketch, Fig. 45, such as field residue, plant fuel, popped, and sales. When all these volumes are added up they should check the absorber meter volumes or the plant intake volume less the gasoline extracted.

It might be said that the absorber is the dividing line of this system of measurement. All gas coming in is purchased for its gasoline content, and going out it is fuel gas and as such its distribution has to be accounted for, as it is valuable. This will explain the presence of various meters about the plant.

The meters and settings are taken up in a later chapter.

6. Maintenance:

The maintenance of a gathering system comes under three headings: (1) leakage, (2) keeping lines clear for free passage of gas, and (3) regulation. Leakage as mentioned before may mean air in or gas out and is possible throughout the gathering system. Keeping the lines clear refers to the presence of fluids which will retard or even stop the passage of gas, to freezing, and to rust or solid foreign matter which may collect in one spot in the line. This last condition is also prevalent throughout the gathering system but the trouble is located in low places in case of fluid, or at a fitting generally in case of solid matter. Regulation concerns the adjustment of regulators on the leases to suit the producer's requirements for pressure to be held on his lease.

A close check is made daily of the volumes of the whole system by means of the meter readings and the whole system is partially covered by the chart changer. Regular line walking is seldom necessary until trouble is known to exist then the lines are inspected by walking. In cold weather most of the lines are covered by the drip blower.

Some of the causes of leakage, their means of detection, and method of repair are given in the following table:

| CAUSES | USUAL MEANS OF DETECTION | METHODS OF REPAIR |
|---|---|---|
| Corrosion | C,D,E,F, | Welding, Clamp, Plug*, Replacement of joint or fitting. |
| Line pulling in two | A,B,C,G, | Dresser coupling, weld, block up line. |
| Thread leaks | C,D,E,F, | Make-up, caulking, welding, fitting leak clamp. |
| Valve Stems | C,D,F, | Packing stem |

| | | |
|---|---|---|
| End Drip Valves Leaking | D,F, | Clean Valve or replace. |
| Foreign Interference<br>1. Road grader | road men<br>A, generally notify | Weld, bury deeper, dresser coupling. |
| 2. Trucks running over line | A,G, | Weld, bury deep, dresser coupling. |
| 3. Punching (for gas connection) | C,D,F, | Clamp, weld, plug*, tap and plug. |
| 4. Drip tampering (for gasoline) leaving valves open | B,C,D, | Close valves. |

*A wooden plug is quite often used as a temporary repair and should be permanently repaired as soon as possible.

The usual means of detection of the leaks listed and indicated by letters in column two are as follows:

A. Sudden increase or decrease of master meter volume (vacuum increase, pressure decrease).

B. Unaccounted for change in volume indicated by lease meter. (If leaks are on leases then the meter localizes the trouble to its lease).

C. Air tests. (Vacuum operation, these tests are made at plant and at taps at strategic points throughout the gathering system.)

D. Sound or feel. (Hear the gas whistling, or feel current of escaping gas on hand, or suction on hand when holding it tight over suspected leak such as a drip valve.)

E. Water being sucked in line in wet weather.

F. Pressuring system (if not already) and dragging torch over lines. (Dangerous, as noted below.)

G. Report of producer operators. (Any leaks discovered by pumpers or other employees of producers are reported. This works both ways, gasoline plant men report oil leaks or anything wrong to the producers.)

The method under F of pressuring the lines and dragging a torch over them is a case of last resort. Careful and close inspection is always done first to see if the leaks cannot be found and repaired. If then leakage is still known to exist by air being present in gas this method may be resorted to. The following precautions are recommended:

A. Have enough men in crew dragging torch to take care of all emergencies such as grass fires or large gas fire. They should be equipped with wet sacks and shovels and repair tools necessary to repair line.
B. The torch itself, usually an oil soaked rag, should be attached to a long pole, with a wire and dragged over the line with the man holding pole on the windward side. Reason for this is to prevent leaking gas from flashing near the workman and burning him. A fishing pole has been found suitable for this.
C. Thick grass or brush over the line which is dry should be cleared away to prevent starting a fire which might get out of control.
D. Stay away from tankage, buildings, wells, and any other flammable material which might ignite.

The pictures in Fig. 46 show leak clamps and dresser coupling used in repair work. Welding is familiar to all. In welding, it is essential that safety precautions be taken. If the line has pressure on it, it should be blocked off and pressure removed. On a vacuum line small holes may be welded up with safety. In bell holes (hole dug to work on pipe) the hole should be tested before the welder enters with lighted torch. No welding is done in the presence of gasoline or vapors.

Keeping the lines clear for free passage of gas has always been a problem. Condensed liquid or oil from separators has been the major source of trouble and

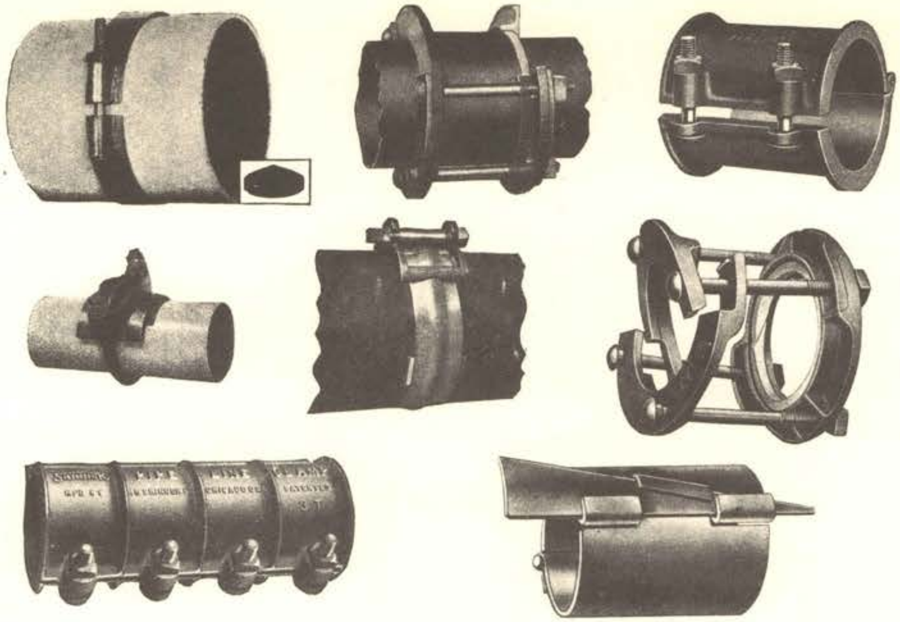


Fig. 46

the method of drawing the fluid from the gas line is by the installation of drips. A common type of drip still in use is that shown in Fig. 1. Where more fluid is involved, especially gasoline, a larger tank is installed and if on a vacuum system a pressure line from the residue system, which generally parallels the main vacuum lines, may be installed if there is no way to gravity the fluid out. Fig. 47 shows one such type with connections. The operation of this drip is: normal position to drain vacuum line of fluid, valve A open and B and C closed. To empty tank, valve A is closed, B is opened, pressuring tank, and C is opened at same time to allow fluid to come out of tank. When free gas is coming out at C, B is closed, C is closed, and A is opened and drip is back in service.

On the pressure line which is swaged to 1 inch or ½ inch, it has been found good practice to use two valves with a union between. When the line is not in use the valves are closed and the union broken apart as shown in Fig. 47. This prevents any recycling of residue gas back through the vacuum system. Pressure connections are used where pressure is available and the drip cannot be drained by gravity.

As drips often are under ground, both intake and outlet valves are buried. These valves have to be protected and open so they can be reached for operation. To do this a nipple of 6", 8", or large pipe is cut from scrap, slipped over the wheel and bonnet of the valve, and the dirt back filled. Fig. 48 shows this method of keeping the valves open for operation. Another type of protection is a box. When the valves are too low to reach by hand an extension handle, as shown in the same figure, can be made in a few moments by the welder. The extension can be car-

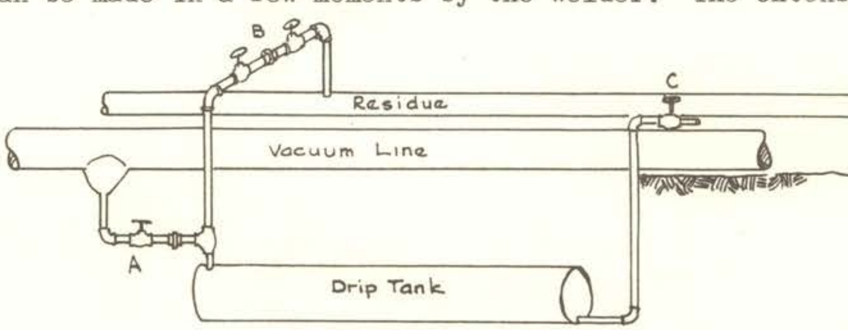



Fig. 47

ried by the drip blower.

To prevent damage by fluid from the drips a small pit may be excavated near the outlet, the fluid run into it and any oil or gasoline burned. This is not necessary if the fluid is gasoline and is being picked up.

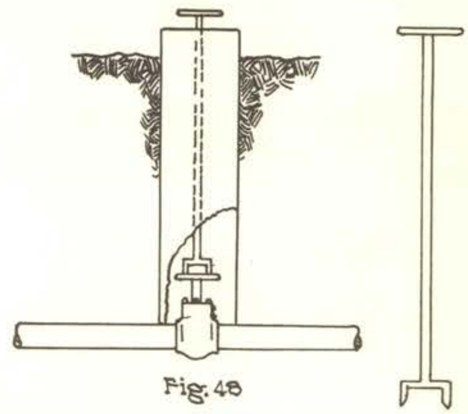


Fig. 48

Often a line becomes clogged with sand, rust, rags and other foreign material. The indication of this is a pressure drop in the line. By pressure drop we mean the difference in pressure of the two ends, or across a section of the line, called a pressure differential. If a section of line beginning on a certain lease has five pounds on it and there is an 8" vacuum on the main vacuum line, the pressure drop is 5 + 8/2 or 9 lbs. If the volume of gas passing in the size line in use is not enough to cause this much pressure differential, then it is apparent that the line is partially stopped or clogged. If the stoppage is nearly complete the place may be located by the whistling of gas through the small opening. The remedy is to vent the line on the lease shut vacuum gate at the main line, part the line, turn the lease gas back in and blow it out. A temporary remedy may be had by pounding with a hammer on the line where the whistling is and jarring loose the foreign material so it will spread out down the line. Liquid, also, may be introduced in the line on the upstream side in an attempt to wash the foreign material to the next drip. This may work, and it may stop up the drip connections making it necessary to dig up and clean out the drip.

Freezing off of vacuum lines occurs during freezing weather, where the gas carries a high percentage of water vapor. This generally occurs near the well. Buried lines and a drip buried also are the best remedies. Lines above ground all are liable to freeze off during cold weather. Open fires may be used to thaw the lines but at a great risk. Great caution should be taken in this method and if possible hot water should be used instead of open fire.

Regulators on the leases without attention soon become sluggish and cease to function. This makes the producer dissatisfied, it, therefore, is essential that the field man, chart man, or any one who is responsible for the regulators know the function and operation of gas regulators.

A regulator is an automatic valve that holds a constant pressure on either the upstream or downstream side of it by opening or closing its valve to admit such passage of gas as is necessary to hold the desired pressure.

There are two types of regulators used for two distinct purposes, the back pressure regulator and the reducing pressure regulator. The function of the back pressure regulator is to hold a desired pressure on its upstream side. The function of the reducing pressure regulator is to hold a desired pressure on its down stream side.

Practically all the gasoline plant gathering system regulators are of the first type or back pressure regulators. Back pressure regulators are built in various sizes to hold high and low pressures. There is a group of these back pressure regulators built especially for gathering systems and this group is called casinghead regulators. The popular sizes are 2", 4", and 6" with other sizes available. The construction of these regulators is for operation under low pressures and are fairly sensitive, hence they have large diaphragm and double disc valves. Fig. 49 shows a casinghead regulator. Note the upstream or controlled pressure is on the lower side of the diaphragm and the valve stem also operates in the upstream portion of the valve and no packing is required. In fact, this type of regulator is often operated from pressure coming through the valve stem opening and no control pressure line used. The upper side of the diaphragm is vented to the atmosphere. This regulator may be installed on the meter setting, at the trap, or near the well. A trap or separator is shown in Fig. 50 to explain the location of the gas outlet line.

In operation, as the controlled upstream pressure increases the pressure on the under side of the diaphragm increases and this raises the valve, opening it. The valve opening allows gas to pass through decreasing the pressure on the

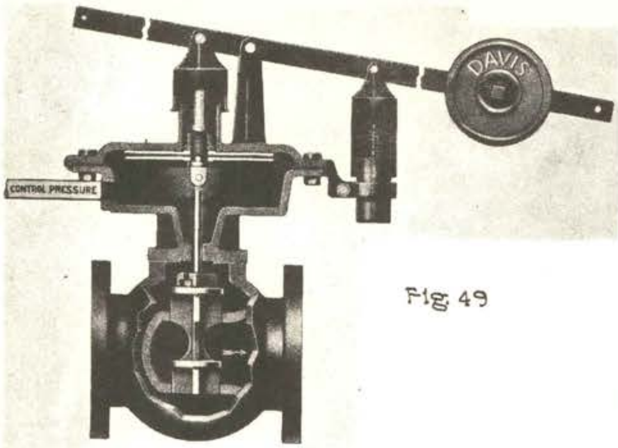



Fig. 49

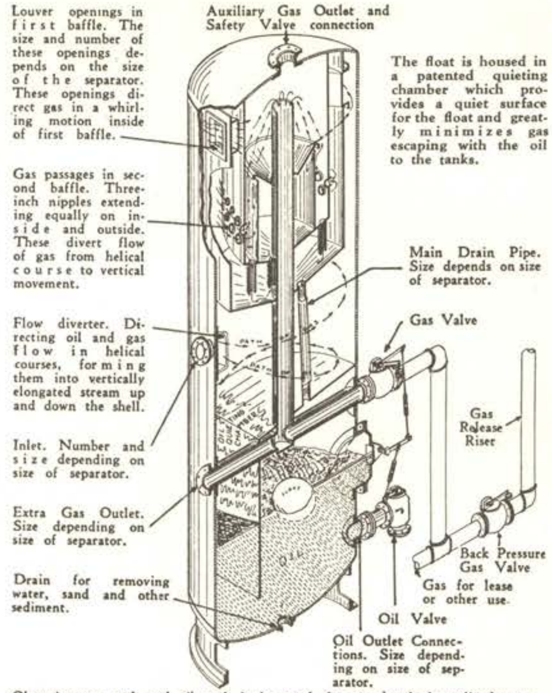



Fig. 50

Observing gas path and oil path it is noted that gravity is immediately permitted to influence the flow. The oil goes in a downward helical course while the gas travels in an upward helical course, insuring the immediate release of the gas from the oil. By not keeping the gas and oil together in a travel path the freed gases escape upwardly and do not tend to cut the oil or further emulsify it when water and sand are present.

upstream side and in decreasing this pressure lessens the pressure on the diaphragm and the valve lowers. As stated, the diaphragm was large, the reason being to get enough pressure area to move the valve. For instance, a 12" diaphragm has approximately 113 square inches, and it is desired to hold atmospheric pressure on the upstream side (on the casinghead of a well or on the separator). Then when atmospheric pressure is below and above the diaphragm the pressures are balanced and only the weight of the valve stem and discs tend to close the regulator. By removing the weights from the lever arm and sliding the lever arm to the proper position it will balance or offset the weight of the stem and discs. Assume now, a flow of gas from the upstream side, this increases the pressure under the diaphragm and where there was equalized pressures before, now there is more than atmospheric (14.4 lbs.) below and only atmospheric above. Assume the flow increased the pressure 1/10 of a pound, then let's see how much lift the diaphragm will give the stem. The area is 113 square inches and 1/10 of a pound per square inch makes 1/10 of 113 or 11.3 lbs. lift and the stem probably will go clear up opening the valve wide. This illustrates that only a small variation in pressure is required to operate the valve. Probably less than an 11 lb. pull is required to move the valve so less than 1/10 of a pound variation is required to operate the valve.

To hold less back pressure on the upstream side, the weight is adjusted on the lever as shown in the illustration, Fig. 49. The weight on this (first class) lever tends to lift the valve and hold it open or it removes part of the effect of atmospheric pressure on the upper side of the diaphragm. It does not then require atmosphere or 14.4 lbs. pressure on the under side to balance the pressures above and below on the diaphragm.

The following problem on the same regulator illustrates this. A 10-pound weight is clamped on the lever 30" from the fulcrum. How much vacuum will be held on the upstream side? It is 3" from the fulcrum to the stem or weight, Fig. 51.

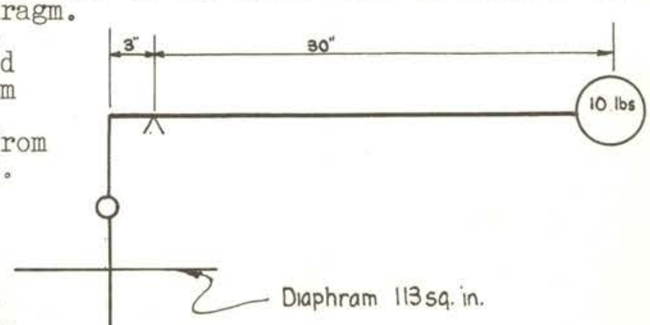



Fig. 51

The mechanical advantage of the lever is 30/3 or 10. Then the 10 lb. weight has a lifting effect on the valve stem of 100 lbs. The force down on the diaphragm from atmospheric pressure is 14.4 lbs. per square inch or 14.4 x 113 = 1630, less lever lift, 1630 - 100 = 1530. 1530 ÷ 113 = 13.5, the pounds pressure required under diaphragm to balance the weight. 14.4 lbs. - 13.5 lbs. = 0.9 lb. or 1.8" mercury vacuum will be held on the upstream side of the regulator (1# = 2" mercury).

By sliding the weight back and forth, this pressure (or vacuum as commonly called) may be varied. By reversing the lever so the weighted side pushes down on the diaphragm (2nd class lever) instead of lifting on it, then more than atmospheric pressure is required to lift the valve and the upstream pressure is held to some pressure greater than atmospheric.

It would be excellent practice and information to weigh the weights on a regulator in use, measure the required distances and areas and solve for the back pressure it is carrying.

The double cylinder arrangement (shown in Fig. 49) bolted to the diaphragm case and pinned to the lever is a dash-pot. Its construction is shown in the following sketch, Fig. 52. The inner cylinder is the pot and is filled with oil. The piston is a disc and has enough clearance so that free movement is allowed but rapid movement is prevented.

The purpose of the pot is to prevent the regulator from "chattering" or the valve opening and closing rapidly. This chattering pounds out the seats. What causes a regulator to chatter might well be explained by the action of a car starting up over a rough road in low gear. The driver steps on the accelerator, hits a bump which throws his body out of balance and his foot lifts off the throttle. Then, he slams his foot back on the throttle, which jerks the car forward throwing him out of balance again, and the process is repeated until the driver can steady his foot on the throttle and then the car moves forward smoothly.

In the regulator the gas pressure coming in opens the valve and due to the inertia of the moving parts the valve opens too wide, this reduces the upstream pressure rapidly under the diaphragm and the valve slams shut, the pressure builds up and the valve opens too wide again and the process is repeated until a damper is put on the rapid movements of the stem and lever. The dash pot is the damper.

The dash pot occasionally is removed and lost because it is not properly adjusted and the regulator operates without it at that particular location. When the regulator is reclaimed and used in another location the chances are it needs a dash pot and none is available. Best practice indicates that the dash pot should remain with the regulator. The other type, reducing pressure regulator, is taken up in the next chapter.

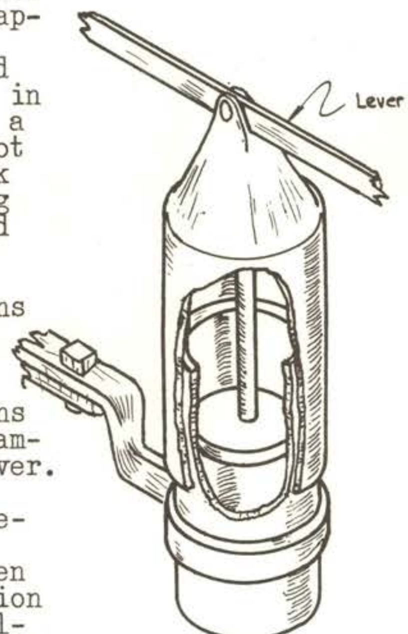



Fig. 52

7. Drip Gasoline:

During the winter months in oil and gas producing fields where the G. P. M. of the gas is high, an appreciable volume of gasoline is condensed in the gathering lines and collects in the drips. In one plant's system as high as 2,000 gallons per day has been known to condense in the lines. When this is the case it becomes necessary to gather the gasoline from the drips and take it into the plant. This generally is done with a tank truck.

Drip gasoline is valuable due to the fact that it is condensed at low pressures and contains the heavier hydrocarbons of stable gasoline. It will run 60 to 80 gravity; the field, pressures, and weather controlling this. If the lines are clean the gasoline may be of good color, but generally, some crude or dirt in the line requires that it be rerun at the plant.

There are two difficulties encountered with drip gasoline: (1) theft from the drips and (2) inaccessibility of drips. The drips are scattered over a wide territory, making it impossible to consider watching all of them for protection from stealing, although this is done to some extent. The method of protection much used is that of installing a locking device on the outlet of the drip. This is not as successful as it first might appear. Lock stops with the padlock in the open are easy prey for a small bar. Neither is protecting the lock enough, as a pipe wrench can be applied to the pipe back of the stop and it is unscrewed. A number of different locking devices have been built and used. Fig. 53 is one such patented locking device in use.

The inaccessibility of the drips is due to the fact that drips have to be installed in the low places in the line and in most cases none of them are near a road. Approach is made through fields and the truck is stopped by ravines and various other ground irregularities. Some of this disadvantage is overcome by the use of a long hose on pressure drips. Other places a portable pump, or one mounted on the truck, is used. If the drip is reasonably close to the plant and makes a large volume it may be piped into the plant.

Thus, we learn, that gathering drip gasoline may accomplish two things: it saves the gasoline and clears the lines for free passage of the gas.

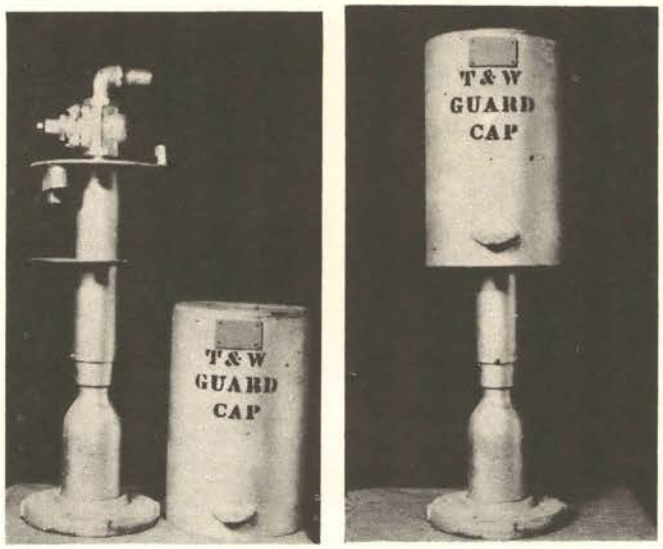



Fig. 53

UNIT III

AUTOMATIC PLANT CONTROL DEVICES

1. Pressure Control:

One of the secrets of successful operation of a natural gasoline plant is that of having complete control of the pressures in all the lines, tanks, stills, etc. To obtain the required pressures in the many places desired, is the job of mechanical valves and devices which operate automatically. By "automatic" is meant that they operate themselves under certain designated conditions. The automatic valves hold steadier pressures than hand-controlled or manually operated valves because they are more sensitive to pressure changes. No doubt many men in the industry have had the experience of opening and closing a valve trying to hold a pressure constant while a regulator is out of service. After an hour or two of trying to juggle a pressure by hand control of a valve the automatic regulator is highly appreciated.

2. Back Pressure Regulation:

We have already discussed the value of the back pressure regulator on the field lines and the same type of back pressure regulator is in use in a number of places in the plant proper. For instance, the operating pressure of the absorbers is controlled by a back pressure regulator. The only difference between it and a casing head regulator is that the diaphragm is smaller. This is because the 25 or 50 lbs. on the underneath side of a large diaphragm would require too much weight on the lever to balance it. That is the reason the higher pressure regulators use smaller diaphragms. The absorber back pressure regulator is located on the pop relief line or on the high stage cylinder intake line.

In like manner, the still pressure is held by a back pressure regulator of a smaller size as it does not pass so much gas. The stabilizer may use a still smaller one as it operates at a higher pressure.

3. Reducing Pressure Regulation:

There are operations in the gasoline plant that require the reduction of high pressure. For instance, the absorbers have 50 lbs. and only 25 lbs. are required for the field fuel or residue system. In this case a reducing pressure regulator is used. Fig. 54 is a cross section of a reducing pressure regulator. The back pressure and the reducing pressure regulators operate on the same principle and at first glance they appear to be the same. Close examination reveals that the pressure line on the diaphragm is on the top side instead of on the bottom as in the back pressure type and that it goes to the down stream side of the regulator.

The pressure line being on top instead of on the bottom has no particular significance as back pressure regulators are built to operate with the pressure control line on either side of the diaphragm. The controlling pressure line going to the down stream side is significant as the downstream side is the side where it is desired to have the pressure controlled.

In this regulator, commonly called spring loaded, the lever mechanism is replaced by a compression spring and adjusting nut. The tendency of chattering is practically eliminated in this type.

In operation, assume there is 50 lbs. on the upstream side and 25 lbs. is required on the downstream side. The spring is adjusted until the pressure gauge on the down stream side reads 25 lbs.

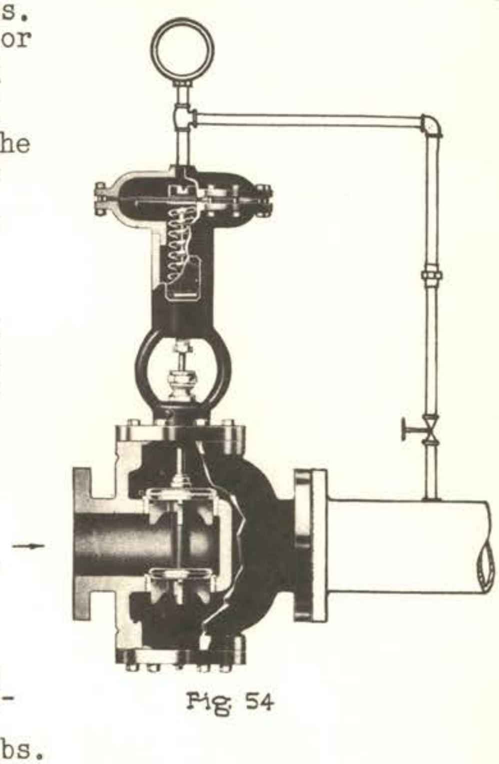


Fig. 54

The spring tends to open the valve and hold it open until the pressure on the upper side of the diaphragm becomes so great as to overcome the spring pressure and close the valve. As gas is used or drawn away from the down-stream side the pressure falls and the spring again opens the valve. Here again, if the dimensions and pressures are taken from a regulator in use and the pressure on the diaphragm calculated, good information will be secured and also the reason for the heavy springs used will be understood. Don't forget to use absolute pressures in the calculations.

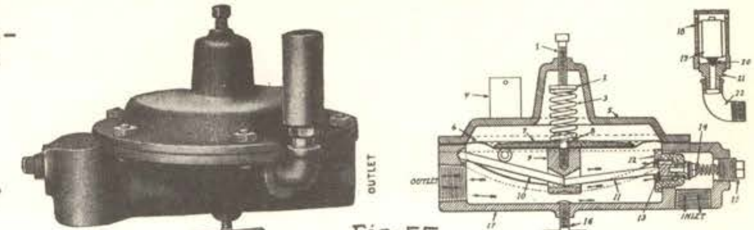


Fig. 55

This regulator in Fig. 54 as well as many others is built so the body may be removed, turned over, and a back pressure regulator be made of it.

Reducing pressure regulators have numerous applications in the plant. After the 50 lb. pressure is reduced to 25 lbs., the 25 lbs. may be piped to the engines, boilers, and houses for fuel. However, 25 pounds is too high for all of these places and the pressure has to be reduced again to suit the fuel requirement. In the house, for instance, only 6 to 8 ounces of pressure is required so another regulator is installed. Fig. 55 shows a commonly used regulator for houses. The valve has a cut-off arrangement operated by the toggle that closes the inlet completely if the gas goes off on the high pressure side and will not open when the gas comes back on. This is a safety feature to prevent filling the house with gas in case the gas supply is shut off and turned on again without warning. To open the inlet valve, the automatic screw in the bottom is screwed up until gas passes, then screwed back down. The screw in the top of the regulator adjusts the pressure on the down stream side. An examination of one of these regulators will show the action of the toggle.

The size of the diaphragm is proportioned to the pressure to be applied to it, and these matters of size and pressure are the principal controlling points determining the sensitiveness of the apparatus. In general a low pressure regulator is more sensitive than a high pressure regulator because it has more diaphragm space. To illustrate the difference, let us think of a high pressure regulator with a diaphragm area of 200 square inches. In the first case, a change of one pound will change the total pressure on the diaphragm only 10 pounds, while on the second diaphragm the change will be 200 pounds. If the resistance to motion is anywhere near the same in the two regulators the low pressure regulator will be 20 times as sensitive as the high pressure, and it will require only 1/20 as much pressure to operate.

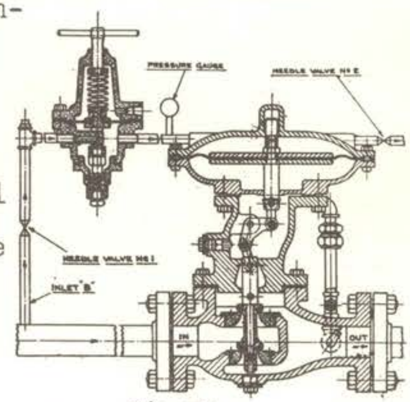


Fig. 56

When a considerable reduction of pressure is made, two or more regulators are set in the line, a high pressure regulator to reduce the pressure to a medium point, then a medium pressure regulator for the distributing system, and perhaps a low pressure regulator at the point of consumption.

It is apparent then that high pressure regulators are not as sensitive as low pressure regulators, consequently do not afford as accurate control of the flow in the line. A method has been devised for making high pressure regulators more sensitive by the use of a pilot regulator. The set-up consists of a low pressure regulator diaphragm on the high pressure line regulator with a small high pressure regulator set into the control line of the main regulator, Fig. 56. In this way the sensitiveness of a low pressure regulator is obtained by using a large diaphragm, since it is not exposed to high pressure. The small high pressure regulator is called the pilot regulator.

When two separate units are used as just described, the main regulator may be installed in the pipe line and the pilot regulator be placed in some convenient place, such as a regulator station. In this way the pressure of the line is under rather remote control, it being only necessary to change the pilot regulator to regulate the line pressure. In some cases, however, the pilot is built into the same housing with the main regulator, the stem of the pilot connected directly to the control valve of the main regulator, Fig. 57.

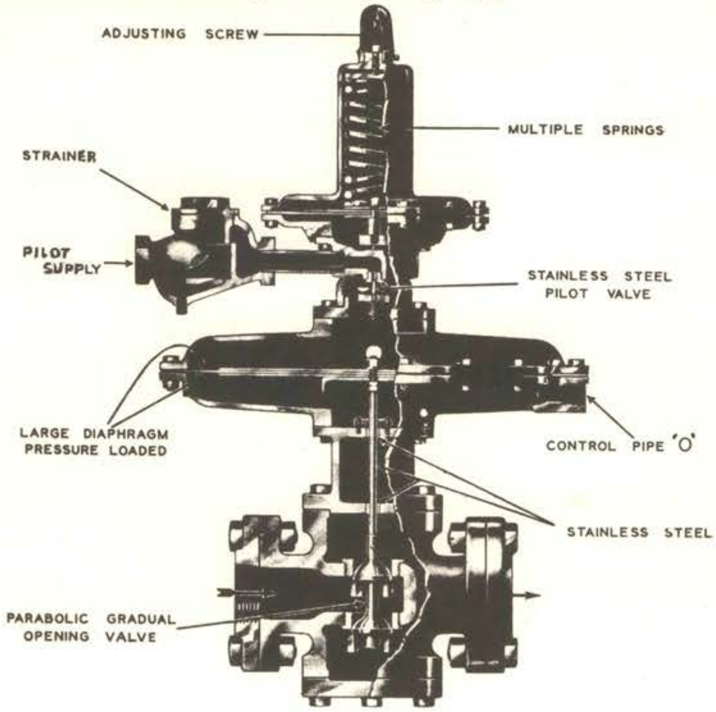



Fig. 57

All the regulators so far considered, either pilot or main, have been operated against mechanical resistance, either a spring or a weight, except in Figs. 56 and 57. A method employed to make these regulators still more sensitive is to admit the upstream pressure to one side of the diaphragm, as in the spring and weight loaded regulators, and the downstream pressure to the lower side, one working against the other and controlling the line pressure differential and serves as a back pressure regulator to the upstream line and a reducing regulator to the down stream line. Fig. 58 shows the principle of operation. This type of regulator is known as a "pressure loaded" diaphragm regulator.

Even the pressure loaded regulator may be made more sensitive by the use of pilot regulators. Fig. 59 shows an installation in which both the upstream and the downstream control lines are equipped with pilot regulators, thus making it possible to use a large diaphragm and secure extreme sensitiveness.

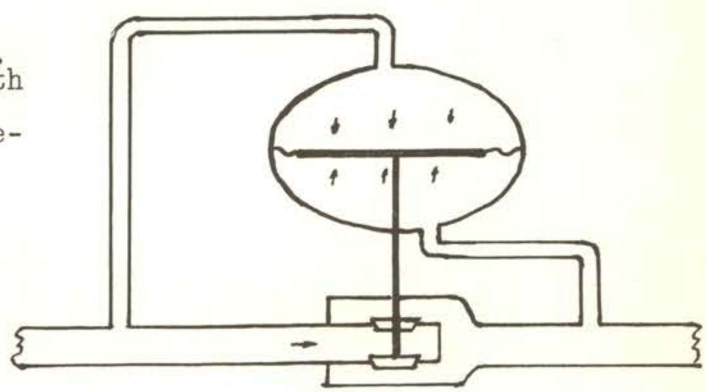


Fig. 58.

Fig. 60 shows an installation of a "pilot loading system" for a high pressure line. The pilot is operated by a control line carrying high pressure gas. This pilot controls the flow to the upper side of the diaphragm and exhausts to the atmosphere or to some low pressure line. Both sides of the diaphragm are protected by a double acting safety valve, thus insuring it against excessive pressure from the control lines. Only a few pounds difference in the two chambers will operate the safety valves and relieve the pressure.

In order to observe and control various pressures about the plant, it has been found practical to collect the control instruments in one building. A panel is mounted in it with the instruments on it. To control a regulator from this building an installation such as in Fig. 60-A may be used. The pilot valve shown in upper right of the figure is mounted on the control panel and broken

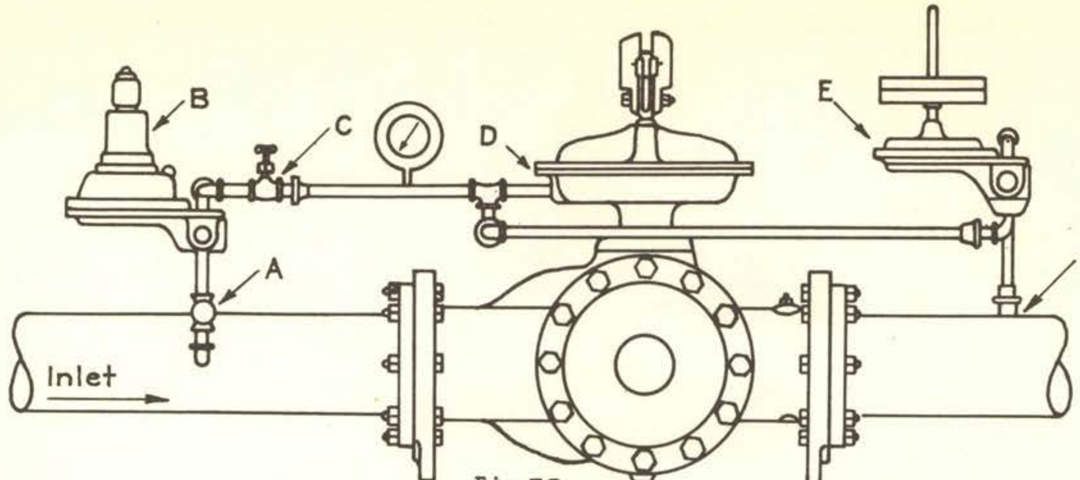

B
C
D
E
A
F
Inlet

Fig. 59

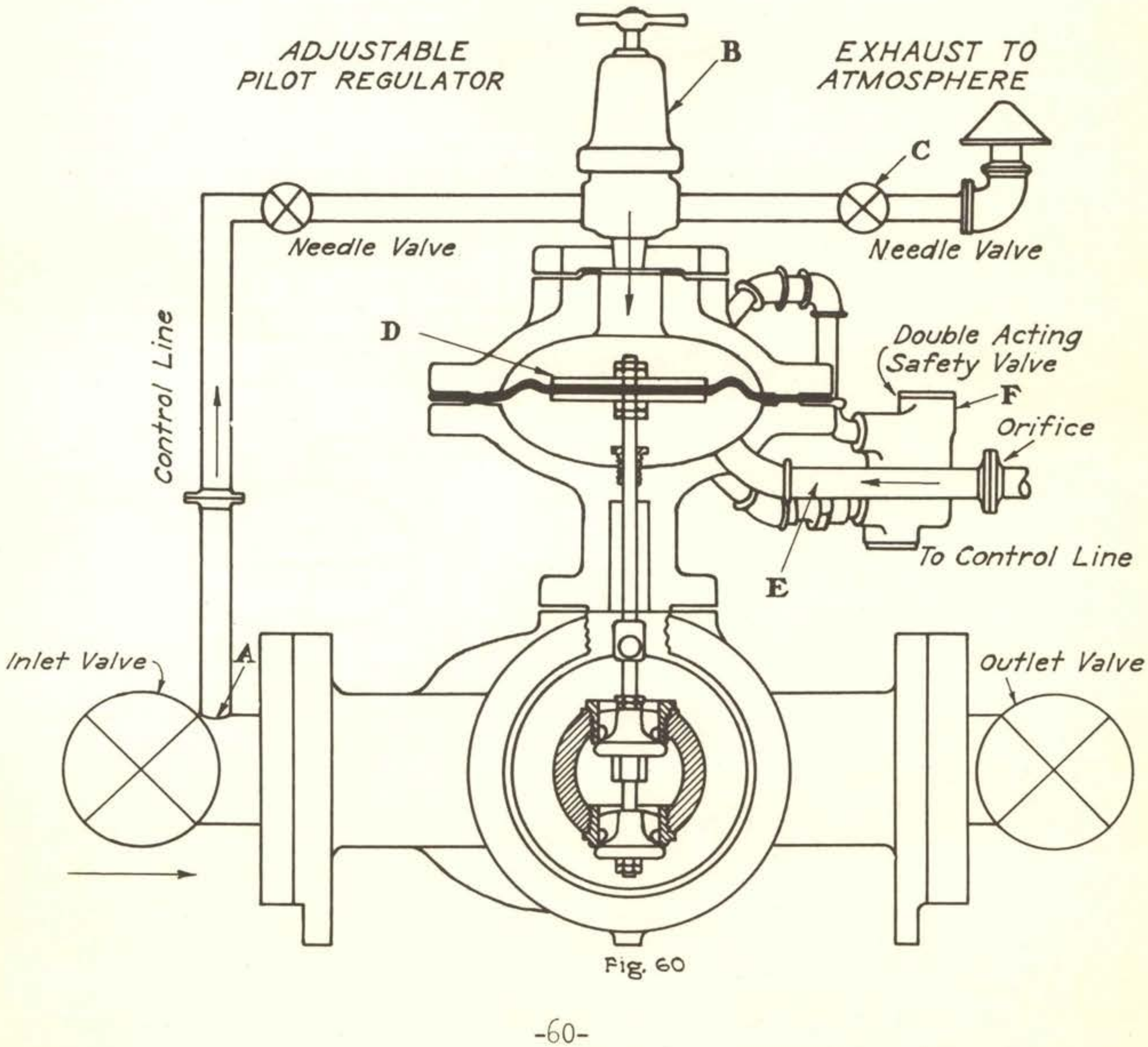

ADJUSTABLE
PILOT REGULATOR
B
EXHAUST TO
ATMOSPHERE
C
Needle Valve
Needle Valve
Control Line
D
Double Acting
Safety Valve
F
Orifice
To Control Line
E
Inlet Valve
A
Outlet Valve

Fig. 60

lines lead to the regulator. The auxiliary pressure supply is generally air and is dehydrated to prevent freezing. The regulator diaphragm pressure is varied by a leak in the pilot mechanism. The hook-up may be made whereby increased pressure opens the regulator or decreased pressure opens the regulator. The latter method is safer as any failure of the auxiliary supply allows the regulator to stay open, rather then closing it and shutting down any operations on which it works.

When a regulator is installed it should be placed on raised connections so that it will clear the floor and afford plenty working space in every direction. Being extremely delicate instruments, they must have the best of care to keep them working perfectly, and this can be done only in the best of work conditions.

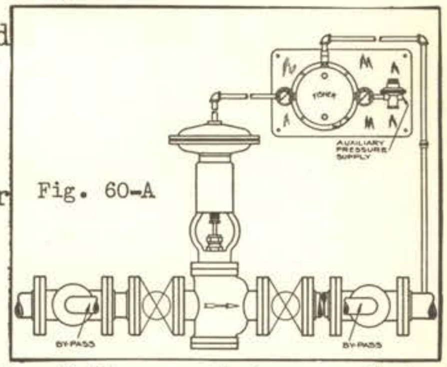


Fig. 60-A

When a high pressure and a low pressure regulator are set in the same line, they should be separated enough to supply a receiving space for the high pressure regulator and a supply space for the low. If distance will not permit this separation a piece of extra large pipe, a receiving chamber, or parallel lines will afford the desired capacity.

Always place a safety valve on the downstream side of the regulator so that in case the regulator sticks no harm can come to the line or the equipment on the other end of the line. The safety valve should be set at the safe pressure, realizing that it is not the intention to produce and waste gas, but to supply it to place wanted economically and safely.

A regulator should be supplied with a by-pass line of sufficient size to carry the load in case the regulator must be repaired or replaced. The pressure can be hand controlled for a short time. It is customary to set low pressure regulators in parallel so that one may carry the load while the other is off. Free working valves must be provided to control the passage of gas through the regulating system.

Leaky valves are the greatest source of difficulty in any gas regulating installation. If natural gas were always clean, there would be little cause for complaint, but scale from pipe, sand, pipe cuttings, etc., are always getting into the lines, and are carried with the stream at a very little lower velocity than the gas itself. Since a valve of most any type offers some resistance to flow this dirt is lodged against the seal of the valve either to cut the metal or to be forced into the metal when the valve is closed, thus causing a leak in either case.

Many more factors both for efficiency and for safety could be mentioned here but each gasoline plant has methods of its own that will furnish the basis for class discussion. It would be a loss of time to discuss them here as they might not even apply to any other installation except where intended. Consequently, the study is here turned to the operator's own local situation.

4. Flow Control:

Just as it is important to control pressures, it likewise is important in certain phases of the plant operation to have an even control of the flow of gases and liquids. The absorbers should not only have an even distribution of the gas through each but also an even distribution of the absorbing oil. The oil flow into the still and out should be even, not irregular. The raw gasoline pump into the stabilizer has to be steady or the efficiency of the unit is lowered.

The control of flow in these various places is accomplished with various types of valves and controllers. They can be divided into three groups: the gas controlling device sometimes called proportioning meters, the liquid level controls, and the liquid volume control.

The gas controlling devices which proportions the amount of gas entering the absorbers or any other distribution by proportion is accomplished with meters operating pilot controlled valves. This is an application of remote control referred to under regulation. The detail of operation of these proportioning meters is too extensive for this discussion.

The liquid level controls are used on any system of liquid transfer from one vessel to another where it is essential that a certain level be held in any of the vessels. Fig. 61 shows one type of the liquid level control on an absorber. This level has to be held in the absorber by some valve regulation in order to separate the oil and gas. The gas pressure forces the oil out, the pumps force oil in at the top and the seal is held against the gas going out with the oil at the bottom by holding the oil level above the oil outlet. The ball float in the liquid level chamber operates a system of levers so that as the float rises the levers open the oil outlet valve and as the float lowers the valve is closed. Another method of installation is for the ball float to be inside the vessel as shown in the oil separator, Fig. 50. In this installation the float

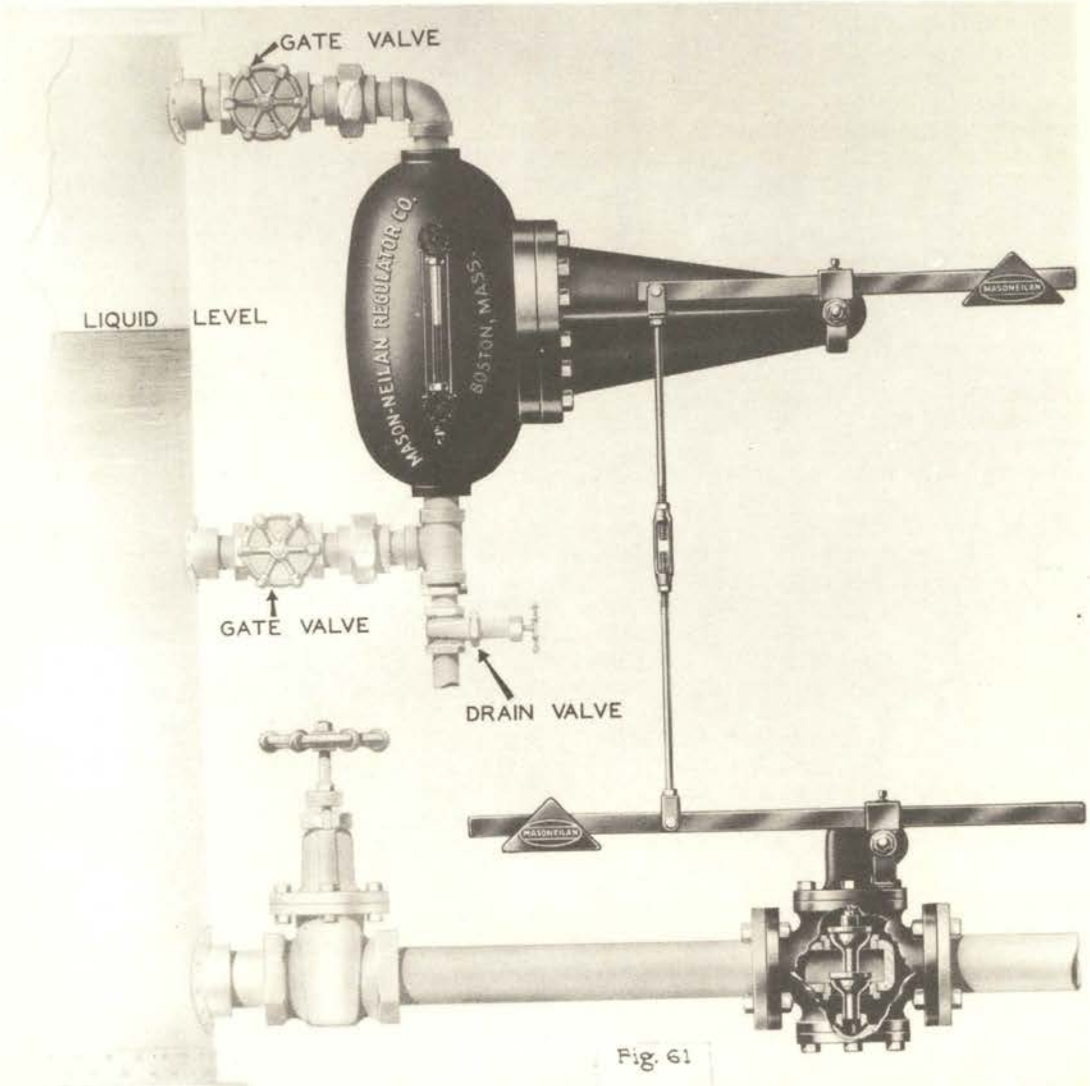



Fig. 61

operates both the oil outlet and gas relief valve; if the oil level rises, the oil outlet is opened and the gas is pinched off increasing the pressure in the trap which helps to force the oil out until the oil level is lowered. Fig. 62 is a horizontal tank installation.

Liquid level controls are used on the still outlet, the rich and lean oil volume tanks, accumulators, and various other places where a liquid seal needs to be held automatically.

An interesting use of the float mechanism also is made on the condensed reflux from the stabilizer. Fig. 63 shows the hook-up. In operation, the more water that is circulated the more reflux is condensed. To control the volume of reflux condensed, the float is connected to a valve in the water circulating system through the condensers, then as the reflux is condensed, filling the accumulator, the float rises and pinches off the water, thus slowing up the condensation.

In like manner, the float on the still may operate the steam throttle of the oil pump carrying oil away from the still rather than operating the oil outlet valve.

Where air is available for the operation of motor valves it is common practice to use this auxiliary air supply on liquid level control valves such as is shown in Fig. 63-A. This allows the pilot controlled valve to be placed at any convenient place, which cannot be done with the mechanically connected valve shown in Fig. 61.

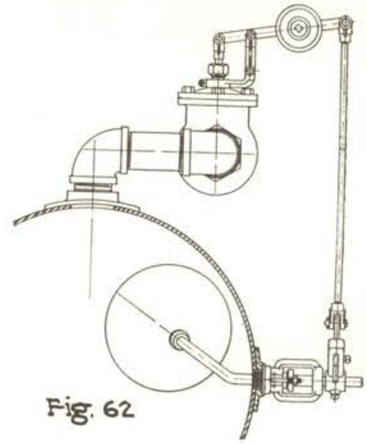


Fig. 62

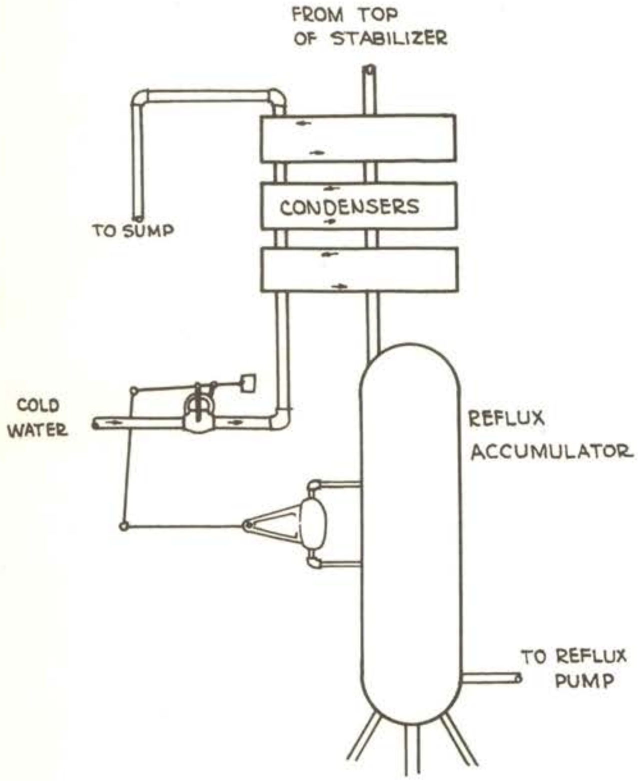



Fig. 63

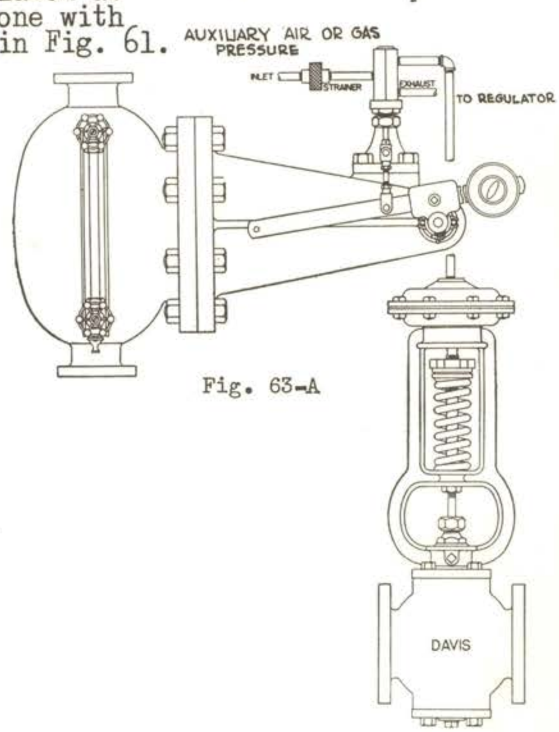



Fig. 63-A

Liquid volume control is essential in feeding the raw gasoline to the stabilizer. Gasoline is pumped into the stabilizer by the raw feed pump. The pump discharge is liable to vary due to a change in intake pressure, a change in steam pressure, or to the closing of a throttle valve due to vibration. Any of these changes will change the charging rate into the stabilizer and as it is adjusted to operate efficiently on an even charge it is best that an even flow be maintained, also, the charging rate may be set to take care of the production.

Flow control equipment as obtained on the market has proven efficient in many ways. One way it is accomplished is by inserting an orifice in the pump discharge line and the pressure differential used to operate a pilot throttle valve on the raw feed pump. The desired differential (indicating the volume being pumped) is set and any variation of the differential operates the throttle valves speeding up or slowing down the pump until the desired differential is reached. Fig. 64 shows a flow control installation.

3. Temperature Control:

One method of temperature control has been mentioned that of controlling the condenser temperature to condense reflux vapors. However, even more sensitive temperature control is desired in the still and "knock out" or dephlamator towers. The reason for this was explained previously, that the correct temperature must be maintained to vaporize all the gasoline hydrocarbons, then, in the dephlegmator to "knock down" or condense all the absorbing oil that has carried over from the still. The mechanics of the still and dephlegmator are taken up later.

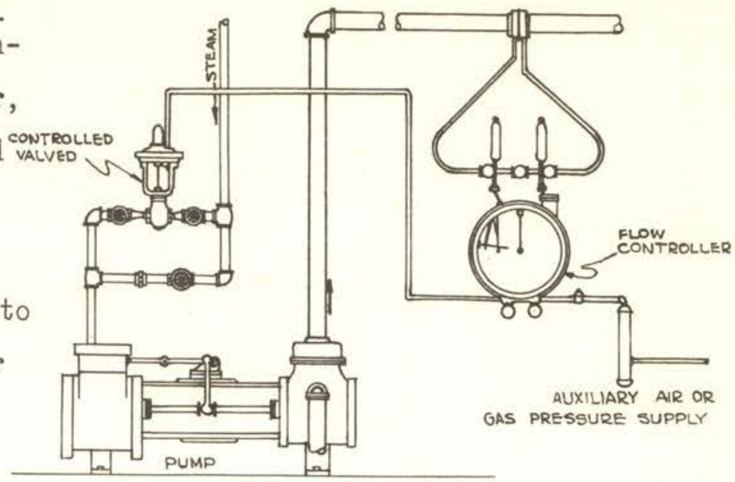


Fig. 64

The problem of holding the tube bundle or cooling portion of the dephlegmator at the exact temperature to separate the vapors can readily be seen to be of great importance. In one type of cooling medium, water is pumped through the cooler and the rate of flow is changed to hold the temperature constant. This rate of flow is controlled automatically by a recording temperature controller. Fig. 65 shows the hook-up.

Water is pumped through the knockout bundle, but the by-pass valve controls the volume. The temperature in the lower registers in the recorder-controller instrument which in turn operates the pilot valve to by-pass more or less water to hold the desired tower temperature. The control valve may be placed directly in the water line, controlling the volume directly. This is only one of various temperature controllers used.

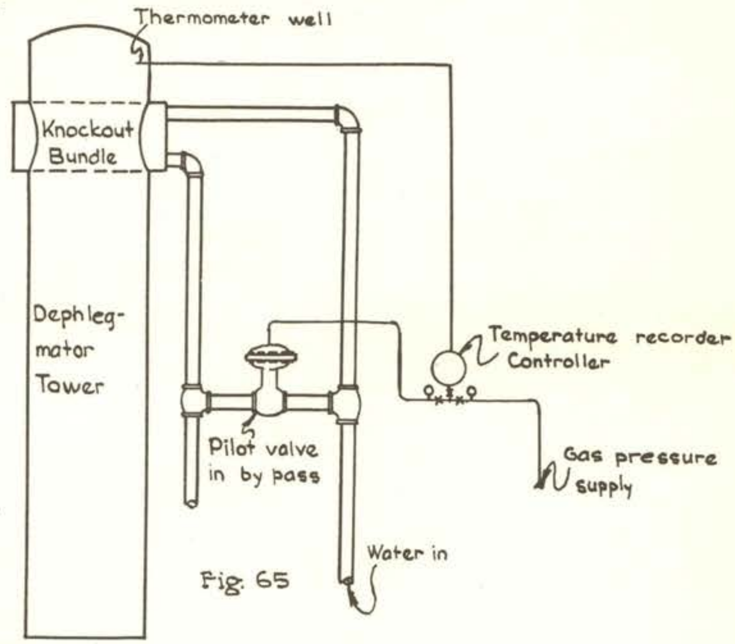


Fig. 65

One type of the temperature control apparatus operates by having a metal rod in the thermometer well. The changing temperature causes the rod to expand and contract. One end of the rod is fixed and the other end connected to the air leak mechanism, whose pressure operates the motor valve.

Temperature controls are used on the dephegmator tower, stabilizer kettle, certain refrigeration processes and other special places needing temperature control.

## UNIT IV

## DISTILLATION

1. The Absorber:

The function of the absorber is to bring enough contact between the wet gas and the absorbing oil so that all the soluble hydrocarbons of natural gasoline are absorbed in oil. This is accomplished by bubbling the gas up through the oil. The bubbling process might be done by bubbling up through a long column of oil, but with a large volume of gas, it would have a tendency to blow the oil on out of the absorber and the gas would course up through the oil and not get enough contact for efficient absorption. To spread the gas and oil and give the gas more than one contact with the oil, bubble trays are built in the absorber. Figs. 66 and 67 are outside views of an absorber and section showing bubble trays. The Fig. 68 shows a battery of absorbers and piping.

Each tray has a number of bubble caps. The cross section shows the construction of the caps. In operation the oil level is just above the caps, held there by the overflow down spout. Gas comes up through the tube inside the cap, passes down outside the tube inside the cap, through the oil and out of the cap and "bubbles" to the surface of the oil and on up to the next tray. Thus, if there are 10 trays in the absorber all the gas has to bubble through 10 layers of oil.

The gas travels up and the oil down and the rich gas at the bottom of the absorbers, first meets the oil that has already absorbed a good deal of the gasoline from the upper trays. The oil, however, still has absorbing capacity and picks up a good portion of the gasoline of the fresh or green gas. The oil then goes to the still with a "full load".

At the top of the absorber there is lean oil, ready to absorb any gasoline available in the gas. The gas has come up through a series of trays and most of the gasoline has already been absorbed out of it. Any yet in the gas is absorbed by the fresh oil entering the top tray. Thus, the counter flow of the oil and gas makes for greater efficiency.

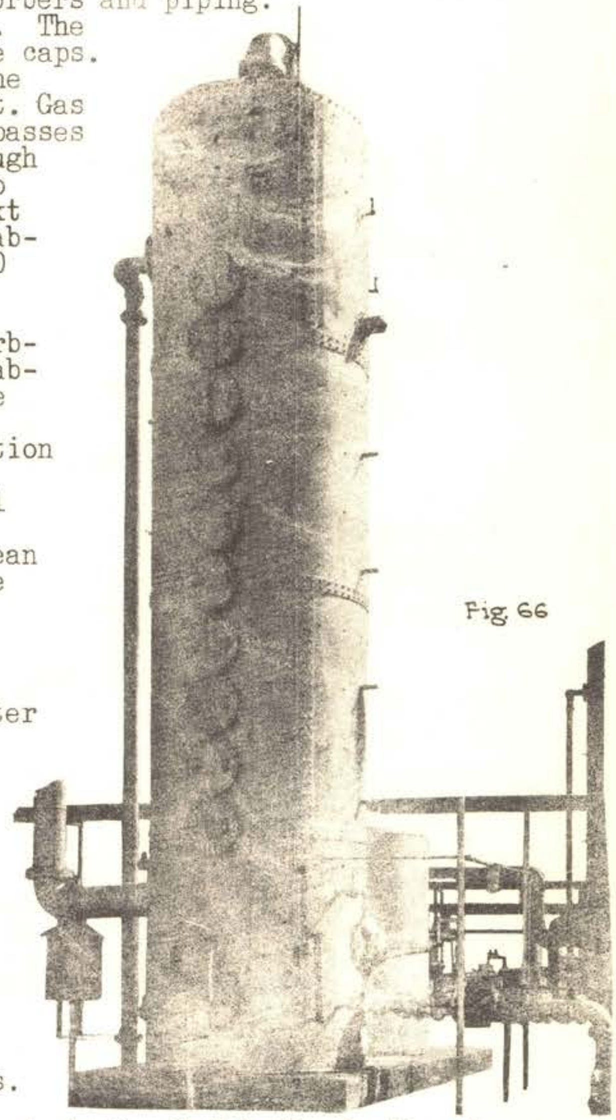


Fig. 66

The oil down spout between the trays, Fig. 67, ends at the lower tray in a cup, the rim of the cup is higher than the lower end of the spout thus making the oil flow outwards, and up, and over into the tray to make a liquid seal, thus preventing gas from passing up through the oil down spout. The liquid level in the spout arrangement stands higher, thus offering a greater resistance than the bubble cap level, and the gas takes the line of least resistance and goes through the bubble caps. This is only one type of absorber tray arrangement, the pressure used and the volume to be handled both of oil and gas controls the size and types to be used.

There are a number of factors effecting the efficiency of absorption:

a. The temperature of the oil and gas must be comparatively low, preferably not over 80°F. The temperature in the past has been secured by water cooling, both oil and gas being cooled in open or closed type coolers. Later

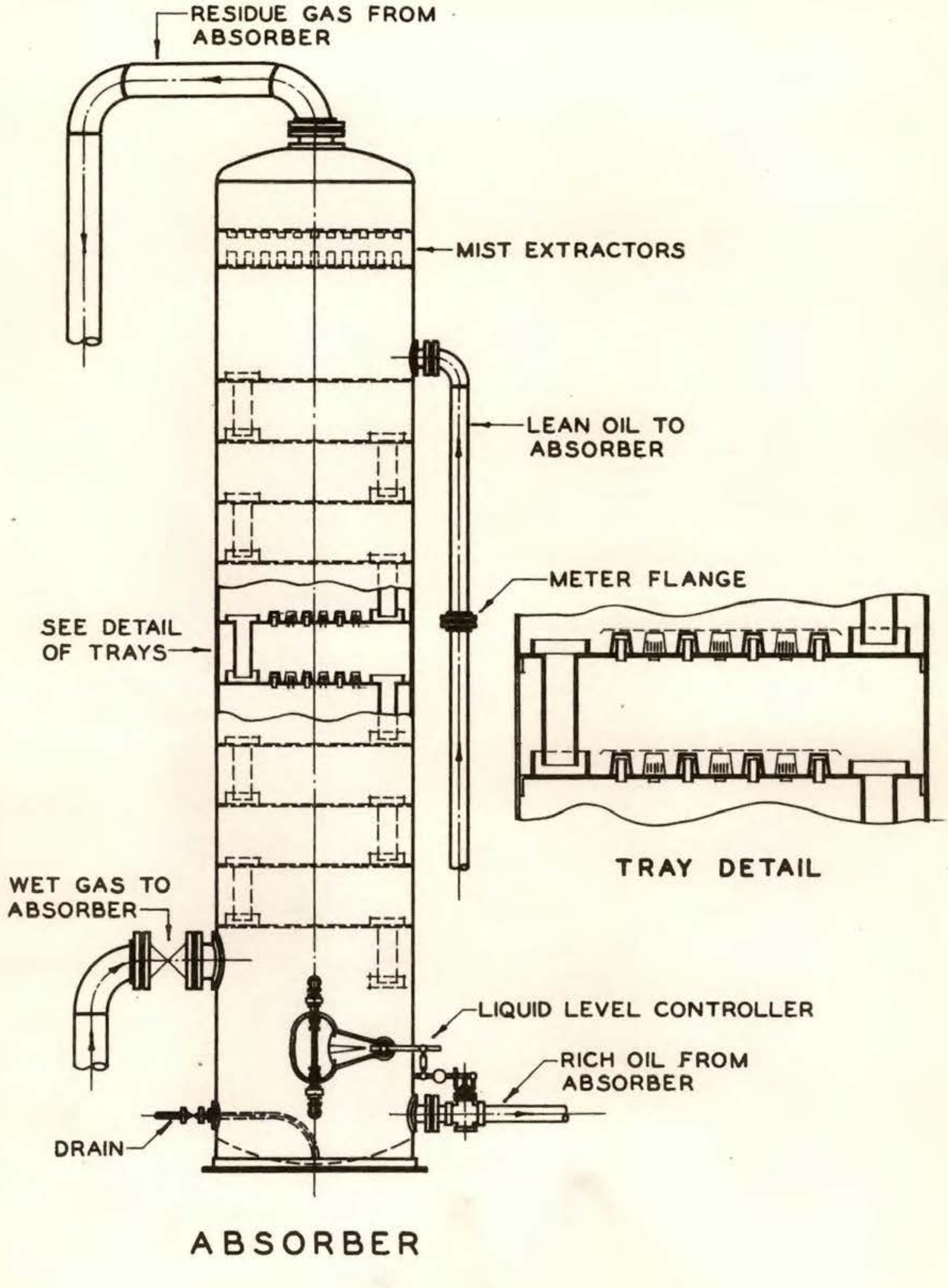

RESIDUE GAS FROM ABSORBER
MIST EXTRACTORS
LEAN OIL TO ABSORBER
METER FLANGE
SEE DETAIL OF TRAYS
TRAY DETAIL
WET GAS TO ABSORBER
LIQUID LEVEL CONTROLLER
RICH OIL FROM ABSORBER
DRAIN
ABSORBER

Fig. 67

installations include refrigerating units which are essentially the same as the water cooling closed coolers, but instead of the cooling medium being water, expanded propane or propane and butane are used. These refrigerating units are installed in the oil circuit either before the oil enters the absorber or in the absorber itself, three or four trays from the bottom. The absorbing efficiency is greatly increased by either of these methods as the oil absorbs better at low temperatures and the heat of absorption raises the temperature of the oil above an efficient point in traveling from top of absorber to the bottom. A temperature of 60° to 70° is obtained in the oil with refrigerating equipment, during summer months. To show the importance of cooling oil, a 10° decrease in oil temperature will permit a 20% decrease in oil circulation, maintaining the same absorption efficiency.

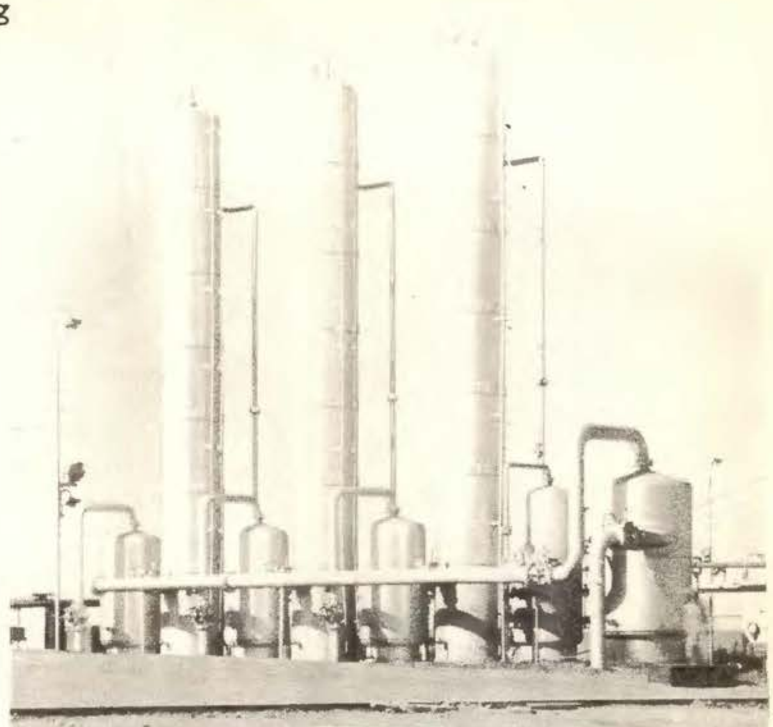


Fig. 68

b. The pressure carried on the absorber effects directly the absorption capacity of the oil. This is seen readily if we refer to the compression operation in which increased pressure increases the tendency to liquefy. For this reason the gallons per thousand cubic feet circulated may be decreased as the pressure is increased.

c. The efficiency of absorption is lessened if not enough oil is circulated. The oil ratio is the gallons of oil circulated through an absorber per one thousand feet of gas treated. The correct ratio of oil to circulate for the content of the gas and pressure carried may be solved by the chemist but he checks the operation by taking a content test of the residue gas. If this shows any gasoline, then an immediate check of absorber operation is made and the circulation increased as the most probable reason for its lessened efficiency.

d. The quality of the absorbing oil used is another factor. This falls in the hands of the chemist to a certain extent to determine the type of oil best suited to the gas being treated, the pressures carried, and type of equipment being used. The oils used range from kerosene to mineral seal oils. Once the oil is in the system it must be kept as free as possible from all foreign material. Crude oil from the gathering system may reduce the absorbing oils' efficiency to the point where it may have to be discarded. Dirt, rust, and water may be drained off occasionally at the flow and vent tanks and at the absorber. Even with these drains sludge collects in the oil and filters are installed in the oil line to continually filter a part of the oil. The best process of keeping clean oil is that of continuous distillation whereby a part of the oil is continuously stilled off, condensed, and put back in circulation. This keeps the oil clear and in good condition for absorption.

e. The number of plates in the absorber effects the contact between the oil and gas and directly effects the efficiency. The number of plates may vary from 8 to 22 depending on the pressure, circulation, and gasoline content of gas to be treated. These factors are considered in the installation. Low pressure absorbers run from 10 to 20 plates.

The economy of plant operation and the recovery efficiency depends upon the absorber operation. Selective absorption is the goal set, and to operate the absorber at the pressures, oil circulations, and temperatures which will absorb the desired portions is the problem.

2. Heat Exchangers:

One of the most economic inventions that has been made for the oil industry

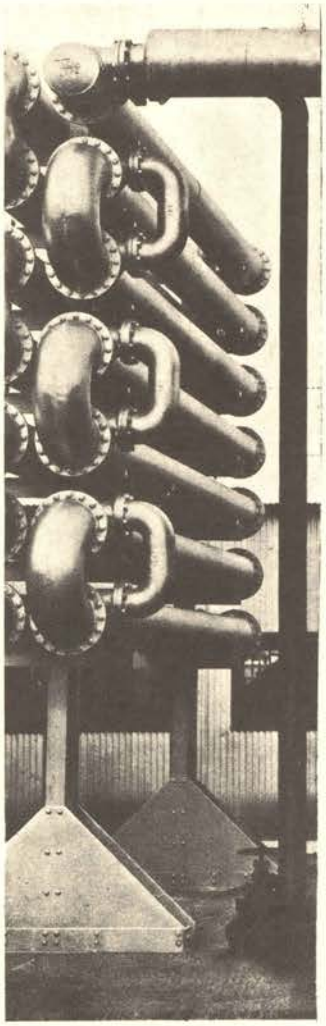


Fig. 69

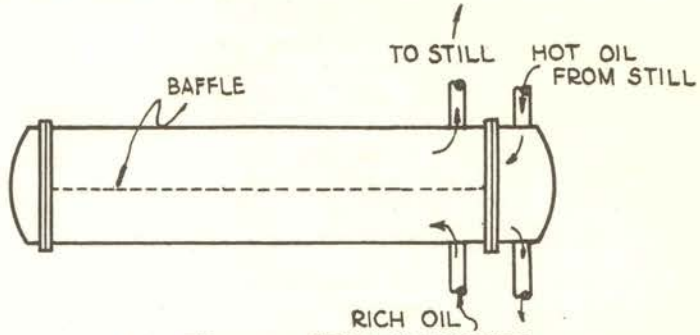



Fig. 70

is the heat exchanger. It is a simple operating piece of equipment that performs two operations in one, either operation performed independently would be expensive. The conditions calling for the use of the heat exchanger are: (1) a hot fluid needed to be cooled, and (2) a cool liquid needed to be heated.

In the distillation process two problems arise: (1) hot oil coming from the still, the temperature of which has to be reduced for efficient absorbing and (2) rich oil from the absorber, the temperature of which has to be raised to still or boil off the gasoline vapors.

To bring these two fluids together and let them exchange heat without mixing the two is the job of the heat exchanger. Fig. 69 shows a bank of heat exchangers. They are built with a large number of small diameter tubes inside similar to the cooler shown in Fig. 12. Fig. 70 is a diagramatic picture of the action of the heat exchanger. In order to get as complete an exchange as possible a number of exchangers are connected in a series. The results are that by the time the cool oil from the absorbers gets through the exchangers it nears the temperature of the hot oil coming from the still and the hot oil coming from the still and the hot oil leaving the exchangers nears the rich oil temperature coming in.

The saving made by the use of the exchanger can readily be seen if the hot oil had to be completely cooled by water or some other method and the rich oil had to be raised to the temperature required completely by steam.

To understand better the transfer of heat taking place the following oil temperatures are given. They were taken from one plant's exchangers:

Rich oil from absorber to Exchanger---102. from exchanger---265
Lean oil from still to Exchanger------326. from exchanger---155

The temperatures for oil to absorber show a marked decrease in newer plants, due to the use of a refrigerator.

3. Pre-heaters:

After the rich oil has left the exchangers, its temperature is not high as will be needed in the still so it is run through a preheater, which is constructed similar to this exchanger and cooler, but uses steam on one side of the tubes. This raises the oil temperature to the place that when the oil enters the still, the gasoline starts separating. Pre-heaters, also, are of various sizes and shapes.

The temperatures involved in the heat exchange and that obtained in the preheater are taken by means of thermometers in thermometer wells or in some cases the temperatures are recorded automatically on the still room temperature sheet. The temperatures are not the same on two different types of stills but sample records are obtained easily to learn what these temperatures run in the individual plants.

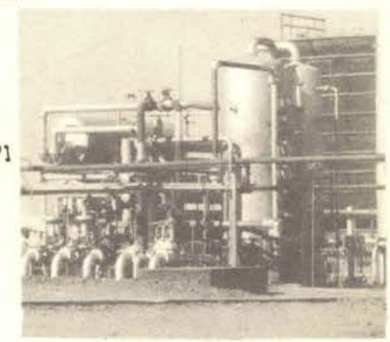
4. Oil Cooler:

The same condition exists in cooling the oil to the desired temperature after it leaves the exchangers as in heating it as it goes toward the still. To bring the oil temperature down farther it is cooled by water and in some installations with the butane refrigeration. When water is used it may be a similar cooler as the gas closed or open type cooler. Cool oil is essential in its absorbing efficiency. From the cooler the oil is pumped back over the absorber, thus completing the oil cycle except passing through the still.

5. Still:

The function of the still is to vaporize and separate the gasoline the oil has carried with it from the absorbers. This is done by raising the temperature of the oil above the vaporization point of gasoline, but below the vaporization point of the oil at whatever still pressure is carried. The process of steam distillation being the opposite of absorption, live steam is introduced at bottom of still to reduce the vapor pressure of the rich oil, increase the boiling surface, and thereby increase the efficiency of separation. Approximately 0.2 of a pound of steam per gallon of oil is required to efficiently strip the oil. This is at a still pressure of 40 lbs. At lower still pressures less steam volume and lower still temperature are required for same degree of efficiency. In the portion of the still where agitation goes on, trays are installed with bubble caps similar to the absorber caps and the fluids collecting and going down and vapors going up all assist in the separation process. There are a number of different stills being manufactured and some carry features others do not, their function is all the same. One still has steam coils built in that act as a reheater, another has the still and knockout built in one tower. Fig. 71 shows the installation of stills, dephlegmators, and piping.

Fig.71



Efficient still operation requires the complete stripping of all gasoline from the oil. This is understandable when we think of the use of the oil at the absorber. It is there to take up or absorb gasoline, if it has any gasoline in it, not removed in the still then its function is greatly impaired.

The still construction of one type is shown in Fig. 72. The gasoline vapors rise and go out the top to the knockout (reflux or dephlegmator) tower.

6. Dephlegmator:

The knockout tower was not shown in the sketch, Fig. 21, being considered part of the stilling operation. In operation the gasoline vapors from the still carry over oil vapors with it. In other words, it is impossible to boil off the gasoline vapors without some of the oil vapors being boiled off, too. To separate these carried over oil vapors is the function of the dephlegmator. To accomplish this a cooling medium is introduced in the dephlegmator tower and the temperature of the vapors so regulated (mentioned under temperature control for the pressure carried) that the oil molecules are condensed or knocked out of the gasoline vapor. The end point of the gasoline (see specification) is controlled by the top temperature of the dephlegmator. More is given concerning the end point under laboratory testing. Water vapor in the form of steam also comes over with the gasoline and oil vapors and the water also is condensed and knocked down in the tower. The gasoline vapors pass on out to the condensers.

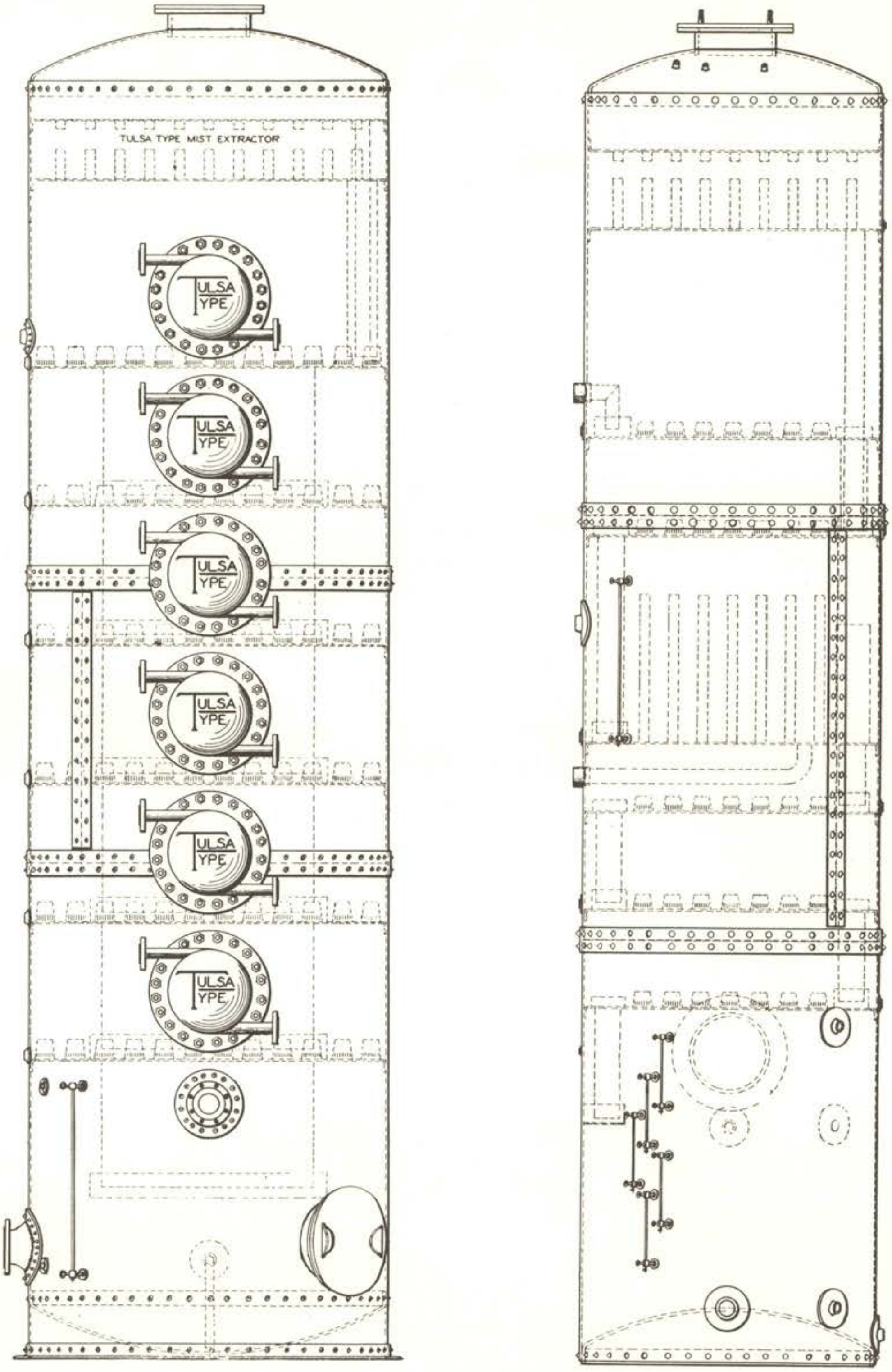

TULSA TYPE MIST EXTRACTOR
TULSA TYPE
TULSA TYPE
TULSA TYPE
TULSA TYPE
TULSA TYPE
TULSA TYPE

Fig. 72-A

The oil knocked down in this tower is called reflux or rundown and the tower is sometimes called a reflux tower, Fig. 72-A. The reflux is returned to the still in the lower tray by ejectors. On installation where the dephlegmator is above the still this distillation is continuous and this reflux or rundown disappears in the process.

The water and oil both fall to the bottom of the dephlegmator tower and water being heavier settles to the bottom and is drawn off there by means of a trap, Fig. 73, or liquid level controls whose floats are of such weight that water will float it but oil will not. In the same way the oil is trapped off. These traps are of various types and installations. In the combination type referred to above the water is drawn off at the water tray. Water excess goes back to boiler or cooling tower and balance is cooled and recirculated.

Fig. 73

7. <u>Oil Circulating Pumps</u>:

In all the discussion up to now little has been said about the motivating force to keep the absorbing oil in motion. So far the only places any pressure has been mentioned as being applied to the oil is in the absorber where the gas pressure forces it out, and in the still. The pressure supplied in either of these, in the lower pressure plants is not sufficient to force the oil through the route it takes. From high pressure absorbers it is sufficient.

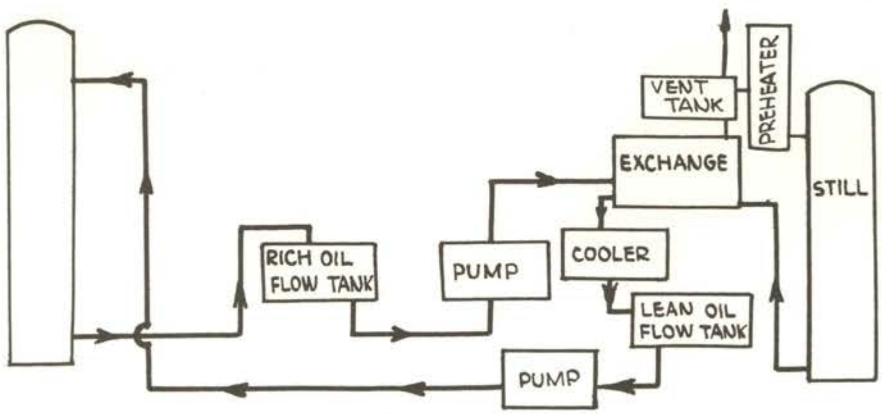



Fig. 74

To supply the circulating force, oil pumps are used, one or more for the lean oil forcing it into the absorber and one or more to pump the rich oil through the exchangers and into the still. In order to keep an evenly regulated flow of oil in these two circuits flow tanks or vent tanks are installed so that there is always oil for the intake of the pump. Fig. 74 shows the arrangement. The liquid level controls keep the tank levels well above the intakes of the pumps. The location of these tanks with regard to the equipment is not always as shown, the lean oil tank may be between the cooler and exchanger, etc. In some installations with good fluid control equipment the lean oil tank may be omitted.

The pumps used are of both the reciprocating and centrifugal types, steam gas and motor driven. The discharge of the pumps has to be kept the same. This is done by various automatic control devices, such as the liquid level control on the still controlling the pump throttle as mentioned under automatic control devices. In this case the speed of the other pump is the controlling speed. The oil circulated is regulated according to the gallons per thousand cubic feet required. The circulation is recorded on a chart of an orifice meter installation or other fluid volume recording device.

It is essential that oil circulation be kept constant and not stopped for when it stops production stops. For this reason stand-by pumps are installed so that repairs and adjustments can be made without interfering with production. This, also, is true of the pumps circulating cooling water for the knockout and the oil cooler.

Often the pump and distillation equipment is enclosed in a building. Needless to say that flammable vapors are quite likely to be present. A special warning is here given to be cautious of anything that might cause a spark or open flame in such a building. Fire fighting equipment in the way of steam snuff lines, fog nozzles, and foam and carbon dioxide extinguishers are made available and each man in the plant should know the operation of this equipment for any emergency. Fig. 75 shows a plant yard and a good portion of the equipment mentioned in this book. Note the extinguisher.

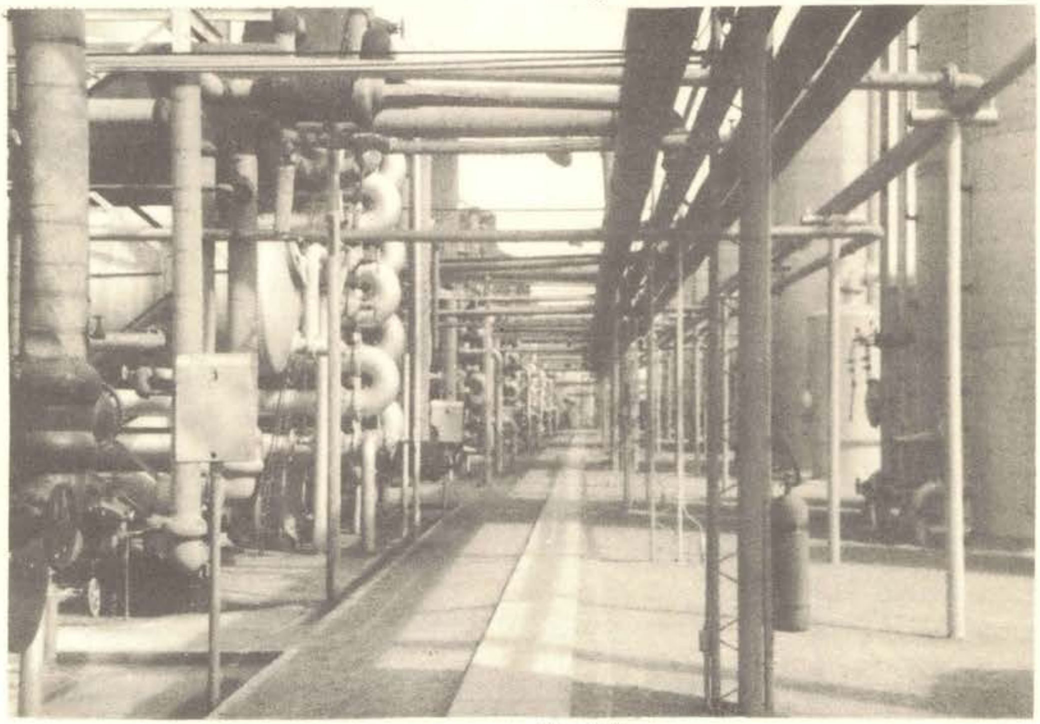


Fig. 75

8. Gasoline Condenser and Accumulator:

Fig. 76 is the condenser and water leg. The condenser may be the open or closed type and may use expanded butane instead of water for cooling. The liquid seal is held with a liquid level control as shown here or trap.

The recompressor is a small compression plant and the gasoline obtained is run into the raw make. The recompression product is made and blended with plant make for the stabilizer charge stock. This blending is done under pressure either in the charge line or in a pressure tank. The percentage of recompressor gasoline in the charge stock runs 15 to 40. The variations are due to (1) gravity desired in the raw make, (2) make tank pressure, and according to (3) amount or proportion of light hydrocarbon content of gas being treated, and (4) recompression pressure and temperature.

The vapor from the recompressor accumulator contains certain desirable hydrocarbons which can be extracted and saved by the use of a tail absorber. These tail gases or vapors from the recompressor run through the conventional type absorber built for the pressure to be used (higher pressure necessary to hold the lighter ends).

When the volume of these vapors is not great they are piped back into the plant intake gas line. In this way the heavier hydrocarbons are reabsorbed and saved, the lighter going on into the residue fuel.

The recompressor instead of acting as a compression plant may have its discharge piped direct to one of the trays in the plant stabilizer where the heavier and lighter hydrocarbons are separated as required.

The gasoline from the water leg or separator is piped to raw storage tanks or may be piped to a surge or flow tank and pumped directly to the stabilizer. The purpose of the surge tank is similar to that of the oil flow tanks in that it always keeps a fluid head on the intake of the pump. In the case of raw gasoline it also prevents "gasing up" of the intake. Gasing up is a term used to describe the condition in a pipe or vessel where the fluid it carries has vaporized. When this happens at the intake of a fluid pump, the pump receives gas only and as it will not pump gas it ceases to function. Fig. 77 shows such a surge tank installation. Pressure is held on the tank and such vapors as form are piped in with the storage and accumulator tank vapors.

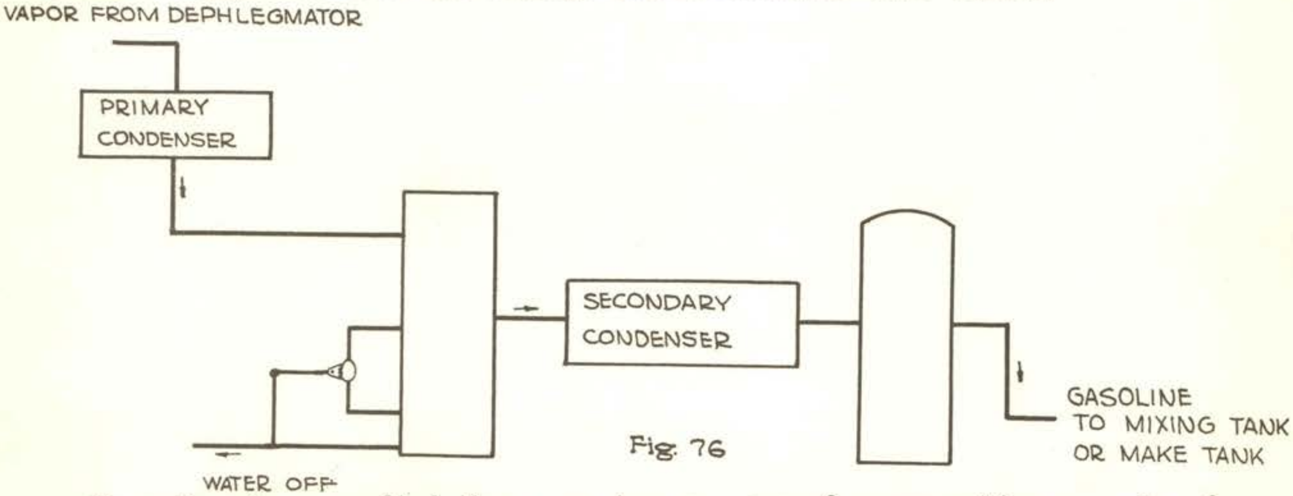


Fig. 76

From the above we find there are two sources of raw gasoline, namely, from the still condenser and the recompressor accumulator. In plants treating very rich gas a third source, mentioned elsewhere, furnishes as much as 50 per cent of the raw make and that is at the coolers and accumulators on the discharge of the compressors. These may be named: (1) condensate at coolers, (2) make tank, and (3) recompressor. Another source is drip gasoline.

9. <u>Accessories</u>:

To make a complete list of the distillation accessories is impossible as new patented devices are coming on all the time and many "kinks" are installed in the individual plants. The piping system itself is a problem in each installation and seldom are there two installed alike. Individual sketches of certain piping sections have been shown purposely because it is nearly impossible to show all the piping in one picture. The piping arrangement can best be traced in the plant itself.

Other accessories such as automatic control equipment has already been described. Gauge glasses are installed on all equipment carrying liquid levels to observe by sight. Pop relief valves are installed on the still, the flow tank (if under pressure) and other vessels with pressure.

Steam meters are installed on the steam line to still to measure the amount of steam being used. Oil meters are on the circulating lines to check circulation. The oil meter usually has a column of differentials with gallons per hour or day posted opposite so the operator can change or set his circulation to the desired rate.

An installation of stilling equipment is shown in Fig. 78.

Pressure gauges are used on all pressure vessels and sometimes in addition to the recording pressure gauges and meters as a check. Pressure gauges should be removed and tested periodically and report made of their condition.

Drips or tanks occasionally are installed on the floor drain under oil pumps and stills to catch and save oil that leaks or escapes during repair. Fig. 79 shows such a hook-up with pressure line to drip to blow oil into tank and drain for water and sludge. The operation of the valves when in service and blowing the drip may be easily worked out.

Ladders, walkways, lights, and guard rails all are accessories necessary for safe operation and each plant presents its own problems. Steam and hot oil lines are insulated to conserve heat and act as safe guards to prevent burns. It is suggested as an additional safeguard that exhaust lines also be insulated where contact is liable to be made even though exhaust steam lines are not generally insulated.

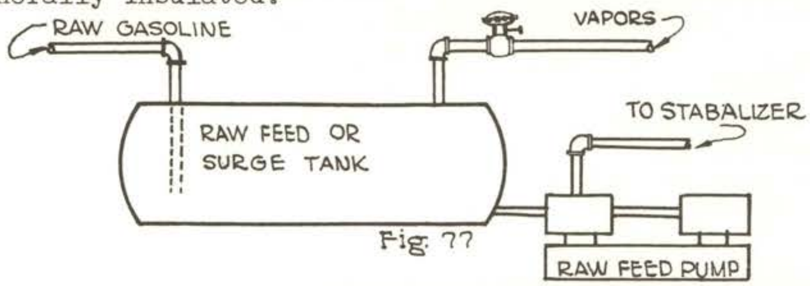



Fig. 77

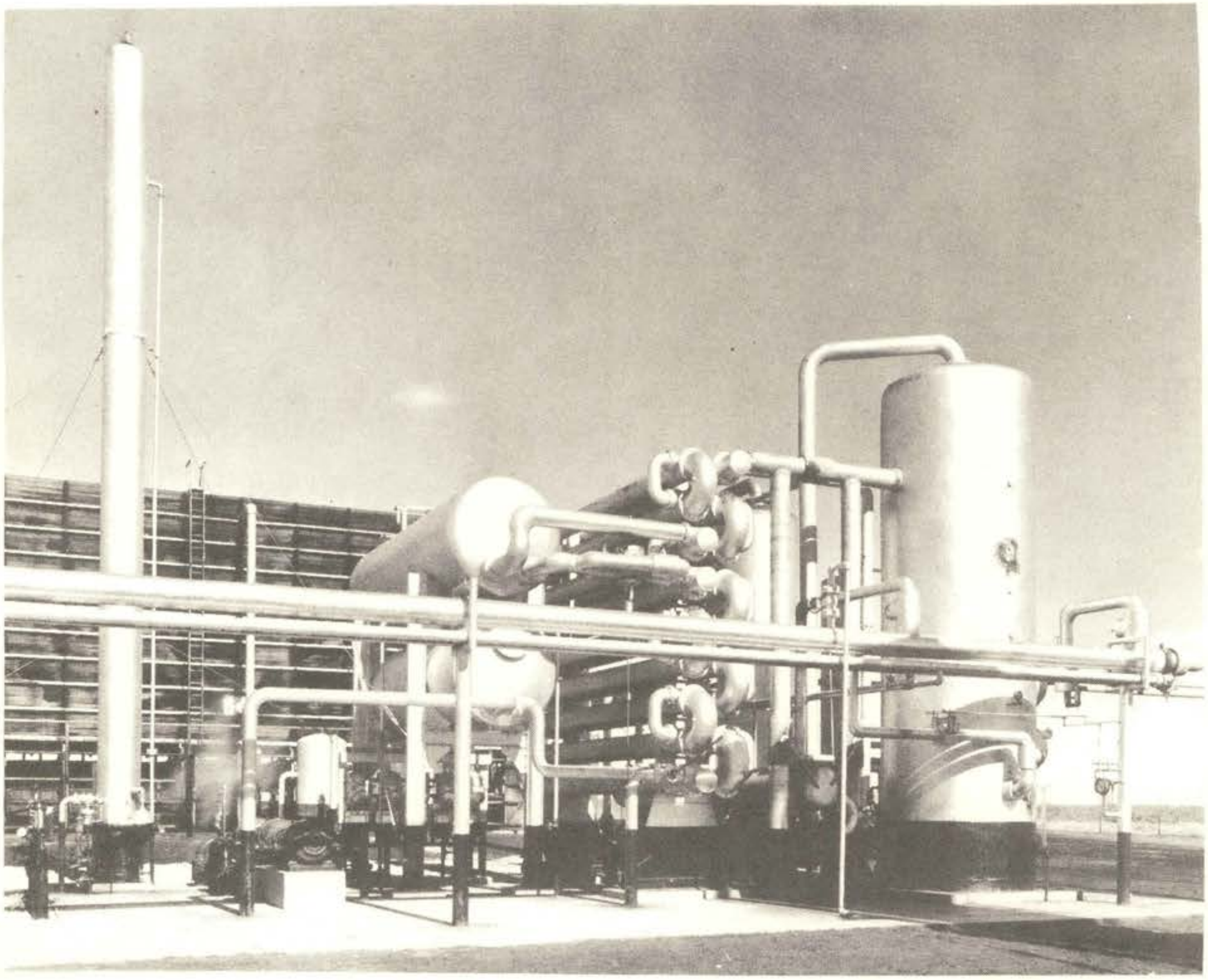


Fig. 78

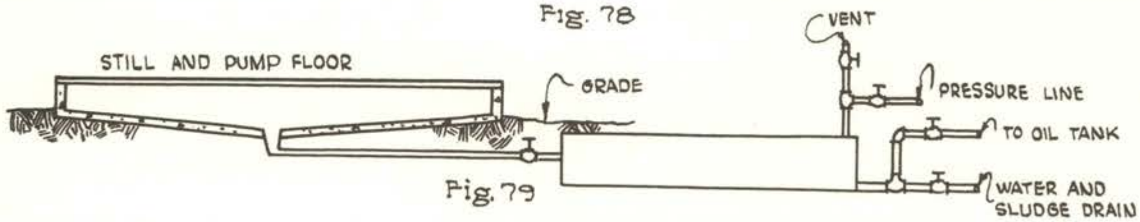



Fig. 79

# UNIT V

## BOILER AND STEAM SUPPLY

Steam power and steam pumps are taken up in detail in another text of this series and recommended for those in charge of the boilers and pumping equipment. Only a brief picture is given in this chapter.

1. Uses of Steam:

Already the use of steam for the distillation process, for the pumps, and for heating valves to prevent freezing has been mentioned. The main use of course is in distillation, and steam is the only heat used so far in the stabilizing process. The following list gives the various uses of steam in the gasoline plant including the above.

1. Distillation
2. Stabilization
3. Steam pumps
4. Steam turbines (driving pumps and generators)
5. Steam air compressors
6. Heat in offices and buildings in winter
7. Valve jackets
8. Thawing frozen lines
9. Steam snuff lines for fire
10. Steaming oil and vapors out of pipe and tanks for safe welding
11. Vapor pressure bomb bath
12. Washing rags.

The first four are constant uses. Some of the pumps such as the loading pump are intermittant. Numbers six and seven are constant during freezing weather. The rest are intermittent. There are other uses of steam that can be brought out in class discussion.

2. Steam Boiler Construction:

When water is heated in a boiler, it expands until it finally vaporizes. If there is sufficient space in the boiler, the steam will occupy about 1700 times as much space as was occupied by the water from which it was vaporized. In other words, a cubic inch of water at atmospheric pressure will vaporize into approximately one cubic foot of steam.

In a closed vessel such as a boiler, however, the space into which the steam may expand is limited. Consequently, after the space is filled with steam, further evaporation of water causes the pressure to go up. The amount of pressure rise is in inverse proportion to the amount of space the steam occupies. If the steam vaporized into one cubic foot of space, water is forced to occupy a space equal to one-half cubic foot, its pressure will be doubled.

In other words, the more water evaporated into steam within a given space, the higher will be the steam pressure. If 1000 cubic feet of steam is held within a space of 100 cubic feet, the pressure will be ten times atmospheric pressure or approximately 150 pounds to the square inch.

3. The Locomotive Type Boiler:

The locomotive or fire-box type boiler is by far the most commonly used boiler in the oil industry. It is frequently referred to as an oil country boiler. Its principal claims to superiority are its low first cost, its portability, accessibility for repairs, and the fact that comparatively little skill is required to operate it. A locomotive type boiler, less fittings, is shown in Fig. 80.

4. Fire-Tube and Water-Tube Boilers:

Anyone who is fairly familiar with boilers has heard the expressions "fire-tube" and "water-tube" boilers. If the hot gases pass through the flues and

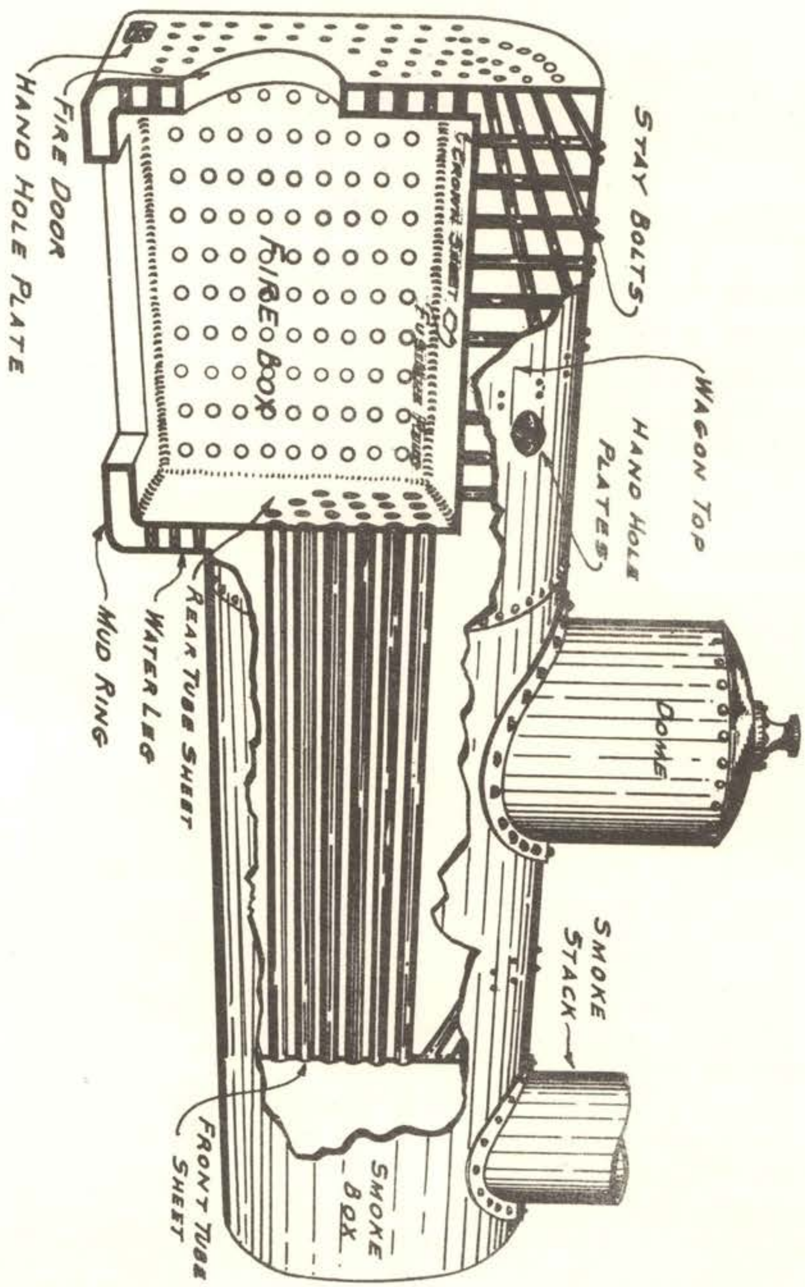

STAY BOLTS
WAGON TOP
HAND HOLE PLATES
DOME
SMOKE STACK
SMOKE BOX
FRONT TUBE SHEET
REAR TUBE SHEET
WATER LEG
MUD RING
FIRE DOOR
HAND HOLE PLATE
FIRE BOX

Fig. 80

the water is on the outside of them, the boiler is referred to as a fire-tube boiler. The boilers previously described are of the fire-tube type.

In the water-tube boilers the water is contained within the tubes, and the fire is on the outside. Water-tube boilers are manufactured in comparatively large sizes and are of the stationary type, requiring considerable brick work to encase them. They possess a high rate of evaporation, and are capable of being forced beyond their rated capacity without danger of serious damage. Also, the explosion hazards are less with these boilers than with fire-tube boilers. The construction of a water-tube boiler is illustrated in Fig. 81.

5. The Rate of Evaporation:

The rate at which a boiler will evaporate water into steam determines its capacity. An engine operating with a given steam pressure requires a certain number of pounds of steam per hour, and the boiler which supplies it must be capable of producing steam fast enough to insure the required volume and pressure at all times.

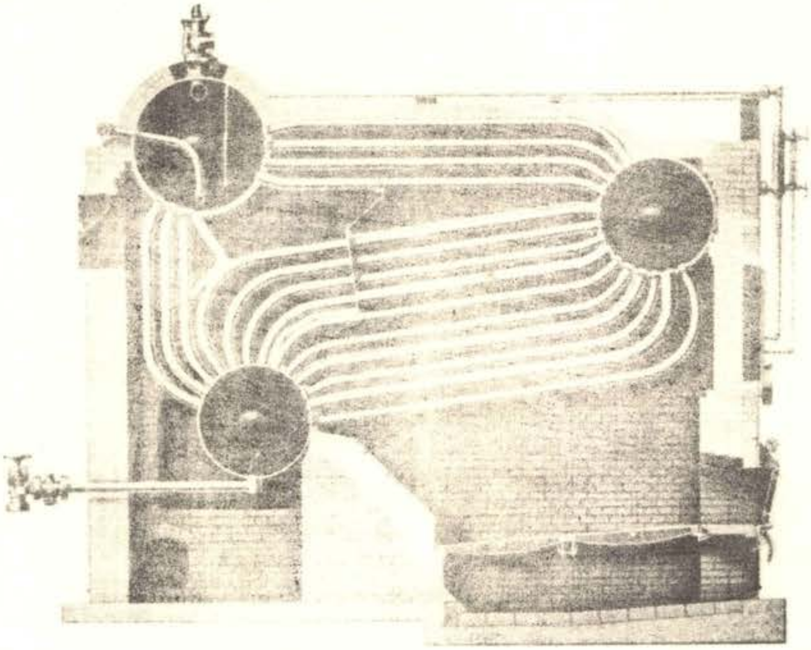


Fig. 81 --Type H Stirling Water-tube Boiler

There are several factors which determine the rate of evaporation, for example, the rate of combustion of the fuel, the design of the fire box, the amount of heating surface, the temperature and the feed water, and the setting and insulation of the boiler. Another factor worthy of mention here is the amount of scale and soot which the operator allows to accumulate on the boiler surfaces, and which tends to retard the conduction of the heat of combustion to the water within the boiler. This is a factor dependent upon the human element and beyond the power of the designer to control.

6. Heating Surface:

When specifications of a boiler are given, the number of square feet of heating surface is always given. By square feet of heating surface is meant the number of square feet of boiler surface exposed to the products of combustion, such as the surfaces of the tubes, the firebox sheets, and the tube sheets.

In calculating the heating surface of tubes, the outside surfaces are taken for tubes of water-tube boilers, and the inside surfaces for tubes of fire-tube boilers. Hence, a tube of a water-tube boiler presents considerably more heating surface than the same size tube in a fire-tube boiler. All boiler tubes, whether for water-tube or fire-tube boilers, are sized according to the outside diameter.

7. Water Space and Steam Space:

The water space of a boiler is the space occupied by the water, and the steam space is the space above the water line. These spaces vary slightly, of course, according to the height of the water carried in the boiler. The water level must always be a little above the top row of tubes or the highest heating surface, such as the crown sheet in a locomotive type boiler. A fire tube boiler requires a large volume of water as compared with the water carried in water-tube boilers.

8. Horse Power Rating of Boilers:

Since steam engines are rated in terms of horse power, it is logical that boilers should have a similar rating. When boiler horse power is spoken of, it simply means that the boiler has the capacity to supply an engine of that rating with steam. If the boiler is to supply steam for auxiliaries, such as pumps, ejectors, or heaters their demands for steam must be taken into account. It is always a good policy to select a boiler with a horse-power rating considerably above the combined horse-power ratings of the engines and accessories it is to drive, so as to provide for overloads and future installations.

Manufacturers sometimes calculate boiler horse power according to the number of square feet of heating surface, a heating surface of from 10 to 12 square feet being considered as the equivalent of one horse power. The American Petroleum Institute standard for locomotive type boilers calls for 10 square feet of heating surface per boiler horse power. This method of rating is very convenient and offers a basis on which boilers of different manufacturers may be readily compared. For this purpose, it is sufficiently accurate.

To arrive at a more accurate horse-power rating of a boiler, other factors beside heating surface should be considered. The standard adopted by the American Society of Mechanical Engineers is based on actual rather than theoretical capacity to produce steam. By this standard 34½ pounds of water must be evaporated per hour for each horse power from a feed water temperature of 212°F. into dry steam at the same temperature.

9. The Shell:

Boiler shells are rolled from flat steel plates into cylindrical shape, and joined at the edges by riveted joints. The steel from which boiler shells are rolled is known commercially as "boiler plate". It is made specifically for this service according to definite standards of physical properties which have been established by the American Society of Mechanical Engineers. Shells vary in thickness according to size, design, and the working pressure the boiler is expected to carry.

Next to a sphere, a cylinder offers greater resistance to rupture from internal pressure than any other shape of vessel. Since steam and water pressure is transmitted equally in all directions, a boiler would tend to become cylindrical even if it were constructed in a rectangular shape.

Fig. 82 illustrates the construction of a boiler shell for a return tubular boiler. It will be noted that there are three sections joined by rivets, and that the longitudinal seams of the sections are not in line, but are staggered. This is done purposely to add strength to the boiler.

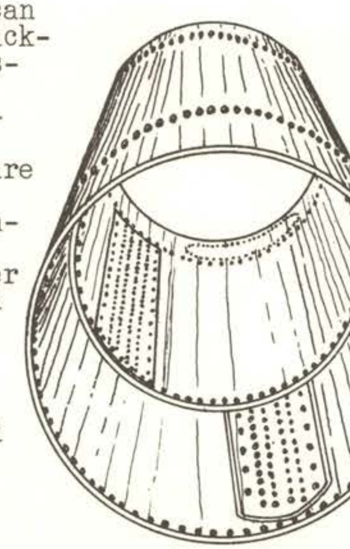


Fig. 82 --The Shell

Boiler tubes are made of seamless or lap-welded tubing which is accurately finished to outside diameter and thickness. Standard sizes range from 1" to 13" in diameter. The diameter of a boiler tube always refers to its outside diameter regardless of whether it is to be used in a fire-tube or water-tube boiler. Tube thickness is designated by Birmingham Wire Gauge sizes, which stand for certain fractional parts of an inch. Thus, when we speak of 11 gauge, we mean a thickness of .12" or slightly less than 1/8".

The most common sizes of tubes found in boilers used in the oil industry range in size from 2" diameter and 13 gauge to 4" and 10 gauge. A very large majority of field boilers use 3" flues with thicknesses ranging from 12 gauge to 9 gauge, 11 gauge being the choice of most manufacturers. Thicknesses vary according to the pressure for which the boiler is recommended and are selected from A. S. M. E. tables. Some manufacturers, in order to offer a higher factor of safety, use tubes one gauge thicker than are specified in the tables.

10. Tube Sheets:

At each end of a boiler is a tube sheet drilled to admit the ends of the tubes. (See Fig. 83) After being put in place, the tube ends are expanded by means of a tube expander to make a water and steam tight joint with the plate. The tube ends, which extend a little beyond the tube sheet, are thin and beaded-over to give additional strength to the joint.

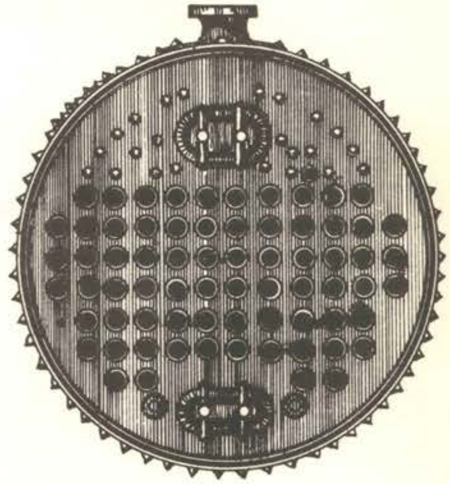


Fig. 83 --Tube Sheet of Return Tubular Boiler Showing Manhole Plates and Staybolt Ends

11. The Crown Sheet:

The crown sheet is the sheet that forms the top of the fire box in a locomotive type boiler. It must always be kept covered with water or a disastrous explosion may result. Since it is exposed to the direct rays of the fire, it will overheat very rapidly when uncovered, with a consequent weakening of the plate. Even if the plate does not rupture and cause an explosion, it will become "bagged" or warped, and the staybolts which support it will be strained so that leaks will appear around their ends. It is because of the very great danger that exists when the water level gets below the top of the crown sheet that new operators are admonished "never to let the water get below the crown sheet".

12. Fusible Plugs:

In order to guard against the dangers incident to low water, crown sheets are equipped with fusible plugs, commonly known as "safety plugs" or "soft plugs" These plugs are hollow shells, filled with block tin and threaded to screw into a tapped hole in the crown sheet of locomotive type boilers or at a point in the rear head of horizontal, return tubular boilers at least one inch above the top row of tubes. Water tube boilers of the B. & W. type have fusible plugs located in the upper drum and in such a position that the products of combustion will come in contact with them on their first pass. Three types of plugs are shown in the accompanying illustration, Fig. 84.


Fig. 84 --Fusible Plugs

Since tin melts at about 450°F., the safety plug will open up at this temperature, and the steam in the boiler will blow out into the fire box to extinguish the fire before the crown sheet is unduly over-heated. The blowing of a safety plug almost invariably indicates poor operation. It should remind the operator that he has exposed himself and the equipment to an unnecessary hazard.

Fusible plugs often undergo a change in use, and sometimes fail to melt at ordinary operating temperatures, thereby causing disastrous accidents. For this reason, it is imperative that these plugs be renewed at least once a year. Some authorities advocate the renewal of fusible plugs every time the boiler is cleaned.

The cost of the plugs, and the labor necessary to install them are trivial compared with the possible loss of life and property damage caused by boiler explosions.

13. Manholes and Handholes:

Boilers always are constructed with manhole and handhole openings to provide for inspection and cleaning. These openings are oval shaped and are closed by means of manhole plates, handhole plates, and suitable gaskets. Manhole and handhole plates are similar in construction, and the only important difference is in their size.

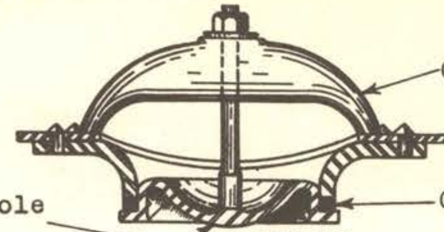


Fig. 85

Manhole and handhole plates are held in place against the inside of the boiler shell by means of bolts and crowfeet yokes which span the openings on the outside, Fig. 85.

Manhole openings usually are 11" x 15" and are located in the shell above the tubes. This opening is large enough to admit the average-size man. And 3½" x 4½" is the average size for handhole openings. Most locomotive type boilers have ten handhole openings - - four at the bottom corners of the water legs, one at the bottom of the front tube sheet, one in the front head just above the crown sheet, and two on each side of the wagon top slightly above the crown sheet.

14. Staybolts and Braces:

Referring back to Fig. 80, it will be noted that all flat surfaces are reinforced by means of staybolts or braces. Tube sheets are supported by the tubes which act as stays. But above and below the tubes some means of bracing is necessary. The sheets of the fire box, including the crown sheet, would be sure to buckle unless they were tied to the shell. Fig. 86 illustrates the common method of reinforcing these sheets.

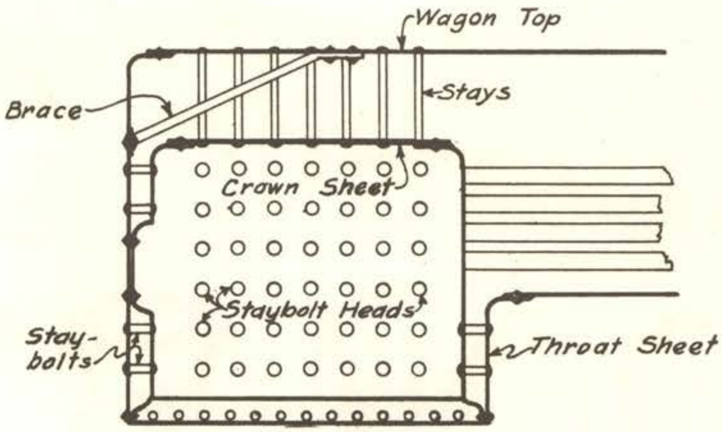


Fig. 86

15. Steam Domes:

The purpose of the steam dome is to increase the steam space and to afford a space high above the water line for dry steam to collect. This dry steam is taken from the steam dome by the main steam line to the engine. The dome may be located on the barrel or directly over the crown sheet. The latter construction conforms to the Canadian practice. Its advocates claim that this construction makes for drier steam and reduces the tendency of the water to pull over under heavy loads. Since 1927, the A. S. M. E. code has permitted domes over the crown sheet to be made with a diameter of 80 per cent of the barrel diameter. Most manufacturers seem to favor this construction for oil country boilers, although some makers still place the dome on the barrel. In either case braces must be employed.

16. Boiler Settings:

Fig. 87 shows a recommended setting for locomotive type boilers. A. P. I.

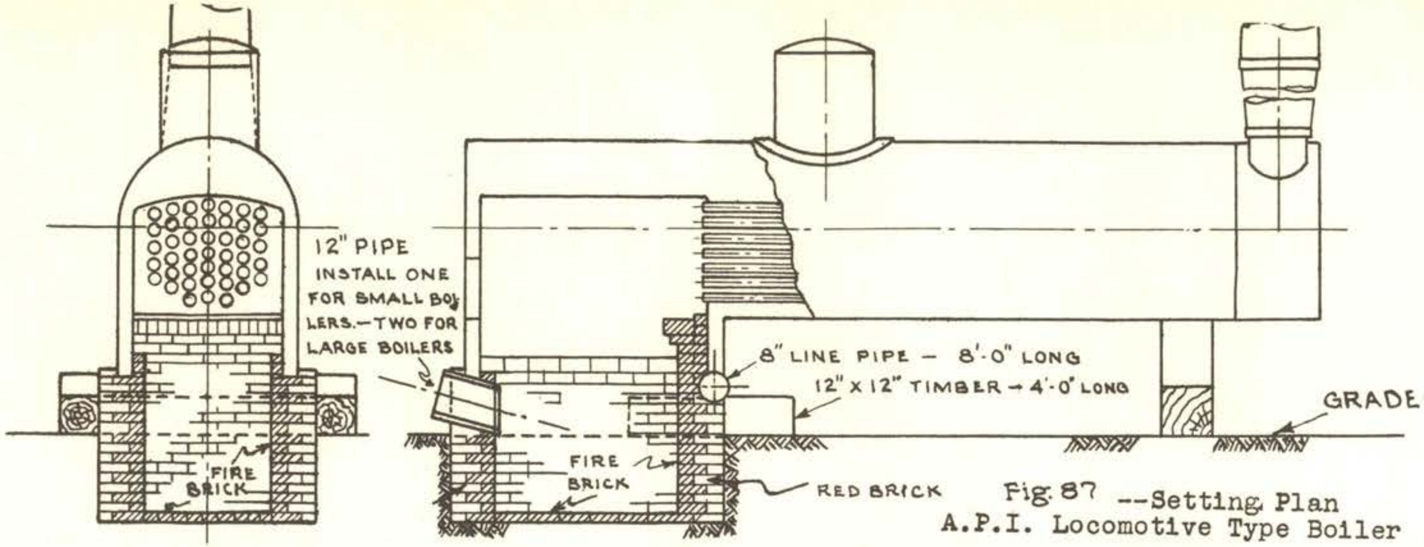



Fig. 87 --Setting Plan
A.P.I. Locomotive Type Boiler

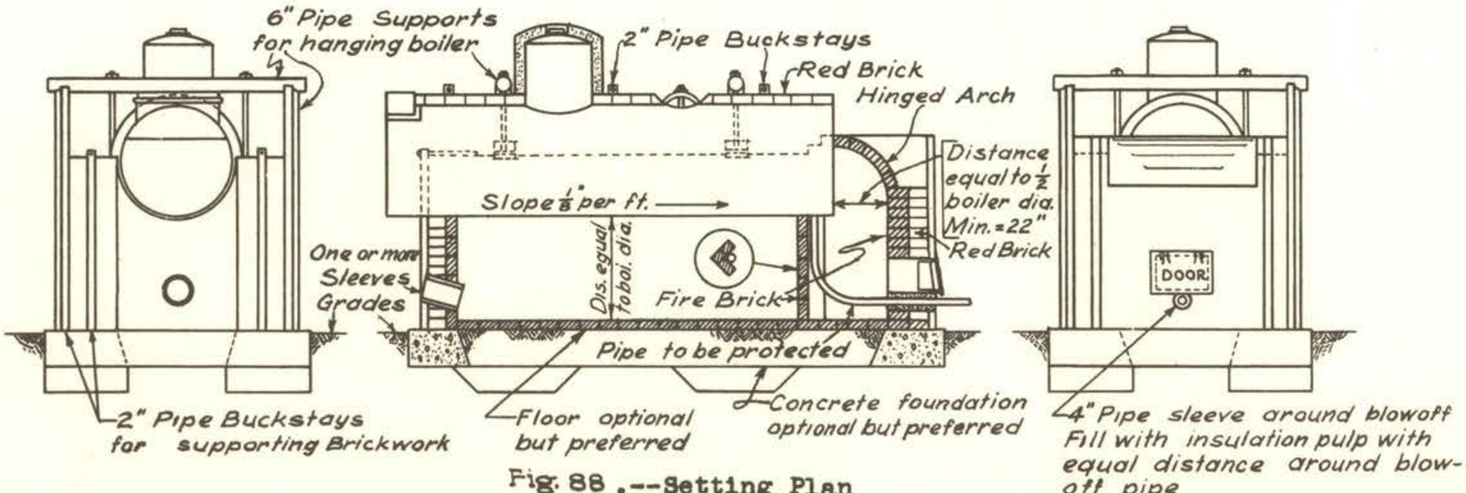



Fig. 88 .--Setting Plan
A.P.I. Return Tubular Boiler

specifications* call for supports under the mud ring below the throat sheet, and under the barrel just back of the smoke box. Note that a piece of 8" pipe resting on wood timbers is used for the support, and that brick is used to encase the combustion chamber. The construction of the brick work will be influenced somewhat by the type burner used. In any case the combustion chamber should be air tight, and air for combustion should enter at the burner opening only.

The A. P. I. Setting plan for return tubular boilers is shown in Fig. 88. This is the suspension type of setting which is recommended by most engineers and manufacturers. Note that none of the load is supported from the side walls which form the fire box. All brick work must be air tight to insure a good draft.

In setting a boiler outdoors care should be used to place it so that the fire door will not open toward the prevailing winds. If this precaution is ignored, the steaming capacity may be reduced greatly.

17. Putting Boilers into Service:

Before the boiler is put into service, all scale, oil, and other foreign matter should be removed and the manhole and handhole gaskets inspected. If it appears that these gaskets may leak, new ones should be put in.

In filling the boiler with water, open a valve above the normal water line, such as the top gauge cock, or remove the pop valve or other fitting to permit the escape of air. Otherwise, the entrapped air will be compressed, and when its pressure becomes equal to that of the water pressure, the flow of water will be stopped. Water should be admitted until it shows from one-third to one-half way up in the gauge glass.

Operators frequently make the mistake of firing a cold boiler too fast in order to bring up steam in a hurry. A hot fire will raise the temperature of the parts closest to it quite rapidly, while remote parts of the boiler, exposed to the combustible gases, will remain comparatively cool. These differences in temperature cause an uneven expansion of the plates and tubes. Leaks at seams and rivets and at the tube ends are the inevitable consequence of uneven expansion. A slow fire should be burned under a cold boiler for at least three hours before a full fire is turned on.

18. Cutting Boilers in on Line:

Too much emphasis cannot be placed upon the necessity for properly cutting boilers into service. If steam is suddenly cut into a cold line, some of it will condense. The condensate will be driven ahead with great force, causing what is commonly known as water hammer. When the water reaches a closed valve, water hammer puts a tremendous strain on valves and fittings. Water hammer is sure to cause leaky joints and may rupture the line.

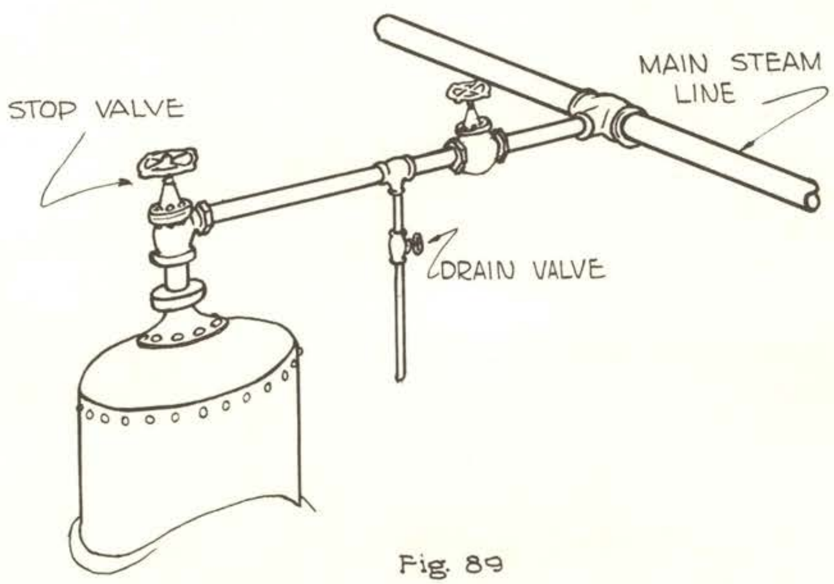



Fig. 89



* Consult A. P. I. Standards, 11-a, "Specifications for Oil Field Boilers"; also, A. P. I. Code No. 2, "Recommended Field Practice, Oil Field Boilers"; and A. P. I. Poster No. 6, "Installation and Operation of Oil Field Boilers"; obtainable from American Petroleum Institute, 1508 Gulf States Bldg., Dallas, Texas.

Boilers should be connected to the main steam line by two stop valves with a drain valve between them (see Fig. 89). When ready to cut the boiler into the line, the drain valve should be opened wide and the stop valve next to the line opened gradually to permit any condensate that may be in the line to drain out. Then the valve next to the boiler may be opened slowly to permit the line to warm up. It should be opened about one turn at a time with about three minutes between openings. If water hammer is heard, the valve should be closed promptly and left closed until the noise ceases. Then opening of the valve may be started over again.

When a boiler is to be placed on the line with others of a battery already in service, its steam pressure should be exactly equal to the pressure of the other boilers before its stop valve is opened. Boiler explosions have been caused by unequal pressure in boilers when they were being connected.

Stop-check valves, often referred to as non-return valves, offer a very safe means of connecting a battery of boilers to the main steam line. With one of these valves installed next to each boiler, it is a simple matter to not flow through the check valve until the boiler pressure equals the line pressure, the valve handwheel may be opened wide when the boiler pressure gets to within ten pounds of the line pressure. Then, when the field pressure of the main line is reached, the boiler will be automatically connected.

Another great advantage of the stop-check valve, Fig. 90, from the standpoint of safety, is the impossibility of steam from the main line passing through this valve into an empty boiler if the valve is opened by mistake. This eliminates the danger of scalding men who may be at work in empty boilers. Furthermore, in case a tube should blow out or othe other accident happen to suddenly reduce the pressure in the boiler, the valve would close automatically and prevent the back-flow of steam from the main line.

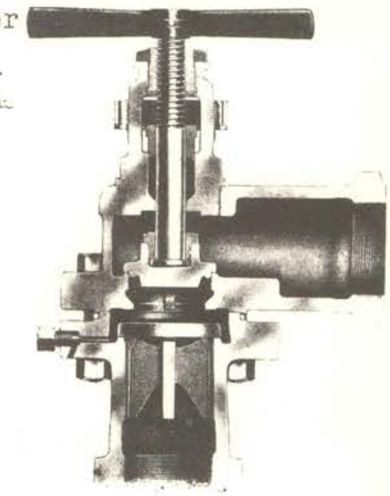


Fig. 90

19. Feed Water:

Feed water should be admitted to boilers at a sufficient rate to maintain a fairly constant water level. Intermittent feeding, by which the water level is permitted to drop near the bottom of the gauge glass and then brought up rapidly by pumping in water, is not only hard on the boiler, but causes fluctuations in the steam pressure. When the boiler attendant learns the rate at which his boilers use water, he can adjust the regulating valves in the feed lines so that they will seldom have to be changed unless there is a change in the demands for steam from the boilers. Automatic feed-water regulators are the best means of obtaining a uniform feed, but all boilers are not provided with them.

The water level should be tested several times daily by opening the gauge cocks. This gives a check on the level in the gauge glass and keeps the gauge cocks in operating condition. If they are not opened occasionally, they become stopped with scale. If water disappears from the gauge glass and does not show at the bottom gauge cock, cut the boiler off the line, put out the fire, and open the fire door. Do not under any circumstances turn on the feed water, and leave the safety valve alone. When the boiler has thoroughly cooled, water may be added and the fire put back under it.

20. Cleaning:

If a boiler is to be shut down for cleaning, and it is desired to cool it rapidly, close the stop valve in the steam line and fill with water until the gauge glass is full. Next cut off the fire and open the fire door and smoke-box door so that air will circulate through the fire box or furnace. After the boiler begins to cool, blow down one gauge of water at a time, and replace with fresh water. When the pressure drops below ten pounds, the blow-off valve may be opened wide to let all of the water run out.

Cleaning should proceed immediately after the water has run out and before the scale has had time to harden. The first step is to remove the manhole and handhole plates and lock the main steam valve and feed-water valve in the closed position to guard against having them opened while a man is at work in the boiler. If considerable quantities of scale and mud have collected at the bottom of the boiler, a hoe or shovel should be used to remove it instead of washing it out through the blow-off valve. The entire inside of the boiler should then be washed with a hose.

Water-tube boilers require much more time to clean than do fire-tube boilers. The reason is that thorough cleaning calls for washing out each tube individually. After the tubes have all been opened up, washing should start with the top row.

21. Scale Removal:

When scale has collected on the tubes to a thickness of one-sixteenth of an inch or more, it should be removed by a mechanical means. Light blows with a hammer will jar most of the scale off, and some of it may be removed by scraping. These are slow tedious processes, and the tubes of water-tube boilers are so close together that it is difficult to get to them.

Mechanical tube cleaners offer the easiest method of removing scale from tubes. Types of cleaners for both fire-tube and water-tube boilers are shown in Figs. 91 and 92. The only difference in the two cleaners is in the shape of the hammer. The hammer for water-tubes has cutting edges to chip the scale.

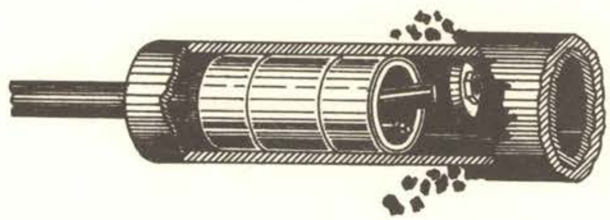


Fig. 91 --Removing Scale from a Tube of a Fire-Tube Boiler

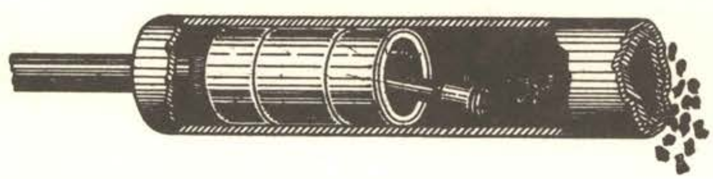


Fig. 92 --Removing Scale from a Tube of a Water-Tube Boiler

The mechanical tube cleaner consists of a cylindrical body made to fit loose in the tube. Inside the body is a piston, which drives the hammer. Steam or air is supplied to the cylinder through a flexible hose and pipe. A small slide valve admits the air or steam to opposite ends of the piston. The hammer is moved at a rapid rate and strikes from 3500 to 10,000 light blows per minute on the walls of the tube. This causes the tube to vibrate and loosen the brittle scale.

In using a mechanical tube cleaner, just enough pressure to loosen the scale should be used. High pressures may cause the hammer to strike blows heavy enough to injure the tubes.

Scrapers and brushes for cleaning soot from the inside of fire-tube boilers are illustrated in Fig. 93. These tools are screwed on rods or pieces of pipe and pushed through tubes. They are adjustable for different size tubes.

Regular use of flue scrapers and brushes will add much to the efficiency of boilers by permitting a better transfer of heat from the fire to the water in the boiler. Generally speaking, flues should be cleaned once each eight hours, but this will vary with the fuel being used and the completeness of the combustion.

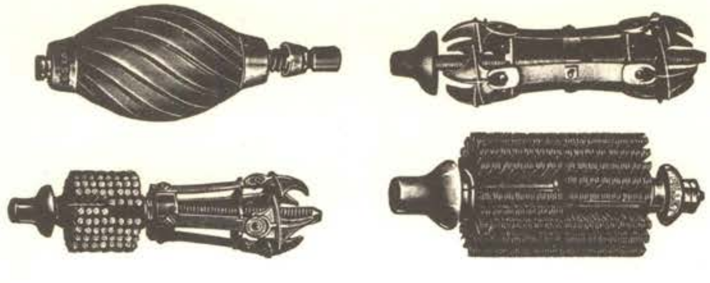


Fig. 93 --Scrapers and Brushes for Cleaning Soot from Inside of Fire-tube Boilers

22. Feed Water and Treatment:

All natural waters, whether taken from lakes or streams on the surface of the earth or pumped from deep wells, contain impurities such as calcium and magnesium salts. Previously, these impurities have been referred to as scale forming elements. Such water is commonly known as "hard water". The degree of hardness of a water depends upon the amount of calcium carbonate (limestone), or its equivalent, which it contains. It is usually expressed as so many grains per gallon.

Four methods of softening boiler feed-water are in use. They are distillation, the cold lime-soda process, the hot lime-soda process and the zeolite process. Distillation is an expensive process and is rarely used.

23. The Lime-Soda Process:

In the cold lime-soda process, lime and soda ash are added to a tank of hard water, and the whole solution is thoroughly agitated by means of paddles or a circulating pump. About four hours is allowed for the precipitated sludge to settle to the bottom of the tank before the water is used. The sludge must be drawn off before the next charging.

It is customary to use two tanks so that one can be charged and left for settling while the softened water is being drawn off the other one.

24. The Hot Lime-Soda Process:

The hot lime-soda process is very similar to the cold lime-soda process except that it is carried out at temperatures approximating the boiling point. The hot water speeds up the reaction and results in a greater degree of softening. The apparatus, however, is more complicated than that required in the cold process.

25. The Zeolite Process:

The zeolite process has gained widespread use because of its simplicity and the comparatively little skill required of operators of the equipment. The softening agent is a flinty, porous mineral resembling coarse sand, and known as zeolite. Zeolite is found naturally in some parts of the country, and may be manufactured by fusing together sand, soda, kaoline, and feldspar.

When raw, hard water is passed through a bed of zeolite, the hardness is removed by absorbing the calcium and magnesium salts, and replacing them with sodium salts. The latter are not scale forming and, therefore, do no harm. The water softening capacity of the zeolite is limited, but it may be "regenerated" and made active again by passing a common salt solution through it.

An understanding of the operation of a typical zeolite softener can be had by reference to Fig. 94. In the lefthand tank, a bed of zeolite rests on a gravel bed. Raw water enters at the top and filters down through the zeolite and gravel to the bottom of the tank. In its passage through the zeolite, the chemical change previously described has taken place, and it is ready to be piped to the boiler. The function of the gravel bed is to remove any substance which may be held in suspension.

When the zeolite begins to lose its water softening properties, it must be cleaned and regenerated. Cleaning is accomplished by admitting water at the bottom and forcing it up through the zeolite bed for a few minutes. A drain valve

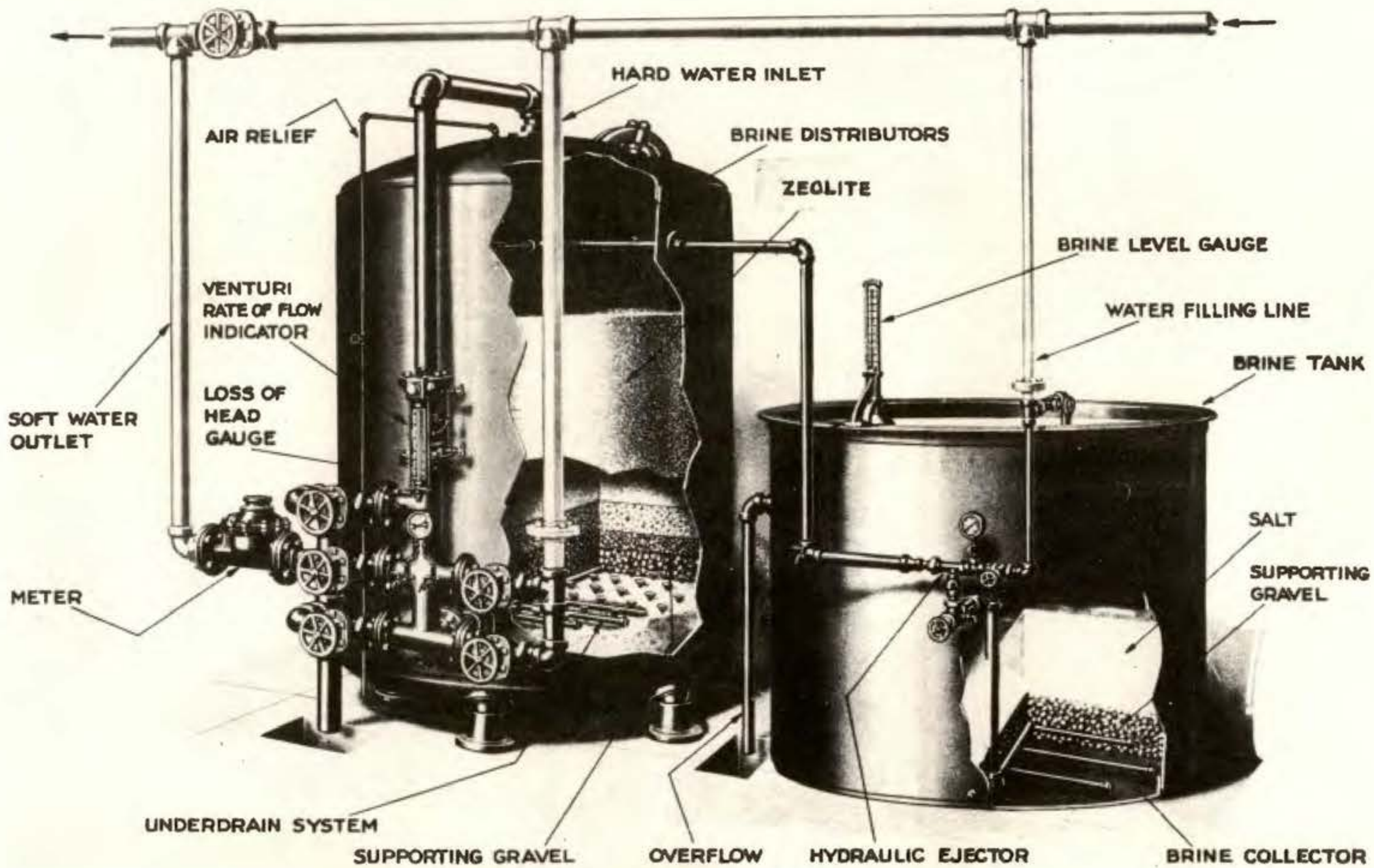



Fig. 94 --Zeolite Water Softening Apparatus

is then opened at the bottom to permit all water to drain off.

To regenerate the zeolite, a measured quantity of common salt brine is pumped from the brine tank at the right, into the zeolite tank where it is allowed to remain for several hours. The brine is then drained off, and the filter beds thoroughly flushed with clean water. After this, the apparatus is ready to be put back into service.

In practice it is customary to have two zeolite tanks. While one is in service, the other can be cleaned and regenerated.

26. Boiler Compounds:

Boiler compounds are chemical reagents which are fed into the boiler with the feed water when it does not seem feasible to install water softening equipment. Some boiler compounds, like soda ash and caustic soda, combine chemically with the scale forming substances and form a sludge which collects at the bottom of the boiler. The collected sludge can be blown off. Other compounds, such as the gelatinous compounds of tannin, depend upon mechanical action. They have the property of forming a protective coating on the metal of the boiler to prevent the formation of scale. It is also claimed that they will penetrate scale which has already formed and cause it to drop off, so that it can be blown off.

The use of boiler compounds is, at best, a poor substitute for water softening apparatus. The place to remove the scale forming solids is outside the boiler. Using boiler compounds simply makes a water softener out of the boiler, causing sludge to collect at the bottom of the boiler where it will cause trouble if it is not regularly blown off.

Some soft water testing zero hardness in the usual hard water tests has caustic in it and sets up a chemical action in the boiler called caustic embrittlement. No scale is formed but the rivets, in particular, are weakened to the place that they fall out with the tap of the boiler inspector's hammer. This water condition is remedied by the addition in the boiler feed water reagents or compounds that will prevent the embrittlement taking place. The tests for the amount and kind of reagents is left to the chemist. It is then essential that the compound be added regularly by the fireman as instructed.

27. Fuel:

Gas is the universal fuel used in gasoline plants. The burning of gas to get maximum heat value from it consists of getting a good mixture of air and gas


Fig 95

at the burner. This is accomplished by various type burners. Most of these burners of late construction use low pressure gas. Some of the older type burners used higher pressure - - 20 to 50 lbs. - - and depended on the gas stream to form a jet that would pull sufficient air in for combustion. Home-made burners made in the field are used this way. It was found that most of these high pressure burners were not getting good combustion and used more gas. Further the heat had a tendency to concentrate in one portion of the fire box and burn out the sheets or tubes.

With lower pressure burners a better mixture for combustion and a more even spread of heat in the fire box are obtained. Fig. 95 shows some of the different type burners in use for natural gas. Most modern burners are built to fire with gases with different B. T. U. content. This happens in the gasoline plant when residue is short and it is desired to burn the stabilizer vapors. Care has to be used with these vapors that they do not condense before entering the burner. To prevent condensation, a preheater on the vapor line is used or the vapor line may be run through part of the flue to heat the gases.

The main fuel header supplying the boilers should have a block valve at a reasonable distance from the boilers or outside the boiler house to cut off the fires in case of an emergency. One plant has these block valves in two or three places, strategically located about the plant yard. This is particularly desirable if there is a break in gas or gasoline lines that would permit vapor or gases to blow towards the boiler house. One hook-up on this outside gate automatically opens steam snuff lines into the fire boxes when the fuel is cut off.

28. Pop Safety Valves:

If steam is generated in a boiler faster than it is consumed, the pressure will continue to build up. If some means were not provided to release steam when the pressure exceeded the point of safety, an explosion would be the inevitable result. For this reason, it is imperative that every boiler be equipped with a safety valve.

Pop valves are so-called because they open suddenly with a popping noise. Instead of a weight, a coil spring is used to hold the valve on its seat. Adjustment of popping pressure is made by changing the pressure on the spring. Under the present code in Oklahoma this spring pressure is set and sealed by the manufacturer only. A bad valve must be returned for adjustment. Never tamper with the seal.

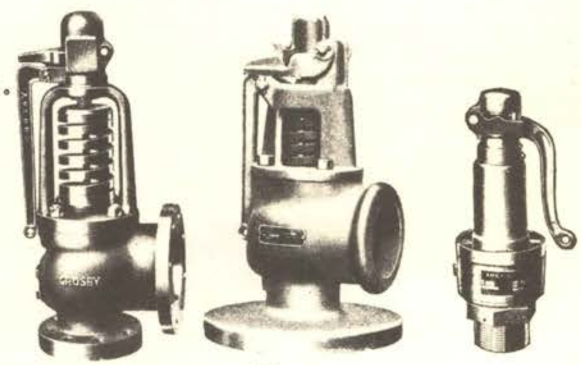


Fig. 96

Fig. 96 shows three common types of pop valves. Note that the spring is exposed on some types, while on others it is enclosed.

All pop valves are provided with a lever by means of which the valve may be lifted from its seat for testing and to blow out dirt which has accumulated. A chain or wire should be attached to the lever so that the boiler attendant may open the valve from the ground.

At least once a week a pop valve should be made to pop automatically bringing the boiler pressure up to the popping point. The fireman should observe the steam gauge carefully and note the exact pressure at which the valve opens and whether or not it cuts off promptly when the excess pressure has been relieved. If the valve chatters on its seat or if it leaks after popping, the condition should be reported promptly to someone who is authorized to make adjustments and repairs.

Safety valves should be mounted in a vertical position and as close to the boiler as possible. All unnecessary fittings should be omitted. In no case should a valve be placed between the safety valve and the boiler.

When the boiler is housed in a building, the pop valve should be provided with a discharge pipe installed as shown in Fig. 97.

The discharge pipe should be of ample size, and its weight carried from above instead of on the pop valve.

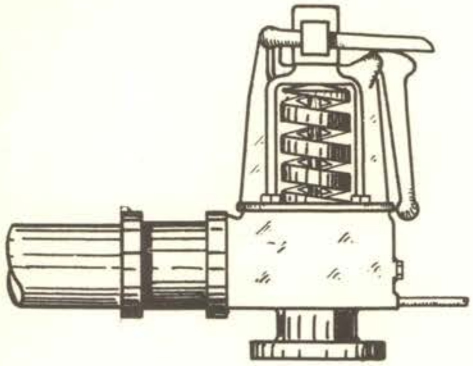


Fig. 97 --Safety Valve Showing Proper Installation of Outlet Pipe

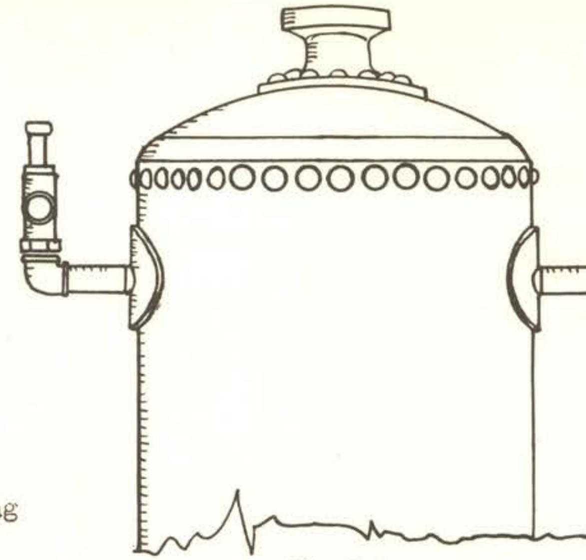


Fig. 98

Boilers of 50 h.p. or more should be equipped separately, as shown in Fig. 98, or on a Y fitting.

In either case the connection to the boiler should be independent of any other steam outlet.

29. Feed-Water Regulators:

Feed-water regulators are devices for automatically controlling the flow of feed water to boilers. Some types maintain a constant water level in the boiler for all load conditions. Others permit a considerable variation in the water level as the demands for steam change. When a sudden load comes on the boiler, the water level is permitted to fall below the normal level. On the other hand, when very little steam is being used, water will be fed in above the normal level. This type of control is known as differential pressure regulation.

Fig. 99 illustrates the installation of a Copes feed-water regulator, a type

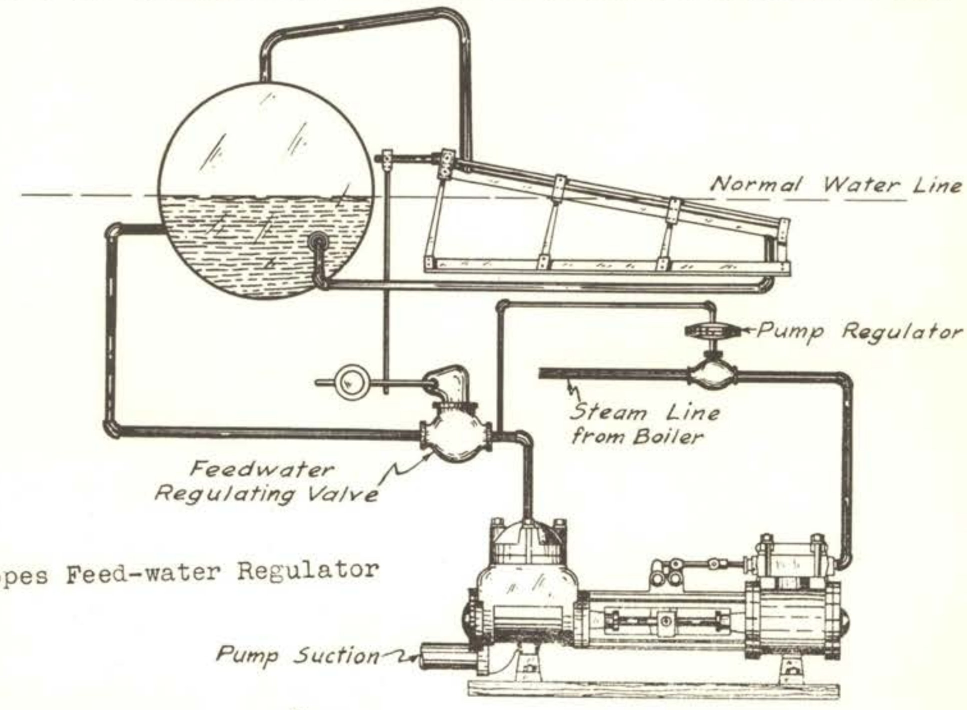



Fig. 99 --Copes Feed-water Regulator

which is widely used in the oil industry. The inclined thermostatic expansion tube is located on a frame work outside the boiler. The upper end of this tube is connected to the steam space of the boiler, and the lower end is connected to the water space. Water stands at the same level in the tube as in the boiler. The lower end of the tube is filled with water up to the boiler's water level. The space above the water is occupied by steam.

Radiation of the piping cools the water in the tube; consequently, its temperature is considerably lower than the steam above it. The tube expands and contracts with differences in temperature. Obviously, the more of the tube exposed to steam, the greater will be its expansion; and, conversely, the more water in the tube, the cooler it will become and the shorter it will get by contraction.

Expansion and contraction of the tube actuates the bell crank lever causing the feed-water regulating valve in the discharge line from the feed-water pump to open and close. The valve is opened wider as the water level in the boiler drops, and gradually closes as the water level goes up.

If the feed-water pump were to run at constant speed, excessive pressures would be built up in the discharge line when the feed-water regulating valve was closed. Therefore, its speed must be regulated to correspond with the amount of water that is being fed to the boiler. This is accomplished by means of a pump regulator in the pump steam line. This regulator, by admitting more or less steam to the pump, causes it to maintain a fairly constant pressure in the discharge line. Where centrifugal pumps are used, it is not necessary to use a regulator, as this kind of pump cannot be damaged by throttling its discharge.

30. Insulation:

If a heated material such as a boiler shell be exposed to the outside air, much of the heat will be conducted away by the air with the result that an excessive amount of fuel will have to be burned to maintain sufficiently high temperatures within the boiler to produce steam. The faster the air circulates, the greater will be the heat loss. Hence, a boiler exposed to the wind will give up a considerable portion of its heat to the circulating air.

Any substance or body which readily transmits heat is called a conductor. Steel, copper, water, and air in circulation are examples of conductors. Dead air, that is, air confined so that it cannot circulate, will not transmit heat. Therefore, if a dead air space could be confined around a boiler, it would very effectively check the flow of heat to the atmosphere surrounding the boiler. In other words, the dead air space would serve as an insulator.

Several materials have been found to be excellent insulators of heat because they are porous and confine little air cells which prevent the movement of air within the material. Examples of insulating materials are cord, mineral wool, magnesia, and asbestos.

Since water is a good conductor of heat, boiler insulation must be water proof. The water logged boiler covering is worse than useless.

The materials which are most widely used for insulating boilers are block magnesia and asbestos, a cement compound of silica, asbestos fibres and clay, and asbestos blankets. All of these insulating materials are good, the choice between them depending upon the service to which the boiler is to be put.

Magnesia block lends itself well to stationary boiler use, but it is not to be recommended for portable boilers because breakage during moving is unavoidable, and considerable skill is required to install it. It has long been a favorite in power plants and is probably the most efficient boiler insulation known today.

Magnesia block is applied by wiring it to the boiler with annealed galvanized wire. After the blocks are in place, hexagonal mesh wire is wound around them, and the entire surface is then covered with an insulating cement. Two kinds of cements are used for this purpose - - a cement of mineral-wool asbestos and a cement of long fibre asbestos.

The insulating cement composed of silica, asbestos fibre and clay is very satisfactory for field boiler use. It may be applied and repaired by unskilled labor in a comparatively short time. Since it can be removed, remixed with water, and applied again and again, it makes cheap insulation even for boilers which must be moved often.

Asbestos blankets, made in sizes to fit standard boilers, are being welcomed in some oil fields. They are made in sections which are laced together on the boiler. Installation is very rapid and little skill is required. When it becomes necessary to move the boiler, the sections may be just as readily removed. Although more expensive than other insulators, these jackets have the advantage of being the easiest to install, and there is no waste of material in moving.

The cost of operating a boiler is not confined to the cost of fuel. Increased repair bills, more frequent shutdowns, shorter life, and wet steam are certain results of operating a boiler which is not properly protected. This is not a mere theory, but a fact proved by actual tests. In some cases the cost of insulation has been saved within less than a month. For example, a battery of four 75 h.p. boilers were unable to supply the demand for steam; it was necessary to improve the efficiency of these boilers or to install an additional boiler. The former course was decided upon, and the boilers were insulated with block magnesia and asbestos. The result was astounding. After the insulation was installed, three boilers carried the load with ease.

Insulated boilers should be suitably housed to protect the insulation from rain. If the insulation becomes water soaked, it cannot perform the service for which it is intended. It is folly to insulate a boiler and then fail to give the insulation a chance to function.

31. Boiler Housing:

The boiler house in the field plant is of steel frame and corrugated iron construction. This makes a fire resistant building and is practically 100 per cent reclaimable when it becomes necessary to move to another location. Roof ventilation is supplied by chain operated windows and conventional ventilators. Ample doors, and windows are allowed, and the smoke box portion of the boiler is all that extends outside the building. Fig. 100 is a typical boiler house.

Concrete floors make for good housekeeping in the boiler house, and eliminates a muddy mess at boiler washing time. Good lights in front of the boilers are essential for the operator to observe the pressure gauges and water levels. Using the boiler room for storage space is bad practice, and no material should be piled around, under, or on the boilers.

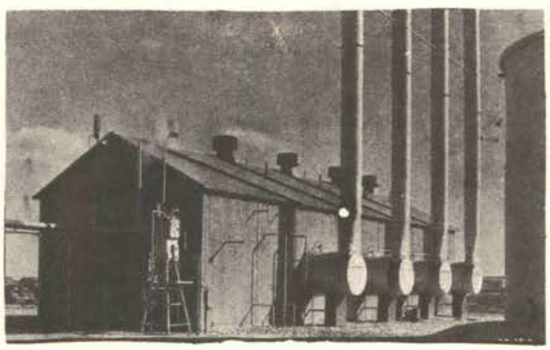


Fig 100

UNIT VI

WATER SUPPLY

1. Source of Supply:

The common source of water supply for the gasoline plant is drilled wells in or near the yard. A pump jack operated by a motor, gasoline engine, or steam engine is used to lift the water to the storage tank or if the air compressor is of sufficient size the water may be lifted by compressed air. A centrifugal type pump also is used extensively. Fig. 101 shows different jacks and pumps, Fig. 102 shows method of installing air line in the tubing for air lift.

The size of air line, tubing, depth of well, air pressure and volume available and the height the water stands in the well all have to be taken into consideration in putting a well on air (sometimes gas) lift. Hand books are available giving this information.

To get a supply of water in wells the depth varies from a few feet in sandy low ground to 1,000 feet and more. The depth of the well tells pretty well what the expense of raising the water to ground level will be. The foot pounds of work involved is a ready explanation; for instance, a 1,000 bbls. a day from a fifty-foot water well will require 1,000 x 42 x 8.33 x 50 or 17,500,000 foot pounds of work. For a well 500 feet deep the foot pounds required will be ten times the amount of the 50-foot well. This means that additional horse power is needed and additional horsepower is additional cost and maintenance.

The life above ground level is an additional number of feet depending on the well location, height of storage tank and difference in elevation of the well and tank. If the wells are not close to storage then additional power must be supplied to overcome friction of water in pipes.

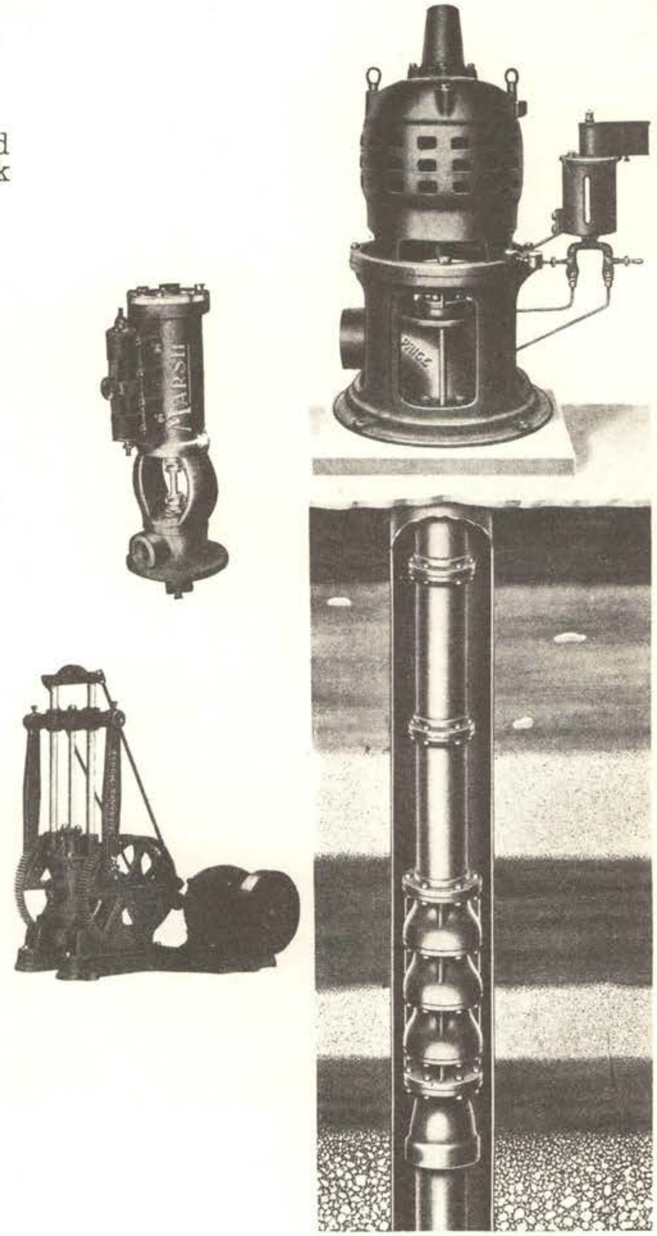


Fig. 101

When the water supply is some distance from the plant this throws additional load on the well pump. This may be satisfactory up to certain limits, then to take the load off the well pump, a reservoir or tank is used at the well site for the well pump to discharge into and conventional pipe line pumps used to pump through the lines to the plant. This is often done and equipment of enough capacity installed to sell water to other users in the oil field, thus, setting up a regular water system similar to that used for towns and cities. The difference being that distribution is not carried to the user. They generally lay their own line to the water main where a meter is installed or it is sold on a day to day basis. Fig. 103 illustrates such a water system. There are many details not shown such as block gates for repairs, lines buried below frost line, pipe connections, and the actual well locations. The well locations will be in a comparatively small area, an acre possibly, and drilled or dug at such locations as will give the maximum water production. The gasoline plant may operate such a water system or purchase from one. Due to the necessity of a constant positive supply for plant use it is seldom that the plant depends on others furnishing water to them unless the delivery is well assured at all times.

Ponds and streams have been used for plant water, but they are unsatisfactory due to the dirt and other foreign matter coming into the plant water system. Clear water is the better. The mud and silt tends to settle out in the cooling equipment greatly hampering its cooling capacity.

2. Storage:

Wood and metal tanks and ponds are used for storage. In the gasoline plant wood has been found very satisfactory. Metal tanks are more expensive and tend to corrode rapidly. Ponds are not commonly used and when they are they are an emergency supply only in case of well trouble.

Where wood tanks are used, precaution should be taken that the hoops be periodically inspected for weakening due to corrosion and new hoops added when the old hoops show weakness. Additional hoops may be made from discarded sucker rods with special lugs to tie the ends. A great deal of damage has been done by the bursting of these tanks. It would be well to calculate the stress on the bottom hoops of your water storage tanks.

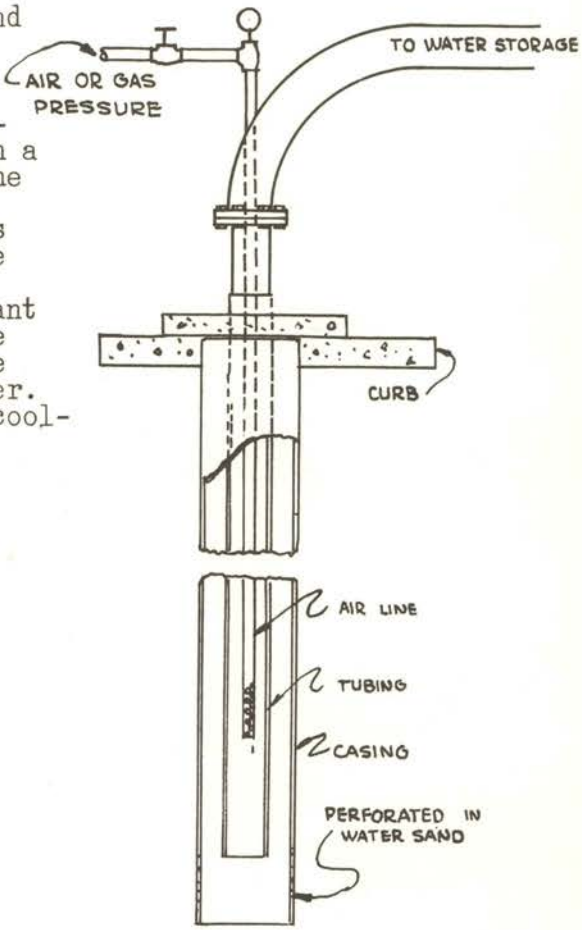


Fig. 102

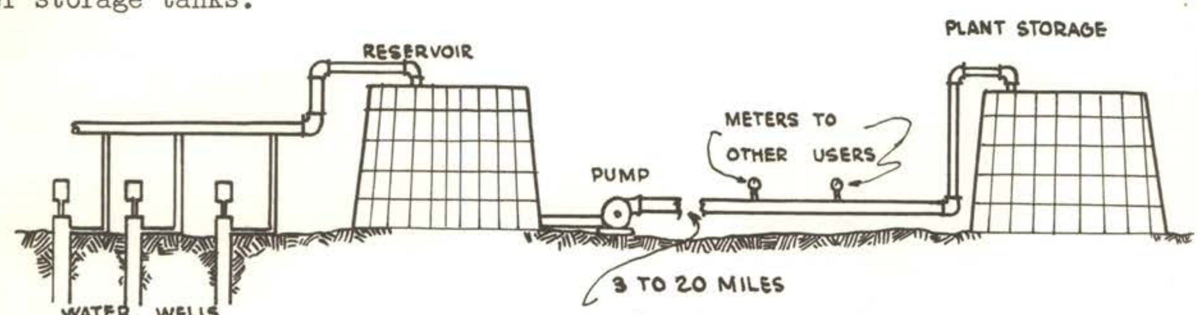


Fig. 103

The capacity of water storage tanks ranges from 250 to 1,000 barrels, depending on the size of plant and accessibility and volume of water supply. When the water supply is just enough for normal operation, it is reasonable to have enough storage that can be filled and used in abnormal weather conditions or other sudden loss of water.

The storage tanks may be made part of the cooling circuit, that is, the cooling tower is mounted high enough or over the tank so that the outlet is into the storage tank. Fig. 104 is a picture of such an illustration.

Again the cooling tower tanks or pans may be of large enough capacity and an easy source of supply in shallow wells available so that no storage tanks are necessary.

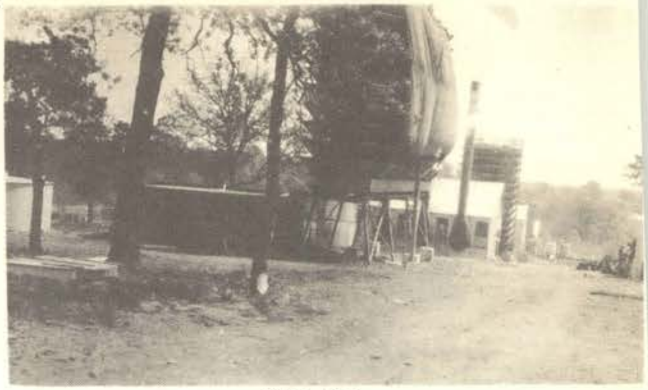


Fig. 104

3. Cooling:

A familiar system of water cooling is used in the automobile engine plant. The engine has excess heat that must be carried away by the water circulating in the jackets around the cylinder heads and walls. In turn the water has to be cooled and returned back to the engine to carry away more heat. The automobile radiator accomplishes the cooling by large volumes of air passing through it that takes up the heat from the water.

In like manner we have in the plant heat we want taken from the engines, compressors, coolers, and condensers, and we circulate cool water around and through them to carry the heat away. This cooling water in turn must have a chance to give up its heat. To cool the water, instead of a closed radiator, an open cooling tower is used. The hot water is pumped to the top and distributed over slat decks that break it up like rain as it falls from deck to deck. Air passes through the tower, it being open on all sides. Water

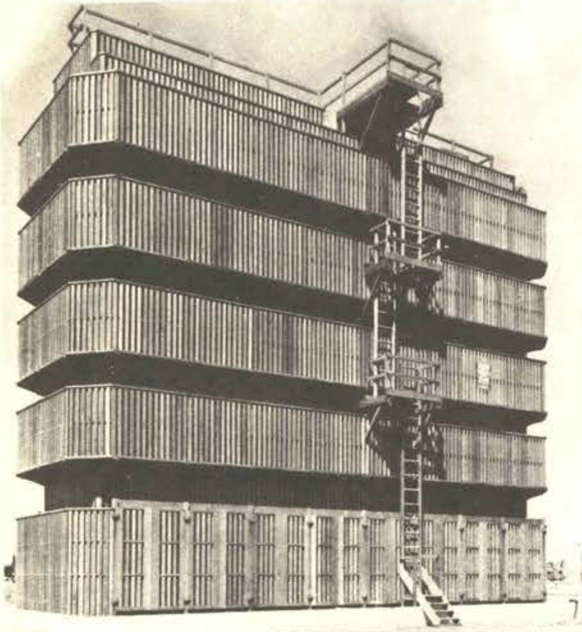


Fig. 105

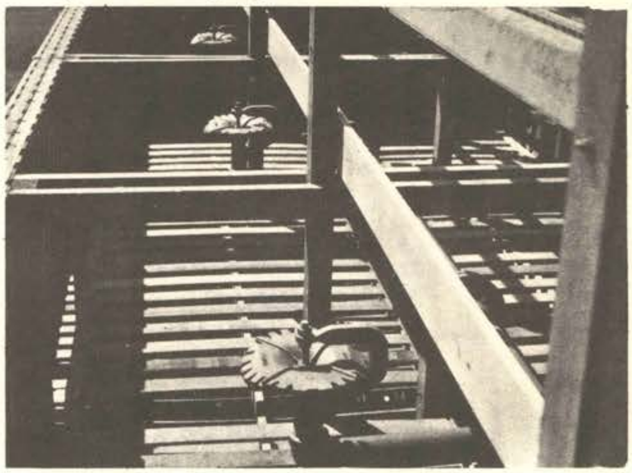


Fig. 106-A

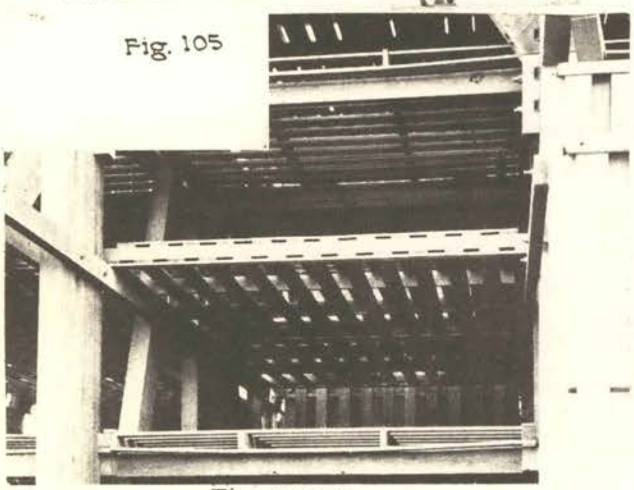


Fig. 106-B

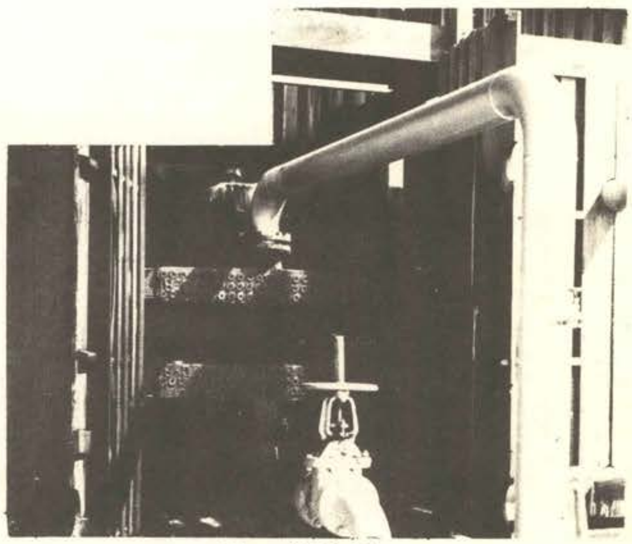


Fig. 106-C

evaporates and in doing so the vapor formed takes up the heat and by the time the water reaches the bottom of the tower it is cool enough for recirculating. Fig. 105 pictures one common type of cooling tower. Fig. 106 shows (A) one type of distributing system, (B) the slat decks and (C) installation of the open type gas coolers in the tower.

The louvre arrangement on the tower has a great deal of effect on its efficiency, not only with regard to the free passage of air through it for cooling, but also with regard to preventing water from blowing out. A few hours of high wind with poorly louvred towers will let most of the plant water supply blow away.

In some territories the wind does not blow sufficiently at times to cool the water. Forced draft towers without louvres are being used to offset this condition. Fig. 107 shows two types of this installation. Large motor driven fans force the air through the tower, which are the closed type rather than the open louvred type giving a draft in and up through the tower.

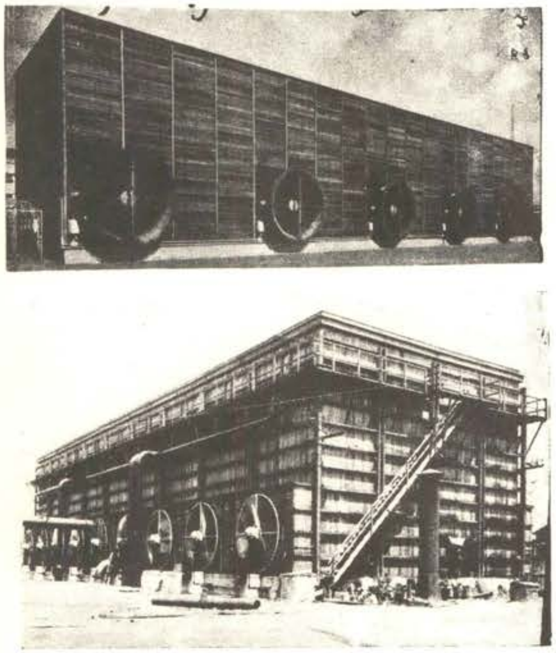


Fig. 107

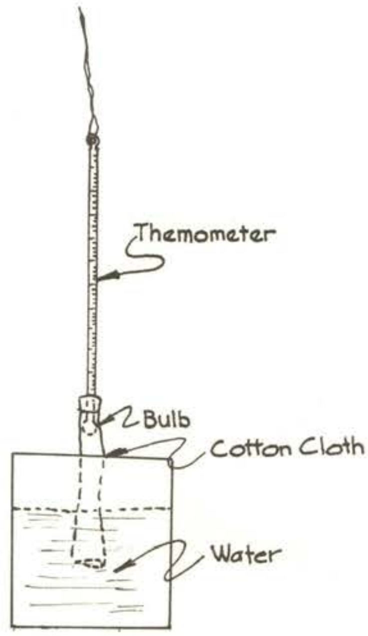


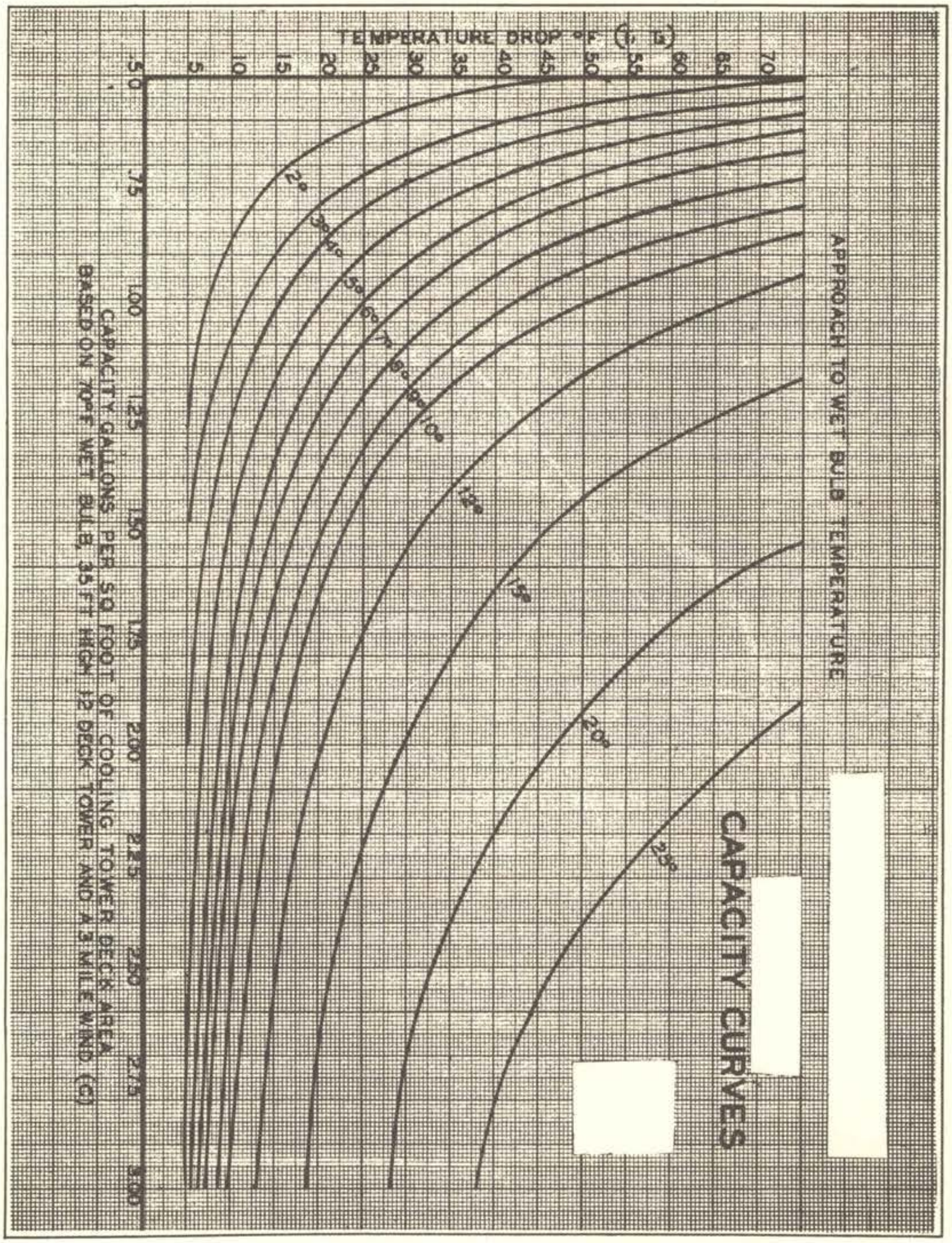

Fig. 108

Provision is made for winter operation in the slat deck towers by a winter spill which is an outlet about ¼ of the way up on the water line to the top of the tower. In cold weather this is opened and sufficient cooling is obtained on the lower decks. This, also, prevents ice forming in the upper decks and possibly becoming of such weight as to over-load the tower.

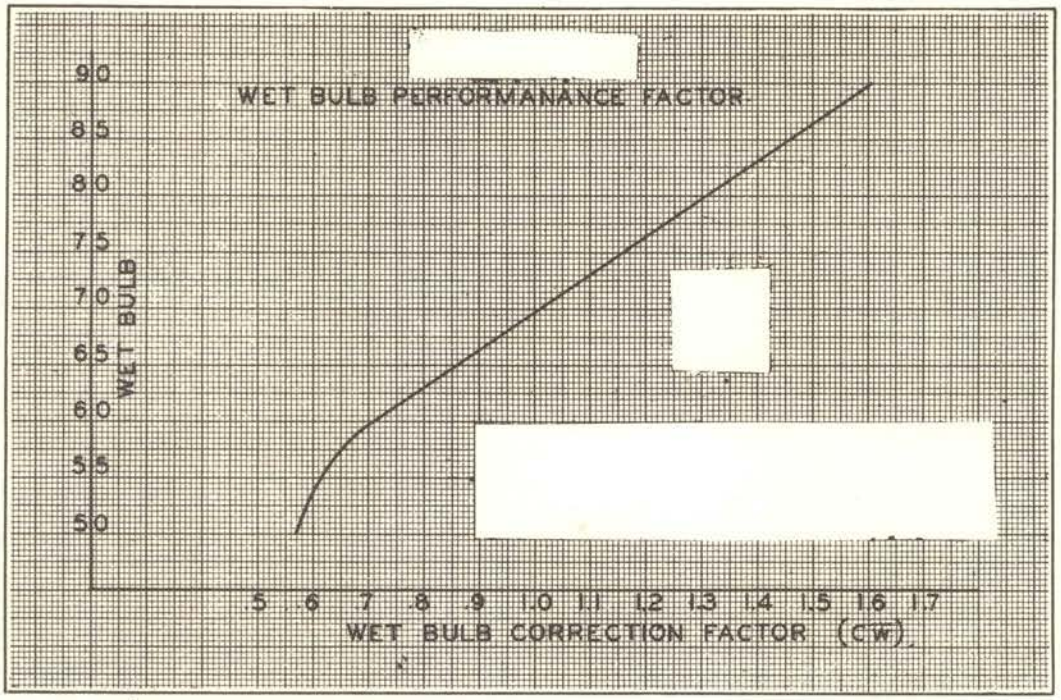
The following charts for calculating cooling tower sizes are self-explanatory except for the following points: The wet bulb temperature is the temperature reading from a thermometer whose bulb is moist and is exposed to atmospheric conditions. A wet bulb can be made as shown in Fig. 108. A thin cotton cloth or piece of cotton is wrapped and tied around the bulb, the cloth hangs down in water. The water rises around the bulb, the cloth acting as a wick. The water evaporates cooling the bulb and the cooler temperature is registered on the thermometer.

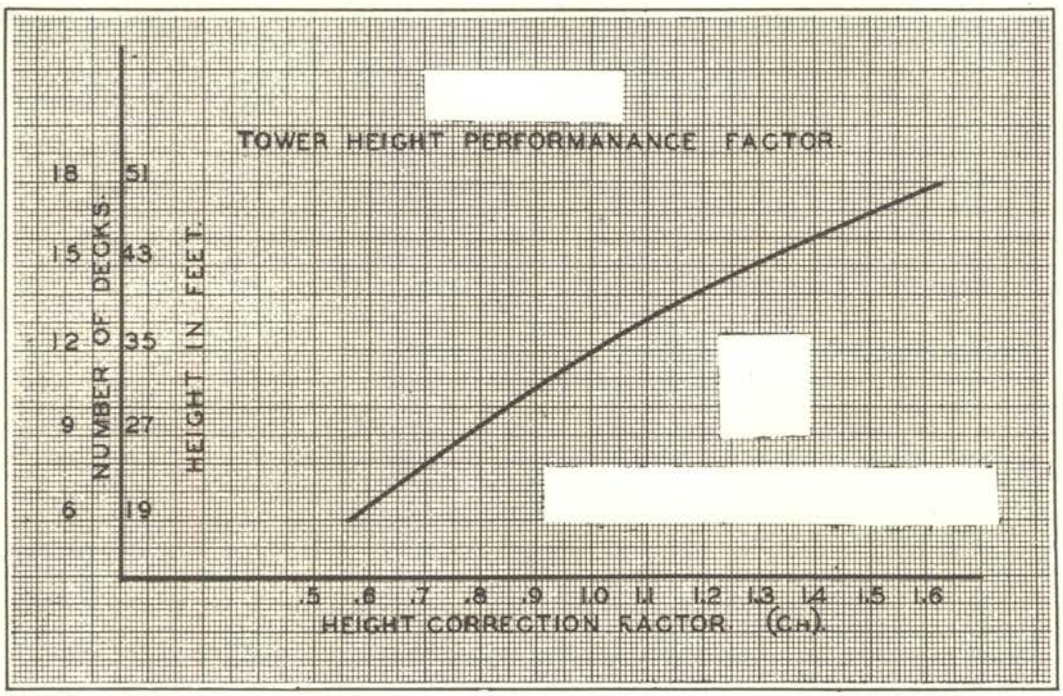
Referring to two Laws of Evaporation: (1) Evaporation increases with the extent of exposed surface, and (2) Evaporation increases as the vapor is removed from the surface of the liquid, we understand the application in the cooling tower. The decks and spreaders break the water up into drops and increases the exposed surface, increasing evaporation. By the tower being open or by forced draft, the vapors are carried away increasing the evaporation rate.

We learned in the study of science, that evaporation cools the remaining liquid. The amount of cooling possible in any particular location at atmospheric condition is learned by taking the wet bulb temperature and comparing with the dry bulb temperature. The wet bulb temperature is under ideal cooling conditions,



CAPACITY CURVES
APPROACH TO WET BULB TEMPERATURE
TEMPERATURE DROP °F (T-Ts)
5 10 15 20 25 30 35 40 45 50 55 60 65 70
2° 3° 4° 5° 6° 7° 8° 9° 10° 12° 15° 20° 25°
.50 .75 100 125 150 175 200 225 250 275 300
CAPACITY GALLONS PER SQ FOOT OF COOLING TOWER DECK AREA
BASED ON 70°F WET BULB, 36 FT HIGH 12 DECK TOWER AND A 3 MILE WIND (C)


WET BULB PERFORMANANCE FACTOR
WET BULB
90
85
80
75
70
65
60
55
50
.5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7
WET BULB CORRECTION FACTOR (CW)


TOWER HEIGHT PERFORMANANCE FACTOR
NUMBER OF DECKS
HEIGHT IN FEET
18 51
15 43
12 35
9 27
6 19
.5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5 1.6
HEIGHT CORRECTION FACTOR (CH)

# METHOD OF CALCULATING COOLING TOWER SIZE

(Based on charts on two preceding pages)

The purpose of these charts is to show how the approximate size of a cooling tower may be calculated to meet your conditions. Assume the following:

1500 G. P. M. to be cooled from 90° F. to 75° F., with a 3-mile wind and a 70° Wet Bulb.

Problem 1.

Problem is to obtain the number of 6' sections of a 35'-0" high, 12'-0" wide tower, 12 deck tower.

From these conditions:

T1 (inlet temperature) = 90° (final temperature) = 75°. Tw (the approach to a Wet Bulb = 5°.

C = Concentration per sq. ft. of horizontal deck area obtained from Fig. 1.

A (Area of one standard tower section, 12'-0" wide, 6'-0" long) = 72 sq. ft.

N = No. of 12'-0" wide, 6'-0" long, tower sections.

To determine the number of sections under the above conditions, the following equation is used:

$$\frac{\text{G. P. M.}}{C \times A} = N$$

From Fig. 1.

C for 35'-0" high tower, for a Tw of 5° and a T1-T2 of 15° = 1.17. Then substituting in the above equation:

$$\frac{1500}{1.17 \times 72} = 17.8$$

Therefore, under these conditions an 18 section tower 35' high is required.

Problem 2.

If the Wet Bulb is other than 70° upon which Problem 1 is based, a Wet Bulb correction factor must be used. This factor is Cw, obtained from the Wet Bulb curve Fig. II. The problem then becomes one of figuring the number of sections required with the same tower height.

Conditions to be met:

Assuming 65° Wet Bulb, 5° approach, 15° temperature drop or T1-T2. To determine the number of sections under these conditions, the following equation is used:

$$\frac{\text{G. P. M.}}{C \times Cw \times A} = N$$

C for 35'-0" high tower, for a Tw of 5° and a T1-T2 of 15° = 1.17, Fig. I. Cw (correction factor for Wet Bulb) is obtained from Fig. II and in this problem = .85.

Then substituting in the above equation:

$$\frac{1500}{1.17 \times .85 \times 72} = 20.8$$

Therefore, under these conditions a 21 section tower 35' high is required.

Problem 3.

Assuming that a 35'-0" high tower does not meet your requirements due to plant conditions, then a tower of greater or lesser height must be figured. Therefore, a height correction factor must be used. This factor, Ch, is obtained from the height curve Fig. III. Required a tower 51'-0" high, instead of 35'-0" high, for conditions stated in Problem 1.

To determine the number of sections under the above conditions, the following equation is used:

$$\frac{\text{G. P. M.}}{C \times Ch \times A} = N$$

Ch, correction factor for height is obtained from Fig. III and in this problem = 1.63.

Then substituting in the above equation:

$$\frac{1500}{1.17 \times 1.63 \times 72} = 10.9$$

Therefore, under these conditions an 11 section tower 51' high would be required.

In this last problem if the Wet Bulb is other than 70°, Cw the Wet Bulb correction factor becomes a part of the equation:

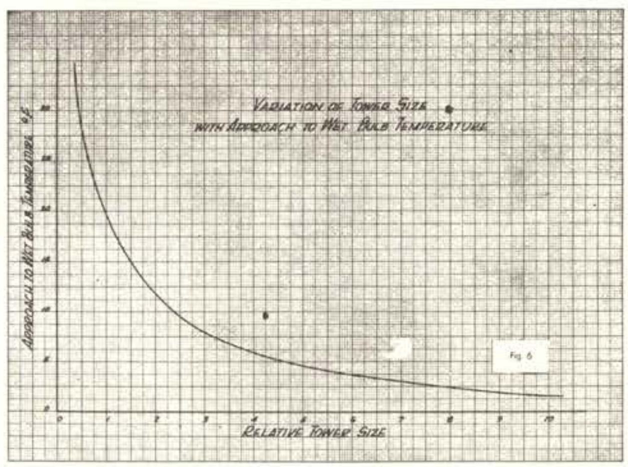
$$\frac{\text{G. P. M.}}{C \times Cw \times Ch \times A} = N$$

The engineering data and the above problems are approximate only, and the sizes of the towers determined therefrom are not necessarily our recommendations.

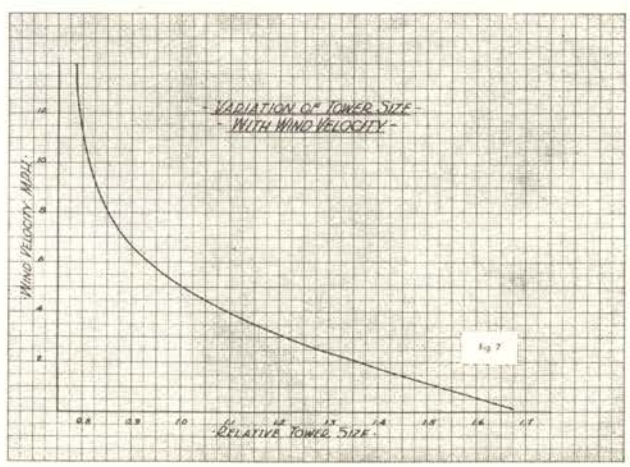
The size of a tower required to handle a given heat load varies greatly with the performance required, and care should be used in specifying the Wet Bulb temperature, the final approach of the tower water to the Wet Bulb temperature, the wind velocity and the quantity and temperature range of the tower water being circulated.

If plant operation requires the maintenance of a definite minimum temperature it is essential that the highest prevailing Wet Bulb temperature, usually occurring during July, August and the early part of September, be used in rating the tower. Then, when the Wet Bulb temperature drops and colder tower water is obtained, the quantity of cooling water being circulated may be decreased.

The approach of the final tower water to the Wet Bulb temperature should be made as large as possible to avoid unnecessarily increasing the tower size. Fig. 6 illustrates the above point by showing the relation between tower size and approach to the Wet Bulb temperature while circulating a constant quantity of water through a given temperature range. In specifying the operating conditions an approach of not less than five degrees and preferably ten degrees or greater is recommended.




The relative size of a tower varies with the wind velocity as shown in Fig. 7. In order to obtain the required minimum temperature during the summer months, care should be taken to specify a wind velocity which is representative of the poorest conditions experienced during the warmer months rather than a figure which represents the average wind velocity over a period of years.



especially if the cloth is dampened and the thermometer is whirled on the end of a string. The cooling tower is not under this ideal condition and is the reason for the term "approach to wet bulb temperature."

It has been said, that the cheapest way to keep up production is keeping the cooling towers in good shape. This means cleaning, replacement of broken louvres and slats, keeping free of moss and keeping a proper distribution of water.

## UNIT VII

## FRACTIONATION OR STABILIZATION

In an explanation of the use of these terms, it might be said that they are not synonomous but often are used so. The first term that came into use was stabilization as the stabilizers were first needed to separate the light ends and bring the product down to refinery requirements. The second term, fractionation, which means separating the different fractions or hydrocarbons came into use with the separating of propane and butane for the bottled gas and industrial trade. Stabilization is not necessarily fractionation except in the sense that the lighter fractions are separated. Fractionation generally is thought of as separation of each fraction from the others. Especially is this true in making C. P. products.

1. Reasons for Stabilization:

The main reason for stabilization has been discussed as being that of necessity of meeting refiner's requirement. Something has been said about the price factor for the different grades affecting stabilization. In fact, today there is no market for unstabilized natural gasoline.

Back of all this is fuel requirements for the automobile where most of the gasoline goes, and the rapidly developing market for the lighter fractions.

Automobile engines are built to operate with a stable fuel. The refiner has all the lighter fractions he needs for his own use from his vapor recovery plant which is nothing but a natural gasoline plant, so it is not to his interest to buy natural gasoline with more lighter ends. This is general except that some refineries with the proper cracking and polymer equipment with market outlet can and do handle the lighter fractions.

The gasoline plant now has a rapidly developing market for its lighter fractions, hence the installation of fractionating columns in practically all new installations.

The purpose of the natural gasoline fractionator may be summed up:

1. Stabilize raw gasoline to a suitable grade for the motor fuel market.
2. Separate and liquefy the light hydrocarbons for the liquefied gas market.
3. Remove all traces of undesirable "fixed gases" from all products.
4. Separate any desired hydrocarbons (or component) from raw natural gasoline and render it available for any special demand.

2. General Characteristics of Raw Product:

Raw gasoline has some marked physical characteristics of interest. It is wild or very volatile. If a small amount is poured on the palm of the hand it will start boiling immediately and soon will vaporize. A cupful thrown in the air will vaporize entirely before reaching the ground.

In explanation of this, refer again to our hydrocarbon table, Fig. 3, and it will be noted that the liquefying or boiling temperature at atmosphere for propane is -49° and butane 34° and the others higher. Now, even though the raw gasoline contains the pentanes and heavier it has this characteristic, that when the lighter fractions boil off they carry the heavier off with them, especially at atmospheric or no pressure and in the presence of other circulating gas (air, in this case).

The percentage of the different gasoline hydrocarbons in the raw product varies widely, depending on the contents of the natural gas being treated. One field plant may make a 26 lb. product and only lose by stabilization 20 per cent of the gross make, another may lose as high as 50 per cent. The 26 lb. product contains approximately 35 per cent butane and balance heavier.

The best method of carrying out fractionation is to bring into intimate contact a stream of condensing vapors and one of boiling liquid. The streams flow in opposite directions. The device used to insure intimacy of contact is called a fractionator column. The most effective type of fractionator column is the bubble-cap type. The column is divided into a number of sections by horizontal partitions. Each section, or plate, is equipped with bubble caps and down taker. The liquid flows from plate to plate by means of the down taker and across each plate. A liquid level is maintained by a baffle at the down take entrance. The vapor bubbles through the slots in the bubble caps and is brought into intimate contact with the liquid of each plate.

Fractionation, as employed in the gasoline industry, calls for equipment as follows:

1. Fractionator kettle or reboiler
2. Fractionator column
3. Feed tanks and pumps
4. Feed preheaters
5. Heat exchangers
6. Coolers
7. Reflux condensers
8. Reflux accumulator (in some instances, final accumulator)
9. Reflux pumps
10. Miscellaneous temperature and pressure recorders, and control

3. <u>The</u> <u>Stabilizer</u>:

Fig. 109 shows the construction of the stabilizer. Raw feed or raw gasoline is pumped into the stabilizer at inlet shown on the figure. Heat in the form of steam is applied through tubes in the kettle. Enough heat is required to boil the gasoline at whatever pressure is carried. Pressures vary from 100 to 350 pounds and, of course, the higher the pressure the higher the temperature necessary to boil the gasoline and vaporize it.

To save some confusion, the conditions in the stabilizer are not the same as when boiling the gasoline in your hand as mentioned above. The stabilizer is a closed vessel under pressure and no other gas or vapor is present in it except gasoline vapors and the gasoline as liquid so that the vapors do not mingle with other gases and go off and be lost.

As the raw make enters the stabilizer it starts boiling and vaporizing and this condition will be found: The lighter hydrocarbon vapors travel up through the plates, and in so doing it carries some heavier with it, but as the vapors go up, the tower is cooler and the heavier start to condense, fill the plates, and come back down, as it comes down it absorbs the heavier ends going up and brings them back down. Thus, in the continuous state of agitation due to vaporization and condensation, the lighter continues on to the top and the heavier to the bottom. The heavier hydrocarbons have a tendency to bring down the lighter but at the increased temperature near the bottom they boil off and go up again. The result is that by varying the temperature of the reboiler the vapor pressure of the gasoline coming off the bottom can be closely regulated.

The lighter ends going on to the top are run through a cooler and condensed and is called reflux. This is pumped back to the top trays as a cooling medium, keeping the top temperatures as desired. Excess stabilizer vapors are utilized as boiler fuel or charge stock to other equipment.

Theoretically, a fractionating column having an infinite number of plates, or partitions would require no extra wash-back liquid or reflux; but because of the economy involved, a tower of too many plates would be impracticable. Therefore, a reflux must be manufactured.

In further fractionation for butane and propane, two common hook-ups are in use. Fig. 110 shows these. On the left the first column is similar in operation to the stabilizer mentioned above. The butane ($C_4H_{10}$), propane ($C_3H_8$), and ethane ($C_2H_6$) vapors come off the top and go into the second column. Butane comes off the bottom and butane and ethane vapors go to the third column where the propane comes off the bottom and ethane is returned to the residue.

The diagram on the right shows another hook-up which is practically the reverse. These diagrams do not show the regulators, pumps, condensers, etc., which are similar to the conventional stabilizer installations.

In the manufacture of the chemically pure products, a sensitive well controlled fractionation tower is used and selected charge stocks used.

The feed to a fractionating column is usually pumped into the tower and is

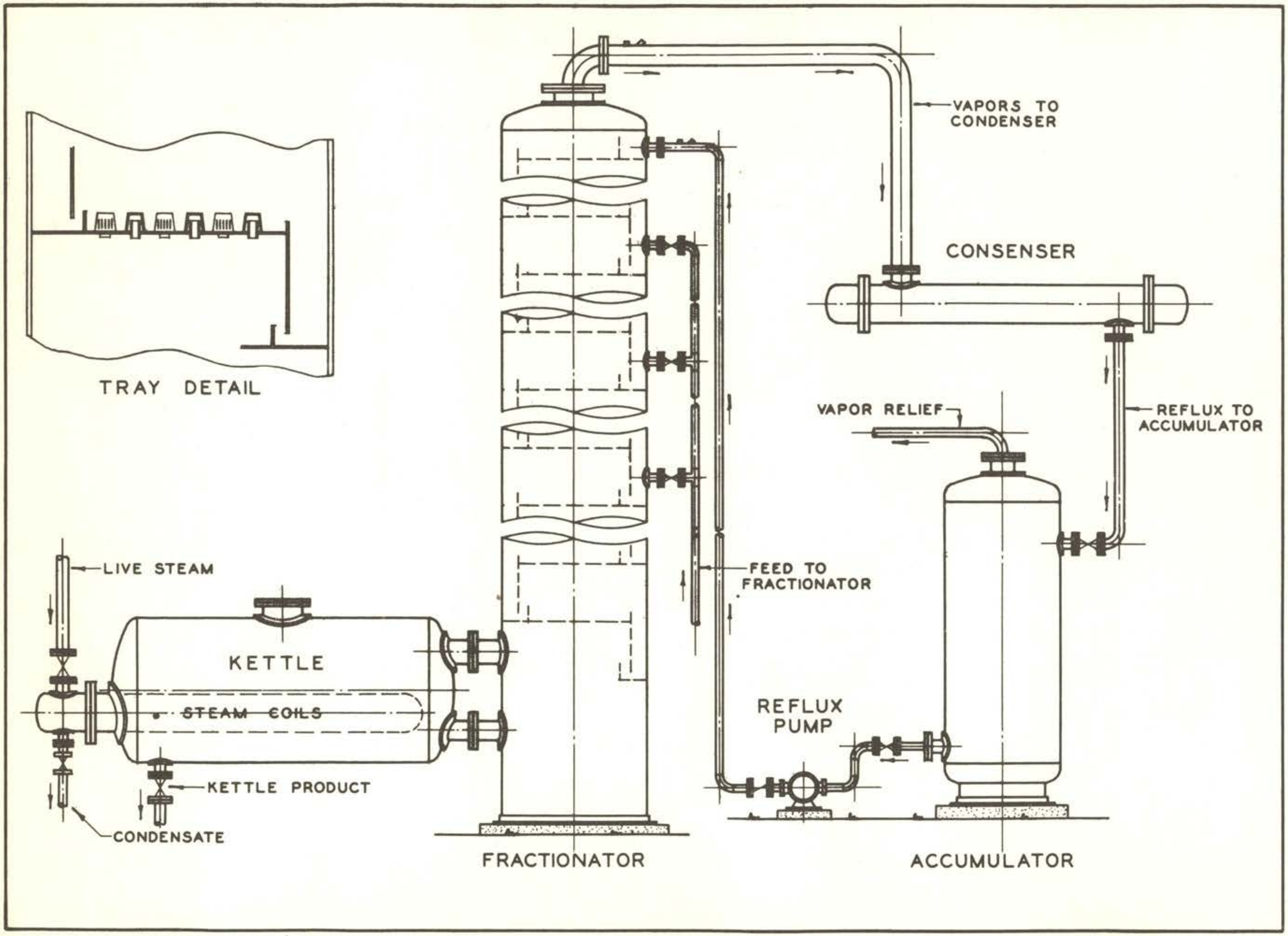

TRAY DETAIL
VAPORS TO CONDENSER
CONSENSER
REFLUX TO ACCUMULATOR
VAPOR RELIEF
LIVE STEAM
FEED TO FRACTIONATOR
KETTLE
STEAM COILS
REFLUX PUMP
KETTLE PRODUCT
CONDENSATE
FRACTIONATOR
ACCUMULATOR

Fig. 109

preheated to a temperature near the temperature of the column plate at the point of feed entrance. This point of entrance is determined by various methods. For our study we can say that it enters at a point about midway in the tower. The

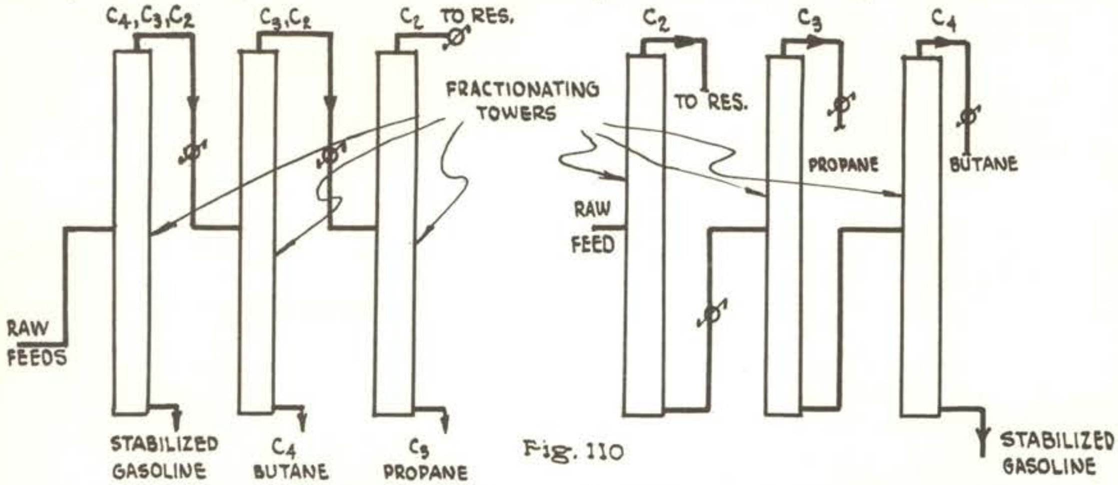



Fig. 110

gasoline feed should be of about the same composition as the liquid on the entrance feed plate. This allows for equilibrium of the liquid and gas when it enters the column. The lighter ends of the raw feed makes its way to the top of the column when the undesirables are removed, and the heavy ends find their way to the kettle where a set temperature governs the vapor pressure and gravity of the finished product. Of course, the column operates under certain temperatures and pressures, these conditions being governed by several factors, chief of which is the quality of the kettle product desired. Heat exchangers and coolers are used for the purpose of assisting in the preheating of the raw feed and the cooling of the finished kettle product to storage.

Some of the factors affecting fractionation:

1. Rate of feed.
   (a) A rate of feed whichis constant is desirable. Also, a rate not too high for column capacity is best.
2. Quality of feed.
   (a) A feed of unvarying gravity, vapor pressure, and composition is desirable.
3. Temperature of feed.
   (a) A temperature approximating that of the liquid on the feed plate allows for closer and better fractionation. This can be determined by establishing a gradient based on the number of plates and correlated by the difference in the kettle and top temperature.
4. Column Pressure.
   (a) A pressure should be carried which will give maximum capacity with lowest reflux ratio. This is usually governed by feed quality and product desired.
   (b) A pressure should be carried above to the vapor pressure of the overhead product at column top temperature.
5. Kettle Temperature.
   (a) Practically speaking, it can be stated that the Reid Vapor Pressure of the finished product is controlled by the kettle temperature, while the distillation characteristics are governed by the column and reflux rates. A suitable temperature should be carried to give the proper vapor pressure without the use of too much reflux.
6. Number of Plates.
   (a) The more plates in a column, the less reflux is needed. For extremely close separation, a column of many plates is desirable even if a high reflux ratio is used.
7. Reflux Ratio.
   (a) Generally speaking, the reflux ratio is defined as the ratio of the

number of gallons of overhead product condensed and returned to the column to the number of gallons represented in the discard gas from the column. An example: If 100,000 gallons per day is condensed and returned to the column as reflux, and gas representing 10,000 gallons per day is discarded, then the reflux ratio would be ten to one.

(b) While it is true that a high reflux ratio will result in an increase in yield and allow for closer separation of the desirables from the undesirable, a too-high reflux ratio can be harmful in that it will require more steam for reboiling the product. This increases water consumption and boiler load.

All operating conditions of a fractionator should be constant. Any variation in the operation as outlined by the above factors can result in erratic and uneconomical fractionation.

Various control instruments are essential to fractionation. Commonly used are:

1. Feed meters
2. Reflux meters
3. Temperature controls
4. Pressure controls
5. Temperature recording thermometers
6. Pressure recording gauges
7. Potentiometers for continuous record

NOTE: The data, as herein outlined, is general in nature and is not meant to be accepted in all cases. The idea is to outline certain high points of fractionation which may be of value. Other material of more specialized nature is available if needed.

4. Vapor Pressure:

It is suggested at this point in this study or sooner that the most recent regulations regarding the vapor pressure, classification, and testing natural gasoline be brought to class and discussed. Although the standards now used are thought to be nearing the desired requirements, they are a result of a number of changes and may be changed again. For that reason, the specifications referred to, Fig. 111, should be as of the date indicated and any changes should be noted.

Prices are quoted in the journals and newspapers on 26-70 natural gasoline. That grade of gasoline has a maximum vapor pressure of 26 lbs. at 100°F., and the per cent over in the distillation process is 70 or more at 140°F. Price of the other grades is higher as the vapor pressure is reduced.

The Reid vapor bomb and method is used as indicated. The vapor pressure of the product is the indication of its stability. In winter a higher vapor pressure product for fuel can be used than in summer. However, the demand in either season for natural gasoline ranges up and down the vapor pressure scale with the majority of it between 12 and 26 lbs.

The Reid method of taking vapor pressures is further described under Plant Laboratory.

5. Blending:

The daily production of a plant is quite often stored for future sales or a better market. When the market is available it may be for a different vapor pressure product than that on hand. Stored gasoline under low pressure generally is 12 to 44 lbs. pressure. If the market demands are for 22 lbs. then enough of the higher fraction is added to bring the product up to 22 lbs.

This is a matter of proportioning the volumes as indicated in the chart, Fig.111-A

The mechanics of the vapor pressures and their action in the fractionation tower is left to a further study in fractionation and liquefied gases.

# Official Specifications and Testing Methods for Natural Gasoline

Effective January 1, 1932

Natural gasoline is a liquid petroleum product consisting of the heavy hydrocarbons extracted from natural gas by such means as compression, absorption, and other processes.

Natural gasoline is defined further for commercial purposes by the following specifications:

1. Reid Vapor Pressure—10 to 34 pounds.
2. Percentage Evaporated at 140° F.—25 to 85.
3. Percentage Evaporated at 275° F.—Not less than 90.
4. End point—Not higher than 375° F.
5. Corrosion—Non-corrosive.
6. Doctor Test—Negative, "sweet."
7. Color—Not less than Plus 25 (Saybolt).

In addition to the above general specifications, natural gasoline shall be divided into twenty-four possible grades on a basis of vapor pressure and percentage evaporated at 140° F. Each grade shall have a range in vapor pressure of four pounds, and a range in the percentage evaporated at 140° F. of fifteen per cent. The maximum vapor pressure of the various grades shall be 14, 18, 22, 26, 30 and 34 pounds respectively. The minimum percentage evaporated at 140° F. shall be 25, 40, 55 and 70, respectively. Each grade shall be designated by its maximum vapor pressure and its minimum percentage evaporated at 140° F., as shown in the accompanying table.

GRADES OF NATURAL GASOLINE

Percentage Evaporated at 140° F.

| Reid Vapor Pressure | 25 – 40 | 40 – 55 | 55 – 70 | 70 – 85 |
|---|---|---|---|---|
| 34 – 30 | Grade 34-25 | Grade 34-40 | Grade 34-55 | Grade 34-70 |
| 30 – 26 | Grade 30-25 | Grade 30-40 | Grade 30-55 | Grade 30-70 |
| 26 – 22 | Grade 26-25 | Grade 26-40 | Grade 26-55 | Grade 26-70 |
| 22 – 18 | Grade 22-25 | Grade 22-40 | Grade 22-55 | Grade 22-70 |
| 18 – 14 | Grade 18-25 | Grade 18-40 | Grade 18-55 | Grade 18-70 |
| 14 – 10 | Grade 14-25 | Grade 14-40 | Grade 14-55 | Grade 14-70 |

## TESTING METHODS

### Reid Vapor Pressure

Same as A. S. T. M. Method D323-37T.

### Corrosion Test

Same as A. S. T. M. Method D130-30.

### Color Test

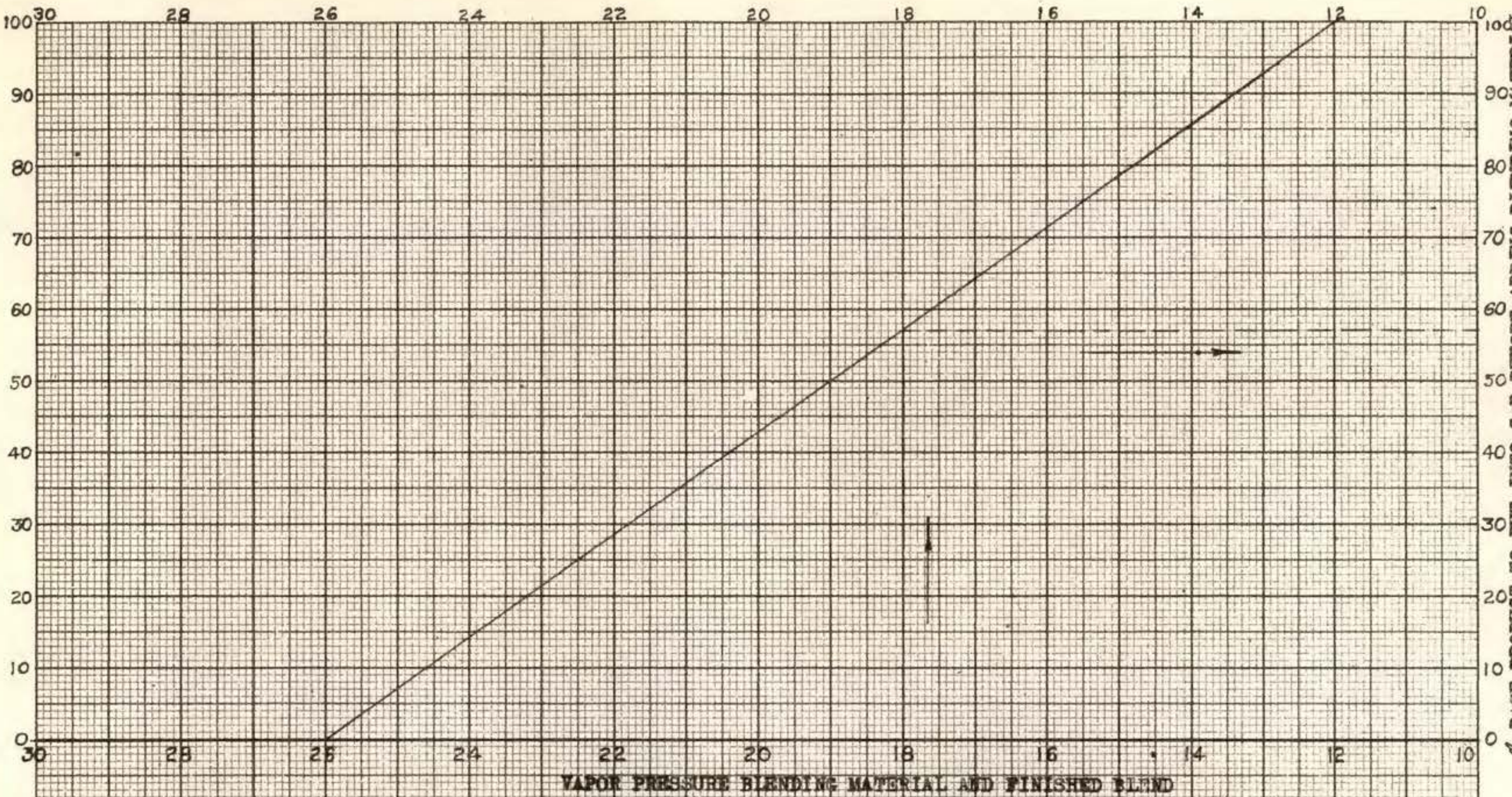
Same as A. S. T. M. Method D156-23T.

### Distillation Test

Same as A. S. T. M. Method D216-32T.

Complete description of apparatus can be found in 1932 standards of the American Society for Testing Materials, obtained from the Society at 260 South Broad Street, Philadelphia, Pa.

Fig. 111




EXAMPLE

Prob: To make an 18# Finished Blend from a 12# base & a 26# Blending Material

Ans: 1. Lay a straight edge from the 12# at the top to 26# at the bottom as shown by solid line.

2. Draw a vertical line from 18# (top or bottom scale) to intersect with solid line, then draw horizontal line to right or left to give % of base product to use, (in this case is 57% of 12#)

3. 57% of 12.0# = 6.84#
43% of 26.0# = 11.18#
Vapor Pres.
Finished Blend = 18.02#

Fig. 11-A.

KEUFFEL & ESSER CO. N.Y.

## UNIT VIII

## TREATING

### 1. Sour and Corrosive Gasoline:

Nearly all natural gasoline, when it is first condensed from the coolers, contains certain sulphur ingredients which must be removed before the gasoline can be marketed. One compound, hydrogen sulphide, is particularly objectionable, being corrosive and poisonous. These ingredients left in the gasoline cause pitting and corroding of valves and cylinder walls of motors. The process of removing these objectionable ingredients is called treating.

The presence of ordinary sulphur compounds in the gasoline gives it the characteristic called "sour". The presence of hydrogen sulphide, $H_2S$, makes it corrosive and the product is so described as "corrosive". Any natural gas containing 12 grains or more of $H_2S$ per 100 cubic feet of gas is called sour gas and will make the natural gasoline product corrosive. Lower amounts are described as a "trace". Some gases contain as much as 10,000 or more grains per 100 cubic feet. Specifications call for the gasoline to be "sweet" and "non-corrosive", hence, gasoline which is sour and corrosive must be treated. The tests for these conditions are the "doctor" test and the "corrosion" test, described in detail in the A. S. T. M. manual.

Briefly, the doctor test is made by bringing a sample of the gasoline in intimate contact by agitation with doctor solution, containing caustic soda, distilled water, and lead oxide, after which free sulphur is added and the agitation is repeated. Discoloration of the sulphur indicates sourness.

The corrosion test is made by heating a sample of the gasoline with a clean copper strip in it and holding the desired temperature for the time required by the test. Any discoloration of the copper indicates that the gasoline is corrosive.

As a general rule, the sulphur compounds have a boiling range lower than butane, which means that only the fractionating kettle product will have to be treated. The hydrocarbons lighter than pentane usually are sweet in their natural condition and do not require treating. This is not true of $H_2S$. A popular means for the removal of $H_2S$ is the caustic wash.

The presence of $H_2S$ not only is a problem in natural gasoline but also in natural gas. The following treating methods do not remove corrosion due to $H_2S$ but only remove the sulphur compounds which give the gasoline its "sourness". Natural gasoline is termed sour when it contains sulphur compounds which are removable by the following treating methods, whereas natural gas is termed sour when it contains $H_2S$ gas. The treatment for $H_2S$ removal from gasoline or natural gas is a separate process. Caustic wash for gasoline as mentioned above or for natural gas will remove $H_2S$. Another common method for $H_2S$ removal from gas is the treatment with iron oxide. $H_2S$ is a special problem for the chemist and is beyond the scope of study in this text.

### 2. Methods of Treating:

A number of methods or processes for the treatment of gasoline have been and are being used. Due to the variation of these different types only the two more popular methods are discussed here. The local plant chemist may discuss other local methods.

The most popular method until the last few years and still largely used is the sodium hypochlorite process. The equipment for this method is shown in Fig. 112. The mixing tank is used only for the purpose of preparing the treating solution or recharging the treating solution. The contact with the gasoline is made as shown in the treater tank.

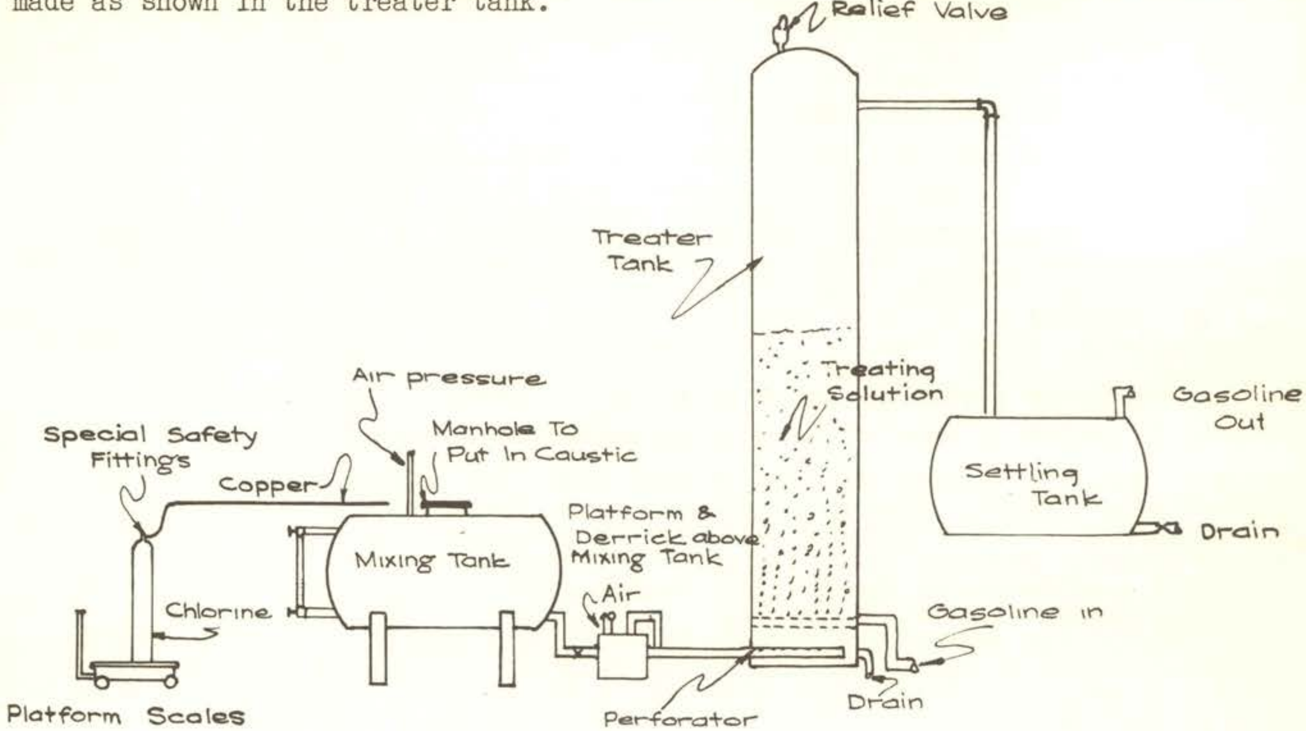



Fig. 112

The treating solution consists of caustic, chlorine, and water. Caustic comes in solid form and is melted with steam or hot water into the mixing tank. Chlorine is absorbed into the solution through copper tubing from the chlorine cylinder. The usual proportions are:

Caustic -- 1.1 pounds per gallon of water.
Chlorine-- 0.5 pounds per gallon of caustic water solution.

The treating solution is blown by air pressure into the treater tank. The solution will treat gasoline until the chemical solution is used up by the reaction of the sulphur in the gasoline. The volume of gasoline treated will depend on the amount of sulphur compounds it contains.

In this process the treating chemicals, caustic and chlorine, are extremely hazardous. The caustic on contact with flesh causes bad burns. Chlorine gas, the same used during the world war for a poisonous gas, if inhaled, forms hydrochloric acid in the lungs and burns the tissues. Consequently, extreme precautionary measures are required in handling either chemical.

Caustic soda comes in solid or crystaline form in drums weighing 700 lbs. to 800 lbs. Best practice requires the use of a special crane and platform at the mixing tank to safely handle the drum. Steam or hot water lines are permanently installed for safe operation. Guards around the mixing tank opening to prevent splashing out are necessary during the melting of the caustic. Vinegar should be available at all times to neutralize the caustic that gets on the operator. Goggles should be worn, and rubber aprons and gloves are recommended.

The chlorine cylinder valve should never be opened to the atmosphere. All connections and fittings from cylinder to tank should be carefully made up and inspected. Best practice indicates that no building be installed over the cylinder and mixing tank. Any escaping chlorine gas would have a tendency to collect in dangerous quantities. If a building is used for protection of scales and cylinder, complete ventillation should be provided, Fig. 113.

The Cuprous (copper) Chloride method recently developed has been found to be much more efficient in treating of gasoline, both from an operating expense and treating viewpoint. The equipment required is shown in Fig. 114, and con-

Fig 113

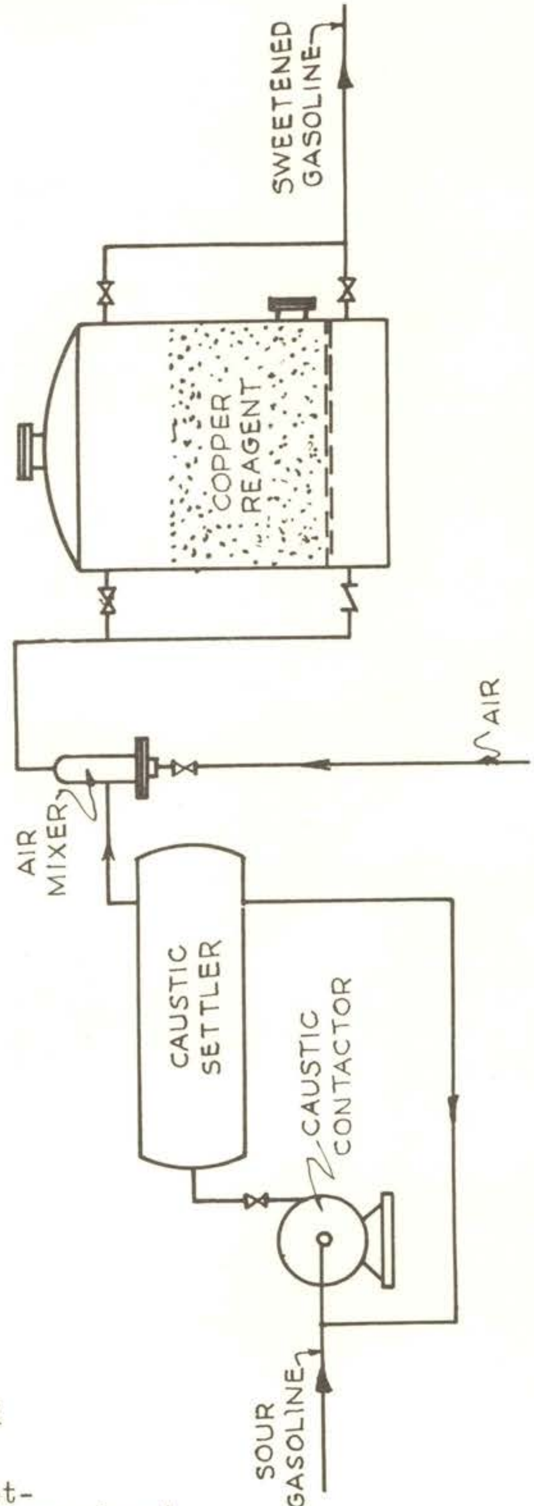



Fig 114

sists mainly of a tank containing the copper reagent, air mixer, caustic settler and the caustic contactor.

Several modifications of the original process have been devised to meet the conditions encountered in the treatment of the various types of gasoline. One of the most important is the development of a "solid" treating process especially adapted to natural gasoline. The reagent is prepared by impregnation of adsorbents such as fuller's earth and the like with the copper solutions. The sour gasoline is contacted with the reagent by filtration. The filter bed is formed by supporting the reagent on a layer of mineral wool inside a steel filter tank protected from corrosion by a coat of resinous varnish. Where the solid reagent is used it is continuously regenerated in place by dissolving a predetermined amount of air in the sour gasoline before it enters the filter. The gasoline is sweetened so quickly that almost unbelievable flow rates are possible.

The advantages of the copper sweetening processes over the older methods are almost too numerous to mention. Treatment with other solutions in any form has always been cumbersome and unsatisfactory.

Some of the more important advantages of copper sweetening are outlined below.

(1.) Saving in Chemical Costs--Since only air is used up in the treating it is evident that the only chemical cost is that due to mechanical loss of the treating solution. This loss has been almost negligible in the commercial application of the process. The cost of doctor treating or of hypochlorite treating, is quite variable, depending to a great extent on the degree of sourness in the gasoline and on the means of regenerating the doctor solution. But in any instance the chemical cost has been a big item in the treating cost to every natural gasoline manufacturer. Almost all of this cost is eliminated by the new process.

(2.) Decreased Operating Costs--A marked reduction in operating costs has been made through the replacement of doctor and hypochlorite units with the new copper sweetening units. The extent of this reduction is discussed in the section on commercial installations.

(3.) Low Investment--New equipment for either the solution or solid copper treating processes costs less than that for the older methods of sweetening.

(4.) This method eliminates most of the hazards encountered with the other processes. This safety feature is one that is taken into consideration as the old type methods were accountable for numerous accidents.

UNIT IX

STORAGE

1. Types:

Natural gasoline at the plant is almost universally stored in horizontal cylindrical tanks with convex or dished ends, with capacities ranging from 10 to 25 thousand gallons. There are two reasons for this type tank; first, they will withstand a comparatively large amount of pressure (30 to 40 lbs.), and second, they are portable.

We know that natural gasoline is highly volatile and under atmospheric pressure and temperatures will vaporize rapidly, especially the raw product. To keep down vaporization, enough pressure is carried on the storage to prevent practically all vaporization. In the study of pressures in vessels, it was learned that using the same material the type vessel that would hold the most pressure is spherical and the next the cylinder with spherical ends. The cylindrical tanks with convex ends approach the second type.

Most plants are of semi-temporary installation and tanks of this type may be reclaimed and moved to another location intact. The expense of dismantling and rebuilding is eliminated.

For larger storage and pressure storage the spherical, spheroidal, and cylindrical tanks, with spherical ends similar to those shown in Fig. 115 are used. The spheres are built to hold up to 100 lbs. pressure and the spheroids up to 25 lbs. pressure.

The conventional 55 and 80 thousand bbl. oil storage tanks are being used for the stabilized product. In this case where the tank will hold no pressure it has been the practice to install water sprays over the tank to keep the temperature down during hot weather, and thus prevent excessive evaporation loss. Dykes are required in tankage of 10,000 barrels and over and in congested areas on smaller tanks.

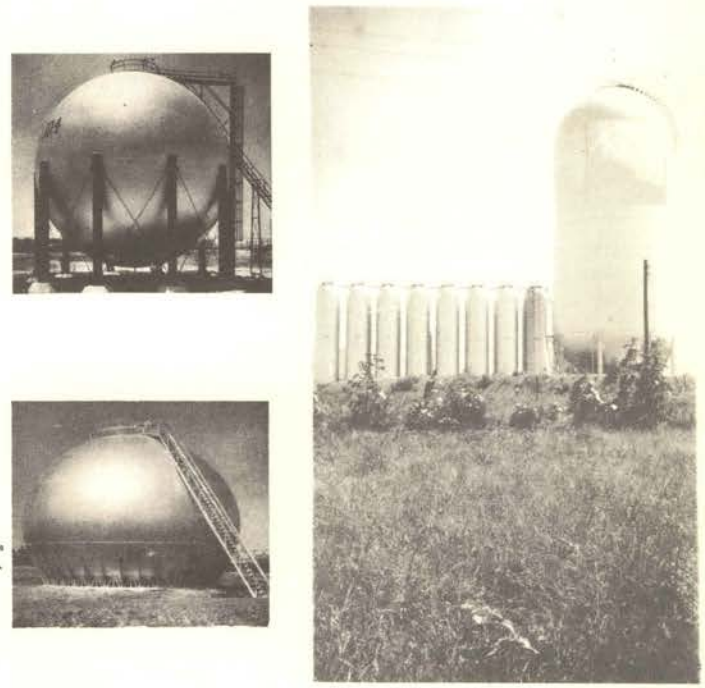


Fig. 115

2. Pressures Carried:

In the earlier days of the natural gasoline business, stabilizers were not used, and the only method of holding most of the liquid was by pressure. However, it was soon learned that the expense of high pressure tanks would not pay as the higher vapor pressure hydrocarbons held did not offset this expense. The wild gasoline was not used. Pressures of 20 to 30 lbs. were used and the vapors from the tank recirculated, wasted, or possibly burned in the boilers. Now with the stabilized product only such pressure as is necessary for the particular gasoline in storage is carried.

The highest pressure generally carried now is on the raw make tank. This may be from 25 to 40 lbs. For the pressure to be carried on the stabilized gasoline the curve and explanation Fig. 116 may be referred to. In plants making butane and propane storage for much higher pressures are provided.

# DETERMINING CORRECT STORAGE PRESSURE

When pressure storage is used for natural gasoline, maximum economy is secured by specifying a pressure sufficient to prevent all standing storage loss. This pressure depends upon the vapor pressure of the product and the daily temperature variations of the vapor space and the liquid surface. When these factors are known, the storage pressure required to eliminate venting can be computed by the following relation:

$$SP = FP + \left[(14.7 - IP)\ \frac{FT}{IT}\right] - 14.7$$

where:

SP—Required storage pressure in lbs. per sq. in. gage.

FP—Vapor pressure of liquid at maximum surface temperature in lbs. per sq. in. absolute.

IP—Vapor pressure of liquid at minimum surface temperature in lbs. per sq. in. absolute.

FT—Maximum absolute temperature in vapor space.

IT—Minimum absolute vapor space temperature.

The curves in the accompanying graph are presented as a general guide to the selection of the correct storage pressures for various products. The data for plotting the curves was computed from the above relation using the following assumptions:

(1) Minimum surface temperature 10 deg. less than maximum surface temperature.

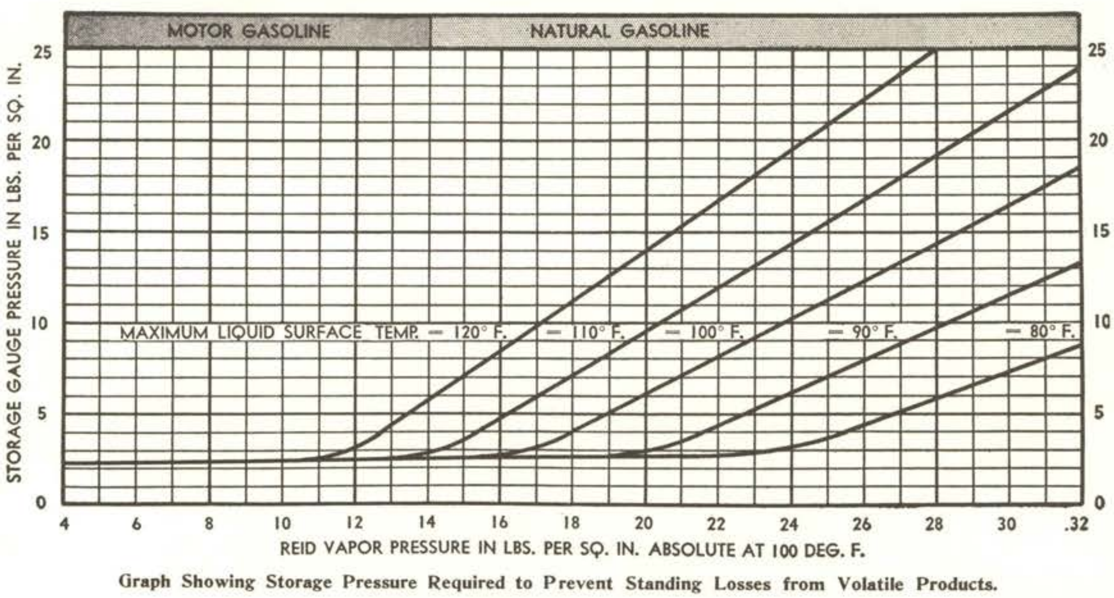
(2) Maximum vapor space temperature 40 deg. greater than maximum liquid surface temperature.

(3) Minimum vapor space temperature 15 deg. less than maximum liquid surface temperature.

Although these variations are extreme, they were purposely made so to give values slightly above the pressures actually required to eliminated venting. This allows a small operating margin. In order to use the curves, it is necessary to know the Reid vapor pressure of the product and the greatest temperature likely to be reached by the liquid surface. The vapor pressure determined by the Reid method is slightly less than the true absolute vapor pressure but the necessary correction is included in the curves.

Maximum liquid surface temperatures in the United States of America vary from 85 deg. F to 115 deg. F. In the absence of definite information regarding the maximum value for a given locality, sufficient accuracy will usually be attained by assuming that it is 10 deg. F. higher than the maximum temperature attained by the body of the liquid in a tank at that location.

To illustrate the use of the curves, suppose that 24-lb. natural gasoline is to be stored in a locality were the liquid surface temperature may reach a maximum of 110 deg. F. A vertical line extended upward from the 24-lb. mark at the bottom of the chart intersects the 110 deg. curve at a height of 14.5 lbs., the required pressure. A 15-lb. pressure should be used.




**Graph Showing Storage Pressure Required to Prevent Standing Losses from Volatile Products.**

Fig. 116

3. <u>Vapor Losses</u>:

We know from the study of the nature of natural gasoline that it vaporizes easily and even under pressure some of it goes out in the vapor recovery system. This brings up the question, is it a loss? Actually it is not as the vapor either is run back through the recovery system and made over again or is charged into the stabilizer. This makes a problem in the daily storage report. If the tanks show a loss in volume then the corresponding volume is made into the make tank along with the regular production and to get a true production figure for the day the gallons vaporized from storage must be deducted from total production. Various methods of handling the storage and production are used and more of this is given later.

The volume of vapor loss varies in direct proportion to the vapor pressure of the gasoline providing the same pressure is carried on the tank. This is reasonable as the molecular action actually is measured to be less in a 12-lb. product than a 26-lb. product.

Vapor loss today is a comparatively low percentage due to the correct pressures being carried, storage used, and the product being stabilized.

4. <u>Protective Relief Valves</u>:

In the discussion of regulators the statement was made that relief valves should always be installed on the downstream side of the reducing regulator. In the case of storage it either may be the downstream side of the reducing regulator when it is being pressured or the upstream side of the regulator holding a back pressure on the tank. If either regulator ceases to function the tank is liable to excessive pressure and it is essential that a pressure relief valve be installed to prevent an excessive pressure. A common type of valve used for this service is shown in Fig. 117. The weight on this regulator may be adjusted easily, for safety at different pressures to be used in the tank and the valve may be checked easily to see if it is stuck by lifting the lever.

Fig. 117

Another relief valve on storage which is just as important as the pressure relief is the vacuum relief valve. As much or more damage has been done to storage tanks by vacuum than by pressure. Although the same thing may be said about vacuum as was said about pressure in spherical and cylindrical containers that they will withstand more vacuum than other shapes, it does not apply to the size vessel that storage tanks are built.

There are three ways in which a storage tank may have a vacuum formed in it. First, if the back pressure regulator on the vapor recovery system ceases to function or sticks upon, then the plant vacuum or recompressor intake vacuum is on the tank. To keep this vacuum from building up (or the pressure from reducing) the vacuum relief valve on the tank must open, thus permitting the pressure on the interior of the tank to remain near atmospheric pressure.

Second, in hot weather the temperature of the contents of a tank goes up and the vapor space is filled with a lighter gas due to higher temperature. A sudden summer cloud and shower comes up and the cold rain falls on the tanks. This makes the tank act as a condenser, cooling the warm gases and condensing them. To see what the results of this condensation are, let us refer to some previous figures on gallons and cubic feet. It was said that 35 cubic feet of gas is the average vapor volume of one gallon of gasoline which makes a volume ratio of 35 x 7.5 to 1 or 610 to 1. Now, if the gas in the tank occupying 35 cubic feet is suddenly, say, half condensed, it will only occupy half the space with a resulting lowering of pressure or forming of a vacuum. This is what happens in the tank and the relief valve must open and let air come in to occupy the space of the gas condensed. This source of danger is more marked in the large 55,000 and 80,000 bbl. oil tanks. In one area, a sudden change of atmospheric temperatures and rain pulled in 6 or 7 of these tanks, because the relief valves were not large enough to permit the air to come in fast enough and equalize the pressures.

Third, steaming out of a storage tank for cleaning or preparing it for safe welding is common practice. When the steam is shut off, the tank must have sufficient opening to permit air to come in rapidly and take the place of the steam condensing. This is the same condition existing in the tank as in the case of gas condensing, except that the steam condensation will be more rapid when it starts. One cubic inch of water makes 1 cubic foot of steam of volume ratio of 1728 to 1. The rapidity of the condensation is well illustrated with an ordinary tea kettle. With only a cupful of water in the teakettle, it is set on the fire and boiled until the balance of the teakettle is full of steam and all air driven out. Then remove the tea kettle and place the spout under the cold water faucet, the first cold water entering the tea kettle will condense all the steam so rapidly that air can be heard plainly as it rushes in around the lid and in the spout. Many tanks have been collapsed by not leaving openings in them after steaming out.

When there is pressure in the tank the metal is under a tensile or pulling stress and is evenly distributed throughout the metal but when there is a vacuum inside, the atmospheric pressure on the outside puts the metal under a compression stress. The comparatively thin shell of a large tank which is not in a perfect circle will not stand this compression stress and soon collapses. Fig. 118 illustrates the direction of pressure on the tank shell under the condition of vacuum and pressure.

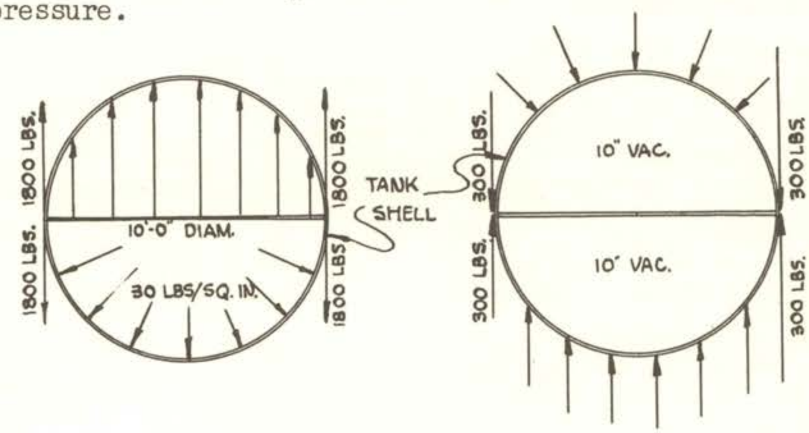



Fig. 118

In the sketch showing pressure on the tank, assume that it is a 10-foot diameter tank and the pressure is 30 lbs. and the tank shell is 1/4" thick. The internal pressure tends to tear the tank apart at the ends of a diameter. Though the pressure is everywhere at right angles to the surface of the tank, as shown in the lower half of the figure, the effect is as if it were exerted in the directions shown by the arrows in the upper half. While the diameter there shown is horizontal, the effect is the same at the ends of all possible diameters, that is, at all parts of the circumference of the tank.

The force tending to split the tank is resisted by the tensile strength of the metal. The formula for stress in the metal is:

$$S = \frac{dp}{2t}$$

Where d = inside diameter of tank
p = gauge pressure
t = thickness of metal

Then, the stress tending to tear the tank apart at the end of any diameter is $\frac{10 \times 12 \times 30}{2} = 1800$ lbs. per linear inch of tank. The stress in one linear inch of tank is 1800 lbs., and the tank is 1/4" thick, therefore, the stress in the metal equals: $\frac{1800}{\frac{1}{4}} = 7200$ pounds per square inch. If the metal has a tensile strength of 55,000 lbs. per square inch then, the factor of safety is: $\frac{55,000}{7200} = 7.6$.

Of course, the margin of safety decreases as the pressure increases on the tank. Taking into consideration the large area of the tank containing possible flaws, the possibility of corrosion, and the connections in a tank, this is near the maximum working pressure for a tank of this type.

Under conditions of vacuum then the stresses are reversed as shown in the right hand sketch of Fig. 118. Using the same formula as above we learn that the stress at any diameter is

$$S = \frac{120 \times 5}{2} \text{ (10" HG = 1 lb. pressure) = 300 lbs. per lineal inch of tank.}$$

$$\text{or } \frac{300}{\frac{1}{4}} = 1200 \text{ lbs. per square inch.}$$

If the tank were a perfect circle it is possible that it would withstand this stress without collapsing, but any small bend or distortion throws the forces out of balance and the tank goes in. All tanks of this size and thickness of shell are distorted enough to cause this to happen. The problem ceases to be one of compression strength of the material (iron has a compression strength of 36,000 lbs. per sq. inch), and becomes one of bending stresses, whose formulae for calculation are too complicated for this text. From a practical point of view, however, it may be seen that quarter inch iron with 300 # pushing at both ends as in the figure is very likely to give way.

The vacuum relief valve popularly used on small tanks is a vertical check valve. Fig. 119 shows this. With very small amount of vacuum the atmospheric pressure raises the disc. As long as there is pressure or atmosphere on the tank the disc remains seated but as soon as the atmospheric pressure is greater all it has to overcome is the weight of the disc in the check valve. The amount of pressure required to lift the check can be calculated by weighing the disc and calculating the area of the disc exposed to the atmosphere. For example, a two-inch check disc weighs approximately $\frac{1}{4}$ of a pound and the area of the disc is approximately three square inches. Then a vacuum removing $\frac{1}{4} \times 1/3$ or $1/12$ of a pound (less than $\frac{1}{4}$" mercury vacuum) per square inch above the disc would lift it and allow air to enter the tank. It is evident that these check valve discs should be lifted regularly and reported to see that they are not stuck or inoperative.


Fig. 119

There is a requirement with regard to the installation of both safety valves that should always be followed, namely, that they be near the tank and no valves or stops between the valves and tank. This is to prevent any possibility of the tanks not being safeguarded at all times. Fig. 120 shows a piping installation on storage tanks, note the relief valves next to the tank.

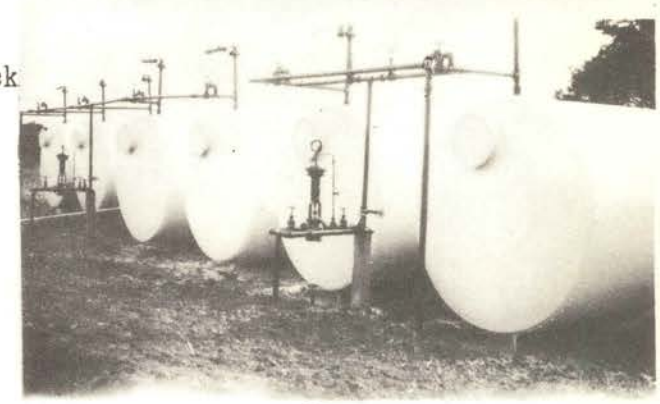


Fig. 120

5. <u>Installation</u>:

Storage should always be installed on the lower or down-hill side of the plant proper and at a safe distance in case of fire. If there is a break, leak, or run over the gasoline at storage, then the drain will not be towards the boiler house. In case of fire at storage and a tank bursts then the plant is not endangered. The location should also take into consideration the direction of the prevailing wind and the storage be placed on the off-wind side so that vapors from storage will not blow towards the boiler house but away from it.

The horizontal tanks are placed in concrete or steel cradles which have enough footing to hold the filled tanks without settling. The piping headers for gasoline in and out, and for gas pressure and vapor recovery are installed with a minimum of pipe for convenience in operation. Walkways overhead may be used to operate the pressure line and check relief valves, or light ladders may be used.

The location of the headers are according to the individual design and may be influenced by the outlets built into the tanks. Fig. 121 is a piping sketch of a storage hook-up. There are many variations and other connections such as the treater and transfer lines.

When the ground slants are suitable and soil is easily moved, storage may be covered. This is done by a partial excavation, the tanks set, and dirt slipped back over tanks. Buried tankage keeps the product much cooler during the summer months thus preventing a great deal of evaporation.

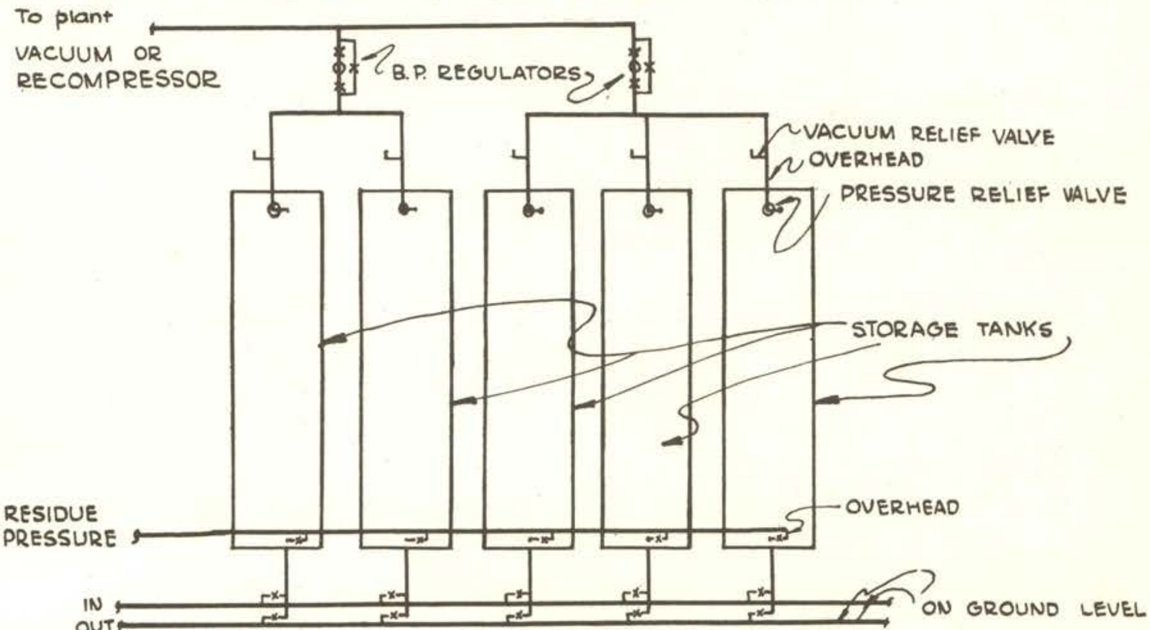



Fig. 121

6. Maintenance:

Maintenance of the tanks proper consists mainly of keeping them coated with a rust preventing paint. For open storage, various paints are available. Aluminum and white paint are used to reflect the heat from the tank. Where sprinkling is used, a periodic cleaning and repainting is required. On underground storage, a coating of tar and tarpaper is used. Water drains are installed in the bottom and the regular and frequent draining of the water assists in preventing corrosion on the inside. Weeds and plant growth should be cleaned away from under and around storage tanks. They are a fire hazard. A steam snuff line is good practice near storage.

A water drain of the type shown in Fig. 122 is used and given as a suggestion to prevent freezing of the valves. Water standing in the fittings and valves under the tank in the usual location freeze and burst. With this type drain the water can be drained or blown out of the bottom of the tank through the outer valve, the upper valve closed. The outer valve is closed and the upper valve opened to allow any water to return back into the tanks and not freeze up in the outer fittings.

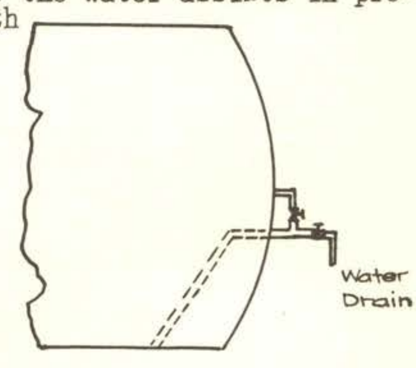



Fig. 122

7. <u>Gauging</u>:

Gauging on the horizontal tanks is practically all done by means of staggered gauge glasses, a permanently fixed gauge pole along side the glasses and the tank gauge tables. Fig. 123 shows one arrangement of the glasses and pole. The gauge tables are calculated and made up from strappings by the engineering department or tank manufacture and made available at the plant. The table reads to ¼" divisions.

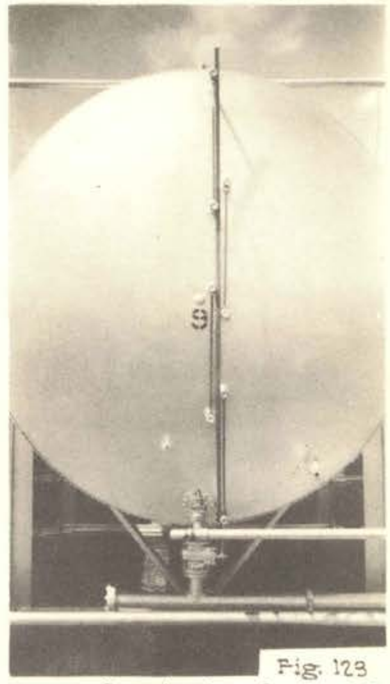


Fig. 123

On the large tanks, where no pressure is carried, tapes similar to that shown in Fig. 124 are used. To gauge gasoline (which evaporates rapidly) with this type of tape chalk or some other substance has to be used to retain the liquid level mark. (Tanks under pressure without a gauge glass.)

In the study of expansion and contraction of materials at different temperatures it was learned that each material had a definite coefficient of expansion. The expansion of liquids is more rapid than solids and is so great that in order to get a correct volume reading of gasoline it is necessary to make a temperature correction. The standard temperature for all transactions and to which the correction is made is $60^{o}$. The reason for this choice is that it is as near an over-all average temperature winter and summer as could be estimated at an even figure.

The correction factor used is .0008 per degree. An example: if 8000 gallons is the gauge figure of a tank of gasoline and the temperature is 75, what is the corrected gallonage?

$75 - 60 = 15$ degrees

then $8000 - (15 \times .0008 \times 8000)$ or $8000 - 96 = 7904$ gallons.

If the temperature is less than $60^{o}$ then the correction would be added. Different correction factors are now being used for different grades of gasoline.

This correction usually is made only on sales, transfers, or on long storage. The reason for this is evident when you think of how much work it would make to get the temperature of each tank carried on the storage reports with corrected gallons. To avoid this all plant storage is assumed to be $60^{o}$, except possibly in the case of a large tank holding 2 to 3 million gallons. In this case, the correction for one degree on 2 million gallons would be 1600 gallons and in all probability it should be carried at the corrected figure.


Fig. 124

The gauging of tanks and tank cars under pressure and with gauge glasses is done in various ways. Fig. 125 shows two of these methods. On the left the float and weight are attached on either end of the tape. Gauge reading is made on the tape through a glass window over the pulley supporting the weight.

The second method on the right is the one used on propane and butane tank cars. The small steel tube, about the size of ¼" pipe, is graduated. The lower end is open and it slips up and down through a stuffing box built in the tank top or dome. There is a valve on the top end of the pipe. To gauge the tank the tube is raised, the valve opened and vapor only passes out the valve. The tube is then lowered slowly until at the point the lower end meets the surface of the liquid and the liquid appears at the upper valve. The gauge can then be read on the graduated tube.

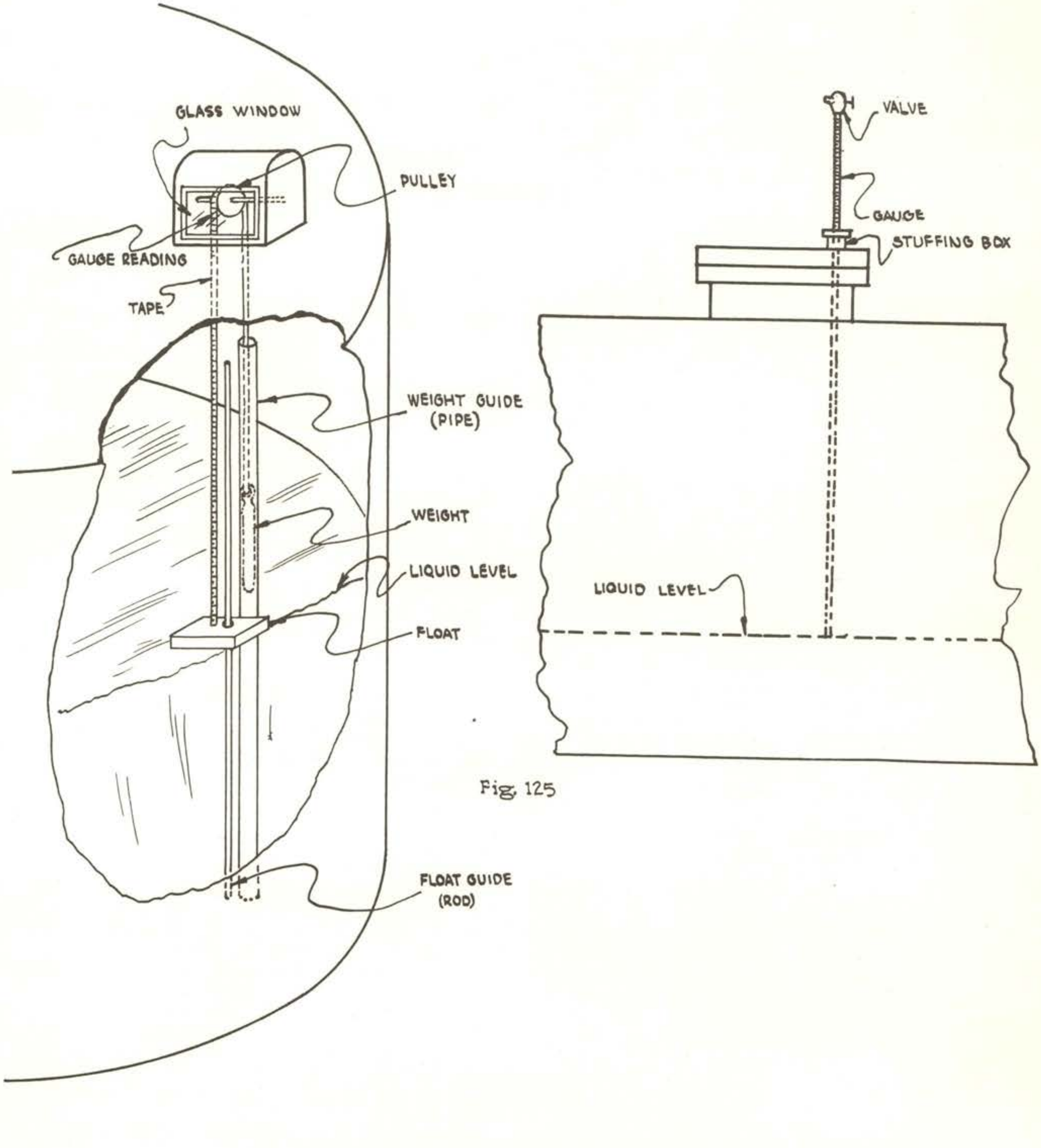

GLASS WINDOW
PULLEY
GAUGE READING
TAPE
WEIGHT GUIDE
(PIPE)
WEIGHT
LIQUID LEVEL
FLOAT
FLOAT GUIDE
(ROD)
VALVE
GAUGE
STUFFING BOX
LIQUID LEVEL

Fig. 125

UNIT X

LOADING AND PRODUCT DISPOSAL

1. Loading Rack:

Loading rack construction varies from a pipe sticking up along side a spur track to 50 and 100 car racks. As soon as a plant site is established the nearest point possible on the railroad is leased for a spur track and loading rack and work is started on its construction in time to take care of production when the plant starts.

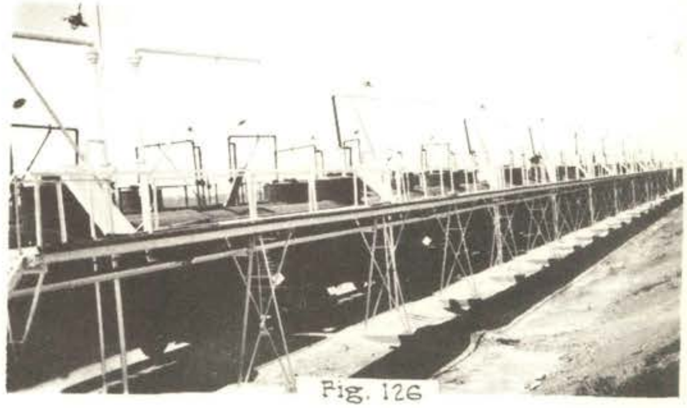


Fig. 126

The equipment at the spur varies to suit the existing conditions. The rack proper, Fig. 126, may be all that is used. Auxiliary storage tanks may be installed for blending and transfer purposes. A vapor recovery system is used when near enough to the plant or its vacuum systems. A complete recovery plant is installed at large isolated racks.

2. Tank Car:

Fig. 127 is a typical natural gasoline tank car. Its dimensions are approximately 7'0" x 29'0" and the dome approximately 2'0" x 4'7". The approximate capacity is 8,000 gallons. This gives vapor space of about 3+ per cent. The

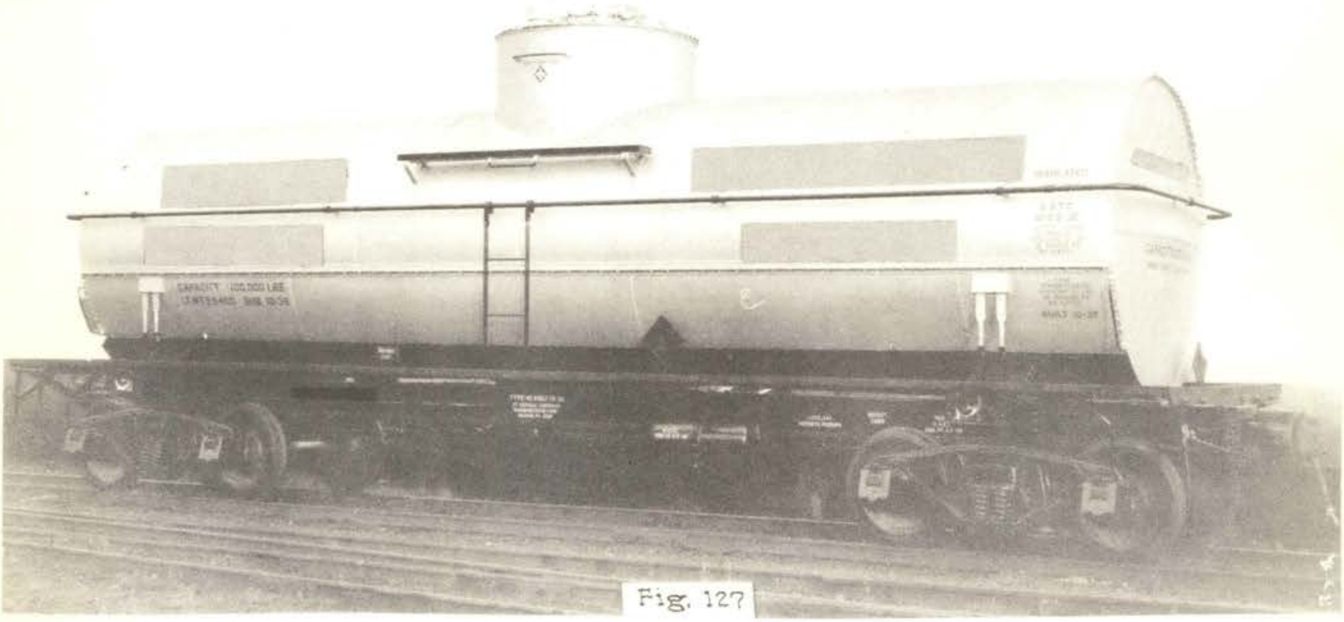


Fig. 127

dome has pressure relief valves set to relieve it and are inspected and tested every six months. The whole tank and dome has two inches of insulating material. The thin metal cover over the insulation is the painted shell seen. The outlet valve is operated by a hand wheel inside the dome shown in Fig. 128.

Loading is done through the dome by removing the cover. The car is unloaded through the outlet valve and belly plug.

The rules are given and reasons follow to show why rules are used. Various other rules and practices can be brought out by the loader in class discussion.

The loading of butane and propane is done under pressure and more particular care is required. Attention is called to the weight allowed. The car is stamped "Water capacity of tank ___lbs." By using the gravity and temperature of the loaded product an equivalent weight in gallons is calculated and by using the tank gauge table the height to which the car is to be filled is read and used. This gauge is watched closely and the car is filled to the exact gauge for two reasons. One, to ship the car loaded to capacity and, two, not to go over the gauge indicated. This leaves a safe margin of vapor space for temperature changes. In the natural gasoline car the dome takes care of this, but there is practically no dome on the butane and propane cars.

The taking of a sample from the car after loaded is an operation requiring care. A number of methods of attaching weights and inverting mechanisms to bottles are used in order to get representative samples from the car. Immediate capping of the bottles is necessary. It has been found advisable to add a small amount of water to the sample in the bottle and to keep the bottle inverted. (See Fig. 129). Any leakage then is water and preserves the gasoline sample. Better sample bottles whose caps are tight eliminating this requirement are now in use.

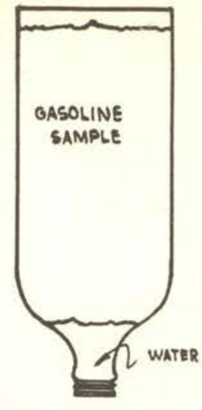



Fig 129

Fig. 130

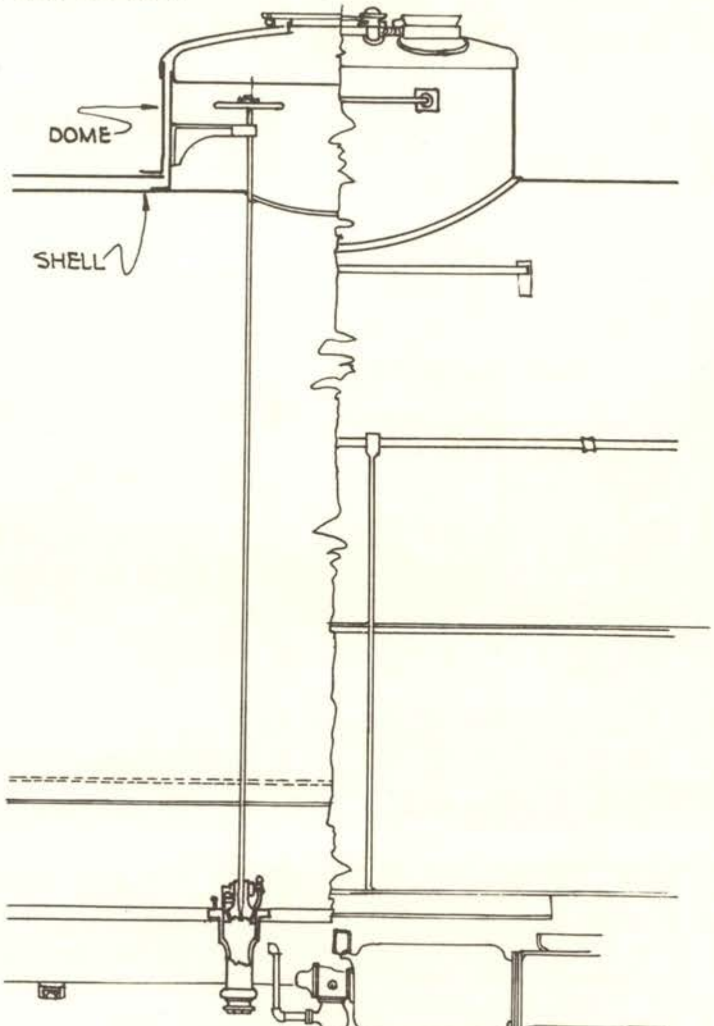



Fig. 128

Temperature of the car product is taken with a special tank thermometer, Fig. 130. The cup around the bulb retains gasoline around the bulb when the thermometer is drawn up out of the tank thus keeping the thermometer bulb temperature the same long enough to read.

3. Tank Truck:

In some instances as mentioned before, natural gasoline is transported by tank truck. These trucks may be the usual gasoline transportation trucks seen on the road, but they have to be specially equipped with a dome or loaded less than shell full and with relief valves. Loading is done near the plant but at a safe distance from any vapors on account of the motor of the truck being liable to ignite them. Greater precaution is necessary on this account taking care of the loading vapors and in seeing the tank does not run over. A tank truck for natural gasoline and propane and butane is shown in Fig. 131.

Fig. 131

4. Bottles:

Propane and butane are marketed in small quantities for home use. They are filled under pressure similar to tank loading. These bottles, Fig. 132, resemble oxygen bottles used for welding and are built to hold the pressure required plus a large factor of safety.

5. Pipe Line:

If the pipe line takes the plant production, the procedure is to gauge and pump out under the pipe line gaugers' supervision. The product is tested and handled on a similar basis as tank car or other sales.

6. Vapor Recovery:

Loading in an open tank car (with dome cover off) especially in hot weather and with the higher vapor pressure products has caused the loading loss from vaporization to run into considerable figures. To save this loss a special dome cover is used, Fig. 133, if the car dome cover does not have proper connections, and the tank is loaded under a slight pressure and the vapors taken off a second connection in the cover through a regulator which is set to hold the required back pressure, and then run into the plant intake or vacuum system. In this manner, although loading will show some loss in gallons, the gallons are recovered back in the plant. The vapor recovery header is run along the rack with an outlet for each spot and one regulator may be used for all loading.

Another method of reducing loading loss is that of refrigerating or cooling the product being loaded. With the cold product, the vaporization during the loading period is reduced to a very small per cent.

Fig. 132

7. Safety Precautions:

Loading itself appears to be an inconsequential task, that is, turn the gasoline into the cars and shut them off. However, experience shows that to do the job correctly, the loader should watch out for all hazards and preparing the car for shipment is no mean task. None of the regulations can be neglected. Complete instructions are always made available, and the Interstate Commerce Commission and Bureau of Explosive rules with regard to the car must be followed. A few of the rules for general information follow:

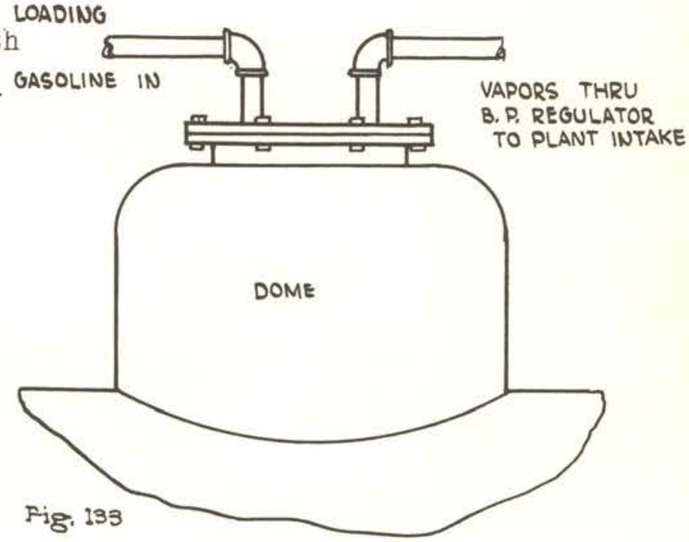



Fig. 133

The belly plug is to be removed and left off until loading is completed. The reason is that the outlet valve above it may be stuck or bad and when the buyer receives the car he is unable to unload through the belly plug. The outlet valve should be opened and closed before loading to see that it is in good operating condition. The location of the belly plug and outlet valve with reference to one another (one type) is shown in Fig. 128.

The dome cover gasket should be carefully inspected and a new one used if faulty. When loaded cover is to be bolted down securely and sealed. Flammable placards are to be placed in all holders.

Car is to be filled only shell full. Fig. 128 shows what is meant by shell full. The dome is for expansion space as the gasoline will occupy more space if the temperature increases.

With the best of walk ways and rack to car bridges, the job of preparing the cars to load and closing them for shipment is hazardous. In wet weather and under icy conditions it is particularly so. In using a wrench on the dome cover bolts be sure the feet are well planted and if possible keep one hand with a good hold on the step or cover in case the wrench slips.

It is good practice and almost universally done, to bond all the rails together along the rack by means of a flexible wire being welded to the ends of adjacent rails, then a good ground bonded to the rails and rack proper if of metallic construction. The reason for this is that gasoline passing through a line or moving around inside its container generates static electricity. This is especially true with regard to some loading hose and it has been found expedient to ground or bond the hose to the rack to carry off the static. Under suitable atmospheric conditions an unbonded rack has been known to become so charged with the static that it was impossible to load. One instance is known of eight fires starting in one evening on such a rack.

## UNIT XI

## PLANT LABORATORY

The laboratory is the place where the finger is put on practically all the plant operation. Just as all phases of any manufacturing processes have to be checked on, so each phase of operation in the gasoline plant is checked on in the laboratory. Any faulty operation of the equipment that is not apparent, low production or experimentation for improvements is connected with the laboratory. The final check on a product ready for shipment is also made here. The more important jobs done in the laboratory are taken up in this chapter.

1. Absorption Oil Control:

Under distillation the fact was stressed that the oil be completely stripped of its gasoline content. The efficiency of absorption also depends on not attempting to overload the oil with gasoline. To check the condition of the lean oil to see if it contains any gasoline and the condition of the rich oil to see if it is carrying the required amount of gasoline fractions, samples of each are brought to the laboratory.

Each sample is then raised to a temperature that will drive off or vaporize all gasoline vapors in the A. S. T. M. distillation apparatus shown in Fig. 134. The vapors are condensed and collected in the receiving jar shown at the right. If the lean oil shows any content of gasoline then adjustments are due in the still temperatures or in the rate of oil circulation or in both. If the rich oil is carrying a higher percentage of gasoline than recommended under the conditions and too much to get complete absorption of all fractions wanted from the gas (selective absorption) again adjustments in ratio and still temperatures may be required. The rich oil content is adjusted by changing the oil gas ratio to get more selective absorption.

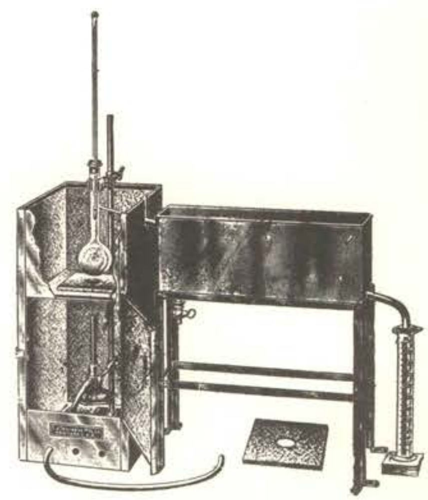


Fig. 134

The mechanics of the distillation process in the laboratory is carefully set out in the A. S. T. M. manual. Class discussion of this process will be very beneficial especially with a visit to the laboratory.

2. Stabilizer Control:

The point at which the most interest is on the stabilizer is the outlet product. If 20 lb. V. P. product is desired then 20 lb. (slightly under is best practice) is wanted at the outlet. To check this frequent "bombs" are run. The adjustment to raise or lower the vapor pressure of the product is by varying the temperature in the reboiler. This is after the pressure to be carried on the tower is settled on for best results. To change the temperature of the reboiler is a matter of resetting the automatic temperature control device. By increasing the temperature, the vapor pressure of the product is decreased and by decreasing, the vapor pressure is increased. This follows up the operation given under fractionation in which the heavier vapors were going down and lighter up. If the temperature is raised in the bottom of the stabilizer more lighter vapors are going to be driven up and likewise if the temperature is reduced in the bottom, more of the lighter fractions will remain condensed.

The laboratory is responsible for checking the Reid Bombs for leakage and for correcting the pressure gauges and final check of the vapor pressure of the product. The Reid bomb, Fig. 135 is the A. S. T. M. approved bomb and method.

Construction of the bombs conforms strictly with A. S. T. M. specifications. The bomb consists of a lower cylinder, or gasoline chamber, connected to a larger upper cylinder, or air chamber which is surmounted by a pressure gauge. When possible fill the gasoline chamber by immersing it in the gasoline to be tested. The upper and lower cylinders are then connected, and the bomb is inverted several times before being placed in a water bath maintained at 100°F. After five minutes the bomb is withdrawn, shaken vigorously and again returned to the bath; this repeated at two-minute intervals, until the vapor pressure reaches a maximum as indicated by the gauge.

The Reid bomb is not only used in checking the stabilizer but also all other gasoline in storage and the loaded product.

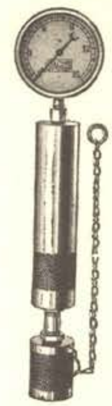


Fig. 135

3. Treater Control:

The treater is to sweeten the sour raw make. Treaters have to be constantly checked to see that the treated product does not go sour. Gasoline samples before and after treating are taken to the laboratory and checked with the doctor solution and powdered sulphur as mentioned above. By increasing the amount of gasoline in the sample and watching to see if the sulphur turns or feathers is one method of seeing if the treater is nearing the place of recharging. Another method where the raw make is not too sour is to add a small amount of raw into the sample to see if it turns the sulphur. Some experience is needed with the individual plant to get reliable information as to the condition of the treater.

4. Shipping Tests:

The following sheet, Fig. 136, is a typical sheet of data on the product shipped.

The equipment for distillation is the same as that used for the oil samples. Precedures for running the gasoline recovery test are specific and a copy should be brought to class and discussed. If possible the class should be held in a laboratory and a distillation run through with explanations.

5. Gas Analysis for Air:

The test for the presence of air in natural gas is done with the Hays equipment, Fig. 137. The sample of gas is let into the first burette which is graduated and a carefully measured quantity is retained. An experienced operator can best explain this and the complete operation by using an available analyzer in the presence of the class. This original sample then is forced over into the pipette containing pyro-gallic acid which absorbs all the oxygen (if any is present) in the sample. The gas sample is then drawn back into the first burette and the decrease in volume measured. The burette is so calibrated that the reading on it is multiplied by 4.78 which gives the per cent air present in the original sample.

The other two pipettes are for removing and thus checking the volume of carbon monoxide (CO) and carbon dioxide ($CO_2$) present in the sample. Neither of these gases generally appear in natural gas treated by plants. Some fields do produce a large percentage. All three pipettes are used in checking the flue gases of a boiler to see if proper combustion is taking place.

In case the gas sample has to come from a vacuum line, a pump, Fig. 138, is used. Great care must be taken that all connections are tight to prevent pulling air in from the atmosphere with the sample. The pump itself should be immersed in water occasionally and pressure applied to see if it leaks. If the vacuum line is near the laboratory a motor driven vacuum pump, such as in Fig. 139, may be used.

6. Other Laboratory Equipment:

Laboratories are supplied with various accessory equipment according to the products made and the amount of experimenting or research carried on. Some of the following equipment and accessories may appear other than that already mentioned.

A compressed air line may be piped in and used for agitation and various other purposes. A butane and propane line may be run to the laboratory and expanded through the condenser and receiving jar in copper coils to make ice.

Electric heaters are used to replace gas for heat in the distillation units, for the Reid bomb baths and for the corrosion tests.

Various flasks, thermometers, receiving jars, tubes, receiving graduates can best be explained in the laboratory.

A gauge tester is essential equipment for checking the bomb gauges. The

# Engler Distillation Test

Date ______ Barometer ______ Mm. A.S.T.M. Engler No. D216-32

| | | | |
|---|---|---|---|
| Obs. Gr. °API | | @ | °F. |
| Corr. Gr. °API | 81.0 | @ 60° F. | |
| Room Temp. | 92 | | °F. |
| Measured @ | 32 | | °F. |
| Condensed @ | 32 | | °F. |
| Received @ | 32 | | °F. |
| Recovery | 97 | | % |
| Residue | .6 | | % |
| Loss | 2.4 | | % |
| Color | 30 plus | | Saybolt |
| Corrosion | Neg. | | |
| Doctor | " | | |

Description of Sample:—

18# Natural Gasoline

Grade - 18/55

% Evaporated @ 100°F - - 27.4

% " @ 140°F - - 57.4

% " @ 212°F - - 88.4

Thermometer No. ______

Thermometer Temp. at start ______ °F.

Thermometer Temp. after 2 min. ______ °F.

Time from start to first drop ______ Mins.

Vapor Pressure ______ @ ______ °F.

Vapor Pressure 18# @ 100 °F.

Run by ______

| % Over | TEMP. °F. Obs. | TEMP. °F. from cve. |
|---|---|---|
| First Drop | 82 | |
| 5 | 86 | |
| 10 | 89 | |
| 20 | 97 | |
| 30 | 107 | |
| 40 | 118 | |
| 50 | 131 | |
| 60 | 147 | |
| 70 | 167 | |
| 80 | 195 | |
| 90 | 226 | |
| 95 | | |
| D.P. | | |
| E.P. | 314 | |
| 25 | | 100 |
| | | 122 |
| 55 | | 140 |
| | | 161 |
| | | 199 |
| 86 | | 212 |

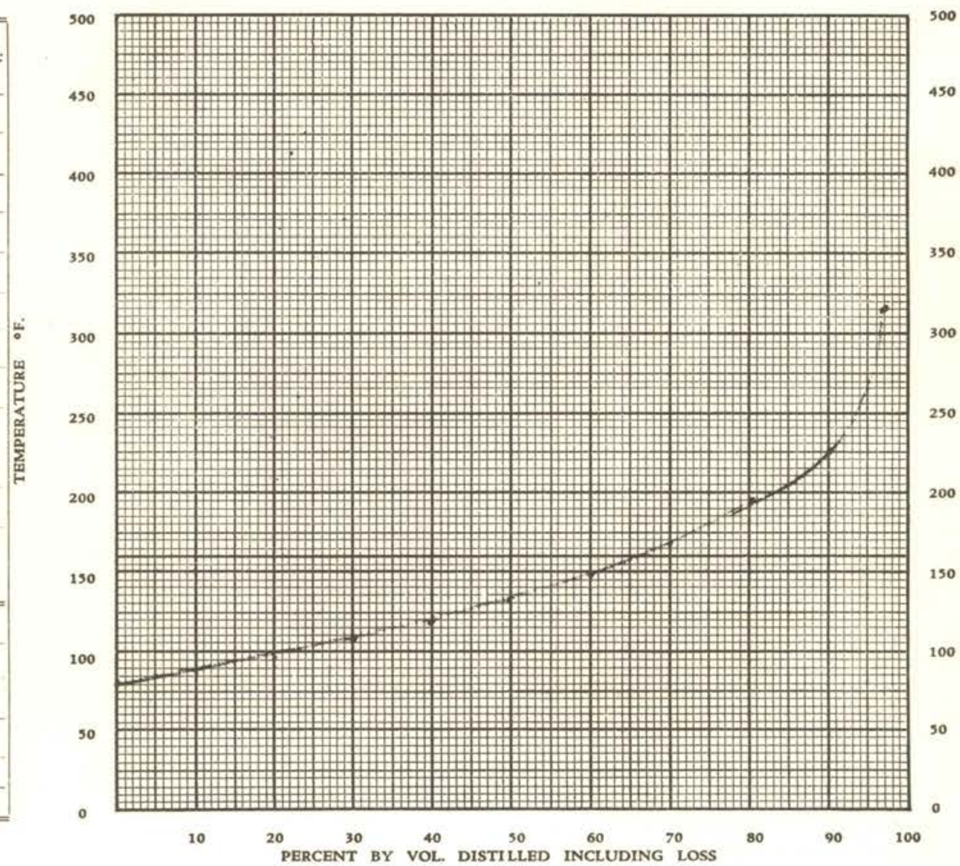



Fig. 136

Fig. 137

Fig. 138

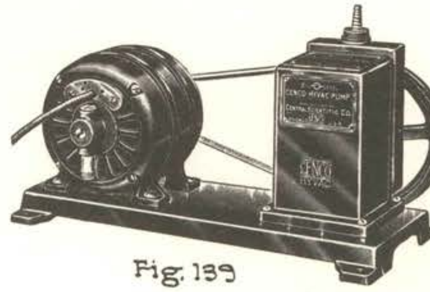


Fig. 139

mercury column with calibrated scale is the approved type. They are often constructed in the plant. Fig. 140 is one possible arrangement. A column of mercury 2.08 inches high is equal to 1 lb. pressure. The glass tube and scale will need to be a little over 54 inches high to gauge up to 26 lbs. and higher for higher pressures.

In areas of lean gas and for testing the residue content a small charcoal absorber and meter, Fig. 141, is part of the equipment. The gas sample is metered through the charcoal and the charcoal with glycerine or mercury is placed in a flask and the vapors driven off and condensed with the same distillation apparatus mentioned before or with special apparatus as in Fig. 142. Method of procedure is given in manual.

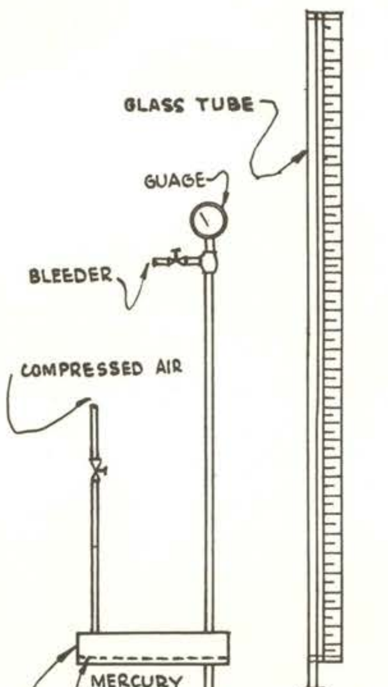



Fig. 140

Fig. 141

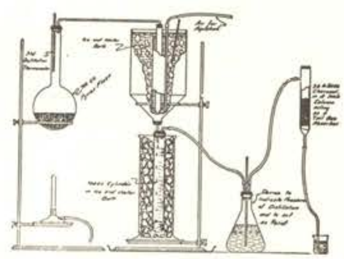


Fig. 142

UNIT XII

## ORIFICE METERS

Someone has said that measurement is the finding of "how much or how many" of "what". In this case the "what" is natural gas. The question of "how much" does not enter into the picture until the product is sold to someone else. Then it must be measured in definite quantities by a standard measurement.

1. The Unit of Measure:

The unit of measure in both the natural and manufactured gas industry is the cubic foot. A cubic foot of a solid or a liquid is a definite quantity, but a cubic foot of gas may be exceedingly variable. The U. S. Bureau of Standards in its Circular 32, "Standards for Gas Service" sets up the following specifications for a cubic foot:

> "When the gas itself is to be tested under these rules a cubic foot of gas shall be taken to be that amount of gas which occupies the volume of one cubic foot when saturated with water vapor and at 60°F. and under a pressure of 30 inches of mercury. For purpose of measurement of gas to a consumer a cubic foot of gas shall be taken to be the amount of gas which occupies a volume of one cubic foot under the conditions in such consumers meter as and where installed."

Later the same specifications were made to read "a pressure of 30 inches of ice cold mercury at standard gravity". Although this sounds theoretical, and in fact is not adhered to as closely as the specification indicates, two facts are apparent; first, that to measure gas in cubic feet a definite temperature is necessary, and second, a definite pressure must be adhered to. This is not beyond our thinking, because we learned from Charles' law that the volume varies inversely with pressure, hence the necessity of standards or bases of both temperature and pressure. It must be remembered that all temperature measurements will be absolute temperature and also that all pressure measurements will be absolute pressure since they are the only standard bases.

2. Temperature Base:

The standard of temperature is called the "temperature base". Unfortunately no universally recognized temperature base exists for the country as a whole, consequently, only a supposed base can be used and the operator must use that which is customary in his own locality. Supposing that a temperature base of 60°F. is adopted, a measurement made at any other temperature can be expressed at the desired base by multiplying the measurement by the direct ratio of the base to the temperature of measurement, both expressed in degrees absolute. Thus, if 10,000,000 cubic feet of gas have been measured at the well at 35°F. but sold at the base temperature of 60°, the correct measurement may be found as

$10,000,000 \times \frac{60 + 460}{35 + 460}$ which equals 10,505,000 cubic feet. The quantity of gas is exactly the same by weight in both cases, but at the high temperature occupies more space.

Tables are prepared giving the multipliers to use in converting measurement temperature to base temperature. These tables vary with localities because of the variance in base temperatures.

3. Pressure Base:

The standard of pressure is called the "pressure base", and as with temperature, no universally accepted pressure base is in use. That indicated in the Bureau of Standard specification is atmospheric pressure at sea level, which is absolute, and expressed in pounds per square inch is 14.7. Since atmospheric pressure differs with different altitudes and atmospheric conditions, no standard is possible and all pressures must be changed to absolute. Commonly 14.4 is used in the gas fields of the Mid-Continent area, but in California 14.73 has been adopted as standard. In some localities the pressure base is made a certain amount above atmospheric pressure, thus the figure 14.65 is frequently used, this being a pressure four ounces over an assumed atmospheric pressure of 14.4 pounds.

Since there is no universal pressure base, it is absolutely necessary to state what pressure base is used in any measurement of gas. The pressure base should be stated in terms of absolute pressure, in order to avoid any possibility of uncertainty from the fact that the atmospheric pressure is different at different places because of difference in altitude.

Quantities measured at any pressure base can be expressed at any other. Thus, suppose that gas has been measured with a pressure base of 14.4 pounds per square inch and we want the quantity at 14.7 pounds. Since the volume varies inversely with the absolute pressure the measured volume can be multiplied by

$\frac{14.4}{14.7}$ to get the desired volume at a pressure base of 14.7 pounds per square inch absolute.

4. Measurement of Volume:

The volume of gas can be measured on a commercial scale by one of three methods; first, find how many times it will fill a vessel of known capacity; second, measure the velocity of a stream from a pipe of known size; and third, measure the amount of heat required to raise the temperature of the gas a certain number of degrees.

The first method, finding how many times the gas will fill a vessel of known capacity is called the displacement method, and the best known apparatus for this method measurement is the domestic meter. In this the gas fills a measuring space, trips the mechanism and is discharged into the consumers line. The operation is repeated and each time the amount is tallied by the counting mechanism. It is apparent that the displacement meter can be used only for small quantity measurements, else the meter would have to be too large and too rapid acting to be usuable. However, some are made for measuring gas at pressure measured in hundreds of pounds. The displacement meter is explained in the Natural Gas text. Measuring the velocity of the gas stream to determine volume is the method used in gasoline plants.

The measurement of volume of gas by the temperature method is exceedingly complicated and seldom used, it giving way to the velocity method.

5. The Orifice Meter:

The orifice meter is used far more than any other for the measurement of large quantities of gas. It makes use of the fact that a narrowing of a pipe through which a gas stream is flowing causes an increase in the velocity of the stream. This increase in velocity is best explained in the use of a fire hose. So long as the stream is in the hose, it can be carried where desired, but when it becomes necessary to carry a stream of water from the end of the hose against the resistance of air and gravity to a fire, extra velocity must be attained. In other words the velocity of the water stream at the end of the hose must be increased to the extent that it will carry through space perhaps a hundred feet to the point desired. To do this a nozzle is attached to the hose narrowing down the size of the stream. As has been stated in the course in Elementary Science, this gives the center of the stream added velocity, and although not so much water leaves the nozzle, the stream has enough velocity to carry it to the point desired.

Just so with a stream of gas in a pipe line. A narrowing of the space in the pipe increases the velocity of as much of the stream as can pass through the narrowed opening. Especially is this true if the narrowing is done with an orifice plate, that is, a plate that will fill the pipe but has a hole through its center, Fig. 143. When this plate is set into a gas line it is apparent that the gas stream passing through the orifice will have a greatly increased velocity, but will emerge on the down stream side and again fill the pipe center with less pressure than

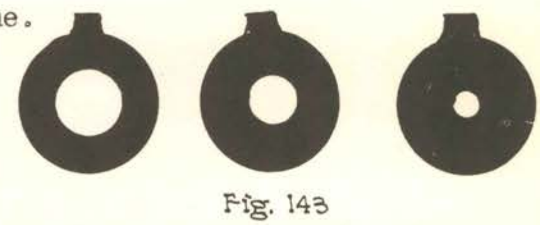


Fig. 143

it had on the upstream side of the plate, due to the fact that a part of the pressure energy was lost in the impact against the solid part of the plate. After the stream has spread into the pipe, velocity will be decreased in proportion to the decreased pressure.

The two different pressures, one above and the other below the orifice form a basis for computing the rate of flow of gas through the orifice. This difference is referred to as a "pressure differential". It also is apparent that the difference of pressure and consequent flow will be determined by the size of the orifice. Thus, by knowing the pressure differential at the orifice, and knowing the size of the orifice it is possible to determine the amount of flow or volume of gas.

The pressure differential only indicates the rapidity with which gas is passing through the orifice and the entire flow would be changing the line pressure. Thus, if the line is carrying a certain volume of gas at 110 lbs. absolute pressure and the pressure is increased to 140 lbs. the flow would be increased by 140/110 of the original volume.

Formulas and tables have been worked for determining the volumes of gas passing through to a gas line based upon the following factors:

a. Size of the line
b. Size of the orifice
c. Static line pressure
d. Pressure differential
e. Temperature absolute of gas
f. Density of gas

Fig. 144 shows a simple arrangement for obtaining these data. The pressure differential is measured as the difference in the levels of the water columns as "1 inch of water" and so on. The static or line pressure is indicated by the spring pressure gauge. Either the gauge begins numbering at absolute zero or gauge reading must be changed to absolute. The other factors, size of the line, size of the orifice, density of the gas, and temperature of the gas must be determined to start with. The method of computing volume will be given in a following section of this unit due to the fact that it applies to other means of measurement.

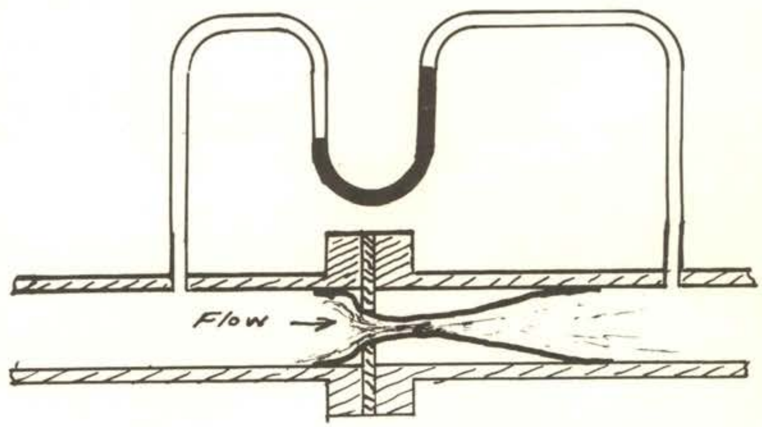



Fig. 144

6. Density and Specific Gravity in Measurement:

The specific gravity of a gas is a ratio of its density to the density of air. This has been fully explained in the course in Elementary Science. Knowledge of the specific gravity of gas is essential when the gas is being measured through any type of orifice meter. When gas passes through an orifice creating a pressure differential, the differential will be changed in direct proportion to the density, and the gas measurements obtained must be adjusted according to the density of the gas.

Natural gas is usually composed of a number of hydrocarbon gases. These gases have different densities and the density or specific gravity (the density ratio) of any particular gas depends upon whether or not it is composed of heavy or light gases. Referring to a specific gravity table it is found that the different hydrocarbon constituents have the following specific gravities:

| | |
|---|---|
| Methane.......... | .5546 |
| Ethane........... | 1.0400 |
| Propane.......... | 1.5230 |
| Butane........... | 2.0070 |

Consequently, the specific gravity of natural gas may run from one extreme to the other.

To illustrate the use of the specific gravity factor, we may consider that gas with a specific gravity of .60 is being put through an orifice plate at the rate of 100 M cubic feet per hour, causing a differential of 10 inches on the manometer. Now, if this gas be shut off and gas with specific gravity of 1.2 were turned through the same orifice meter at the same pressure and at the same rate of 100 M cubic feet per hour, the differential would show 20 inches due to the doubling of the density. This shows that the density of the gas is a determining factor in that if the pressure differential were kept the same the volume would be measured high for the greater density volume gas. Most measurement tables are made for a specific gravity of 1.0 and any deviation from that must be considered in the calculations.

7. Computing the Flow of Gas:

The engineers formula for computing the flow through an orifice looks like this:

$$Q = 218.40\ C_v d^2 \frac{T_B}{P_B}\sqrt{\frac{hp}{T_f G}}$$

In this formula, the symbols have the following meanings:

- $Q$ = volume of gas flowing in cubic feet per hour.
- 218.40 = a factor generally adopted that includes a group of conditions that cannot otherwise be accounted for.
- $C_v$ = the coefficient of velocity, the ratio of actual velocity to theoretical velocity.
- $d$ = the diameter of the orifice in inches.
- $T_B$ = the pressure base in pounds absolute.
- $P_B$ = the static pressure in pounds absolute.
- $h$ = the differential in inches of water.
- $p$ = the static pressure in pounds absolute.
- $T_f$ = the temperature of the flowing gas in degrees absolute.
- $G$ = the specific gravity of the flowing gas, air = 1.

Now, that would be some job if the operator had always to use that formula. Fortunately though, many factors are eliminated and others combined until the formula has been shortened to the following: $Q = C\sqrt{Ph}$ in which

- $Q$ = the volume of gas flowing in cubic feet per hour.
- $C$ = the hourly coefficient of the meter, that is with a certain size orifice in a certain size pipe, with the gas at a definite temperature, generally 60°F. and with a definite specific gravity.
- $P$ = the static pressure in pounds absolute (gauge pressure + 14.4).
- $h$ = the differential of pressure in inches of water.

If, however, some of the factors included in the simplified formula are not constant, corrections must be made. Among these factors are temperature, gravity, size of pipe, size of orifice, etc.

Now, it is easy to see that under the above standard conditions, a table can be arranged for each meter, using definite sized orifices in definite sized pipes. These tables are furnished with each meter by its manufacturer and apply to that particular meter only.

Moreover, it is apparent that if a line be operated at a constant pressure and a constant differential, it is predetermined that just so many cubic feet of gas are passing the orifice per hour, and the number of hours is the only variable. The table showing "how much per hour" for a particular set-up at a definite static pressure and a definite differential is all that is needed to compute the total volume flow.

8. Mechanical Factors that Influence Measurement:

It is apparent that all the methods for measuring natural gas that have been described are methods of precision, that is, conditions must be just right if they are to be accurate. The mechanical operation of the gas flow may affect these measurements. Two such conditions are "turbulence" and "pulsations". Turbulence is the out-of-round or unsymmetrical shape of the gas stream and has no relation to turbulence as used in hydraulics. It is caused by obstructions in the gas stream such as valves, fittings, and rough conditions. Tees placed so that they are not in the same plane will cause a turbulent stream. To prevent this condition particular caution must be taken that causes of turbulence do not exist near the metering devices, as an unsymmetrical stream is hard to gauge due to the uneven pressure.

It has been found that the flow of gas must be made as nearly steady as possible if the correct readings are to be obtained. Otherwise velocity readings will be incorrect and useless. Such unsteady flows are known as "pulsations" and are caused by the discharge or suction action of compressors. The pulsations caused by compressors die out or are used up as the stream passes on through the line, and if the meter can be set at a sufficient distance from the source, no trouble is caused. However, it sometimes is necessary to set meters near the compressor station then some remedy for pulsations must be provided.

Two plans of overcoming pulsations are used; first, by putting resistance in the line; and second, by increasing the capacity of the line. Resistance put into the line consists of small and probably crooked channels. In this way the pulsations of the stream are neutralized and run together until they disappear.

The capacity of the line is increased by putting short pieces of large pipe or tanks into the line or by installing two or three lines of pipe in parallel. This increased capacity absorbs the pulsations and evens out the flow.

Another sort of pulsation is due to the accumulation of liquid in the line. The only remedy of course is to remove the liquid.

Since the orifice method of measuring the volume of natural gas is the common method used in the industry, some further study must be made of the construction, installation, and operation of the orifice meter. As described the method requires three definite mechanisms; first, the orifice plate; second, a pressure differential measuring mechanism; and third, a static pressure gauge.

9. <u>The Orifice Plate</u>:

The orifice plate is a plate of thin metal, commonly steel, and ordinarily 1/8 or $\frac{1}{4}$ inch thick. They are made in different sizes to fit different pipes and with different size orifices, several plates with different sized holes being provided for each pipe size. The hole is selected for each pipe size to give the proper differential for a certain flow at the indicated static pressure to be put on the line. The orifice plate is set between flanges, Fig. 145, and held in place by tightening the bolts. It can be removed by loosening all the bolts, removing those on one side and spreading the flanges sufficiently to pass the plate. Special orifice fittings, made by manufacturers of meters, are used extensively.

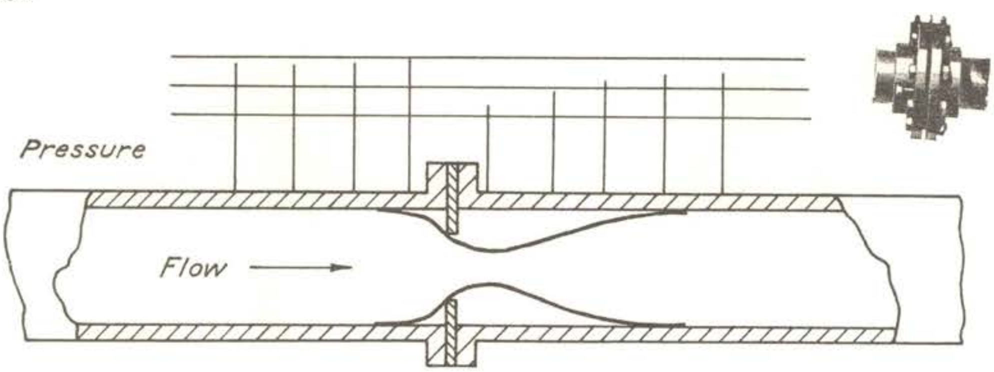



Fig. 145

The orifice in the plate is clean cut, generally with square edges. So much depends upon the condition of the edges of the hole that the plate must be handled with care. Only the upstream side of the hole is important, consequently, a plate with a square edged hole can be reversed when worn. If a beveled orifice is used, the sharp edge must be upstream. Due to the fact that the outer part of the upstream is directed toward the center of the hole, it is necessary that the upstream edge be square and free from dirt. Fig. 146 shows a clean square edge plate, and a dirty edge plate. The effect of the different conditions on the gas stream is shown. It is evident that the dirty condition will cause the gas stream to be larger and the meter reading to be low. A wire edge on the hole may cause either a high or a low reading. It is also important that the orifice be centered in the pipe for perfect measurement.

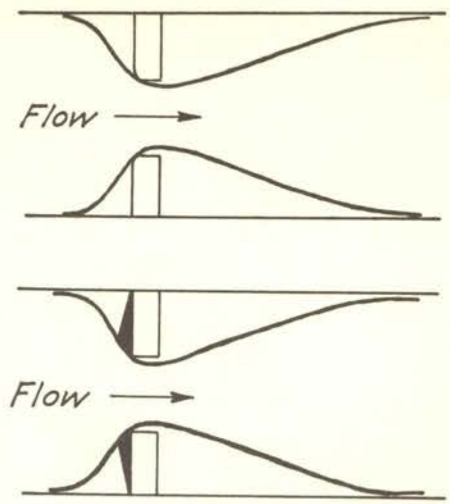



Fig. 146

10. Straightening Vanes:

Internal obstructions in a pipe line cause the gas stream to become uneven and out of shape. Since the flow depends so much upon the pressure differential, it is important that the stream be symmetrical when it reaches the orifice plate. To insure a symmetrical stream at the plate, the pipe leading to the meter should be in straight runs. If possible all fittings near the meter should offer as little resistance as possible.

If, however, an unsymmetrical stream cannot be avoided, straightening vanes may be installed. They consist either of small tubes or straight ways, Fig. 147, and tend to straighten out the turbulent flow of the stream. They should be installed not less than six pipe diameters above the pressure tap.

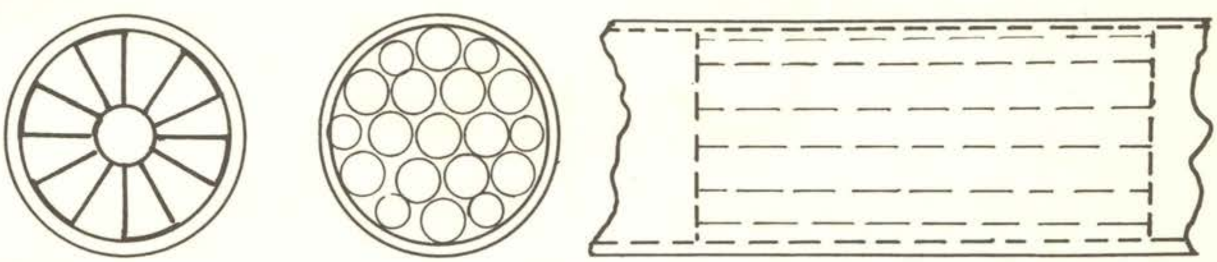


Fig. 147

11. Pressure Connections:

Pressure connections are to be made one up-stream and one down-stream so as to obtain the differential. Above the orifice there is little change in pressure

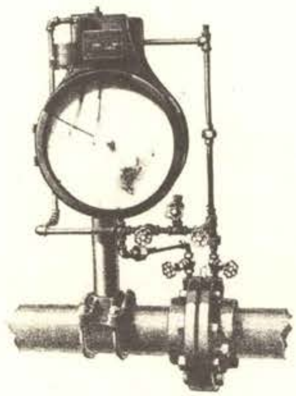


Fig. 148

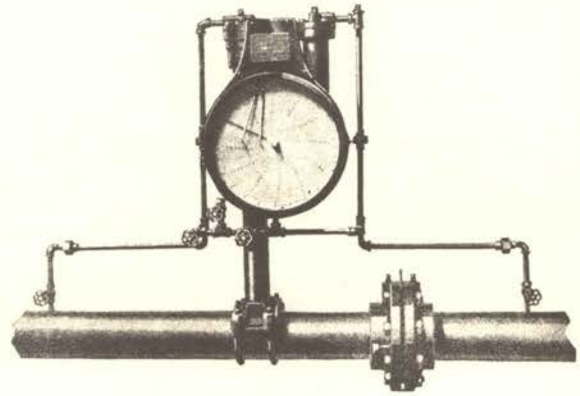


Fig. 149

except at the face of the plate where it increases slightly. Downstream from the orifice the pressure decreases to the point where the gas stream has the least diameter, and then increases to the point where the stream again fills the pipe. Below this point there is very little change.

Pressure connections are made in two ways, one by drilling and tapping the pipe, and the other by welding a collar to the pipe, then drilling a hole through the pipe wall and screw the pressure pipe to the collar. It is important that the edges of the hole on the inner surface be free from burrs, and should be slightly rounded off.

Various positions of these taps on the pipe have been tried, but only two are regarded as standard. A "flange connection", Fig. 148, in which the taps are in the orifice flanges. The center of the upstream tap is one inch from the upstream face of the plate, and the center of the down-stream is not less than 1 1/8 inch and not more than 1¼ inch from the upstream surface of the plate. The "pipe connections" or "full flow" is made with the upstream tap 2½ pipe diameters from the upstream face of the plate, and the down-stream tap 8 diameters from the upstream face, Fig. 149.

While the upstream pressure is practically the same for both types of connections, the down-stream pressure is considerably higher for the pipe connection than for the flange connection. Therefore, there is a different differential for the same flow of gas and the coefficients will be different, a factor to be considered in taking measurements. One reason for the two types of connections is that pipe taps are made in the field and slight errors will make no difference, while flange taps are made in the shop and can be accurate.

Static pressure can be measured either at the upstream or down-stream connection unless the differential is equal or nearly equal to the static pressure, then a mean of the up and down-stream pressures must be used.

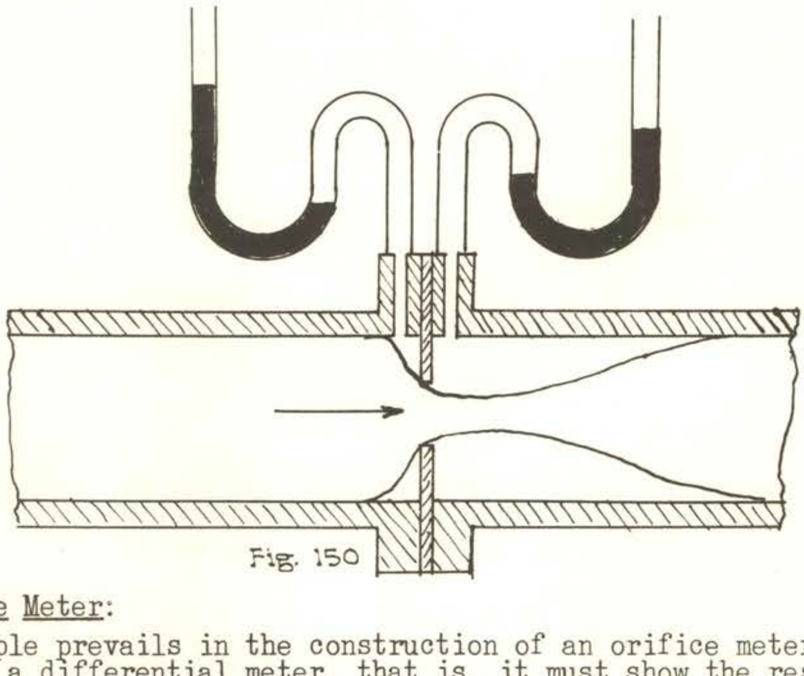


Fig. 150

12. The Orifice Meter:

One principle prevails in the construction of an orifice meter, and that is that it must be a differential meter, that is, it must show the results of two pressures working one against the other.

The simple arrangement shown in Fig. 150 provides the mechanical set-up for balancing one pressure against the other, but it is scarcely usable because of the inability to measure the difference in liquid levels. For light pressures water is the balancing liquid and for heavy pressures mercury, the heaviest known liquid, is used.

To make it possible to read the difference in the meter shown above a mechanical arrangement might be added as in Fig. 151, whereby the difference in level would be indicated by the pointer on the graduated dial that corresponds to the liquid being used. Nevertheless, the principle of this homely apparatus is used in constructing the highly mechanicalized orifice meters. Fig. 152 shows a phantom view of the construction of a recording orifice meter. It is called a mercury float meter due to the fact that the indicator connects to the float on the mercury column. The difference in pressure of the up and down stream flows causes the change in the level of the mercury in the float chamber, thus operating the indicator. The static pressure is measured by a separate unit and a separate pointer. To prevent the mercury from being blown out a check valve is placed above the differential float and operated by it. When the differential becomes dangerous the float closes the valve and protects the meter. Since the meter must be level to assure accuracy a leveling glass is provided in the top. The instrument must be checked from time to time to insure its being level.

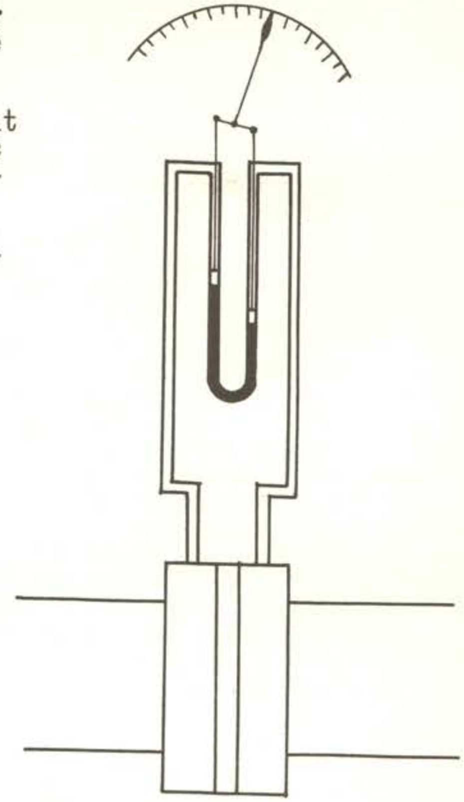


Fig. 151

13. Recording Meters:

An orifice meter may be either an indicating meter or a recording meter. The recording meter has the same metering mechanism but is equipped with a clock works that revolves the dial under the pointer. The dial revolves once each 24 hours, and is divided on the circumference into that many spaces and marked as to hours a.m. and p.m. On the radius of the circle pressure divisions are made. The indicator is tipped with a pen point that is inked from a small reservoir attached.

The dial is set into place at a certain hour and removed at the same hour the following day. In the complete revolution the pressure differential is recorded by the inked line on the chart.

Most orifice meters are equipped with a second indicator that is shorter than the first and works under it. This indicator is connected to the static pressure spring and records the static pressure on the same chart with the pressure differential, Fig. 153.

Thus, each 24 hours a chart similar to Fig. 154 is turned in that shows both the static and the differential pressure for the entire time, and from which the 24 hours flow of gas can be computed, all other factors being standard.

Since most plants calculate part or all their charts, class discussion should take up the use of the following formula in calculating charts. A local chart is the best illustration.

$$V = C \times 24\sqrt{d \times p}$$

in which V = volume of gas per 24 hours
C = Coefficient for size disc in use and corrected as to pressure base and gravity.
d = differential (average) for 24 hours in inches of water
p = absolute pressure in lbs. per square inch

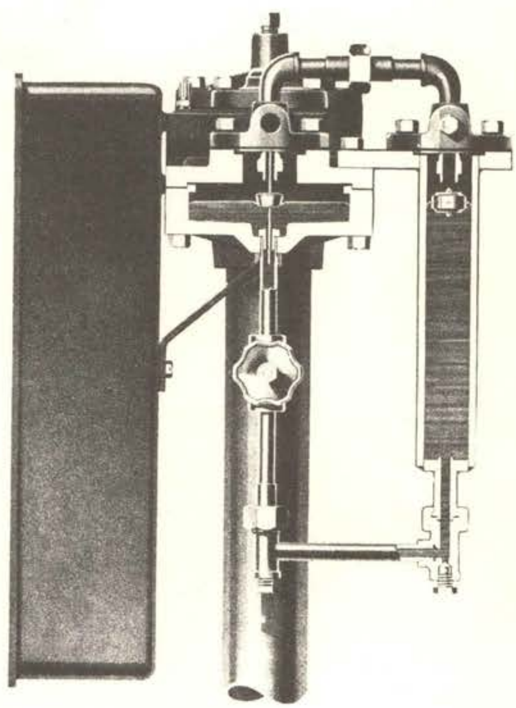


Fig. 152

Fig. 153

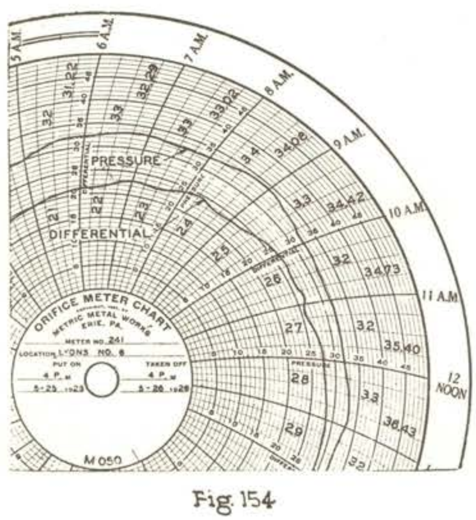



Fig. 154

## UNIT XIII

## THE TEST CAR

1. Purpose:

The purchase of any commodity in quantities brings into consideration the price per unit purchased. In the grocery store, sugar is bought at so many cents per pound and vinegar at so many cents per gallon. The purchase of casinghead gasoline is based on the current price per gallon. However the gasoline is in the natural gas in the form of vapor and since the gas is purchased upon the basis of its gasoline content, some means had to be devised to extract and condense this vapor at each lease to determine the payment rate. The test car is the means used.

The test car is a small compression plant. It measures an accurate volume, temperature connections are made, and the volume of gasoline extracted in that quantity measured, is transmitted into gallons per thousand cubic feet. The tests generally are run every three months to get the seasonal average. The gas meter on the lease measures the gas passed during the period and the number of thousands of cubic feet is multiplied by the gallons per thousand cubic feet obtained in the test. This gives the gallons of gasoline obtained from the lease over a period of time used for payment. Monthly payments generally are made. It is apparent that the daily charts from each lease become the basis of determining the amount of the bill which the gasoline company must pay the producer for gasoline purchased from his lease. It follows then that meters must be operating in a first class manner and must be kept thus in order that both the producer and gasoline manufacturer are treated fairly.

2. Gas Contract:

Due to the many factors involved in the tests and measurement of gas and to get uniform regulations a gas contract has been made up in blank covering the purchase of natural gas for gasoline plants. This contract is practically universal, other contracts being similar in most respects. Copies of this contract can be obtained and used for class discussion, but certain points specifically set up in the contract bearing on the operator's work and of general interest are discussed here. These points when understood will give a better understanding of certain field and plant operations. All legal terms and extraneous conditions are omitted.

1--PURPOSE--The gas hereby sold is conveyed to the Buyer for the purpose of manufacturing therefrom gasoline or such other product or products as may be manufactured at Buyer's plant.

2--DELIVERY PLACE--The delivery of the casinghead gas shall be made at vapor tight flow tanks and/or gas traps furnished by Seller and/or at the casingheads of the wells. Buyer may, with Seller's consent, install equipment acceptable to Seller on Seller's storage tanks for the purpose of saving and utilizing vapors therefrom, which vapors for the purpose of this contract shall be considered casinghead gas.

3--LEAN AND FLUSH GAS--The Buyer agrees to take all the gas testing more than _____ gallons of gasoline per thousand cubic feet of gas; provided that during flush casinghead gas production from the property covered hereby the Buyer shall only be obligated to take ratably as to quantity with all other flush production connected to its plant. Seller shall have the right to dispose of any gas not taken or paid for by the Buyer; provided that Buyer shall have the right to take any or all of such gas at any time thereafter conditioned upon Buyer giving Seller at least 90 days' notice of its election to so do.

Seventy-five hundredths of a gallon is the general figure inserted here in fields where the gas volume is not high and most of the gas is above this figure and where the gas is run through compressors. During flush production, which does not exist as in the previous days without proration, it was uneconomical to build a plant to take care of all flush production as the gas volume fell rapidly and would leave idle expensive machinery.

4--RESIDUE GAS--The Buyer shall return to the nearest boundary line of the Seller's lease, above described, sufficient residue gas for the development and operation of said lease, the amount of such gas not to exceed that remaining from the quantity of casinghead gas delivered to the Buyer from said lease after the extraction of gasoline therefrom, less the proportionate part of said residue gas necessary for gasoline plant operation, both determined by the residue gas curve attached hereto; (Fig. 155) provided that in the event residue gas to be returned hereunder by the Buyer shall be insufficient in quantity for the purpose of developing and operating said lease, the Seller hereby reserves the right to use casinghead gas from its lease sufficient in quantity to make up the deficiency. Utilization of said residue gas so returned by the Buyer shall be at the Seller's risk. In the event Seller accepts and uses dry gas, furnished by Buyer, in excess of the amount of residue gas to which Seller is entitled, Seller shall pay Buyer for such dry gas at delivered cost to Buyer.

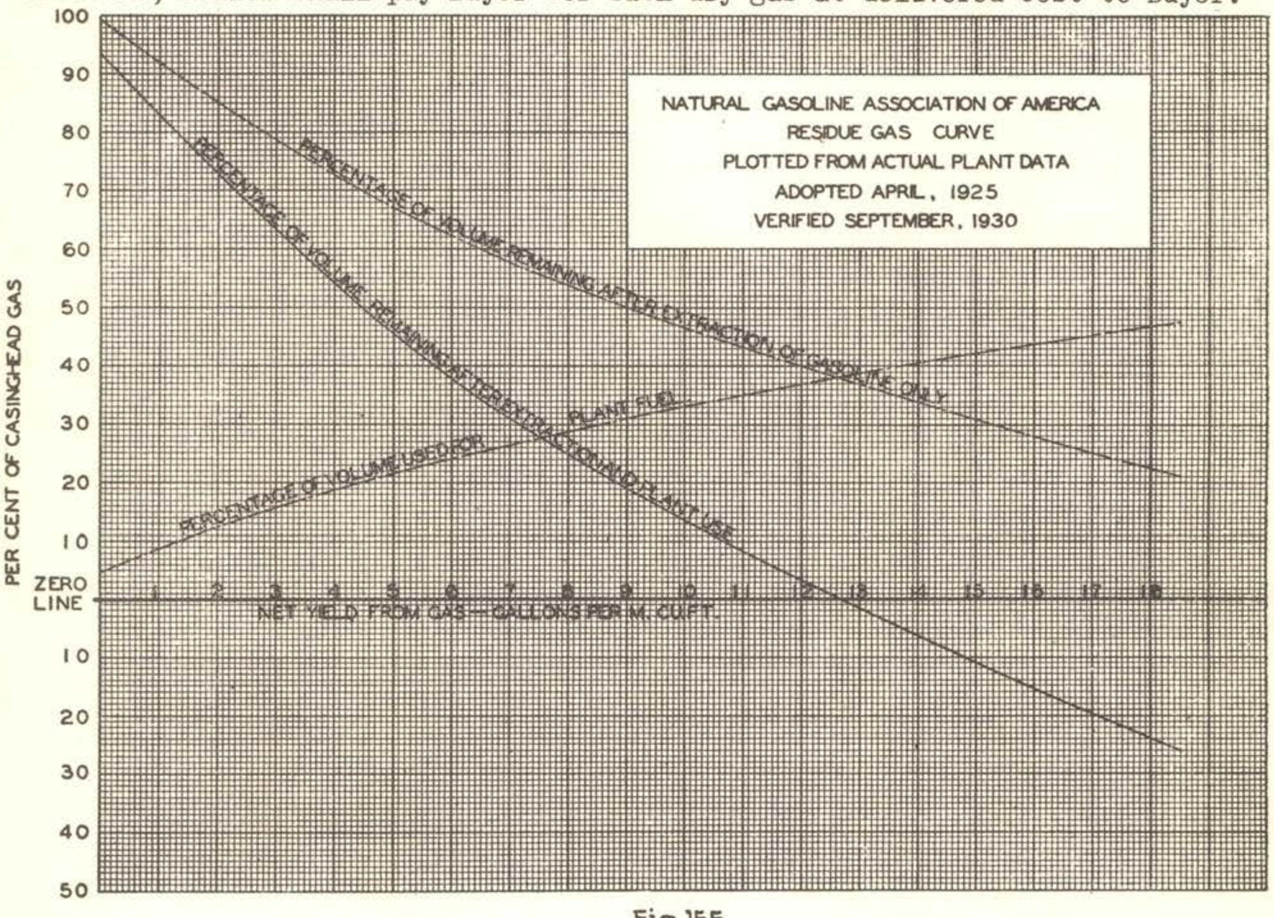



Fig. 155

It is agreed and understood by and between the parties hereto, that if and when the residue gas remaining after the extraction of gasoline from such casinghead gas shall be more than sufficient for the needs of Buyer in the operation of said gasoline plant and more than sufficient for the needs and requirements of Seller for the development and operating purposes upon the premises from which the said casinghead gas is produced, then, and in that event, the Buyer shall have the right to sell any or all surplus residue gas so remaining, provided that in the event of sale by the Buyer of any or all of such residue gas, Buyer shall pay to the Seller herein fifty per cent of the net proceeds received from sale of such gas, such payments to be made at the same time as other payments hereunder. Net proceeds as herein used is defined as the gross proceeds less any cost of boosting and/or transportation necessary to market such gas. It is further agreed and understood that as a basis of settlement hereunder for the sale of residue gas, it shall be determined how much residue gas the Seller was entitled to have returned and the volume that actually was returned during the month for which settlement is to be made, and the difference shall be regarded as the volume of surplus residue gas available for sale from the casinghead gas delivered hereunder. The volume of surplus residue gas sold from the casinghead gas delivered hereunder shall be determined by the proportion which the volume of surplus residue gas available for sale from said delivery bears to the total volume of surplus residue gas available for sale from all casinghead gas delivered to said plant.

5--RIGHT OF WAY--In so far as Seller's lease permits, Buyer is granted the right to lay and maintain lines and to install any necessary equipment on said lease and shall have the right to free entry for any purpose incidental to gasoline plant operations so long as such purpose does not interfere with lease operations or the rights of owners in fee. All lines and other equipment placed by Buyer on said lands shall remain the property of the Buyer and, subject to the terms of this contract, may be removed by Buyer at any time.

6--SETTLEMENT TESTS--The gasoline content shall be determined by a field compression test made in accordance with the official code of the Natural Gasoline Association of America for testing natural gas for gasoline content. The specific gravity shall be determined in accordance with the specifications and test procedure of said association for the determination of specific gravity of natural gases by the balance method. The tests for gasoline content, air content and specific gravity of the gas shall be made by the Buyer quarterly except when, in the opinion of either party, a change in the method of operations of the lease will affect materially the gasoline content and specific gravity of the gas, in which event the tests shall be made at the demand of either party upon five (5) days' notice to the other party. The Buyer shall notify the Seller in writing ten (10) days previous to the quarterly tests in order that it may have a representative present to witness said tests and/or make joint tests with its own appliances. The content tests shall be computed on the basis of four (4) ounces above an assumed atmospheric pressure of 14.4 pounds per square inch absolute and at a base temperature of sixty (60) degrees Fahrenheit.

Fourteen and four-tenths pounds per square inch is the approximate atmospheric pressure for Oklahoma. In other fields of higher or lower altitude this figure is changed to suit.

7--METERS--The casinghead gas delivered hereunder shall be measured by a suitable orifice meter, or meters, of standard make to be furnished, installed, and kept in repair by Buyer on the lease herein covered. The amount of gas so metered shall be computed on the basis of four (4) ounces above an assumed atmospheric pressure of 14.4 pounds per square inch absolute at a base temperature of sixty (60) degrees Fahrenheit and at an assumed flowing temperature of 60 degrees Fahrenheit. The Buyer shall test, and if necessary adjust and repair, said meter, or meters, at or about the time the tests for gasoline content are made. Said meter, or meters, shall be open to inspection at all times by Seller in the presence of Buyer. In case any question arises as to the accuracy of the meter measurement said meter, or meters, shall be tested upon the demand of either party. The expense of such tests shall be borne by the party demanding same if the meter is found to be correct and by the Buyer if found incorrect. A registration within 3% of correct shall be considered correct. Settlement for any period of inoperation or inaccurate measurement shall be in accordance with the average readings taken during the last preceding ten days when the meter was registering accurately and the first ten days after the meter was restored to accuracy. If requested Buyer shall send the charts to Seller for checking after which they are to be returned to Buyer.

8--PRICE--The Buyer shall pay to Seller for the casinghead gas delivered hereunder: a price per thousand cubic feet to be computed on the following basis:

1. When gasoline content is less than .75 gallons per thousand cubic feet:
   (a) When average price is 2¢ per gallon, or less, 5% of the value of the gasoline.
   (b) When average price is more than 2¢ per gallon, but less than 4¢ per gallon, 10% of the value of the gasoline.
   (c) When average price is 4¢, but less than 6¢ per gallon, 15% of the value of the gasoline.
   (d) When the average price is 6¢ per gallon, or more, 20% of the value of the gasoline.
2. When gasoline content is .75 gallons per thousand cubic feet, but less than 1.75 gallons per thousand cubic feet:
   (a) When average price is 2¢ per gallon, or less, 10% of the value of the gasoline.
   (b) When average price is more than 2¢ per gallon, but less than 4¢ per gallon, 15% of the value of the gasoline.
   (c) When average price is 4¢, but less than 6¢ per gallon, 20% of the value of the gasoline.
   (d) When the average price is 6¢ per gallon, or more, 25% of the value of gasoline.
3. When gasoline content is 1.75 gallons per thousand cubic feet, or above:
   (a) When average price is 2¢ per gallon, or less, 15% of the value of the gasoline.
   (b) When average price is more than 2¢, but less than 4¢ per gallon, 20% of the value of the gasoline.
   (c) When average price is 4¢, but less than 6¢ per gallon, 25% of the value of the gasoline.
   (d) When the average price is 6¢ per gallon, or more, 33 1/3% of the value of the gasoline.

The value of the gasoline contained in a thousand cubic feet of gas shall be determined by multiplying the gasoline content (determined as hereinabove provided) by the average Oklahoma price for Grade 26-70 natural gasoline or its substantial equivalent as quoted in the National Petroleum News for the period of settlement.

Note: A revised price schedule has become optional with the parties of the contract.

9--VACUUM--Upon request of Seller the Buyer shall apply and maintain on Seller's wells a vacuum substantially equal to that maintained on offset wells by gasoline plants. Up to such maximum Seller shall have control of said vacuum at all times.

10--DRIP--The Buyer shall keep reasonably clear of obstruction all its pipe lines through which said gas is being delivered and shall own all liquid collected in such lines.

There are a number of other conditions set forth which may be discussed but are not of general concern to those operating.

3. Tests:

The test car operator is interested primarily in determining the G. P. M. of the gas. He, also, checks the meter, tests for air content, and gets the gravity of the gas. To determine the content of the gas he has a meter thermometer in the gas line, a compressor and a condenser. The meter is tested frequently for accuracy. The thermometer registers the gas temperature to make corrections to 60°, see contract. He carries a cc or cubic centimeter glass graduate in which he draws off the condensed gasoline for measurement. He then has a certain number of cubic feet of gas measured on the meter that has been treated and a certain number of cc's of gasoline condensed. To get the gallons per thousand cubic feet he uses the following formula:

$$G.\ P.\ M. = \frac{B \times 1000}{A \times 3785} \quad \text{or} \quad \frac{.264\ B}{A}$$

In which A = Volume of gas treated (corrected to $60^{\circ}$)

B = Volume in cc's (at $60^{\circ}$) of gasoline

There are 3785 cubic centimeters in one gallon. If 10 cubic feet were treated and 155 cc's received, then:

$$G. P. M. = \frac{.264 \times 155}{10} = 4.1$$

To shorten the calculation process it is common practice to treat 13.2 cubic feet (or volume corrected to $60^{\circ}$ temperature), then if 140cc are received

$$G. P. M. = \frac{.264 \times 140}{13.2} = 2.80$$

Then it is only necessary to multiply the cc's received by .02 to get the G. P. M. The air test is made with the Hays gas analysis as described under laboratory equipment.

The specific gravity of the gas is taken to make corrections on the meter volume readings. Correction tables always are available. As the specific gravity increases the correction multiplier decreases, and vice versa. The reason for this is that gas of high specific gravity gives a higher differential across the orifice than the actual volume of gas represented. This in turn is due to the heavier molecules of the higher specific gravity gas causing the increased differential.

The gravity actually is measured with the instrument shown in Fig. 156 and Fig. 157 shows it set up for use. The method of operation is to fill the balance with air and balance the metal bulb. Then fill with gas and change the pressure until the bulb again balances.

The specific gravity of gas as defined by the Bureau of Standards is: "The ratio of the weight of a given volume of gas to the weight of an equal volume of dry air, free from carbon dioxide, measured at the same temperature and pressure." Since the specific gravity is a very important factor in the measurement of gas, it is necessary to use an accurate dependable method for determining the specific gravity of gas. The balance method is correct as it is based on the following law of physics: "According to Boyle's law the density of gas is

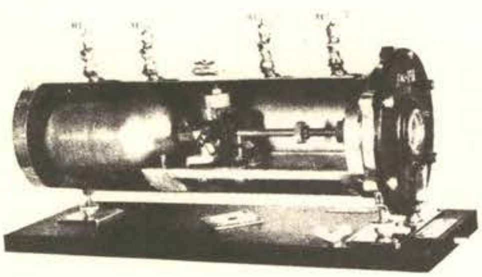


Fig. 156

Fig. 157

proportional to its pressure; and the buoyant force exerted upon a body suspended in a gas is proportional to the density of the gas and therefore to its pressure. Therefore, if the buoyant force exerted upon a body is made the same when suspended successively in two gases, then the densities of the gases must be the same at these pressures; or the densities of the two gases at normal pressures are in inverse ratio to the pressures when of equal buoyant force."

4. Construction:

The apparatus for testing is mounted in the rear compartment of a coupe or in the rear seat area of a two-door sedan. Fig. 158 shows the apparatus as it appears in a two-door sedan. Fig. 159 is the general arrangement of the equipment and shows the path of the gas. The condenser tank is filled with ice and water.

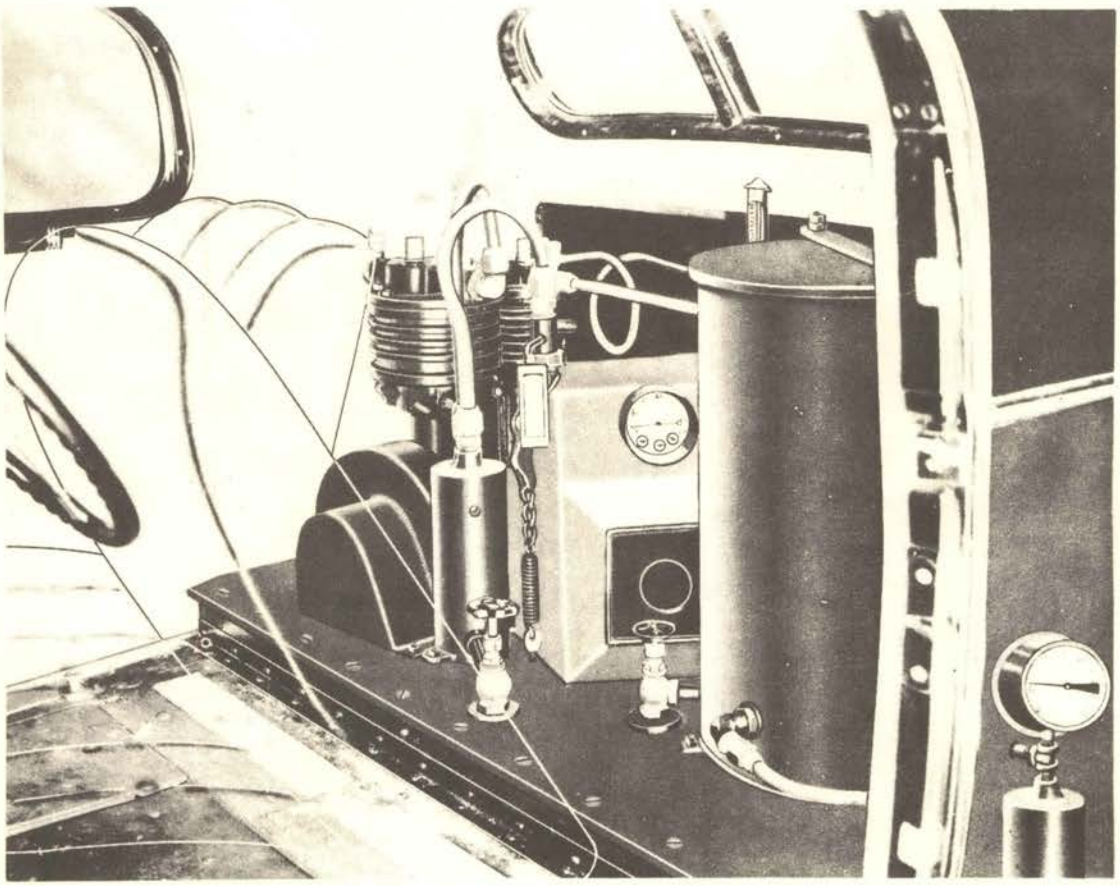


Fig. 158

# GENERAL ARRANGEMENT OF GAS TESTING EQUIPMENT

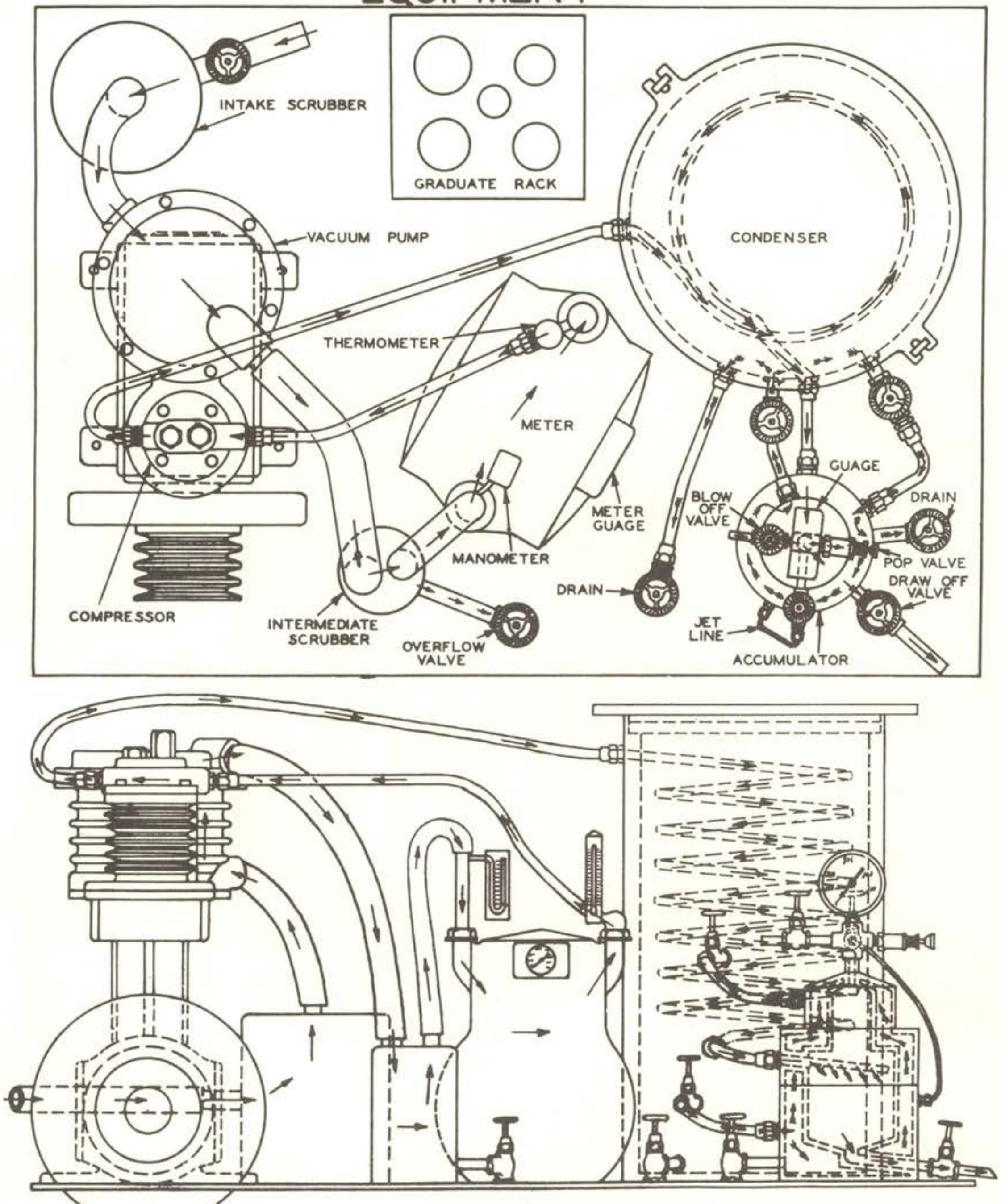



Fig. 159

UNIT XIV

PLANT RECORDS AND REPORTS

1. Operation Sheets:

Throughout the second section of this report, repeated reference has been made to the pressure in this vessel or the temperature in that one. The importance of these temperatures and pressures is emphasized by the various pieces of equipment developed to control them. In order to have efficient operation regularity is required of these items as well as others. In order for the operator to know the importance of these and to provide a record it has been customary to supply forms on which at stated intervals record can be made.

The various companies have made up their own forms and no two of them are alike. However, in a general way these records can be divided into four classifications, namely: still room, engine room, fractionator, and chemist's report. All of the reports are made for a 24-hour period.

The still room report, of which Fig. 160 is a sample, is self-explanatory. All of the columns are not necessarily used, depending on the equipment in use. Also, 24-hour recording charts eliminate the necessity of a number of the columns shown.

The engine room report, Fig. 161, is likewise self-explanatory as to pressures, temperatures, etc., to be recorded. The operator making these records can explain the reason for any one of these columns of figures. For instance the temperature of the discharge gas from a compressor indicates the condition of the compressor valves as well as the load it is carrying. Attention is called to "Units Down" and "Remarks" which can be discussed along with the other parts of the form.

The fractionator report, Fig. 162, gives the important data concerning the operation conditions of the fractionator. It is especially important in its operation as the finished product is the one being prepared for sales and must meet the specifications required. In other words, the finishing touch is being made on the product for sale and the operation is closely checked. Unless a constant check is made on all operating conditions, especially as to the quality of the overhead product (which represents the quality of the discard gas), a loss of valuable gasoline may result and the plant yield and finished production will be lowered.

1ST. TOUR

| KETTLE PRODUCT | | | OVERHEAD | |
|---|---|---|---|---|
| | GRAVITY | V. P | I. B. B. | E. P |
| 8 | 90.6 | 26.0 | -18 | +29 |
| 9 | 90.0 | 21.2 | -17 | +29 |
| 10 | 89.8 | 26.2 | -22 | +30 |
| 11 | 90.8 | 26.4 | -18 | +29 |

REMARKS: ______

SIGNED ______

2nd TOUR

Fig. 162

The chemist's report is a summary of the complete operation for the day. Fig. 163 is an example of this type of sheet. The purpose of this sheet is to give the superintendent and the main office a daily running record of all phases of plant operation. This is the report that exemplifies the statement made that the plant laboratory has control of all phases of plant operation. Another sample sheet of this nature is shown in Fig. 164. Note that certain information such as distillation is omitted and others added.

2. Storage Reports:

Storage reports are for the purpose indicated by the name, to show the amount stored. To gauge tanks and fill out the storage reports seems at first a job easy to perform. However, with a large number of different sized tanks, shipments out, transfers, raw make, and stabilized gasoline, the gauging and filling out of a storage report becomes a task requiring some experience. Each company, also, has its own forms of storage report. Fig. 165 is a section of one report which concerns the tanks only. The summary is carried on other sheets or one of the operating sheets as in Figs. 163 and 164.

GS 5

DAILY OPERATION REPORT FROM ______________ GASOLENE PLANT ______________ 193___

| Time | Temp. | Absorbers | | | Still | | | | | | | Exchanger Temp. | | Gas Treated | Oil Pumped | Oil Ratio | Boiler No.___ | | | Gravity | | Press. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a.m. | At-mos-phere | Temp. Gas Inlet | Temp. Oil Inlet | Gas. Pres. | Pre-Heater Temp. IN | Pre-Heater Temp. OUT | Pres. | Temp. of K.O.T. | Temp. Look Box | Lk. Bx. Pres. | Grav. Look Box | Outlet from Still | Outlet to Coils | M. Cu. Ft. ___ Basis | Gallons | | Steam Pres. | Feed Water Gallons | Feed Water Temp. | Lean Oil | Rich Oil | Main Line |
| 9 | | | | | | | | | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | | | | | | | | |
| 1 p.m. | | | | | | | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | | | | | | | |
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| 10 | | | | | | | | | | | | | | | | | | | | | | |
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| 12 | | | | | | | | | | | | | | | | | | | | | | |
| 1 a.m. | | | | | | | | | | | | | | | | | | | | | | |
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| 7 | | | | | | | | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | | | | | | | | |
| Aver. | | | | | | | | | | | | | | | | | | | | | | |

**PRODUCTION**

| | Absorption | | | | | | | Compression | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TIME | TANK NO. | Temp. | Start Ft. | Start In. | Finish Ft. | Finish In. | Gallons | TANK NO. | Temp. | Start Ft. | Start In. | Finish Ft. | Finish In. | Gallons |
| 8-4 | | | | | | | | | | | | | | |
| 4-12 | | | | | | | | | | | | | | |
| 12-8 | | | | | | | | | | | | | | |
| Total | | | | | | | | | Total | | | | | |
| Naptha Used | | | | | | | | | | | | | | |
| Total Rerun Storage Loss | | | | | | | | | | | | | | |
| Net Compression Production | | | | | | | | | | | | | | |
| Net Total Production | | | | | | | | | | | | | | |

**SUMMARY**

| | |
|---|---|
| Gas Treated | M. Cu ft. |
| " " | M. Cu. ft. |
| Gasolene Recovery | Gals./M. Cu. ft. |
| " " | " " " " |
| Oil Circulated | Gallons |
| " " | " |
| Oil Ratio | Gals./M. Cu. ft. |
| " " | " " " " |
| Source of Gas. | |
| | |
| Gas Used per Boiler HP. hour | |

**TESTS**

| | |
|---|---|
| Inlet Gas | Gals./M. Cu. ft. |
| Disch, Gas | " " " " |
| Enriched Oil | % |
| Stilled Oil | % |
| Water in Stilled Oil | % |
| | |
| | |
| | |
| Absorber Efficiency | % |
| Recovery " | % |
| Overall " | % |

**TESTS**

GASOLENE

| TIME | Grav. | 5 @ 100° | 5 @ 140° | E. P. | Rec. | Reid V. P. |
|---|---|---|---|---|---|---|
| 8-4 | | | | | | |
| 4-12 | | | | | | |
| 12-8 | | | | | | |

Doctor Test

Water Meter Reading

" " "

" Used this date

| | |
|---|---|
| Absorption Oil Used | 8-4 |
| | 4-12 |
| | 12-8 |
| Cause of Units Down | |

Changes in Plant Operation and remarks.

| | | | |
|---|---|---|---|
| Fireman or Asst. Oper. | 8-4 | Stillman or Operator | |
| " " " | 4-12 | " | " |
| " " " | 12-8 | " | " |

Asst. Supt. or Tester Superintendent

Fig. 160

GS 12

DAILY OPERATION REPORT FROM ____________ GASOLENE PLANT ____________ 193____

| TIME | PRESSURE | | | | | TEMPERATURE | | | GAS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Low Stg. Intake | HIGH STG. Intake | HIGH STG. Disch. | Main Line | Residue | Atmos-phere | Low Accumu. | High Accumu. | % Air | Meter | Meter | Meter | Meter | Total |
| 9 A.M. | | | | | | | | | | | | | | |
| 10:00 | | | | | | | | | | | | | | |
| 11:00 | | | | | | | | | | | | | | |
| 12:00 | | | | | | | | | | | | | | |
| 1 P.M. | | | | | | | | | | | | | | |
| 2:00 | | | | | | | | | | | | | | |
| 3:00 | | | | | | | | | | | | | | |
| 4:00 | | | | | | | | | | | | | | |
| 5:00 | | | | | | | | | | | | | | |
| 6:00 | | | | | | | | | | | | | | |
| 7:00 | | | | | | | | | | | | | | |
| 8:00 | | | | | | | | | | | | | | |
| 9:00 | | | | | | | | | | | | | | |
| 10:00 | | | | | | | | | | | | | | |
| 11:00 | | | | | | | | | | | | | | |
| 12:00 | | | | | | | | | | | | | | |
| 1 A.M. | | | | | | | | | | | | | | |
| 2:00 | | | | | | | | | | | | | | |
| 3:00 | | | | | | | | | | | | | | |
| 4:00 | | | | | | | | | | | | | | |
| 5:00 | | | | | | | | | | | | | | |
| 6:00 | | | | | | | | | | | | | | |
| 7:00 | | | | | | | | | | | | | | |
| 8:00 | | | | | | | | | | | | | | |
| Total | | | | | | | | | | | | | | |
| Avg. | | | | | | | | | | | | | | |

**PRODUCTION**

| TIME | Tank No. | Temp. | Start Ft. | Start In. | Finish Ft. | Finish In. | Net Gallons |
|---|---|---|---|---|---|---|---|
| 8-4 | | | | | | | |
| 4-12 | | | | | | | |
| 12-8 | | | | | | | |

| | |
|---|---|
| Total | |
| Rerun Stor. Loss | |
| Sales | |
| Net Production | |
| Gasolene Recovery | Gals. Per M. Cu. Ft. |

**LUBRICATING OIL USED**

| | |
|---|---|
| 8-4 | Qts. |
| 4-12 | Qts. |
| 12-8 | Qts. |

**WATER TEMPERATURE**

| Eng. No. | Eng. | Comp. | Temp. Comp. Disch. |
|---|---|---|---|
| | | | |

**GAS**

| | |
|---|---|
| Total Gas Pumped | M. |
| Gas Used at Plant | M. |
| Gas To Leases | M. |
| Gas To Main Line | M. |

**WATER**

| | |
|---|---|
| Water Meter Reading Today | M. |
| Water Meter Reading Yest. | M. |
| Water Used | M. |

**GASOLENE**

| Grav. | % Evap. 100 | % Evap. 140 | E. P. | Rec. | Reid V. P |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |

| | |
|---|---|
| Doctor Test | |
| Corrosion Test | |
| Inlet Gas Content | G per M. |
| Disch. Gas Content | G per M. |

**UNITS DOWN**

| No. | TIME From | TIME To | CAUSE (Explain in Detail) |
|---|---|---|---|
| | | | |

REMARKS:

Engr.

Engr.

Engr.

Tester

Supt.

Fig. 161

____________________ Plant

## CHEMISTS DAILY REPORT

Date____________________

| PRODUCTION DATA | |
|---|---|
| Vacuum Gas Treated, M. cu. ft. | |
| Pressure Gas Treated, M. cu. ft. | |
| Total Gas Treated, M. cu. ft. | |
| Gross Production, Gallons | |
| Net Production, Gallons | |
| Total Losses, Gallons | |
| Plant Loss, Gallons | |
| Loading or Trf. Loss, Gals. | |
| Gross Yield, G. P. M. | |
| Net Yield, G. P. M. | |
| No. of Cars Loaded | |
| Loss per car, Gallons | |
| Stock on Hand, Gallons | |
| Available Storage, Gallons | |
| Mineral Seal Used, Gallons | |
| Mineral Seal Stock, Gallons | |

| GEN'L. ATMOS. & OPER. DATA | |
|---|---|
| Dry Bulb Temperature °F | |
| Wet Bulb Temperature °F | |
| Relative Humidity, % | |
| Water to Cooling Tower °F | |
| Water to Coils °F | |
| Water in Pit °F | |
| Water Circulation, Gal./Min. | |
| Carbondioxide in gas, % | |
| Air in gas, % | |
| | |

| VAPOR & FRACT. | Temp. | Press |
|---|---|---|
| Make Tank | | |
| | | |
| L. S. Recompressor | | |
| H. S. Recompressor | | |
| Fractionator Top | | |
| Fract. Generator | | |
| | | |

| STEAM DATA | |
|---|---|
| Press. at Boilers, Lbs. | |
| Pressure at Plants, Lbs. | |
| Temp. of Hot Well, °F | |
| Temp. of Exhaust to Sup. Htr. | |
| Temp. of Sup. Htd. to Stills | |

| WATER SOFTENER DATA | |
|---|---|
| Amount Treated, Bbls. | |
| Treated per lb. of salt bbls. | |
| Hardness of Water, Supply | |
| Hardness of Hot Well | |
| | |

| GASOLINE TREATER DATA | |
|---|---|
| Gallons Treated | |
| Caustic Used, Lbs. | |
| Chlorine Used, Lbs. | |
| Gal. per Lb. of Chlorine | |

| DISTILLATION EQUIPMENT OPERATING DATA | Unit No. 1 | | Unit No. 2 | | Unit No. 3 | | Unit No. 4 | | Unit No. 5 | | Unit No. 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Temp. | Press | Temp. | Press | Temp. | Press | Temp. | Press | Temp. | Press | Temp. | Press |
| Comp. Gas? or Well Press? | | | | | | | | | | | | |
| Inlet Gas | | | | | | | | | | | | |
| Gas to Coils | | | | | | | | | | | | |
| Gas from Coils | | | | | | | | | | | | |
| Rich Oil to Heat Exc. | | | | | | | | | | | | |
| Rich Oil to 2nd Heat Exc. | | | | | | | | | | | | |
| Rich Oil to Preheaters | | | | | | | | | | | | |
| Rich Oil to Still | | | | | | | | | | | | |
| Still | | | | | | | | | | | | |
| Lean Oil to Heat Exc. | | | | | | | | | | | | |
| Denuded Oil to 2nd Heat Exc. | | | | | | | | | | | | |
| Denuded Oil from Heat Exc. | | | | | | | | | | | | |
| Oil to Coils | | | | | | | | | | | | |
| Oil from Coils | | | | | | | | | | | | |
| Oil to Absorber | | | | | | | | | | | | |
| Dephlegmator | | | | | | | | | | | | |
| Oil Circulation Last 24 Hrs. | | | | | | | | | | | | |
| Gas Treated Last 24 Hrs. | | | | | | | | | | | | |
| Oil Circulation per M. cu. ft. | | | | | | | | | | | | |
| Saturation of Denuded Oil | | | | | | | | | | | | |
| Gravity of Lean Oil A. P. I. | | | | | | | | | | | | |
| I. B. P. of Lean Oil | | | | | | | | | | | | |
| G. P. M. of Residue Gas | | | | | | | | | | | | |
| Gravity of Res. Cond. A. P. I. | | | | | | | | | | | | |
| Potential Loss (Gal. in Res.) | | | | | | | | | | | | |
| | | | | | | | | | | | | |

| LABORATORY TESTS OF MAKE AND STORAGE | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tank No. | | | | | | | | | | | | | | |
| (Fold in Here) | | | | | | | | | | | | | | |
| Gravity A. P. I. | | | | | | | | | | | | | | |
| Vapor Pressure | | | | | | | | | | | | | | |
| Color Say. No. | | | | | | | | | | | | | | |
| Doctor + or — | | | | | | | | | | | | | | |
| Corrosion + or — | | | | | | | | | | | | | | |
| Initial B. P. | | | | | | | | | | | | | | |
| 5 Percent | | | | | | | | | | | | | | |
| 10 Percent | | | | | | | | | | | | | | |
| 20 Percent | | | | | | | | | | | | | | |
| 30 Percent | | | | | | | | | | | | | | |
| 40 Percent | | | | | | | | | | | | | | |
| 50 Percent | | | | | | | | | | | | | | |
| 60 Percent | | | | | | | | | | | | | | |
| 70 Percent | | | | | | | | | | | | | | |
| 80 Percent | | | | | | | | | | | | | | |
| 90 Percent | | | | | | | | | | | | | | |
| 95 Percent | | | | | | | | | | | | | | |
| End Point | | | | | | | | | | | | | | |
| % @ 100 | | | | | | | | | | | | | | |
| % @ 212 | | | | | | | | | | | | | | |
| Recovery | | | | | | | | | | | | | | |
| Residue | | | | | | | | | | | | | | |

REMARKS: ____________________

Fig. 163

FORM 86 REVISED—SKELLY

# DAILY PLANT OPERATING SUMMARY

THIS FORM IS BASIS FOR PHONE REPORT TO HOME OFFICE COVERING
24 HOUR PERIOD ENDING 7 A. M.

PLANT ____________________

DATE ____________________

| PRODUCTION: | GALLONS GROSS | GALLONS NET |
|---|---|---|
| NATURAL: PLANT NO. | | |
| NATURAL: PLANT NO. | | |
| NATURAL: PLANT NO. | | |
| NATURAL: PLANT NO. | | |
| SKELGAS: | | |
| BUTANE: | | |
| **GAS VOLUME** | **M. CU. FT.** | **M. CU. FT.** |
| INTAKE: | | |
| INTAKE: | | |
| RESIDUE SOLD | | |
| RESIDUE SOLD | | |
| RESIDUE PURCHASED | | |
| RESIDUE POPPED | | |
| **LOSSES** | **GALLONS** | |
| LOADING | | |
| TRANSFER | | |
| STABILIZING | | |
| **OPERATING DATA** | | |
| V. P. RAW MAKE | | |
| V. P. FINISHED PRODUCT | | |
| OIL TEMP. | | |
| AVG. VACUUM | | |
| AIR PERCENTAGE | | |
| PROCESSING DATA | GALLONS | V. P. |
| CHG. TO FRACTIONATOR | | |
| FINISHED PRODUCT | | |
| FRAC. REFLUX | I. B. P. | E. P. |

**STOCKS ON HAND**

| VAPOR PRESSURE | TREATED (GALLONS) | UNTREATED (GALLONS) | SOL. | GALLONS |
|---|---|---|---|---|
| MOTOR FUEL | | | A | |
| LBS. | | | B | |
| LBS. | | | C | |
| " | | | D | |
| " | | | E | |
| " | | | F | |
| RAW | | | G | |
| SKELGAS | | | H | |
| BUTANE | | | | |
| MINERAL SEAL | | | | |

**GASOLINE DELIVERIES OR PURCHASES**

| DATE | NUMBER | GRAV. | GALS. | V. P. | GALS. | V. P. | GALS. | V. P. |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

| CYLINDER | SIZE | B | C | 10 | 55 |
|---|---|---|---|---|---|
| AND DRUM | EMPTIES | | | | |
| INVENTORY | FILLED | | | | |
| SHIPMENTS | SHIPPED | | | | |

**EMPTIES RECEIVED**

| INITIAL | CAR NO. | INITIAL | CAR NO. | INITIAL | CAR NO. |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

| ON | SIZE | 4s | 6s | 8s | 10s | SKELGAS | BUTANE | SOLVENT |
|---|---|---|---|---|---|---|---|---|
| HAND | NUMBER | | | | | | | |

**CARS LOADED**

| | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

| LOADED | NUMBER | | | | | | SKELGAS | |
|---|---|---|---|---|---|---|---|---|
| CARS | SIZE | | | | | | BUTANE | |
| ON HAND | V. P. | | | | | | SOLVENT | |

**UNFILLED ORDERS**

| ORDER NO. | CARS | SIZE | GRADE | DESTINATION |
|---|---|---|---|---|
| | | | | |
| | | | | |
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**BILLINGS**

| DATE | ORDER NO. | INITIAL | CAR NO. | DESTINATION | FRT. PAID |
|---|---|---|---|---|---|
| | | | | | |
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| | | | | | |

Fig. 164

# DAILY STORAGE REPORT

PLANT

| DATE AND TIME | GALS. AT 60° TEMP. TK. NO. | | GALS. AT 60° TEMP. TK. NO. | | GALS. AT 60° TEMP. TK. NO. | | GALS. AT 60° TEMP. TK. NO. | |
|---|---|---|---|---|---|---|---|---|
| | IN | OUT | IN | OUT | IN | OUT | IN | OUT |
| GRAVITY A.P.I. | | | | | | | | |
| VAPOR PRESSURE 100°F. | | | | | | | | |
| RECOVERY | | | | | | | | |
| GAUGE--FT., INS. | | | | | | | | |
| TEMPERATURE °F: | | | | | | | | |
| RAW GASOLINE | | | | | | | | |
| BLEND | | | | | | | | |
| NAPHTHA | | | | | | | | |
| TRANSFERRED OR SOLD | | | | | | | | |
| PRODUCTION | | | | | | | | |
| TOTAL--RERUN STORAGE LOSS | | | | | | | | |
| TOTALS | | | | | | | | |
| BALANCE | | | | | | | | |
| TODAYS GAUGE GALS. | | | | | | | | |
| STORAGE LOSS TO RERUN | | | | | | | | |
| GAUGE--FT., INS. | | | | | | | | |
| TEMPERATURE °F. | | | | | | | | |
| | GALS. AT 60° TEMP. TK. NO. | | GALS. AT 60° TEMP. TK. NO. | | GALS. AT 60° TEMP. TK. NO. | | GALS. AT 60° TEMP. TK. NO. | |
| | IN | OUT | IN | OUT | IN | OUT | IN | OUT |
| GRAVITY A.P.I. | | | | | | | | |
| VAPOR PRESSURE 100°F. | | | | | | | | |
| RECOVERY | | | | | | | | |
| GAUGE--FT., INS. | | | | | | | | |
| TEMPERATURE °F. | | | | | | | | |
| RAW GASOLINE | | | | | | | | |
| BLEND | | | | | | | | |
| NAPHTHA | | | | | | | | |
| TRANSFERRED OR SOLD | | | | | | | | |
| PRODUCTION | | | | | | | | |
| TOTAL--RERUN STORAGE LOSS | | | | | | | | |
| TOTALS | | | | | | | | |
| BALANCE | | | | | | | | |
| TODAYS GAUGE GALS. | | | | | | | | |
| STORAGE LOSS TO RERUN | | | | | | | | |
| GAUGE--FT., INS. | | | | | | | | |
| TEMPERATURE °F. | | | | | | | | |

Fig. 165