THE PROBLEMS OF THE GAS DEPARTMENT

A THESIS
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BY
SIMON MERENBACH
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INTRODUCTION

It is a well known fact that most successful business enterprises are judged by the profits they bring, and the ability of each department head is measured by the results his particular department produces, all unusual and unavoidable occurences are, of course, given proper allowance; therefore, when I was appointed head of the gas department, I made it my policy to make the department most profitable and at the same time dealing honestly, fairly and squarely with every one.

It was no easy task to have had to adhere to such a policy, because not all the people with whom I had business dealings had a similar policy, others were accustomed to get the best in all their transactions with the large corporations, that they actually believed that they were on the short end of the deal when they were given an even break, and there were some who for a long time misunderstood me, and thought that I was merely ambitious.

You can readily see that I had to follow a rough and rugged path in trying to inforce my policy with those who had dealings with my department, and my methods of enforcing those concerned to conform with my policy and the results obtained are regarded confidential. However, I will quote a few words from the conclusion of my "First Annual Report" where I said in part: "I wish to make it plain to all outside companies who are in any way connected with the gas belonging to the company I represent, that I expect them to deal with us fairly and squarely and that I am both able and willing to see that they do."

A year later the President of one of the largest companies who had dealings with our gas department and whose company fought the greatest battles with our gas department, said in the presence of his Assistant General Manager and his Superintendents: "Gentlemen, the

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THE PROBLEMS OF THE GAS DEPARTMENT

This thesis is devoted to the gas conservation as actually practiced by the gas department of which I am the head. Since it is one of the largest gas departments in the country, and the methods of running the department meet with the approval of the Superintendents and Managers of the Company, I take the liberty in concluding that the gas department's work is efficiently performed, and, therefore, the methods introduced and practiced by this department could well be regarded as much standard methods as those that may be practiced by similar departments in otherlarge companies. I sincerely recommend them as an example to those who may be in need of practical and efficient methods in dealing with similar problems.

A large oil company maintains a Geological Department which keeps a careful record of the progress made in drilling each oil well, i.e., the various formations penetrated, the depth at which water is encountered, where showing of oil and gas was observed, and finally the strata or stratas where oil sand are, or in other words, the goal for which the driller is aiming. All this information is carefully plotted in a form of a "log". When sufficient logs are obtained at various portions of the oil field, the geologist is enabled to determine the geological structures of the oil region and is then able to arrive fairly accurately at the most desirable location for the next well or wells.

The gas and oil from the well flow into an oil and gas separator, commonly known as a "trap". The purpose of the trap is to separate gas from the oil and sand. The gas is then conveyed by means of pipe lines to the gasoline plants for the purpose of gasoline extraction. This gas after being treated in the gasoline plants is known as "Dry Gas" and is then used for fuel in the boilers, homes, etc.

When the well "heads", i.e., periodically discharges large quantities of oil and gas, it produces a considerable pressure in the trap and unless the gas has a quick get away, a "back pressure" on the well will result and it may cause a considerable falling off in the oil and gas production of the well, or even kill the production entirely, which will then require considerable expense to bring the well back to life. It is evident then that it is important to provide a "Relief Valve" which is to be regulated to open up automatically when the pressure in the trap reaches the critical point.

Since the gas outlet from the trap is connected directly to the gas line leading to the gasoline plant, the lack of plant capacity of the plant or plants may also cause a back pressure on the traps, so a "Check" is generally placed in the line near the trap and in favor of the trap, so that the high pressure in the line will not back up into the trap and be wasted through the relief valve.

Although the capacity of the plant is generally sufficient to take care of all the gas, a temporary shut down or break down of one or more units used in compressing the gas, will cause a temporary lack of plant capacity. To remedy the above evil we have always advised to maintain an auxiliary unit in each plant, and from time to time relieve and overhaul each unit so as to avoid break downs since the plant is operated continuously for twenty-four hours daily. An auxiliary unit can also be of great use when the bringing in of a new well with an initial large quantity of gas raises the total gas production of the field considerably for a few days, until the well settles itself down to normal production.

When the plant capacity is greater than the gas production, a vacuum is formed in the gas line. The vacuum in the gas lines is desirable since it tends to make the gas richer in gasoline content, however, the vacuum on the well itself is objectionable since it may cause the well to sand up and in general decrease the richness of the oil. To prevent the vacuum from extending to the well a "Gasometer" is installed which automatically operates a butterfly, protecting the well from the effect of the vacuum.

After having installed the necessary devices for separating gas from oil and protecting the wells from vacuum and excessive pressures, it is desirable to determine the amount of gas all the wells produce and their gasoline content. For the measurement of gas we use the "Orifice Well Tester" (see attached drawing) on wells producing up to 1,000,000 cubic feet of gas per twenty-four hours. On larger wells a "Pitot Tube" measurement is used.

To test the quantity of gas with the "Orifice Well Tester", send all the gas through the blow-off pipe into the air by disconnecting the gasometer. Let the gas blow out for a few minutes into the air and then screw in the "tester" which carries a three inch thread by means of a collar. Connect a U-tube gauge to the nipple on the side of the orifice well tester, using a short piece of three-eighths inch rubber tubing. The U-tube should be filled with water up to the zero mark on the scale. Insert the slide which contains several sized orifices, starting with the largest orifice first, and if the height of the water does not rise much, slide it over to the next smaller size orifice until the difference between two water levels is at least two inches. By referring to the chart which was prepared for the use of our "Orifice Well Tester" or to the tables that accompany a somewhat similar tester that could be purchased, the flow of the well for a twenty-four hour period will be found. We then apply the corrections for the specific gravity and the temperature of the gas to obtain a corrected amount of the quantity of gas produced by the well in twenty-four hours.

To determine the specific gravity of the gas we use the Specific Gravity Apparatus. The process of determining the specific gravity of the gas can be found in a number of hand books.

Although the measurement of the quantity of gas of a well with the Orifice Tester takes only a few minutes, the results obtained are quite satisfactory with wells that flow steady. In case a well heads periodically, more care and judgment is needed to determine the quantity of gas flow. It is then necessary to measure the "cycle of flow", i.e., from the beginning of "one head" to the next one, which seldom exceeds fifteen minutes. With the aid of a stop watch or an ordinary watch, the length of heads and the quiet periods are recorded, the quantity in each case is measured and by interpolation the approximate flow of the gas per twenty-four hours is computed. Such measurements should be repeated two or three times and then averaged. A skilful well tester can obtain very satisfactory results with almost every type of well.

The gasoline content of the gas is determined by what is known as the "Newton Absorption Tester". The apparatus consists of an absorber, ten feet of one-fourth inch rubber tubing, a U-tube a relief valve or regulator, and some mineral seal oil of 35 deg. Baume gravity.

After connecting the gas to be tested as shown on the sketch that comes with the "Newton Tester", the gas is allowed to run through the tubing for a few minutes. The absorber is placed in a vertical position and the mineral seal oil is poured into the absorber until 125 cc is reached, which is indicated on the glass on the side of the absorber. The rubber tubing is then connected with the absorber. The water pressure is maintained eight inches by the aid of the relief valve, which assists in keeping the pressure constant. Allow the gas to go into the absorber for thirty minutes. Deduct from the reading of the mineral seal oil level, the original reading and multiply this increase in c.c. by 1/6 and you will obtain the amount of gallons of gasoline per thousand cubic feet of gas tested. The temperature of the gas during the test should be about 80 deg.F., although a variation in temperature of 10 deg.F. above or below will not have any appreciable effect upon the results obtained. The tester is designed to give the results as obtained in an average absorption plant.

When very accurate results are necessary, the "Charcoal Absorption Apparatus" is used. The principle of this method of testing casing head gas for gasoline content consists in absorbing the gasoline vapors in highly activated charcoal, and subsequently recovering the gasoline by distillation.

After the quantity of gas produced by each well has been determined, an estimated daily total gas production of the entire field is arrived at and one is then able to determine whether the gas lines are large enough to transport all the gas to the plants which maintain 10" vacuum without producing a pressure greater than three pounds per square inch at the trap. The next thing necessary is to determine whether the plants have enough capacity to take care of all the gas that the wells produce and maintain about 10" vacuum in the plants.

It is essential that the gasoline plants should at all times have sufficient capacity to take care of all the gas that seeks admission for otherwise the gas pressure in the pipe lines will build up above three pounds and will pop off into the air through the relief valves. To assure ample plant capacity to take care of all our gas at all times was the greatest problem of our gas department, since the gasoline plants treating our gas are neither owned nor managed by our company.

There were ten large plants and four different methods were employed in extracting the gasoline. Some plants used a combination of two different methods which made it stil more complicated to inspect the plants intelligently, therefore, a thorough knowledge and understanding of all the plants treating our gas was absolutely necessary.

As far as our gas department was able to determine, there were no flow sheets showing the methods used by each individual plant or any information showing the capacities of the plants. I realized that in order to be able to inspect the plants intelligently our gas department should posses all the facts concerning the plants, especially the working and ultimate capacities of each plant, the gasoline content of the gasoline entering, and leaving the plants. From this information our gas department would be in the position to judge whether the plants have sufficient capacity to take care of all the gas, also if the mechanical efficiency and the extraction efficiency are satisfactory.

The gas department made a thorough study of all the plants and prepared technical reports on all of them. This type of work was originated and worked out by our gas department under my supervision and all efforts were concentrated to make these reports as correct and complete as possible. Several representative technical reports are described elsewhere in this thesis.

When the reports of all the plants were completed it opened the eyes of our gas department, for we were then able to see what the plants were doing, how much gas they could handle and we knew how much they should handle. The results of the information obtained from these reports can not be overestimated for the recommendation made by the gas department on the strength of these reports have since then netted many additional thousands of dollars monthly from the revenues derived from the gas and gasoline production.

The technical reports on the plants were pronounced complete and correct by the Superintendent of the Plants and have received high praise from our management.

There are three different methods for the gasoline extraction used by our plants and for the benefit of the students who may desire to follow the gas and gasoline end of the petroleum industry, I am presenting in details the description of processes and equipment used, also a "Flow Sheet" of each method.

A few years ago it was the belief of the engineers in our region that gas with a gasoline content of over one gallon per 1000 cu.ft. can be treated more economically by the compression method, while gas having gasoline content from 0.1 to 1.0 gallon per 1000 cu.ft. can be treated more economically by the absorption method. At present the absorption process is fast replacing the compression process in the oil fields of California.

The compression method was mostly used in extracting gasoline from our gas, so I will describe this method first:

COMPRESSION PLANT

General Discussion of the Process

The blue print shows the flow of gas from the well until it is released from the Plant.

The compression plant derives its gasoline yield from wet gas by the compression process.

A portion of the gas enteringthe compression plant comes in under a vacuum produced by a booster. The wet gas, before being drawn into the compressors passes through a scrubber where any dirt or other detrimental foreign substance is removed.

The wet gas after passing through the scrubber enters the low pressure cylinder of the compressor and is polytropically compressed to 70 lbs. with a resulting temperature rise to 200 degrees F.

One compressor has two low pressure cylinders; the other five compressors have one low pressure cylinder and one high pressure cylinder. The details of the compressors will be found on the equipment sheet.

After the gas is discharged from the low pressure cylinders the gas passes through a series of cooling coils. These coils absorb the heat of compression. The temperature of the gas being decreased from 200 deg.F. to 66 deg.F. The condensed liquid is drawn off into an accumulator tank. It is estimated that 20% of the total gasoline in the gas is extracted in these low pressure coils.

The gas passes out of the top of the accumulator tank and enters the high pressure compressor intake. It is then compressed polytropically to 300 lbs,, with a consequential rise in temperature to 210 deg.F.

The gas, after discharge from the high compression cylinders, passes through a series of high pressure coils. The heat of compression is absorbed in these coils by means of a water spray that falls continuously upon them. This cooling of the gas of course decreases the temperature with a further condensation of the gasoline contained in the natural gas. The liquid condensed in the high compression cooling coils is drawn off into an accumulator tank. About 60% of the total gasoline in the gas is extracted in these high pressure coils.

The gas passes out of the top of the accumulator and enters a Baker heat exchanger; relatively, this gas still contains a considerable quantity of heat. This warm gas flows through the heat exchanger and enters the power end of an expander.

The expanding of the gas from 300 lbs. to 30 lbs. causes the temperature to drop to 150 deg.F. below zero. This intensely cold gas leaves the expander (power end) and again enters the Baker heat interchanger. The heat, contained in the incoming warm gas from the accumulator tank, is absorbed by the cold gas from the expander. Consequently, further condensation of the gasoline takes place. About 15% of the total gasoline in the gas is extracted in the heat exchanger.

After leaving the heat exchanger, the gas now enters the booster end of the expander. Here it is boosted to 35 lbs. and goes to the field for use.

Discussion of the function of various apparatus.

A. Scrubber

A cylinder tank used to clean the incoming gas of any dirt, thereby insuring a clean compressor feed.

B. Compressors

To condense the products of natural gas; which must be either cooled or pressure exerted thereon or both. Casing head gas contains in varying percentages, methane, ethane, propane, butane, pentane and hexane. The liquifaction point of these constituents vary greatly from 735 lbs. pressure and 95.5 deg. centigrade for methane, to 522 lbs. pressure and 153.2 deg. centigrade for lentane.

It is impossible to designate a particular condensation pressure and temperature that will be applicable to all cases. It is now almost the universal practice to compress the gas to 250 lbs.- 300 lbs. per square inch. This is accomplished in two stages. The low, or sometimes called the inter-stage, pressure is from 25 lbs.- 50 lbs. per square inch depending on the design of the machine. The heavier condensate is removed at this pressure when the gas is cooled in the low pressure cooling coils.

C. Booster

Some wells contributing wet gas to the compressor plant, have not enough natural rock pressure to enable the gas to reach the plant, consequently a booster is installed to overcome this condition. This machine draws the gas in on a vacuum of approximately 6" and then compresses the gas to a discharge pressure of 2 lbs.

D. Gas Engines

Four cycle engines are exclusively employed for this work. The primary reason for belt driven compressor, that is, compressors driven by a gas engine as a separate unit, is that a greater value can be realized in a second hand market in case the plant is dismantled.

E & F. Cooling Coils

Since the critical temperature as well as the critical pressure must be obtained, thorough cooling of the gases is essential. Either the submerged flow or open flow type is available. With the open flow type used at the compressor plant, the gas is expanded and travels through the coils giving it ample opportunity to come into intimate contact with the cooling surface. By spraying, or allowing the water from the towers, to drop on and over the coils, the added advantage of bringing the water into contact with the air results in efficient cooling. It is well to remember that evaporation of the water will result in a greater number of B.T.U's absorbed than possibly could be obtained by straight conduction of heat through submerged cooling. In other words, too much cooling water is detrimental.

The Bureau of Mines states that for a plant similar to the compressor plant, there should be 0.5 sq.ft. of cooling surface per 1000 cu.ft. of gas treated in the low pressure coils. The same amount of surface is ample for the high pressure coils.

G. Accumulator Tanks

The purpose of the accumulator tank is to collect the gasoline and water condensed from the gas and to separate the gas from the gasoline as it is carried over. It also acts as a storage tank, enabling the operator to repair the gas trap in case it fails to operate.

A baffle plate is placed directly inside of the tank and opposite the point at which the gas enters. Consequently any chance of gasoline being carried over with the gas is much lessened. These tanks have gasoline gauges to indicate the amount of condensate cotained at all times.

H. Heat Exchanger

The function of the Heat Exchanger is to cool the incoming warm gas suddenly. This sudden coolingextracts the last possible amount of gasoline that is practicably obtainable from the compression process.

The heat exchanger used at the compression plant is simply a large shell divided into five compartments. In each compartment there are a double series of coils. One within the other. The warm gas flowing in one, the cold gas from the power end of the expander flowing in the other.

The heat interchange is by radiation and conduction; convection can for all practicable purposes be considered negligible. The amount of heat radiated will depend upon the difference in temperature between the bodies and upon the substances of which they are composed. In this case (tubing iron) .0920 B.T.U's per sq.ft. per hour per degree difference in temperature (Fahrenheit) can be considered a good value.

The amount of heat conducted will depend upon the material of which the body is composed and upon the difference in temperature between the two sides of the body, and is inversely proportional to the thickness of the material. In this case 932 B.T.U's per sq.ft. per degree difference in temperature per hour can be considered a good value.

I. Expander

Its function is to cool the gas in the power end of the machine for use in the heat exchanger, and to boost the gas from the heat exchanger for field use. The expander was originally designed as a steam unit compressor. The high pressure gas now being used as the prime mover.

It was impossible to obtain the temperature of the gas after expanding because of its extremely low temperature. It is possible though to calculate it by means of thermodynamics. The following being the calculator data:

Gas Pressure (Initial 315# absolute pressure
(Final 45# " "

Gas Temperature (Initial 0 deg.F. (0° F.)

Theoretically of course the expansion is polytropic; in actual practice when gas is suddenly compressed or expanded, the compression curve is approximately adiabatic, a slow action would give an isothermal curve. Considering then that the expansion is adiabatic we have:

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{r-1}{r}} \quad \text{or} \quad \underline{T_2} = \underline{T_1} \left(\frac{P_2}{P_1}\right)^{\frac{r-1}{r}}$$

$$\text{Then } T_2 = (0 + 460) \left(\frac{45x144}{315x144}\right)^{\left(\frac{1.406-1}{1.406}\right)}$$

$$\text{Or} \quad T_2 = 460 \left(\frac{45}{315}\right)^{0.29} \text{Then } T_2 = 460 \times (0.142)^{.29}$$

$$\text{Log } T_2 = \text{log. } 460 + .29 \ (\text{log. } 0.142)$$

$$\text{Log } T_2 = 2.6628 + (.29 \times (9.1523 - 10)$$

$$\text{Log } T_2 = 2.6628 + (0.2459 = 2.4169)$$

$$T\text{-}2 = 261^\circ \text{ absolute} =$$

$$261^\circ - 460^\circ = - 199^\circ \text{ Fahrenheit}$$

Then 199° below zero Fahrenheit is the calculated theoretical value; the actual value will be less due to radiation and convection losses. If these are estimated at 25% (especially on a warm day) then 150° below zero Fahrenheit can be considered about the correct value of the temperature of the gas after expansion.

EQUIPMENT

A. Scrubber
  1. From pressure wells
    a One scrubber 3'6"x12'
    b Pressure 1# to 5#
  2. From vacuum wells
    a Two scrubbers 3'6"x12"
    b Pressure 6" vacuum

B. Compressors
  1. Number used (6)
    a One unit has 2 low pressure cylinders
    Five units have 5 high pressure and 5 low pressure cylinders.

B. Compressors
  2. Dimensions
    a High pressure cylinders 8" x 16"
    b Low pressure cylinders 16" x 16"

  3. Pressures
    a In low pressure cylinder inlet 2# sq.in.
    b In high pressure cylinder discharge 300# sq.in.

  4. Temperature
    1 Low pressure cylinder line
    a (an inlet 90° F
      (discharge 180° - 200° F

    2 High pressure cylinder
      (inlet 70° F
      (discharge 210° F

5. Capacity
  Low - 5,500,000 - 6,000,000 cu.ft.
  High 5,500,000 - 6,000,000 cu.ft.

6. Boosters
  1. Type - Ingersol - Rand "Imperial"
  2. Number used 2
  3. Dimensions
    (A Bore 27" & (C. Bore 27")
    (B Stroke 16" (D. Stroke 27")

  4. Pressure
    A. Intake 6" vacuum
    B. Discharge 2# pressure

D. Gas Engines
  1. Type - "Foos" 4 cylinder, 4 cycle, vertical
  2. Number used 8
  3. Dimensions
    a. Bore 11-1/2"
    b. Stroke 15"
  4. Horsepower 165
  5. Revolutions per minute - 280

E. Cooling Coils -(Low Pressure)
  1. Type 2" pipe connected by header
  2. Dimensions
    a. Length 60'
    b. Number of pipes - 28
  3. Temperature of gas
    a. Inlet 190° (estimated)
    b. Discharge 66° F.
  4. Pressure of gas
    a. Inlet) Not equipped for such a measurement
    b. Discharge)

F. Cooling Coils -(High Pressure)
  1. Type 2" pipe connected by triangler headers
  2. Dimensions
    a. Length 60'
    b. Number of pipes - 28
  3. Temperature of gas

F. Cooling Coils - (High Pressure)
  3. Temperature of Gas
    a Inlet) 200° F)Estimated
    b Discharge) 70° F) "
  4. Pressure of Gas
    a Inlet) Not equipped for such a
    b Discharge) measurement

G. Accumulator Tanks
  1. Number used - 5
    a Four for condensate from I P coils
    b One for condensate from H P coils
  2. Dimensions (approximately)
    a Low - Height 6'; diameter 3'
    b High height 10' " 4'

H. Heat Exchanger
  1. Type - Baker (5 compartments
  2. Temperature of Gas
    a Inlet 66° F
    b Discharge 0° F
  3. Pressure of Gas
    a Inlet 300#
    b Discharge 300#

I. Expander
  1. Type Ingersol - Rand
  2. Number used - 1
  3. Dimensions
    a Power end - (9" x 16"
    b Booster end (13" x 16"
  4. Speed 175 R.P.M.
  5. Temperature of gas (power end)
    a Inlet 0 F
    b Discharge 150° F below zero
  6. Pressure (Power end)
    a Inlet 300# sq.in.
    b. Disdcharge 30# sq.in.
  7. Pressure (Booster end)
    a. Inlet 30# per sq.in.
    b Discharge 35# " "

J. Pumps
  1. Type Centrifugal
  2. Make - Cameron
  3. Dimensions 4"

  2. Auxilliary Pumps

    Number used - 2
    Type - Worthington
    Dimensions - 6" x 8-1/2" x 6-1/2"

K. Boilers (Used for thawing only)
    Type - Fire tube
    B.H.P. 70
    Number installed - 2.

Next in importance was the absorption process for gasoline extraction so I am presenting the description of one of the largest plants using this process on our gas.

THE ABSORPTION PLANT

General Discussion of the Process

The Absorption Plant employs both the compression and absorption methods for recovering gasoline from natural gas; the absorption method predominating.

There are eleven compressors at this plant. Four of them have each two high pressure cylinders; one has two low pressure cylinders and the remaining six have each one high and one low pressure cylinders.

The low pressure gas after passing through a scrubber, where it is cleaned of any detrimental substance, goes into the Plant's lowpressure intake main. The pressure in this main is approximately 6 lbs. The compressors are arranged to feed in multiple. That is, each compressor feeds from a common main. The gas passes from the low pressure main into the low pressure cylinder where it is polytropically compressed to approximately 55 lbs. per sq.in. The temperature corresponding to this pressure is 215 deg.F. to 230 deg.F. After leaving the low pressure cylinders the gas passes into the low pressure cooling coils.

The gas from the high pressure wells enters directly the low pressure discharge main.

The low pressure cooling coils, cool the gas, that is, they absorb the heat of compression. Consequently, the temperature of the gas is lowered and condensation of the vapors result. This condensate is drawn off into a low pressure accumulator. The gas passes out the top of the accumulator and enters the bottom of the first absorption tower. The gas inlet is about 3' from the bottom of the towers or a trifle higher than the oil level. The gas flows upwards and encounters a stream of oil descending over baffles. The gasoline in the natural gas is absorbed by the oil in its downward course.

The absorption towers are connected in series so that the gas which leaves the top of the first tower enters the bottom of the second tower. Any gasoline that is not absorbed in the first towers is absorbed in the second tower.

The gas leaves the top of the second absorption tower and enters the high pressure intake main. The high pressure cylinders feed from this main. Allconnections are in multiple.

The high pressure cylinders compress the gas, polytropically, to approximately 290 lbs. per sq.in.

The temperature of the high pressure discharge gas is approximately 290 deg.F. From the high pressure discharge main the gas passes through the high pressure cooling coils. These coils absorb the heat of compression and the temperature of the gas is greatly lowered. The sudden decrease in temperature causes the vapors in the coils to condense. The condensate is drawn off into a high pressure accumulator. The gas now being stripped off its gasoline constituents enters the Midway Gas lines.

The Oil Circuit

Since the oil makes a complete circuit it will be assumed for convenience that the starting point of the oil circuit is at the top of the first tower. From this position the oil descends and strikes a series of wooden baffles. This causes the oil to divide into a myriad of tiny streams. This descending oil absorbs the gasoline in the natural gas, which flows upwards. The oil falls to the bottom of the tower and is then pumped to the top of the second tower. In the second tower, the procedure is the same as in the first tower. The oil from the second tower is drawn off and goes into an oil accumulator tank. This oil is known as cold saturated oil.

From the oil accumulator tank the oil passes through a series of heating coils in the still. This must not be confused with the oil going into the still for the purpose of vaporizing the gasoline. The saturated oil passes from these dephlegmator coils into and through two heat exchangers. From the heat exchangers the oil passes through a preheater. The oil that leaves the preheater is known as hot saturated oil. After leaving the preheater the oil enters the still. Here it encounters live steam. This intimate contact of oil and steam vaporizes the gasoline contained in the oil.

The water vapor and gas vapor pass out the top of the still and are condensed. The water is then separated from the gasoline by gravity.

The oil leaving the still is known as hot lean oil. From the still the hot lean oil is run into a tank. At this point a pump forces it thru the two heat exchangers. The heat of this hot lean oil is absorbed by the cold saturated oil.

To insure a thorough cooling of the oil before entering the towers, the oil leaving the heat exchangers passes thru an oil cooler, and into a tank. From this tank the oil is pumped to the top of the first absorption tower and is again ready to complete its cycle.

DISCUSSION OF THE FUNCTIONS OF VARIOUS APPARATUS

SCRUBBERS

The scrubbers are used to separate from the gas, any foreign matter contained therein, that would be harmful if allowed to pass into the main intake line.

COMPRESSORS

The compressors at the absorption plant serve a dual purpose. First they compress the gas, in the low compression cylinders to a pressure necessary for efficient absorption in the towers. Secondly, the high compression cylinders act as boosters.

The pressure used in conjunction with the quantity of oil in the towers, determines to a large extent the cross-sectional area of the towers. If the pressure is too great the oil and gas will be in contact too brief a time, and poor absorption will result. Another undesirable result is that oil may be carried over mechanically into the gas outlet line.

The absorbing quality of the oil increases with the pressure. Consequently it will be seen that pressure affects the absorption process mechanically and physically. Mechanically it determines the weight and strength of material used for towers, lines, valves and traps. Physically, it controls the actual volume of gas, and thereby affects the speed of gas flow and is a factor in determining the percentage of saturation to which absorption oil may be raised while removing the maximum quantity of condensate.

COOLING COILS

The cooling coils absorb the heat of compression and cool the gas to as low a temperature as is practical. The absorbing oil will absorb greater quantities of gasoline at low temperatures than at high temperatures. Also the boiling point of some of the constituents of gasoline is rather low and the gas line would not be recovered by oil at temperatures higher than that point. Efficient cooling is then a very important factor of plant operation.

ACCUMULATORS

The accumulators act as storage tanks for the condensates from the cooling coils. They also separate this condensate from the gas. The gas passes out through the top of the accumulators.

ABSORPTION TOWERS

Two types of absorption towers are used in present day practice. The horizontal and the vertical. The latter type is proving best adapted in meeting the requirements. The height of the tower is a function of the gas pressure and of the desired minimum oil flow. Increasing the height of a tower would lengthen the time of descent of the oil and increase the time of contact between gas and oil. Consequently a decrease in the amount of oil circulated results. Also an equal recovery with less power for pumping and less heat in the stills is accomplished.

The amount of oil circulated besides vary with the pressure, height of the tower, and condensable content recovered from the gas, varies also with the temperature of the oil and gas, and with the characteristics of the hydrocarbons recovered. At the absorption plant, the quantity of oil circulated was 40 gallons per minute.

OIL ACCUMULATOR TANK

This tank is sometimes called an "Oil weathering tank." This tank the only unit of the system where a storage or variation of content is llowable or possible. It therefore takes care of any irregulatities in the antity of oil circulated.

This tank also "weathers" the oil, that is, it relieves the oil of s taken up during the absorption. This gas can not increase the gasoline ield and is troublesome and detrimental in distilling and cooling.

Ordinarily from this tank the oil is forced through the heat xchangers to the still. At the absorption plant, however, the oil goes through ome dephlegmator coils first. These coils are shown on the blue print as he upper set of coils in the still. They are really heating coils. From hese coils the oil goes through the heat exchangers. It is well to bear in ind that the hot oil should always flow upwards to avoid gas pockets.

HEAT EXCHANGER

The function of a heat exchanger is to heat the oil going to the till as much as possible in order to save fuel and to cool correspondingly he outgoing oil in order to save cooling surface and water.

There are several types of heat exchangers used at the various lants under consideration. It seems that the controlling factors of design e first cost, and the cost of upkeep.

The most satisfactory type of heat exchanger is the counterflow acketed type made of pipe and standard fittings. In practice a radiating rea of 0.25 to 0.35 sq.ft. is allowed for each gallon per hour passing thru he unit on its way to the still.

PREHEATER

In order to insure that the oil going into the still will be as hot s is practicable, without actual evaporation taking place, it is heated in preheater. Consequently the gasoline contained in the oil as it enters the till is rapidly evaporated and the time of circulation of the oil should not e as great as at other plants that are not using a preheater.

STILL

There are two types of stills in general use at present. The rizontal or pan type and the vertical still. The latter type is used at absorption plant.

The temperature in the still is from 210 degrees F. to 225 degrees F. pending on heating effect obtained in the heat exchanger. The oil meeting e steam from perforated pipes completes the separation of the volatile hydrorbons.

The pressure in the still is necessarily low in order to keep the mperature of evaporation of gasoline within practical limits.

CONDENSER

Vapors coming from the still have temperatures between 200 degrees and 225 degrees F. These are vapors of gasoline and water. There are also ses present that were liberated from the oil by the heat and steam in the ill; undoubtedly there is also a small portion of the absorption oil itself; e latter, both as vapor and as finely divided particles of liquid.

The condensing, that is, the cooling of the vapors is accomplished coils exposed to water and air in "Louver" towers. An area of 2.5 square et per gallon per hour is considered sufficient for effective cooling. The pes are made of standard 2" pipe materials and fittings.

AFTER - ABSORBER

There is considerable vapor tension in the gasoline storage tanks and me of the volatile hydrocarbons would be lost were it not for the aftersorber. This is a small absorption tower approximately 10" x 20'. Oil for is tower is taken from the oil line leading to the main towers and the saturated oil from the after-absorber is sent to the still. Over 10% of the total ant production of gasoline is usually recovered by this treatment.

THE PRODUCT

Gasoline made by the absorption process has a high gravity between degrees to 80 degrees Baume, and a low vapor tension (3 to 6 lbs)

By virtue of these desirable qualities a premium in the open market n be obtained.

EQUIPMENT

A. SCRUBBERS
1. Number used for heating high pressure gas ------1.
Number used for heating low pressure gas -------1.
2. Dimensions

B. COMPRESSORS
1. Type --Ingersoll-Rand (Imperial)
2. Number used----------11.
3. Number used having 2 L P Cylinders--------1.
Number used having 2 H.P.Cylinders--------4.
Number used having 1 H P & 1 L.P.---------6.
4. Dimensions of H P Cylinders 8" x 16"
Dimensions of L P Cylinders 16" x 16"
5. Temperature (low)
a Intake (not equipped for measurement)
b Discharge 215 deg. - 230 deg F
6. Pressure (low)
a Intake 6# per sq.in.
b.Discharge 50 to 60# per sq.in.
7. Temperature (high)
a Inlet 220 deg.F (approximately)
b Discharge 290 deg F.
8. Pressure (high)
a Inlet 50-60# sq.in.
b Discharge 275 - 310# sq.in.

C. COOLING COILS (Low pressure Gas)
1. Type Triangular headers
2. Number of coils---------66
3. Length of coils---------66 feet
NOTE: Temperature and pressure measurements not obtainable

D. COOLING COILS (High pressure Gas)
1. Type Triangular Headers
2. Number of coils-----------33
3. Length of coils-----------66 feet

E. COOLING COILS (Engine Water)
1. Type vertical return headers
a Length of coils---------20'
b Diameter of coils------- 2 inches

F. ABSORPTION TOWERS
1. Type - vertical designed for high pressure
2. Number of units ----------2
3. Dimensions
a Heights -------50'
b Diameter------- 4'
4. Capacity--------5,500,000 cu.ft. daily each
5. Temperature Oil
a Inlet - 70 deg.F.
b Discharge - 70 deg F.
6. Gallons of oil circulated per minute - 40
7. Time for a complete circuit - 30 minutes
8. Gas pressure
a Entering tower 50# - 60# per sq.in.
b.Leaving tower 50# - 60# per sq.in.

AFTER - ABSORBER
1. Type - vertical
2. Dimensions
a Height - 20'
Diameter -10"

PUMPS
1. Cold oil pumps
a Dimensions 9" x 5-1/4" x 10"
b Make, Worthington
c Number used - 3
2. NOT OIL PUMP
a Dimensions - 9" x 5-1/4" x 10"
b Make -Worthington
c Number used - 2
3. Engine Circulating Pump
a Dimensions - 3"
b Make - Centrifugal
c Number used - 11

GAS ENGINES
1. Type - Bessemer - 2 cylinders - 4 cycle
2. Number used - 11
3. Dimensions
a Bore - 14-1/2"
b Stroke - 20"

HEAT EXCHANGER
1. Type - Tubular
2 Number used - 2
3. Capacity - no data avilable

I. PREHEATER
1. Type - Vertical
2. Number used - 1
3. Temperature of oil
a Entering (not equipped for measurement)
b Leaving (not equipped for measurement)

J. STILL
1. Type - Vertical
2. Dimension
a Height - 15' approximately
b Diameter - 3' "
3. Gallons of gasoline evaporated per 24 hours - 3600

K. ACCUMULATOR TANKS
1. High pressure
a Dimensions - 8' 0" x 30"
2. Low pressure
a number used-2
b Dimensions 5'0" x 30" & 7'0" x 30"

L. CONDENSER
1. Type Pipe Vertical return headers
2. Number of coils - 32
3. Present capacity 3600 gallons per 24 hours

M BOILERS

1. Type - Scotch Marine
2. Number of units - 2
3. Number of units used - 1
4. Boiler - H.P. - 200

The gas after being stripped of its gasoline content enters our fuel system as "dry" gas. After all our fuel needs are satisfied the excess gas is sold to a Gas Company. To give you an idea of the amount of gas sold by our Company to the Gas Company, I may say that it supplies about one third of the fuel needs of the City of Los Angeles.

The Gas Company has a large Boosting Plant in the field which boosts all the gas to 450 lbs. pressure per square inch, which is sufficiently high to travel a distance of 127 miles through a pipe line to the City of Los Angeles without further boosting.

The Gasoline Company that treats our gas conceived the idea that they can strip some more gasoline from this dry gas, and obtained a contract from the Gas Company to take another "crack" at the gas before it leaves for Los Angeles. The Gas Company granted such a contract with the understanding that the entire treatment of the gas should not reduce the initial pressure of the gas over 7 lbs. To fulfill this requirement the Gasoline Company constructed "The Refrigeration Plant".

THE REFRIGERATION PLANT

General Discussion of the Process

The Refrigeration plant is radically different from the other gasoline plants in the field. It is neither an absorption or compression plant. Referring to the drawing it will be seen that the gas enters the plant at a pressure of 450 lbs., per sq.in. There are four very long sets of cooling coils in multiple with the inlet main. These coils are shown broken on the drawing in order to conserve space. If shown in their true length, which is 300 feet, they would extend well past the middle of the drawing. The gas passes through these coils where the heat of compression is removed. The compression of gas is done entirely by the Midway Gas Co.

The Refrigeration Plant has no gas compressors. At the end of these long cooling coils there is an accumulator that removes the condensed vapors of water and some gasoline.

The Refrigeration Plant consists of four identical units. The blue print shows one complete unit; namely, Unit Four. The warm gas, relatively speaking, passes out the top of the accumulator and thence through the inside pipe of a horizontal shaped cooler and enters the tower near the bottom.

This tower is not an absorption tower as used in an absorption plant, that is, there is no gasoline absorbing medium used. For convenience the writer will call it "A Knock-Out Tower". The gas passes into this tower near the bottom and blows upwards. It encounters a very cold calcium chloride mixture that descends. This calcium chloride has a great affinity for water but not for gasoline, consequently, the water in the gas is absorbed. The gasoline in the gas is knocked out or precipitated by the coldness of the calcium chloride. The calcium chloride and water form a solution that is drawn off into a calcium chloride dehydrator.

The gasoline being lighter than the calcium chloride solution floats on top of it, and is drawn off, as is shown, to the gasoline storage tanks.

The cold stripped gas passes out the top of the tower and enters the outside shell of the horizontal U shaped cooler. The cold gas in its passage through this cooler cools the incoming warm gas thereby reducing the amount of cooling to be done by the calcium chloride in the towers. The gas leaves this U shaped cooler at a pressure of 443 lbs. and goes to the Gas Company's Plant near Los Angeles without further boosting.

THE CaCl-2 CIRCUIT

After the calcium chloride has absorbed the water from the gas in the tower, its concentration is reduced. In order that efficient freezing of the CaCl-2 may result, the concentration of the solution has to be maintained at 29%. That is 29% CaCl-2 and 71% H_2O. This concentration is maintained at 29% by drawing the solution from the tower into a cylindrical tank shown on the blue print as a dehydrator.

This dehydrator is an open cylindrical tank approximately 5' in diameter and 4' in height. On the bottom of this tank there is a set of steam coils. The heat from these coils evaporates the water in the CaCl-2 solution until the correct concentration has beenreached. The solution is then pumped to the tower again. The flow of the CaCl-2 solution from the tower to the dehydrator is not a steady or continuous flow, but intermittent. That is, it flows to the dehydrator only when the solution has to become more concentrated by evaporating the water.

When the CaCl-2 solution is of the correct concentration it is drawn from the bottom of the tower to a pump. This pump forces the solution through the inside pipe of a vertical U shaped "Ammonia cooler". The CaCl-2 solution is cooled and passes from this ammonia cooler to the top of the Knock-Out tower, and descends absorbing the water contained in the incoming gas and precipitating the gasoline. The CaCl-2 solution being heavier than gasoline settles to the bottom and is again drawn off to the pump thus completing its cycle.

THE AMMONIA CIRCUIT

The CaCl-2 solution is cooled by means of expanding liquid ammonia in the following manner:

Since the ammonia makes a closed or complete circuit, it will be assumed that its starting point is at the ammonia receiver. The liquid ammonia is expanded from the receiver through a needle valve into the outer shell of the "Ammonia Cooler". This expansion causes a great drop in temperature, consequently, cooling the CaCl-2 solution flowing through the inner pipe of the "ammonia cooler".

When liquid ammonia is expanded it becomes a vapor and this ammonia vapor is drawn off the top of the ammonia cooler by means of the vacuum created by the ammonia compressor. This ammonia vapor is then compressed and discharged through a set of cooling coils. These coils absorb the heat of compression and cause the vapors to condense to a liquid. The liquid is caught by the ammonia receiver where it is again ready to complete its cycle. A brief summary then shows three distinct flow schemes:

1st - The Gas Flow
2nd - The CaCl-2 Flow
3rd - The Ammonia Flow

The CaCl-2 acting as the absorbing or dehydrating agent absorbing the water in the gasoline and precipitating the gasoline by virtue of its "coldness". The expansion of liquid ammonia gives to the CaCl-2 its coldness.

Technically the expanded liquid ammonia absorbs the heat contained in the CaCl-2 solution.

EQUIPMENT OF THE REFRIGERATION PLANT

A. COOLING COILS
Type - Triangular Headers
Diameter - 2"
Length - 300'
Number per set - 96
Number of sets - 4
Pressure in coils, 450# per square inch.

B. COMPRESSORS
1. Number used - 4
2. Make - York
3. Dimensions
a Bore - 12-3/4"
b Stroke - 14"

C. ABSORBING TOWERS - or Knock-Out Towers
1. Number used - 4
2. Type - Vertical
3. Dimensions
a Height - 35'
b Diameter - 4'
4. Absorbing medium - CaCl-2

D. GAS COOLERS
Number used - 4
Type - U shaped pipe

E. CaCl-2 COOLERS
1. Number used - 4
2. Type - Double Pipe U shaped

F. ENGINES
1. Number used - 4
2. Type - Bessemer
3. H. P. - 60
4. R P M - 180
5. Used to drive ammonia compressors.

G. AMMONIA COOLING COILS
1. Number of sets - 4
2. Type - Pipe Vertical Headers
3. Number of pipes per set - 26

H. PUMPS (JACKET WATER)
1. Number used - 4
2. Type - Cameron
3. Diameter - discharge 1-1/4"

I. PUMPS - (CIRCULATING TOWER H-20)
1. Number used - 4
2. Type - Cameron
3. Diameter of discharge - 4"

J. AUXILIARY ENGINE
1. Number used - 1
2. Type - Bessemer
3. Horse Power -60

K. DEHYDRATOR
1. Number used - 1
2. Type - Cylindrical open tank
3. Dimensions
  a Height - 5'
  b Diameter - 4'

L. STORAGE TANKS
1. Number used - 3
2. Capacity - 4392 gallons per tank

The Causes for Pressure Fluctuations in Gas System

There are a number of problems that our gas department had to solve from time to time and quite often we had very little information to begin with. We have to reason out the causes for the difficulties, then try to solve the problems on the basis of these suppositions and judge the correctness of our deductions by the results obtained. I will not attempt to present many of these problems in this thesis, but I will discuss a few of them.

One of the problems was entitled "The Causes for the Pressure Fluctuations in the Wet Gas System during the 24 hours."

The main artery of our wet gas system is a 16" pipe line. The pressure in that line must not at any point exceed 3 lbs. and should preferably be 0#, or atmosphere pressure, since it is the best pressure to obtain the gasoline enrichment of the gas without hurting the well or lessening the richness of the oil. The 16" line extends for about four miles and has a number of subsidiary lines ranging from 12" down to 4" lines with individual 3" lines leading to each well. There are eight gasoline plants located at convenient places along the 16" line that feed off this line, and the capacity of each plant and its operation has to be such as to assure as closely as possible the most desirable pressure at each well.

The operation of plants to meet such conditions is no simple matter, for they have to please more than 400 wells, a number of which are capricious at times, i.e., sometimes "heading" very heavily and at other times "dying down" practically to nothing, nor do the wells guarantee us to act the same way every day, for our carefully metered 24 hours tests convinced us that each well reserves the right to change its schedule without notice. Fortunately, the wells have apparently no secret alliance and do not act alike at the same time and quite often the periods of "heads" of some wells are balanced by "quiet" periods of other wells which tends to maintain a constant supply of gas for the plants. This is evident from the continuous chart records that are kept at all plants.

After considerable manipulations at the plants we have finally arrived at conditions which produced the most desirable pressures along the entire system and with the exception of minor adjustments, all was well for several months.

During the summer months we were confronted with difficulties once more, for we discovered a three pound increase in pressure all along the system during the day, while normal conditions prevailed at night. The range of allowable pressure in the 16" line being very small, 0# to 3# gauge pressure, a substantial portion of the gas was popping off during the day time on account of having exceeded 3# pressure. It was necessary for us to discover the cause or causes for the increase in pressure in order to be able to conserve all the gas during the 24 hours.

There were three general causes for the increase in the gas line pressure, namely:

1. Increase in temperature during the day.
2. Increase in gas production during the day.
3. Decrease in plant capacities during the day.

Our gas department began to experiment in order to find the true cause or causes for this increase. The following apparatus was used: One Bristol Recording Gauge, in connection with a 2" orifice meter with 1/4" to 1-1/4" range in orifices. One Schaeffer & Buddenburg Columbia Recording Gauge instrument, comparatively sensative and used mainly in connection with a 3" orifice meter with 1/4" - 2" range in orifices, also with clamped-on Pitot tube, where such arrangement was advisable.

Extreme care was used in checking measurements at each well. Orifice meter pressures were checked by means of a water or mercury manometer connected into the gauge line. Pitot measurements were checked by means of a standard Pitot tube with manometer.

A Bristol Recording Thermometer registered the temperature over the 24 hours. The season for the tests was July 21st to August 26th, the typical period for the hot weather conditions.

The general procedure was as follows:- Each chart was removed after a 24 hour period, the graph was inspected and a method of grouping the heads determined upon. In the case of a steady flowing well this was not necessary. The flows as recorded during twelve hours of day and twelve hours of night, were figured as cubic feet separately, corrected to 60° F. and Specific Gravity as determined, and added together to obtain the total 24 hours flow. Practically in all cases the wells showed an increase of day flow over night flow.

Calculation of Actual Volume of Gas Handled at Plant

With the aid of Bristol Recording Thermometer, temperatures were read at equal intervals of time.

TEMP. IN [illegible]. AT 16" INTAKE LINE

	DAY TEMPERATURE				NIGHT TEMPERATURE			
DATE	7:30 AM	10:30 AM	1:30 PM	4:30 PM	7:30 PM	10:30 PM	1:30 AM	4:30 AM
7/21	91	106	119	121	93	79	73	77
7/22	92	109	117	121	91	78	74	76
7/23	92	110	114	120	92	78	73	77
7/24	90	107	117	121	94	77	72	76
7/25	92	110	116	121	92	78	71	75
7/26	90	111	117	121	91	79	70	74
Average	91	109	117	121	92	78	72	76

Day Average - 110° F. Night Average - 80° F.

Charles Law states that if volume of gas remains constant the increase in temperature causes an increase in pressure or $\frac{T}{T_1} = \frac{P}{P_1}$ where

T = 570° F. - Temperature during the day - absolute

T_1 540° F. " " night - "

P ? Pressure during the day - absolute in lbs. per sq.in.

P_1 17.7# " " night - " " "

Atmosphere 14.7#

Therefore, $P = \frac{570}{540} \times 17.7 =$ 18.7# pressure absolute or
4.0# gauge pressure

This shows that the increase in the temperature caused only 1.0# increase in gauge pressure. The next step was to determine whether there was an actual increase in the gas production during the day.

The actual measurements at atmosphere pressure of the amount of gas produced during the day, average temperature 110° F. was 8,367,250 cu.ft. while during an equal period of time at night, average temperature 80° F. and at atmosphere pressure the production was 7,836,350 cu.ft., reducing both values to the standard temperature, i.e. 60° F. we get.

$$\frac{V_0}{T_0} = \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

T_0 = 520° F. or absolute temperature standard
T_1 540° F. " " at night
T_2 570° F. " " during day
V_0 volume of gas at standard temperature
V_1 7,836,350 cu.ft. of gas delivered at night
V_2 8,367,250 cu.ft. of gas delivered during day

$$V_0 = \frac{V_1 T_0}{T_1} = \frac{7,836,350 \times 520}{540} = 7,540,000 \text{ cu.ft.}$$

$$V = \frac{V_2 T_0}{T_2} = \frac{8,367,250 \times 520}{570} = 7,630,000 \text{ cu.ft.}$$

This shows that there was not an appreciable increase in production during the day to cause an increase in pressure, therefore, the only thing that could cause the increase in the unaccounted 2# pressure was the decrease in the plant capacities during the day. On further investigation it was revealed that most of the repair work on the engines and compressors was done during the day for it is the most convenient time, however, since the plant did not have any emergency units to replace the ones that were being repaired the capacity of the plants was naturally reduced during the day time.

As the result of this experiment several additional units were installed in order to be able to conserve all the gas at all times.

The Effect of Vacuum upon Gas and Oil

Another interesting and important problem that we were called upon to solve was "The Effect of Vacuum upon Gas and Oil". Under the present condition we do not permit any vacuum from extending into the trap where it will have effect upon the oil. The management of the gasoline plants advocated the extension of the vacuum to the traps, claiming that it will cause the enrichment in gasoline content of the gas, increase the gas and oil production of the wells, and the gravity Baume of the oil will not be affected since the enrichment of the gas would come from the gasoline vapors given off by the oil, which were too volatile to be preserved by the oil.

In theory the proposition sounded logical, but the gas department preferred to test the theory out before it would recommend its acceptance or rejection.

To begin with, the change in our present method or in other words, in order to allow the vacuum to be extended to the traps, would require considerable modification in the designs of the present traps and a number of present traps would have had to be discarded entirely and new ones replaced. This change in equipment would involve an expenditure to our Company of about $100,000.00, and it was, therefore, essential for us to be convinced that the increase in the gasoline production would justify such an expenditure. I wrote for information to several professors of Petroleum Engineering, as well as to the U.S.Bureau of Mines, and all the replies indicated that very little information was available on the problem and the only reliable way to solve our problem was to perform field experiments in the region where it was intended to be used. Without much delay our gas department began the experiments.

FIELD INSTALLATION

A 15" Vacuum Trap was installed at Well #1 (See Plate No.1 for detail drawing of trap) The crude oil coming from the well discharged through the trap directly into the flow tank, without passing through a flow or sand trough. The oil production was gauged at the flow tanks for each 24 hours of the test.

A recording vacuum and pressure gauge and a recording thermometer were installed in the trap above the oil level and 24 hours records of pressure and temperatures were kept throughout the test. A 1/4 inch nipple and valve were inserted in the bottom of the oil discharge of the trap and all oil samples were taken at this point.

FIELD WORK

The trap was shut off from the gathering line and the gas was allowed to blow open to the atmosphere for two days prior to the start of the test. The casing head gas was measured and found to have a volume of 91,000 cu.ft. per 24 hours and an average gasoline content of 2.17 gallons, per 1000 cu.ft. A crude sample was then taken at atmospheric pressure at the trap and taken to the laboratory for distillation. This was the initial or fresh crude sample and was unaffected by vacuum or pressure from the gathering line.

The gas was then turned into the gathering line through the trap and crude samples were taken daily and sent to the laboratory. Daily records of the temperature and vacuum in the trap and daily production records were also kept.

SAMPLING

A five gallon galvanized iron sample can designed to fill from the bottom was connected to the valve in the oil discharge of the trap by means of 3/4" rubber hose. The valve was then opened, the can filled, sealed immediately upon filling, and sent to the laboratory. This method eliminated all loss from pouring or over-shot filling.

LABORATORY WORK

The gravity (Baume) volume losses of each sample were determined in the laboratory.

DETERMINATION OF GRAVITY LOSS

The initial samples of fresh oil, sample No.1, as brought from the field, was chilled until the temperature of the oil was 60 deg.Fahrenheit. A portion of the sample, slightly in excess of 1000 c c was placed in a separatory funnel and allowed to stand until most of the free water in the oil had settled out. This water was then drawn off. The oil, still in excess of 1000 c c, was poured into a graduated glass cylinder, where its gravity and temperature were measured. The gravity was measured with a corrected Tagliabue Hydrometer, graduated in tenths of a degree. The temperature was measured with a corrected Tycos Thermometer graduated for each degree. These readings were then corrected, using the tables in the Taglibue Manual, to obtain the true gravity of the oil at 60° F. The gravity of the fresh oil, Sample No.1 was found to be 26.2 deg Be' at 60° F.

The gravity of each sample as it came from the field was measured in the above manner, and its gravity loss was determined by subtracting its corrected gravity from 26.2 deg. Be., i.e. the gravity of the initial sample.

DETERMINATION OF VOLUME LOSS

The method used by Mr.J.W.Wiggins in Bulletin 200 Bureau of Mines, for the determination of volume loss from distillation data, was used in these experiments.

DISTILLATION

After the gravity of the sample had been taken, 1000 c.c. of the oil were accurately measured in the graduated glass cylinder and poured into a copper topping flask of about 2500 c.c. capacity. The vapor-take-out of the flask was connected to a 30" Liebig condenser set at an angle of 75 degrees to the vertical. Heat was applied to the bottom and sides of the copper flask until the oil boiled, care being taken not to heat the flask too strongly while the water was coming over. The vapors passed upward through the neck of the flask to the vapor-take-out. The bulb of a nitrogen filled thermometer was placed in the neck of the flask opposite the take-out, and the temperature read at each cut. The vapors continuing, passed downward through the condenser, and the resulting liquid was caught in a glass graduate surrounded by ice and ice water. Distillation was made at the rate of 5 c.c. per minute. Temperatures were read at each percent distilled up to five percent, and from then on for each five percent distilled until the temperature of 518 degrees was reached, when the sample was topped.

The tops were then redistilled in a short necked glass flask of 1000 c.c. capacity connected to a 12 inch Hemple fractionating column filled with 8 inches of glass beads. The vapor-take-out of the Hemple column was connected to the Liebig condenser. Gravity cuts were made as follows: Gasoline 54° Be', Distillate, 42° Be', Kerosene, 38° Be'. The volume of the bottoms was then measured and the gravity taken. The residue in the copper flask was measured by weight and its gravity taken. The percentage of water in the sample was determined during the topping distillation. The distillation loss was determined by adding up the percentages of gasoline, kerosene, distillate, bottoms, residue and water, subtracting the sum from 100%.

This initial sample was taken at atmospheric pressure and was considered basic and all other subsequent samples were taken under varying vacuums and the percentage of gasoline, distillate, etc., were determined by distillation as before and the results compared with that of the basic sample.

Certain corrections were applied to distillation data in order to determine the true volume loss and the results of the distillations were plotted with per cent distilled as abscissas, and the temperatures, in degrees Fahrenheit, at which the cuts came over, as ordinates, but at present the problem is still in the experimental stage and is regarded confidential, however, certain results may be given here.

LOSS IN GRAVITY

In the nine days of the test, under an average vacuum of 6.2" of mercury, the crude oil dropped from 26.2 degrees Baume' to 25.5 degrees Baume' and thus suffered a loss in gravity of 0.7 degrees Baume'.

ACTUAL VOLUME LOSS

The volume loss was found to be 3.17 per cent or an equivalent of 1.33 gallons per barrel of crude. All this loss was suffered by the gasoline fraction of the crude, as the percentage of distillate, kerosene, bottoms, residue and water remained practically the same through the test. o it has been assumed that the 3.17 percent volume loss represents a loss of 1.33 gallons of gasoline per barrel of crude.

ACTUAL VALUE LOST

In determining the loss in actual value, that is, in cents per barrel, the current crude oil prices were used. It was found to be 7.68¢ per barrel.

GASOLINE RECOVERED PER BARREL OF CRUDE

Throughout the test the increase in the gasoline content of the gas due to the increased vacuum, was measured and was found that under ideal conditions the gasoline content of the gas was increased by 1.33 gallons for every barrel of oil passing through the trap.

On the basis of 90% of the gasoline in the gas usually recovered in the gasoline plants, it would mean an increase of only 1.20 gallons of gasoline. At the current price, the increase in royalties due our company would be 7.23¢ per barrel of crude passing through the trap.

NET LOSS PER BARREL

The net loss per barrel of crude was determined by subtracting this royalty of 7.23¢ from the gross loss of 7.68¢ per barrel. This net loss amounts to 0.45¢ per barrel.

CONCLUSION

As stated before this investigation is still in the experimental stage and so far only a limited number of wells were experimented with and the conclusion given below, is not to be regarded as final, but assuming that further experiments under varying conditions will show somewhat similar results our conclusion will be as follows:

The installation of a gathering system operating at a vacuum inside the traps would prove unprofitable for this Company for the following reasons:

1. It would reduce the gravity of the crude oil.
2. The crude oil would also suffer a loss in volume.
3. The increased royalty in gasoline would not be sufficient to offset these losses and the added expense of installing vacuum traps.

It is possible that the installation of such a gathering system might prove profitable under the following conditions;

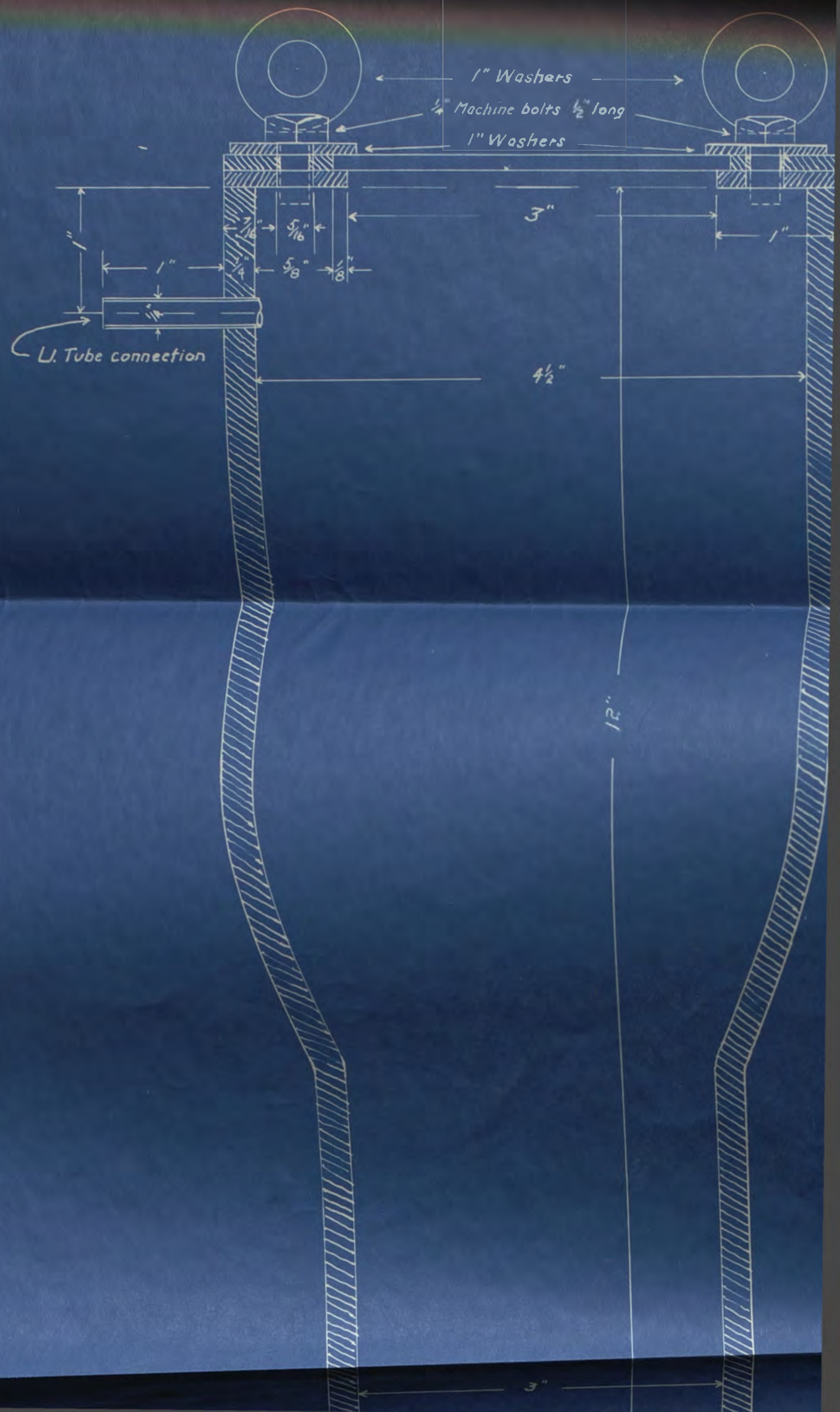
1. If the gasoline royalty were increased to the point where the revenue from this source would offset the gravity and volume losses of the crude, pay for the installation of vacuum traps, and leave a reasonable margin of profit.

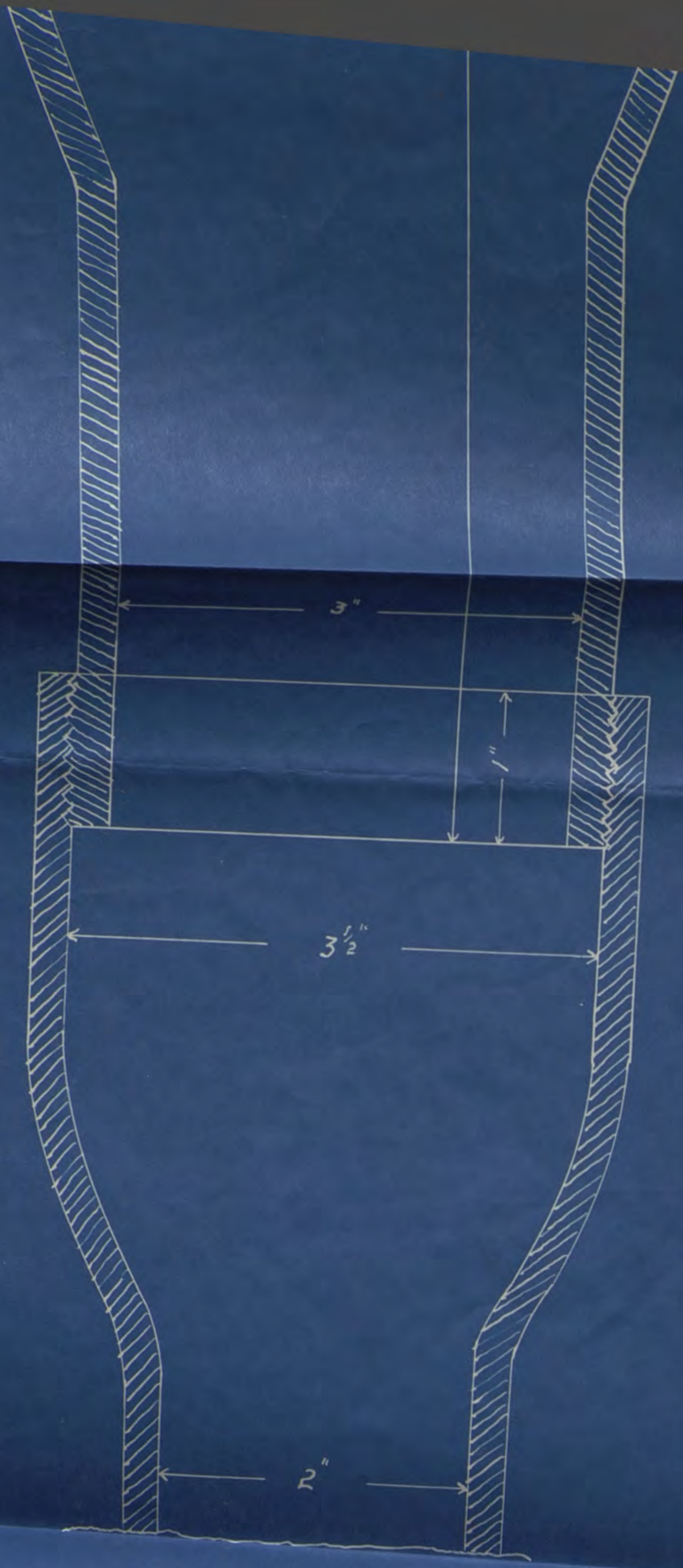
2. If our Company owned the gasoline plants.

There are a number of other problems of lesser importance that were experimented with, and solved by our gas department, and I will be pleased at any time to give a detailed report on them to students and members of the faculty who may be interested in this branch of petroleum engineering.

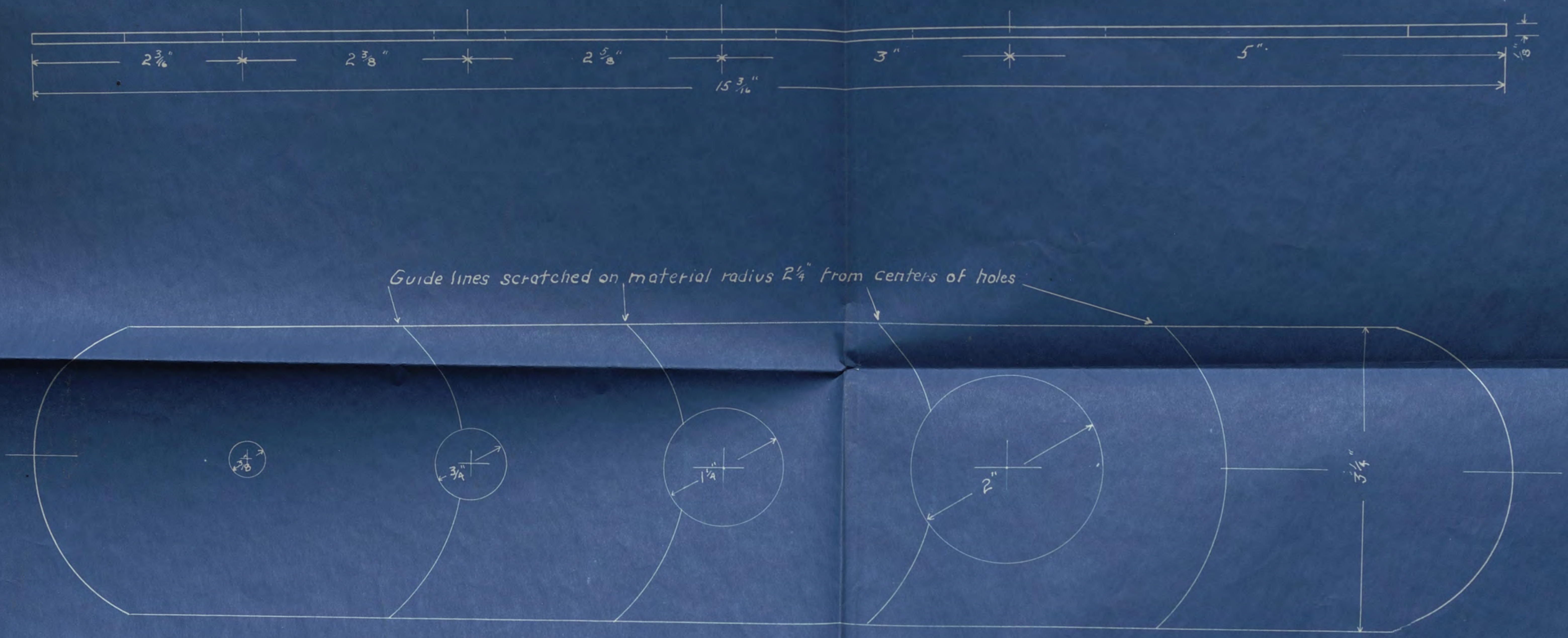
Respectfully submitted,

S. Merenbach


1" Washers
1/4" Machine bolts 1/2" long
1" Washers
3"
1"
1"
1"
7/16"
5/16"
1/4"
5/8"
1/8"
1/4"
U. Tube connection
4 1/2"
12"
3"

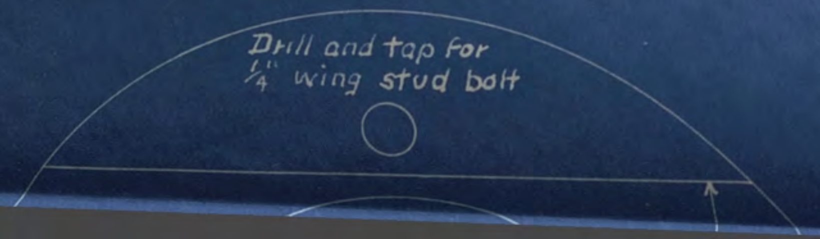


Vertical Section

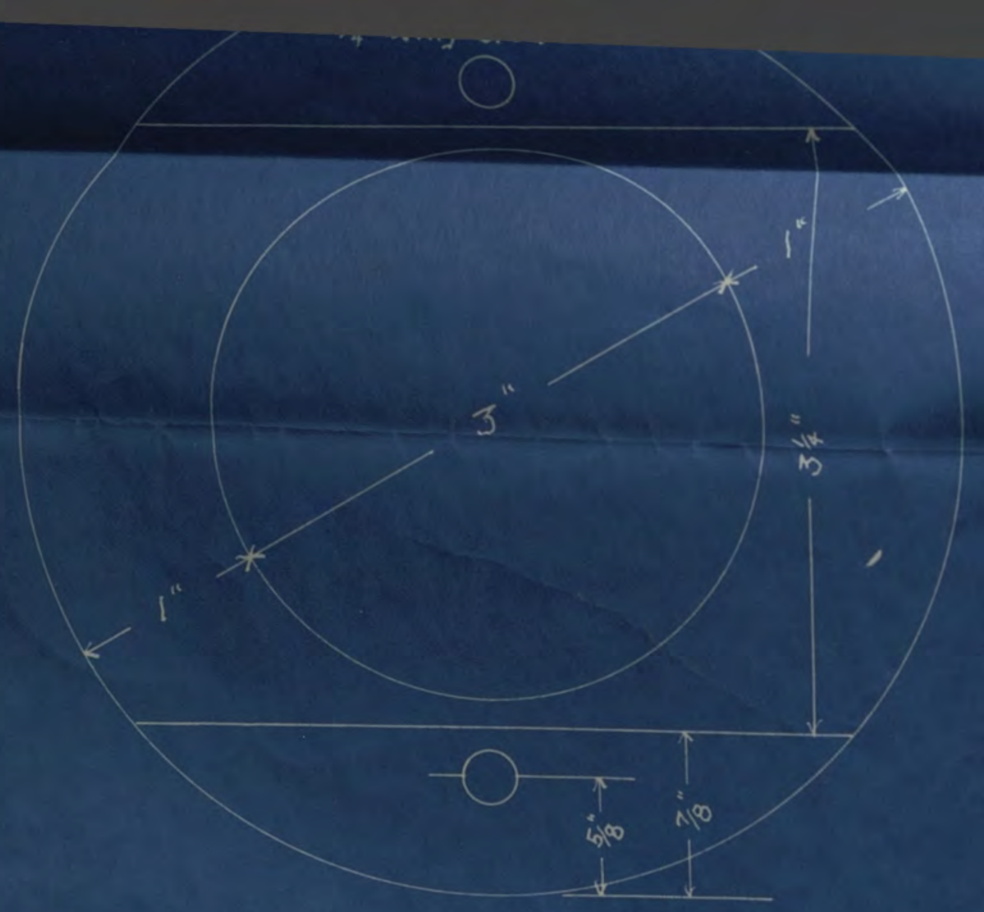


Guide lines scratched on material radius 2 1/4" from centers of holes

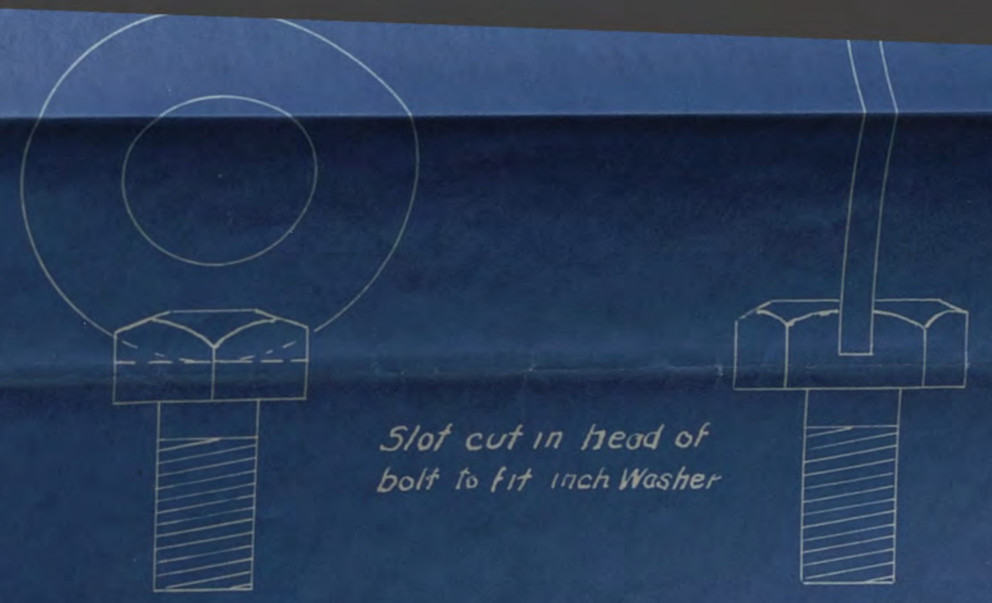
Slide



Drill and tap for 1/4" wing stud bolt



Top Elev. slide and set bolts removed



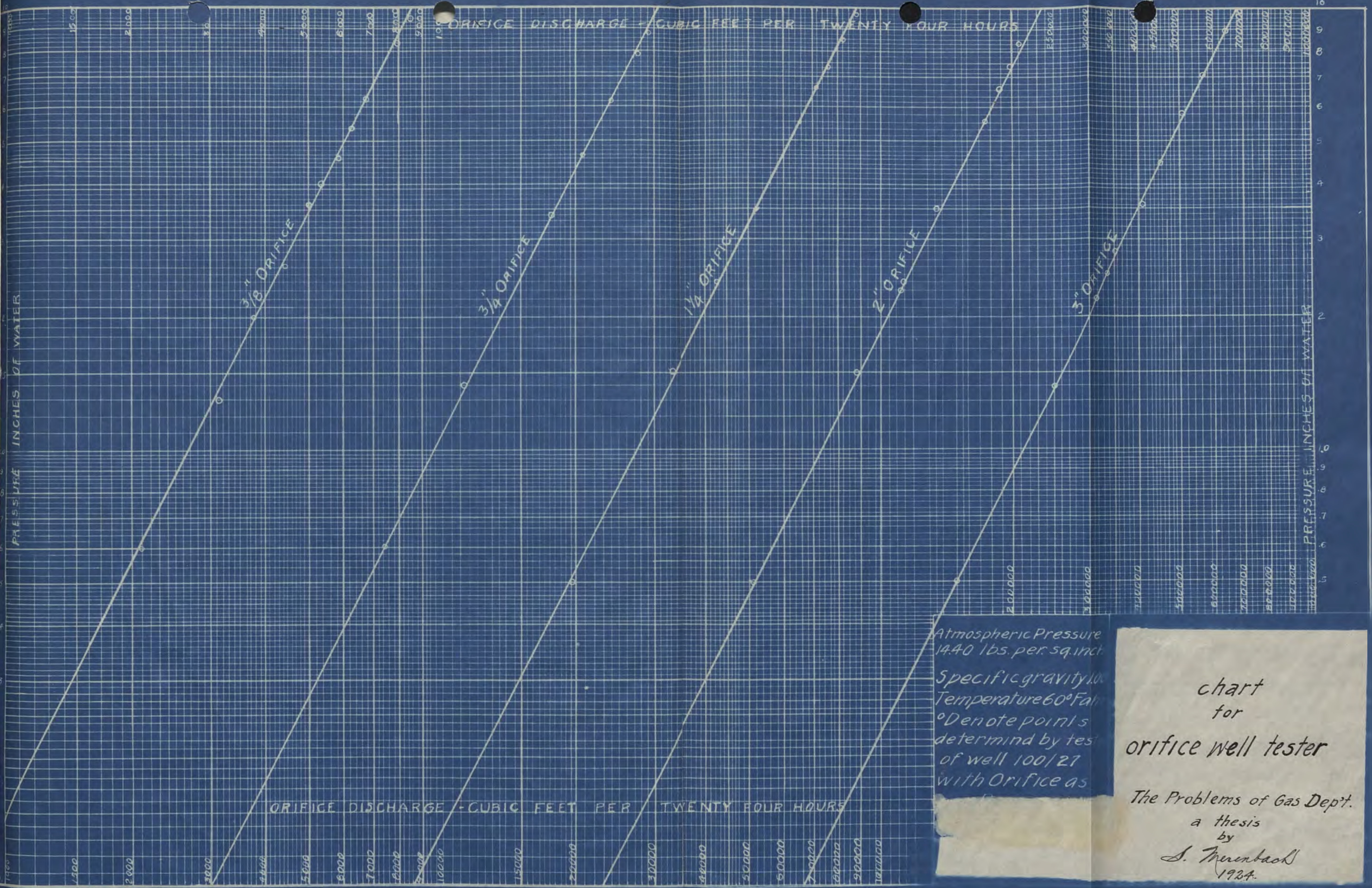
Slot cut in head of bolt to fit inch Washer

Set Bolts
Scale 2"=1"

Revisions

orifice well tester

The Problems of Gas Department
a thesis
by
S. Meunbach.
1924.



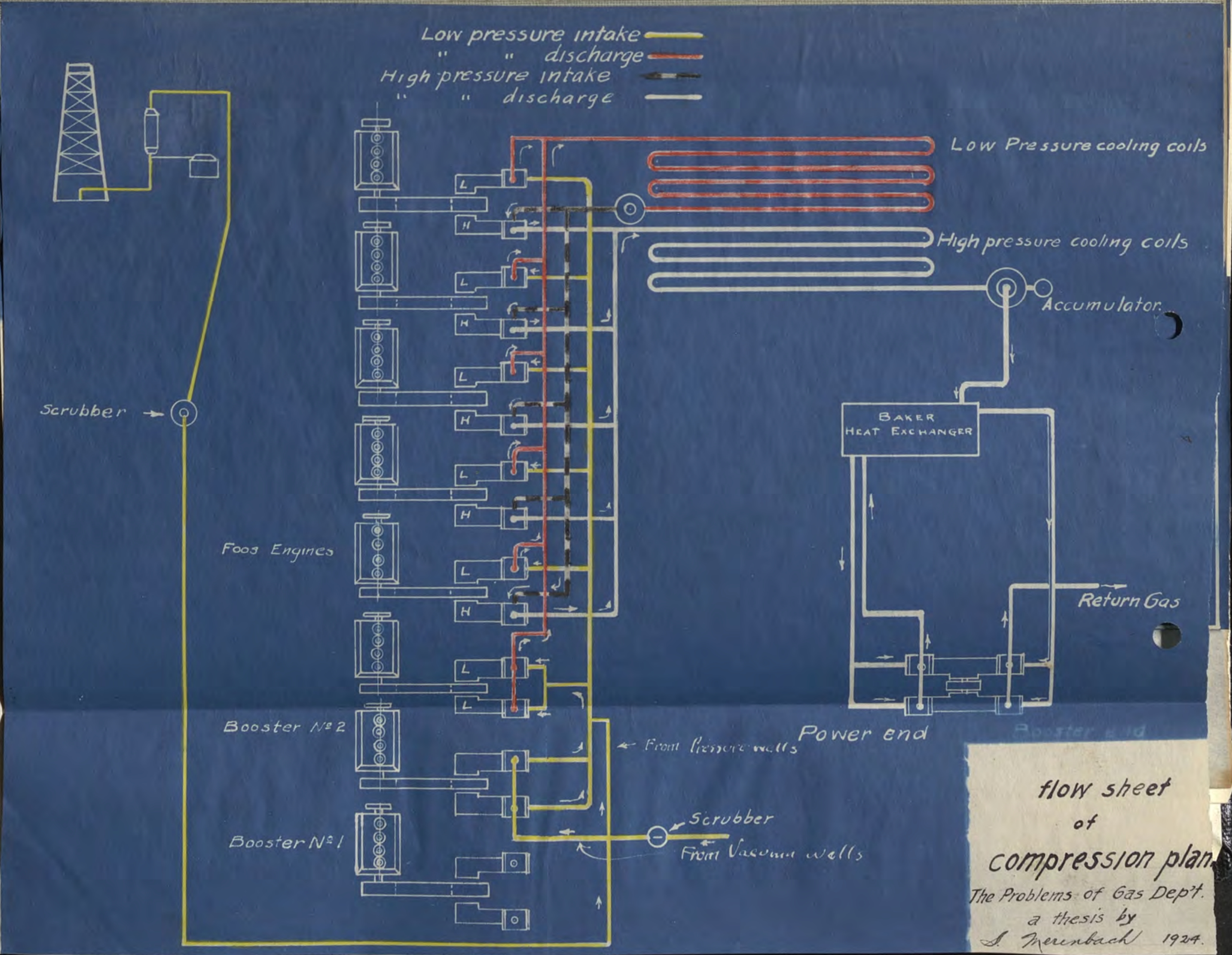
Atmospheric Pressure
14.40 lbs. per. sq. inch

Specific gravity 1.0
Temperature 60° Fa
°Denote points
determind by tes
of well 100/27
with Orifice as

chart
for
orifice well tester

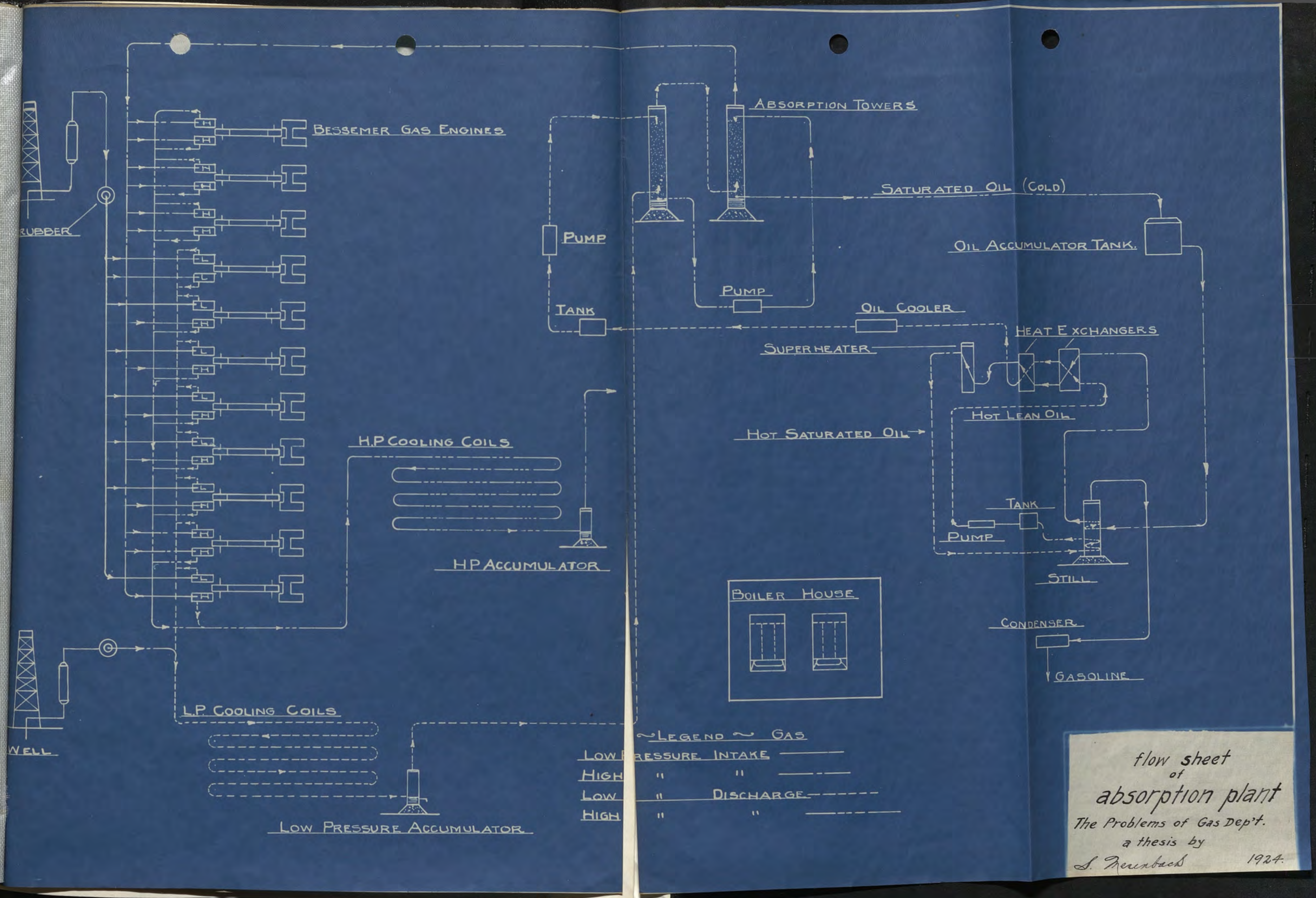
The Problems of Gas Dep't.
a thesis
by
S. Merenbach
1924.

2-A-25

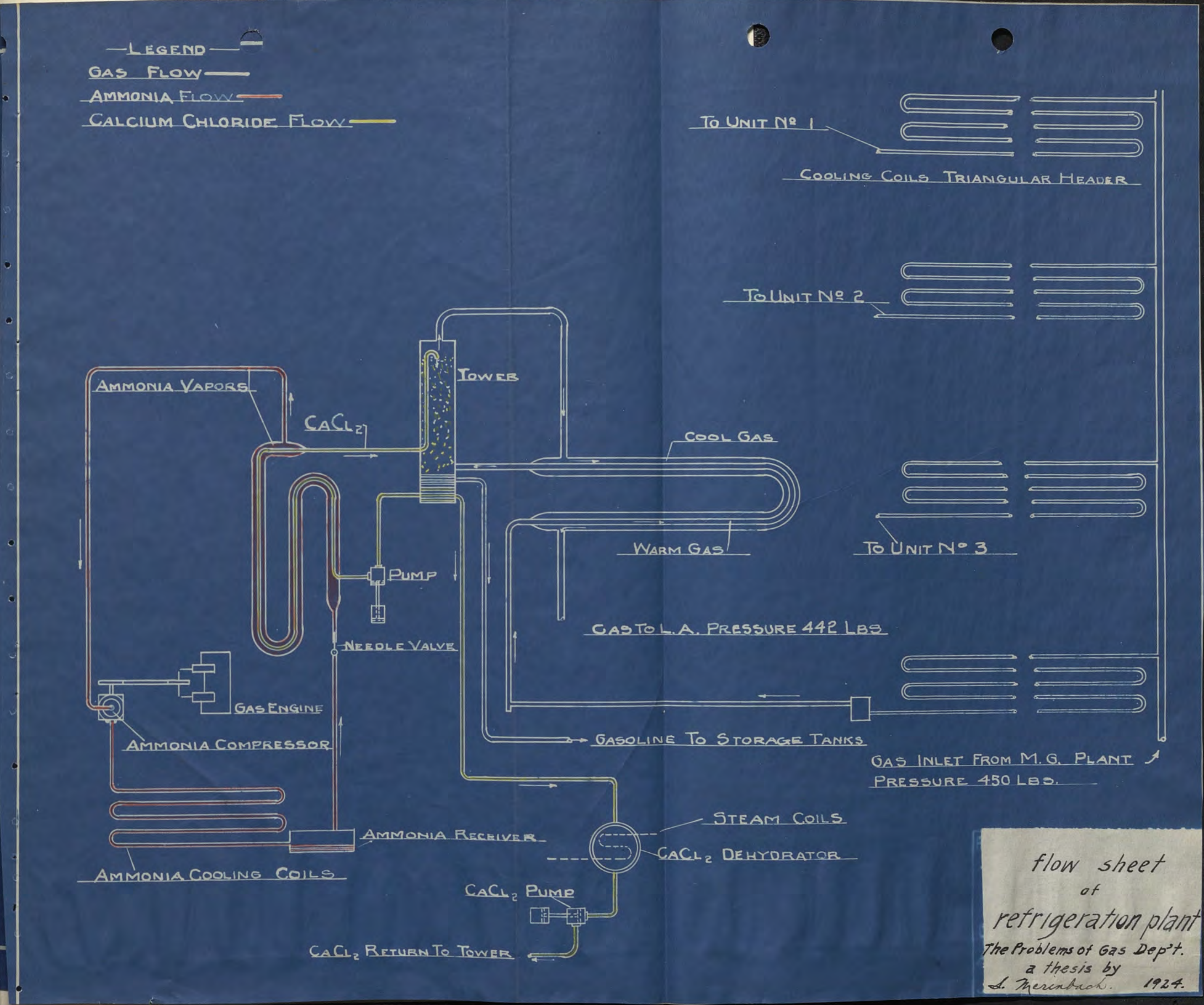


flow sheet
of
compression plan

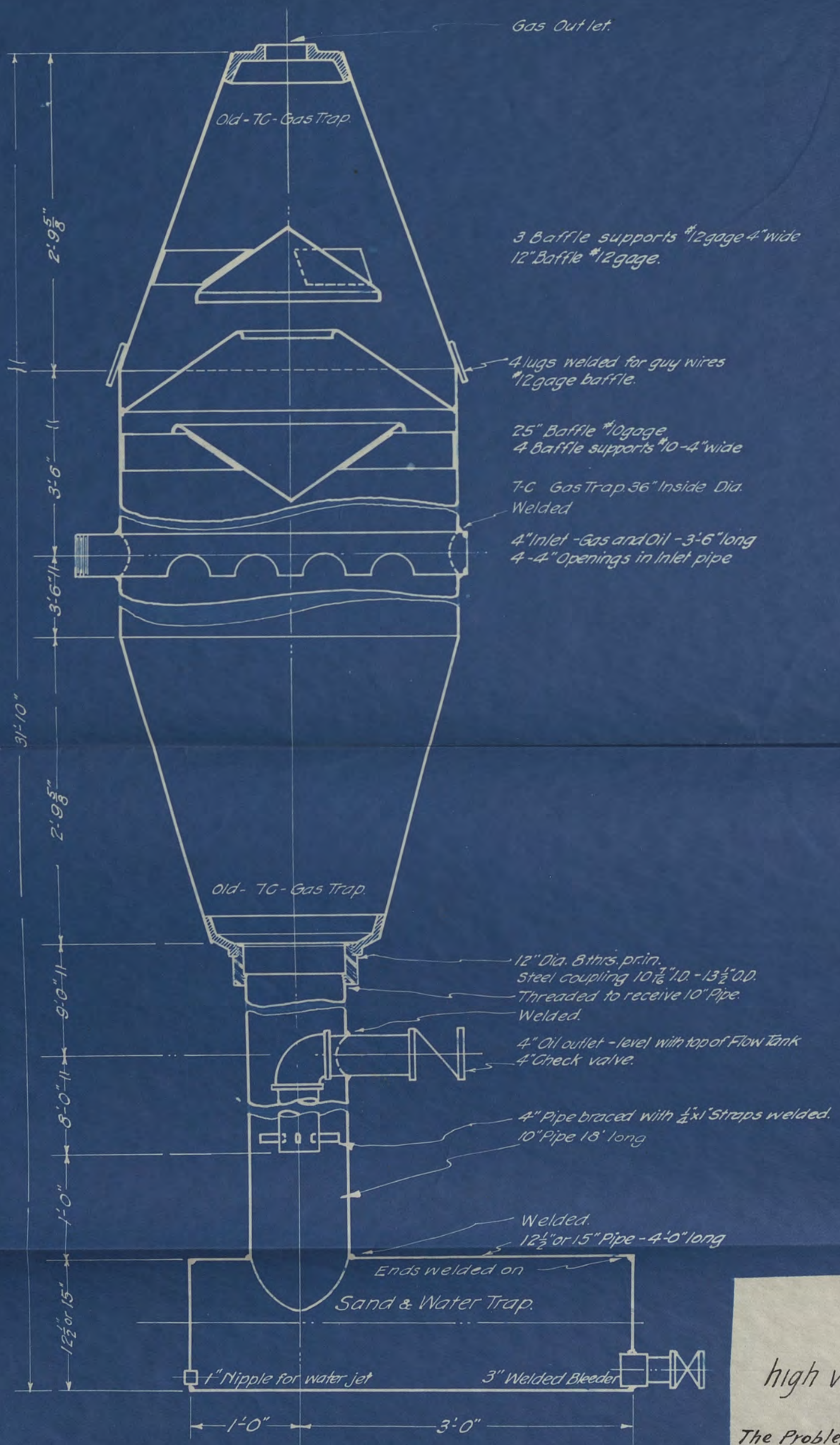
The Problems of Gas Dep't.
a thesis by
S. Merenbach 1924.



flow sheet
of
absorption plant
The Problems of Gas Dep't.
a thesis by
S. Merenbach 1924.



flow sheet
of
refrigeration plant
The Problems of Gas Dep't.
a thesis by
S. Merenbach. 1924.



SECTION THRU GAS TRAP.

high vacuum trap

The Problems of Gas Dep't.

a thesis by

S. Merenbach 1924.