CONSTRUCTION AND OPERATION OF A SINGLE-TUBE CRACKING FURNACE FOR MAKING GASOLINE

BY

C. P. BOWIE
The Bureau of Mines, in carrying out one of the provisions of its organic act—to disseminate information concerning investigations made—prints a limited free edition of each of its publications.

When this edition is exhausted copies may be obtained at cost price only through the Superintendent of Documents, Government Printing Office, Washington, D. C.

The Superintendent of Documents is not an official of the Bureau of Mines. His is an entirely separate office and he should be addressed:

SUPERINTENDENT OF DOCUMENTS,
Government Printing Office,
Washington, D. C.

The general law under which publications are distributed prohibits the giving of more than one copy of a publication to one person. The price of this publication is 10 cents.

# CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>5</td>
</tr>
<tr>
<td>Description of cracking process</td>
<td>5</td>
</tr>
<tr>
<td>Construction of experimental plant</td>
<td>6</td>
</tr>
<tr>
<td>Foundation</td>
<td>6</td>
</tr>
<tr>
<td>Furnace</td>
<td>7</td>
</tr>
<tr>
<td>Tube</td>
<td>8</td>
</tr>
<tr>
<td>Flanges</td>
<td>8</td>
</tr>
<tr>
<td>Tar pot</td>
<td>8</td>
</tr>
<tr>
<td>Basket</td>
<td>8</td>
</tr>
<tr>
<td>Stirring rod</td>
<td>9</td>
</tr>
<tr>
<td>Paddle</td>
<td>9</td>
</tr>
<tr>
<td>Bearing boxes</td>
<td>9</td>
</tr>
<tr>
<td>Machinery</td>
<td>9</td>
</tr>
<tr>
<td>Preheater for oil</td>
<td>10</td>
</tr>
<tr>
<td>Condenser</td>
<td>10</td>
</tr>
<tr>
<td>Pipe and fittings</td>
<td>10</td>
</tr>
<tr>
<td>Gages</td>
<td>11</td>
</tr>
<tr>
<td>Packing and gaskets</td>
<td>11</td>
</tr>
<tr>
<td>List of material required for construction of plant</td>
<td>11</td>
</tr>
<tr>
<td>Cost of construction</td>
<td>12</td>
</tr>
<tr>
<td>Precautions in construction and operation</td>
<td>12</td>
</tr>
<tr>
<td>Drying the furnace</td>
<td>12</td>
</tr>
<tr>
<td>Testing the furnace</td>
<td>13</td>
</tr>
<tr>
<td>Number of men required to operate the plant</td>
<td>13</td>
</tr>
<tr>
<td>Relative pressures on pump and tube</td>
<td>13</td>
</tr>
<tr>
<td>Starting up the plant</td>
<td>13</td>
</tr>
<tr>
<td>Rate of feed</td>
<td>14</td>
</tr>
<tr>
<td>Sampling the oil</td>
<td>14</td>
</tr>
<tr>
<td>Use of pyrometer</td>
<td>14</td>
</tr>
<tr>
<td>Recovering the gasoline</td>
<td>15</td>
</tr>
<tr>
<td>Miscellaneous precautions</td>
<td>15</td>
</tr>
<tr>
<td>Taking samples</td>
<td>15</td>
</tr>
<tr>
<td>Starting the furnace</td>
<td>15</td>
</tr>
<tr>
<td>Removing cover of cracking tube</td>
<td>15</td>
</tr>
<tr>
<td>Publications on petroleum technology</td>
<td>16</td>
</tr>
</tbody>
</table>
ILLUSTRATIONS.

PLATE I. View of motors, fan, and driving pulleys................................. 8

II. View showing arrangement of air and gas supply lines to furnace, and pyrometer rod.................................................. 8

III. Stirring-rod drive, and end of tar pot........................................... 8

IV. A, View showing arrangement of oil meters and strainers, hot-water type of preheater, and oil inlet to cracking tube; B, Oil pump showing suction connections with oil strainers, and relief valve.................................................. 8

V. Plan and sections of foundation for 13-inch single-tube furnace...... 14

VI. Plan and sections of 13-inch single-tube furnace.......................... 14

VII. Vertical sections of 13-inch single-tube cracking furnace............. 14

VIII. Sections of tube and furnace for 13-inch single-tube furnace...... 14

IX. Details of 13-inch single-tube furnace......................................... 14

X. Sections of 14-inch single-tube furnace...................................... 14
CONSTRUCTION AND OPERATION OF A SINGLE-TUBE CRACKING FURNACE FOR MAKING GASOLINE.

By C. P. Bowie.

INTRODUCTION.

It is the purpose of this report to outline briefly the general principles involved in the cracking of oils and distillate by the Rittman process, to describe the construction of a one-tube experimental plant, and to give in some detail those methods of operation that have given the best results.

This paper is intended primarily for those who have obtained a license for the use of the process. It is assumed that such persons have a working knowledge of the modern processes of refining oils, and have read the bulletin* recently published by the Bureau of Mines on the results of experiments with this process.

DESCRIPTION OF CRACKING PROCESS.

The object of a cracking process is to alter the heavier hydrocarbon molecules so that low-boiling hydrocarbons will be formed. High temperatures are favorable to such a reaction. In the usual two-phase cracking system (one in which both liquid and vapor are present) the pressure is dependent upon the temperature; that is to say, to reach any desired pressure a correspondingly high temperature must be carried; hence the two are interdependent. The Rittman process is a one-phase system. In the heated zone the hydrocarbons are all in the vapor form and there is no liquid present.

This process has the following advantages over a two-phase system:
1. Temperature and pressure can be varied at will.
2. It is possible to use with safety much higher temperatures and pressures than in the two-phase systems.

3. A speedy reaction, which is very desirable and can be had only through the use of high temperatures, can be readily attained.

4. The hydrocarbon material is expanded into a gas immediately upon entering the still and the danger of explosion from possible failure of the still is reduced to a minimum.

When petroleum is cracked condensable and noncondensable gases are formed. The condensable gases are heavier than the noncondensable gases, and if permitted to do so will pass downward and out at the bottom of the tube, whereas the noncondensable gases tend to remain in the upper part. If cracking takes place under conditions favorable to gasoline formation in an atmosphere containing all of the hydrocarbon combinations except gasoline hydrocarbons, one may expect that the only product that will be formed in any quantity will be gasoline, until there is enough gasoline present to satisfy conditions of equilibrium. In the Rittman process advantage is taken of these principles by having the zone of reaction or heating zone in the upper part of the tube and the vapor taken off at the bottom. As oil is constantly supplied at the top, the tendency is for condensable rather than noncondensable gases to form.

CONSTRUCTION OF EXPERIMENTAL PLANT.

It is recommended that prospective users of this process first construct an experimental plant consisting of a single-tube furnace. This is deemed advisable in order that the necessary adjustments and refinements in construction and in operation, which will be required to obtain maximum yield from the particular oil to be treated, can be determined, so that a battery of such furnaces of maximum efficiency may later be erected at minimum cost.

Plates V to X (p. 16) show the essential features of a one-tube installation. It is not expected that the licensee will follow these drawings to the letter, as he will no doubt have numerous materials and fittings about his refinery which he may substitute for many of those shown on the plans. The drawings are therefore furnished merely as a guide to enable the licensee to erect an experimental plant that will cover the essential features of the process.

FOUNDATION.

The foundation, of which the plan and elevation are shown in Plate V, should properly be constructed of concrete. The depth of piers will not need to be as great as shown, provided a site is chosen where the nature of the soil justifies a change. The spacing of foundation bolts should be varied to suit the style of tar pot, bearing boxes, etc., to be used.
CONSTRUCTION OF EXPERIMENTAL PLANT.

FURNACE.

The furnace, which is shown in plan and elevation in Plates VI and VII, is 17 feet 1½ inches long by 6 feet 3 inches wide by 17 feet 1 inch high. This size of furnace has given satisfactory results and it is recommended that these figures be adhered to as nearly as possible if gas is to be used as fuel. In one or two instances the channel-iron buck stays have been replaced by single angle irons. For permanent construction, however, this can not be considered good practice.

The furnace, from the floor line up, is constructed of red brick and concrete, reinforced with angle irons as shown, and is lined with fire brick. It is fired simultaneously from the front and the rear, the rear fire box being a little higher than the one in front. The purpose of this arrangement is to get as even a temperature as possible on the tube. Above the front fire box is a 6-inch piece of pipe, intended for the terminals of a pyrometer, which extends through the inner heating chamber. The draft is downward. The exhaust gases are allowed to escape through an opening in the back wall of the furnace close to the bottom, where they enter a flue which passes through a brick oven constructed immediately under the rear fire box. This construction is shown more clearly in Plate VIII.

The oven has solid brick walls on three sides, but the fourth side is only loosely bricked. Its function is to heat the air that is used in the fire boxes. The air is drawn through the oven and forced into the fire boxes by means of a fan. This effects a considerable saving in fuel. A view of such a fan is shown in Plate I, and its relative position is shown in Plate X.

The furnace is intended to be gas-fired. It is probable that slight modifications in the construction of the fire box will be necessary if fuel oil is used. The arrangement of lines supplying air and gas to the furnace, and the pyrometer inlet, are shown in Plate II.

The lower part of the flue is a casting made in the shape of a long, sweep ell, on the short leg of which is a damper. This casting could, no doubt, be replaced by a brick flue, as shown in Plate X, leading to the base of the stack. The stack should be provided with the usual dampers.

The first furnaces constructed in the development of the process were of the multiple-tube type, as many as 10 tubes being placed in a single heating chamber. The difficulties, however, of maintaining even temperature throughout such a furnace have caused the number of tubes to be successively reduced, until to-day the most favored type of construction is a single-tube furnace.
TUBE.

The most satisfactory results are being obtained from tubes 13 to 14 inches in outside diameter, which are made of steel, lap welded, and have walls approximately 1 inch thick. Stock fittings can be used for a tar pot with the 14-inch tube, but a special casting is required if the 13-inch tube is used. The tubes are standard size, and can be obtained from any of the larger tube mills. The tube used in the construction shown in Plate VIII is 13 feet 2½ inches long over all and 13 inches in outside diameter. The one shown in Plate X is 13 feet 5 inches long over all and 14 inches in outside diameter.

FLANGES.

The top and bottom of the tube are fitted with cast-steel flanges, as shown in Plates III, IV, A, and IX. Up to the time of writing these are made with parallel threads, six threads per inch, but there is no reason why they could not have the standard pipe thread, eight per inch, provided the flange is always made up loosely. The cover for this tube is also a casting made with a stuffing box and gland as shown in Plates IV, A, and IX. These castings can be made by any properly equipped foundry.

TAR POT.

On the bottom of the tube is a tar pot. This has always been a special casting and has varied in form from a heavy, cumbersome affair to the one shown in Plate VIII, which is the simplest one to be constructed to date. The tar pot contains three essential features; it must be fitted with a stuffing box and gland for the stirring-rod shaft, it must allow easy removal of carbon and tar, and must be heavy enough to withstand the required pressure. No detail drawings of a tar pot are shown, as it is believed that all of the pots heretofore cast have been too elaborate. Plate X, however, shows a tar pot made from a 12-inch extra heavy cross and a 12-inch extra heavy reducing tee. That face of the cross which comes against the bottom of the tube should be turned down about 3/8 inch to form a female recess to take a gasket as shown. It is not necessary that the other flange connections be male and female. The bottom of this cross is fitted with a casting provided with a stuffing box and gland as shown.

BASKET.

In the inside of the tube at the top is a cast-steel basket. This basket was intended to serve the double purpose of a bearing for the upper end of the stirring rod and a receptacle for steel balls or angu-
MOTORS, FAN, AND DRIVING PULLEYS.
ARRANGEMENT OF AIR AND GAS SUPPLY LINES TO FURNACE, AND PYROMETER ROD.
A. ARRANGEMENT OF OIL METERS AND STRAINERS, HOT-WATER TYPE OF PREHEATER, AND OIL INLET TO CRACKING TUBE.

B. OIL PUMP, SHOWING SUCTION CONNECTIONS WITH OIL STRAINERS, AND RELIEF VALVE.
lar pieces of metal, over which the oil on entering the tube would pass in a thin film, causing rapid vaporization. Spray nozzles, however, are being used and are found to be more effective than either balls or angular pieces of iron. Some such basket device is necessary, however, to provide an upper bearing for the stirring rod.

**STIRRING ROD.**

The stirring rod shown in detail in Plate IX, except for two small castings, one at the top and one at the bottom, is made from 3-inch extra strong pipe, to which is fastened by through cotter pins four vertical rows of chains spaced 3 inches apart. Each chain is 10 inches long and has 1-inch links. The castings can be made at any foundry and the pipe drilled and fitted with the chains at a machine shop. A view of the stirring-rod drive and gears is shown in Plate III.

**PADDLE.**

On the lower part of the stirring rod is a cast-iron paddle, which is intended to prevent the carbon from building up on the ledge made by the stuffing box and choking the neck of the tar pot, and to prevent grit from getting between the stirring-rod shaft and liner. Detail drawings of the paddle are shown in Plate IX.

**BEARING BOXES.**

The bearing box for the stirring rod is placed on the foundation immediately beneath the tar pot, as shown in Plate X. The bearing box is shown in detail in Plate IX. This bearing, with the gears and shaft bearings, can be supplied by any dealer in such accessories.

**MACHINERY.**

The machinery generally used for operating such a plant consists of a small steel-plate planing-mill blower which furnishes hot air to the fire boxes, as previously stated, and a small power pump capable of delivering oil under a working pressure up to 300 pounds per square inch. There will also be required the necessary pulleys and shafting and two 5-horsepower electric motors, one to drive the blower and pump and one for the stirring rod. It is believed that such a machinery equipment is sufficient to operate a battery of six single-tube furnaces. Steam, of course, can be used as a motive power if desired. The relative positions of the various parts of machinery are shown in Plate X. The motors, fan, and driving pulleys are shown in Plate I, and the pump is shown in Plate IV, B.
PREHEATER FOR OIL.

To facilitate vaporization of the oil a preheater is provided. A special type of hot-water heater (Pl. IV, A) is being used for this purpose, through which the oil is passed, where its temperature is raised from normal to 200° F. or higher. Such an arrangement is expensive, because of the high first cost and the fact that gas must be used for fuel. It is suggested that a cheaper and more satisfactory preheater could be arranged by passing the oil through coils heated by the flue gases. A heater of this kind made on the principle of an economizer is shown in Plate X. The essential thing in operating such a heater would be to so regulate the temperature by manipulating the dampers that the oil in the heater would not become too highly heated and gasify or coke. Although the use of flue gases has not been tested in actual practice, it is believed that such a heating system could be arranged to give satisfaction.

CONDENSER.

The ordinary box type of condenser is being used. Condensation takes place at practically atmospheric pressure, a pressure-reducing valve being placed in the vapor line close to the carbon pot. The pressure, however, can be carried through the condenser if desired. It may be found advisable to have a separate condenser coil for each tube.

PIPE AND FITTINGS.

The pipe and fittings from the pump discharge to the condenser box should all be extra strong and should withstand a test pressure at least twice as high as the pressure at which they will be operated. If pressure is carried on the condenser, the tubes of which it is composed should also be extra strong.

The suction pipe of the pump is 2 inches in diameter and contains a strainer through which the oil passes before entering the pump; the discharge pipe is 1½ inches in diameter. These sizes of pipe for suction and discharge will probably be large enough for a battery of five single-tube furnaces. Between the discharge and the suction is a by-pass (Pl. IV, B) which contains an automatic relief valve that can be set at the pressure desired to be carried and will permit the oil to by-pass into the suction when this pressure is exceeded.

From the pump the oil passes through the preheater coils, which are one-half inch in diameter, thence through a strainer, a meter where the amount of flow is measured, a needle valve used for regulating the flow, and into the cracking tube (Pl. IV, A). In the first installations meters were not used, but they have since been found
very valuable, because they will indicate by a diminished flow any clogging of the system. Moreover, they furnish a means of determining definitely the amount of oil entering the tube.

The meter has heretofore been placed between the preheater and the tube. There is no reason, however, why the meter should not be placed on the cold side of the preheater, as shown in Plate X, provided a separate heater is used for each tube.

Strainers and meters are arranged in pairs, as shown in Plate IV, A, so that one set can be by-passed at any time and removed or cleaned without shutting down the tube.

GAGES.

Three 6-inch gages registering pressures up to 500 pounds are required. One is placed on the pump discharge, one on the vapor line near the tar pot, and the other on a branch from the vapor line leading to a position such that the gage will be visible from the heater platform.

PACKING AND GASKETS.

The most satisfactory type of packing for the stuffing box on the bottom of the stirring rod has been found to be sectional ring packing, made of asbestos, containing a small proportion of rubber. For the flanged joints and oil inlets into the cracking tube copper-covered asbestos gaskets have been used.

LIST OF MATERIAL REQUIRED FOR CONSTRUCTION OF PLANT.

An approximate list of material required for the construction of a single-tube installation, exclusive of material for the building and for condensing apparatus, would be as follows:

Foundation and furnace bottom: 16 yards of crushed rock or gravel, 10 yards of sand, and 18 barrels of cement.

Brickwork: 14,000 red brick, 3,500 fire brick, 1 ton of fire clay, 20 yards of sand, and 10 barrels of lime.

Tie-rod, backstays, and angles as shown in the drawings.

Foundation bolts to suit conditions.

One furnace tube 13 or 14 inches in outside diameter, with 1-inch walls, approximately 13 feet 6 inches long.

One flange for top of tube.

One flange for bottom of tube.

One tube cover, complete with stuffing box and gland.

One cast-iron cover plate (in two sections) for top of furnace around tube.

One cast-iron flanged ring bearing for cover plate.

One cast-iron cover plate for bottom of furnace around tube.
One basket bearing for top of stirring rod.
One stirring rod.
One tar pot, complete with stuffing box and gland.
One set of bevel gears.
Stirring-rod shafting, complete with bearing boxes and pulley.
One paddle for bottom of stirring rod.
One small oil pump suitable for working pressures up to 300 pounds.
Two electric motors, about 5 horsepower each.
One small planing-mill blower, with necessary belting, counter-shaft, and pulleys.
Two 2-inch oil strainers for pump suction.
One 1\(\frac{1}{2}\) -inch automatic relief valve for pump suction.
Three 6-inch gages that will register pressures up to 500 pounds.
One preheater.
One thermometer for measuring temperature of preheated oil.
Two \(\frac{1}{2}\) -inch oil strainers.
Two \(\frac{5}{8}\) -inch oil meters.
One \(\frac{1}{4}\) -inch needle valve.
Three spray nozzles for top of tube (two are spare nozzles), capacity about 60 gallons per hour under pressure of 50 pounds.
Two relief valves for vapor line.
Necessary pipe valves and fittings, dependent on layout of piping.
One stack, at least 12 inches in diameter, with damper.
One straightway blow-off cock for tar pot.
Two peephole castings, complete.
One pyrometer for measuring temperature in tube.
Necessary gaskets and packing.

COST OF CONSTRUCTION.

It is estimated that one single-tube furnace, such as is described above, can be erected at a cost of not more than $3,000, exclusive of a building, or other protective covering, and condenser box. The cost of erecting additional furnaces should be considerably less, because the machinery required for the single-tube furnace will operate five or more units.

PRECAUTIONS IN CONSTRUCTION AND OPERATION.

DRYING THE FURNACE.

When the brickwork is completed it should be allowed to dry, preferably at atmospheric temperature provided this is not below 40° F., for a week or more, after which time the regular gas or oil fires may be lighted, and the temperature, beginning at a low heat which is maintained for several days, be brought gradually up to.
maximum intensity. In all at least three weeks, under average atmospheric conditions, should be consumed in the drying process. If these precautions are followed it will be found that the outer walls will be comparatively free from cracks and that the life of the fire brick will be materially increased.

TESTING THE FURNACE.

Before a cracking run is attempted the whole apparatus, including the cracking tube, tar pot, pump, pipe fittings, etc., should be subjected to a hydrostatic pressure of at least 300 pounds per square inch, with preferably the same oil or distillate that is to be cracked. It will invariably be found that numerous leaks at pipe collars and fittings will develop, which must be fixed before the plant is put into operation. In short, it is absolutely imperative for the safety of the operators that all joints be made tight enough to withstand a pressure of 300 pounds.

NUMBER OF MEN REQUIRED TO OPERATE THE PLANT.

Under ordinary conditions two men are required to operate the plant. Of course, when a tube is to be removed or repair work done, a larger crew will be needed, but it is assumed that such work would be done by the usual repair gang employed around any refinery.

One of the operators is stationed on the ground floor; it is his duty to look after the pump, tar pot, condenser, etc. The other one is stationed on the heater platform; he regulates the fires and the rate at which the oil is being fed into the tube, and also looks after the preheater. Switches for shutting off the electric power are placed on the ground floor and also on the heater platform, so that should anything go wrong either operator can shut down the plant.

RELATIVE PRESSURES ON PUMP AND TUBE.

As previously stated, gages showing the pressure in the cracking tube are also placed above and below the platform, so that each operator may be able to see at a glance just what the pressure is.

When a spray nozzle is used in the upper part of the tube the pressure at the pump should be at least 50 pounds higher than is carried in the tube.

STARTING UP THE PLANT.

In starting up the plant the tube should be brought gradually up to the desired temperature before oil is admitted. It is recommended that for experimental work temperatures ranging from
1,000° to 1,300° F. and a feed of 50 to 75 gallons per hour, with a pressure of 100 to 150 pounds, be used. These control factors will, however, depend entirely upon the oil to be cracked, and must be varied to suit conditions. The pump should then be started and a pressure built up that is about 50 pounds higher than that desired in the tube. The needle valve is then opened slowly, permitting the oil to enter the tube, but always at such a pressure as to insure perfect atomization. As the pressure in the cracking tube builds up, the needle valve is opened sufficiently wide to permit the desired flow.

RATE OF FEED.

The proper rate of feed will depend entirely on the oil or distillate that is to be used and also on the temperature of the tube. By using a constant pressure approximately equal results can be obtained with high temperatures and rapid feed or with low temperatures and slow feed.

SAMPLING THE OIL.

To determine the proper control conditions, samples of the cracked oil produced should be taken at least every half hour from the condenser and the tar pot. These samples should be passed through the laboratory still and the gasoline cut taken off. Slight variations in temperature and pressure at the tube should then be made until cracked oil is produced that gives a maximum yield of gasoline, based on the amount of oil being cracked. When this cracked oil is determined its gravity should be taken and thereafter temperature and pressure control be based on the gravity of the oil produced. It is the practice, once the most favorable pressure is determined, to hold this pressure and vary the temperature according to the rate of feed—that is, if it is desired to run the oil more rapidly through the tube a higher temperature is required, and vice versa. When the temperature and feed are varied care should be taken that the predetermined gravity of the cracked oil is not changed. It is good practice after the experimental work is finished, to take test samples every hour as long as the tube is in operation.

USE OF PYROMETER.

It is recommended that a pyrometer be used, at least, in the experimental work, because it provides a means of judging temperatures and will greatly facilitate the work of determining the control conditions for a given oil. Once these conditions are ascertained, runs may thereafter be made based on the specific gravity of the cracked oil. The position of the pyrometer rod in the furnace is indicated in Plate II.
PLAN AND SECTIONS OF FOUNDATION FOR 13-INCH SINGLE-TUBE FURNACE.
SECTION A-A

SECTION B-B

SECTION ON C OF TUBE

VERTICAL SECTIONS OF 13-INCH SINGLE-TUBE CRACKING FURNACE.
SECTIONS OF TUBE AND FURNACE FOR 13-INCH SINGLE-TUBE FURNACE.
DETAILS OF 13-INCH SINGLE-TUBE FURNACE.
RECOVERING THE GASOLINE.

The usual procedure is to run all the cracked oil that is taken from the condenser, and also that from the tar pot, through a crude still and remove the gasoline cut. The residuum from this run can then be again passed through the cracking tube, if desired, but it is better not to mix the residuum with the original oil, as oil that has been through the cracking process may require a slightly different temperature and pressure in order to produce a satisfactory yield of gasoline. The gravity of the cracked oil from this second run that will yield a maximum of gasoline will also be slightly different from the gravity of the cracked oil from the first run.

MISCELLANEOUS PRECAUTIONS.

TAking SAMPLES.

Extreme caution should be exercised in taking samples from the tar pot and from the condenser. The outlet from these should be a reasonable distance, at least 50 feet, away from the furnace, as the liquid contained in them carries a large percentage of highly inflammable gases. Too great stress can not be placed on care in sampling for the reason that all the accidents in connection with the process that have occurred up to the present time have been due to carelessness in permitting these gases to come in contact with the furnace fires.

STARTING THE FURNACE.

In starting up the furnace a lighted torch should always be placed in the fire box before the gas is turned on. In shutting down the furnace the gas should first be turned off and then the blower shut down.

REMOVING COVER OF CRACKING TUBE.

The cracking tube under ordinary conditions will remain full of highly inflammable gas for several hours after a shut down, for which reason great care should be taken in removing the cover. The safest way is to have a one-half inch steam connection in the oil line close to where it enters the cracking tube. When the tube has been shut down and the pressure released by gradually opening the valve into the sludge line, dry steam is admitted into the tube and the gases blown out through the sludge line. It is highly important that the steam be thoroughly dry because a plug of water might injure the tube. For this reason a small cock should be placed on the steam line so that the steam may discharge into the atmosphere until it becomes dry.
CONSTRUCTION OF SINGLE-TUBE GASOLINE FURNACE.

PUBLICATIONS ON PETROLEUM TECHNOLOGY.

A limited supply of the following publications of the Bureau of Mines is temporarily available for free distribution. Requests for all publications can not be granted, and to insure equitable distribution applicants are requested to limit their selection to publications that may be of especial interest to them. Requests for publications should be addressed to the Director, Bureau of Mines.


TECHNICAL PAPER 32. The cementing process of excluding water from oil wells, as practiced in California, by Ralph Arnold and V. R. Garfias. 1913. 12 pp., 1 fig.


TECHNICAL PAPER 42. The prevention of waste of oil and gas from flowing wells in California, with a discussion of special methods used by J. A. Pollard, by Ralph Arnold and V. R. Garfias. 1913. 15 pp., 2 pls., 4 figs.

TECHNICAL PAPER 45. Waste of oil and gas in the Mid-Continent fields, by R. S. Blatchley. 1914. 54 pp., 2 pls., 15 figs.

TECHNICAL PAPER 49. The flash point of oils; methods and apparatus for its determination, by I. C. Allen and A. S. Crossfield. 1913. 31 pp., 2 figs.


TECHNICAL PAPER 68. Drilling wells in Oklahoma by the mud-laden fluid method, by A. G. Heggem and J. A. Pollard. 1914. 27 pp., 5 figs.

TECHNICAL PAPER 70. Methods of oil recovery as practiced in California, by Ralph Arnold and V. R. Garfias. 1914. 57 pp., 7 figs.

TECHNICAL PAPER 72. Problems of the petroleum industry; results of conferences at Pittsburgh, Pa., August 1 to September 10, 1913, by I. C. Allen. 1914. 20 pp.

TECHNICAL PAPER 74. Physical and chemical properties of the petroleum of California, by I. C. Allen, W. A. Jacobs, A. S. Crossfield, and R. R. Matthews. 1914. 38 pp., 1 fig.


TECHNICAL PAPER 117. Quantity of gasoline necessary to produce explosive vapors in sewers, by G. A. Burrell and H. T. Boyd. 1916. 18 pp., 4 figs.