Dec. 12, 1950 R. L. HASCHE 2,533,457

FURNACE WITH JET COOLING

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Fig. 4.

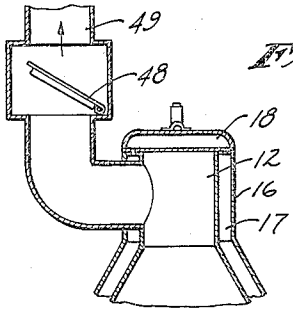


Fig. 2.

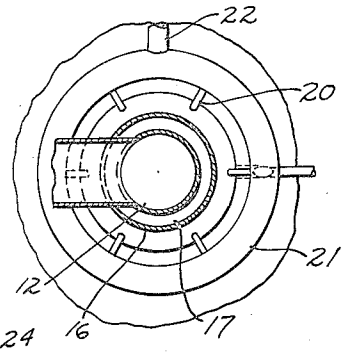


Fig. 1.

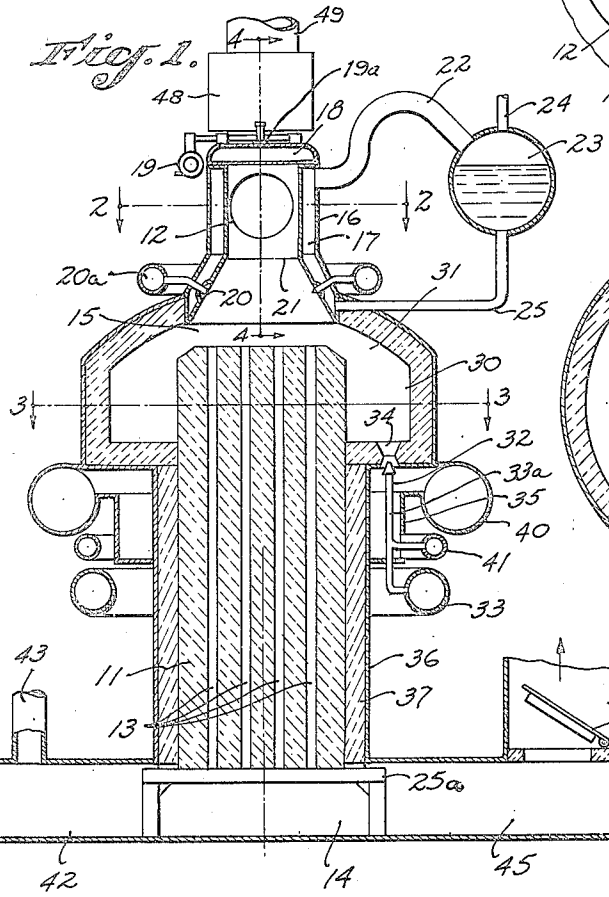
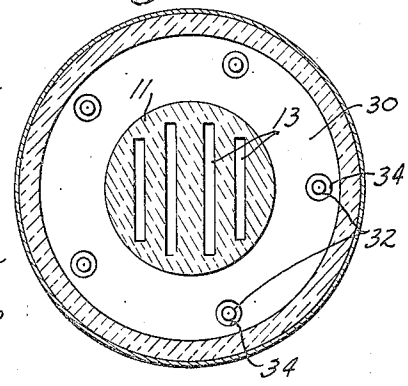


Fig. 3.



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FOR THE FIRM
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FURNACE WITH JET COOLING

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2 Claims. (Cl. 23—277)

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My invention relates to regenerative furnaces, that is, to furnaces containing a regenerative mass which is operated through a recurrent cycle in which the regenerative mass is first heated by passing hot combustion products therethrough, and which is then used to heat gases that are passed therethrough, the heat stored in the mass being given up to the gases so heated. The furnace is particularly designed to process gases which must be very quickly heated to a high temperature and very quickly cooled after reaching the desired maximum temperature; for example, it is designed for use in processes in which acetylene is made from methane. A furnace for this purpose must be not only a furnace in which the methane is heated as near the highest temperature to which the furnace lining, such, for example, as Carborundum, may be heated, for example, to 3000° F., but the furnace must provide that the methane be heated in as short a time as is practicable, for example, $\frac{1}{10}$ second or preferably less, and be as quickly cooled as is practicable to a temperature at which the acetylene is stable, for example, to 900° F.

It is an object of my invention to provide a furnace capable of producing acetylene in the manner above described. Such a furnace has other uses, the manufacture of acetylene from methane being given to illustrate only one use of my invention.

In any furnace of this type, in which a mass of Carborundum or other heat refractory substance is held at temperatures in excess of 2800° F., sometimes for a period of several months, the problem of supporting the incandescent mass of Carborundum is a troublesome one, and it is a further object of the invention to provide means for raising the temperature of certain portions of the regenerative mass to a temperature higher than the maximum temperature to which it is desired to heat the gases to be processed, for example, to a maximum temperature of 3000° F., and to provide a construction which will permit the cooler portion of the regenerative mass to be supported on steel supports in such a manner that these supports will not be weakened by high temperatures.

It is a further object of the invention to provide means by which the regenerative mass is so heated that, although the gases are heated to this high temperature of 2800° F., no portion of the regenerative mass will be subjected to an excessive temperature, for example, in excess of 3000° F., which temperature is close to the maximum temperature at which Carborundum can be economically used.

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In producing acetylene from methane, and when other gases are produced from other substances, it is often desirable to very quickly cool the mixture containing the acetylene after it is formed to prevent the acetylene from itself changing into undesired products, and it is a further object of my invention to provide a furnace having means for cooling or quenching the gases as quickly as possible after they leave the regenerative mass.

It is a further object of my invention to provide a furnace structure which will allow effective and rapid means for purging, thereby preventing contamination of the gases to be heated with the combustion products and also loss of heated gas in the combustion products.

Another object of my invention is to provide a relatively cold section directly above the top of the incandescent regenerative mass, having the dual purpose of protecting the quenching means and absorbing radiation, thereby preventing overheating of the regenerative mass.

It is a further object of my invention to produce a furnace which will operate over long periods without need of repairs, and in which the productive capacity is high as compared with the bulk and cost of the furnace.

Further objects and advantages will be made evident hereinafter.

Referring to the drawing, in which I illustrate a preferred form of furnace embodying my invention:

Fig. 1 is a vertical cross section through the furnace, shown somewhat schematically, various valves, pumps, etc., ordinarily used with the furnace but readily supplied by one skilled in the art, being omitted;

Fig. 2 is a section through the furnace shown in Fig. 1, this section being viewed in the direction of the arrows adjoining the line 2—2 of Fig. 1, this line identifying the horizontal plane of the section shown in Fig. 2;

Fig. 3 is a section of the furnace shown in Fig. 1, this section being viewed in the direction of the arrows adjoining the line 3—3 of Fig. 1, this line identifying the horizontal plane of said section shown in Fig. 3; and

Fig. 4 is a section through the furnace shown in Fig. 1, this section being viewed in the direction of the arrows adjoining the line 4—4 of Fig. 1, this line identifying the horizontal plane of the section shown in Fig. 2.

The preferred form of furnace shown in the drawing is generally symmetrical about a vertical axis 4—4 and includes a regenerative mass 11 above which a quencher 12 is supported, if

necessary, by a structure external to the surface and not shown. The regenerative mass 11 may be formed of loose Carborundum bricks so placed as to provide vertical, substantially straight, and open primary passages 13 which extend through the mass 11 and connect a primary space 14 below the mass with a secondary space 15 above the mass. The quencher 12 consists of a shell 16 preferably formed of steel and having a chamber 17 therein which is kept full of water. An explosion door 18 is pivoted at 19 and suitably weighted or closed by hydraulic means to form a tight seal with the walls of an opening in the top of the quencher 12. This door 18 also has a chamber 19a therein which is kept full of water by flexible pipe connections (not shown) which connect the chamber 19a with the chamber 17. Nozzles 20 fed from a manifold 20a project a cooling or quenching agent, such as water or steam, into a tertiary space 21 inside the shell 16.

Cooling water is circulated in the chambers 17 and 19a by means of standard boiler feed and exhaust devices (not shown). If desired, the chambers 17 and 19a may be kept full of water, which flows to a steam drum 23, in which the steam separates from the water. Steam is taken from the drum 23 through a pipe 24, and, due to thermo-siphon and gravity action, water flows from the drum 23 through a pipe 25 back into the shell 16 near its lower end.

The nozzles 20 are evenly spaced around the periphery of the tertiary space 21, and the water, steam, or other cooling agent is projected therefrom under sufficient pressure to project the cooling agent to a point near the axis of the furnace, thus intimately mixing this cooling agent with the hot gases as they emerge from the primary passages 13 and very quickly cooling the gases. It is of the utmost importance that the jets of cooling agent be as close to the top of the regenerative mass 11 as possible without coming into actual contact with the mass 11. The nozzles may be so disposed with relation to each other that impingement occurs, or they may project a flow of cooling medium tangentially into the tertiary space 21.

For convenience in illustration, the passages 13 are somewhat simplified in the drawing, being much more numerous and of greater area in proportion to the diameters of the mass 11 and the quencher 12 in the actual furnace than they are shown in the drawing.

The regenerative mass 11 is so constructed that it can be supported wholly on a steel structure 25a in the primary space 14. This space 14, as will be understood from the description appearing later herein, never contains gas at a temperature which will substantially impair the strength of steel, and the lower end of the regenerative mass 11 never reaches such a destructive temperature.

While in the furnace which I have constructed carborundum is the preferred lining for the combustion chamber 30 and to form the regenerative mass 11, a combustion chamber may be lined with any other highly refractive material, such as high alumina tile, since it is not called upon to be a heat transfer medium. However, it is essential that the regenerative mass 11 be composed of Carborundum or an equivalent highly conductive and refractory material for reasons herein set forth.

Surrounding the upper end of the regenerative mass 11 is the annular combustion chamber 30, which is in communication with the secondary space 15 through an uninterrupted annular throat 31. The combustion space 30 is preferably lined with Carborundum brick or any other highly refractory material. Combustion in this space is provided by five equally spaced burners 32 each fed with gas through pipes 33a from a fuel gas manifold 33. The combustion products in the space 15 may have a temperature of 3200 to 3400° F. The burners 32 discharge through openings 34 in the lower wall of the combustion space 30, these openings connecting the combustion space 30 with pipes 35 forming part of each burner. A shell 36 surrounds the combustion space 30 and the mass 11, forming a gas-tight joint with the shell 16. Surrounding the mass 11 inside the shell 36 is an annular layer of heat-insulating material 37. The quencher 12 and various pipes may also be heat-insulated externally by heat-insulating material (not shown). Air is supplied to the pipes 35 from an air manifold 40, and steam may be supplied to the pipes 33a from a steam manifold 41.

The primary space 14 is provided with an inlet pipe 42 through which the gas to be processed may be supplied to the space 14, and steam or other inert diluent gas may be supplied to the primary space 14 through a pipe 43. The pipes 42 and 43 are provided with valves, as are the pipes that supply fuel gas to the pipes 35, and as is the pipe supplying steam to the burners 32, these valves also not being shown. The primary space 14 also has an outlet pipe 45 through which combustion gases are conducted to a stack 45 through a valve 47. Processed gases are taken from the tertiary space 21 through a valve 48 to a pipe 49, these gases being the product desired.

The water-cooled inner surface of the dome 16 and door 18, which looks downward in a vertical projection plane onto the top of the hot regenerative mass 11, serves a most important function of absorbing radiation and protects the latter from overheating.

The operation of the furnace may be manually controlled by operating the various valves, but in practice these valves are automatically controlled by mechanism forming no part of the furnace and hence not described or shown.

The operation in producing acetylene from methane will be described, as such operation is typical of many uses for which the furnace may be utilized. The furnace is operated in a periodically recurring cycle consisting of a heating, a purging, and a treating period. At the beginning of the heating period, the valve 43 is closed and the valve 47 is open, and during this heating period no gas or diluent is supplied to the primary space 14 through the pipe 42. The tertiary space 21 during the treating period is preferably kept full of steam supplied by the nozzles 20 at a slow rate so as to furnish a relatively inert blanket of steam in the tertiary space 21.

Fuel gas is supplied to the burners 32 from the manifold 33, and air for combustion is supplied to the pipes 35 from the manifold 40. It is important to so regulate the flow of air and gas that each of the burners will produce combustion products of about the same volume and at about the same temperature. In the drawing, I show five burners 32, but in large furnaces more than five burners are desirable. It is understood that the burners may also be inserted through the side walls of the combustion chamber. Their location depends upon convenience of construction and upon the size of the furnace. If the burners are properly operated, the combustion chamber 30 is filled with

an annular ring of combustion gases at a fairly uniform temperature of 3200° F. to 3400° F. I have found that in a properly designed furnace a heat liberation of 750,000 to 1,000,000 B. t. u. per hour for each cubic foot of combustion space is possible. It is very important that the rate of burning or heat liberation be maintained close to the maximum. By so doing, it will prevent combustion occurring in the checkers, which makes for non-uniformity of heating and insures that the lower end of the checkers never gets too hot. It also provides a minimum amount of combustion volume requiring purging. I have found that the total volume of the combustion space as related to the total volume of the regenerative passages 13 should be maintained within the limits of ratios 1.0 to 3.0. This ring of combustion products surrounds the upper end of the regenerative mass 11 and tends to heat it.

The combustion products flow evenly through the throat 31, which is constricted to an area perpendicular to the gas flow of about one-third of the area on a horizontal plane of the combustion space 30. This constriction tends to promote an even and uniform flow of combustion products from the combustion chamber 30 through the throat 31 into the secondary space 15. Carborundum stands up well at temperatures materially below 3000° F., but deteriorates rapidly at temperatures materially above 3000° F. I prefer to operate the furnace so that the upper and hottest portion of the regenerative mass is at a temperature of about 3000° F., or as close as practicable to this temperature, so as to improve the degree of conversion of the methane to acetylene. A uniform heating of the mass 11 can only be accomplished by uniformity of temperature of the combustion products in the combustion chamber 30 and a uniform flow of gases through the throat 31.

The primary passages 13 should be of such size and the volume of the combustion products should be such that the combustion products passing downwardly through the primary passages attain a high velocity, preferably in excess of 10,000 feet a minute. These products lose heat rapidly by convection; in fact, I have found that in a properly designed and operated furnace the combustion products lose about 80% of their sensible heat in their passage from the throat 31 to the primary space 14. The products of combustion are drawn from the primary space 14 through the pipe 45 and valve 47 into the stack 46, which provides a draft, thereby aiding in the withdrawl of the products of combustion from the furnace. The regenerative mass 11 should be of sufficient length to insure a temperature at the bottom of the mass of about 900° F. when the top of the mass is at 3000° F., and when the mass reaches these temperatures the firing period terminates, and the flow of gas to the burners 32 from the manifold 33 and the flow of air to the pipes 35 are shut off. This firing period, when the furnace is operating on the cycle, may be from one to two minutes. During the firing period I allow steam to flow slowly from the steam manifold 41 through the pipes 33a and the burners 32 to protect the burners and adjacent structure from the effects of the hot combustion gases.

The purging period, which may require three seconds, then occurs. Steam is admitted to the combustion space 30 from the pipe 41 through the pipes 33a and burners 32, and flows downwardly through the primary passages 13, the space 14, and the outlet pipe 45 to the chimney 46 through the valve 47. This flow purges the primary passages 13 of combustion products.

During the treating period, the valve 48 is opened and the valve 47 is closed, and a mixture of methane and diluent is delivered to the primary space 14 from the pipe 42, which diluent flows upwardly through the primary passages 13, being heated by contact with the hot regenerative mass. In making acetylene, I prefer not to heat the methane-diluent mixture before it enters the primary space 14, as preheating occurs in the lower portion of the regenerative mass. In its passage upwardly through the primary passages, the mixture is heated to a temperature of about 2800° F. Somewhat below this temperature, the methane is converted into acetylene, hydrogen being released. This reaction absorbs large quantities of heat which is obtained from the regenerative mass 11. At this high temperature, the reaction is very rapid, taking not more than $^2/_{100}$ of a second, and it is important that the flow of gas should be such that the gas passes through the upper ten per cent of the regenerative mass in $^2/_{100}$ of a second or less.

Acetylene is quite unstable, and it is important that the converted products of the primary passages be cooled quickly, which is accomplished in the tertiary space 21. Sufficient cooling agent should be supplied through the nozzles 20 so that the gases are cooled in the tertiary space to about 900° F. and so that the time required for such cooling will be $^1/_{10}$ of a second or less. It is not advisable to cool the gas much below 900° F., as at lower temperatures any tars carried in the gases tend to condense and collect carbon, thus blocking the conduits through which the gas passes from the pipe 49. This tar and carbon can be removed in a scrubber after the gas leaves the pipe 49. The treating period continues until the regenerative mass 11 cools to such a degree that it is not highly efficient in its conversion of methane to acetylene, when the treating period ends by shutting off the flow of mixed methane and diluent into the primary space 14, by partially shutting off the flow of steam into the pipes 33a, and by opening the valve 47 and closing the valve 48. The cycle is then complete, and the firing period of the next cycle starts. The treating period may have been about one minute.

While I have described the use of my furnace in producing acetylene from methane, it may be also used to produce butadiene, and the olefins, such as ethylene, propylene, and butylene, or the aromatics, such as benzene, toluene, and xylene, or hydrocyanic acid from the reaction of hydrocarbons and ammonia. All of these products are endothermic in nature, and the formation is very rapid at high temperatures. These products are also unstable at high temperatures and must be quickly cooled if they are to be preserved against disintegration. To successfully produce and preserve each of these other products, they must be held at formation temperatures no longer than a fraction of a second.

While I have described my furnace as using methane as a gas to be processed, in practice it will be more often used to process natural gas, which is largely methane, waste hydrocarbon gases from oil refineries, or other sources which may or may not contain methane but contain other hydrocarbons such as ethane, butane, propane, or the like, or natural gasoline or other petroleum derivatives which are liquid at normal temperatures and which must be gasified by heat-

ing prior to being delivered to the primary space 14.

The general dimensions of the regenerative mass in regard to the dimensions of the primary passages therethrough and the thickness of the walls therebetween may be those set forth in the Hasche et al. patents, No. 2,318,688, issued May 11, 1943, and No. 2,319,679, issued May 18, 1943. Other structural modifications of apparatus of the type illustrated and described herein are also shown and described in applicant's copending applications Serial No. 633,839, now Patent No. 2,432,885, and Serial No. 633,834, now abandoned, both filed December 8, 1945.

I claim as my invention:

1. A regenerative furnace comprising an outer shell enclosing an enlongated upright regenerative mass having passageways extending lengthwise therethrough, a chamber surrounding one end of said regenerative mass forming a substantially annular combustion space about the end portion of said regenerative mass, a plurality of burners opening into said annular combustion space, an annular throat constituting a communication between said annular combustion space and a space adjacent said end of said mass into which said passageways open, a heat exchanger in proximity to said last mentioned space, said heat exchanger including spaced nozzles positioned to project a fluid heat exchange medium directly into said last mentioned space, a second chamber providing a primary space in direct communication with said passageways at the opposite end of said regenerative mass, an inlet communicating with said second chamber for admitting gas to be treated during a treating cycle and an outlet communicating with said second chamber for the escape of products of combustion during a heating cycle.

2. A regenerative furnace comprising an outer shell enclosing a regenerative mass having passageways extending lengthwise therethrough, a chamber surrounding one end of said regenerative mass forming a combustion space about the end portion of said regenerative mass, a plurality of burners opening into said combustion space, a throat constituting a communication between said combustion space and a space adjacent said end of said mass into which said passageways open, a heat exchanger in proximity to said last mentioned space, said heat exchanger including spaced nozzles positioned to project a fluid heat exchange medium directly into said last mentioned space, a second chamber providing a primary space in direct communication with said passageways at the opposite end of said regenerative mass, an inlet communicating with said second chamber for admitting gas to be treated during a treating cycle and an outlet communicating with said second chamber for the escape of products of combustion during a heating cycle.

RUDOLPH LEONARD HASCHE.

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The following references are of record in the file of this patent:

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