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APPARATUS FOR PYROLYSIS OF HYDROCARBONS

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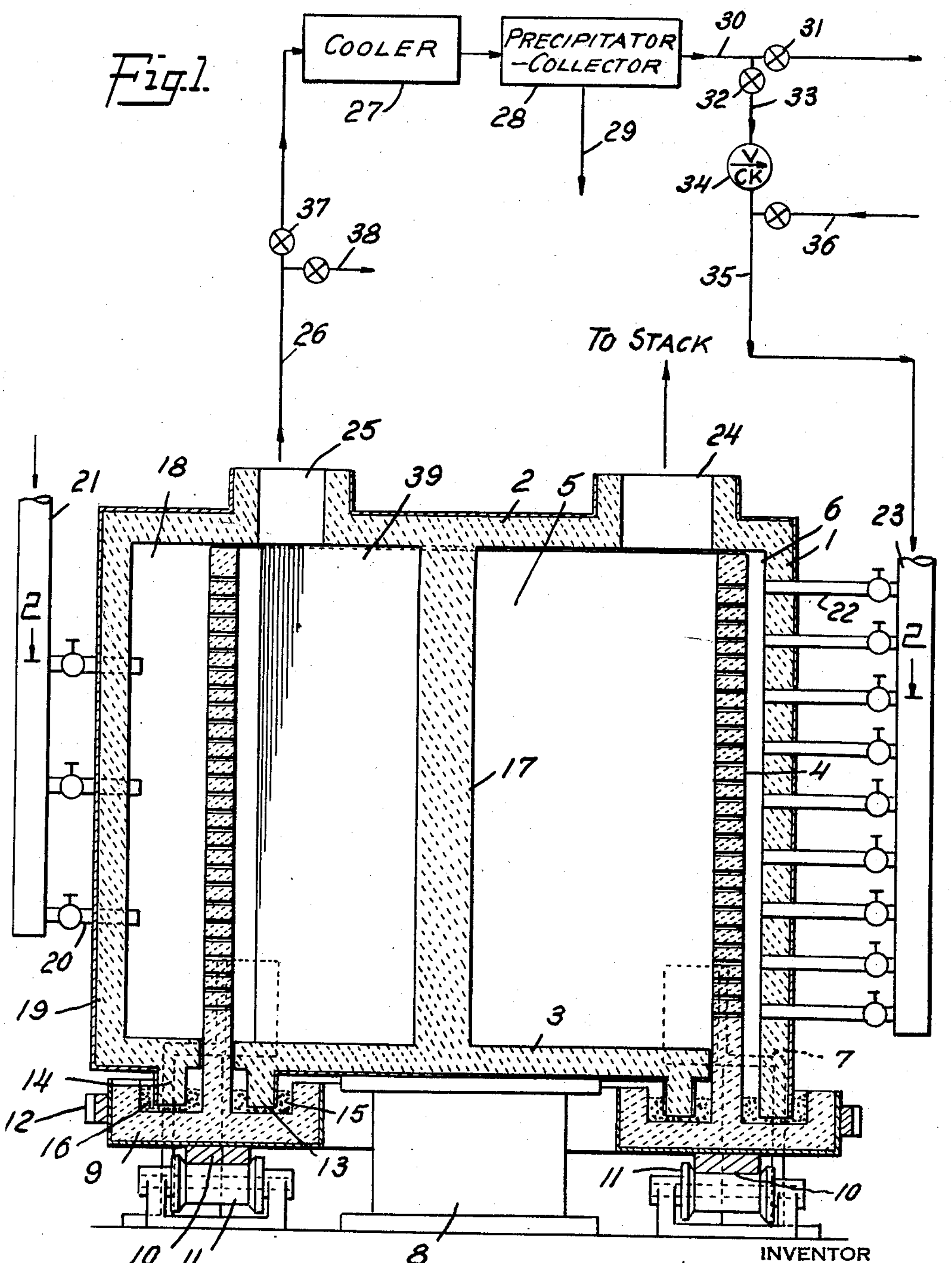


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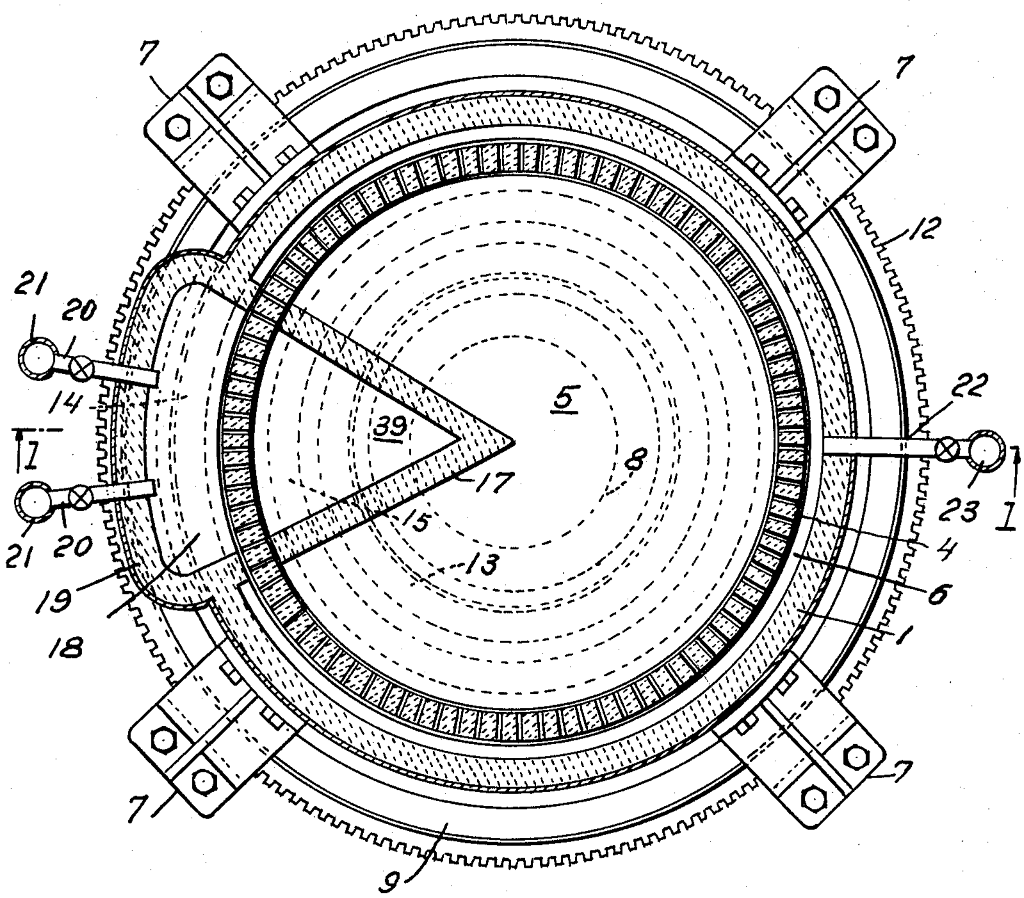
Fig. 2.

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# APPARATUS FOR PYROLYSIS OF HYDROCARBONS

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1 Claim. (Cl. 23—279)

The present invention relates to the pyrolysis of gaseous hydrocarbons and, more particularly, to operations of the type in which the pyrolysis is effected by passing the gaseous hydrocarbon in contact with hot refractory surfaces. The invention provides novel apparatus particularly adapted to that purpose.

The invention is especially useful in the production of carbon black by the destructive pyrolysis of gaseous hydrocarbons, i. e., either gas or vapor, but may also be used, with advantage, in the pyrolysis of hydrocarbons to a lesser degree or in the reforming of such materials.

It has previously been proposed to produce carbon black from natural gas by intermittently passing the gas in contact with hot refractory materials, e. g., brick checkerwork, and periodically reheating the checkerwork by burning a combustible gas in contact therewith. That procedure has the disadvantages of lack of continuity and lack of uniformity of temperature conditions and has been subject to the further objection that carbon deposits form on the refractory surfaces and tend to clog the passages through the checkerwork, through which the gas must pass.

These carbon deposits tend to insulate the refractory surfaces from the gaseous hydrocarbons and must be periodically removed, as by burning, or otherwise. Further, after the burning and the period of reheating, the system must be purged before productive operation can be resumed. Also, in order to prolong the period of productive operation and to promote greater uniformity of operating conditions during that period, extensive heat retaining refractories have been required, and to avoid objectional plugging of the system by carbon deposits, it has been customary so to construct the checkerwork as to provide relatively large passages therethrough, thus lessening the rate of heat conduction to and from the refractory mass.

The apparatus of my present invention avoids the difficulties heretofore experienced with that type of operation. It may be operated substantially without interruption, is compact, relatively inexpensive and has other advantages as will hereinafter appear.

A primary advantage of my present invention is that productive operation may be carried on continuously over long periods without interruption, either for cleaning or reheating. This is accomplished by providing the refractory surfaces in the form of a perforated refractory cylinder adapted to be rotated about its axis. One segment of this cylinder is continuously heated in a heating zone while the pyrolysis of the hydrocarbon is continuously effected by passing the hydrocarbon in contact with a different, previously heated segment of the cylinder in a pyrolysis zone, the cylinder being so positioned that during rotation successive segments of the cylinder pass successively through the heating zone and then through the pyrolysis zone and back to the heating zone for reheating.

In accordance with this invention, the gaseous hydrocarbon is continuously passed through the perforation, in contact with the freshly heated segment of the refractory cylinder and in this way substantially uniform temperature conditions are constantly maintained. Further, any carbon deposits formed on a segment of the cylinder in the pyrolysis zone may be burned therefrom in the heating zone, and in this way any accumulation of carbon which would tend to insulate the refractory surfaces from the hydrocarbons or to plug the passages through which the gases must pass through the refractory, is avoided.

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Thus, the temperature of the refractory surfaces and the rate of heat transfer therefrom may be maintained remarkably uniform. Further, the temperature of the refractory may be nicely controlled by adjustment of the rate of heating, the speed of rotation of the cylinder, and the rate of feed of the hydrocarbons, so as to effect the desired extent of pyrolysis, i. e., either to form carbon black or a lesser degree of pyrolysis.

The invention will be further described and illustrated by reference to the accompanying drawings which represent conventionally and somewhat diagrammatically one particularly advantageous embodiment thereof.

Figure 1 of the drawings is a vertical section of the furnace along the lines **1—1** of Figure 2, and

Figure 2 of the drawings is a horizontal section of the furnace taken along lines **2—2** of Figure 1.

The furnace is enclosed by a vertically positioned, impervious cylindrical wall **1**, an impervious roof wall **2**, and an impervious floor wall **3**. A cylindrical perforated refractory partition wall **4** is positioned within the enclosure, coaxially with respect to the wall **1**, so as to form an inner chamber **5** and an annular chamber **6**. The outer wall **1** and the roof wall **2** are stationary and are supported by supporting members of any conventional type, for instance, as more particularly shown by the elements **7** of Figure 2. The floor wall **3** is likewise stationary and is supported by the column **8**.

The perforated wall **4** is supported by, and, at its lower end, is securely fastened to an annular shaped sealing member **9**. At its lower side, the member **9** is provided with an annular track **10** which rests upon, and is supported by, a plurality of flanged rollers **11**. The member **9** is further provided with means adapted to cause its rotation about its axis such, for instance, as a toothed wheel **12**, extending about the member **9** and securely fastened thereto, the toothed wheel **12** being adapted to cooperate with a driving gear, not shown in the drawing.

The floor wall 3, and the outer wall 1, are provided, respectively, with flanges **13** and **14** extending downwardly into annular trough-shaped depressions **15** and **16** in the sealing member. These annular trough-shaped depressions are adapted to be filled with a powdered sealing material such, for instance, as silicon oxide, magnesium oxide, or silica gel.

Within the inner chamber, there is an effluent chamber **39** delineated by the impervious V-shaped wall **17** and a segment of the perforated partition member. This wall **17** is supported by, and securely fastened to, the floor wall **3** and extends upwardly the entire height of the inner chamber and is securely sealed to the roof wall **2**. The outer edges of the V-shaped wall terminate just short of the inner surface of the cylindrical partition wall so as to permit free rotation of the latter.

Also extending over the entire height of the partition wall, there is provided an inlet chamber **18** in open communication with the annular chamber and radially positioned with respect to the effluent chamber. This inlet chamber is delineated by the walls **19** which extend inwardly to a position just short of the outer surface of the perforated partition wall so as to form an effective seal between the inlet chamber and adjacent segments of the annular chamber while permitting free rotation of the perforated cylindrical partition.

Leading to the inlet chamber are a plurality of valved hydrocarbon inlet conduits **20** spaced over the height of the chamber and connected at their outer ends with the hydrocarbon manifolds **21**. A plurality of blast burners, adapted to inject a blast flame into the annular chamber so as to impinge upon the perforated partition wall **4**, are shown at **22** positioned diametrically opposite the inlet chamber and connected to the fuel gas manifold **23**.

The inner chamber is provided with a stack gas outlet **24** and the effluent chamber is provided with an outlet **25**.

The several walls of the chamber, including the perforated partition wall, are composed of highly refractory material, advantageously a ceramic material, such as conventionally used as furnace refractories, and adapted to withstand extremely high temperatures. The outer walls of the chamber should be well insulated to reduce heat losses. Where desired, a suitable catalyst may be deposited on the walls of the perforations to promote the desired reaction.

In operation, the perforated cylinder is highly heated by blast flames impinging thereon from the blast burners 22. Under some conditions, it may be desirable to use a single blast burner, or some other type of heater adapted to heat the perforated cylinder substantially uniformly over its entire height. For my present purpose, I prefer to use a plurality of blast burners uniformly spaced over the entire height of the furnace chamber, as shown.

During the heating, the refractory cylinder is, with advantage, rotated about its axis and highly heated before introduction of the hydrocarbon to be decomposed is initiated. At least a segment of the perforated cylinder sufficiently wide to extend past the inlet chamber should be thus preheated. When the segment of the perforated cylinder within the inlet zone has been brought to the desired temperature, the gaseous hydrocarbon to be pyrolyzed is passed to the inlet chamber under sufficient pressure to force it through the perforations in that segment of the refractory cylinder moving past the inlet chamber.

It is desirable, of course, that the passing of the hydrocarbons through the perforations be as uniform as possible over the entire height of the chamber and, for this reason, it is advantageous to introduce the hydrocarbon to the chamber through a plurality of inlet chambers uniformly spaced over its height.

Advantageously, the effluent chamber is maintained under a subatmospheric pressure so as to minimize loss of the hydrocarbon through the narrow clearances between the surfaces of the cylindrical wall and the walls of the inlet chamber and effluent chamber, respectively. By maintaining the pressure just sufficient to minimize such loss of hydrocarbon, the influx of combustion gases from the inner chamber is also minimized.

After the apparatus had been brought up to temperature and other operating conditions established, the process may be carried on continuously without interruption of the productive cycle. Temperature conditions may be maintained constant, as previously noted, by regulation of the blast flames, or other heating means, and the speed at which the perforated refractory cylinder is rotated.

In operations of this sort, whether in the production of carbon black, or to effect a lesser degree of pyrolysis, some carbon will almost inevitably be deposited on the perforated refractory cylinder. In some types of operation, this is actually desirable, as the deposited carbon tends to catalyze the reaction. Also, a relatively thin deposit of carbon tends to seal the clearances between the surfaces of the perforated cylinder and the walls confining the inlet chamber and the effluent chamber. However, where desirable, the blast burners may be so adjusted as to burn-off, in the heating zone, any carbon deposited on the perforated cylinder in the pyrolysis zone. Such burning-off of the carbon deposits may be facilitated by the use of a somewhat oxidizing blast flame in the heating zone.

It is generally preferred that the perforated refractory cylinder be rotated continuously as more uniform operation is thereby obtained. However, if desired, the cylinder may be intermittently rotated so as to interpose a fresh, highly heated segment in the path of the hydrocarbons when the previous segment has been cooled to some predetermined temperature.

The dimensions of the apparatus are subject to considerable variation depending primarily upon the desired capacity of the apparatus and extent of pyrolysis required. In the particular apparatus shown, the segment of the rotating cylinder within the pyrolytic zone is only about one-seventh of its circumference. This, of course, may be increased, or decreased, as desired, without departing from the spirit of the present invention.

As illustrative of suitable dimensions of the apparatus, the perforated refractory cylinder may, for instance, be three feet in diameter and three feet in height, the walls thereof being four inches thick with perforations $\frac{3}{8}$ inch in diameter and positioned on $\frac{3}{4}$ inch centers. The optimum thickness of the wall and size and positioning of perforations will vary depending upon the contemplated operation and the extent of contact and heating period required. In the pyrolysis of natural gas, for instance, the temperature of the refractory cylinder should be sufficient to heat the gas to a temperature of about 2500° F. and a contact time of the order of 0.01 second will generally be found adequate. Where destructive decomposition of the hydrocarbon to produce carbon black is desired, the rate of throughput will ordinarily be reduced and, hence, the contact time will be very substantially increased.

In the heating zone, the blast flames of the hot products of combustion will impinge directly on that segment of the refractory cylinder within that zone and will pass through the perforations thereof into the inner chamber 5. The resultant flue gases may be withdrawn from the chamber through the outlet 24 and pass to a stack, or otherwise disposed of.

The hot pyrolysis gases from the effluent chamber are withdrawn therefrom through the outlet 25 and may be treated in various ways, depending upon the character and purpose of the operation. In the production of carbon black, the effluent gases, carrying particles of carbon in suspension, may be passed through conduit 26, through cooler 27 to carbon black precipitator-collector 28, suitable coolers and precipitators being well-known to the art. The carbon black is thereby separated and collected at 29. From the precipitator-collector, the residual gases pass off through line 30 and may be disposed of, as desired.

Usually, this residual gas will contain a substantial proportion of gas suitable for heating purposes and may be used, to advantage, in the reheating of the rotating refractory cylinder. When such disposition of the gas is contemplated, valve 31 may be closed and valve 32, in conduit 33 opened and the residual gas passed through the check valve 34 and line 35 to the fuel gas manifold 23. Where desired, this gas may be supplemented by other fuel gas supplied through valved connection 36.

Where pyrolysis is of a lesser degree than that resulting in carbon black, valve 37 in line 26 may be closed and the effluent gases withdrawn through the valved connection 38.

In the production of carbon black, for instance, the hydrocarbon to be pyrolyzed, in accordance with my present process, may consist primarily of methane, natural gas, for instance, or it may consist of hydrocarbons of higher molecular weight than methane, either normally gaseous, or adapted to vaporize without objectionable coking. For instance, natural gas enriched by mixing the vapors of higher molecular weight therewith, may be used either as such, or diluted with steam, or other diluent.

Suitable means for maintaining the effluent chamber under a reduced pressure are well known to the art and need not here be described. It is, of course, usually desirable to place such means in the effluent line beyond the point where the effluent gases have been substantially cooled. Advantageously, it may be interposed in line 33 or 35, where the gases are to be used for reheating the refractory cylinder. Under other conditions, it would be placed in line 30 or 38.

I claim:

Apparatus for the pyrolysis of hydrocarbons comprising a vertically extending, stationary outer wall and top and bottom walls delineating a vertically extending cylindrical furnace chamber, a substantially uniformly, radially perforated refractory cylindrical partition wall of substantial thickness coaxially positioned in the furnace chamber, extending substantially the full height of said chamber, having an imperforate portion extending through the said bottom wall and being rotatably supported by means outside of said chamber, sealing means between the lower end of said partition wall and the side and bottom walls of the furnace chamber, the said walls forming an annular chamber and an inner chamber, means outside of the furnace chamber for rotating said partition wall about its vertical axis, an impervious partition wall within the inner chamber, an effluent chamber within the inner chamber delineated by said top and bottom walls, said impervious partition walls within the inner chamber and a segment of the perforated partition wall, an inlet chamber separated from said annular chamber and radially positioned with respect to the effluent chamber, the inner wall of said inlet chamber being the segment of the perforated partition forming a wall of the effluent chamber, a burner port extending through the outer wall and removed from the inlet chamber, an inlet for passing hydrocarbons into said inlet chamber and separate outlets from the effluent chamber and the inner chamber, respectively.

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