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COMPLETE SPECIFICATION

Improvements in or relating to apparatus for the preparation of Gas Mixtures Containing Hydrogen and Carbon Monoxide

We, N.V. DE BATAAFSCHE PETROLEUM MAATSCHAPPIJ, a company organised under the laws of The Netherlands, of 30 Carel van Bylandtlaan, The Hague, The Netherlands, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a process and apparatus for the preparation of gas mixtures containing hydrogen and carbon monoxide by partial combustion of a hydrocarbon with oxygen, with the optional supply of steam, in a reaction chamber in which the partial combustion occurs at super-atmospheric pressure, in particular between 5 and 35 atm. abs., and results in the production of free carbon. Such a process and apparatus will be referred to in this specification as being " of the type specified ".

The gases produced by the process and apparatus of the type specified generally have a temperature between 1000 and 1500°C and are therefore a potential source of energy. It has not yet however been possible to utilize this energy, because the gases have a very high temperature and as mentioned contain free carbon. If, for example, use is made of conventional heat exchangers of the flame tube type great difficulties are encountered. Flame tubes of the usual type cannot be used, or only with very poor effect, as it is impossible to employ the same apparatus for a long period without repairs being required. The reason for this is that a considerable deposit of soot is frequently formed on the inside wall of the tubes, as a result of which the heat transmission coefficient is greatly reduced. The great differences in temperature occurring in the present case also require the apparatus to be of a special quality and strength, and it is found that the usual heat exchangers do not fulfil the mechanical requirements.

[*Price 3s. 6d.*]

An object of the present invention is to provide a process and an apparatus for the preparation of gas mixture containing hydrogen and carbon monoxide utilizing a heat exchanger in which the above-mentioned difficulties do not occur. According to the present invention a process of the type specified comprises cooling the hot gases by passing them together with the free carbon produced by the partial combustion through one or more helical pipes, and causing a coolant to flow around said pipes. An apparatus according to the present invention of the type specified for carrying out the above process comprises, as a heat exchanger for cooling the hot gases, one or more helical cooling pipes in direct communication with the reaction chamber through which pipes the hot gases flow in operation and around which coolant flows.

The reason why in the process and apparatus according to the invention the above-mentioned difficulties do not arise is probably to be ascribed to the occurrence of high speeds in the pipes, and as a result of the curvature of these pipes, of the great centrifugal force which may be accompanied by secondary whirls, whereby soot deposits in the pipes are prevented. This is especially surprising as it was to be expected that the drawback of carbon deposits on the inside of the pipes would be still greater with the use of helical pipes than with straight ones, as additional cleaning difficulties would be involved. Moreover, this drawback can be further reduced by constructing the cooling pipes in a particular way.

The or each cooling pipe of the heat exchanger is preferably constructed so that the helical portion can be caused to vibrate by the media flowing through and/or around it. The helical portion of the cooling pipes of the operating heat exchanger are thus constantly kept slightly vibrating, this vibration phenomenon probably being caused by the resilience of the pipes and where the coolant is a liquid,

by the coolant vaporizing as it passes over the pipes, during the heat exchange. The rapid upward movement of the vapour bubbles between the liquid leads to collision effects and an intense movement in the liquid, to which phenomena the vibrations of the cooling pipes may be attributed.

In preferred embodiments of the present invention the supply line for coolant to the heat exchanger is in the form of a channel of annular cross section surrounding a supply pipe for the hot gases to be cooled.

The advantage of this method of supplying the coolant is that it is contacted most intimately with the hot gases at the very points where they have the highest temperature and when the coolant is at its lowest temperature. This arrangement also prevents the apparatus from being subjected to excessive heat load.

In one such embodiment of the apparatus according to the present invention the heat exchanger is a vertical cylindrical vessel in which is mounted a coaxial inner tube, the cooling pipe or pipes being connected at their inlet end to openings in one of the vessel, and being arranged in the annular space between the vessel and the inner tube, the coolant flowing through the annular space in operation and passing into said space from the inner tube.

The high heat load to which are subjected the parts in contact with the hot gases, and in the case of this heat exchanger, that part of the cooling pipe(s) in particular which directly adjoins the openings in the one end of the vessel which forms the bottom plate, also results in the mechanical strength being adversely affected; it is, in fact, known that mechanical strength declines with increase in temperature.

In order to ensure that this heat exchanger fulfils the mechanical requirements, the cooling pipe may be provided with thickened lengths adjoining their inlet ends; the remaining part of the pipe must, in fact, be thin-walled so as to afford the greatest possible flexibility. It has been found that a thickened length of over approximately half a turn of a helix of the cooling pipe is sufficient to resist the forces occurring at the ends of the pipes but does not affect the vibration of the main helical portion of the pipes.

In order to ensure a good cooling, particularly in the hottest points, namely where the hot gases enter, the inner tube may be provided near said one end with a spray nozzle arranged so that the coolant is sprayed on to the said one end of the vessel.

It has, in fact, been found that the bottom plate and the initial length of the cooling pipes are exposed to a very high heat load and that it is necessary to bring these parts into contact with the coolant as intensely as possible. If this procedure is omitted, there is a risk of the coolant, for example, water, vaporizing before it reaches the bottom plate as a result of the high temperature if it is not replaced in time by new coolant, and the formation of premature vapour or gas bubbles would greatly impede the heat transfer.

In another embodiment of the apparatus of the present invention the heat exchanger consists of a vertical cylindrical vessel, provided with at least one inlet and one outlet for the coolant, and with at least one helical cooling pipe provided with an inlet and an outlet for the hot gases to be cooled, arranged in an annular space formed by the outer wall of the vessel and a concentric inner tube, the said inner tube being in communication with said annular space at the lower end of the vessel and open at the upper end, the inner tube being provided at its lower end with an outlet for liquid coolant.

The advantage of this embodiment of the heat exchanger is that a part of the coolant heated to boiling point as a result of the high temperature in the hot gas to be cooled finds its way into the inner tube via the open end thereof, i.e. that part of the boiling coolant which is still liquid, and that the vaporized part may be discharged via the top of the heat exchanger. In this way a separation between liquid and vaporous coolant is already obtained inside the heat exchanger. The additional advantage of the construction according to the present invention is that, unlike the bubbling and boiling vapour-liquid mixture in the annular space where the heat transfer occurs, a substantially quiescent liquid column is present in the inner tube, the level of which may be observed and maintained at substantially the same height as the liquid in the annular space, an index thus being provided to the quantity of liquid required to be circulated, dependent upon the degree of vapour formation.

In this embodiment of the invention the cooling pipe or pipes of the heat exchanger preferably consist(s) of two parts which are coaxial in relation to the axis or centre line of the helix and are interconnected by means of a connecting piece in the upper part of the vessel. It is clear that in this manner the cooling pipe or pipes may be accommodated in a relatively small space and, in addition, that the supply and discharge lines of the gases will be at approximately the same height.

A cyclone is preferably provided in the vertical cylindrical vessel at the upper end, the inlet of which cyclone is connected to the space within the vessel and which cyclone is provided with a vapour outlet connected to a discharge line, and is also provided with another discharge line for liquid coolant, which discharge line extends down through the open end of the inner tube into this tube. The coolant, for example water, will then, as a result of the compact construction of the spiral itself, be heated fairly rapidly, reach the boiling point and partly pass over into steam or

vapour. When operating at high speeds there is a likelihood of much liquid being entrained with the steam or vapour; this liquid is removed in the cyclone.

The bottom of the vessel and the inner tube are preferably connected by means of small openings, so that the spaces formed by the two tubes are fully connected. These openings constitute a means of removing the liquid entirely from the heat exchanger when it is not in operation.

In a further embodiment of the apparatus of the present invention each or all of the cooling pipes are arranged in a wider helical pipe of the same kind, the annular helical space between the two pipes being provided with a supply and a discharge line for the coolant.

The special advantage of this embodiment is that, should the pipes become fractured, the risk of accident is comparatively small, even at the high pressures which are liable to occur, as the pipe used is one whose function is comparable to that of the pipes of a so-called "monotube once-through boiler" (Benson type or the like). Furthermore, in the case of fractured pipes water or steam losses will be relatively small. In addition, it is quite possible to replace a defective set of helical pipes during operation by temporarily disconnecting the set of the pipes in question, at any rate provided the heat exchanger comprises more than one set of helical pipes.

Finally, the use of a heat exchanger with more than one set of helical pipes enables the capacity of the heat exchanger to be controlled by connecting up or disconnecting one or more sets of pipes.

Each set of pipes, formed by a cooling pipe and a wider pipe of the same kind, is preferably connected to common distributing lines in such a way that each inlet of a cooling pipe is connected to a distributing line connected to the outlet of the reaction chamber, and that each space between a cooling pipe and a wider pipe is connected to a distributing line for the coolant, each outlet for the cooled gases and each outlet for the coolant also being connected to a collecting line for the cooled gases and for coolant respectively. The usefulness of this becomes apparent if it is desired to employ more than one series of cooling pipes, as it is thus possible to disconnect each set of helical pipes in a simple manner by providing valves between the distributing elements for supplying the hot gases and each cooling pipe, and also between the collecting lines and each cooling pipe without impeding the continuous passage of each of the media from the distributing elements to the collecting line.

It is also desirable to cool each connecting piece forming a connection between the distributing element for the gases to be cooled and an inlet end of a helical pipe, as otherwise the very high gas temperature would make excessive demands on the material. In this embodiment of the present invention this cooling may be effected by providing each connecting piece including the connecting flange with a cooling channel. Each set of helical pipes may finally be housed in a closed cylindrical space in order to reduce the risk still further in the case of fractured pipes.

Different embodiments of apparatus according to the present invention will now be described by way of example with reference to the accompanying diagrammatic drawings in which:—

Figure 1 is a diagrammatic representation of the whole apparatus,

Figure 2 shows a longitudinal cross section of a heat exchanger forming part of one embodiment,

Figure 3 shows a section at the line III—III in Figure 2,

Figure 4 shows a section at the line IV—IV in Figure 2,

Figure 5 shows a spray nozzle forming part of the heat exchanger,

Figure 6 is a longitudinal section of a heat exchanger forming part of a second embodiment,

Figure 7 is a section at the line VII—VII in Figure 6,

Figure 8 is a diagrammatic representation of a third embodiment,

Figure 9 is a section at the line IX—IX in Figure 8, and

Figure 10 shows a detail of part of Figure 9 on an enlarged scale.

Referring now to Figure 1 of the drawings, the apparatus includes a reactor A which is provided with a fuel supply line *a* leading to a burner A^1 as well as an oxygen supply line *b* through which steam also may be supplied if it is used. The hot gases are led through a connection B and a connecting piece C to a heat exchanger D in which the gases pass through a helical cooling pipe to a discharge *c* for the cooled gases, and which has also coolant inlet and outlet lines *d* and *e*. The coolant may for example be water in which case some steam may leave through the line *e*. The gases issuing through the discharge *c* may, if desired, be subjected to purification treatment in known manner.

Figure 2 is a longitudinal cross-section of one embodiment of the heat exchanger D shown in Figure 1. This heat exchanger has a generally cylindrical outer shell 6 having a bottom plate 1 which is provided with a flange 2. The outer shell 6 is connected to the bottom plate 1 by means of a welding seam, for example. A spray nozzle 3 forms the lower end of an inner tube 7 which is coaxial with the outer shell 6 and is fitted with guide strips 5 for two helical interlaced cooling pipes 4. At its upper end, the inner tube 7 joins a conical part 8 leading into a narrower terminal pipe 10. A partition 12 separates the pipe 10 into two lengths to the lower one of which a coolant

inlet line 15 (corresponding to line *d* in Figure 1) is joined. The length above the partition 12 is a gas discharge 13 (corresponding to discharge *c* in Figure 1) which is joined to the helical pipes 4 by pipes 9 (only one of which appears in Figure 2) which are thickened for strengthening purposes.

The inner tube 7 is freely supported from the terminal pipe 10. The advantage of such a construction is that the inner tube 7 and other parts of the heat exchanger can expand freely with increases of temperature and vice versa.

The top plate 11 of the heat exchanger is provided with a coolant outlet pipe 14 (outlet *e* in Figure 1). The hot gas enters the heat exchanger through the inlet openings in the bottom plate 1 and thickened initial sections 16 of the cooling pipes 4.

It may also be desirable to provide some support for the thin-walled cooling pipes which are of considerable length. In order to allow a wholly or partially free vibration of the helical portions of the pipes 4 the heat exchanger is provided at various intermediate points with elements 17 for the free and/or fixed support of the cooling pipes 4.

Figure 3 is a section of the upper part of the heat exchanger at the line III—III in Figure 2, showing the manner in which the cooling pipes 4 are connected to the gas discharge 13. Figure 4 is a section at the line IV—IV in Figure 2 and shows the disposition of the spray nozzle 3 for the coolant in relation to the initial sections 16 of the cooling pipes 4. Moreover, this figure shows that the thickened sections 16 of the cooling pipes 4 extend through approximately half a turn of the spirals but does not affect the vibration effect along the pipes.

It is necessary to replace the coolant by fresh coolant sufficiently quickly and at the right point, and it has been found that both the shape of the spray nozzle 3 and the point at which it issues are particularly important. The spray nozzle 3 is therefore slit shaped and is situated near the inlet openings of the pipes 4 in the bottom plate 1. Actually these are the hottest points in the heat exchanger, and it is, in fact, by means of this special shape of the spray nozzle 3 that the coolant is able to reach these points in sufficient quantity. At the same time this shape ensures satisfactory distribution of the coolant over the bottom plate 1. A section through the spray nozzle 3 adjoining the bottom of the inner tube 7 is shown as a separate detail in Figure 5, viewed from the direction indicated by arrow P in Figure 4. The narrow slit ensures that a properly directed stream of coolant is sprayed with great speed and force against the bottom plate 1 of the heat exchanger.

It should also be observed that the helical form of the cooling pipes 4 enables the required cooling surface to be obtained in a vertical heat exchanger of a moderate height.

In a heat exchanger as shown in Figures 2—5, water was employed as coolant, which for the sake of a proper heat transfer was passed through by means of forced circulation (i.e. the quantity of water supplied to the inlet of the heat exchanger is ten times the quantity of water which is converted into steam by the heat derived from the hot gases to be cooled). The temperature of the circulating water was approximately 215°C in the heat exchanger in operation. The temperature at which hot gases were introduced was approximately 1300°C and the temperature at which the cooled gases were discharged was approximately 250°C.

Figure 6 shows a longitudinal cross-section of another heat exchanger which may be used as the heat exchanger D in the apparatus of Figure 1 and Figure 7 is a section taken at the line VII—VII in Figure 6. In this heat exchanger the pipe 101 is the supply pipe for the hot gases which are received from the reactor and are to be cooled.

Near the heat exchanger a pipe 102 is arranged concentrically around the supply pipe 101 in such a way that the two pipes form an annular space 112 through which the coolant, usually water, is supplied (cf. inlet line *d* in Figure 1). That part of the water which is converted to steam leaves the heat exchanger through the outlet line 103, and the water is discharged through a separate outlet line 104. The cooled gases leave by the discharge 105.

The heat exchanger comprises a cylindrical vessel 106, provided with a coaxial inner tube 107 which is open at its upper end, and is closed at its lower end which extends through the bottom of the vessel 106. The annular space 108 between the vessel 106 and the tube 107 houses helical pipes 109 and 110, the upper ends of which are interconnected by means of a pipe 111. The two pipes 109 and 110 are each helical, but the radius of the coils of the pipe 109 is greater than that of the pipe 110. If necessary more than one set of such helical pipes may be provided in the annular space 108, two interlaced sets being shown in Figure 6. The duplicated supply pipes 101 and discharges 105 are shown in Figure 7.

One or more catch plates 113 (only one is shown by way of example) may be provided in the upper part of the vessel 106 in order to prevent too much liquid being entrained in the vapour leaving the outlet line 103, should the coolant boil up excessively.

A cyclone separator 114 in the upper part of the vessel 106 also serves to separate liquid from the vapour, the liquid being returned to the liquid circuit by a return pipe 115. A gauge glass 116, fitted in a conventional manner, is arranged outside the vessel 106 and in communication with the inner tube 107, to enable the level of the liquid in the tube 107 to be

observed. A draw-off 117 is provided at the bottom of the inner tube 107, while a number of small openings 118 are provided to enable the annular space 108 to be emptied. The openings 118 also allow the liquid level in the vessel 106 to be substantially the same as the level in the tube 107.

It is desirable that the liquid coolant in the inner tube 107 should not be exposed to extra heating near the outlet line 104 and accordingly the closed end of the inner tube 107 extends beyond the bottom of the vessel 106 the outlet line 104 for the liquid coolant being situated below the vessel 106.

It will be clear that the whole unit must be capable of resisting an elevated pressure.

The heat exchanger of the embodiment according to Figures 6 and 7 operates as follows:

The hot gases are supplied through one or more pipes 101 (the number depending on the number of sets of helical pipes provided) and cooling commences even before they enter the heat exchanger proper as the coolant for example water, is supplied through the annular spaces 112 around the pipes 101. Inside the heat exchanger, the pipes 101 lead into the helical pipes 109, so that the hot gases pass upwards through them. At the upper end of the pipes 109, the gases reverse their direction and flow down through the other helical pipes 110, finally leaving, having been cooled, through the discharges 105.

The coolant entering through the annular spaces 112 is heated very quickly in the annular space 108 and reaches its boiling point. The boiling coolant will vaporize and this vapour stream is stripped of residual liquids in the cyclone 114, the liquid passing to the inner tube 107 through return pipe 115. The catch plate(s) 113 ensure that the amount of liquid entrained is not excessive. The return pipe 115 of the cyclone extends below the liquid level maintained in the inner tube 107 which can be checked by means of gauge glass 116, to ensure that a liquid seal is automatically maintained.

A further embodiment of apparatus according to the invention is shown in Figures 8—10.

Referring to Figure 8, the reactor 201 (A in Figure 1) is provided with a fuel supply line 202 (*a* in Figure 1) and a burner 203 (A^1 in Figure 1) and also with an oxygen supply line 204 (*b* in Figure 1), through which steam also may be supplied. A convergent part 205 forms the connection between the reactor 201 and a gas distributing line 206. Through this distributing line 206 and connecting pipes 207, the hot gases are passed to sections 208 of the heat exchanger, in each of which is housed a set of helical pipes. Each section is provided with a cooled gas discharge 209 (*c* in Figure 1) as well as with a coolant inlet line 210 (*d* of Figure 1) (see Figure 9) and a coolant outlet line 211 (*e* in Figure 1). The coolant inlet lines 210 are connected to a coolant distributing line 212, the gas discharge 209 being connected to a collecting line 213 and the coolant outlet lines 211 to a collecting line 214. Each distributing line or collecting line is provided with a blind flange, such as the flange 215 on the distributing line 206. This facilitates inspection of these lines, while new elements may be connected up in a simple way.

Figure 10 shows the initial part of a set of pipes 216 on an enlarged scale, and also the connection to the gas distributing line 206 and the other connections. The inner pipe 217 through which the hot gases are led forms together with the outer pipe 218 channel 220, through which the coolant is passed. This coolant is supplied through the channels 221 which are provided in a flange 219 and are connected to the annular channel 222 provided around the flange. The coolant distributing line 212 may be connected directly to the inlet (not shown) to the annular channel 222. The connecting piece 207 is provided with the inlet line 210 for the coolant. The coolant flows through the annular channel 226 formed between the inner pipe 227 and the outer pipe 228, and also through channels 224 and a flange 225 to an annular channel 223 arranged around this flange. If desired, the discharge 229 may be directly connected to the inlet to the annular channel 222, so that the two cooling systems are connected in series, alternatively it may be connected to the coolant collecting line 214.

Finally, the various elements may be provided with suitable valves, which, for the sake of simplicity, are not shown in the drawing. They enable one or more of the elements 208 to be connected up or disconnected as required.

WHAT WE CLAIM IS:—

1. A process of the type specified which comprises cooling the hot gases by passing them together with the free carbon produced by the partial combustion through one or more helical pipes, and causing a coolant to flow around said pipes.

2. A process according to claim 1, comprising permitting the helical pipes to vibrate slightly under the influence of the hot gases passing through them and/or of the coolant flowing around them.

3. A process of the type specified substantially as described.

4. Apparatus of the type specified for carrying out the process according to any one of the preceding claims comprising, as a heat exchanger for cooling the hot gases, one or more helical cooling pipes in direct communication with the reaction chamber, through which pipes the hot gases flow in operation and around which coolant flows.

5. Apparatus according to claim 4, in which the or each helical cooling pipe is constructed

observed. A draw-off 117 is provided at the bottom of the inner tube 107, while a number of small openings 118 are provided to enable the annular space 108 to be emptied. The openings 118 also allow the liquid level in the vessel 106 to be substantially the same as the level in the tube 107.

It is desirable that the liquid coolant in the inner tube 107 should not be exposed to extra heating near the outlet line 104 and accordingly the closed end of the inner tube 107 extends beyond the bottom of the vessel 106 the outlet line 104 for the liquid coolant being situated below the vessel 106.

It will be clear that the whole unit must be capable of resisting an elevated pressure.

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The coolant entering through the annular spaces 112 is heated very quickly in the annular space 108 and reaches its boiling point. The boiling coolant will vaporize and this vapour stream is stripped of residual liquids in the cyclone 114, the liquid passing to the inner tube 107 through return pipe 115. The catch plate(s) 113 ensure that the amount of liquid entrained is not excessive. The return pipe 115 of the cyclone extends below the liquid level maintained in the inner tube 107 which can be checked by means of gauge glass 116, to ensure that a liquid seal is automatically maintained.

A further embodiment of apparatus according to the invention is shown in Figures 8—10.

Referring to Figure 8, the reactor 201 (A in Figure 1) is provided with a fuel supply line 202 (*a* in Figure 1) and a burner 203 (A^1 in Figure 1) and also with an oxygen supply line 204 (*b* in Figure 1), through which steam also may be supplied. A convergent part 205 forms the connection between the reactor 201 and a gas distributing line 206. Through this distributing line 206 and connecting pipes 207, the hot gases are passed to sections 208 of the heat exchanger, in each of which is housed a set of helical pipes. Each section is provided with a cooled gas discharge 209 (*c* in Figure 1) as well as with a coolant inlet line 210 (*d* of Figure 1) (see Figure 9) and a coolant outlet line 211 (*e* in Figure 1). The coolant inlet lines 210 are connected to a coolant distributing line 212, the gas discharge 209 being connected to a collecting line 213 and the coolant outlet lines 211 to a collecting line 214. Each distributing line or collecting line is provided with a blind flange, such as the flange 215 on the distributing line 206. This facilitates inspection of these lines, while new elements may be connected up in a simple way.

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Finally, the various elements may be provided with suitable valves, which, for the sake of simplicity, are not shown in the drawing. They enable one or more of the elements 208 to be connected up or disconnected as required.

WHAT WE CLAIM IS:—

1. A process of the type specified which comprises cooling the hot gases by passing them together with the free carbon produced by the partial combustion through one or more helical pipes, and causing a coolant to flow around said pipes.

2. A process according to claim 1, comprising permitting the helical pipes to vibrate slightly under the influence of the hot gases passing through them and/or of the coolant flowing around them.

3. A process of the type specified substantially as described.

4. Apparatus of the type specified for carrying out the process according to any one of the preceding claims comprising, as a heat exchanger for cooling the hot gases, one or more helical cooling pipes in direct communication with the reaction chamber, through which pipes the hot gases flow in operation and around which coolant flows.

5. Apparatus according to claim 4, in which the or each helical cooling pipe is constructed

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so that the helical portion can be caused to vibrate by the media flowing through and/or around it.

6. Apparatus according to either claim 4 or claim 5, in which the heat exchanger is provided with a coolant supply pipe in the form of a channel of annular cross section surrounding a supply pipe for the hot gases to be cooled.

7. Apparatus according to either claim 4 or claim 5, in which the heat exchanger is a cylindrical vessel in which is mounted a coaxial inner tube, the cooling pipe or pipes being connected at their inlet ends to openings in one end of the vessel and being arranged in the annular space between the vessel and the inner tube, the coolant flowing through the annular space in operation and passing into said space from the inner tube.

8. Apparatus according to claim 7, in which the cooling pipes are provided with thickened lengths adjoining their inlet ends.

9. Apparatus according to claim 8, in which the thickened lengths constitute approximately half a turn of a helix.

10. Apparatus according to any one of claims 7 to 9, in which the inner tube is provided near said one end of the vessel with a spray nozzle arranged so that the coolant is sprayed on to the said one end of the vessel.

11. Apparatus according to any one of claims 4 to 6, in which the heat exchanger consists of a vertical cylindrical vessel provided with at least one inlet and one outlet for the coolant, and with at least one helical cooling pipe provided with an inlet and an outlet for the hot gases to be cooled, arranged in an annular space formed by the outer wall of the vessel and a concentric inner tube, the said inner tube being in communication with said annular space at the lower end of the vessel and open at the upper end, the inner tube being provided at its lower end with an outlet for liquid coolant.

12. Apparatus according to claim 11, in which the cooling pipe or pipes of the heat exchanger consist(s) of two parts which are coaxial in relation to the axis or centre line of the helix and are interconnected by means of a connecting pipe in the upper part of the vessel.

13. Apparatus according to claim 11 or 12, in which a cyclone separator is provided in the vertical cylindrical vessel at the upper end, the inlet of which cyclone separator is connected to the space within the vessel and which cyclone separator is provided with an outlet for vaporous coolant, which outlet is connected to a discharge line, and is also provided with another discharge line for liquid coolant, which discharge line extends down through the open end of the inner tube into said inner tube.

14. Apparatus according to any one of claims 11 to 13, in which the space formed by the wall of the vessel and the inner tube and the space in the inner tube are connected to each other by means of one or more openings near the bottom of the vessel.

15. Apparatus according to claim 4 or 5, in which each or all of the cooling pipes are arranged in a wider helical pipe of the same kind, the annular helical space between the two pipes being provided with a supply and a discharge line for the coolant.

16. Apparatus according to claim 15, provided with several cooling pipes, in which each set of pipes formed by a cooling pipe and a wider pipe of the same kind is connected to common distributing lines in such a way that each inlet of a cooling pipe is connected to a distributing line connected to the outlet of the reaction chamber wherein the partial combustion of the hydrocarbon is carried out, and that each space between a cooling pipe and a wider pipe is connected to a distributing line for the coolant, each outlet for the cooled gases and each outlet for the coolant also being connected to a collecting line for the cooled gases and for cooling respectively. coolant

17. Apparatus according to claim 16, in which each connecting piece forming a connection between the distributing line for the gases to be cooled and an inlet of a cooling pipe is surrounded by a cooling channel.

18. Apparatus of the type specified substantially as hereinbefore described with particular reference to the accompanying drawing.

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