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(54) Constant volume tubular reactor.

(57) Gasification reactor for synthesis gas production wherein the break-through-time of the reactants is maximal. The reactor is top-down fired with a top outlet and the reactor has a predetermined length over diameter ratio.

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CONSTANT VOLUME TUBULAR REACTOR

The invention relates to a constant volume tubular reactor for carrying out a gasification process wherein synthesis gas (carbon monoxide and hydrogen) is obtained by partial oxidation of a hydrocarbon-containing fuel and an oxygen-containing gas.

The oxygen-containing gas used in the partial oxidation may be pure oxygen, mixtures of oxygen and steam, air or mixtures of pure oxygen, air and steam.

In view of the depletion of oil reserves, the production of synthesis gas, which is a feedstock for many chemicals, is a subject of growing interest.

The partial oxidation of hydrocarbon-containing fuels can take place according to various established processes. Gaseous, liquid or solid hydrocarbons or mixtures thereof can be used. Advantageously, methane is used as fuel. More advantageously, the partial oxidation may take place in the presence of steam.

These processes include the Shell Gasification Process. A comprehensive survey of this process can be found in the Oil and Gas Journal, September 6, 1971, pp. 85-90.

The partial oxidation of gaseous fuels is usually carried out at temperatures around 900 to roughly 1600 °C, advantageously 1100 to 1500 °C and pressures up to 100 bar, advantageously 5 to 100 bar.

In a reactor for carrying out these partial oxidation processes the reactants are supplied thereto in any suitable manner through an inlet and the product gas obtained is leaving the reactor through an outlet.

It has now appeared that the performance of such a gasification reactor is strongly dependent on the break-through time of the residence-time-distribution of the reactants in the reactor and not so strongly on the average residence time. The break-through time of a reactor can be defined as the shortest possible residence time of a fluid parcel.

Top-down firing as applied in conventional reactors with a bottom outlet leads to minimal break-through times as a result of fluid short-circuiting.

It is an object of the invention to provide a reactor wherein the break-through time of the reactants is increased without increasing the volume of the reactor.

The invention therefore provides a constant volume tubular reactor for improving the performance of a partial oxidation process of a carbon-containing fuel and an oxidant, said reactor comprising an inlet for the reactants and an outlet for the product gas, characterized in that the inlet and outlet are located at a same side of the reactor and wherein the reactor length (L) over diameter (D) ratio is in the range of $2.8 < \frac{L}{D} < 3.2$.

In this manner the reactor has a maximal breakthrough time, which is approximately a factor 2 higher than for a reactor of the same volume with bottom outlet. Advantageously, both the inlet and the outlet are located at the top of the reactor.

In another advantageous embodiment of the invention, both the inlet and outlet of the reactor are located at the bottom of the reactor. More advantageously, the reactor length (L) over diameter (D) ratio L/D is equal to 3.

The invention is based upon the fact that the major parameters for the break-through time are the reactor length ($t \sim L^2$) and the momentum (thrust) of the jet ($t \sim (m.v)^{-1}$) and that the volumetric averaged reactor residence time is a much less significant parameter. According to the invention, for a given reactor volume, an increase of the break-through time leads to an improvement of the process performance and a maximum break-through time is obtained by specific inlet/outlet position and specific L/D ratios.

The invention will now be described in more detail by way of example by reference to the accompanying drawings, in which:

fig. 1 represents a break-through-time and residence time distribution of conventional fluid top-feed, bottom-release reactors;

fig. 2 represents a break-through-time and residence time distribution of fluid top-feed, top-release reactors; and

fig. 3 represents schematically a top-feed, top-release reactor according to the invention.

Referring now to fig. 1, a break-through time and residence time distribution for conventional reactors (fluid top-feed, bottom-release) is shown. The horizontal axis represents residence time (in seconds) whereas the vertical axis represents residence time distribution (in $seconds^{-1}$).

Distribution a) represents a reactor with a cylindrical outlet, distribution b) represents a reactor with a central outlet hole, and distribution c) represents a reactor with an annular outlet. In all cases the L/D ratio = 5.

Fig. 2 shows the break-through time and residence time distribution for a fluid top-feed, top-release reactor. The horizontal and vertical axes represent the same quantities as in fig. 1.

Distribution d) represents a top-feed, top-release reactor with L/D = 5.0; distribution e) represents a top-feed, top-release reactor of the invention with L/D = 3.0 and distribution f) represents a top-feed, top-release reactor with L/D = 1.8. It appears that the break-through time of distribution e) has considerably increased.

Referring to fig. 3, a longitudinal section of a top-in, top-out reactor has been shown. The release of product gas takes place at the top via a co-annular slot having an inner diameter D_i and an outer diameter D. The inlet has a diameter d (in this example d = 0.22 metres). The reactor diameter D may vary from 1.0 to 1.4 metres and the reactor length L from 2.50 to 5.00 metres.

Table A shows an example of the dimensions of the reactor:

TABLE A

Reactor: fluid top-in, top-out			
Considered dimensions:			
L	D	Di	$(D-D_i)/2$
5.00	1.00	0.83	0.085
4.16	1.10	0.93	0.085
3.75	1.15	0.97	0.090
3.56	1.19	0.98	0.105
3.40	1.21	1.00	0.105
2.50	1.41	1.09	0.160

Thus, the reactor with top feeding and top release having L/D 3 is superior to a conventional top-down fired reactor with bottom outlet. Given the same burner, the same throughput and reactor volume the break-through time is doubled, leading to a much better gasification performance. Or, for twice the capacity, the break-through time is the same, giving similar gasification performance.

Experiments have been carried out with the following jet characteristics (Table B) and reactor and burner characteristics (Table C):

Table B

Jet characteristics	
axi-symmetrical round turbulent jet orifice:	
mass flow	5.8 kg/s
velocity	30. m/s downward, no swirl
momentum	43.5 $kg.m/s^2$ (low)
fluid density	5. kg/m^3
equiv. diameter	0.22 m

Table C: Reactor and burner characteristics

reactor (prior art)				outlet at BOTTOM		
length (m)	diameter (m)	volume (m^3)	length / diameter (-)	inner diameter (m)	outer diameter (m)	reactor-diameter / burner-eq. diam. (-)
5.00	1.00	3.93	5.00	0.00	1.00	4.5
5.00	1.00	3.93	5.00	0.00	0.50	4.5
5.00	1.00	3.93	5.00	0.83	1.00	4.5
reactor (invention)				**outlet at the TOP**		
length (m)	diameter (m)	volume (m^3)	length / diameter (-)	inner diameter (m)	outer diameter (m)	reactor-diameter / burner-diameter (-)
5.00	1.00	3.93	5.0	0.83	1.00	4.5
3.56	1.19	3.93	3.0	0.98	1.19	5.3
2.50	1.41	3.93	1.8	1.09	1.41	6.4
4.16	1.10	3.93	3.8	0.93	1.10	4.9
3.75	1.15	3.93	3.3	0.97	1.15	5.2
3.40	1.21	3.93	2.8	1.00	1.21	5.5

It will be appreciated that the present invention is not restricted to a reactor with a co-annular outlet at the top. Arrangements of outlet ports, or of a single outlet in combination with burner protrusion are also possible. The reactor of the invention has a better volume utilization than a conventional one. Consequently the load can be higher, or the conversion deeper.

The top-feeding of reactants and the top-release of products allows integrated heat-recovery (reactants heating and syngas cooling) within the gasifier vessel. This is in particular advantageous for fuel-air gasification under non-slagging conditions.

Various modifications of the present invention will become apparent to those skilled in the art from the foregoing description and accompanying drawings. Such modifications are intended to fall within the scope

Table C: Reactor and burner characteristics

reactor (prior art)				outlet at BOTTOM		
length (m)	diameter (m)	volume (m^3)	length / diameter (-)	inner diameter (m)	outer diameter (m)	reactor-diameter / burner-eq. diam. (-)
5.00	1.00	3.93	5.00	0.00	1.00	4.5
5.00	1.00	3.93	5.00	0.00	0.50	4.5
5.00	1.00	3.93	5.00	0.83	1.00	4.5

reactor (invention)				outlet at the TOP		
length (m)	diameter (m)	volume (m^3)	length / diameter (-)	inner diameter (m)	outer diameter (m)	reactor-diameter / burner-diameter (-)
5.00	1.00	3.93	5.0	0.83	1.00	4.5
3.56	1.19	3.93	3.0	0.98	1.19	5.3
2.50	1.41	3.93	1.8	1.09	1.41	6.4
4.16	1.10	3.93	3.8	0.93	1.10	4.9
3.75	1.15	3.93	3.3	0.97	1.15	5.2
3.40	1.21	3.93	2.8	1.00	1.21	5.5

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The top-feeding of reactants and the top-release of products allows integrated heat-recovery (reactants heating and syngas cooling) within the gasifier vessel. This is in particular advantageous for fuel-air gasification under non-slagging conditions.

Various modifications of the present invention will become apparent to those skilled in the art from the foregoing description and accompanying drawings. Such modifications are intended to fall within the scope of the appended claims.

Claims

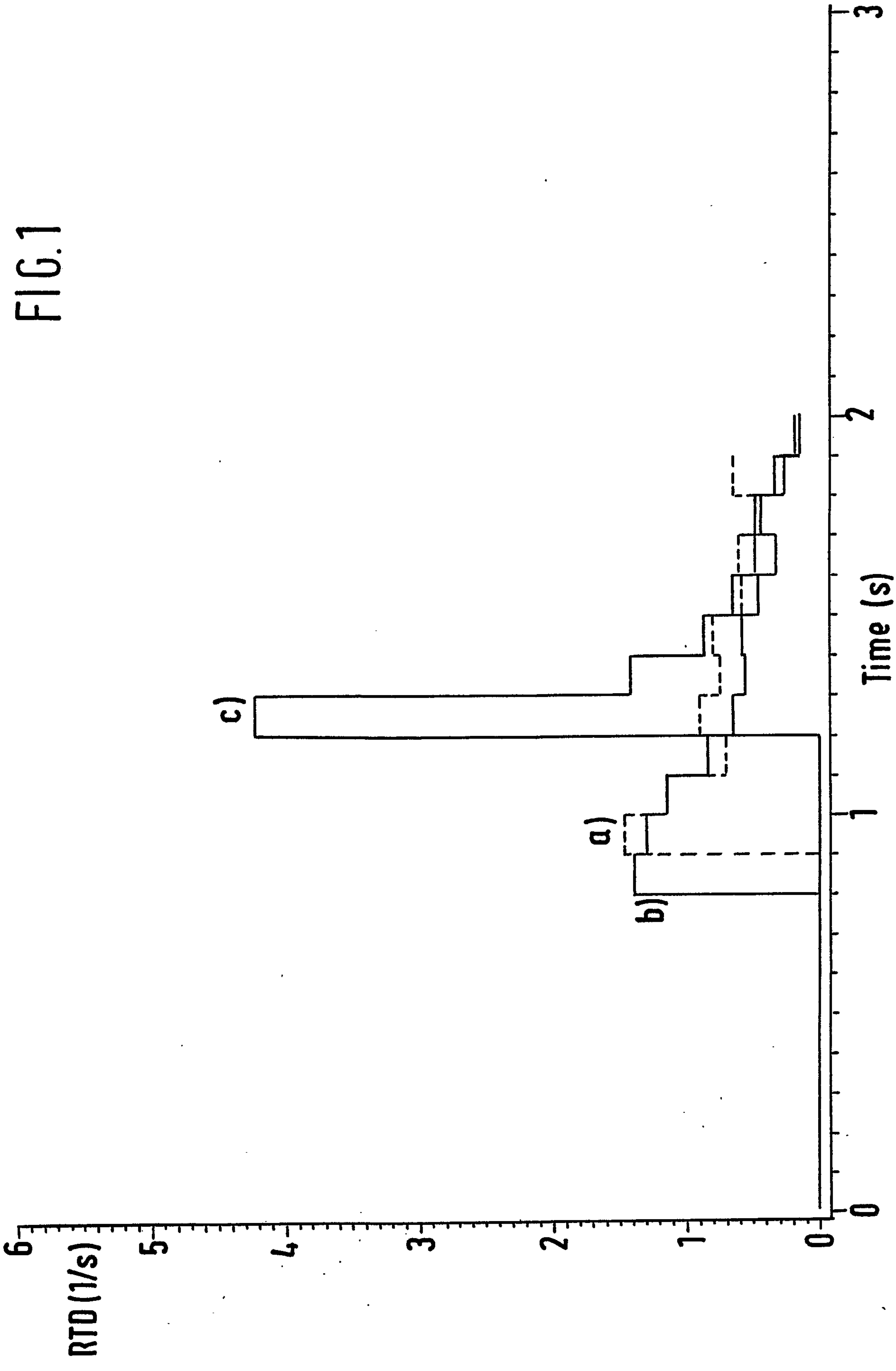
1. A constant volume tubular reactor for improving the performance of a partial oxidation process of a carbon-containing fuel and an oxidant, said reactor comprising an inlet for the reactants and an outlet for the product gas, characterized in that the inlet and outlet are located at a same side of the reactor and wherein the reactor length (L) over diameter (D) ratio is in the range of $2.8 < \frac{L}{D} < 3.2$.

2. The reactor as claimed in claim 1 characterized in that the said inlet and outlet are located at the top of the reactor.

3. The reactor as claimed in claim 1 characterized in that the said inlet and outlet are located at the bottom of the reactor.

4. The reactor as claimed in any one of claims 1-3 characterized in that the $\frac{L}{D}$ ratio is equal to 3.

FIG.1



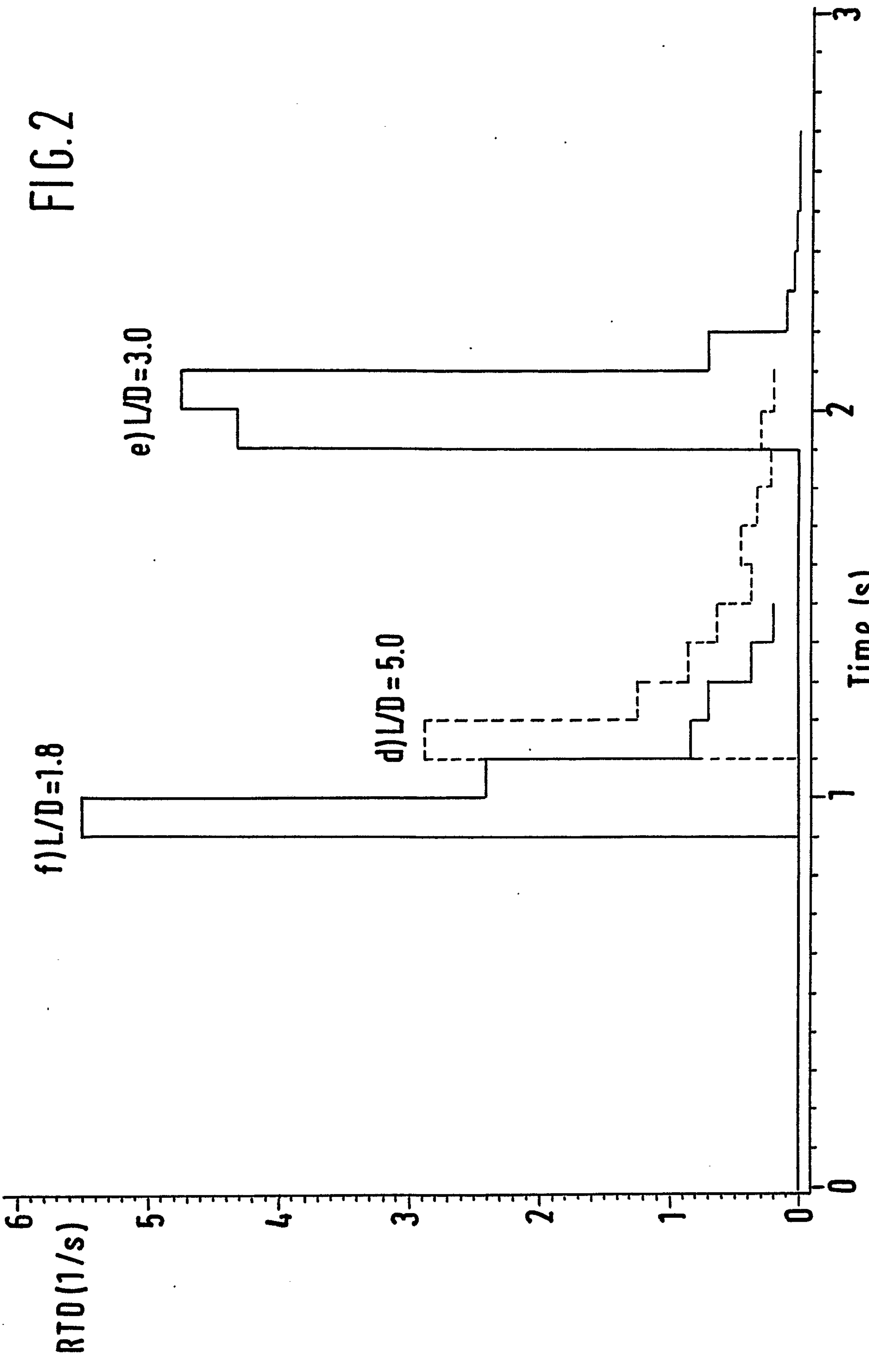


FIG. 2