

(19)



Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number:

0 101 143
A2

(12)

EUROPEAN PATENT APPLICATION

(21) Application number: 83300733.9

(51) Int. Cl.³: **C 10 J 3/26**
C 10 J 3/32

(22) Date of filing: 15.02.83

(30) Priority: 18.08.82 US 409099

(43) Date of publication of application:
22.02.84 Bulletin 84/8

(84) Designated Contracting States:
AT BE CH DE FR GB IT LI LU NL SE

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(54) Conversion of biomass into combustible gas.

(57) A movable grate (50) is mounted on an upright pipe (36) is disposed within and spaced above the bottom of an upright vessel (12, 14) of a gasifier. A layer (54) of loose, high heat resistant, ball-like elements is established on the grate (50). Biomass is continuously charged into the vessel (12, 14) above the grate (50) and combusted so as to form a char-bed of biomass immediately above the layer (54). Combustion-supporting gas is introduced into the char-bed and drawn downwardly through the char-bed, the layer (54) and the grate (50). The gas generated thereby is withdrawn from the vessel (12, 14) below the grate (50) by means of a fan (72). The grate (50) is moved so as to move the individual elements of the layer (54) and effect gravitational filtering of char-coal particles from the char-bed. The char-bed is agitated and combustion-supporting gas is introduced into the char-bed by the pipe (36) and the tubular branches (62, 64, 66).

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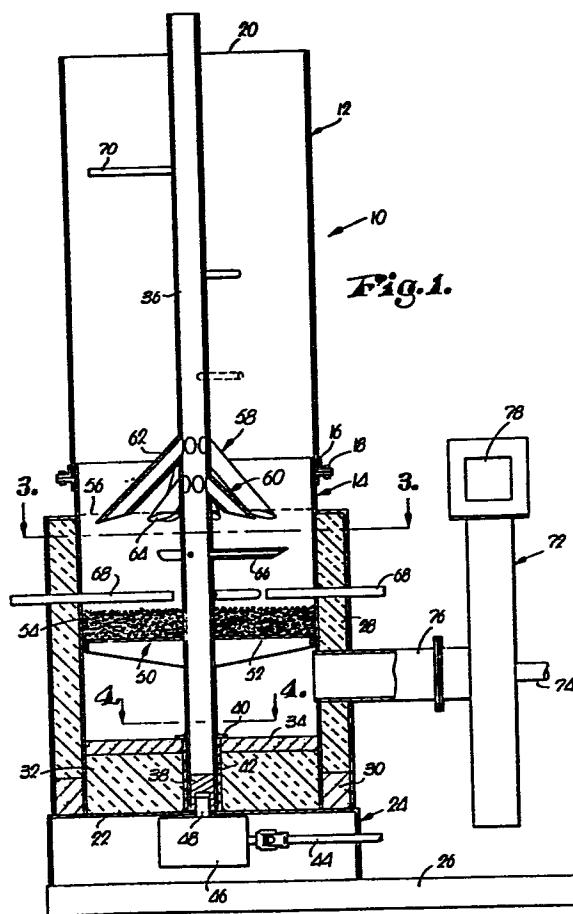


Fig. 1.

CONVERSION OF BIOMASS INTO COMBUSTIBLE GASDESCRIPTION

This invention relates to the conversion of biomass into combustible gas.

5 A gasifier is known for continuous conversion of biomass into a combustible gas and comprising an upright vessel for receiving biomass.

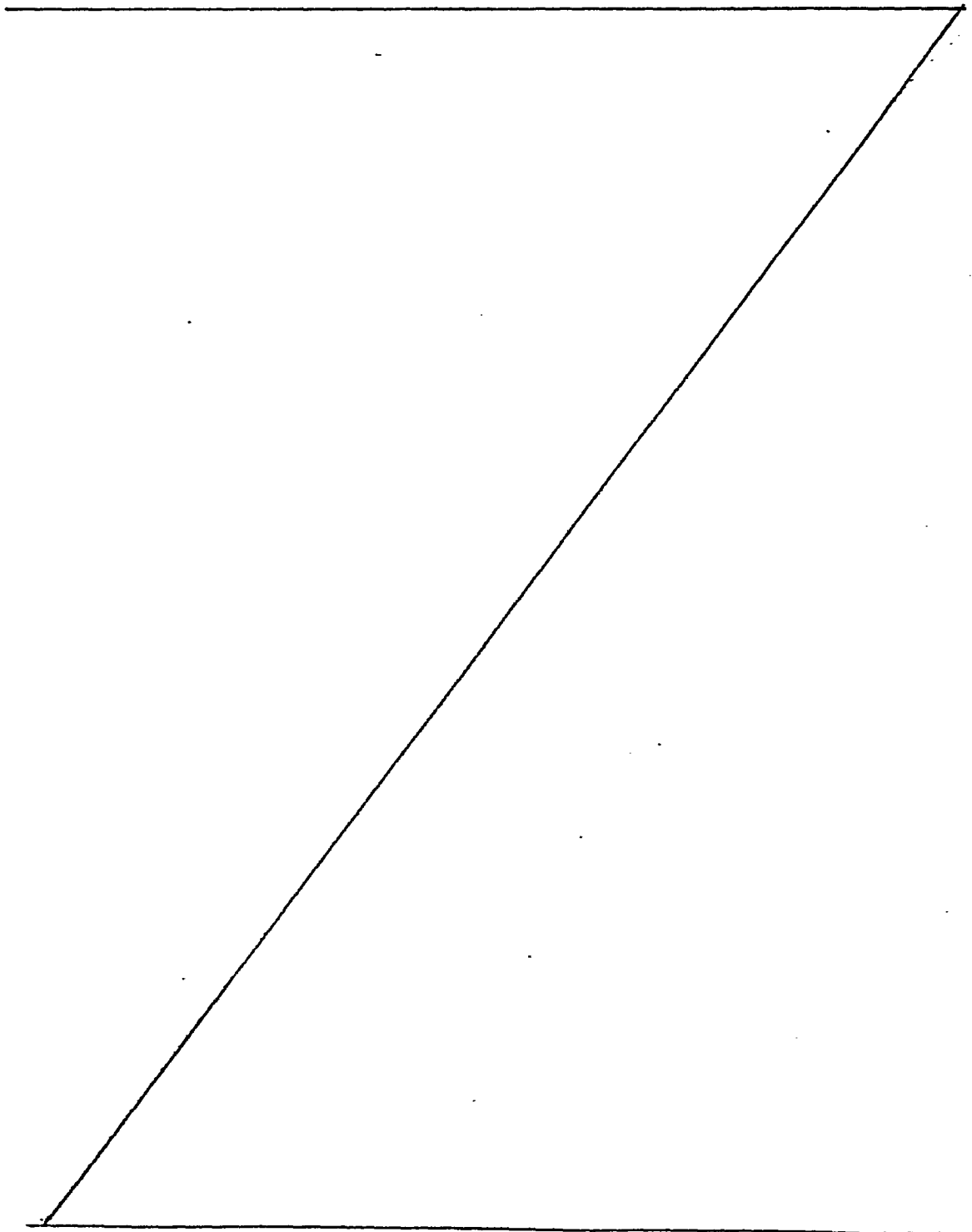
10 One aspect of the invention is characterised in that the gasifier also comprises a movable grate disposed within the vessel and spaced above the bottom thereof, the grate being intended to support a column consisting, in ascending order, of a layer of loose, high heat resistant, discrete, ball-like elements covering the grate, a char-bed of biomass, and newly charged biomass, means for agitating the char-bed and introducing thereinto combustion-supporting gas, and suction means communicating with the vessel
15 below the grate for drawing combustion-supporting gas downwardly through the char-bed, the layer and the grate and continuously withdrawing generated gas from the vessel.

20 Another aspect of the invention is a process of generating gas from the combustion of biomass, characterised by providing a gasifier as above, establishing a layer of loose, high heat resistant, discrete, ball-like elements on the grate, continuously charging the vessel with biomass above the layer, combusting the biomass so as to form a char-bed of biomass immediately
25 above the layer, introducing combustion-supporting gas into the char-bed, drawing the combustion-supporting gas downwardly through the char-bed, the layer and the grate and withdrawing generated gas from the vessel below the grate, moving the grate so as to move the individual elements of the layer and effect
30 gravitational filtering of charcoal particles from the char-bed, and agitating the char-bed.

In the above process, the ball-like elements are joggled and displaced without interruption so as to cause a break-up of the char-bed into extremely hot, partially burned particles and induce

the particles to sift downwardly into the layer of ball-like elements for high temperature, live particle reaction therewith. The amount of ash drawn through the grate along with the gas is generally minimised and the time required the biomass into a usable combustible gas is reduced to a fully acceptable rate,

An embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings.



In the drawings:

Figure 1 is a cross-sectional view of a biomass gasifier made in accordance with our present invention taken on line 1-1 of Fig. 2;

5 Fig. 2 is a top plan view thereof; and

Figs. 3 and 4 are cross-sectional-views taken on line 3-3 and 4-4 respectively of Fig. 1.

For the purpose of biomass gasification, there is provided a gasifier 10 which includes a hollow gas generator having an upper and a lower tubular section 12 and 14 respectively, relatively telescoped and interconnected by a series of flanges 16 coupled together through use of releasable fasteners 18. The section 12 has an open top 20 and the section 14 is closed by an upper plate 22 of a hollow base 24 resting on a pair of beams 26.

15 The section 14 is substantially of double wall construction for receiving outer insulation 28 overlying outer insulating material, such as sand 30, supported by the plate 22. Insulation 32 is also supported by the plate 22 within the section 14, together with sand 34 or the like overlying the insulation 32.

20 The open top 20 of the section 12 is adapted to receive a supply of biomass materials (not shown) for confinement in a column by the section 12, and an elongated, upright (preferably vertical) downdraft air supply pipe 36 in the generator 10 (preferably coaxial therewith) is open to the atmosphere at its uppermost end above the biomass materials in the generator 10. The pipe 36 has a socketed plug 38 resting on the plate 22 and a flange 40 resting on a collar 42 secured to the plate 22 and surrounding the pipe 36 within the insulating materials 32 and 34.

The pipe 36 is rotated by a prime mover (not shown) through a shaft 44 extending into a gear box 46 within the base 24, the output of the gears within the box 46 being a rotatable, polygonal stub 48 extending through the plate 22 and mating with the socket in the plug 38.

A grate 50, in the nature of a circular, plate-like, holding platform, provided with a multitude of openings such as slots 52, surrounds the pipe 36 spaced above the insulation 34 and is rigidly secured to the pipe 36 for rotation therewith, the diameter of the grate 50 being less than the inside diameter of the section 14. A layer 54 of loose, high heat resistant, discrete, ball-like (preferably spherical) elements covers the grate 50. Resting on the layer 54 is a charcoal bed (not shown) of the biomass materials reacting in the section 14, the level 56 of such bed normally reaching no higher than about the upper limits of the insulation 28, depending on the nature of the materials being converted to gas, and many other conditions and circumstances.

Means for directing combustion-supporting air or other fluid from the atmosphere into the charcoal bed includes upper and lower assemblies 58 and 60 of tubular branches respectively, all communicating with and secured to the pipe 36 within the generator 10. The upper assembly 58 includes a top set of such branches 62 and a lower set of branches 64, all extending downwardly and outwardly at an angle from the pipe 36, discharging onto the level 56 or slightly therebelow. Still further, there is provided a row of air discharge branches 66 within the charcoal bed, communicating with and secured to the pipe 36, all

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of the branches 62, 64 and 66 being rotatable with the pipe 36.

5 A plurality of radial rods 68 extending into the generator 10, through the insulation 28 and the walls of the section 14, toward the pipe 36, are disposed above the layer 54 and within the charcoal bed to prevent or retard rotation of such bed by the rotating layer 54. The rods 68 are removable from the outside of the generator 10 to permit lifting and removal of the pipe 36 and its attached parts from the generator 10.

10 A number of stirring elements 70 for the biomass materials in the section 12 are arranged at different heights and are secured to the pipe 36, radiating therefrom for rotation therewith.

15 Suction means, such as a centrifugal exhaust fan 72, having an internal vaned rotor (not shown) provided with an input shaft 74, communicates with the section 14 below the grate 50 by means of inlet 76 of the fan 72 which extends through the walls of the section 14 and through the insulation 28 thereof. The fan 72 has for its purpose (a) drawing fluid into and through the charcoal bed from the branches 62, 64 and 66, (b) pulling the fluid through the char-bed and into the layer 54, (c) drawing air downwardly through the biomass in the section 12, and (d) withdrawing generated gas and entrained ash from within the generator 10.

20 In the event the gas being drawn downwardly through the slots 52 by the fan 72 contains any unburned ash, the ash-entrained gas may be forced from outlet 78 of the fan 72 into a filter, such as a cyclone separator (not shown), before the clean gas is directed by the fan 72 to a point of use and/or prior cooling.

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OPERATION

5 The continuous, gasification process of
converting biomass materials into a combustible,
gaseous fuel through use of the gasifier 10 and
associated equipment above described includes
maintenance of the section 12 substantially full
of such materials by feeding the same through the
open top 20 by any suitable means (not shown). Such
materials include wood chips as a prime example,
but the term "biomass", as hereinused, is intended
to also include sawdust, crop residues, industrial
wastes and virtually all other burnable substances
capable of undergoing chemical reaction above and
within the layer 54 and to release combustible gas
as the result of such reaction. In the method
also, we deem it necessary or somewhat desirable,
for best results, to maintain the materials in the
section 12 somewhat loose and against bridging by use
of the rotating, stirring or agitating elements
70, depending on such factors as the nature, den-
sity, moisture content, ambient humidity conditions
and caking tendency of the biomass materials being
used. This enhances free flow of air through the
materials to further support combustion.

25 The next step is to produce and maintain
a charcoal bed between the layer 54 and the level
56 within the section 14, it being anticipated
that such bed will react at very high temperatures,
at least up to about 2400° F. Manifestly, this is
accomplished by continually supplying the bed, by
use of the slowly rotating pipe 36 and its branches
62, 64 and 66, with an adequate supply of reaction-
supporting fluid such as air from the atmosphere
or by feeding oxygen to the upper end of the pipe

36 in the downdraft, negative pressure system. The fact that the branches 62, 64 and 66 are constantly rotating, helps to accomplish such even fluid dispensing results.

5 The rotating branch 66 keeps the constantly agitated char-bed of biomass loose as it might otherwise tend to cake and reduce the reaction rate. However, best results may not be possible if the bed tends to rotate as a homogeneous mass; therefore, such tendency is overcome by
10 the provision of the retarder rods 68, assuring a constant pulling of the fluid through the continuously rotating dispersal system and providing both accurate and even mixing with the fuel. The
15 reaction is such as to break down the char, cracking the tars and oils and releasing the oxygen and gas content, such gas being constantly pulled through the char-bed by the fan 72.

 Perhaps the most important feature of
20 the continuous generator 10 is the layer 54 and the step in the process which it provides. Gas and char proceed through such conversion kinetics system of our invention consisting of the rotating grate or holding platform 50 on which is provided
25 the high temperature balls of the layer 54. In the layer 54, tars and oils are further cracked and the char is then broken down to a filterable ash. The kinetic movement of the balls provide a very active, random movement, producing a live bed
30 therewithin, and by such movement, the gas and ash are evenly pulled into the gas suction fan 72.

 Notable is the fact that the pipe 36 is not restrained for rotation about an exact vertical axis but that, instead it can and does, to a
35 limited extent of course, undergo some lateral

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movement within the limits of movement (other than rotational) of the grate 50 as confined by the section 14. This, to some possible extent, improves the actions and desired effects of the elements 70 and the branches 62, 64 and 66. But more importantly, the balls of the layer 54 are constantly joggled because of the vibrational effect thereon; and, not to be overlooked is the frictional, rubbing movement of the red hot balls along the inner face of the section 14, causing the balls to tumble, shift and roll about in and out on the grate 50 during rotation of the grate 50 and the layer 54 at a rate, for example, of but one revolution each six minutes. Manufacturing tolerances are not maintained and the inner face of the section 14 is not perfectly cylindrical, all of which causes and enhances the filtering of the charcoal particles into the anti-plugging bed 54 for further reactive results therewithin.

The fan 72 pulls a static pressure to maintain an even gas production rate while providing a positive pressure at the fan exit 78. The pressurized gas then moves through a cyclone system to remove particulates down to approximately 15 microns. The clean gas may then be further filtered, if desired, cooled and placed in industrial use. All movement in the system is synchronized and the gas production may be varied to suit the output desired.

The amount of potash actually pulled from beneath the grate 50 for flow into the inlet 76 is quite minimal (depending, of course, upon the nature of the biomass being used) because of the reactions produced by the use and movement of the balls within the layer 54, the result being a

high quality gas having a heat quantity (BTU) as high as 200 or better.

After long periods of use, we have found no slag or clinker residue above the grate 50 and noted that much of the time most rocks and metals within the biomass have also completely disintegrated the reaction zones.

The nature, size and shape of the generally round balls of the layer 54 may vary although diameters of 1/2" to 2" are quite satisfactory with the slots 52 being, for example, approximately 3/8" x 1" in size or at least small enough not to pass the balls of the layer 54, while at the same time not impede the flow of gas and ash. Stainless steel is suggested as one possibility if obtainable without undue cost, but from an expense standpoint, use of balls having a 90 to 98 percent aluminum content might be preferred. We also contemplate use of balls coated with any heavy, ductile, malleable metal which fuses with difficulty, such as platinum; and the extent to which the platinum does, in fact, dissolve in the process will further enhance the quality of the gas.

In summary, the reaction-supporting fluid pulled downwardly into the open top 20, as well as into pipe 36, flows readily through the materials stirred by the elements 70, and is dispersed evenly throughout the char-bed by the branches 62, 64 and 66 inasmuch as the char-bed is kept loose by the branch 66. Hence, there is no reaction slow-down because of fluid starvation or because of caking or clinkering as the result of the heat.

The action causes break-up of the char-bed into small particles but such break-up is

more the result of the action of the balls on the char-bed. This causes the particles and fines to gravitate from the char-bed and sift or filter into the constantly moving layer 54 wherein further re-
5 action takes place such that the particles disintegrate rather quickly well supported by an adequate supply of the fluid being pulled into the layer 54.

The balls of the layer 54 constantly act frictionally on the lower face of the char-bed to
10 cause the break-up and induce gravitation of the partially burned particles. Also, because the balls are kept in a loose condition, the particles readily sift into the layer 54 and are not only kept in motion, but are further broken up by the
15 continuous movement of the balls within the layer 54.

The ball movement is not limited to the rotation of the layer 54. The particles therewithin are constantly riled also by the fact that ball
20 movement takes place as the periphery of the layer 54 frictionally engages the inner wall of the section 14 during rotation of the layer 54. Still further, inasmuch as the pipe 36 rotates
: unsteadily, the platform 50, and therefore, the
: layer 54, tend to wobble and vibrate. The pipe 36
25 is unrestrained by bearings, sleeves or collars and its fit within the collar 42, as well as the fit of the stub 48 in the plug 38 is loose and sloppy.

All in all then, the balls roll, joggle,
30 vibrate and become otherwise constantly displaced on the platform 50 and within the layer 54 such that a very high degree of distintegration takes place to a point of only a small amount of easily
35 removed, dusty ash passing into the fan 72. The

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result is high speed, substantially complete conversion of a wide variety of biomass into a relatively clean, high quality gas, with the conversion kinetics system, coupled with the downdraft, negative pressure system, successfully contributing to the solution of the heretofore unsolved problems generally existing in prior biomass gasification processes and equipment.

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CLAIMS

1. A gasifier for continuous conversion of biomass into a combustible gas, comprising an upright vessel (12, 14) for receiving biomass, characterised in that the gasifier also comprises a moveable grate (50) disposed within the vessel (12, 14) and spaced above the bottom thereof, the grate (50) being intended to support a column consisting, in ascending order, of a layer (54) of loose, high heat resistant, discrete, ball-like elements covering the grate (50), a char-bed of biomass, and newly charged biomass, means (36, 62, 64, 66) for agitating the char-bed and introducing therein combustion-supporting gas, and suction means (72) communicating (at 76) with the vessel (12, 14) below the grate (50) for drawing combustion-supporting gas downwardly through the char-bed, the layer (54) and the grate (50) and continuously withdrawing generated gas from the vessel (12, 14),

2. A gasifier according to claim 1, wherein the vessel is cylindrical in that the means (36, 62, 64, 66) for agitating the char-bed and introducing therein combustion-supporting gas comprises an upright pipe (36) mounted (at 40, 42) at the bottom of the vessel (12, 14) for rotation within the vessel (12, 14) and having an inlet at its upper-end for introduction of combustion-supporting gas, and branch pipes (62, 64, 66) extending from the upright pipe (36) intermediate its ends for both agitating the char-bed and introducing therein combustion-supporting gas, and in that the grate (50) is circular and is mounted on the upright pipe (36) for rotation therewith below the branch pipes (62, 64, 66)

3. A gasifier according to claim 2, characterised in that stirring elements (70) extend from the upright pipe (36) above the branch pipes (62, 64, 66) and are rotatable with the upright pipe (36) for agitating the newly-charged biomass.

4. A gasifier according to claim 2 or 3, characterised in that stationary elements (68) extend inward from the wall of the vessel (12, 14) towards the upright pipe (36) intermediate the branch pipes (62, 64, 66) and the grate (50) for retarding rotation

of the char-bed.

5. A gasifier according to claim 2, 3 or 4 characterised in that the upright pipe (36) is mounted (at 40, 42) only at its lower end for rotation in the bottom of the vessel (12, 14) and the circular grate (50) has a clearance from the wall of the vessel (12, 14) so that the upright pipe (36) can wobble while rotating.

6. A gasifier according to any preceding claim, characterised in that the vessel (12, 14) is open to atmosphere at its upper end.

7. A process of generating gas from the combustion of biomass, characterised by providing a gasifier (10) according to any preceding claim, establishing a layer (54) of loose, high heat resistant, discrete, ball-like elements on the grate (50), continuously charging the vessel (12, 14) with biomass above the layer (54), combusting the biomass so as to form a char-bed of biomass immediately above the layer (54), introducing combustion-supporting gas into the char-bed, drawing the combustion-supporting gas downwardly through the char-bed, the layer (54) and the grate (50) and withdrawing generated gas from the vessel (12, 14) below the grate (50), moving the grate (50) so as to move the individual elements of the layer (54) and effect gravitational filtering of charcoal particles from the char-bed, and agitating the char-bed.

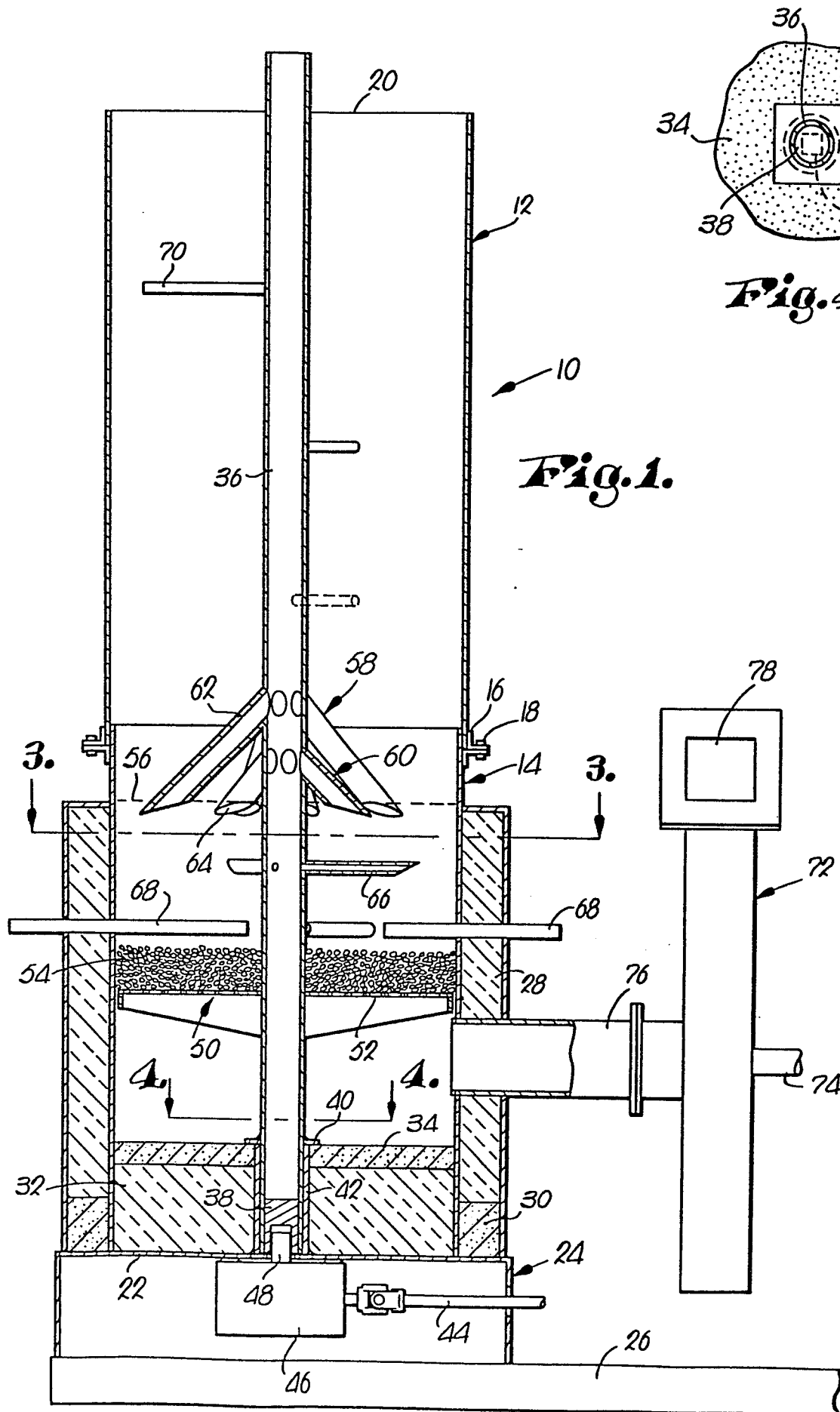


Fig. 1.

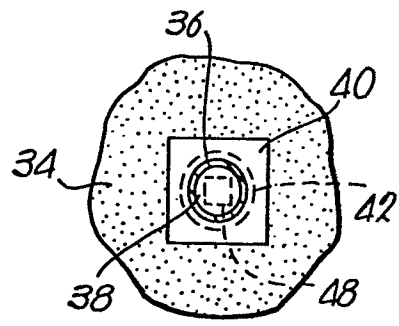
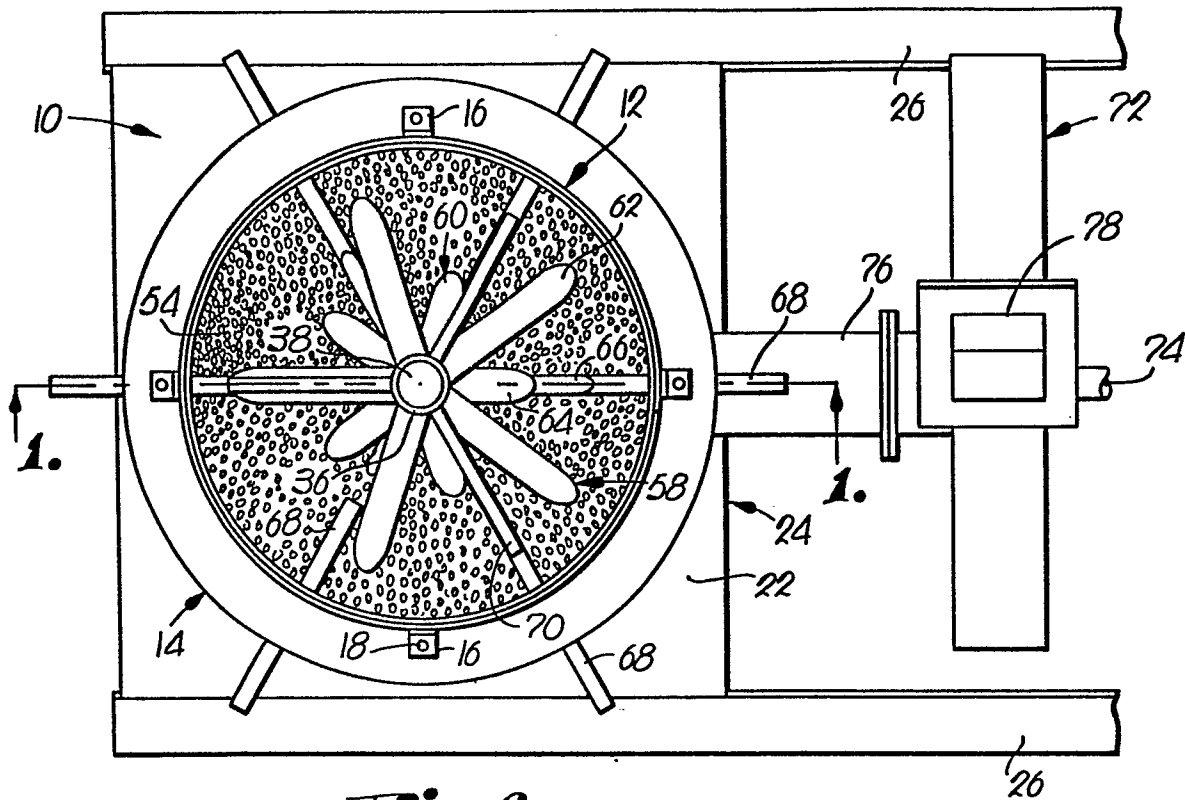
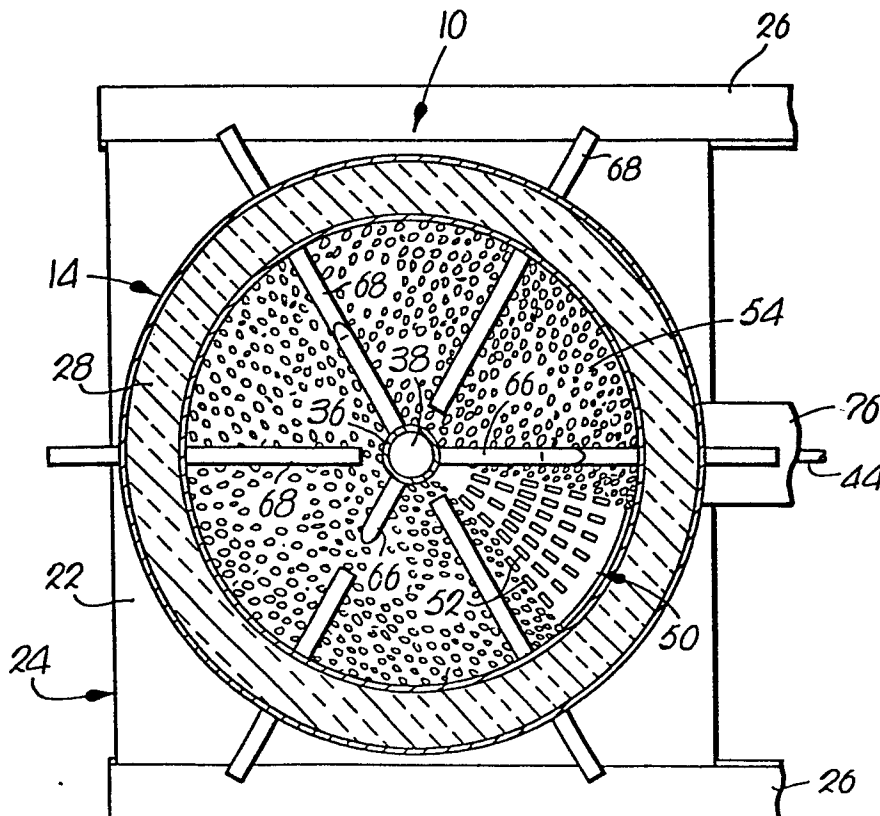


Fig. 4.

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**Fig. 2.****Fig. 3.**