



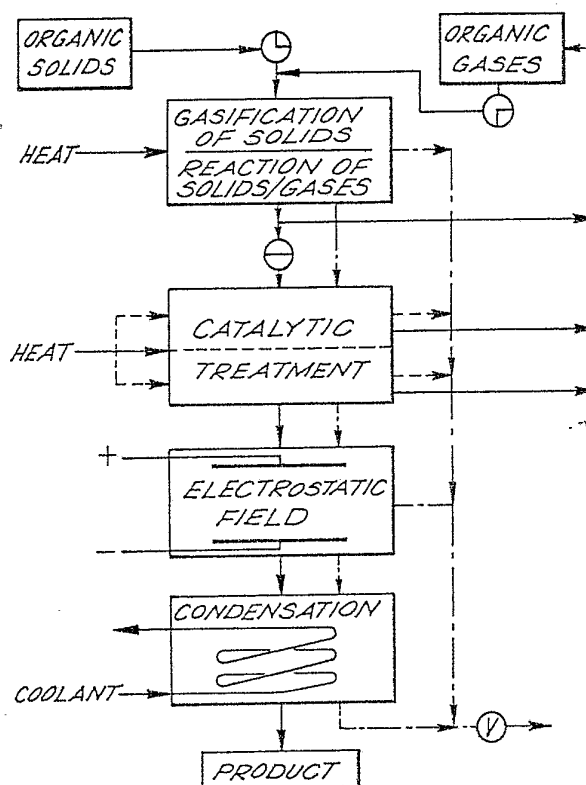
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(54) Title: LIQUID FUEL PRODUCTION AND ENERGY CONVERSION SYSTEMS

(57) Abstract

A process and apparatus for converting organic material, especially organic waste matter, into a liquid composition useful as a fuel, which is suitable for the operation of diesel and other i.c. engines. The apparatus consists of a feedstock charging unit (11) which introduces solid finely-divided organic matter into a sealable first reactor (14), where gasification occurs and an autogenous pressure is built up until a valve (16) is opened and the first gas mixture passes to a first catalytic treatment zone (18) and there to a second catalytic treatment zone (26), the gas product from which is then subjected to a silent electric discharge in an electrostatic energy field unit (29) prior to undergoing reduction to normal pressure and temperature in a condenser (32). The resultant product is a liquid composition. In a preferred embodiment, operation with an initial solid feedstock alternates with operation with a gaseous feedstock (Fig.3b) which produces an additional quantity of liquid product, prior to resumed operation with a further solid feedstock charge.



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1 LIQUID FUEL PRODUCTION AND ENERGY CONVERSION SYSTEMS
DESCRIPTION

5 This invention relates to the production of a liquid composition which is useful as a fuel and is concerned in particular with methods and apparatus for the production of such liquid compositions and their use as fuels, for instance for operating internal combustion engines. The invention is based upon a series of discoveries in relation to the anaerobic
10 thermal decomposition of organic matter, especially waste vegetable matter. Major advantages of the invention include both the disposal of virtually any waste organic matter and also the efficient production of an easily-utilizable fuel and consequently the efficient generation
15 of energy. The process of the invention avoids the production of significant amounts of solid residues or other by-products which would give rise to disposal problems. Moreover, the liquid fuel produced in carrying out the invention and also various intermediate organic
20 gaseous compositions can supply many times the energy required by the process itself, so that the invention can be realised as a total energy system having a substantial positive output, by utilizing a portion of the liquid fuel or a bleed-off or recycle of a proportion of the
25 gases produced in carrying out the process to generate the thermal, electrical and kinetic energy required by the process.

The initial step involved in the process of



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1 the invention is the gasification of organic matter at
elevated temperature while excluding air, so that the
organic matter is first put into a physical form
suitable for gasification and then subjected to anaerobic
5 thermal decomposition. Many known processes in which
vegetable waste is treated have an initial step of this
kind, including the destructive distillation of wood,
which was the main source of methanol or "wood alcohol"
before synthetic methods were developed, based mainly on
10 the catalytic hydrogenation of carbon monoxide under
elevated temperature and pressure. As indicated in
more detail below, the initial step in the process of the
invention involves thermal decomposition of organic
matter under conditions of elevated temperature and
15 elevated pressure, with the exclusion of atmospheric
oxygen.

According to an aspect of this invention, a process
of production of a liquid composition, useful as a fuel,
comprises:

- 20 (a) subjecting a first organic gas mixture to at
least one stage of catalytic treatment at elevated
temperature and elevated pressure so as to cause inter-
action of the components of the first gas mixture and
formation of a second organic gas mixture, and
25 (b) exposing the second gas mixture to an
electrostatic energy field of the silent discharge type,
wherein steps (a) and (b) are each conducted in
the substantial absence of molecular oxygen, step (b) is
conducted at an elevated pressure not greater than the
30 maximum pressure attained in step (a) and step (a) is
conducted at an elevated temperature not less than that
used in step (b). The first gas mixture is preferably
produced by subjecting finely-divided solid organic
matter to decomposition at elevated temperature under
35 autogenous pressure so as to effect substantially complete



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1 gasification of the organic matter; the gasification step
is conducted in the absence of molecular oxygen, like
steps (a) and (b).

In accordance with an important and preferred
5 embodiment of the process of the invention, step (a)

10

comprises a first catalytic treatment of the first gas
mixture in the presence of a catalyst comprising calcium
oxide and alumina and a second catalytic treatment of the
15 resultant product in the presence of a catalyst comprising
calcium oxide, carbon and metallic copper, so as to form
the second gas mixture, whereby the product of the first
treatment has a higher range of number of carbon atoms in
the molecule than the first gas mixture and the second gas
20 mixture has a still higher range of number of carbon atoms.

In accordance with another important feature of the
process of the invention, the process is carried out by a
multiple batch procedure, in which a first charge of solid
organic matter is subjected to fine sub-division, if nece-
25 ssary, and is then subjected to treatment in a reaction
zone, until the gasification step has been completed and
the first gas mixture so formed is then transferred to a
second reaction zone in order to undergo step (a). Any
solid residue from the first charge which remains in the
30 reaction zone can either be removed, for instance after
returning the reaction zone to a lower pressure, or it
can remain, subject to the capacity of the vessel forming
the reaction zone. In either case, a second charge of
solid organic matter is then introduced into the reaction
35 zone and the process is then repeated. In this way,



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1 charges of organic matter can be processed on what is
essentially a continuous basis. The necessity to exclude
oxygen from the apparatus in which the process is carried
out and the importance of the build-up of the autogenous
5 pressure in the gasification step mean that a multiple
batch type of operation, as opposed to a wholly continuous
procedure, has many practical advantages. The invention
includes a further and highly advantageous method of oper-
ation, which avoids the need to remove a solid residue
10 from the reaction zone each time gasification has been
carried out, or at least, when this step has been carried out a number
of times so that the residues occupy the space available. In accor-
dance with this preferred embodiment of the invention, after gasifi-
cation has been completed and while the reaction zone remains at the
15 elevated temperature or is maintained at another elevated temperature
and also while the reaction zone and the residue in it are subject to
an elevated pressure derived from the autogenous pressure of the
gasification step, a combustible organic gas feed is supplied to the
reaction zone and reaction of it with the essentially carbonaceous
20 residue yields a quantity of another gas mixture, which then undergoes
steps (a) and (b), resulting in the production of additional liquid
composition and substantial removal of the residue from the reaction
zone. When operation using this gas feed is completed, a further
batch of organic matter is then introduced into the reaction zone and
25 is subjected to gasification. This especially advantageous embodiment
of the process thus involves the carrying out of these three steps
repeatedly and each gasification operation alternates with an opera-
tion using this gas feed. The gas feed step is essentially an alter-
native way, in comparison with the gasification of organic matter of
30 a comminuted solid form, to produce a first gas mixture, prior to
subjecting it to the one or more catalytic treatments and the electro-
static energy field of steps (a) and (b).

In carrying out the process of the invention, the organic matter
constituting the feedstock can be of virtually any composition of anim-
35 al or vegetable origin. Waste vegetable matter and vegetable products
generally are very suitable for carrying out the inven-



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tion, as they can usually be subjected to fine subdivision without difficulty, in preparation for the gasification step. Also, waste materials would otherwise represent a disposal problem. Coal and other essentially organic carboniferous materials are also suitable starting materials for the process of the invention. It is necessary to be able to introduce the feedstock into a reaction zone, such as a furnace chamber or other heatable enclosure, in the absence of oxygen and the feedstock is therefore most conveniently a material in or capable of being processed to a flowable or pumpable state. Organic vegetable matter such as wood, leaves, grasses, potatoes, root vegetables, straw or the like is preferably ground or chopped to a fine particle size range. Metallic or mineral matter such as stones should be excluded, as well as any animal or vegetable materials which are too hard or coarse to be suitable for fine grinding.

The gasification step is preferably carried out in a reaction zone, for example, an electric furnace chamber, maintained at a temperature in the range from 1000° to 1500°C and, preferably from 1000° to 1200°C . In one form of apparatus suitable for forming the reaction zone, the chamber is preferably lined with or fitted with electrical heating elements embedded in CaO_2 slabs or blocks. The chamber has to be evacuated so as to exclude molecular oxygen. In practice, the entire apparatus is evacuated so that the atmosphere in it during the steps of the process is essentially the mixture of gases produced in the gasification step or the gaseous or liquid products derived from it as the later steps are carried out. The feedstock can be advantageously introduced into the pre-heated chamber, on starting up the process, at a pressure in the range of 2000 to 3000 psi or 125 to 200 atms (approximately $14,000$ to $20,000 \text{ kN/m}^2$). Introduction can be made through an injector of



1 the kind used in a Diesel engine, but, in accordance
with a preferred embodiment of the invention, the
feedstock is introduced in the reaction zone by purpose-
built apparatus which carries out the necessary
5 treatment of the charge of organic material to put it
into a form suitable for the gasification step.
Introduction of the feedstock is continued and gasifica-
tion commences, the gaseous and vapour products forming
the first gas mixture being retained in the furnace
10 chamber until the pressure reaches a predetermined value,
for instance in the range from 500 to 1000 psi and
preferably 700 psi (3500 to 7000 and preferably 5000
kN/m²); this predetermined autogenous pressure should
not be less than 450 psi or 30 atms (3000 kN/m²), and
15 when the selected pressure has been attained, a pressure-
sensitive valve is opened and the gas/vapour mixture
produced is discharged from the furnace. The introduction
of feedstock, its gasification and discharge of the gas/
vapour product at the selected predetermined pressure
20 can proceed indefinitely, when operating according to
a continuous or multiple batch form of the process, as
described in more detail below. It has been found that
the treatment of organic matter under these conditions
leads to its virtually total gasification. The product
25 of this step in the process is a gaseous or vapour-phase
mixture which consists mainly of water vapour and carbon
monoxide with small amounts of carbon dioxide and traces
of ammonia; the actual composition will obviously depend
upon the nature of the organic materials in the charge
30 fed to the reaction zone in order to carry out the
gasification step.

The gas/vapour mixture passes via the pressure-
sensitive valve to a second reactor or, preferably, to
the first of two successive reactors, in which or in each
35 of which catalytic reaction of the components of the



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1 mixture occurs. In a preferred form of the process,
the first gas mixture is fed into a reaction zone in
a reactor maintained at a temperature in the range from
300° to 750°C, preferably at 500°C, and at a pressure in
5 the range from 450 to 900 psi or 30 to 60 atms (3000 to
6000 kN/m²). In any case, the second reaction zone is
operated so that the reaction step carried out in it is
conducted at a pressure which is equal to or below the
maximum autogenous pressure developed in the gasifica-
10 tion step and also at a temperature which is equal to or
below that used in the gasification step. As a general
rule, the temperature and pressure used are below those
used in the gasification step. The catalyst comprises
calcium oxide, CaO, and alumina, Al₂O₃, preferably in
15 the proportion of 50-70% and most preferably 55% of CaO
and 30 - 50% and most preferably 40% of Al₂O₃, by weight,
together with a small amount, say 1 - 5% by weight of
powdered graphite. The catalyst is preferably made by
admixing the selected components in a uniform manner and
20 the mass can then be pressed to form a round billet or
block, having a plurality of passageways bored or other-
wise formed lengthwise in it. Alternatively and
preferably, the catalyst mass is in granular or particulate
form and the reaction chamber is arranged so as to effect
25 maximum contact between the gas mixture and the catalyst.
This also applies naturally to the second and any other
catalytic treatment stage.

Use of solid multiperforate catalyst blocks is
one of a number of ways in which a catalyst component of
30 high surface area can be provided so as to allow the gas/
vapour mixture to pass through and undergo the desired
reaction. The effects of the temperature, pressure and
catalyst on the gas/vapour mixture produce a vapourous
product which appears typically to comprise methyl ether,
35 CH₃OCH₃, and methanol, CH₃OH, derived from hydrogenation



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- 1 and other reactions between the water, CO, CO₂, N₂ and other components and their products of decomposition. The resultant reaction product mixture is then treated, e.g. in a second and similar reactor, where the catalyst
- 5 is of similar shape and construction, but comprises CaO, powdered graphite and finely-divided metallic copper. These catalyst components are preferably present in amounts ranging from 30-50% and preferably 40%, in the case of each of the calcium oxide and the copper, and
- 10 from 15-30% and preferably 20% in the case of the graphite, by weight. The second reactor is preferably operated at a lower temperature than the first, e.g. 250°-350°C and preferably 300°C, while the pressure can be in the same range as in the first catalytic reactor chamber.
- 15 The effect of the second thermal catalytic treatment appears to be to initiate some measure of reaction between the simple organic substances and the nitrogen, so that a much denser vapour product arises. Typically, the product of the first catalytic treatment step contains organic
- 20 compounds having from 1 to 4 carbon atoms in the molecule and the effect of the second catalytic step is the cracking and reformation of these compounds into a range of substances of larger molecular size, typically comprising from 5 to 8 carbon atoms, in conjunction with other, non-
- 25 organic components.

In the next stage in the process, the product is preferably first cooled, typically to 100°C to 200°C and preferably to 150°C, which causes the product to remain substantially in vapour form. The product is then passed

30 into another reaction chamber fitted with elements for the production of an electrostatic energy field, e.g. at 25,000 to 40,000 volts DC and preferably at 30,000 volts DC. The energy field chamber is maintained under pressure at the temperature to which the product has been cooled and,

35 further condensation and possibly nitration of the



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1 components of the product is apparently caused by this
further treatment step. The organic compounds in the
product obtained after the gas mixture has undergone
the energy field step have a range of molecular sizes
5 greater than those in the product subjected to this
treatment. Typically, the organic compounds in the
product are mainly in the range from C_6 to C_{12} in terms
of the numbers of carbon atoms present. Each stage after
the gasification step appears to increase the molecular
10 size of at least the organic components present and this
is responsible for the ultimate formation of a complex
product which is largely organic and which becomes a liquid
when reduced to normal temperature and pressure.

The product is then cooled to ambient
15 temperature or, in general, a temperature in the range
from 10° to 25°C , preferably 20°C and typically comprises
a liquid mixture, the main components of which are methyl
ether, which may constitute 55% to 75% and usually about
60% by volume of the product, and methanol, which may
20 constitute most of the remainder. The actual make-up of
the product depends upon the material used, as will be
readily understood. Conversion of the feedstock to a
liquid mixture in this way can readily be achieved with
a conversion efficiency of 95% or even higher. The
25 product is eminently suitable for use as a fuel for
internal combustion engines operating either by car-
buration, fuel injection or on the Diesel principle.
Operation of the overall process can be conducted so as
to use 15 kW of energy, for instance, and it has been
30 found that by using the most preferred conditions at each
stage enough fuel is made to generate 60 kW of energy.
Thus, the product of the process can yield enough fuel
to operate the entire system and also an excess amount
of fuel capable of generating as much as 3 times the amount
35 of energy as is required by the apparatus in which the



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- 1 process is conducted.

The process also consists in an apparatus for producing a liquid composition useful as a fuel from organic matter and comprises:

- 5 (a) a first reaction zone capable of being evacuated and heated, having a sealable inlet for the introduction of a charge of organic matter, heating of which causes gasification and the formation of a first gas mixture under the autogenous pressure of such
- 10 gasification step, and a sealable outlet for effecting discharge of the first gas mixture from the first reaction zone,
- (b) a second reaction zone capable of being heated and arranged to contain at least one catalyst substance
- 15 for effecting reaction of the components of the first gas mixture to form a second gas mixture, the second reaction zone having an inlet for introduction of the first gas mixture connected to the sealable outlet from the first reaction zone and an outlet for effecting discharge of
- 20 the second gas mixture from the second reaction zone,
- (c) a third reaction zone including means for generating an electrostatic energy field of the silent discharge type and having an inlet for introduction of the second gas mixture connected to the outlet from
- 25 the second reaction zone and an outlet for effecting discharge of a third gas mixture produced by the action of the energy field upon the second gas mixture as it passes through the third reaction zone,
- (d) a condenser connected to the outlet from
- 30 the third reaction zone and serving to effect reduction of the temperature of the third gas mixture to produce the desired liquid composition and
- (e) means for connecting the first, second and
- 35 vacuum.



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1 In order that the invention may be fully
understood, a producer plant comprising a first
embodiment of apparatus for carrying out the process,
a flow-sheet of the main steps of the process and an
5 apparatus comprising a second and preferred embodiment
of apparatus according to the invention are described
below, by way of illustration in the non-limitative
accompanying drawings, in which:

Fig. 1 shows an apparatus according to a first
10 embodiment of the invention, in diagrammatic view;

Fig. 2 shows in flow-sheet form the steps of
the process of the invention;

Fig. 3 comprises Figs. 3a, 3b and 3c taken
together and showing an apparatus according to a further
15 and preferred embodiment of the apparatus of the inven-
tion, in sectional view, where

Fig. 3a shows a feedstock preparation and
introduction unit, which also serves to seal the first
reaction zone when a feedstock charge has been formed and
20 introduced;

Fig. 3b shows a two-purpose unit comprising a
thermal decomposition chamber containing the first reaction
zone and serving to effect gasification under autogenous
pressure of the feedstock charge supplied to it, the
25 thermal decomposition chamber being located for heat
economy purposes within a first catalytic treatment
chamber containing a first catalyst and forming a second
reaction zone; and

Fig. 3c shows a two-purpose unit comprising a
30 first part including a second catalytic treatment chamber
containing a second catalyst and forming a third reaction
zone, arranged to receive the gas product from the first
catalytic treatment and subject it to another catalytic
treatment step and a second part including a fourth
35 reaction zone equipped with electrodes for generating an



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1 electrostatic energy field, both parts of the unit being
traversed by a heat exhaust pipe for maintenance of the
desired temperature and also being connected in series
to the outlet from the first catalytic treatment chamber,
5 together with a coolant-supplied condenser connected
to the outlet from the fourth reaction zone and itself
having an outlet for directing the liquid composition
to a product storage arrangement.

Referring to Fig. 1, organic feedstock in the
10 form of raw vegetation, coal, wood or other primarily
vegetable and/or animal matter is first prepared by
collecting it in a feedstock storage arrangement 10 and
grinding it to a fine pulp or other finely sub-divided
form in a grinder or pulping unit 11. This feedstock is
15 fed via line 12 to an injector 13, by means of which it
is then injected into an evacuated chamber 14. The
injection step can be effected at high pressure or,
alternatively, at a lower pressure, e.g. atmospheric,
so that the chamber 14 is then closed after a suitable
20 quantity has been introduced. In the chamber 14, the
charge is totally gasified at high temperature, as
indicated above, the temperature being maintained by,
for instance, electric heating elements, such as are
indicated diagrammatically at 15. In the chamber 14,
25 the gasification produces a gaseous product containing
carbon monoxide and water vapour, together with small
amounts of carbon dioxide, ammonia and free nitrogen.
The injection of the feedstock via the injector 13 or
otherwise continues until the gasification produces a
30 pressure within the chamber 14 preferably in the range
from 30-40 atms ($3000-4000 \text{ kN/m}^2$). At a predetermined
pressure typically above 30 atms, (3000 kN/m^2), e.g.
35 35 atms (350 kN/m^2), the gaseous products are then
vented through a valve 16 into a line 17 leading to a
further evacuated chamber 18 containing a catalyst 19A



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1 and heated by elements indicated diagrammatically at 20.

The catalyst 19A comprises a mixture of 55% calcium oxide and 40% alumina thoroughly mixed together, with 5% powdered graphite, to provide a uniform mix which
5 is then pressed into a round billet or it is formed into a gas-permeable mass of particles. The catalyst 19A is heated to a temperature of 500°C. As the gases enter the chamber 18 and the pressure increases to that of the gasification chamber 14, i.e. 30-40 atmospheres, the
10 gaseous products are forced through the catalyst 19A where a reaction occurs producing vapours containing $\text{CH}_3\text{-O-CH}_3$ plus $\text{CH}_3\text{-OH}$ and free nitrogen. This product is then passed through a line 23 and a cooling unit 24A via another pressure-sensitive valve 25 to a further catalyst chamber
15 26 constructed in the same way as the chamber 18. The catalyst 19B is similar to the catalyst 19A, but comprises 40% of calcium oxide, 20% of powdered graphite and 40% of finely-divided copper. The catalyst 19B is also heated to 350°C and the chamber 26 is also maintained under a
20 pressure of 30 atmospheres.

The reactions occurring at this stage link the free nitrogen molecules to the $\text{CH}_3\text{-O-CH}_3$ or $\text{CH}_3\text{-OH}$ molecules, producing a much denser vapour, which is apparently slightly nitrated. This vapour is then sub-
25 jected to cooling to 150°C in a second cooling unit 24B and it is then passed via a valve 27 and a line 28 to a chamber 29 in which elements 30 establish a high-intensity electrostatic field of a silent discharge nature. From the chamber 29, the product is passed via a line 31 to a
30 condenser 32 in which it is cooled to around 20°C, producing a solution comprising $\text{CH}_3\text{-O-CH}_3 + \text{CH}_3\text{-OH}$. This is then fed via line 33 to an outlet 33A, leading to a storage tank for instance, or alternatively the line 33 passes the solution via a control valve 34 to a nitration
35 vessel 35, where the product is further nitrated, to



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- 1 produce a final product of nitrated $\text{CH}_3\text{-O-CH}_3 + \text{CH}_3\text{-OH}$,
which is then returned via line 33B to the outlet 33A.

The whole process is dependent upon a total
pressure throughout of not less than 30 atmospheres,
5 which is produced initially by the gasification step in
the chamber 14. Air must be excluded at all times,
in order to exclude molecular oxygen and therefore to
prevent contamination of the final product and oxidation
of the catalysts 19A and 19B. It is also essential for
10 the catalyst compositions to be correctly maintained, as
alteration of the constituents and/or their percentages
can affect the final product.

The precise nature of the reactions which take
place as the feedstock undergoes the successive steps of
15 the form of the process which takes place in the apparatus
illustrated in Fig. 1 has not been determined fully.
However, it is believed that the general reaction sequence
is as described below, where the typical values of the
main operating conditions are also set out. The
20 temperatures indicated for the respective steps are
typical within the respective ranges usable. As indicated
at the beginning, the main constituent of the organic
matter can be considered to consist of a number of organic
compounds having the general formula $\text{C}_6\text{-H}_{12}\text{-O}_6$. The
25 gasification step converts these to the above-mentioned
first gas mixture, comprising water vapour, carbon monoxide,
carbon dioxide, ammonia and nitrogen, possibly with small
amounts of other materials. Treatment of the first gas
mixture in the first catalytic stage converts the bulk of
30 the carbon-containing components of the mixture to
dimethyl ketone and methanol and further conversion of this
kind, i.e. formation of compounds having longer carbon
chains or at least higher numbers of carbonations, is
effected in the second catalytic treatment step. Some
35 element of nitration of the mixture by virtue of the nitro-



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1 gen-containing compounds included in it appears to occur as the vapours
are subjected to the electrostatic field. This is taken further if
there is a subsequent chemical nitrogen step in the overall process,
though this is not usually included. The liquid fuel product can be
5 regarded as an optionally nitrated solution of dimethyl ether and
methanol, the main nitrated product presumably being methyl nitrate
derived from nitration of the methanol content of the product produced
after completion of the successive catalytic treatment stages.

In a preferred embodiment of the process of the invention, step
10 (a) is carried out in the presence of one or more catalysts capable,
under the conditions of temperature and pressure employed, of conver-
ting organic compounds having a given range of numbers of carbon atoms
therein to organic compounds having a higher range of numbers of carbon
atoms. Most preferably, step (a) comprises a first catalytic treatment
15 of the first gas mixture in the presence of a catalyst comprising cal-
cium oxide and alumina and a second catalytic treatment of the result-
ant product in the presence of a catalyst comprising calcium oxide,
carbon and metallic copper, so as to form the second gas mixture,
whereby the product of the first treatment has a higher range of number
20 of carbon atoms in the molecule than the first gas mixture and the
second gas mixture has a still higher range of number of carbon atoms.

Fig. 2 illustrates in diagrammatic flow-sheet form several
preferred embodiments of the process and apparatus of the invention. A
sequence of reactors are involved, which respectively carry out, with
25 heat and under pressure, either the gasification of a solid feedstock
or the reaction of solid carbonaceous residues from previous gasifica-
tion steps with gaseous organic feedstock, then one or more catalytic
treatments, as just described, followed by exposure of the gaseous
product to the electrostatic energy field and, finally, condensation
30 or some equivalent step returning the reaction product to ambient
pressure and temperature and thereby forming it into a liquid compo-
sition. The first step involves the introduction either of solid
feedstock or gaseous feedstock. Valves are indicated diagrammatically,
as also is the input of heat, whilst the arrowed chain-dotted lines
35 leading to the vacuum take-off valve V in the lower right corner indi-



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- 1 cate in schematic form that the reactors can be connected to a source of vacuum for oxygen removal purposes, either in series or in parallel or in any combination thereof. The arrowed solid lines extending from the outputs from the first two reactors indicate
- 5 different forms of the total energy systems included in this invention, wherein part or all of one of the gas products of the process is recycled to produce the heat energy and, by conversion, other forms of energy needed to maintain operation of the process and system.



General Reaction Sequence - Use of apparatus shown
in Fig. 1

<u>Step</u>	<u>Probable Chemical Composition</u>	<u>Temperature Relative to Next Step</u>	<u>Range in °C</u>	<u>Relative to Previous Step</u>	<u>Pressure Psig</u>	<u>Range kN/m²</u>
(a) <u>Gasification</u>	$C_6H_{12}O_6 \rightarrow CO, CO_2, H_2O, NH_3, N_2$	Not less than	1200-1500	Not more than	450-1000	3000-7000
(b) <u>First Catalytic Cracking and Reforming and formation</u>	$N_2 + (CH_3)_2O + CH_3OH + C_1-C_4$ compounds	Not less than	300 - 750	Not more than	450-900	3000-6300
(c) <u>Second Catalytic Cracking and Reforming and formation</u>	$N_2 + (CH_3)_2O + CH_3OH + NO_2 + C_5-C_8$	Not less than	250-350	Not more than	450-900	3000-6300
(d) <u>Electrostatic Field Effect</u>	As in (c) + $C_6 - C_{12}$	Not less than	100-200	Not more than	450-900	3000-6300
(e) <u>Condensation</u>	As in (d)	-	10-25	product is liquid		

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1 Another aspect of the invention resides in the
apparatus, typified by that illustrated in Fig. 1 of the
drawing, for carrying out the process of the invention
and consisting essentially of a gasification chamber
5 having means for injecting or otherwise introducing
ground organic feedstock matter and for releasing the
products of gasification of the organic matter when a
predetermined pressure has been attained, a catalytic
treatment chamber or, preferably, two (or even more)
10 successive catalytic treatment chambers, containing
catalysts of the kind indicated above, an electrostatic
field unit for subjecting the product to the energy
field, leading to a condenser which delivers a liquid
product to a receptacle which either serves as a storage
15 receptacle for the product or can introduce the product
into a reactor for effecting an optional final nitration
step of the process, prior to delivery of the product
to the liquid storage receptacle.

 Steps (a) to (c) in the reaction sequence are
20 preferably conducted at the same elevated pressure, not
less than 450 psig (3000 kN/m²), achieved as a result of
the gasification step (a) and maintained by setting the
valves, e.g. the valves 16, 25 and 27 (Fig. 1) to open at
the selected elevated pressure. The exclusion of atmos-
25 pheric oxygen from the apparatus is very important and,
although in theory this could be achieved by sweeping out
the apparatus with an inert gas such as nitrogen before
starting up the reaction sequence, it has been found that
operation proceeds much more satisfactorily, as indicated
30 above, if the apparatus is first evacuated and the atmos-
phere produced in each chamber in turn is that evolved
in the gasification and later steps.

 A preferred embodiment of the process of the
invention, involving no nitration step, and a preferred
35 embodiment of an apparatus for carrying it out are described

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1 below in conjunction with the three components, Figs. 3a
to 3c, making up Fig. 3 of the drawings. Fig. 3a shows
a unit for receiving, comminuting and introducing charges
of feedstock into a thermal converter containing a first
5 reaction zone formed within a gasification chamber; Fig.
3b shows on the same scale the thermal converter with the
gasification chamber and, surrounding the latter, a
second reaction zone constituting a first catalytic treat-
ment chamber; Fig. 3c shows on the same scale a reactor
10 tower comprising, in its lower part, a third reaction zone
constituting a second catalytic treatment chamber and, in its
upper part, a fourth reaction zone constituting an electro-
static energy field unit and, connected to the upper outlet
from the energy field unit, a condenser unit.

15 Referring to Fig. 3a, the charging unit, shown
generally at 50, consists of a hopper 51 for receiving
any desired material, generally of an organic nature, i.e.
essentially from the vegetable and/or animal kingdoms,
for operating the process. The hopper 51 has its lower
20 opening 52 arranged above the inlet end 58A of a feeder
screw 53, consisting of a shaft 54 carrying a feeding
and comminuting screw blade 55 and located in an elongated
tubular housing 56. The feeder screw 53 operates to
comminute any material received from the hopper 51 and
25 advance it along the housing 56. The feeder screw 53 is
operated by a power unit, such as an electric motor 57
attached to the inlet end 58A of the screw shaft 54 where
it projects beyond the inlet end of the housing 56. The
outlet or discharge end 58B of the housing 56 is attached
30 to a feedstock charging container 59, in the form of a
chamber or housing, into which the housing 56 discharges
via an opening 60. Above the opening 60, the container
has a vertically-movable vapour-lock piston 61 attached by
a rod 62 to a hydraulic piston 63 which is vertically
35 reciprocable inside a cylinder unit 64. The hydraulic

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1 piston/cylinder assembly 63,64 includes connections 65
to a source of hydraulic fluid (not shown) for actuating
the piston 63 and therefore the vapour-lock piston 61.
The feedstock charging container 59 is the cylinder of the
5 piston/cylinder assembly 61,59, the purpose of which is
to receive ground feedstock supplied by the feeder screw
53 via the housing 56 and compress it within the lower
part of the container 59. This lower part communicates
via an opening 66 with a feedstock injector tube 67 and
10 also via a diametrically-opposite opening 68 with a
feedstock injection piston 69. The latter is housed in a
cylinder 70 under the action of the pressure of hydraulic
fluid, derived from the same or a different source of
pressurized hydraulic fluid (not shown) via connections 71.
15 The preparation and introduction of a feedstock charge by
operation of the unit 50 shown in Fig. 3a is carried out
by putting organic material into the hopper 51 with
the motor 57 driving the feeder screw 53, so as to convey
the material in ground form into the chamber of the
20 container 59, where actuation of the piston/cylinder unit
63,64 causes the piston 61 to compress the charge in the
lower part of the container 59 and also seal the latter
from communication with the exterior, e.g. via the feeder
screw housing 56 and the hopper 51. Actuation of the piston/
25 cylinder unit 69,70 causes the injection piston 69 to
advance across the container 59 and force the compressed
comminuted charge into the injector tube 67 and so into
the first reaction zone, as described below. The charging
unit 50 is operated until a sufficient number of charges
30 have been introduced into the first reaction zone to form
the first feedstock batch required to carry out the process
of the invention.

Referring to Fig. 3b, the thermal converter unit,
shown generally at 75, contains two of the reaction zones
35 used in carrying out the process. One receives the charge

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1 from the unit 50 and subjects it to the gasification
step, while the other receives the first gas mixture
so produced and subjects it to the first catalytic
treatment step. The gasification is carried out in
5 a reaction zone within a decomposition chamber 76 and the
catalytic treatment is carried out in a reaction zone
within a first catalytic treatment chamber 77. The
decomposition chamber 76 and the catalytic treatment
chamber 77 are both constituted by hollow steel cylinders,
10 that forming the chamber 76 preferably being heavy-gauge
stainless steel, and the chamber 76 is located concentri-
cally, within the chamber 77, and also so that there is a
substantial annular space between the two chambers, in
which the catalyst is located as described in more detail
15 below, and also spaces at each end. The decomposition
chamber 76 contains an aperture 78 in its wall 79 near
its upper end, through which the injector tube 67 (Fig.3a)
passes, so as to discharge the organic material into the
first reaction zone within the chamber 76. Stainless
20 steel plates 80 and 81 respectively form the upper and
lower ends of the chamber 76 and a central aperture 82
is made in the upper plate 80 and another central
aperture 83 is made in the lower plate 81. An outlet
tube 84 passes through the aperture 82 and terminates in
25 a solenoid-actuated or other remotely-controllable pressure
vent valve 85. Inside the upper part of the chamber 76,
a steel disc 86 is mounted on spacer bars 87 so as to
shield the end of the outlet tube 84. An inlet tube 88
passes through the aperture 83 and supports a conical
30 feed gas shield funnel 89 having an annular supporting
flange 90 around its upper rim. The inlet tube 88 extends
downwardly out of the lower end of the unit 75 and
connects via a gas feed control valve 91 with a gas feed
source (not shown). An open-topped cylindrical graphite
35 decomposition chamber or pot 92 is mounted within the

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1 chamber 76 so as to be concentric with it. The pot 92
has an integral cylindrical wall 93 and a thick base 94
and rests with the lower surface 95 of its base 94 on
the flange 90. A circular steel disc 96 can be welded
5 to the flange 90 and have a diameter equal to that of the
pot 92, so that the latter is supported over the whole of
the area of its base 94. Within the circular area of the
base 94 inside the funnel flange 90, the pot base 94 and,
if provided, the disc 96 have a number of through-going
10 gas vents 97, via which the gas inlet tube 88 communi-
cates with the inside of the pot 92, by way of the funnel
89 and the vent holes 97 in the pot base 94. Within the
pot 92, a perforated plate 98 for supporting a mass 99
of particulate catalyst is provided, preferably by being
15 force-fitted or otherwise supported, and on its underside
dependent spacer bars 100 support a circular feed gas
deflector plate 101, which is located above the area of the
pot base 94 containing the vent holes 97. Thus, gas from
the source (not shown) can be passed via the tube 88
20 under the control of the valve 91 to the funnel 90 and then
via the vent holes 97 to the inside of the graphite pot
92, where it is directed outwardly by the deflector plate
101 and can then pass via the perforated plate 98 through-
out the mass of particulate or otherwise gas-permeable
25 material supported on the plate 98 after the gasification
of a charge of organic matter, as described below.

The chamber 76, the graphite pot 92 in it and the
charge of material, 99A, from which the mass 99 of residue
is formed, are raised to and maintained at the requisite
30 temperature by indirect heating. Any form of heating can
be used and Fig. 3b shows the use of indirect gas-fired
heating. The end plates 80 and 81 of the chamber 76
contain correspondingly arranged series of apertures 102
and these match up with each other and also with similar
35 series of apertures, described below, made in the end

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1 plates, also described below, of the catalytic treatment
chamber 77. The apertures 102 are also aligned with
throughgoing holes 103 in the thickness of the wall 93 of
the pot 92. Steel flame tubes 104 pass through the
5 treatment chamber 77 from a burner chamber 105 at the
lower end of the converter unit 75, as described below,
to a heat expansion chamber 106 at its upper end, also as
described below. These flame tubes 104 thus pass also
completely through the chamber 76 by way of the ring of
10 apertures 102 in the lower end plate 81, the holes 103 in
the pot 92 and the ring of apertures 102 in the upper
end plate 80. Gasification is carried out with the gas
feed control valve 91 closed, with the vent valve 85 in
the outlet tube 84 from the chamber 76 also closed and
15 with the charging unit 50 closed by the piston 69 sealing
the injection tube 67 and/or the piston 61 in the vapour-
lock position and sealing the chamber 59 from the tubular
housing 56 and thus the hopper 51. The heat necessary for
effecting gasification is derived from a gas burner unit
20 107 located in the burner chamber 105, described in more
detail below, and passes through the ring of flame tubes 104.
Since the decomposition chamber 76 and the other reaction
zones of the apparatus are effectively free of oxygen during
operation of the process, the high temperature in the
25 chamber 76 and the solid construction of the pot 92 cause
little if any decomposition of the graphite structure.
This also applies to the preferred alternative stage in
which an organic gas is fed into the hot chamber 76 after
conclusion of the gasification step, in order to remove
30 the finely-divided solid residues represented by the mass
99 and produce additional quantities of gas mixture for
processing in the later steps into further liquid compo-
sition. Although the bulk of the mass 99 is carbon and is
thus essentially the same elemental material as the pot 92,
35 it is the mass 99, which is predominantly removed by

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1 reacting with the gas and forming more liquid composition because of its finely-divided character and other physical attributes.

5 The catalytic treatment chamber 77 consists of a cylindrical steel tube 108 closed at each end by circular plates 109 (upper) and 110 (lower). Each of the plates 109, 110 contains a circular array of apertures 111 (upper plate 109) and 112 (lower plate 110) for receiving the flame tubes 104, which pass through the apertures 111 in the upper
10 plate 109 and project into the heat expansion chamber 106 and, at their lower ends, the flame tubes 104 are welded to the plate 110 at the apertures 112. Another aperture 113 in the centre of the upper plate 109 accommodates the actuating rod 114 of the vent valve 85, under the control of an
15 electrical actuator 115, while an aperture 116 is provided in the centre of the lower plate 110 to allow passage of the gas inlet tube 88, from outside the convertor unit 75 to the interior of the chamber 76. The tube 108 is wholly encased in a heavy thermal insulation jacket 117
20 and a further circular insulation slab 118, having apertures 119 for the flame tubes 104 and an aperture 120 for the rod 114, is applied over the upper plate 109. Near the upper end of the chamber 77, an aperture 121 is aligned with the aperture 78 in the chamber 76 to allow the in-
25 jector tube 67 of the charging unit 50 to pass through the insulation jacket 117 and the tube 108 and across the annular space 122 between the chambers 76 and 77 and into the decomposition chamber 76. At the bottom of the chamber 76, it is supported inside the chamber 77 by mounting struts
30 123, which also support permeable means, such as an annular mesh grid 124 upon which the catalyst mass 125 is carried. The lower plate 110 is not provided with an insulation slab like the slab 118, because a separate cylindrical housing 126, comprising a drum-like wall 127 and a circular base
35 plate 128 is mounted under the lower plate 110 and forms

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1 the burner chamber 105. A tubular insulation jacket 129
surrounds the wall 127 of the burner chamber 105 and
thermal insulation units 130 lag the inlet tube 88 where
it is located between the base plate 128 and the lower
5 plate 110, in the housing 126, and between the lower plate
110 and the lower plate 81. Within the burner chamber
1-5, the annular gas burner unit is located, being supported
for instance upon the base plate 128, and is connected
to a source of gas (not shown) by a gas feed tube 130
10 connected to a combustion air inlet branch 131 containing
a gas inlet nozzle 132. At the top of the catalyst
chamber 122, the flame tubes 104 are surrounded by
insulation blocks 133 where they pass to the heat expansion
chamber 106 and this is a steel drum-like housing 134 of
15 the same general circular cross-section as the chamber 77
and it is surrounded on all sides by a heavy insulation
jacket 135 except at an aperture 136 in the side of the
housing 134 which communicates with an outlet flue 137 also
surrounded with thermal insulation 138. At the bottom
20 end of the chamber 77, below the grid 124, a gas transfer
tube 139 passes from an aperture 140 in the tubular wall
108 of the chamber and through an aperture 141 in the
insulation jacket 117, to the bottom end of the reactor
tower shown in Fig. 3C, as described below. The outlet
25 flue 137 from the heat expansion chamber 106 is connected
to the top of the reactor tower of Fig. 3C, as will appear
from the more detailed description below. Means for
monitoring the pressure and temperature in the various
reactor zones of the apparatus are provided together with
30 electrical circuitry for operation of the vent valve
actuator, 115 and operation of the hydraulic piston/
cylinder assemblies of Fig. 3a, but these components have
not been shown in order to ensure that Figs. 3a, 3b and
3C show the parts described in detail with sufficient
35 clarity.

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1 Referring to Fig. 3c, the reactor tower,
shown generally at 150, contains two of the reaction
zones used in carrying out this embodiment of the process
of the invention. One is the second catalytic
5 treatment chamber 151, forming the lower part of the
tower 150, and the other is the electrostatic energy
field unit 152, forming the upper part of the tower 150.
Fig. 3c also shows the final unit in the apparatus of
this embodiment, namely the condenser 153.

10 The reactor tower 150 consists of a superposed
pair of similar cylindrical housings made of sheet steel,
the lower housing 154 comprising a tubular structure with
a lower end plate 155 and an apertured upper end plate
156 and the cylindrical housing 154 is surrounded by a
15 tubular thermal insulating jacket 157 and a circular
insulating slab 158 covers the underside of the end plate
155. An aperture 159 in the housing 154 adjacent the
end plate 155 and a mating aperture 159A in the jacket
157 allow the gas transfer tube 139 (Fig. 3b) to be
20 connected from the bottom of the first catalytic treatment
chamber 77 to the bottom of the second catalytic treatment
chamber 151. Above the aperture 159, a perforated support
plate 160 is mounted across the catalyst chamber 151 and a
mass of catalyst particles, shown at 161, is supported on
25 the plate 160 and substantially fills the reaction zone
formed by the annular space within the housing 134 surround-
ing the outlet flue 137 from the heat expansion chamber 106
at the upper end of the thermal converter unit 75 (Fig. 3b).
This outlet flue 137 is in the form of an elongated pipe
30 of substantial internal cross-section, which extends
horizontally from the chamber 106 through a short distance
and then passes vertically downwards through the reactor
tower 150 and terminates in a lower outlet 162, which forms
the vent from the burner chamber 105 via the flame tubes 104
35 and the chamber 106. This arrangement utilizes the heat in

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1 the exhaust gases to raise the temperature within the catalyst chamber 151 and the electrostatic field unit 152, as explained in detail below. The outlet 162 can be vented to the atmosphere.

5 Above the chamber 151 containing the catalyst 161 for effecting the second catalytic treatment of the product of the gasification step effected in the chamber 76, the electrostatic field effect unit 152 is located. It consists of the housing 152, having a perforated lower
10 end plate 163 which allows the gas product leaving the chamber 151 to pass into the housing 152 and a similar apertured upper end plate 164. The cylindrical housing 152 is thermally insulated by means of an exterior jacket 165 and, further, an electrically insulating layer 166
15 covers the exterior of the length of the flue 137 which passes through the housing 152 from the upper end plate 164 to the lower end plate 163. An upper outlet chamber 167, consisting of a drum-shaped housing 168 having a circular upper end plate 169 and an apertured lower end
20 plate 170 matching the end plate 164 of the housing of the field effect unit 152, is located at the top of the reactor tower 150. Thermal insulation in the form of a jacket 171 covers the outer surfaces of the housing 168 and abuts the insulation 138 surrounding the outlet flue
25 137 where it forms an elbow between the horizontal exit portion from the expansion chamber 106 and the top of its vertical portion passing down through the unit 152 and then the catalytic treatment chamber 151. The housing 168 includes a lateral aperture 172 forming the entry to an
30 outlet duct 173 which passes through another aperture 174 in the jacket 171 and serves to convey the gaseous mixture forming the product leaving the unit 152, so as to convey such product to the condenser 153.

In order to generate the electrostatic field
35 required to effect the gas mixture leaving the second

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1 catalytic treatment chamber 151 via the apertures
in the end plates 156,163 as it passes through the unit
152 and is then discharged to the outlet chamber 167
via the apertures in the end plates 164,170 and proceeds
5 to the condenser 153 via the outlet duct 173, an open-
ended tubular positive electrode plate 175 is mounted
upon the exterior of the outlet flue 137 within the unit
152, being located upon the insulating layer 166 and a
corresponding open-ended tubular negative electrode
10 plate 176 surrounding and concentrically-spaced from the
positive electrode plate 175 is mounted upon the interior
surface of the housing 152A of the field unit 152. The
negative electrode plate 176 can extend throughout the
height of the unit 152 from the end plate 163 at the bottom
15 to that, 164, at the top, but the positive electrode
plate 175 is advantageously disposed so that it is spaced
at the bottom and top from the respective end plate 163,
164, by means of lower and upper spark insulators 177,178.
The negative potential input to the unit 152 can be provi-
20 ded in any desired way, such as by means of a negative
connecting lead 179 attached to the plate 176 inside the
unit 152 and to a mains connecting terminal 180 located
in a suitably insulated manner on the exterior of the
jacket 165. The positive connection to the electrode
25 plate 175 extends from the upper end of the latter and
passes out of the unit 152 via an insulating grommet 181
located in the end plate 170 and another such grommet 182
located in an aperture in the upper end plate 169 of the
housing 168, the connection itself being indicated at
30 183. In practice, it connects the electrode plate 175
with a positive terminal 184 located in an insulated
manner on the exterior of the insulating jacket 171.
The positive and negative terminals 184, 180 are connected
to a source of direct current voltage (not shown) capable
35 of providing current at a voltage in the range, preferably,

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1 from 25,000 to 40,000 volts and most preferably of
30,000 volts. The annular space 185 located between
the concentric and mutually-facing electrodes 175, 176
constitutes the means by which the gaseous product
5 leaving the chamber 151 reaches the outlet chamber 167
and passes to the condenser 153 and, as the product
is subjected to the electrostatic field produced by the
potential difference across this space 185, a further
stage of chemical modification takes place.

10 The condenser 153 consists of a long tubular
housing 186 having upper and lower end plates 187, 188 and
upper and lower connections 189, 190 for discharging and
receiving coolant, e.g. water at room temperature, from
a coolant source (not shown). The upper discharge
15 connection 189 preferably includes a coolant control
valve 191. The coolant passes through coolant passageways
192 in the condenser 153 and the gas product arriving at
the top of the condenser 153 via the duct 173 condenses
on the surfaces of these passageways 192 and undergoes
20 liquification and the product is reduced to normal
temperature and pressure. At the foot of the condenser
153, a fluid take-off line 193 is provided and incorporates
a pressure valve 194, together with a branch connection 195,
including a control valve 196, which is coupled to a
25 vacuum source (not shown).

In order to carry out the process according to the
present invention in the apparatus described above in
relation to Fig. 3 (Figs. 3a to 3c together), the preferred
mode of operation is as follows:

30 OPERATION WITH ORGANIC SOLIDS

Feedstock in the form of organic solids of any
origin, preferably having a moisture content up to 65%
down to 0.01% by weight, is placed in the hopper 51 of the
charging unit 50, up to the required level, and is then
35 reduced in particle size by the comminuting action of the

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1 revolving feeder screw 53 and carried by it through the
housing 56 to the feedstock charging container 59.
Once the charging chamber 59 is full, the vapour-lock
piston 61 compresses the feedstock into a form suitable
5 for entry into the injector tube 67, where it is
injected into the graphite pot 92 in the decomposition
chamber 76 by means of the injection piston 69. This
system acts as an effective air and gas-tight seal;
alternative means for introducing charges of feedstock
10 can be employed if so desired.

Once the decomposition chamber 76 has been
loaded with sufficient feedstock, in the form of the
charge 99A, and is sealed by the forward movement of the
injection piston 69, the whole system is then evacuated
15 to a reduced pressure of 1 to 2 mb (0.1 to 0.2 kN/m^2),
for instance 0.13 kN/m^2 or approximately 1 mm of mercury,
in order to remove atmospheric gases and thus molecular
oxygen from the apparatus, which is then sealed. This is
done by closing the communication between the chamber 76
20 and the exterior via the housing 67 by means of either or
both of the pistons 61 and 69, opening the valve 85,
closing the pressure valve 194 and coupling the vacuum
source (not shown) to the branch connection 195, with the
valve 196 open; after the desired evacuation of the series
25 of reaction zones has been carried out in this way, the
apparatus is sealed by closing the valve 196. The vent
valve 85 is also closed, so as to close the decomposition
chamber 76. Heat is then generated by means of the gas
burner unit 107 and the decomposition chamber 76 and thus
30 the graphite pot 92 and the charge 99A are raised to a
temperature of 1000° to 1500°C by means of the heat
passing through the flame tubes 104.

As the temperature of the pot 92 is raised,
the feedstock 99A is decomposed, creating an autogenous
35 and increasing gas pressure within the decomposition

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- 1 chamber 76, due to the expansion of the feedstock matter,
as it is changed from the solid state to liquid materials
and gases. This continues until the whole mass 99A of
the feedstock charge is converted to gaseous products,
5 i.e. the first gas mixture described above, and the
predominantly carbon residue 99.

At a predetermined pressure, for instance in the
range from 60-100 psig, i.e. $420-700 \text{ kN/m}^2$, the gaseous
products react to form carbon monoxide, hydrogen, traces
10 of ammonia and traces of carbon dioxide, together with
traces of superheated water vapour and nitrogen. As the
temperature and pressure increase, the gaseous products
react further and produce carbon monoxide, hydrogen,
methane and traces of other hydrocarbon gases and also
15 traces of free nitrogen.

At a pressure of 100 psi (675 kN/m^2), the
electrically-operated vapour vent valve 85 at the top of
the decomposition chamber 76 is opened and allows passage
of the gaseous products into the first catalyst chamber
20 77 which is maintained at a temperature of $600^{\circ}-800^{\circ}\text{C}$ by
the heat generated in the decomposition chamber 76 and
transmitted through the walls 108, 109, 110 and also
directly from the burner chamber 105 via the lower plate
110. The gaseous product is forced through the bed 99A
25 of catalytic compound granules where the gaseous product
is converted to a mixture of methane and hydrocarbon
vapours with a substantial removal of oxygen. From here,
the mixture of gas and hydrocarbon vapours is transferred
through the vapour transfer tube 139 to the base of the
30 reactor tower 150.

Once in the reaction tower 150, the gas and
vapour mixture is forced up through the further bed 161
of catalyst compound which is maintained at a temperature
of $200^{\circ}-400^{\circ}\text{C}$ by the heat supplied from the exhaust tube
35 or outlet flue 137. On ascending through the bed 161 of

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1 catalyst compound, further reactions are promoted,
converting substantially the whole of the gas and vapour
mixture to hydrocarbon vapours in the C_5 to C_{10} range.
The gas mixture is then passed through the electrostatic
5 force field generated by the potential difference of
25,000 to 40,000 volts DC across the electrodes 175,176.
In this unit, the energy levels of the constituents of
the gas mixture appear to be momentarily raised above the
ground state, causing partial decomposition of the
10 molecules in the lower carbon number range. As the energy
levels return to the ground state, any unsaturated hydro-
carbon chains are saturated and the smaller molecular
fragments add on to the larger chains, forming a mixture
of fully saturated hydrocarbon chains in the range C_8 - C_{12} .
15 On passing through the electrostatic force
field in the unit 152, the product is then transferred
through the outlet duct 173 to the condenser unit 153,
where the product is condensed to a liquid hydrocarbon
containing various fractions, typically in the range from
20 C_8 - C_{12} . The product proves to be a comparable alternative
fuel to that of fossil fuel originated fractions. When
the gasification step has been completed and the product
has undergone the catalytic treatments, exposure to the
electrostatic energy field and condensation, the plant
25 may be shut down for removal of the largely carbon-
containing residue in the housing of the decomposition
chamber 70. The process may then be repeated. It is
also possible to put a further feedstock charge into the
chamber 76 and repeat the process until the pot 92 is
30 filled with the carbon-based residue and so has to be
emptied or otherwise treated.

OPERATION WITH GAS FEEDSTOCK

The plant may also be used to convert natural
gas to hydrocarbon liquid by the use of an alternating
35 feedstock input programme in the following way.

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1 As the liquid product is drawn off from the
condenser 153 and the pressure is again reduced in the
decomposition chamber 76, the charging unit 50 is not
operated and is kept closed so that there is no communica-
5 tion through the housing 56 from the chamber 76 to the
atmosphere. A charge of natural gas is then introduced
into the still-hot chamber 76 through the gas feed
source input system, by opening the gas control valve
91. The gas then passes up through the inlet tube 88 and
10 via the funnel 89 to the feed gas vents 97 in the base 94
of the graphite pot 92, it is distributed by the feed gas
vent shield 101 and passes through the perforated grate or
plate 98 and so percolates through the bed or mass 99 of
residue carbon left by the solids feedstock, which is still
15 at a temperature of 1000° - 1500° C. This is continued,
with the vent valve 85 closed, until a pressure of 60 -
100 psi ($400 - 675 \text{ kN/m}^2$) is achieved in the chamber 76.
The gas reacts with the residual carbon and dissociates the
methane present. The gas supply is turned off by closing
20 the valve 91 and the vapour vent valve 85 is then operated
at approximately 100 psi (675 kN/m^2), so allowing the
products of reaction of the residue with the gas at elevated
temperature and pressure in the effective absence of
molecular oxygen to form and then pass into the catalyst
25 chamber 77, where reactions occur promoting the formation
of long-chain hydrocarbon molecules and the removal of
trace elements such as oxygen. On passing from the
catalyst 77, the catalyst chamber 151 and the electrostatic
force field in the unit 152, essentially the same reactions
30 are promoted as occur when the gasification step is
carried out. Condensation of the product again produces
a compound liquid as before. In this alternative phase
of operation however, the residual carbon which is left
in the decomposition chamber 76 during the operation
35 with solid feedstock is substantially entirely removed by

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1 reaction with the gas feedstock, leaving only a minor
amoung of residue in the pot 92, which is essentially
mineral in nature and consists of the oxides of any
metals present in the original solid feedstock together
5 with any other traces of compounds which are resistant
to either gasification or the alternative carbon/natural
gas reaction phase. Operation with alternative solid
and gaseous feedstock ensures substantially continuous
operation of the apparatus to produce a combustible
10 liquid product. The plant will gradually accumulate
some amount of permanent residue, which can be withdrawn
at intervals, for instance by opening up the chamber 77
at the top and then the chamber 76 and extracting the
residue from the plate 98, for instance by suction; an
15 alternative way to remove any residue is to introduce
a suction line into the pot 92 via the injector tube 67,

In any operation of apparatus according to the
invention or in carrying out any form of the process
of the invention, to make the product of the invention,
20 a number of important points should be observed:

1. Once the first charge of solid feedstock has entered
the decomposition chamber 76 and before heat is applied,
the whole system is evacuated e.g. via the line 33 (Fig.1)
or via the vacuum take-off 195 (Fig. 3c), so that all
25 atmospheric gases are removed and the plant is reduced
to a pressure of 1 mm Hg (1-2 mb). If this were not
done, the reactions described would not occur and there
would be a danger of coating the catalyst 125 in the
chamber 77 with tar, resulting in excess pressure being
30 maintained in parts of the system. Therefore, safety
devices (not shown) are preferably installed to prevent
operation of the initial start-up cycle unless the
pressure is at a desired starting pressure, such as 1 mm
Hg (1-2 mb).

35 2. The vapour vent valve 85 located in the top of the

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1 decomposition chamber 76 is advantageously coupled to
a pressure sensing circuit and this is pre-set to
operate within a given pressure range, i.e. to open at
100 psi and to close at 15 psi (to open at 700 and
5 close at 100 kN/m². This prevents the formation of tar,
which would otherwise be carried over and deposited on
the catalyst 125. On reaching a temperature of 800°C
and a pressure of 20 psi, (about 140 kN/m²), any formed
would decompose to hydrocarbon gases of much smaller
10 molecular size.

3. Advantageously, the feedstock injection is operated
on a cyclic basis, so as to allow one charge at a time
of predetermined mass to enter the chamber 76; with
such an arrangement, a further charge can only enter
15 when the pressure in the chamber 76 has fallen, say,
to 15 psi (100 kN/m²), or below. If the plant is
operated as a dual process plant with natural gas feed,
then the preferred cycle of operation is to use one
charge of solids and then one of gas, one of solids, one
20 of gas and so on. An input of solids and gas together
cannot be employed, as gasification would not then take
place as desired; advantageously, this is prevented
by an electronic interlock circuit, which ensures that
the charging unit 50 and the gas control valve 91 cannot
25 be opened at the same time.

On an initial cold start, the whole system must
be evacuated as described to prevent entry of atmospheric
gases. However, once the process is in operation,
either with all solids or with solids and gas alternately,
30 the system will then generate continuously without the
need for further evacuation, as the only gases present
throughout the system will be those which are purposely
produced on injection and gasification.

Reactivation of the catalysts can be achieved,
35 when required, by passing hydrogen through the system

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- 1 by means of the gas feed line 88. This produces water
vapour and carbon dioxide which are then vented through
the fluid take-off point 193 and the valve 194.
Reactivation is required at approximate intervals of 20-30
5 hours, dependent upon the feedstock; however reactivation
can be automatically indicated when it is required,
by appropriate sensing circuits contained in the main
control system.

- The invention has great versatility and can be
10 embodied in forms of apparatus of widely differing kinds.
For example, in rural areas where farming methods yield
large amounts of waste organic matter and where liquid
fuel normally has to be brought in from distribution
centres by tanker, it is possible to construct the
15 apparatus according to the invention as a mobile organic
matter converting plant. The various components of the
apparatus, such as shown in the embodiment of Fig. 1 or
that of Figs. 3a to 3c, can be mounted upon one or more
truck bodies and brought to rural sites at intervals.
20 The provision of one or more liquid fuel storage tanks
and possibly a storage and grinding centre for organic
waste matter enables the truck-mounted plant to be
operated, either with connection to a local electricity
supply or, if more convenient, the mobile plant can itself
25 include a generator. As soon as the plant is ready for
operation, multiple-batch gasification is commenced.
If a piped or bottled gas supply is also available, the
plant can operate with alternate solid and gas feed, until
the accumulated waste organic matter has all been consumed
30 and converted into liquid fuel which is left in the local
storage tanks, which can feed the fuel as required to
vehicles or fixed units, including heater units for
greenhouses and other buildings. Thus, regular visits
to the area by the mobile plant ensure that adequate
35 supplies of fuel are continuously available and, moreover,

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- 1 that the problem of the disposal of organic waste matter produced in other farming operations is also solved.

Another form of operation would involve a fixed centralized conversion plant which can serve as a
5 collecting and processing centre for waste matter for a large area. Those using the system can, in effect, exchange their unwanted organic waste materials for supplies of liquid fuel made from such material on a continuous multiple-batch alternating-feedstock principle,
10 such as is described in conjunction with Figs. 2 and 3a to 3c.

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1 CLAIMS:

1. A process of production of a liquid composition, useful as a fuel, which comprises:

5 (a) subjecting a first organic gas mixture to at least one stage of catalytic treatment at elevated temperature and elevated pressure so as to cause interaction of the components of the first gas mixture and formation of a second organic gas mixture, and

10 (b) exposing the second gas mixture to an electrostatic energy field of the silent discharge type,

wherein steps (a) and (b) are each conducted in the substantial absence of molecular oxygen, step (b) is conducted at an elevated pressure not greater than the maximum pressure attained in step (a) and step (a) is
15 conducted at an elevated temperature not less than that used in step (b).

2. A process according to claim 1, wherein the first gas mixture is produced by subjecting finely-divided solid organic matter to decomposition at elevated temperature
20 under autogenous pressure, so as to effect substantially complete gasification of the organic matter, and such gasification step is carried out in the substantial absence of molecular oxygen and at an elevated temperature not less than that used in step (a).

25 3. A process according to claim 1 or 2, wherein step (a) is carried out in the presence of one or more catalysts capable, under the conditions of temperature and pressure employed, of converting organic compounds having a given range of numbers of carbon atoms therein to organic com-
30 pounds having a higher range of numbers of carbon atoms.

4. A process according to any of claims 1 to 3, wherein step (a) comprises a first catalytic treatment of the first gas mixture in the presence of a catalyst comprising calcium oxide and alumina and a second catalytic
35 treatment of the resultant product in the presence of a

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1 catalyst comprising calcium oxide, carbon and metallic
copper, so as to form the second gas mixture, whereby
the product of the first treatment has a higher range of
number of carbon atoms in the molecule than the first
5 gas mixture and the second gas mixture has a still higher
range of number of carbon atoms.

5. A process according to claim 4, wherein the first
catalyst comprises, by weight, 50% - 70% of CaO and 30% -
50% of Al_2O_3 , together with from 1% to 5% of graphite,
10 and the second catalyst comprises, by weight, 30% - 50%
of CaO, 30% - 50% of copper and 15% - 30% of graphite.

6. A process according to claim 5, wherein the
first catalyst contains, by weight, 55% of CaO, 40% of
 Al_2O_3 and 5% of graphite and the second catalyst contains,
15 by weight, 40% of CaO, 40% of copper and 20% of graphite.

7. A process according to any preceding claim,
wherein each catalyst is provided in the form of a gas-
permeable particulate mass.

8. A process according to claim 2 or any of claims
20 3 to 7 as dependent thereon, wherein operation is effected
by a multiple batch procedure, in which a first charge of
solid organic matter is subjected to fine sub-division, if
necessary, and is then subjected to treatment in a reaction
zone until the gasification step has been completed and
25 the first gas mixture so formed is then transferred to a
second reaction zone in order to undergo step (a).

9. A process according to claim 8, wherein after
the first charge has been gasified, a second charge is
then introduced and gasified, with or without removal of
30 the residue left by gasification of the first charge.

10. A process according to claim 8 or 9, wherein,
after the gasification step has been completed and while
the reaction zone remains at the elevated temperature or
is maintained at another elevated temperature and also
35 while the reaction zone and the residue in it are subject

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1 to an elevated pressure derived from the autogenous
pressure of the gasification step, a combustible organic
gas feed is supplied to the reaction zone and reaction of
it with the essentially carbonaceous residue yields a
5 quantity of another gas mixture, which then undergoes
steps (a) and (b), resulting in the production of
additional liquid composition and substantial removal
of the residue from the reaction zone.

11. A process according to claim 10, wherein solid
10 feedstock charges are employed alternately with gaseous
feedstock charges, any non-gasifiable residue which
forms being removed.

12. A process according to any of claims 8 to 11,
wherein the gasification step is carried out by subject-
15 ing the or each charge to a temperature in the range from
 1000°C to 1500°C and the autogeneous pressure is raised
to a value in the range from 3500 to 7000 KN/m^2 prior
to releasing the first gas mixture to undergo catalytic
treatment.

20 13. A process according to claim 12, wherein the
temperature is in the range from 1000°C to 1200°C and the
autogenous pressure is 5000 KN/m^2 .

14. A process according to any preceding claim,
in which the or each catalytic treatment step is carried
25 out at a temperature in the range from 300°C to 750°C
and at a pressure in the range from 3000 to 6000 KN/m^2 .

15. A process according to any preceding claim,
wherein step (b) is carried out by subjecting the second
gas mixture to an electrostatic energy field generated
30 at 25,000 to 40,000 volts D.C., prior to cooling and
condensing the resultant product to form the desired
liquid composition.

16. An apparatus for producing a liquid composition
useful as a fuel from organic matter, which comprises:

35 (a) a first reaction zone capable of being

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1 evacuated and heated, having a sealable inlet for the
introduction of a charge of organic matter, heating of
which causes gasification and the formation of a first
gas mixture under the autogenous pressure of such gasi-
5 fication step, and a sealable outlet for effecting
discharge of the first gas mixture from the first
reaction zone,

(b) a second reaction zone capable of being
heated and arranged to contain at least one catalyst
10 substance for effecting reaction of the components of
the first gas mixture to form a second gas mixture, the
second reaction zone having an inlet for introduction of
the first gas mixture connected to the sealable outlet
from the first reaction zone and an outlet for effecting
15 discharge of the second gas mixture from the second
reaction zone,

(c) a third reaction zone including means for
generating an electrostatic energy field of the silent
discharge type and having an inlet for introduction
20 of the second gas mixture connected to the outlet from
the second reaction zone and an outlet for effecting
discharge of a third gas mixture produced by the action
of the energy field upon the second gas mixture as it
passes through the third reaction zone,

25 (d) a condenser connected to the outlet from
the third reaction zone and serving to effect reduction
of the temperature of the third gas mixture to produce
the desired liquid composition, and

(e) means for connecting the first, second and
30 third reaction zones and the condenser to a source of
vacuum.

17. An apparatus according to claim 16, wherein
the second reaction zone comprises a first catalytic
treatment zone for receiving the first gas mixture and
35 subjecting it to a first catalytic thermal conversion

1 to produce a modified gas mixture and a second catalytic
treatment zone for receiving the modified gas mixture and
subjecting it to a second catalytic thermal conversion to
produce from it the second gas mixture prior to discharg-
5 ing it via the outlet from the second reaction zone to the
third reaction zone.

18. An apparatus according to claim 16 or 17, wherein
the first reaction zone is provided with a closable inlet
for introducing into the first reaction zone one or more
10 charges of organic matter to be gasified, an outlet
including a pressure-release valve operable at a pre-
determined autogenous pressure to discharge the first gas
mixture from the first reaction zone and means for heat-
ing the contents of the first reaction zone in order to
15 subject the one or more charges of organic matter to
gasification.

19. An apparatus according to claim 17 or 18, wherein
the first reaction zone is located inside the first cata-
lytic treatment zone, so that the latter is heated by the
20 heat discharged from the first reaction zone and also by
the heat of the first gas mixture discharged therefrom.

20. An apparatus according to any of claims 16 to 19,
wherein the third reaction zone and the second reaction
zone comprising the second catalytic treatment zone form a
25 reactor tower which is traversed by the second gas mixture
leaving the first catalytic treatment zone.

21. An apparatus according to claim 20, wherein a
source of burnable gas forms the means for heating the
first reaction zone and the heat is directed through a
30 plurality of tubes which pass through the first reaction
zone from a lower burner chamber to an upper heat expan-
sion chamber and an outlet flue from the latter traverses
and thus indirectly heats the third reaction zone in which
the electrostatic field operates and then the second
35 catalytic treatment chamber, an outlet for discharging the

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1 fourth gas mixture connecting the third reaction zone to
the condenser.

22. An apparatus according to any of claims 16 to 21,
in which a charging unit for the introduction of organic
5 matter is connected to the sealable inlet to the first reac-
tion zone and such unit consists of a chamber for receiving
organic matter in comminuted form, a reciprocable piston
for compressing such matter and sealing the chamber from
communication with the atmosphere and an injection piston
10 operable to direct compressed comminuted matter from the
chamber to the inlet to the first reaction zone.

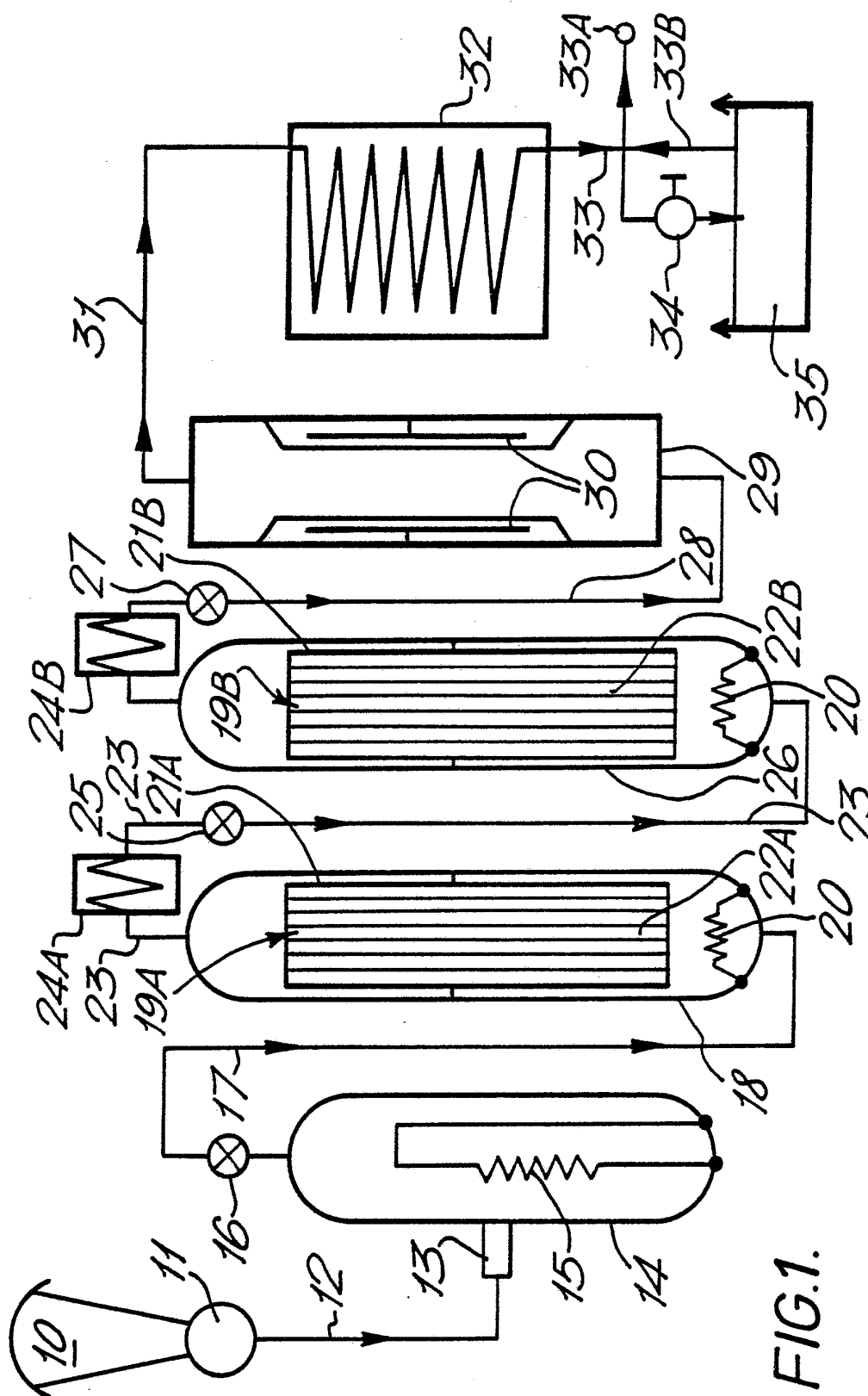
23. An apparatus according to any of claims 16 to 22,
in which a connection to a source of vacuum is provided,
for connecting the reaction zones to such vacuum source
15 prior to the introduction of organic matter, so as to allow
gasification of the organic matter to occur in the substan-
tial exclusion of molecular oxygen.

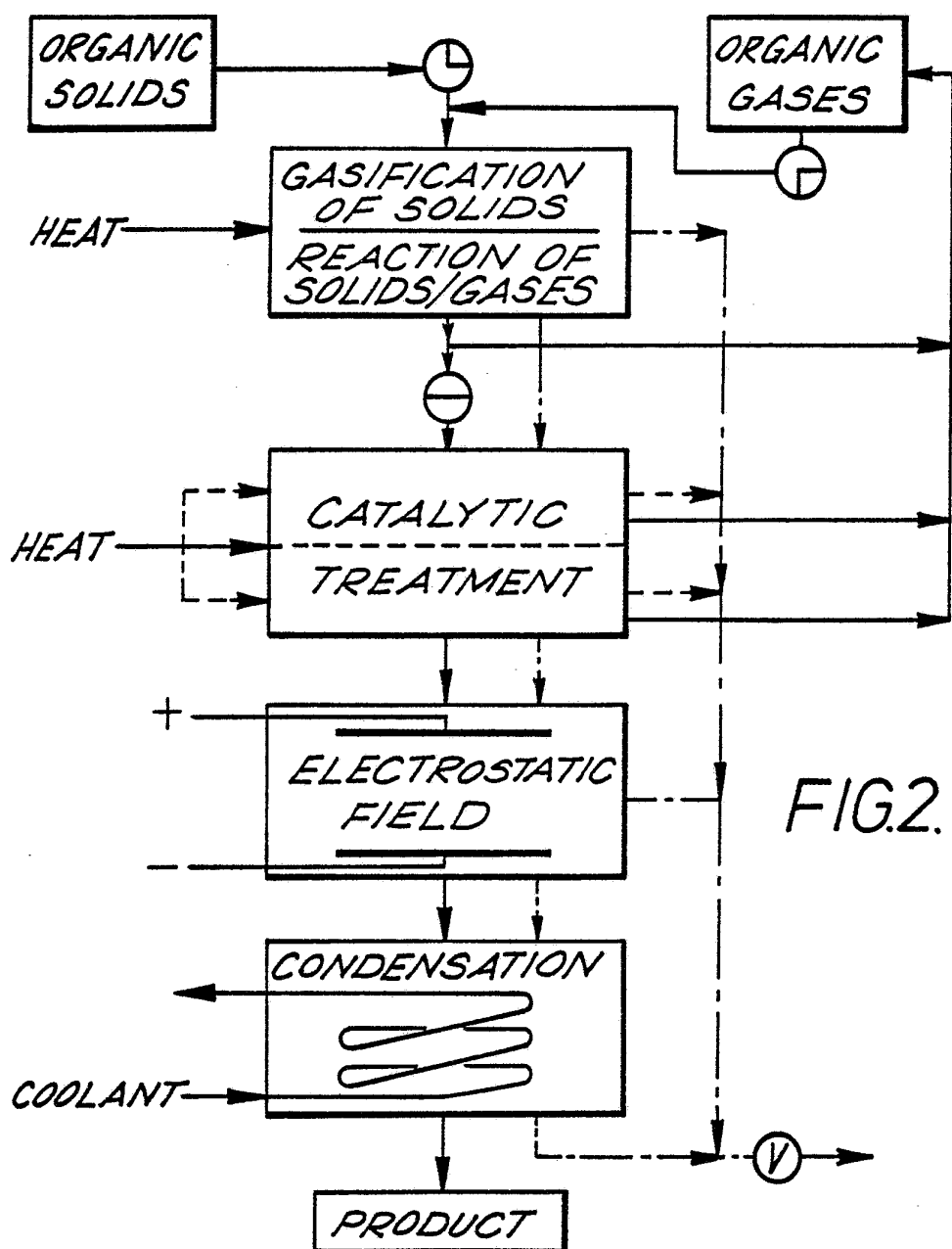
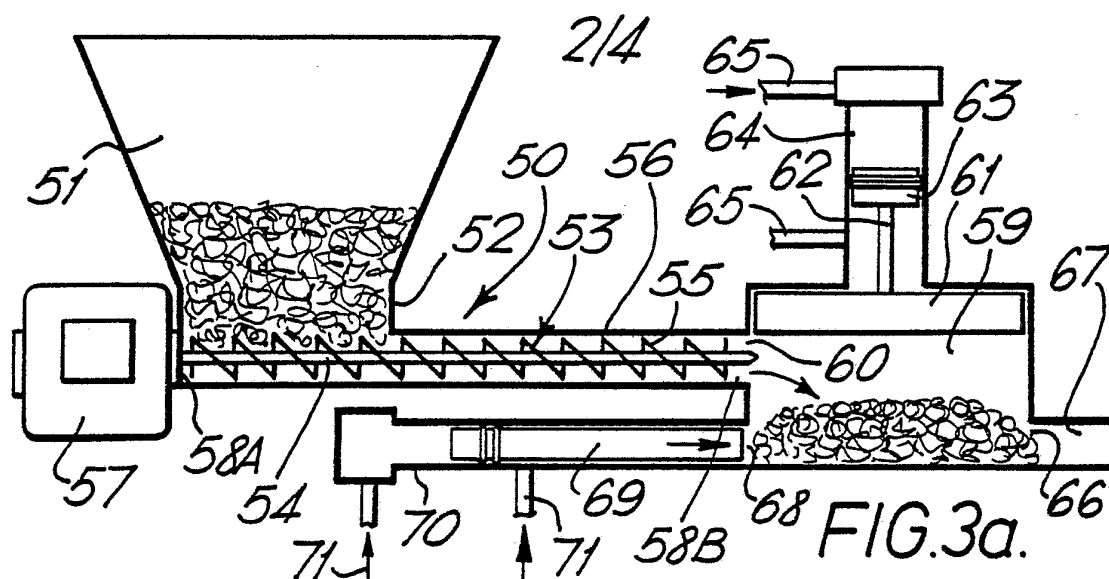
24. An apparatus according to any of claims 16 to 23,
wherein the first reaction zone comprises a steel chamber
20 traversed by burner flame tubes for conveying heat to the
chamber and an open-topped pot of graphite arranged to
receive the charges of organic matter for gasification,
whereby the residue from the gasification step is contained
in the graphite pot in the form of a substantially carbon-
25 aceous finely-divided mass.

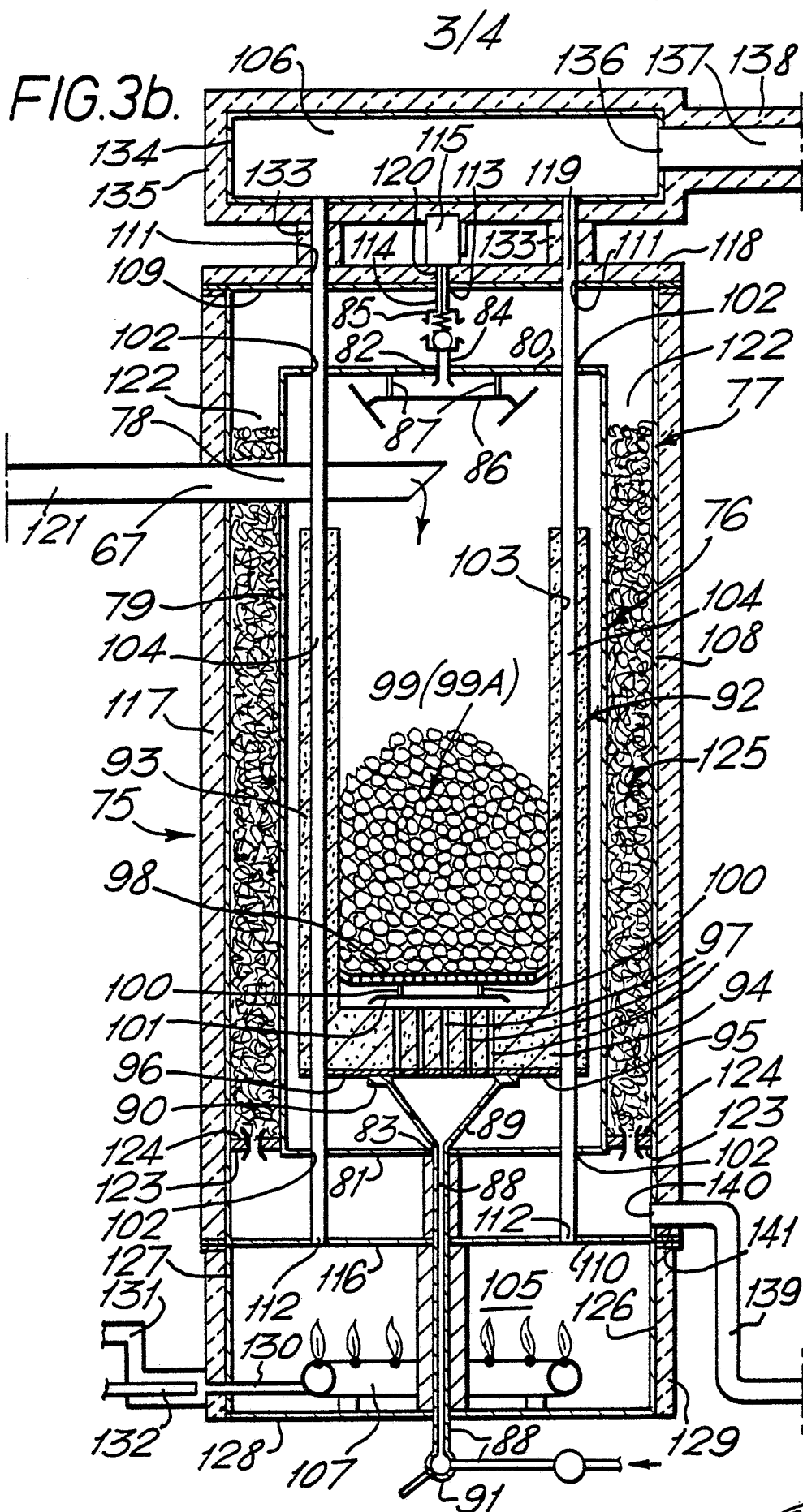
25. An apparatus according to claim 24, wherein a
plurality of vent holes are provided in the base of the
graphite pot for directing an organic gas feedstock into
contact with the residue from the gasification step and a
30 gas feed conduit for such organic gas feedstock connects
with the plurality of vent holes whereby the residue from
a gasification step is reacted with the gas to form addi-
tional quantities of a first gas mixture, prior to the
resumption of operation with the organic matter.

35



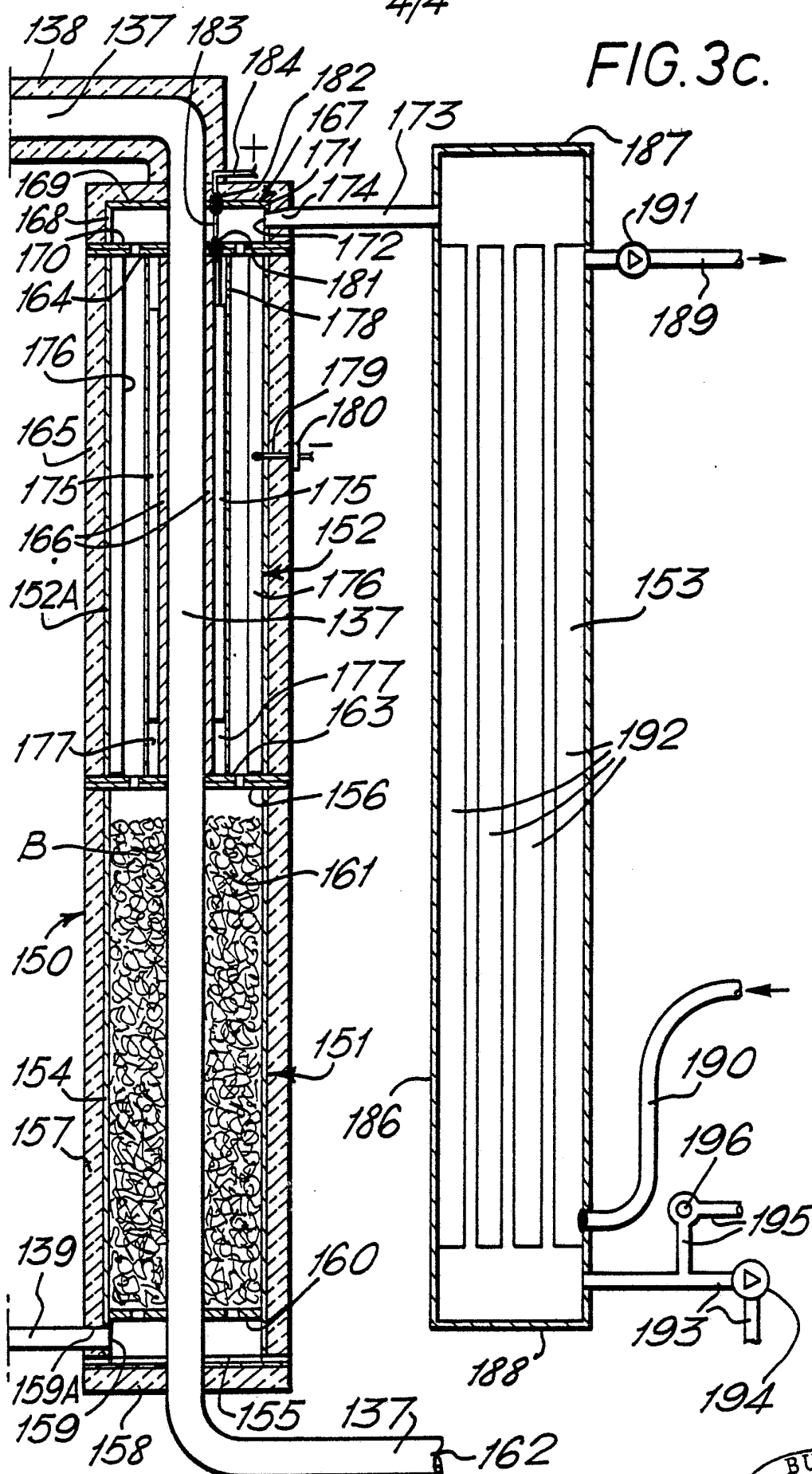
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FIG. 3c.



INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 84/00142

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ³ According to International Patent Classification (IPC) or to both National Classification and IPC IPC ³ : C 10 L 1/00 // C 07 C 9/14; C 07 C 31/04; C 07 C 43/04; C 07 C 1/02; C 07 C 2/80; C 07 C 29/15; C 07 C 41/01								
II. FIELDS SEARCHED Minimum Documentation Searched ⁴ <table style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 20%; border: 1px solid black; padding: 2px;">Classification System</th> <th style="border: 1px solid black; padding: 2px;">Classification Symbols</th> </tr> <tr> <td style="border: 1px solid black; padding: 10px; vertical-align: top;">IPC³</td> <td style="border: 1px solid black; padding: 10px;">C 07 C 29/00; C 07 C 41/00; C 10 L 1/00</td> </tr> </table> Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁵			Classification System	Classification Symbols	IPC ³	C 07 C 29/00; C 07 C 41/00; C 10 L 1/00		
Classification System	Classification Symbols							
IPC ³	C 07 C 29/00; C 07 C 41/00; C 10 L 1/00							
III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹⁴ <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 5px;"> <thead> <tr> <th style="width: 10%; padding: 5px;">Category ⁶</th> <th style="width: 60%; padding: 5px;">Citation of Document, ¹⁵ with Indication, where appropriate, of the relevant passages ¹⁷</th> <th style="width: 30%; padding: 5px;">Relevant to Claim No. ¹⁸</th> </tr> </thead> <tbody> <tr> <td style="text-align: center; vertical-align: top; padding: 10px;">X</td> <td style="padding: 10px;"> FR, A, 540543 (G. PATART) 12 July 1922 see the entire document ----- </td> <td style="text-align: center; vertical-align: top; padding: 10px;">1-3,7</td> </tr> </tbody> </table>			Category ⁶	Citation of Document, ¹⁵ with Indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸	X	FR, A, 540543 (G. PATART) 12 July 1922 see the entire document -----	1-3,7
Category ⁶	Citation of Document, ¹⁵ with Indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸						
X	FR, A, 540543 (G. PATART) 12 July 1922 see the entire document -----	1-3,7						
¹⁵ Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family								
IV. CERTIFICATION <table style="width: 100%; border-collapse: collapse; margin-top: 5px;"> <tr> <td style="width: 50%; border: 1px solid black; padding: 5px;"> Date of the Actual Completion of the International Search ¹⁹ 26th July 1984 </td> <td style="width: 50%; border: 1px solid black; padding: 5px;"> Date of Mailing of this International Search Report ²⁰ 13 AOUT 1984 </td> </tr> <tr> <td style="border: 1px solid black; padding: 5px;"> International Searching Authority ¹ EUROPEAN PATENT OFFICE </td> <td style="border: 1px solid black; padding: 5px;"> Signature of Authorized Officer ²⁰ G.L.M. Kruidenberg </td> </tr> </table>			Date of the Actual Completion of the International Search ¹⁹ 26th July 1984	Date of Mailing of this International Search Report ²⁰ 13 AOUT 1984	International Searching Authority ¹ EUROPEAN PATENT OFFICE	Signature of Authorized Officer ²⁰ G.L.M. Kruidenberg		
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International Searching Authority ¹ EUROPEAN PATENT OFFICE	Signature of Authorized Officer ²⁰ G.L.M. Kruidenberg							

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V. ☒ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE ¹⁰

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☒ Claim numbers 1-25, because they relate to subject matter ¹² not required to be searched by this Authority, namely:

The expression "useful as a fuel" is interpreted as non-limiting and therefore a complete search is not possible.

A limited search based on the clearly identified products and processes mentioned in the description and on liquid fuels of unspecified chemical composition has been carried out.

2. ☐ Claim numbers _____, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out ¹³, specifically:

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING ¹¹

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:
4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

- ☐ The additional search fees were accompanied by applicant's protest.
☐ No protest accompanied the payment of additional search fees.

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO.

PCT/GB 84/00142 (SA 7090)

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 07/08/84

The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
FR-A- 540543		None	

For more details about this annex :
see Official Journal of the European Patent Office, No. 12/82