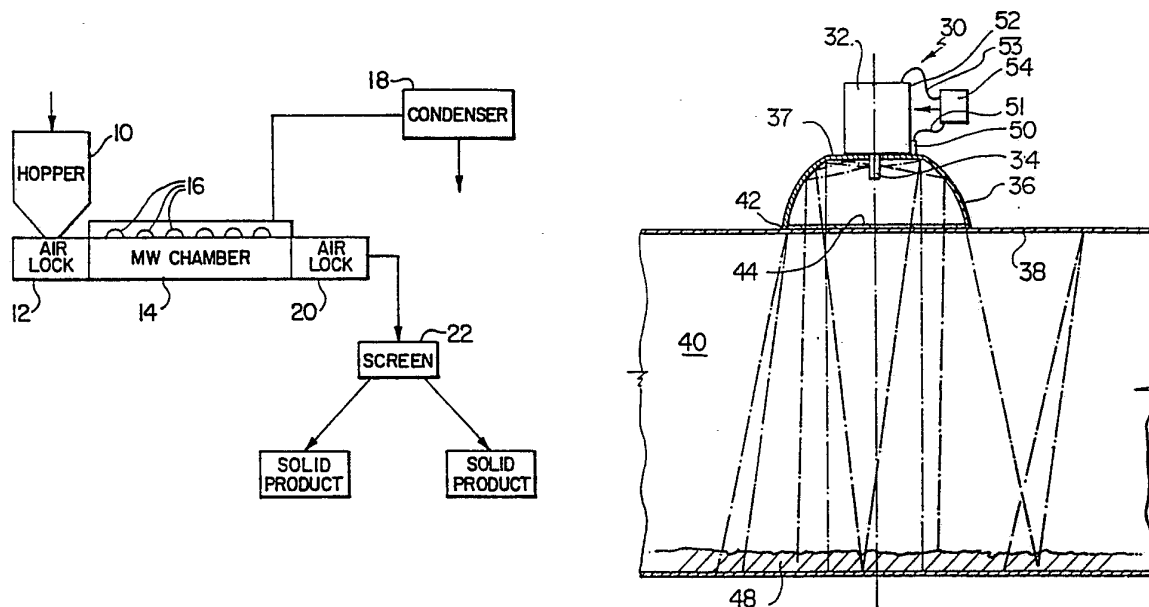




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(54) Title: METHOD AND APPARATUS FOR THE CONTROLLED REDUCTION OF ORGANIC MATERIAL



(57) Abstract

There is provided a method and apparatus for the controlled non-pyrolytic reduction of organic material comprising subjecting the material to microwave radiation in a reducing atmosphere. An apparatus for carrying out the method comprises a microwave chamber (40) or modules of chambers, at least one microwave generator (32), an antenna (34) connected to each said generator and a reflecting surface (36). Means are provided for feeding (48) the organic material into the chamber (40), removing (18) gaseous products and solid residue (22) from the chamber.

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Method And Apparatus For The Controlled
Reduction of Organic Material

FIELD OF THE INVENTION

This application relates to a method and
5 apparatus for the reduction of organic materials using
microwave radiation.

BACKGROUND OF THE INVENTION

There are numerous instances in diverse areas
where it is desirable that organic materials be reduced.
10 Such a requirement may arise in the processing of raw
materials, as, for example, in the extraction of oil from
oil shales, or in the treatment of waste materials.

The waste treatment category will arise in an
endless number of situations. This may be due to the
15 useful life of the product having been completed. For
example, huge quantities of worn out tires are in
existence. The waste may also arise from normal industrial
processes. Refinery sludge and pulp mill effluents are
examples. Municipal sewage and garbage are other sources
20 of large quantities of organic waste.

Various considerations dependent on the
particular waste type mandate that the waste be treated.
In the case of municipal sewage, for example, the waste is
a health and environmental hazard and its toxicity must be
25 neutralized. In the case of tires the emphasis is on
recycling of the very substantial amounts particularly of
oil and carbon black which are the major components of
tires.

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The treatment of various of these waste types as, for example, by burning, may itself lead to environmental pollution problems.

There is therefore an ongoing need for more
5 efficient treatment and recycling methods for organic materials.

Against this background the present invention is directed toward the use of microwave energy in a method and apparatus which is applicable in a very general sense to a
10 very wide range of organic materials.

PRIOR ART

Applicant is unaware of any prior use of microwave energy in the treatment of organic materials for non-pyrolytic reduction purposes. Canadian Patent No.
15 1,158,432, issued December 13, 1983, to Tillitt, suggests the use of microwave energy in drying bulk materials such as grains. The patent offers no aid to the reduction problem discussed above.

U.S. Patent 4,123,230, granted October 31, 1978,
20 to Kirkbride, suggests the use of multiple wave sources, but these are used to provide microwaves of different frequencies. There is no suggestion of focusing nor of creating a uniform or preferred distribution pattern.

U.S. Patent 4,184,614, granted April 10, 1979,
25 also to Kirkbride, describes a somewhat different process than that set out in the preceding reference but contains the same material in respect of the microwave energy.

Similarly, a third Kirkbride patent, U.S. Patent
4,234,402, issued November 18, 1980, describes the same
30 microwave generator arrangement.

U.S. Patent 4,376,034, granted March 8, 1983, to Wall, shows use of a pair of microwave generators at

opposite ends of a reactor. A very inefficient use of reflected waves is the basis of this microwave application.

The prior art has generally not addressed itself to the more efficient use of microwaves, but has simply
5 incorporated into various processes commercially available microwave generation systems.

BRIEF SUMMARY OF THE INVENTION

It has now been determined that a wide variety of organic materials can be treated with microwave energy for
10 controlling toxicity, for recycling purposes and for various processing purposes.

Thus the invention provides a method for the controlled non-pyrolytic reduction of organic materials which method comprises subjecting the materials to
15 microwave radiation in a reducing atmosphere.

In a further embodiment of the invention there is provided a method for the non-pyrolytic breakdown of longer chain molecules in organic materials which method comprises subjecting molecules to microwave radiation in a reducing
20 atmosphere.

In a further embodiment there is provided an apparatus for the controlled non-pyrolytic reduction of organic material by microwave radiation comprising a microwave chamber, means for feeding the organic material
25 into the chamber, at least one microwave generator in the chamber, means for removing gaseous products from the chamber and means for removing solid residues from the chamber.

BRIEF DESCRIPTION OF THE DRAWING

FIGURE 1 illustrates schematically the method according to the invention;

FIGURE 2 illustrates schematically a microwave generator and parabolic wave guide for use in the invention; and

FIGURE 3 illustrates a pattern for application of microwaves in a preferred embodiment of the invention.

While the invention will be described in conjunction with preferred embodiments, it will be understood that it is not intended to limit the invention to such embodiments. On the contrary, it is intended to cover all alternatives, modifications and equivalents as may be included within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the following description, similar features in the drawings have been given similar reference numerals.

The method and apparatus of the invention can be applied to an almost limitless variety of organic materials. It is believed that the microwave energy results in the severing of weaker molecular bonds in longer chain molecules to reduce those molecules to simpler forms. This is in effect a de-polymerization process. The process is controlled to avoid pyrolysis of the organic material.

A general schematic of the invention is illustrated in the drawing. Materials are fed into a hopper 10 or into a similar means suitable to the particular feed material.

The material is then fed via an air lock 12 into a microwave chamber 14. The material is irradiated by microwave energy from magnetrons 16.

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Gaseous products are taken off to a condenser 18 and condensed to liquid products, generally oils and sulfur.

5 Solid residues exit the chamber 14 through a second air lock 20. These products are then separated, as by screen 22, into various groups. Carbon black will normally comprise a substantial part of these products. Others would include, for example, steel in the case of tire reduction.

10 Optimum process conditions and apparatus configuration will be selected for a given material after an initial analysis of that material. Several types of analyses are preferably carried out with differing objectives.

15 Thus, an initial analysis of shape and structure may be made with a view to adapting the microwave chamber and the feeder means to that material. For example, the toroidal shape of tires suggests a different feeder and chamber design than, say, a cube of compressed plastic
20 scrap.

A further analysis is then preferably performed on the material to determine its composition. For example, in treating material which might be categorized essentially as PVC, one would also like to know the quantities of
25 extenders and other such components which might be present.

The results of this analysis will provide information as to the products which are likely to be obtained from the breakdown of the material, the quantities of each such product that might be expected and the order
30 in which the products are likely to be obtained.

A further analysis is then carried out, generally by lab testing, to determine the energy requirement for the process. Having determined that requirement per unit of throughput material, and knowing the volume of material
35 required to be processed, the total energy requirement can be calculated.

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The result of these analyses can then be used to optimize apparatus design and process conditions for the various stages in the process.

In the flow of material through the process the first area of concern is in the feeding arrangement.

While the process can be carried out on a batch basis, it is much preferred that it be continuous. Accordingly, since the microwave chamber must be sealed, the feeding apparatus must meet this requirement. One such feeding apparatus design which is useful with a variety of feed material is a piston and cylinder arrangement. For solid feeds a feed hopper can be located above and toward one end of a cylindrical feed conduit to deliver feed material to the conduit. A piston may then be utilized to move the material along the conduit toward the microwave chamber. The continuous plug formed in the feed conduit by the feed material will serve to seal the inlet to the microwave chamber.

A second preferred apparatus for bulk materials and relatively low temperature operations is in the form of an endless belt conveyor. The belt material must be permeable to microwaves and must not itself break down under conditions of use.

For higher temperature operations another preferred feed apparatus comprises one or more stainless steel screw conveyors.

For certain material configurations an airlock may be introduced at the entry to the microwave chamber.

Similarly, in some cases an airlock will be necessary at the solids outlet from the microwave chamber.

The next consideration in the flow of material through the process is the shape of the microwave chamber itself.

Several factors will influence the physical characteristics of the microwave chamber into which the feed material is introduced.

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The overall shape of the chamber will generally be chosen based on the physical characteristics of the feed material and the type of feed apparatus utilized. For example, where the piston and cylinder feed arrangement is utilized, a cylindrical chamber may be chosen. Where an endless belt conveyor is utilized, a chamber of rectangular cross-section will generally be preferred.

The overall shape is also influenced by the desire to obtain maximum microwave penetration into the material being processed.

Having determined total power requirements and a basic cross section for the chamber, other factors come into play for purposes of optimization.

A number of variables in the process and apparatus can be predetermined for a given application or controlled in the course of carrying out the method. For a given application the objective is to obtain the most efficient operation in terms of energy applied per unit mass of material processed, always subject to various process constraints to be discussed.

The manner of applying the total energy requirement in a given case is generally established by a balancing of factors. In order to supply sufficient energy to initiate the reaction in a reasonable time and then to obtain the desired products from the material in the desired sequence, one must appropriately control applied energy. Thus, the basic microwave generation may be obtained from multiple small wave generators rather than from a single magnetron. The output from the wave generators may be continuous, pulsed or otherwise varied. The strength of the microwaves generated can be varied by varying the power input to the generators.

A typical chamber of rectangular cross section might include 4 transverse rows of 3 microwave generators each.

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In addition to the arrangement and power of the wave generators, the energy applied per unit mass of treated material will be effected by the time of exposure of the material to the microwave; that is, the dwell time of the material. The energy factors must at this point again be taken in context with chamber geometry. Thus, dwell time may be directly affected by the rate of feed of the material being processed, but, as well, the length of the chamber may be varied and the mass under bombardment may be varied by varying the capacity of the microwave chamber.

Furthermore, the focus of the microwaves contributes markedly to efficiency, and parabolic wave guides have been developed to provide a focus for the waves from a given generator. A series of wave guides may be used with a series of wave generators to provide an overlapping series of microwave curtains to allow very good control of the amount of energy applied to the material.

The surface temperature of the material strongly effects microwave absorption by the material, so it is highly preferable that the surface temperature be monitored and that the power input to the microwave generators be adjusted as required to obtain optimum surface temperature. Thus, as the reactions proceed as the material moves through the microwave chamber, less energy input may be required to maintain optimum surface temperature, so that downstream microwave generators may be operated at lower power input.

It is also useful to monitor the internal temperature of the material in the microwave chamber as a means of predicting what products are likely to be coming off the material at any time. The microwave chamber is preferably kept at slightly above atmospheric pressure. The pressure facilitates removal of gaseous products.

It has been found that the process works better in a more dense atmosphere. Accordingly, after the process

is started up and run to the point where the first of the material fed into the chamber has been substantially broken down, the process is found to proceed more efficiently. In that regard the process must be carried out in a reducing atmosphere, and the concentration of reducing gases is increased as the material is broken down. It is theorized that the presence of additional reducing gases may tend to aid in further breakdown of the material, particularly at its surface.

10 It may be preferable in some instances to utilize a two part chamber to isolate the wave generators from the reducing atmosphere. A horizontal microwave permeable gas impermeable barrier would be one solution, with the top and bottom parts of the chamber both being resonant.

15 It may be necessary to add a reducing gas with the feed material. The purpose of the reducing gas is to damp out any oxidation which might otherwise occur during start-up with possible catastrophic results. An inert gas such as nitrogen might also be used, but any compatible reducing gas will do. It should be noted that it is not generally necessary that a reducing gas be added, but that the possibility exists in certain instances.

20 It has been found that some catalysts enhance the efficiency of the process. Thus, the addition of carbon black to the input material in the case of tires results in the oils coming off the material more quickly and at lower temperatures.

30 A further external factor will frequently be present which will be of primary concern in terms of the balancing of the internal factors. The physical space available in a plant to accommodate apparatus according to the invention is often limited, so all of the controllable factors must be balanced in the face of that restriction. The importance of this space consideration is highlighted by the fact that some installations may have a substantial

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overall length. For example, lengths in the order of 30 to 60 feet will not be unusual.

In that regard a preferred approach is to utilize a series of modules connected end to end. This has several advantages. Among these is the ability to remove and replace a single module to carry out repairs, thereby avoiding downtime. A further advantage is in ease of manufacture and handling of smaller modules. A preferred module is about 6 feet in length overall.

Power availability is a further external variable which may be beyond the control of a user, usually because of the particular location of the plant.

The products of the process are obtained in the form of gaseous and solid material. The gaseous materials are recovered utilizing one or more aspirators on the microwave chamber. The solid products are in the form of residues conveyed through a microwave chamber outlet.

The gaseous products are condensed to provide various hydrocarbon liquids. In that regard it may be necessary to provide heat to the exhaust system to prevent premature condensation.

The solid products comprise carbon black in micron size and various inorganic materials which may have been present in the feed. For example, in addition to the various oils and carbon black obtained from tires, the residues will include steel, silica and the like components.

For example, a typical PVC lab sample yielded 125 gms solid residue from 160 gms of the original PVC. The residue was almost entirely carbon black containing in total less than 3.159 ppm of the following elements and compounds: As; Ba; B; Cd; Cr; Pb; Se; U; NO₂ + NO₃; NO₂; Ag; Hg; CN(F); F.

As a further example, typical tires will yield per tone of tires, 3 to 4 barrels of oil, 575 to 700 lbs.

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of carbon black, 85 to 100 lbs. of steel and 70 to 80 lbs. of fibre.

FIGURES 2 and 3 illustrate a preferred apparatus for carrying out one embodiment of the invention.

5 Microwave generators utilized in industrial processes have generally been very inefficient in that they have utilized in general the technique of heating a material simply by bombarding it in a manner which leads to a very non-uniform distribution of microwave energy through
10 the material. The result in such cases is that some parts of the material are undertreated and others overtreated.

In such cases, in order to ensure that all material receives a minimum input of microwave energy, a great deal of energy waste occurs.

15 Furthermore, depending on the material being processed, specific patterns of applied microwaves may be much more efficient than others. With the commonly used general bombarding approach, such varying patterns are not available.

20 Serious problems of energy loss have also existed in using various wave guide types to distribute generated microwaves. For example, some wave guides have had elongated and non-linear paths and have resulted in only weak waves reaching the site of a material to be treated.

25 Further, a view has been firmly held by some manufacturers of microwave units that multiple wave generators are an impractical solution to the distribution problem because of the problem of interference between waves produced by the various generators. The apparatus of
30 FIGURES 2 and 3 addresses these problems.

FIGURE 2 illustrates a microwave generating apparatus 30 according to the invention comprising a magnetron 32, an antenna 34 and a reflecting surface or wave guide 36. The apparatus 30 is illustrated mounted in
35 wall 38 of a microwave chamber 40. The outer extremity 42

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of reflecting surface 36 is mounted flush with wall 38. The opening defined by the extremity 42 of reflecting surface 36 is covered by a ceramic plate 44.

The reflecting surface 36 may be designed to
5 achieve a desired pattern of wave application but in the preferred case is substantially parabolic to provide a substantially circular area of wave application. The top 37 of the reflecting surface 36 is preferably flattened. This allows for easy mounting of the unit but also allows
10 the antenna 34 to be positioned at or near the focus of the parabola.

The boundaries of the pattern may be adjusted by appropriate design of the wave guide in combination with a particular placement of antenna 34. The focus of the
15 pattern can subsequently preferably be adjusted by adjusting placement of antenna 34. The antenna 34 is preferably adjustable over about one inch of travel axially of the reflector 36.

Thus, for example, in the most preferred
20 configuration the combination of the antenna 34 and reflecting surface 36 is adjusted to provide a slightly off focus application of microwaves so that the diameter of the area of application of microwaves is greater than the diameter of the extremity 42 of reflecting surface 36.

25 Application of microwaves is fairly uniform over the circular area.

A series of apparatus 30 can then be arranged as illustrated in FIGURE 3 to provide the desired overlapping pattern 46, the area of which is defined by lines 45
30 through the outer ones 47 of the generators 30 of the array. In this configuration there is produced in effect a microwave cloud which will provide a reasonably uniform distribution of microwave energy to a material 48 in chamber 40.

35 In a preferred configuration the apparatus 30 is provided with a temperature sensor 50 mounted in the

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housing 52 of magnetron 32. Sensor 50 is in turn connected by conductors 51 to a controller 54 which will switch off magnetron 32 via conductors 53 when the sensor 50 registers a limiting temperature and will switch magnetron 32 back on
5 after a preset time period.

Thus, where a non-uniform feed material such as motor vehicle tires is being processed, at times there will be no material beneath an apparatus 30 as, for example, when the open center part of a tire is passing underneath
10 the apparatus. In that case waves reflected from the bottom wall 56 of chamber 40 will cause the apparatus 30 to heat up to the point where the sensor 50 will send a signal to controller 54 causing the magnetron to shut down. After a predetermined period which in the tire case would relate
15 to the time required for the open area of the tire to pass the apparatus 30, magnetron 32 will be switched back on.

This has the combined effect of preventing the apparatus 30 from overheating, and of saving energy.

While the process is widely applicable, and thus
20 highly variable in construction, in a typical case, for example, for reduction of motor vehicle tires, a series of 10 modular tunnels may be used in series to provide a rectangular tunnel of about 60 feet in length and with a cross section of about 14 inches by 36 inches. In a
25 preferred embodiment, two such 60' tunnels would be used in a tire reduction plant. A series of 12 overlapping magnetrons may be used in each module as shown in FIGURE 3. Each magnetron may have 1.5 kilowatts of power at a
wavelength of 2450 MHz.

30 The typical process will be carried out at a slight positive pressure of about 1/4 to 1/2 inch of water and at maximum temperatures of about 350°C. The sensor 50 will typically switch off the magnetron at a temperature of about 70°C.

35 Typically the reflectors 36 have a diameter of about 7 1/2 inches to 7 3/4 inches at the extremity of the

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parabola. The top section 17 is typically about 3 1/8 inches wide and the reflector about 2 1/2 inches deep.

In the preferred tire plant with twin tunnels, operating under the above conditions, a continuous tire
5 feed rate on a conveyor running at 3 feet per minute will give a dwell time of about 20 minutes and a throughput capacity of 1,440 tires per 24 hours for each 60 foot tunnel.

It is notable that this plant would produce no
10 emissions at all. Gaseous products consist of a narrow band of oils about the consistency of No. 2 diesel fuel, along with elemental sulphur which is condensed separately.

The controlled reduction of the invention avoids
emissions problems common in other waste reduction
15 processes, including prior microwave based processes.

CLAIMS:

1. A method for the controlled non-pyrolytic reduction of organic material comprising subjecting said material to microwave radiation in a reducing atmosphere.
2. A method for the non-pyrolytic breakdown of longer chain molecules in organic materials comprising subjecting said molecules to microwave radiation in a reducing atmosphere.
3. A method for the controlled non-pyrolytic reduction of organic material by sequentially breaking down molecular bonds in longer chain molecules by subjecting said material to microwave radiation in a reducing atmosphere.
4. The method of claim 1 comprising continuously feeding a stream of said material through a microwave chamber.
5. The method of claim 4 wherein said method comprises feeding said material in an airtight manner relative to said microwave chamber.
6. The method of claim 5 wherein said method comprises feeding said materials into said chamber through a cylinder and propelled by a piston.
7. The method of claim 5 including feeding said material into said chamber on an endless belt conveyor.
8. The method of claim 5 including feeding said material into said chamber by means of a screw conveyor.

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9. The method of claim 4 comprising in addition controlling the degree of exposure of said stream to microwave radiation.
10. The method of claim 9 comprising controlling said degree of exposure by controlling the dwell time of said stream in said chamber.
11. The method of claim 10 comprising controlling said dwell time by controlling the rate of travel of said stream through said microwave chamber.
12. The method of claim 10 comprising controlling said dwell time by controlling the length of said microwave chamber.
13. The method of claim 9 comprising controlling said degree of exposure by controlling the power of said microwave radiation.
14. The method of claim 13 comprising controlling said degree of exposure by controlling, in addition, the dwell time of said stream in said chamber.
15. The method of claim 9 comprising controlling said degree of exposure by predetermining the shape of said microwave chamber.
16. The method of claim 15 wherein said chamber is a resonant tunnel whereby microwaves reflected from the walls of said tunnel are in synchronization with said microwave radiation.
17. The method of claim 9 comprising controlling said degree of exposure by focusing said microwave radiation on at least one predetermined point in said stream.

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18. The method of claim 1 comprising treating said material in a microwave chamber in which at least one microwave generating unit is disposed.
19. The method of claim 18 in which at least two said generating units are disposed.
20. The method of claim 19 comprising controlling the degree of exposure of said material to microwave radiation by selectively varying the microwave energy output of individual ones of said microwave generating units.
21. The method of claim 18 comprising continuously feeding a stream of said material through said chamber and controlling said microwave generating units to generate a higher level of microwave energy toward an inlet end of said chamber and a lower level of microwave energy toward an outlet end of said chamber.
22. The method of claim 4 wherein said material comprises tires.
23. The method of claim 4 wherein said material comprises municipal garbage.
24. The method of claim 4 wherein said material comprises oil shale.
25. The method of claim 4 including adding a reducing gas to said chamber.
26. The method of claim 4 including adding an inert gas to said chamber.
27. The method of claim 26 wherein said inert gas is Nitrogen.

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28. The method of claim 4 wherein said chamber is maintained at a pressure above atmospheric.

29. The method of claim 28 wherein said pressure is in the range of 1/4 to 1/2 inch of water.

30. The method of claim 4 including the step of monitoring the surface temperature of said material in said chamber and controlling the degree of microwave exposure responsive to said monitored temperature.

31. The method of claim 4 including the step of adding a catalyst to said chamber.

32. The method of claim 31 wherein said catalyst is added to said material prior to feeding said material into said chamber.

33. The method of claim 31 or 32 wherein said catalyst is carbon black.

34. The method of claim 4 including the step of continuously removing gaseous products from said chamber.

35. The method of claim 34 wherein said gaseous products are removed sequentially from more volatile/lighter to less volatile/heavier gases.

36. The method of claim 35 wherein the temperature of the material in the chamber is controlled to control the sequential production of gaseous products from said materials.

37. The method of claim 4 wherein said solid residues are continuously removed from said chamber.

38. A method for the controlled non-pyrolytic reduction of organic material comprising:
continuously feeding a stream of organic material into a microwave chamber;
maintaining a reducing atmosphere in said chamber;
subjecting said material to microwave radiation;
and
continuously withdrawing gaseous and solid products from said chamber.

39. The method of claim 38 including the step of monitoring the surface temperature of said material.

40. The method of claim 38 including subjecting said material to sufficient microwave radiation to break down longer chain molecules in said material.

41. The method of claim 38 including the step of controlling the amount of microwave radiation to which said material is subjected by controlling at least one of:

- (i) the power input to the microwave generator,
- (ii) the number of microwave generators,
- (iii) the focus of the microwave generators,
- (iv) the orientation of the microwave generators, and
- (v) the shape of the microwave chamber.

42. The method of claim 41 including the step of controlling the amount of microwave energy to which said material is subjected by controlling at least one of:

- (i) the speed of said material through said chamber, and
- (ii) the length of said chamber.

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43. The method of claim 38 wherein said microwave chamber is maintained at a positive pressure of 1/4 to 1/2 inch of water.
44. The method of claim 38 wherein said method is carried out at a maximum temperature of about 350°C.
45. The method of claim 38 wherein said microwave radiation has a wavelength of about 2450 MHz and produces about 1.5 kW of power.
46. An apparatus for the controlled non-pyrolytic reduction of organic material by microwave radiation according to the method of claim 1, said apparatus comprising:
- a microwave chamber;
 - means for feeding said material into said chamber;
 - at least one microwave generator in said chamber;
 - means for removing gaseous products from said chamber; and
 - means for removing solid residue from said chamber.
47. The apparatus of claim 46 wherein said chamber is cylindrical.
48. The apparatus of claim 47 wherein said means for feeding comprises a piston and cylinder.
49. The apparatus of claim 46 wherein said chamber is a resonant cavity.
50. The apparatus of claim 46 including at least two said generators arranged in said chamber in an upstream and

downstream relationship relative to the flow of said material.

51. The apparatus of claim 50 wherein said upstream generator is of greater power output than said downstream generator.

52. The apparatus of claim 46 including at least one parabolic wave guide for focusing the microwave output of said generator.

53. The apparatus of claim 46 wherein said chamber of rectangular cross section.

54. The apparatus of claim 47 wherein said chamber includes 4 transverse rows of 3 microwave generators each.

55. A modular apparatus for the controlled non-pyrolytic reduction of organic material by microwave radiation, according to the method of claim 1, said apparatus comprising in series at least two modules, the outlet of one module joined to the inlet of the next, each of which modules comprises a microwave chamber and at least one microwave generating apparatus in said chamber; said apparatus further comprising means for feeding said material into a first of said modules and means for removing gaseous and solid products from said series.

56. The apparatus of claim 55 wherein each said chamber is rectangular in cross-section.

57. The apparatus of claim 55 wherein each said microwave generating apparatus comprises:

at least one microwave generator;

an antenna connected to each said generator for transmitting microwave energy from said generator; and

a reflecting surface for reflecting microwave energy from each said antenna in a predetermined pattern onto said material to be treated.

58. The apparatus of claim 57 wherein each said chamber is rectangular in cross section.

59. The apparatus of claim 58 wherein each said chamber includes an array of said microwave generating apparatus for generating microwave radiation in a predetermined overall pattern in said chamber.

60. The apparatus of claim 59 wherein said array comprises 3 rows of 4 said generating apparatus in each row.

61. The apparatus of claim 59 wherein each said generating apparatus in each said array generates a substantially circular area of microwave radiation.

62. The apparatus of claim 61 wherein each said circular area overlaps with each adjacent said area such that said overall pattern is continuous across said array.

63. A microwave generating apparatus for applying microwave energy to a material to be treated, said apparatus comprising:

at least one microwave generator;

an antenna connected to each said generator for transmitting microwave energy from said generator; and

a reflecting surface for reflecting microwave energy from each said antenna in a predetermined pattern onto said material to be treated.

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64. The apparatus of claim 63 wherein the position of said antenna relative to said reflector is adjustable.
65. The apparatus of claim 63 wherein said reflecting surface is parabolic, having an open face.
66. The apparatus of claim 65 having a ceramic plate across said open face.
67. The apparatus of claim 63 including an array of said generators.
68. The apparatus of claim 67 wherein each said pattern is circular area.
69. The apparatus of claim 68 wherein an outer edge of each said pattern overlaps with an outer edge of at least one adjacent pattern.
70. The apparatus of claim 68 wherein each said circular pattern is of slightly greater diameter than the diameter across said face of said reflecting surface.
71. The apparatus of claim 67 wherein said array is a 3 by 4 array.
72. The apparatus of claim 68 wherein said patterns overlap to cover the entire area encompassed within lines through the outer ones of said generators in said array.
73. An apparatus for the controlled reduction of organic materials comprising:
a microwave tunnel; and
an array of microwave generating apparatus for generating focused microwave energy in said tunnel;

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each said apparatus comprising (i) at least one microwave generator; (ii) an antenna connected to each said generator for transmitting microwave energy from said generator; and (iii) a reflecting surface for reflecting microwave energy from each said antenna in a predetermined pattern onto said material to be treated.

74. The apparatus of claim 73 wherein each said reflecting surface is parabolic and is mounted with an open face of the parabola substantially flush with a wall of said tunnel.

75. The apparatus of claim 74 having a ceramic plate across said open face.

76. The apparatus of claim 75 wherein said tunnel is of rectangular cross-section having a top wall.

77. The apparatus of claim 76 wherein said array is mounted in said top wall.

78. The apparatus of claim 77 wherein each said predetermined pattern is circular.

79. The apparatus of claim 78 wherein an outer edge of each said pattern overlaps with an outer edge of at least one adjacent pattern.

80. The apparatus of claim 79 wherein said tunnel has a bottom surface and wherein said patterns together cover substantially all of said surface with a substantially uniform amount of microwave energy.

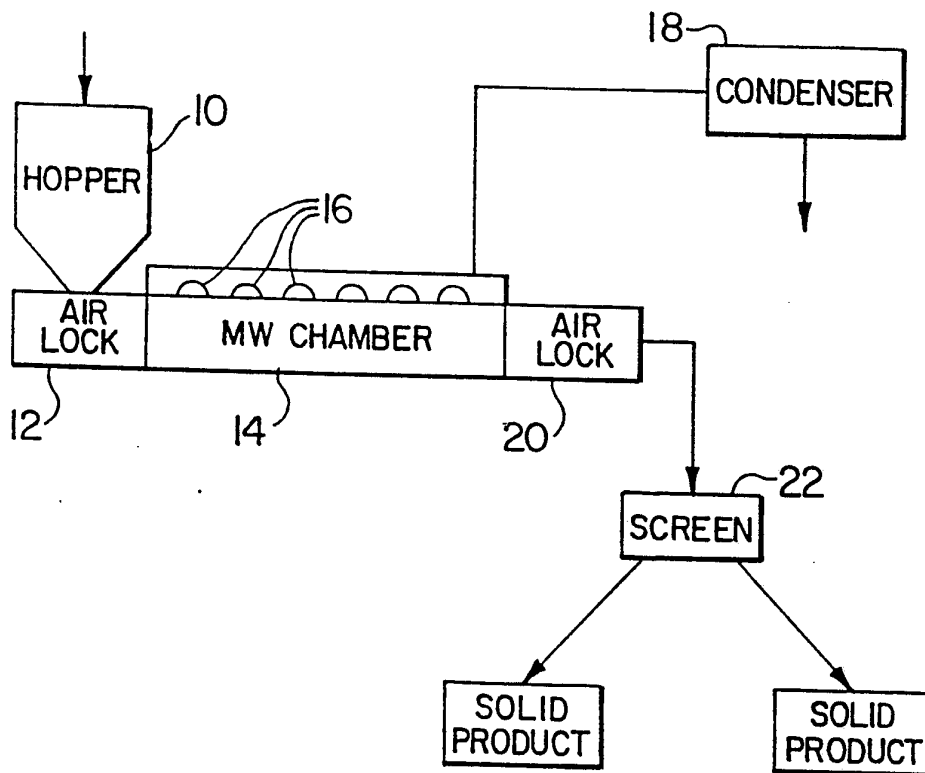


FIG. 1

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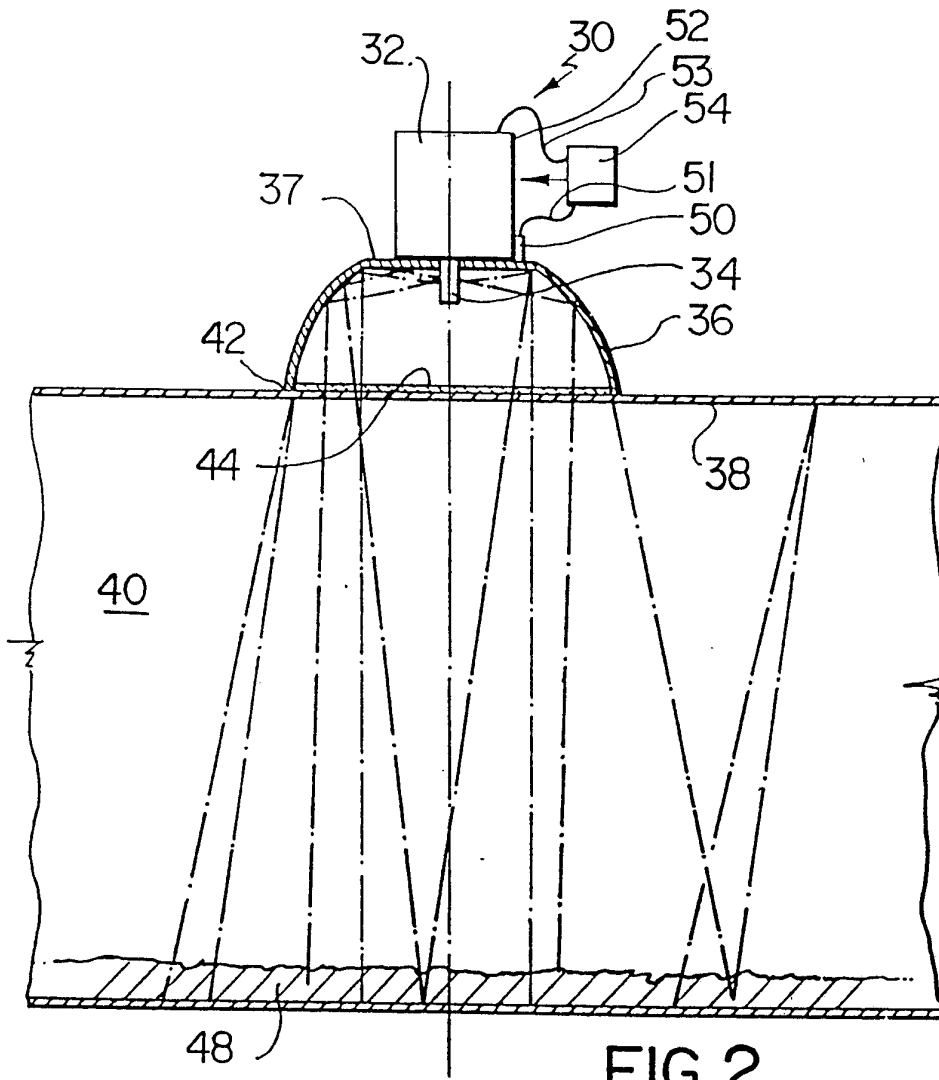


FIG. 2

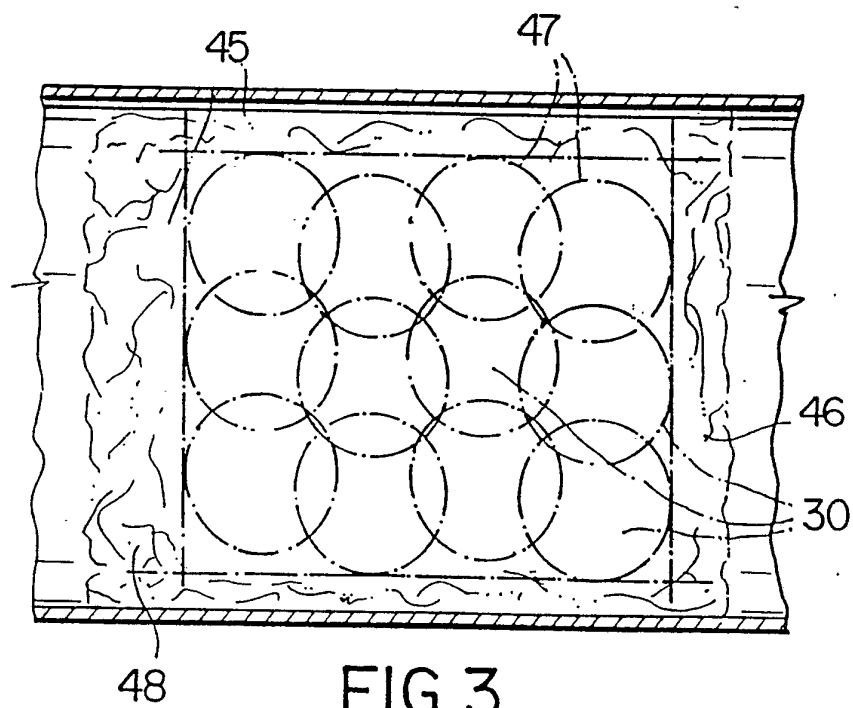


FIG. 3

INTERNATIONAL SEARCH REPORT

International Application No

PCT/CA 93/00021

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int.Cl. 5 A62D3/00; B01J19/12; B09B3/00; C10G1/02		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁷		
Classification System	Classification Symbols	
Int.Cl. 5	B01J ; A62D ; C10B ; F26B	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸		
III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹		
Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
X	WO,A,9 103 281 (EMERY,C.L.) 21 March 1991 * whole document *	1-42, 46-54
Y		55
A	---	56-62
X	DE,A,4 032 496 (WIENEKE,F.) 25 April 1991 * abstract * see column 1, line 68 - column 2, line 56 see column 3, line 19 - line 67 see column 5, line 41 - column 7, line 24 see figures 1-3	46,50, 52,53
A	---	54
	---	-/--
<p>¹⁰ 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</p> <p>"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</p>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
27 APRIL 1993	26.05.93	
International Searching Authority	Signature of Authorized Officer	
EUROPEAN PATENT OFFICE	SIEM T.D.	

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
X	WO,A,9 115 248 (IIT RESEARCH INSTITUTE) 17 October 1991 * abstract * see page 1, line 5 - line 30 see page 36, line 8 - page 37, line 29 see figure 16 ---	46, 50, 53, 63, 67
Y	FR,A,2 599 924 (UNIVERSITÉ DE BORDEAUX I) 11 December 1987 * abstract * see page 2, line 25 - page 3, line 5 see page 4, line 20 - page 6, line 15 see figures 1-4 ---	55
A	US,A,4 376 034 (E.T.WALL) 8 March 1983 * abstract * see figure 2 see column 2, line 58 - column 3, line 24 see column 6, line 29 - line 43 -----	1, 46, 53

**ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.**

CA 9300021
SA 69183

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 The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information. 27/04/93

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WO-A-9103281	21-03-91	AU-A- 6298890	08-04-91
		EP-A- 0490934	24-06-92
DE-A-4032496	25-04-91	None	
WO-A-9115248	17-10-91	AU-A- 7662691	30-10-91
		EP-A- 0522056	13-01-93
FR-A-2599924	11-12-87	EP-A, B 0252542	13-01-88
		FR-A- 2668676	30-04-92
US-A-4376034	08-03-83	None	

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