Disclosure is a scalable pyrolysis system for batch processing of waste vehicle tires and other waste to provide pyrolysis products. The core pyrolysis system includes one or more batch reactors, heating units, solids processing units, gas/liquid processing units, and control units. In operation, the temperature gradients internal to the reactor are controlled by preferential channeling of heat to provide pyrolysis products that are of high quality, and hence commercially advantageous, while facilitating high throughput.
The present invention relates to continuous batch pyrolysis systems for continuous recovery of carbon, hydrocarbons and other materials from waste vehicle tires.

Waste vehicle tires are a major environmental problem. Waste tires in the past have often been discarded in disposal and landfill sites. Sites for storage or land fill of waste tires, however, are becoming less available. Many existing sites for waste tires are reaching capacity with an estimated 3 billion waste tires discarded in sites in the United States. New sites are difficult to open because of increasingly stringent government regulations and public concerns about the environment. Most states now have laws prohibiting the dumping of waste tires in disposal sites.

Tire sites are not only unsightly but they present a risk of being set on fire. When tire sites are set on fire, the burning of tires is environmentally harmful since tire combustion produces dangerous substances such as sulfur-containing acids and other pollutants. The water and air pollution from lighting fires at tire dumps is very hazardous to the environment.

In order to avoid the problems of tire disposal sites, a number of tire recycling programs have been tried. Tire recycling programs have included tire shredding, crumbing, direct tire recycling, tire incineration and tires used as fill. None of these recycling programs has proved to be commercially and environmentally satisfactory. Tire pulverizing is a process that grinds up tires into smaller pieces for use in road surfacing, on athletic fields, paddocks and other uses. Tire shredding or crumbing has had limited success and is not expected to make significant reductions in the national waste tire inventory. The direct recycling of tires reclamations some tires still having useable tread and recaps some tire so that they can be used again as tires. Only a small percentage of tires can be safely recapped for reuse. In some cases, tires are cut into parts to be used as soles for shoes, for loading docks or other bumpers, for floor mats and for other products. The percentage of tires used in this manner is small. Tire incineration burns tires as a fuel source for co-generation and other energy needs, but incineration has not proven to be efficient and environmentally satisfactory for producing energy. Tire incineration plants are expensive to construct because of the environmental problems associated with emissions from burning rubber. A significant number of cement plants burn tires along with coal. However, emissions from these plants often generate local opposition and controversy and the cost of reducing pollution renders the burning as economically questionable. The use of disposed tires as fill material has proven to be of questionable value due to the fire hazards and resulting air and water pollution resulting when tires do occur.

Pyrolysis has the potential for being the most economical and environmentally best process for recycling of waste tires. In order to achieve that potential, however, the pyrolysis systems must be carefully designed and controlled to maximize the quality and the quantity of the pyrolysis products produced. The pyrolysis products are determined by and derived from the many different components of waste tires. In order to understand the economics of tire recycling, it is important to consider the composition of tires.

Tires are made of vulcanized cross-linked polymer chains (rubber) and various reinforcing materials. The most commonly used rubber matrix is the co-polymer styrene-butadiene rubber (SBR) or a blend of natural rubber and SBR. In addition to the rubber compound, tires contain:

Reinforcing fillers: Carbon black, used to strengthen the rubber and aid abrasion resistance.

Reinforcing fibers: Textile or steel fibers, usually in the form of cords, provide the reinforcing tensile strength to tires.

Extenders: Petroleum oils, used to control viscosity, reduce internal friction during processing, and improve low temperature flexibility in the vulcanized product.

Vulcanizing agents: Organo-sulfur compounds, used to act as the catalyst to accelerate the vulcanization process; and Zinc oxide and stearic acid, used to activate the curing (cross-linking) system and to preserve cured properties.

In one typical example and in addition to steel or other reinforcing fibers, the following components by weights are found, in one typical example, in tires SBR 62%, carbon black 31%, extender oil 2%, zinc oxide 2%, stearic acid 1%, sulfur 1% and accelerator 1%.

In order to recover products from tires, pyrolysis applies high temperatures to thermally decompose the tires. Pyrolysis causes the thermal decomposition of tires in an inert atmosphere to form low molecular weight products. Tire pyrolysis produces liquids, gases and solids and the three principal products from tire pyrolysis are gas, oil, and char. The gas and oil comprise about a half of the pyrolysis products by weight and they have energy contents similar to those of conventional fuels. Char is a fine particulate solid composed of carbon black, ash, and other inorganic materials, such as zinc oxide, and silicates.

In batch pyrolysis systems, tires are introduced into a large oven-like reactor for gasification in the absence of oxygen. The lysing occurs at temperatures between 450 and 600° C. or more. The pyrolysis process yields a volatile gas, known as pyrolysis gas, which in addition to water vapor also contains hydrogen, carbon monoxide, carbon dioxide, paraffins, olefins and other hydrocarbons and cooling of the pyrolysis gas yields pyrolysis oil products and pyrolysis gas products. Various products are produced from the solid char that remains in the reactor after pyrolysis is completed such as pigments, semi-reinforcing fillers and activated filtration material. The pyrolysis products obtained from tires consists approximately of 20% oil, 25% gas, 15% steel and other solid materials, together with approximately 40% carbon.

Pyrolysis oil resembles diesel or light fuel oil, with the difference that pyrolysis oil has a relatively high content of sulphur and aromatic hydrocarbons. The high content of sulphur and of other impurities is reduced, for example, by scrubbing, and the hydrocarbon compounds can be separated into different fractions by staged condensation. The temperatures at which oils condense out from the pyrolysis gas differ depending on the density of the oil, but in general the heavier oil fractions condense out at temperatures around 350° C., the medium heavy oils at temperatures between 100 and 350° C. and the light oils at temperatures under 100° C. The oil fractions which have condensed out are stored in
collection tanks as recovered oil products, while the remaining non-condensed pyrolysis gas is used, in part, as fuel for the pyrolysis process and, in part, as recovered products of the pyrolysis process.

[0015] The char from the pyrolysis process is further refined to form, for example, products such as pigments, semi-reinforcing fillers and activated filtration material. In order to refine the carbon, the pyrolysis process includes, among other things, raising the temperature to between 800 and 900°C in order to totally remove from the char any traces of volatile hydrocarbons. The heating is followed by reduction of the temperature and in some embodiments by steam treatment. Further processing can include milling, magnetic removal of iron and steel, classifying and pelletizing.

[0016] Techniques for the recovery of carbon black and hydrocarbons from waste tires by pyrolysis are described in U.S. Pat. No. 6,271,427. In the U.S. Pat. No. 6,271,427 Patent, a method is described which improves control of the pyrolysis process and which makes it possible to recycle significant components such as carbon black and condensed oils from discarded tires in a more efficient way and with a higher quality. The method controls the pyrolysis process based on a predetermined schedule using parameters set depending on the raw materials which are used and depending on which final products are desired. The method places tire waste material for batch-wise processing in a pyrolysis reactor and recycled pyrolysis gas is fed into the reactor to heat the tire waste material. The composition and relative amount of the pyrolysis gas which is produced is measured and the measurements are used to control and regulate the process.

[0017] The economic feasibility of tire pyrolysis is strongly affected by the value of the recovered pyrolysis products. Pyrolysis products have historically yielded poor returns as the prices obtained for the recovered pyrolysis products have failed to fully justify pyrolysis process costs. Although more than 30 major pyrolysis projects have been proposed in the past few years, none are believed to have been commercially successful in the United States.

[0018] The economic feasibility of tire pyrolysis involves several critical factors including quality of the recovered pyrolysis products, capacity of the pyrolysis systems, throughput over time of the pyrolysis systems and environmental acceptability of the pyrolysis system operations. Further factors relating to economic feasibility are the governmentally sponsored incentives such as tire “tipping” fees paid for each recycled tire and CO₂ or other credits for environmentally favorable processes.

[0019] Although attempts at continuous pyrolysis processes have been made in order to increase the throughput over time of the pyrolysis systems, such continuous pyrolysis processes have not been able to produce pyrolysis products of sufficient quality to be able to achieve economic feasibility. Continuous pyrolysis processes tend to suffer from air leaks that introduce oxygen into the pyrolysis chamber and hence reduce the quality of the pyrolysis products. By contrast, batch pyrolysis processes can be made more oxygen free and hence produce higher quality pyrolysis products. However, batch pyrolysis processes have been more difficult to scale to larger sizes in order to increase the throughput over time of the batch pyrolysis systems.

[0020] In order to achieve the potential benefits of pyrolysis for waste tire processing, there is a need for improved pyrolysis systems that increase the quality and value of the pyrolysis products while enhancing the efficiency and throughput of the pyrolysis systems.

SUMMARY OF THE INVENTION

[0021] The present invention is a scalable pyrolysis system for batch processing of waste vehicle tires and other waste to provide pyrolysis products. The core pyrolysis system includes one or more batch reactors, heating units, solids processing units, gas/liquid processing units and control units. In operation, the solids processing units introduce waste tires, or other waste materials, into the reactor and, after pyrolysis processing, the solids processing units extract the solid residue from the reactor. During the pyrolysis processing, the gas/liquid processing units process the pyrolysis gases to extract pyrolysis gas and oil products. A pyrolysis control operates to insure that the sequence of heating and cooling during the pyrolysis processing is optimized for production of pyrolysis products both as to quality and throughput. The reactor design is such that the temperature gradients internal to the reactor are controlled by preferential channeling of heat to provide pyrolysis products that are of high quality, and hence commercially advantageous, while facilitating high throughput.

[0022] In particular embodiments of the present invention, the reactor has a design such that heat transfer to the waste material within the reactor is efficient and controlled. In particular embodiments, a plurality of heat conductors are distributed internal to the reactor chamber in order to facilitate rapid heat transfer internal to the reactor. In one particular embodiment, the internal heat conductors are arrayed as horizontal heat conductors. In another particular embodiment, the internal heat conductors are arrayed as vertical heat conductors.

[0023] In order to increase the capacity and throughput of the pyrolysis system, multiple core pyrolysis systems are replicated in a pyrolysis array. In a simple array, each core pyrolysis system is the same and is replicate one or more times. In more complex arrays, different parts of the liquid gas units of the core pyrolysis system are scaled and shared among reactors. In all of the pyrolysis systems, the control unit sequences the temperatures in the reactor to optimize the generation of pyrolysis products.

[0024] The foregoing and other objects, features, and advantages of the invention will be apparent from the following detailed description in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] FIG. 1 depicts a schematic block diagram of a single reactor batch pyrolysis system.

[0026] FIG. 2 depicts a pyrolysis system array formed of multiple ones of the batch pyrolysis systems of FIG. 1.

[0027] FIG. 3 depicts a pyrolysis system having a reactor with multiple heat entry ports for distributing heat with improved distribution external to the reactor pyrolysis chamber.

[0028] FIG. 4 depicts a pyrolysis system having a reactor with multiple heat entry ports and multiple exhaust ports for distributing heat with improved distribution external to the pyrolysis chamber.
FIG. 5 depicts a closed pyrolysis system having a reactor with vertical heat conductors for injecting heated pyrolysis gas internal to the reactor chamber for distributing heat with improved distribution internal to the reactor pyrolysis chamber.

FIG. 6 depicts a pyrolysis system having a reactor with vertically looped heat conductors for distributing heat within the reactor chamber and with an external fire box for distributing heat with improved distribution both internal and external to the reactor pyrolysis chamber.

FIG. 7 depicts a pyrolysis system having a reactor with horizontal heat conductors for distributing heat through the reactor pyrolysis chamber with improved heat distribution external to the reactor pyrolysis chamber.

FIG. 8 depicts a pyrolysis system having a reactor with vertical heat conductors for distributing heat through the reactor pyrolysis chamber with improved heat distribution external to the reactor pyrolysis chamber.

FIG. 9 depicts a pyrolysis system having a reactor with multiple controlled heat feeds to the vertical conductors and the reactor fire box.

FIG. 10 depicts a top view of the pyrolysis system of FIG. 10 with the cover removed to expose a view of the vertical conductors.

FIG. 11 depicts a pyrolysis system having a reactor with fluted side walls for improving heat distribution external to the reactor pyrolysis chamber.

FIG. 12 depicts a pyrolysis system having a reactor with vertical heat conductors extending from the bottom of the pyrolysis chamber, through the internal portion of the chamber and exiting through the side walls of the chamber.

DETAILED DESCRIPTION

FIG. 1, a schematic block diagram of the batch pyrolysis system 10 is shown. The batch pyrolysis system 10 includes the solid processing units 1, the reactor 2, the heating units 3, the gas/liquid units 4 and the control unit 5.

In FIG. 1, the solid processing units 1 include the supply unit 1-2 and the residue unit 1-3. The supply unit 1-2 functions to introduce waste tires or other supply material into the reactor 2. The waste tires can be either in the form of whole tires or cut tires. Typically, tires are washed and cleaned in a washing machine in supply unit 1-2 to remove foreign matter such as dirt, oil, sand or other undesirable material. The cleaning is done with heated water or steam generated by fuel or heat available from the pyrolysis system 10. The cleaning process also typical functions to preheat the waste tires prior to placement in the reactor 2-2. The waste tires are placed into the reactor 2 in either a whole or cut condition. When cut, the cutting can be into large pieces, such as halves, quarters or eights, or can be shredded into much smaller pieces. The size of the whole or cut pieces of waste tires placed into the reactor 2 affects the rate of heat transfer into the tires during the pyrolysis processing. Accordingly, the whole or cut condition of the waste tires is a variable that is supplied to the control unit 5 in order to allow the control unit 5 to properly adjust the pyrolysis process as a function of the material supplied for pyrolysis. Heat transfer is a function of the density of the waste material. The reactor is of a size such that 100 loose tires are accommodated, 180 to 200 baled tires, 200 to 300 cut tires and 400 shredded tires. The more tires the higher the density and hence the longer the pyrolysis period. While waste tires are a significant environmental problem, other waste materials may be processed by pyrolysis. For example, plastics and organic materials, frequently called “automobile fluff” remaining after the shredding of automobiles at automobile disposal sites provide a large amount of waste material. Similarly, hospital waste is produced in large volumes and is readily processed by pyrolysis.

In one embodiment, a tire baler is used to compress and bind bales of up to about 20 tires which are then loaded into the retort chamber 2-2. Between about 180 and 270 tires are placed in the retort chamber 2-2 per batch cycle, but this range may vary depending on the size of the tires and the size of chamber 2-2.

In one embodiment, the waste tires are cut into segments of approximately 15 cm by approximately 5 cm. The cutting step typically does not separate the reinforcing material of the tire from the other material. The cut segments thus form fragments of tires connected by reinforcing material but which generally can be considered bulk material.

The cleaning of the waste tires is important, among other reasons, to ensure that the pyrolysis char to be formed has a low content of ash. The washing water typically has a temperature of about 40°C. Another reason for the washing is to remove ice and snow in cold climates since any water will lead to the formation of steam and an uncontrolled increase of pressure in the pyrolysis chamber. In order to further ensure that moisture does not enter the pyrolysis chamber, the supply unit 1-2 dries the waste tires or fragments after washing. The drying is suitably carried out in a drying chamber with circulating drying air having a temperature of about 120°C.

In FIG. 1, the residue unit 1-3 functions to extract the solid residue remaining in the reactor after the heating and cooling of the pyrolysis processing is complete. Typically a vacuum system is used to remove the char and other residue. After removal of the residue, the residue is further processed to separate the carbon and other fine material from the steel and other large material.

In FIG. 1, the reactor 2 has a retort chamber 2-2 for receiving the waste tire or other material prior to pyrolysis processing. The chamber 2-2 is surrounded by a heating chamber 2-1 that includes means for heating the retort chamber 2-2 from room temperature up to 1000°C or more. The chamber 2-2 includes insulating walls necessary for safety and heating efficiency. Since the pyrolysis reactor 2 is designed for batch processing, the reactor chamber 2-2 typically includes a covered opening (see FIG. 3) which is opened when the reactor 2 is cool for inserting waste tires
from supply unit 1-2, is closed during pyrolysis processing when the temperature is cycled up and then down and is reopened to remove the residue into residue unit 1-2 when the reactor is cool.

[0048] The heating unit 3 provides heat to the reactor 2. The source of the heat is burner 3-1 which burns fuel of any type, but in particular burns fuel recovered by the gas/liquid unit 4. The heated and combusted gases from burner 3-1 are injected into the reactor heating chamber 2-1 to heat the reactor pyrolysis chamber 2-1 and from there are exhausted to exhaust 2-4. In some embodiments the heated and combusted gases from burner 3-1 are input to a heat exchanger 3-2. The heat exchanger 3-2 receives and heats gases from the gas input unit 4-4 of gas/liquid unit 4 that are then input directly to the reactor pyrolysis chamber 2-2. In some embodiments, when a heat exchanger is employed, the heated and combusted gases from burner 3-1 may all be used to transfer heat in the heat exchanger 3-2 and then exhausted directly with out being input to reactor 2. The heated pyrolysis gases from the pyrolysis chamber 2-2 are vented through pipes 2-6 to the gas/liquid unit 4.

[0049] In FIG. 1, the gas/liquid unit 4 includes a condenser unit 4-1 that receives the pyrolysis gas through pipe 2-6 connected from the reactor chamber 2-2. The condenser unit 4-1 cools the pyrolysis gas to extract condensed liquid into the condenser liquid unit 4-2. The condenser unit 4-1 typically includes a water-cooled pre-condenser, a water-cooled heat exchanger, and a water-cooled main condenser. Water cooled in a water cooling tower is circulated by water pumps through the different water-cooled components of the condenser unit 4. The water is circulated by the pumps from the cooling tower through the main condenser, through the heat exchanger and finally through the pre-condenser and then back to the pumps.

[0050] Typically, the main condenser in the condenser unit 4-1 is multi-staged for cracking the pyrolysis gas at different temperatures. For example, the first stage cools the pyrolysis gas to produce heavier oil fractions at temperatures near 350 °C. The second stage cools the pyrolysis gas to produce medium heavy oils at temperatures between 100 and 350 °C. The third stage cools the pyrolysis gas to produce light oils at temperatures under 100 °C.

[0051] The oil fractions of different weights which are condensed out are indicated as W1 through W3 in the condenser unit 4-1. The oils of different weights are stored by the condensed liquid unit 4-2 in collection tanks as recovered oil products. The remaining non-condensed pyrolysis gas is input from the condenser unit 4-1 to the uncondensed gas unit 4-3 which extracts gas products that are stored in suitable tanks. Additionally, part of the uncondensed gas is supplied to the gas input unit 4-4 for use in the pyrolysis process. Another part of the uncondensed gas is supplied to the burner 3-1 for heat generation through combustion.

[0052] The batch process in one embodiment of the FIG. 1 pyrolysis system runs for an eight-hour batch cycle including approximately 4 hours heating and 4 hours cooling. During the batch cycle, pyrolysis of the tires takes place in a closed system. After the tires are loaded and the reactor chamber 2-2 is sealed, the pyrolysis period begins under control of the control unit 5. First, air within the reactor chamber 2-2 is evacuated during an initial purging with nitrogen gas from the gas input unit 4-4. The inert atmosphere of nitrogen gas is used to prevent combustion from occurring in chamber 2-2. The pressure inside the reactor chamber 2-2 is slightly above atmospheric pressure (+0.5 psi). In one embodiment, the reactor chamber 2-2 is housed in the heating chamber 2-1 which is in the form of a furnace above four burners constituting the burner 3-1 of the heating unit 3. The burners are capable of initially burning diesel fuel, if necessary for start up, and then burn uncondensed gas or oil from the pyrolysis process.

[0053] As the batch of waste tires is heated the pyrolyzing tires emit pyrolysis gas. The pyrolysis gas passes into the condenser unit 4-1 typically formed of three-stage, water-cooled condensation vessels where oil condenses out from the pyrolysis gas. After the condenser unit 4-1, the remaining gases pass to the uncondensed gas unit 4-3. The uncondensed gas unit 4-3 typically includes a wet scrubber to clean the gas before it is piped to the gas burner unit 3-1 to fuel the pyrolysis process.

[0054] The heating cycle continues until the internal reactor chamber 2-2 reaches a temperature of about 880 °C (1600 °F). Thereafter the reactor chamber 2-2 is allowed to begin the cooling cycle. As the reactor chamber 2-2 is cooling, it is once again purged with nitrogen gas from the gas input unit 4-4 and the gas that is released to the exhaust 2-4. Finally, the reactor chamber 2-2 is opened and the remaining carbon and steel are removed, separated, and placed in containers for further process pyrolysis processing.

[0055] A key feature of the pyrolysis process is that it is not labor-intensive, and it can be fully automated once the tires have been loaded into the reactor chamber 2-2. The system design relies heavily on automation under control of control unit 5 ensuring a high degree of safety and quality control.

[0056] A series of sensors, thermocouples, interlocks, and mechanical devices allow the pyrolysis system to operate safely within precisely controlled and timed temperatures and pressures. If any problems occur within the process, the pyrolysis unit will automatically shut down in a safe manner. The pyrolysis system of FIG. 1 automatically shuts down in a safe condition in case of a power failure. In the case of a malfunction, the control unit identifies the source of the problem.

[0057] The pyrolysis system 10 of FIG. 1 is intended to operate 24 hrs/7 days for 365 days per year. Assuming an average of 180 tires per batch run, 3 runs per day, 365 days per year, the pyrolysis system 10 processes (recycles) 197, 100 tires annually. Based on operational records, it is estimated that after recycling 197,100 tires, 3,942,000 pounds of tires (assuming average tire weight of 20 lbs per tire) will be completely recycled within a year. This recycling rate produces 394 tons of gas (20% of recovered products), 552 tons of oil (28% of recovered products), 256 tons of steel (13% of recovered products), and 769 tons of char (carbon black) (39% of recovered products).

[0058] The recovered oil products include 2.5A, 2.5B and 2.5C oil. Pyrolysis oil is similar in composition to light heating oil with slightly higher sulfur content than diesel fuel; 0.5% sulfur for diesel and 1.5% sulfur for pyrolysis oil. While the molecular structure of pyrolysis oil is similar to that of light heating oil, the calorific content is closer to that.
of diesel fuel. The bulk of the pyrolysis oil is typically sold to local fuel oil suppliers that blend the pyrolysis oil with heating oil to produce a lower-sulfur, blended fuel oil.

[0059] Approximately one-third to one-half of the recovered combustible methane/hydrogen gases are consumed by combustion in the burner 3-1 during the pyrolytic heating process. As the sensor on the pyrolysis gas vapor transfer line from the retort indicates the presence of sufficient combustible gases to fire the burners, the initial oil burners are shut down and the gas burners are ignited. The combustible gases pass through a wet scrubber and a water vapor trap in the uncondensed gas unit 4-3 prior to use. Although a flare stack is provided in the system of FIG. 1, it is not normally used since gases have been combusted and therefore consumed during the heating process in the burner 3-1 of the heating unit 3. To the extent that excess gas is available and not needed for the burner 3-1, the gas is used for co-generation or other energy needs.

[0060] The recovered char or carbon black is readily sold. The primary market is to tire manufacturers as a semi-reinforcing additive to rubber. Extensive use of industrial carbon produced using the batch pyrolysis process categorize the char as “semi-reinforcing black filler.” Secondary markets include the plastics industry, activated carbon, carbon filtration media, pigments and inks. Further processing of the carbon into small sizes greatly enhances the commercial value.

[0061] The recovered steel is sold for recycling. The steel consists primarily of ASTM 1080 quality metal and is readily marketable.

[0062] The unburned scrubbed gas and the excess heat produced by the retort heating and cooling processes can be marketed as a function of the location of the pyrolysis system. The excess heat is marketable directly when the pyrolysis system is located in or adjacent to an area where local users require a supply of heat for heating or cooling buildings or for other energy uses.

[0063] CO₂-rich air from the pyrolysis system is provided together with heat to support greenhouse operations. This option is dependent upon local conditions favorable to the greenhouse operation, such as the availability of sufficient nearby land and certain climatic conditions.

[0064] The excess gas, oil and other sources of energy available from the pyrolysis system are used for the direct or co-generation of electricity when there is a local market for electrical power. For such uses, the pyrolysis system is preferably located at a site reasonably close to the electrical power grid.

[0065] Since the batch processing occurs in the absence of oxygen and at very high temperatures, tire pyrolysis produces very little waste. Historically, hazardous air pollutants (HAPs) have been the largest environmental concern with continuous process (as distinguished from batch process) tire pyrolysis plants. These emissions are eliminated with the batch process since the off-gases are scrubbed and used as a heating fuel source. Post-process nitrogen purged gases are passed through a liquid scrubber and then flared. Test data indicates only trace concentrations of several polycyclic aromatic hydrocarbons (PAHs), in negligible quantities, are emitted.

[0066] The largest sources of air emissions are associated with the fuel for burner 3-1. The burner 3-1 is initially fueled with heating oil, if necessary and later with methane/hydrogen gas derived from the pyrolysis process. Air emissions from burning oil and methane have been calculated on the quantities of fuel (oil and gas) consumed during the recyling of 197,100 tires. According to the calculations, the combustion of methane produced 94 lbs. of NO₂ per year under the operating parameters (1,290,000 BTUs produced per day for 365 days per year and 0.2 lbs. of NO₂ released per million BTUs produced). Emissions from the oil burner for the 365-day operational period were calculated to be 0.79 tons PM10, 13.00 tons SO₂, 7.00 tons NOₓ, 0.33 tons CO and 0.39 tons of volatile organic compounds (VOCs).

[0067] Other emissions such as metals, radionuclides, vinyl chloride, fluorides, sulfuric acid mist, hydrogen sulfide, total reduced sulfur (TRS), or reduced sulfur compounds have been shown to be negligible or nonexistent.

[0068] Since pyrolysis occurs in an oxygen-free atmosphere, very little ash is produced. Ash stays mixed with the char remaining in the retort after pyrolysis is complete.

[0069] Incomplete pyrolyzed materials are avoided or if present are reprocessed until fully pyrolyzed. Control unit 5 monitors the retort temperature to prevent incompletely pyrolyzed materials from forming during pyrolysis.

[0070] A scrubber of the type manufactured by the Dural Division scrubs the gases produced by the pyrolytic process prior to their use as fuel. The scrubber wastewater is diluted and discharged to a sanitary system. The scrubber wastewater contains some PAHs and is slightly acidic, but is not a hazardous waste per federal and state guidelines.

[0071] FIG. 1, the pyrolysis system 10 include numerous temperature (T) sensors, gas chromatography sensors (C) and flow sensors (F) for monitoring and providing data for controlling the pyrolysis process. These sensors are generally everywhere present in the system and the typically locations are shown with one or more of the letters “T,” “C” or “F” in a circle. These sensors are typically connected to the control unit 5 and provide information to assist in control of the pyrolysis process. Additionally, each of the units in FIG. 1 receives control instructions from the control unit 5 and provides status and other information to control unit 5.

[0072] In FIG. 2, a pyrolysis system array 11 includes eight batch pyrolysis systems 10, of FIG. 1 type including the pyrolysis systems 10, 10, . . . , 10. The batch pyrolysis systems include the solid processing units 1, 1, . . . , 1, include the reactors 2, 2, . . . , 2, include the heating units 3, 3, . . . , 3, include the gas/liquid units 4, 4, . . . , 4, and the control unit 5 having the control units 5, 5, . . . , 5 all associated with the pyrolysis systems 10, 10, . . . , 10 respectively.

[0073] FIG. 2, each of the pyrolysis systems 10 includes numerous temperature (T) sensors, gas chromatography sensors (C) and flow sensors (F) for monitoring and providing data for controlling the pyrolysis process in each of the separate reactors 2. As indicated in connection with FIG. 1, these sensors are generally everywhere present in the system and are connected to the control unit 5 and provide information to assist in control of the pyrolysis processes. Additionally, each of the units, as in FIG. 1, receives control.
instructions from the control unit 5 and provides status and other information to control unit 5.

[0074] In FIG. 2, each of the reactors 2, including the reactors 2, 2, 2, separately completes a batch pyrolysis processing cycle. While separate heating units 3 and gas/liquid units 4 may be use in the array, economies of scale are provided when the reactors share parts of the heating and gas/liquid units. In one example, gas/liquid units 4 and 4 are replaced with a single gas/liquid unit 4. Such combinations are by way of example, as any combination of the gas/liquid units and/or the heating units is possible.

[0075] In FIG. 2, the control unit 5 control unit operates to sequence the pyrolysis systems 10 so that one or more of the batch pyrolysis reactors 2 is operating in a pyrolysis period whereby the array 11 is in continuous pyrolysis operation.

[0076] In FIG. 3, the pyrolysis system 10 includes a reactor 2 with multiple heat entry ports 3-3, 3-3, and 3-3, for distributing heat with improved distribution to the reactor 2 and the waste material 31. The waste material is shown, by way of example, as non-boiled tires 312-15. Each of the ports entry ports 3-3, 3-3, and 3-3, opens into the fire chamber 2-1 that surrounds the pyrolysis chamber 2-2 for applying the heat from the heat unit 3 more uniformly around the pyrolysis chamber 2-2. The implementation of the heat distribution in the entry ports 3-3, 3-3, and 3-3, the entry ports 3-3, and 3-3, in FIG. 3 are about half way up the walls of reactor 2. Various forms of the FIG. 3 embodiment are employed. For example, a separate burner is placed at each of the port openings into fire chamber 2-1 or alternatively, a centralized heater is used with blower distribution into entry ports 3-3, 3-3, and 3-3. The pyrolysis gas is vented through the ports 2-7 and pipe 2-6 to the gas/liquid unit 4. The reactor 2 includes a cover 2-12 which is removable for providing access to the pyrolysis chamber 2-2 and when closed is bolted or otherwise firmly attached by bolts of which bolts 2-13 are typical. The exhaust 2-4 is ported through the side wall of reactor 2 from the chamber 2-1. If desired the pyrolysis chamber 2-2 may be formed by a stainless steel or other high temperature-resistant material and can be formed as a removable element for ease of loading tires and removing residue.

[0077] FIG. 4 depicts a pyrolysis system having a reactor with multiple heat entry ports and multiple exhaust ports for distributing heat with improved distribution to the reactor. In FIG. 4, the pyrolysis system 10 includes a reactor 2 with multiple heat entry ports 3-3, 3-3, and 3-3, for distributing heat with improved distribution to the reactor 2. Each of the ports entry ports 3-3, 3-3, and 3-3, opens into the fire chamber 2-1 that surrounds the pyrolysis chamber 2-2 for applying the heat from the heat unit 3 more uniformly around the pyrolysis chamber 2-2. The implementation of the heat distribution in the entry ports 3-3, 3-3, and 3-3, the entry ports 3-3, and 3-3, in FIG. 4 are near the top of the walls of reactor 2 through openings 2-8, and 2-8. Various forms of the FIG. 4 embodiment are employed. For example, a separate burner is placed at each of the port openings into fire chamber 2-1 or alternatively, a centralized heater is used with blower or other distribution into entry ports 3-3, 3-3, and 3-3. In order to control the heat flow in the combustion chamber 2-1, the control units 18-1, 18-2 and 18-3 are provided, in some embodiments, for connection at the ports 3-3, 3-3, and 3-3, respectively. The pyrolysis gas is vented through the port 2-7 and pipe 2-6 to the gas/liquid unit 4. The reactor 2 includes a cover 2-12 which is removable for providing access to the pyrolysis chamber 2-2 and when closed is bolted or otherwise firmly attached by bolts of which bolts 2-13 are typical. The exhaust 2-4 is ported through the side wall of reactor 2 from the combustion chamber 2-1. If desired, the pyrolysis chamber 2-2 may be formed by a stainless steel or other high temperature-resistant material and can be formed as a removable element for ease of loading tires and removing residue.

[0078] FIG. 5, the pyrolysis system 10 includes a reactor 2 with vertical heat conductors 2-9 for injecting heated pyrolysis gas internal to the reactor chamber 2-2. In FIG. 5, the pyrolysis system includes a single heat entry port 3-5 for distributing heated gas with improved distribution into the pyrolysis chamber 2-2 through the heat conductors 2-9. The entry port 3-5 receives the heated gas from the heat exchanger 3-2 that in return receives selected portions of the pyrolysis gas from the gas/liquid unit 4. The heat conductors 2-9 open into and receive gas from the heated gas in the chamber 2-9. The chamber 2-9, is formed on the outside by an airtight wall 2-9, that functions to prevent the pyrolysis gas from penetrating the insulating core 2-15. The conductors 2-9 have openings at the top that inject the heated gas directly into the pyrolysis chamber 2-2. The injected pyrolysis gas heats the tires which in turn causes additional pyrolysis gas to be generated. The injected and generated pyrolysis gas is vented through the port 2-7 and piped to the gas/liquid unit 4 through pipe 2-6 for further processing. The reactor 2 includes a cover 2-12 which is removable for providing access to the pyrolysis chamber 2-2 and when closed is bolted or otherwise firmly attached by bolts of which bolts 2-13 are typical. In some embodiments, the pyrolysis chamber 2-2 and or the outer chamber 2-9, may be formed by a stainless steel or other high temperature-resistant material and can be formed so as to be a removable element for ease of loading tires and removing residue.

[0079] In FIG. 6, the pyrolysis system 10 includes a reactor 2 with vertical heat conductors 2-9 for injecting heated pyrolysis gas internal to the reactor chamber 2-2. In FIG. 5, the pyrolysis system includes a pyrolysis heat entry port 3-5 for distributing heated gas with improved distribution into the pyrolysis chamber 2-2 through the heat conductors 2-9. The entry port 3-5 receives the heated gas from the heat exchanger 3-2 that in return receives selected portions of the pyrolysis gas from the gas/liquid unit 4. The heat conductors 2-9 open into and receive gas from the heated gas in the chamber 2-9. The chamber 2-9, is formed on the outside by an airtight wall 2-9, that functions to prevent the pyrolysis gas from penetrating into the combustion chamber 2-1. The conductors 2-9 have openings at the top that inject the heated gas directly into the pyrolysis chamber 2-2. The reactor 2 combustion chamber 2-1 receives combusted gases from a burner in heat unit 3 through the port 3-3. The combustion gases encircle the pyrolysis chamber 2-2 and are vented through the port 2-16 and the exhaust 2-4. The combusted gases from port 3-3 and the injected pyrolysis gases from port 3-5 heat the tires in the pyrolysis chamber and this heating causes additional pyrolysis gas to be generated. The injected and generated pyrolysis gas is vented through the port 2-7 and pipe 2-6 to the
gas/liquid unit 4 for further processing. The reactor 2 includes a cover 2-12 which is removable for providing access to the pyrolysis chamber 2-2 and when closed is bolted or otherwise firmly attached by bolts of which bolts 2-13 are typical. In some embodiments, the pyrolysis chamber 2-2 and or the outer chamber 2-91 may be formed by a stainless steel or other high temperature-resistant material and can be formed so as to be a removable element for ease of loading tires and removing residue.

In FIG. 7, the pyrolysis system 10 has a reactor 2 with horizontal heat conductors 2-11 formed of pipes opening through the sidewalls of chamber 2-2 for distributing heat within the reactor chamber 2-2. In FIG. 7, the horizontal heat conductors 2-11 extend through the reactor chamber 2-2 and receive and carry heated gas from and to the heated combustion chamber 2-1. In FIG. 7, the reactor 2 includes multiple heat entry ports 3-3, 3-3, and 3-3, for distributing the heat from hot combustion gases heat to the reactor 2 and the pyrolysis chamber 2-2 through the heat conductors 2-11. The entry ports, such as ports 3-32 and 3-33, are typically aligned with one or more openings of the heat conductors 2-11 to help force combustion gases through the conductors 2-11 and hence heat the internal ports of the chamber 2-2. Various forms of the FIG. 7 embodiment are employed. For example, a separate burner is placed at each of the port openings into fire chamber 2-1 or alternatively, a centralized heater is used with blower or other distribution into entry ports 3-3, 3-3, and 3-3. In order to control the heat flow in the combustion chamber 2-1, the control units 18-1, 18-2 and 18-3 are provided, in some embodiments, for connection at the ports 3-3, 3-3, and 3-3, respectively. The pyrolysis gas generated by the tires is vented through the heat exchanger 2-7 and the pipe 2-6 to the gas/liquid unit 4 for further processing. The reactor 2 includes a cover (not shown) which is removable for providing access to the pyrolysis chamber 2-2. In some embodiments, the pyrolysis chamber 2-2 may be formed by a stainless steel or other high temperature-resistant material and can be formed so as to be a removable element for ease of loading tires and removing residue.

In FIG. 8, the pyrolysis system 10 includes a reactor 2 with vertically looped heat conductors 2-10 in the form of pipes for circulating heated gas from the heat unit 3 through the conductors 2-10 to the control chamber 2-1 and from there to the exhaust port 2-16. In FIG. 8, the reactor 2 has multiple heat entry ports 3-3, 3-3, 3-3, and 3-3, for distributing heat into the combustion chamber 2-1. The heat from the combustion gases in chamber 2-1 and the heat conductors 2-10 heats the pyrolysis chamber 2-2. The heat conductors 2-10 open at both ends relative to the combustion chamber 2-1 and are airtight with respect to the pyrolysis chamber 2-2 so that no combustion gas is introduced into the pyrolysis chamber 2-2. The pyrolysis gas generated by the tires is vented through the pipes 2-6, and 2-6, to the gas/liquid unit 4 for further processing. The reactor 2 includes a cover 2-12 which is removable for providing access to the pyrolysis chamber 2-2 and when closed is bolted or otherwise firmly attached by bolts of which bolts 2-13 are typical. In some embodiments, the pyrolysis chamber 2-2 may be formed by a stainless steel or other high temperature-resistant material and can be formed so as to be a removable element for ease of loading tires and removing residue.

In FIG. 9, typical ones 2-10, and 2-10, of the vertical heat conductors 2-10 of the pyrolysis system of FIG. 8 are shown. The conductors 2-10, and 2-10, include temperature sensors 9, and 9, respectively, for measuring the temperature internal to the pyrolysis chamber 2-2 of the reactor of FIG. 8. The temperature sensors 9, and 9, are at different heights so that temperatures at different heights in the pyrolysis chamber 2-2 of the reactor of FIG. 8 are obtained. For thermocouple sensors, the wire shields 10, and 10, are welded or otherwise fastened to the conductors 2-10, and 2-10, respectively.

In FIG. 10, the pyrolysis system 10 includes a reactor 2 with vertically looped heat conductors 2-10 in the form of pipes for circulating heated gas from the heat unit 3 through the conductors 2-10 to the combustion chamber 2-1 and from there to the exhaust port 2-16. The reactor 2 has multiple heat entry ports 3-3, 3-3, 3-3, 3-3, 3-3, and 3-3, for distributing combustion gases in the combustion chamber 2-1 and, with conductors 2-10, through the pyrolysis chamber 2-2. The heat from the combustion gases in chamber 2-1 and the heat conductors 2-10 heats the pyrolysis chamber 2-2. The heat conductors 2-10 open at both ends relative to the combustion chamber 2-1 but are airtight with respect to the pyrolysis chamber 2-2 so that no combustion gas is introduced into the pyrolysis chamber 2-2. The pyrolysis gas generated by the tires is vented through the pipes 2-6, and 2-6, to the gas/liquid unit 4 for further processing. The reactor 2 includes a cover 2-12 which is removable for providing access to the pyrolysis chamber 2-2 and when closed is bolted or otherwise firmly attached by bolts of which bolts 2-13 are typical. In some embodiments, the pyrolysis chamber 2-2 may be formed by a stainless steel or other high temperature-resistant material and can be formed so as to be a removable element for ease of loading tires and removing residue.

FIG. 10 depicts a cross sectional view, along section line 10-10 of the FIG. 11 view, of the pyrolysis system 10 and has vertical conductors 2-10 similar to those in the system of FIG. 8 each including an up leg and a down leg connected by a looped leg at the top. In FIG. 10, the vertical conductor up legs 2-10, and 2-10, and the two down legs 2-10, and 2-10, are shown. The conductor legs 2-10, and 2-10, receive heated combustion gas from heat unit 3 through controls 18-3 and 18-4 at the entry ports 3-3, and 3-3, and the heated gases flow upwardly from the bottom toward the top of pyrolysis chamber 2-2. The conductor down leg 2-10, receives heated combustion gases from another one of the vertical conductors 2-10, as indicated more particularly in FIG. 11, and heated gases flow downwardly from the top toward the bottom of pyrolysis chamber 2-2. The conductor up leg 2-10, receives heated combustion gases from another one of the vertical conductors 2-10, as indicated more particularly in FIG. 11, and heated gases flow upwardly from the bottom toward the top of pyrolysis chamber 2-2.

FIG. 11 shows a close up view of the pyrolysis system. FIG. 10 is shown with the cover 2-12 removed to expose a view of the tops of the vertical conductors 2-10. The heated gases from the heat unit 3 connect through control 18-3 to port 3-3, to the vertical conductor up leg 2-10. The vertical conductor up leg 2-10, is the beginning of the chain of connected loop conductors 2-10, 2-10, and 2-10. The conductor 2-10, vents into the combustion chamber 2-1. The heated gases from the heat unit 3 connect through control 18-4 to port 3-3 to the vertical conductor up
The vertical conductor up leg 2-10, is the beginning of the chain of the four most centered connected vertical conductors terminating in the downward leg 2-10₂, that vents into the combustion chamber 2-1. The heated gases from the heat unit 3 connect through control 18-7 to port 3-3, to the vertical conductor up leg of the loop conductor 2-10₁. The vertical conductor up leg for loop conductor 2-10₁ is the beginning of the chain of connected loop conductors 2-10₁, 2-10₂, 2-10₃, and 2-10₄. The loop conductor 2-10₂ has a down leg which vents into the combustion chamber 2-1. While the embodiment of FIG. 10 and FIG. 11 has the pairs of legs in the conductors 2-10 arrayed in two concentric circles, other numbers of circles and other arrays can be employed in order to provide preferential heat flow internal to the pyrolysis chamber 2-2. For example, three concentric rings or rows and columns of pairs of conductors can be employed.

Typically, several or all of the loop conductors 2-10 of FIG. 10 and FIG. 11 have temperature sensors as described for example in connection with FIG. 9 so that as the pyrolysis period is progressing, the temperature of the tire waste material is continuously measured. If any particular region is sensed to have a temperature variance relative to the other regions, the gas distribution through operation of the controls 18 is modified to correct any unwanted variance. The controls are effective both during heating and cooling periods. During cooling periods, the heat unit 3 typically circulates room temperature or cooler air through the combustion chamber and out through the exhaust 2-4.

In FIG. 12, the pyrolysis system 10 includes a reactor 2 (with the cover not shown) with combustion gas heat entry ports from burners 3-1, and 3-1. The FIG. 12 pyrolysis system has a fluted side wall 14 for improving heat distribution in the pyrolysis chamber 2-2 by improving heat distribution in the combustion chamber 2-1. The combustion gases encircle the pyrolysis chamber 2-2 in the combustion chamber 2-1, are directed upwardly by fluted wall 14 and are vented through the port 2-16. The combusted gases heat the tires in the pyrolysis chamber 2-2. While fluted walls are effective to direct the combustion gases from the bottom toward the top, grooves and other forms of contoured walls may be employed to channel heat up and around the pyrolysis chamber.

FIG. 13 depicts a sectional view near the bottom of the pyrolysis chamber of the pyrolysis system of FIG. 12 depicting the burner jets directed at an angle to increase the rotational motion of the combustion gas in the reactor fire box with improved heat distribution external to the reactor pyrolysis chamber. In FIG. 13, the burner jets 3-4, and 3-4, are directed at an angle toward the side walls rather than directly towards the center of the reactor to increase the rotational motion of the combustion gas in the reactor combustion chamber 2-1. The angle of the blown combustion gases (or cooling gases) into the chamber 2-1 helps the fluted wall 14 to receive and direct the gases up toward the vent 2-16 as shown in more detail in FIG. 14.

FIG. 14 depicts a view of a section of the fluted side wall of the pyrolysis system of FIG. 12. The wall of chamber 2-2 includes raised flutes 14, including flutes 14-1, 14-2, 14-3, 14-4 and 14-5. The flutes 14 receive the combustion gases 30 and direct them toward the top of the reactor.

FIG. 15 depicts a top view of the pyrolysis system of FIG. 10 and is labeled to indicate the flutes labeled in FIG. 14.

FIG. 16 depicts a sectional/perspective view of a pyrolysis system having a reactor 2 with vertical heat conductors 2-14 extending from the bottom of the pyrolysis chamber 2-2, through the internal region of the chamber 2-1 and exiting through the side wall of the chamber 2-2 to the combustion chamber 2-1. The vertical heat conductors 2-14 are in the form of pipes for circulating heated gas from the heat unit 3 through the conduits 2-14 to the combustion chamber 2-1 and from there to the exhaust port 2-16. Some of the conductors 2-14 extend from the bottom of the pyrolysis chamber 2-2 and exit near the top into the combustion chamber 2-1 while others of the conductors 2-14 extend from the bottom of the pyrolysis chamber 2-2 and exit the side wall about one third the way up from the bottom into the combustion chamber 2-1. The different heights of the heat conductors 2-14 helps accommodate changes that occur to the waste material in the pyrolysis chamber during pyrolysis. At the beginning of the pyrolysis period, waste tires or other waste material fills to the top of the pyrolysis chamber 2-2. At this time, the heat conductors that exit near the top are effective and heat flow can be preferentially channeled to them. However, when the pyrolysis period is well along, the waste material shrinks so that only approximately the bottom one third of the pyrolysis chamber is filled with a residue. At this time, the heat conductors that exit near the one third height of the pyrolysis chamber are effective and heat flow can be preferentially channeled to them. Accordingly, the preferential channelling during the heating portion of the pyrolysis period is different than during the cooling portion of the pyrolysis period. In FIG. 16, the reactor 2 has multiple heat entry ports 3-3, for example one for each of the conductors 2-14 and one at the base for the combustion chamber 2-1, for distributing heat into the combustion chamber 2-1. The entry ports 3-3 each include a control 18 for regulating the flow to each of the different ports. The controls 18 in some embodiments are dynamic and are adjusted under commands from a control unit (not shown, but like control unit 5 in FIG. 1) running under computer control and in other embodiments are manually changed mechanical configurations for adjusting flow. While a control 18 has been shown separately for each conductor 2-14, controls can be grouped for two or more conductors or may be eliminated entirely. The heat from the combustion gases in chamber 2-1 and the heat conductors 2-14 heats the pyrolysis chamber 2-2. The heat conductors 2-14 open at the top end relative to the combustion chamber 2-1 but are airtight with respect to the pyrolysis chamber 2-2 so that no combustion gas is introduced into the pyrolysis chamber 2-2. The pyrolysis gas generated by the tires is vented through the pipe 2-6 to the gas/liquid unit 4 for further processing. The reactor 2 includes a cover (not shown) which is removable for providing access to the pyrolysis chamber 2-2 and when closed is bolted or otherwise firmly attached.

In FIG. 16, only a single circle of heat conductors 2-14 are shown. However, as described in connection with FIG. 11 two or more circles and other configurations of heat conductors are fully contemplated.

The invention has been shown and described with reference to a number of different embodiments. Common
among the embodiments is preferentially channeling the heat to and from the waste material. The preferential channeling occurs both external and internal to the pyrolysis chamber. In the embodiments of FIG. 3 and FIG. 4, for example, the heat is preferentially channeled external to the pyrolysis chamber 2-2 through multiple input ports to the combustion chamber 2-1. By insertion of heat through the multiple ports not only at the bottom but higher on the sides up from the bottom, the pyrolysis chamber is more uniformly heated and thereby improves the heat transfer in the waste material in the pyrolysis chamber 2-2.

[0093] In the embodiment of FIG. 5 and FIG. 6, the preferential channeling is accomplished internal to the pyrolysis chamber 2-2 by means of vertical heat conductors 2-9. The vertical heat conductors 2-9 are distributed through and in contact with the tire waste material in the pyrolysis chamber 2-2. The heat transfer in the waste material is greatly enhanced both for heating and cooling. Additionally in FIG. 6, channeling is also to the outside of the pyrolysis chamber 2-2 with the ability to balance between internal and external channeling by controlling the balance of the flow between external port 3-3 and internal port 3-5.

[0094] In the embodiments of FIG. 7, FIG. 8, FIG. 10 and FIG. 16, the preferential channeling is accomplished internal to the pyrolysis chamber 2-2 by means of heat conductors 2-11, 2-10, 2-10 and 2-14, respectively, together with the controls 18 when present.

[0095] In the embodiment of FIG. 12, the preferential channeling is accomplished external to the pyrolysis chamber 2-2 by means of angular burners and/or fluted side walls.

[0096] While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the invention.

1. A batch pyrolysis reactor for the recovery of pyrolysis products by batch processing waste material comprising,
   a pyrolysis chamber having an opening for receiving and extracting solids,
   a port for purging oxygen from the pyrolysis chamber,
   cycling means for cycling the temperature of waste material in the pyrolysis chamber over a pyrolysis period including,
   preferentially channeling heat to the waste material to accelerate raising the temperature of the waste material to a pyrolysis temperature, and
   preferentially channeling heat from the waste material to accelerate cooling the temperature of the waste material,
   a port for porting pyrolysis gas from the reactor during the pyrolysis period and leaving a solid residue in the pyrolysis chamber after the pyrolysis period.
2. The reactor of claim 1 including a combustion chamber surrounding said pyrolysis chamber with sides extending from a bottom to a top and wherein said cycling means for preferentially channeling includes one or more ports in said sides for injecting gases into said combustion chamber for accelerating the heating and cooling of said pyrolysis chamber.
3. The reactor of claim 2 wherein said ports are in said sides near the middle of the pyrolysis chamber.
4. The reactor of claim 2 wherein said ports are in said sides near the top of the pyrolysis chamber.
5. The reactor of claim 1 including a combustion chamber surrounding said pyrolysis chamber with sides extending from a bottom to a top and wherein said cycling means for preferentially channeling includes one or more ports in the bottom and one or more ports in said sides for injecting gases into said combustion chamber for accelerating the heating and cooling of said pyrolysis chamber.
6. The reactor of claim 5 including means for controlling the flow to each of said ports whereby the heat is preferentially channeled among said ports.
7. The reactor of claim 1 including a combustion chamber surrounding said pyrolysis chamber and wherein said cycling means for preferentially channeling includes one or more heat conductors extending into, while being sealed from, said pyrolysis chamber whereby combustion gases flow in said combustion chamber and in said heat conductors whereby heating and cooling is accelerated at internal portions of the pyrolysis chamber.
8. The reactor of claim 7 wherein said combustion chamber extends around side walls extending from a bottom to a top of the pyrolysis chamber and wherein said heat conductors are horizontal pipes extending through and from side wall to side wall of the pyrolysis chamber.
9. The reactor of claim 8 including means for controlling the flow to said heat conductors whereby heat is preferentially channeled through said heat conductors.
10. The reactor of claim 7 wherein said combustion chamber extends around a bottom of the pyrolysis chamber and wherein said heat conductors are vertical pipes extending from the bottom of and up into the pyrolysis chamber.
11. The reactor of claim 10 including means for controlling the flow to said heat conductors whereby heat is preferentially channeled through said heat conductors.
12. The reactor of claim 10 wherein said heat conductors are vertical pipes organized in pairs with a closed loop at the top whereby gases flow up in one pipe of a pair and down in another pipe of the pair.
13. The reactor of claim 12 including means for controlling the flow to one pipe of the pair of said heat conductors whereby heat is preferentially channeled up through one pipe of a pair and down in another pipe of the pair to vent into said combustion chamber.
14. The reactor of claim 10 wherein said pairs are arranged in two or more concentric rings.
15. The reactor of claim 1 wherein said cycling means for preferentially channeling includes one or more heat conductors extending into and opening in said pyrolysis chamber whereby pyrolysis gases flow into said pyrolysis chamber through said heat conductors whereby heating and cooling is accelerated at internal portions of the pyrolysis chamber.
16. The reactor of claim 1 including a combustion chamber surrounding said pyrolysis chamber and one or more ports sealed from said pyrolysis chamber whereby combustion gases flow in said combustion chamber around and sealed from said pyrolysis chamber and wherein said cycling means for preferentially channeling includes one or more heat conductors extending into and opening in said pyrolysis chamber whereby pyrolysis gases flow into said pyrolysis chamber through said heat conductors and whereby heating
and cooling is accelerated at internal portions of the pyrolysis chamber and at external portions of the pyrolysis chamber.

17. The reactor of claim 16 including means for controlling the flow to said one or more ports and to said heat conductors whereby heat is preferentially channeled through said heat conductors and said combustion chamber.

18. The reactor of claim 1 including a combustion chamber surrounding said pyrolysis chamber with sides extending from a bottom to a top and wherein said cycling means for preferentially channelling includes one or more burners with nozzles directed at an angle for injecting gases into said combustion chamber so as to cause a rotational swirl to the combustion gases.

19. The reactor of claim 18 wherein said combustion chamber includes contoured walls for directing said combustion gases toward the top.

20. The reactor of claim 19 wherein said contoured walls are fluted.

21. The reactor of claim 1 further including sensor means for sensing the temperature at multiple locations internal to said pyrolysis chamber.

22. The reactor of claim 21 wherein said sensor means includes thermocouples supported by heat conductors internal to said pyrolysis chamber.

23. The reactor of claim 1 where the waste material is waste tires.

24. The reactor of claim 1 where the waste material is automobile fluff.

25. The reactor of claim 1 where the waste material is hospital waste.

26. A pyrolysis system for the recovery of pyrolysis products by processing waste material comprising,

   a batch pyrolysis reactor including,
   a pyrolysis chamber having an opening for receiving and extracting solids,
   a port for purging oxygen from the pyrolysis chamber,
   cycling means for cycling the temperature of waste material in the pyrolysis chamber over a pyrolysis period including,
   preferentially channelling heat to the waste material to accelerate raising the temperature of the waste material to a pyrolysis temperature, and
   preferentially channelling heat from the waste material to accelerate cooling the temperature of the waste material,
   a port for porting pyrolysis gas from the reactor during the pyrolysis period and leaving a solid residue in the pyrolysis chamber after the pyrolysis period,
   a solid processing unit for placing waste material in the pyrolysis chamber prior to the pyrolysis period and for removing the solid residue after the pyrolysis period,
   a heating unit for heating and cooling the pyrolysis chamber during the pyrolysis period,
   a gas/liquid unit for processing the pyrolysis gas to form liquid and gas pyrolysis products,
   a control unit for controlling the pyrolysis system.

27. The pyrolysis system of claim 26 wherein said gas/liquid unit includes a condenser unit for cooling the pyrolysis gas to provided liquid products and uncondensed gas, an uncondensed gas unit connected for processing the uncondensed gas to provide gas products including fuel to fire the batch pyrolysis reactor.

28. The pyrolysis system of claim 27 wherein said condenser unit operates over different temperature ranges to fractionally condense oils of different weights and wherein said gas/liquid unit includes a condensed liquid unit for processing and storing oil products by weights.

29. An array for the recovery of pyrolysis products by processing waste material, said array comprising,

   a plurality of pyrolysis systems and a control unit for controlling the pyrolysis systems, each pyrolysis system comprising,
   a batch pyrolysis reactor including,
   a pyrolysis chamber having an opening for receiving and extracting solids,
   a port for purging oxygen from the pyrolysis chamber,
   cycling means for cycling the temperature of waste material in the pyrolysis chamber over a pyrolysis period including,
   preferentially channelling heat to the waste material to accelerate raising the temperature of the waste material to a pyrolysis temperature, and
   preferentially channelling heat from the waste material to accelerate cooling the temperature of the waste material,
   a port for porting pyrolysis gas from the reactor during the pyrolysis period and leaving a solid residue in the pyrolysis chamber after the pyrolysis period,
   a heating unit for heating and cooling the pyrolysis chamber during the pyrolysis period,
   a solid processing unit for placing waste material in the pyrolysis chamber prior to the pyrolysis period and for removing the solid residue after the pyrolysis period,
   a gas/liquid unit for processing the pyrolysis gas to form liquid and gas pyrolysis products.

30. The array of claim 29 wherein said control unit operates to sequence said pyrolysis systems with one or more of said batch pyrolysis reactors operating in a pyrolysis period whereby said array is in continuous pyrolysis operation.

31. The array of claim 29 wherein two or more heating units are combined for groups of batch pyrolysis reactors.

32. The array of claim 29 wherein said port for purging oxygen from the pyrolysis chamber is supplied with nitrogen.

33. The array of claim 29 wherein two or more gas/liquid units are combined for groups of batch pyrolysis reactors.

34. A method for the recovery of pyrolysis products by batch processing waste material in a pyrolysis reactor comprising,

   placing the waste material in a pyrolysis chamber,
   sealing the pyrolysis chamber to exclude oxygen,
purging said pyrolysis chamber with nitrogen to remove oxygen,
cycling the temperature of the waste material in the pyrolysis chamber over a pyrolysis period including,
first, raising the temperature of the waste material to a pyrolysis temperature by preferentially channeling heat to the waste material to accelerate the heating process, and
second, cooling the waste material by preferentially channeling heat from the waste material to accelerate the cooling process,
extracting pyrolysis gas from the reactor during the pyrolysis period,
processing the pyrolysis gas to form liquid and gas pyrolysis products,
unsealing the reactor,
extracting a solid residue from the pyrolysis chamber.

35. A method according to claim 34 characterized by introducing and circulating a preheated inactive gas in a starting phase of the pyrolysis period in order to preheat the waste material in the reactor.

36. A method according to claim 34 characterized in introducing and circulating a relatively cool inactive gas in a final phase of the pyrolysis period in order to achieve a rapid cooling.

37. A method according to claim 34 characterized by measuring the relative amount and the composition of the pyrolysis gas and using the information obtained for controlling and regulating the pyrolysis period.

38. A method according to claim 37 characterized in that chromatographs are used to determine the composition of the pyrolysis gas.

39. A method according to claim 37 characterized in that the composition of the pyrolysis gas is measured at a port from the pyrolysis chamber and at a condenser in a gas/liquid unit receiving the pyrolysis gas.

40. A method according to claim 34 wherein the waste material is in a largely fragmented condition.

41. A method according to claim 34 wherein the waste material is heated to a temperature of from 450 to 600 degree C.

42. A method according to claim 34 wherein the waste material is heated to a temperature of from 800 to 900 degree C.