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(71) Applicant: **ECO GARB LTD** [BG/BG]; 2B Serdika Str., 8000 Burgas (BG).

(72) Inventors: **TODOROV, Nikolay Vasilev**; jk Slaveykov bl.80, Entr.2, fl.8, 8010 Burgas (BG). **KOHAN Illia,**; Obolonskaya Naberezhnaya 11/2, ap.1, 04211 Kiev (UA). **IVANOV, Emil Ivanov**; 5, Shipeto Str., 1641 Vladaya village, Sofia (BG).

(74) Agent: **PAVLOVA, Silva**; village of Vlado Trichkov, 2299 Sofia (BG).

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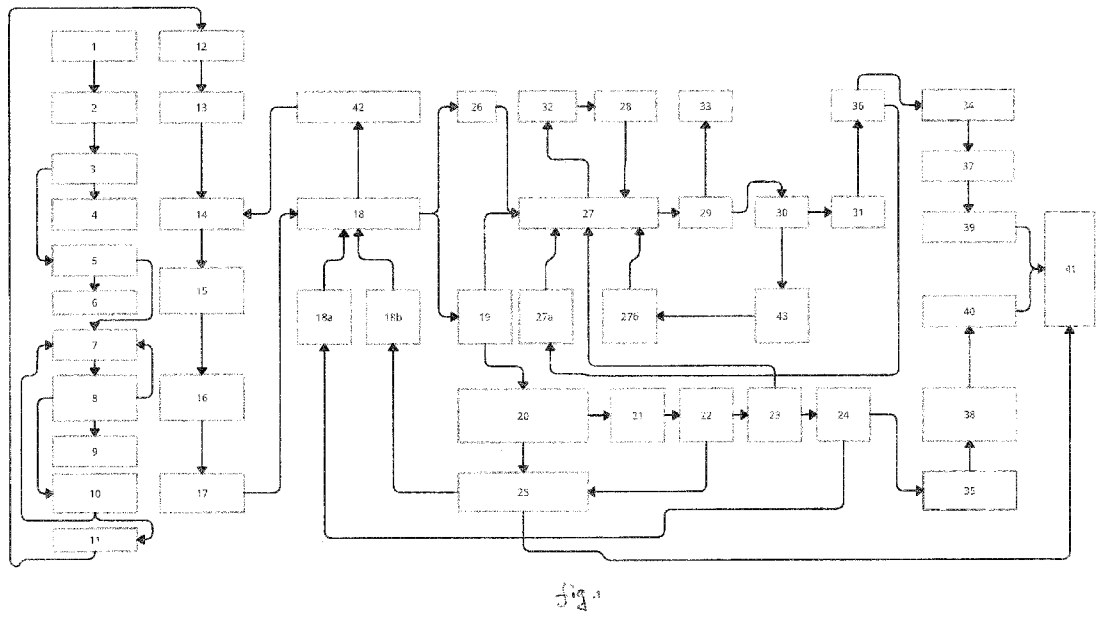
(54) **Title:** TECHNOLOGICAL LINE INTENDED FOR MUNICIPAL SOLID WASTE PROCESSING



Фиг. 1

(57) **Abstract:** This technological line intended for processing of municipal solid waste is used for recovery of biomass, plastic, rubber, paper and other household and industrial wastes which are not recyclable but contain hydrocarbons and constitute an energy source. Pyrolysis is carried out in two separate pyrolysis reactors, the first is a medium-temperature reactor in which mixed waste is processed at temperatures from 850° C to 950° C, and the second is a high- temperature reactor up to 1100 ° C for processing pyrocarbon. As a result, maximum destruction of solid waste is achieved, with a total power generation of 6.6 MW, and the residual product /ash/ is reduced to 2% and used as inert material and soil conditioner, making the technology zero-emission and environmentally friendly.

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TECHNOLOGICAL LINE INTENDED FOR MUNICIPAL SOLID WASTE PROCESSING

FIELD OF THE INVENTION

The technological line intended for municipal solid waste processing refers to the field associated with the recovery of municipal solid waste by means of pyrolysis to generate electricity.

PRIOR ART

Patent documents have been made available and known to public domain disclosing systems for generating electrical energy generated by means of pyrolysis of municipal solid waste.

Document US 4 077 847 A, published on 07.03.1978, relates to a method and an installation intended for waste products processing and recovering components valuable with respect to the economy. The processes involved are shredding of the solid waste in a shredder, magnetic separation aimed at separating the metallic impurities, separation of the organic and inorganic fraction of the non-metallic waste, and separation of the glass. The organic fraction is dried in a dryer and subjected to pyrolysis at temperatures ranging from 600 ^{0} F to 2000 ^{0} F, which releases pyrolysis oil, gas, and ash.

Document BG 66586 B1, published on 30.06.2017, refers to a method and installation associated with the waste hydrocarbon products processing and the recovery of the resulting products. The plant intended for the processing of waste hydrocarbon products and the recovery of the resulting products comprises a pyrolysis reactor equipped with a charging hopper and a device designated for the removal of the solid residue produced during pyrolysis, cyclones intended for cleaning the steam gas mixture of solid impurities and condensers for separating the steam gas mixture into pyrolysis liquid and pyrolysis gas, a re-circulation pipeline for returning part of the pyrolysis gas to the pyrolysis zone and a gasifier connected via a gas mixer to a thermal power station.
The closest technical solution is considered to be document BG 4103 U1 published on 31.08. 2021, in which a technological line intended for the municipal solid waste processing is presented, which includes a shredder - breaker, a metal separator, a second separator for the separation of glass and inert fractions connected sequentially by means of conveyor belts, a second shredder intended for additional shredding, a hopper designed for intermediate storage of the shredded waste, a dryer, a third separator for the inert fraction, a hammermill, a second hopper for intermediate storage, dispenser with shutter and a pyrolysis reactor. The pyrolysis reactor is, on the one hand, connected by means of a gas conveyor to a cyclone connected to a filter for additional clearing of gas mixtures, which is connected to cooling columns

connected via a gas filter to a gas hopper. The gas hopper is **functionally** connected to a power generation module. On the other hand, the pyrolysis reactor is connected to a temporary pyrocarbon storage hopper connected to a gasifier. The filter for further cleaning of gas mixtures is also connected to the gasifier, and the cooling columns are also connected to a pyrolysis oil filter connected to a pyrolysis oil storage hopper which is connected to the power generation module. The gas hopper is connected to the first and second gas burners supplying the pyrolysis reactor and the gasifier respectively. The pyrolysis oil storage hopper is also connected to the first and second diesel burners supplying the pyrolysis reactor and the gasifier, respectively. The gasifier is connected to an ash storage hopper.

TECHNICAL NATURE OF THE INVENTION

The objective of the present invention is to provide a technological line intended for municipal solid waste processing aimed at generating electricity, achieving a maximum recovery rate of the processed waste and consequently increasing the amount of electricity produced.

The objective is achieved by additionally introducing two separate pyrolysis reactors, the first one constitutes a medium temperature reactor in which mixed waste is processed at temperatures from 850° C to 950° C and the second one is a high temperature reactor up to 1100° C designed for pyrocarbon processing. As a result, maximum destruction of solid waste is achieved, with the residual product /ash/ reduced to 2 % and used as inert material and soil conditioner, making the technology zero-waste and ensuring an environmentally friendly mode of operation.

The present installation is used for processing biomass, plastic, rubber, paper and other household and industrial wastes that are not subject to recycling but contain hydrocarbons and that represent an energy source.

Through the shredding and **grinding** operations carried out in three shredders, a reduced particle size of solid waste is achieved, which, combined with the 10% moisture content achieved after the drying process, results in rapid and almost complete combustion of the incoming feedstock in the pyrolysis reactors, where pyrolysis is carried out at pressures of 20 mbar to 25 mbar.

In the shredder-breaker (1) a particle size of about 1000 mm is achieved, in the double-shaft shredder (7) the particle size is ranging from 50 to 250 mm, and in the single-shaft shredder (15) the particle size is from 1 mm to 40 mm, and under certain conditions, depending on the type of solid domestic waste, a particle size of 1 mm to 20 mm is achieved.

Instead of the hammer mill used in the prior art, a single shaft shredder is provided to obtain the specified final particle size of the processed raw material. In this manner, greater efficiency and safety of operation is achieved, as well as a reduction in respect of the amount of electricity utilized.

Due to the small particle size, a low moisture content of 10% is achieved in the treated raw material under optimum water evaporation regime, with which it is stored and fed for pyrolysis.

The introduction of an X-ray scanner in the present technological line constitutes a solution not known from the referenced prior art document, which contributes to a more precise

separation of poor in carbon waste. This leads to an increase in the quality of the feedstock undergoing pyrolysis, which contributes to an increase in the amount of electricity produced per tonne of feedstock.

As a result of the above differences with respect to the prior art, the calorific value of the components released from the pyrolysis process has been increased, with a value of 30.2 MJ/kg and a density of 1.1 kg/m3 for the pyrolysis gas, 31.348 MJ/kg and a density of 1018 kg/m3 for the pyrolysis oil, and 8.28 MJ/kg and a density of 600 kg/m3 with respect to the pyrocarbon.

The improvement of the preparatory operations, such as crushing, separation and drying of the feedstock, as well as the inclusion of a second pyrolysis reactor leads to an increase in the qualities and quantities of components separated per tonne of feedstock, as follows: pyrocarbon - 0.4 t, pyrolysis oil - 0.3 t and pyrolysis gas - 0.3 t. These values are subject to upwards or downwards adjustments in the range of 15-20%, depending on the operating modes of the pyrolysis reactors and the quality of the feedstock.

The data as mentioned above demonstrates that the present technological line intended for municipal solid waste treatment achieves, compared to the prior art, provides a maximum degree of processing of the incoming feedstock to high calorific value products, which are subjected to pyrolysis in two separate pyrolysis reactors, resulting in an increase in the total amount of electricity generated to 6.6 MW.

The technological line intended for the processing of municipal solid waste includes the following devices for the pre-treatment of the incoming feedstock. Consecutively connected by means of conveyor belts are a first shredder-breaker(1), a manual sortation device (2), a first magnetic separator for metal removal (3), a first metal hopper (4), a second magnetic separator (5), a second hopper (6), a double-shaft shredder (7), an aggregate separator (8), a third hopper (9) for aggregate storage, an X-ray scanner (10) and a fourth hopper (11) for cleaned feedstock. The fourth hopper (11) is connected to a fifth hopper (12), which in turn is connected to a dosing hopper (13), a drying hopper (14), a single-shaft shredder (15), a sixth hopper (16) and a dosing hopper with a shut-off valve (17). The first magnetic separator (3) is connected to the second magnetic separator, which is connected to the double-shaft shredder (7). The aggregate separator (8) is connected on one side to the double-shaft shredder (7) and on the other side to the X-ray scanner (10), which is connected to the double-shaft shredder (7). The closed-valve dosing hopper (17) is connected to the medium-temperature pyrolysis reactor (18), which is connected via a first heat exchanger (42) to the dryer (14), the first heat exchanger (42) also being connected to a flue gas stack. The medium-temperature pyrolysis reactor (18) is connected on one side to a pyrocarbon hopper (26), which is connected to a high-temperature pyrolysis reactor (27), and on the other side, by means of a first cyclone (19) again to the high-temperature pyrolysis reactor (27). The high temperature pyrolysis reactor (27) is connected via a second heat exchanger (32) to a steam generator (28) which is connected to the high temperature pyrolysis reactor (27). In turn, the high temperature pyrolysis reactor (27) is connected via a second cyclone (29), a second cooler (30) and a group of filters (31) to a second gas burner (36) connected via a second burner (34) and a second boiler (37) to a first thermal oil heat exchanger (39), which is connected to an electricity module (41). The second cooler (30) is connected via the second pyrolysis oil reservoir (43) to a second oil burner (27b) for heating the high temperature pyrolysis reactor (27).

The first cyclone (19) is connected on one hand, sequentially, with a first cooler (20), a first group of filters (21), first cooling columns (22), a filtration system (23), a filtration system (23), a first gas burner (24), a first burner (35), a first reservoir (38), a second heat exchanger (40) which is connected to the electricity(power) module (41).
On the other hand, the first cyclone (19) is connected via a first cooler (20) and via a first oil reservoir (25) to the electricity(power) module (41).
A first gas burner (24) is connected to a first gas burner (18a), and first cooling columns (22) through a first oil tank (25) are connected to a first oil burner (18b). the first gas burner (18a) and the first oil burner (18b) heat the medium-temperature pyrolysis reactor (18), the filtration system (23) is connected to the high-temperature pyrolysis reactor (27).
A second gas burner (27a) is also used to heat the high temperature pyrolysis reactor (27), which is connected to a second gas burner (36).
The second cooler (30) supplies a second oil burner (27b) via a second pyrolysis oil tank (43).

DESCRIPTION OF THE ENCLOSED DRAWINGS

Fig.1. illustrates a technological line intended for municipal solid waste processing

1 - shredder breaker

2 - manual sorting device

3 - first magnetic separator

4 - first metal hopper

5 - second magnetic separator

6 - second hopper

7 - double-shaft shredder

8 – aggregate(inert material) separator

9 - third hopper

10 - X-ray scanner

11 - fourth hopper

12 - fifth hopper

13 - dosing hopper

14 - dryer

15 -single shredder

16 - sixth hopper

17 - dosing hopper with shut-off valve

18 - medium temperature pyrolysis reactor

18a - first gas burner
18b - first oil burner

19 - first cyclone

20 - first scrubber cooler

21 - first group of filters

22 - first cooling columns

23 - filtration system

24 - first gas generator

25 - first oil tank

26 - pyrocarbon hopper

27 - high temperature pyrolysis reactor

27 a - second gas burner

27 b - second oil burner

28 - steam generator

29 - second cyclone

30 - second cooler

31 - second group of filters

32 - second heat exchanger

33 - ash hopper

34 - second burner
35 - first burner

36 - second gas burner

37 - second reservoir

38 - first reservoir

39 - first heat exchanger for thermal oil

40 - second heat exchanger for thermal oil

41 - electricity (power)module

42 - first heat exchanger

43 - second pyrolysis oil tank

EXAMPLES OF EMBODIMENT OF THE INVENTION

The attached example illustrate preferred embodiments on an illustrative basis with respect to the invention but do not limit to the embodiments described herein.

EXAMPLE 1

Initially, the incoming feedstock is subjected to crushing and separation, entering shredder breaker 1 where it is crushed to a particle bearing size of 1000 mm. This process is subsequently followed by manual sorting, which removes any hazardous waste in the incoming MSW such as flammable items, for example gas cylinders, thereby preventing explosions and mechanical damage to the technological line. After manual sorting 2, the raw material is fed into a first magnetic separator 3 to separate the metal impurities, which are stored in a first metal hopper 4. The cleaned raw material is conveyed by means of a conveyor belt to a second magnetic separator 5, after which it enters a double-shaft shredder 7, where the particle size is reduced from 80 mm to 150 mm. The raw material is conveyed by belt conveyor to separator 8 for separation of aggregates. In the third hopper 9, soil and stones are separated and the coarse fraction from the stream is returned to the double-shaft shredder 7 for further grinding. The remaining raw material stream is conveyed to X-ray scanner 10 where glass, ceramic, etc. carbon-poor waste is separated from the stream and fed into a fourth hopper 11.

The X-ray scanner 10 scans the waste and separates it according to its molecular weight, separating it by type.

The coarse fraction above 150 mm is returned to the double-shaft shredder 7 for additional shredding, and the purified feedstock enters a fifth hopper 12 for storage prior to the dryer 14. From the fifth hopper 12, by means of a belt conveyor, the raw materials enter a dosing hopper 13, after which they are fed into the dryer 14, where their moisture content is reduced to 10%.
After drying, the raw materials are fed via a belt into a single-shaft shredder 15, where they are ground to a particle size of 1 to 20 mm, depending on the type of municipal solid waste. It then enters a sixth hopper 16 for storage of the finished feedstock for pyrolysis.
Raw materials obtained after separation that cannot be separated, recycled or put into reuse, dosed by means of a raw material conveying screw with a frequency regulator, are fed into a dosing hopper with a shut-off valve 17. In this manner, an accumulation of raw materials is ensured which undergo pyrolysis. For this purpose, by means of an auger, the raw materials from the dosing hopper with shut-off valve 17 are fed into a medium temperature pyrolysis reactor 18 for mixed waste.

The medium-temperature pyrolysis reactor 18 is designed for thermal treatment at a temperature of 850°C of the feedstock in an oxygen-free environment to produce pyrocarbon pyrolysis gas and pyrolysis oil. The reactor consists of a combustion chamber and an auger made of heat resistant, stainless materials. The reactor is fitted with heat resistant insulation which contributes to its high efficiency. The sealing materials allow the reactor to operate at temperatures up to 1100° C. In order to distribute the temperature evenly over the entire length of the reactor, three burners are used, located in the furnace below the reactor. The three burners indirectly heat the reactor to ~900-1000° C.

The combustion chamber of the medium temperature pyrolysis reactor 18 is equipped with an exhaust gas removal apparatus. Prior to venting the gases to the atmosphere, their temperature is vented to a first heat exchanger 42 where steam is heated which participates in drying the pyrolysis feedstock in the dryer 14. The residual cooled flue gases (>35 °C) are emitted to the atmosphere in a controlled manner via a stack /not shown in Figure 1/. The venting of the dust-free gas-air mixture (flue gases from the reactor combustor) is related to the following systems:

- for its own continuous (automatic) measurements of emissions of nitrogen oxides, carbon monoxide, total dust (particulate matter), total organic carbon, hydrogen chloride, hydrogen fluoride and sulphur dioxide;

- for its own continuous measurements of the volumetric flow, pressure and temperature of the waste gases and their oxygen and water vapour content;

- for the continuous measurement of total dust, sulphur dioxide, nitrogen dioxide, carbon monoxide, hydrogen chloride, humidity, hydrogen fluoride and total organic carbon.

In the medium-temperature pyrolysis reactor 18, decomposition (destructuring) of municipal waste is carried out to obtain energy raw materials - pyrocarbon 40% (charcoal), pyrolysis gas 60%. After destructuring, the pyrolysis gas separated from the medium temperature pyrolysis reactor (18) enters the first cyclone 19, which cleans it from large particles (pyrocarbon), and then undergoes cooling in the first cooler - scrubber 20, designed for pre-cooling of pyrolysis

gases supplied from the medium temperature pyrolysis reactor 18. The body of the first scrubber 20 is made of heat resistant steel and contains refrigeration copper pipes. A first pyrolysis oil tank 25 is provided for the accumulation of the liquid fraction with waste impurities. Refrigerant circulation is provided by a hydraulic system equipped with centrifugal pumps. The first pyrolysis oil tank 25 is provided with liquid drain hatches, which provides for easier maintenance. The gas mixture is then moved to a first group of filters (bubbler) 21 for additional purification of the associated gases supplied by the scrubber cooler 20. The body of the first group of filters 21 is made of heat-resistant steel and is covered with glass thermal insulation to avoid condensation. After filtration, the mixture is transported to cooling columns 22 where it is cooled and separated into liquid and gaseous mixtures. The cooling columns 22 are designed to maximize the liquefaction and cooling of the associated gases supplied by the first group of filters 21.

The body of the cooling columns 22 is made of heat resistant steel. Reservoirs are provided for storage of the liquid impurity fraction. The refrigerant is supplied by means of a fan. A pyrolysis oil station is installed in the plant for draining the liquid. Hatches are provided for ease of maintenance. The cooled mixture after the cooling columns 22 passes through a filtration system 23, which is designed for final filtration of the associated gases supplied by the refrigeration unit.

The filtration system 23 consists of a number of filters with different degrees of purification, made of heat resistant stainless steel. Special compartments, fitted with hatches for ease of maintenance, are provided for the collection of residues from the liquid fraction with impurities of heavy resins with pyrocarbon particles. After the filtration system 23, the mixture is transported to a first gas storage tank 24, which feeds the gas burner 18a, and a first pyrolysis oil tank 25 feeds the first oil burner 18b, which support the combustion process of the medium temperature pyrolysis reactor 18.

The liquid phase, pyrolysis oil, separated from the filter by the cooling columns 22 is filtered and transported to the first pyrolysis oil tank 25, which on the one hand feeds the electricity module 41 and on the other hand also feeds the diesel oil burner 18b, which supports the operation process of the medium temperature pyrolysis reactor 18. The separated heavy fraction of the pyrolysis oil from the filtration system 23 is fed to the high temperature pyrolysis reactor 27, where it undergoes high temperature pyrolysis up to 1100° C.
The separated pyrocarbon from the medium-temperature pyrolysis reactor 18 is conveyed by means of an auger conveyor to a pyrocarbon hopper 26 for temporary storage, which feeds the high-temperature pyrolysis reactor 27. In the high-temperature pyrolysis reactor 27, at a temperature of 1100 °C, in combination with a dosed steam supply at a temperature of up to 1100 °C from the steam generator 28, pyrocarbon gas is produced. The hydrogen-pyrogen gas enters a second cyclone 29, where it is cleaned of fines, then fed to a second cooler 30 for cooling and is directed to a second group of filters 31 for condensation and then enters a second gas holder 36 for storage.
The second heat exchanger 32 uses the flue gases from the high temperature pyrolysis reactor 27 and preheats the steam for the steam generator 28.

The second cyclone 29, located downstream of the high temperature pyrolysis reactor 27, emits the only waste, ash in an amount of about 2%, which enters the ash hopper 33.
The second cooler 30 is connected to a second pyrolysis oil tank 43, from which the second oil burner 27b is fed to heat the high temperature pyrolysis reactor 27.
The second burner 34 and the first burner 35, fed by gas from the second gas burner 36 and the first gas burner 24, respectively, preheat the first reservoir 38 and the second reservoir 37. Through the first thermal oil heat exchanger 39 and the second thermal oil heat exchanger 40, thermal energy is transferred to the electricity(power) module 41.

EXAMPLE 2

In this example, the processes taking place in the devices of the MSW technological line are identical to the one demonstrated in Example 1. The only difference rests with the particle size of the MSW, which after the double-shaft shredder 7 is about 150 mm, and the final particle size of the feed material for pyrolysis obtained after the single-shaft shredder 15 ranges from 30 mm to 40 mm. In order to achieve an optimum operating mode of the technological line, pyrolysis in the medium temperature pyrolysis reactor 18 is conducted at a temperature of 950° C.

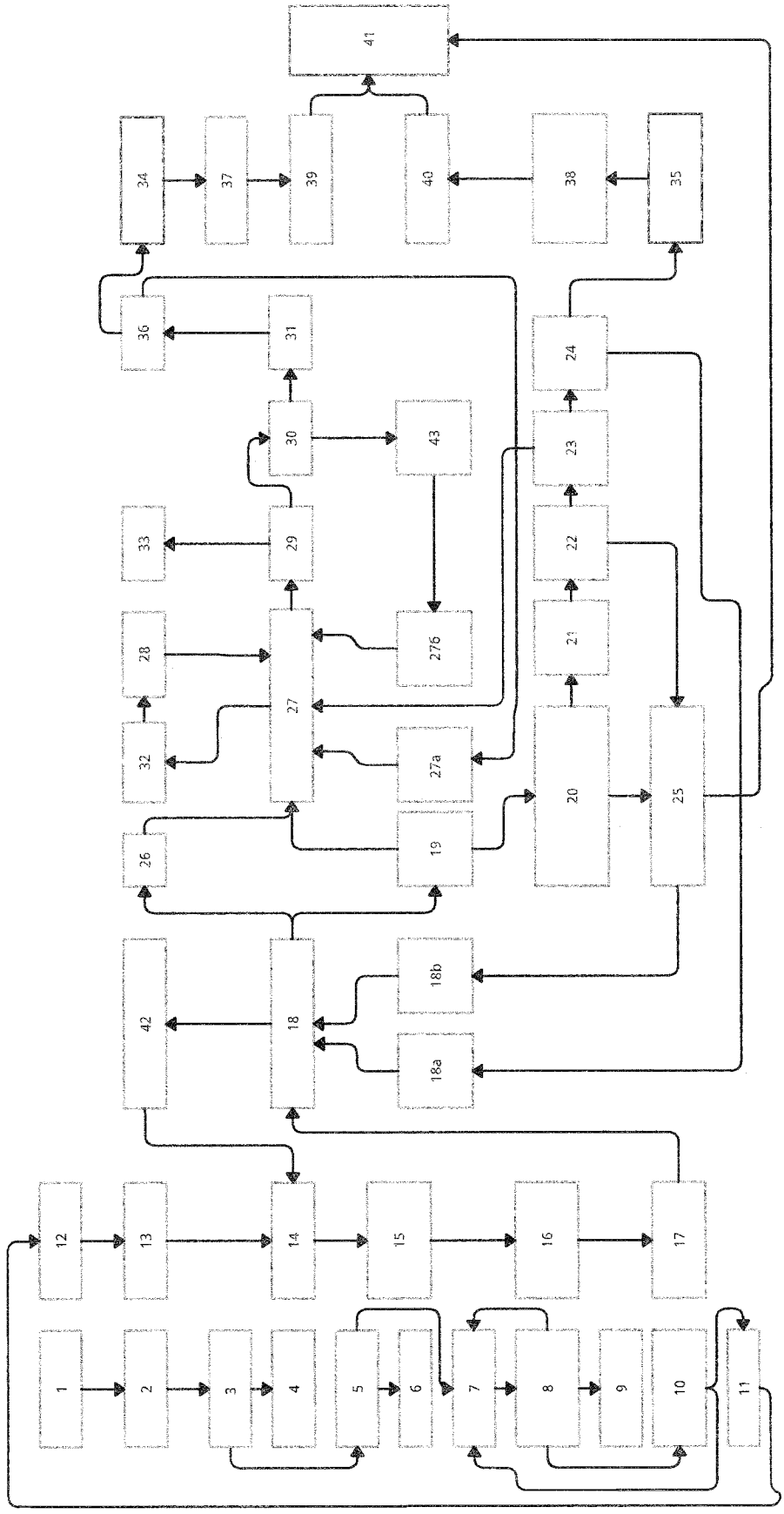
The advantages provided by the invention are :

By means of the present technological line for the processing of municipal solid waste, maximum recovery of the waste is achieved, using 19% of the energy input for its conversion, and the remaining 80.65% of the energy is retained as energy value in the form of thermal energy or electricity produced. This result is due to the optimum mode of operation of the devices included in the plant, as well as the two-stage pyrolysis carried out in two different pyrolysis reactors operating at different temperatures. In this manner, reduced costs and a high rate of waste recovery are achieved. This determines that the MSW treatment plant is highly efficient, since it maximises the energy value of the waste and transforms it into thermal energy or electricity depending on the needs: electricity production by means of steam turbines, internal combustion engines and ORC plants.

PATENT CLAIMS

1.Municipal solid waste technological line which includes shredder breaker, magnetic separator, aggregate separator, dryer, pyrolysis reactor, gas burners, oil burners, cyclones, filters, cooling columns, hoppers and an power module, characterized in that it also includes a second magnetic separator (5), an X-ray scanner (10), two pyrolysis reactors, a first heat exchanger (42), a second heat exchanger (32), a first thermal oil heat exchanger (39), a second thermal oil heat exchanger (40), a steam generator (28), a first reservoir (38), a second reservoir (37), with a shredder-breaker (1) connected sequentially with a manual sorting device (2), a first magnetic separator (3) for removing metals, a first metal hopper (4), a second magnetic separator (5), a second hopper (6), a double-shaft shredder (7), an aggregate separator (8), a third hopper (9), an X-ray scanner (10), and a fourth hopper (11), wherein the fourth hopper (11) is connected to a fifth hopper (12) sequentially with a dosing hopper (13), a dryer (14), a single-shaft shredder (15), a sixth hopper (16) and a dosing hopper with a shut-off valve (17), wherein the first magnetic separator (3) is connected to the second magnetic separator (5), which is connected to the double-shaft shredder (7), and the aggregate separator (8) is connected on one hand to the double -shaft shredder (7) and on the other side to the X-ray scanner (10), which is connected to the double-shaft shredder (7), wherein the metering hopper with shut-off valve (17) is connected to the medium-temperature pyrolysis reactor (18), which is connected via a first heat exchanger (42) to the dryer (14), the first heat exchanger (42) being connected to a flue gas stack and the medium temperature pyrolysis reactor (18) being connected on one side to a pyrocarbon hopper (26) which is connected to a high temperature pyrolysis reactor (27), and on the other via a first cyclone (19) again with the high temperature pyrolysis reactor (27), the high temperature pyrolysis reactor (27) being connected via a second heat exchanger (32) to a steam generator (28) which is connected to the high temperature pyrolysis reactor (27) which in turn via a second cyclone (29), a second cooler (30) and a second group of filters (31) is connected to a second gas burner (36) connected via a second burner (34) and a second reservoir (37) to a first thermal oil heat exchanger (39) which is connected to a power module (41), and the second cooler (30) is connected via a second pyrolysis oil tank (43) to a second oil burner (27b) for heating the high temperature pyrolysis reactor (27), and the first cyclone (19) is connected sequentially with a first cooler (20), a first group of filters (21), first cooling columns (22), a filtration system (23), a first gas generator (24), a first burner (35), a first reservoir (38), a second thermal oil heat exchanger (40), which is connected to the power module (41), on the other hand the first cyclone (19) is connected via a first cooler (20) and via a first pyrolysis oil reservoir (25) to the electricity module (41), wherein the first gas burner (24) is connected to a first gas burner (18a), and the first cooling columns (22) through the first oil reservoir (25) are connected to a first oil burner (18b) heating the medium temperature pyrolysis reactor (18), and the filtration system (23) is connected to the high temperature pyrolysis reactor (27), wherein a second gas

burner (36) is connected to a second gas burner (27a) heating the high temperature pyrolysis reactor (27).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INTERNATIONAL SEARCH REPORT

International application No
PCT/BG2023/000022

A. CLASSIFICATION OF SUBJECT MATTER
INV. C10G1/10 C10G9/18
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C10G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2023/045385 A1 (MENNELL JAMES A [US] ET AL) 9 February 2023 (2023-02-09) paragraphs [0010], [0015], [0022], [0560], [0601], [0638], [0656], [0715], [1037]	1
A	WO 2016/175387 A1 (GREEN SCIENCE CO LTD [KR]) 3 November 2016 (2016-11-03) paragraphs [0002], [0007], [0028], [0032], [0042]	1
A	WO 2023/087075 A1 (PLASTRON SOLUTIONS PTY LTD [AU]) 25 May 2023 (2023-05-25) paragraphs [0052], [0054], [0055], [0112] - [0116]; figures 1,2	1

☐ Further documents are listed in the continuation of Box C.

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European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Chau, Thoi Dai

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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