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(71) Applicant: **INDIAN INSTITUTE OF TECHNOLOGY MADRAS (IIT MADRAS)** [IN/IN]; The Dean, Industrial Consultancy & Sponsored Research [ICSR], Indian Institute Of Technology Madras, IIT P.O, Chennai 600 036 (IN).

(72) Inventors: **R, Vinu**; Department of Chemical Engineering and National Center For Combustion R&D, Indian Institute of Technology Madras, IIT P.O, Chennai 600 036 (IN). **S. R, Chakravarthy**; Department of Chemical Engineering and National Center For Combustion R&D, Indian Institute of Technology Madras, IIT P.O, Chennai 600 036 (IN). **B.V.S.S.S., Prasad**; Department of Chemical Engineering and National Center For Combustion R&D, Indian Institute of Technology Madras, IIT P.O, Chennai 600 036 (IN). **C, Punithan**; Department of Chemical Engineering and National Center For Combustion R&D, Indian Institute of Technology Madras, IIT P.O, Chennai 600 036 (IN). **BHARATHI, Raja**; Department of Chemical Engineering and National Center For Combustion R&D, Indian Institute of Technology Madras, IIT P.O, Chennai 600 036 (IN). **T., Sundararajan**; Department of Chemical Engineering and National Center For Combustion R&D, Indian Institute of Technology Madras, IIT P.O, Chennai 600 036 (IN).

(74) Agent: **SUNDAR, Swapna** et al.; PVS Giridhar and Sai, Advocates, No. 319, Linghi Chetty Street, III Floor, George Town, Chennai 600001 (IN).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, IT, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(54) **Title:** ROTARY KILN INCINERATOR FOR GENERATING ENERGY FROM MUNICIPAL SOLID WASTE (MSW)

(57) **Abstract:** A rotary kiln incinerator for municipal solid waste (MSW) incineration and recovering the heat energy from the combustion gases. A rotary kiln (6) with steam jacket is configured with a sieve mesh (7) for receiving and processing the completely unsegregated municipal solid waste (MSW) from a shedder unit (1) via a belt conveyor (2) wherein a heat exchanger unit (9) configured with the rotary kiln (6) for recovering the heat contained in the gas fuel and continuously produce steam in the kiln system (100), and the ash generated in the rotary kiln (6) is received at ash collecting tray (8). A wet scrubber unit (12) and a filter unit (13) for controlling the toxic emission levels in the gas fuels. An exhaust gas emission analyser unit (12) measures and monitors the exhaust gas emission levels to provide a safe and secure MSW treatment unit.

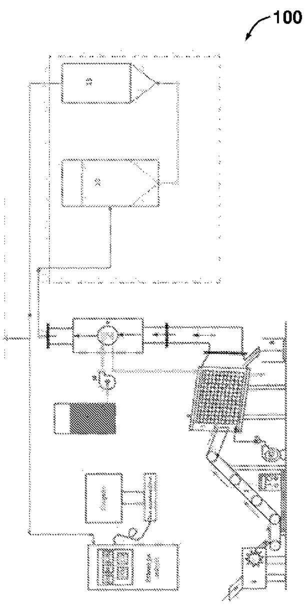

FIG.1

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[Continued on next page]

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ROTARY KILN INCINERATOR FOR GENERATING ENERGY FROM MUNICIPAL SOLID WASTE (MSW)

TECHNICAL FIELD

[0001] The present invention generally relates to waste management systems and methods. The present invention is additionally related to municipal solid waste (MSW) management systems and methods. The present invention also relates to energy generation techniques from municipal solid waste (MSW). The present invention specifically relates to an improved rotary kiln incinerator for municipal solid waste (MSW) incineration and recovering the heat energy along with the emission treatment of flue gases.

BACKGROUND OF THE INVENTION

[0002] Municipal Solid Waste (MSW) management has become a very important aspect of urban living, in particular, in largely populated cities and urban locations across the world. A decade ago, land-fills are popularly used for burying the solid waste which has become unviable due to the large volumes of waste being produced with the growing population in the urban demographics.

Also, contamination of the ground water and soil pollution is a major challenge associated with the conventional land fill approach.

[0003] Across the world, an increasing need emerges for an effective MSW management system for the effective processing of solid wastes. In the current scenario, mostly 80% of the waste collected ends up in landfills without any treatment. In particular in India, 1247 landfills are in use already, 1305 sites have been identified for future use as per the MSW management manual (2016).

[0004] However, landfilling of such a massive amount of waste is extremely harmful where there is an increase of soil pollution and ground water pollution in the urban locations.

[0005] Additionally, such conventional MSW management systems can lead to release of harmful chemicals from the wastes that may percolate through the soil and contaminate the groundwater and soil. Also, in many places, open burning of MSW is still in practice which causes severe air pollution because of uncontrolled combustion leading to uncontrolled release of toxics including CO, SOx, NOx, HCL, PCDD (Polychlorinated dibenzodioxins), and PCDF (Polychlorinated dibenzofurans) into the atmosphere.

[0006] The Notification on Municipal Solid Waste Management (Management & Handling), Rules, 2000 introduced by Govt. of India recommends four popular methods of waste management including composting techniques, vermicomposting, anaerobic digestion, and incineration approaches. Such conventional approaches are helpful in production of useful energy by tapping into the energy potential of combustible materials, and simultaneous reduction in the volume of solid waste to be disposed-off.

[0007] However, the conventional approaches pose several challenges in handling the waste. The MSW is a very low calorific value fuel, with roughly 25-30% of the calorific value of biomass (~ 4-5 MJ/kg). It usually contains a significant fraction of moisture and the drying of MSW (before its combustion) will consume significant amount of energy. A need for efficient design of combustor for MSW is required to achieve complete combustion with residual products such as, for example, but not limited to bottom ash, fly ash and flue gas.

[0008] Furthermore, the incineration of MSW is a challenge where harmful emissions involving acid gases such as, SOx, NOx, HCl and HF; CO, soot and unburnt hydrocarbons; heavy metals such as mercury and lead; PCDDs and

PCDFs may enter the atmosphere via bottom ash, fly ash, flue gas and flue gas cleaning residues. The solid/ liquid residues of flue gas cleaning equipment themselves participate as secondary sources for the production of PCDD and PCDF. Finally, the conventional furnace accessories, cleaning & heat exchange equipment and power generation equipment may themselves be exposed to corrosive components present in the combustion products, which may significantly reduce the life span of the components.

[0009] Alternatively, in one embodiment of prior art, removal of non-combustibles and segregation of plastics from MSW is proposed to address the challenges associated with MSW management. However, the enormous effort involved in the segregation process makes such prior art approaches uneconomical.

[00010] Rotary kilns are simple in construction and offer good mixing because of the rotary motion. Long residence times are also possible for the complete burning of combustible fractions in MSW. Heat recovery using water walls/ tubes can be performed as a post-combustion activity. Gas clean up using wet/dry scrubbers and catalytic converters, and suitable leaching of solid combustion products (bottom ash and fly ash) of harmful chemicals could also be carried out as a post- combustion activity. Also, it may be required to use a secondary fuel (like kerosene) to augment combustion of MSW once in a while when the MSW feed's calorific value is temporarily very low. Energy generation techniques using rotary kilns are energy neutral approach at some scale that needs to be determined empirically.

[00011] However, heterogeneity in MSW is a major challenge both at the site of disposal and in the dumpsites and landfills. A typical MSW contains a number of bio-organic and bio-inorganic components including kitchen wastes, cooked food wastes, plastics, papers, wrappers, garden wastes, flowers/vegetable wastes from markets, coconut shells, used cotton/cloth, jute, waste footwear, foams to name a few. In addition, a number of inerts including sand, gravel, glass bottles, aluminum canisters, metallic bottle caps, etc. are present in a typical unsegregated MSW. The calorific value of the worst type of MSW can be as low as 5-8 MJ/kg with high amount of moisture in it, and that of good quality MSW can be as high as 30 MJ/kg containing plastic wastes and refuse derived fuels (RDF).

[00012] Conventional, thermochemical technologies, including pyrolysis and gasification are not suitable for such poor quality fuels which are mainly attributed to the high and variable moisture content with time. Such processes require a costly pre-drying step to reduce the moisture content in the feed to ~10-15%, which is not economical on a large scale MSW treatment application. Also, conventional furnace designs for MSW incinerators include fixed/inclined grate and vibrating/stoker grate. Owing to the widely varying size of the feedstock and its heterogeneous nature with significant inerts, sustaining the flame without the supply of auxiliary fuel or without segregating the feed is a challenge.

[00013] Based on the foregoing a need therefore exists for an improved rotary kiln for treatment of municipal solid waste (MSW). Also, a need exists for an improved rotary kiln incinerator for municipal solid waste (MSW) incineration and recovering the heat energy along with emission treatment, as discussed in greater detail herein.

SUMMARY OF THE INVENTION

[00014] The following summary is provided to facilitate an understanding of some of the innovative features unique to the disclosed embodiment and is not intended to be a full description. A full appreciation of the various aspects of the embodiments disclosed herein can be gained by taking the entire specification, claims, drawings, and abstract as a whole.

[00015] Therefore, one aspect of the disclosed embodiment is to provide for an improved rotary kiln for treatment of municipal solid waste (MSW).

[00016] It is another aspect of the disclosed embodiment to provide for improved rotary MSW combustor based on the fact that sustained combustion can be achieved in the furnace when the unsegregated wastes are allowed to gently tumble while simultaneously removing the fine inert particles using a novel sieve mesh technique within the combustion zone.

[00017] It is further aspect of the disclosed embodiment to provide for an improved rotary kiln incinerator for municipal solid waste (MSW) incineration and recovering the heat energy along with emission treatment.

[00018] The aforementioned aspects and other objectives and advantages can now be achieved as described herein. An improved rotary kiln incinerator for municipal solid waste (MSW) incineration and recovering the heat energy from the combustion gases generated in the rotary kiln, is disclosed herein. A rotary kiln (6) with steam jacket is configured with a sieve mesh (7) for receiving and processing the municipal solid waste (MSW) from a shedder unit (1) via a belt conveyor (2) wherein a heat exchanger unit (9) is configured with the rotary kiln (6) for recovering the heat contained in the combustion gases, and continuously produce steam in the kiln system (100), and the ash generated in the rotary kiln (6) is received at ash collecting tray (8). A wet scrubber unit (12) and a filter unit (13) for controlling the toxic emission levels in the flue gases and thereby control the toxic emission levels in the rotary kiln system (100), wherein an exhaust gas emission analyser unit (12) measures and monitors the exhaust gas emission levels in order to provide a safe and secure municipal solid waste (MSW) treatment along with energy recovery (100).

[00019] The rotary kiln (6) is a cylindrical drum unit made of aluminum material with a measurement of 450mm diameter and 650mm length wherein the sieve mesh (7) with 400mm diameter and length comprising 1cm×1cm square opening for effective combustion of unsegregated feedstock is configured inside the rotary kiln (6). The rotary kiln (6) comprises a wheel (21) that is operatively configured (welded) with the sieve mesh (7), supporting gear units (23) and a trimming gear

(22) that is connected to a DC motor unit. A forced draft fan (4) connected to a rotameter (5) for supplying air to the rotary kiln (6) for combustion of the MSW in the rotary kiln (6).

[00020] The rotary kiln (6) is insulated on its surface. As it is inclined, the waste material gets automatically pushed into the kiln (6), and the ash particles are collected through an exit port located at the rear bottom end of the kiln (6). The shell and tube heat exchanger unit (9) that is connected to a water tank (11) and a pump (10) is of cross flow type to recover heat from the flue gases exiting in the kiln (6). Stainless steel is used for the construction of the shell of dimension 900 mm × 810 mm × 400 mm. Copper is used for the construction of the tube of diameter 12.7 mm and length 100 m. The tube is fabricated along with the fin made of aluminium.

[00021] The rotary kiln system (100) proposed herein is a unique and improved system comprising the rotary kiln (6) with the rotating sieve mesh (7) to segregate the inerts during combustion, and hence, sustain the flame. The efficient design to treat MSW containing bio-organics and bio-inorganics with moisture (up to 25%) without the use of any auxiliary fuel, and up to 40% with auxiliary fuel spray. The invention teaches better control over NOx and SOx by conducting combustion at low temperatures, which is also facilitated by the moisture present in the feedstock.

BRIEF DESCRIPTION OF DRAWINGS

[00022] The drawings shown here are for illustration purpose and the actual system will not be limited by the size, shape, and arrangement of components or number of components represented in the drawings.

[00023] FIG. 1 illustrates a schematic view of the improved rotary kiln (100) incinerator for municipal solid waste (MSW) incineration and recovering the heat energy from the emission treatment, in accordance with the disclosed embodiments;

[00024] FIG. 2 illustrates a cross section view of the rotary kiln (6) illustrating the internal parts of the rotary kiln (6), in accordance with the disclosed embodiments; and

[00025] FIG. 3 illustrates a schematic top view and front view of the rotary kiln (6), in accordance with the disclosed embodiments.

DETAILED DESCRIPTION

[00026] The particular values and configurations discussed in these non-limiting examples can be varied and are cited merely to illustrate at least one embodiment and are not intended to limit the scope thereof.

[00027] FIG. 1 illustrates a schematic view of the improved rotary kiln (100) incinerator for municipal solid waste (MSW) incineration and recovering the heat energy from the emission treatment, in accordance with the disclosed embodiments. The system 100 includes a rotary kiln (6) with steam jacket is configured with a sieve mesh (7) for receiving and processing the municipal solid waste (MSW) from a shedder unit (1) via a belt conveyor (2) wherein a heat exchanger unit (9) configured with the rotary kiln (6) for recovering the heat contained in the gas fuel and continuously produce steam in the kiln system (100) and the ash generated in the rotary kiln (6) is received at ash collecting tray (8). A wet scrubber unit (12) and a filter unit (13) for controlling the toxic emission levels in the gas fuels and thereby control the toxic emission levels in the rotary kiln system (100) wherein an exhaust gas emission analyser unit (12) measures and monitors the exhaust gas emission levels in order to provide a safe and secure disposal of municipal solid waste (MSW) along with recovery of heat energy in the kiln system (100).

[00028] FIG. 2 illustrates a cross section view of the rotary kiln (6) illustrating the internal parts of the rotary kiln (6), in accordance with the disclosed embodiments. The rotary kiln (6) is a cylindrical drum unit made of aluminum material with a measurement of 450mm diameter and 650mm length wherein the sieve mesh (7) with 400mm diameter and length comprising 1cm×1cm square opening for effective combustion of unsegregated feedstock is configured inside the rotary kiln (6). The rotary kiln (6) comprises a wheel (21) that is operatively configured (welded) with the sieve mesh (7), supporting gear units (23) and a trimming gear (22) that is connected to a DC motor unit to control the speed of rotation of the sieve mesh. A forced draft fan (4) connected to a rotameter (5) for supplying air to the rotary kiln (6) for combustion of the MSW in the rotary kiln (6).

[00029] The rotary kiln (6) is insulated on its surface. As it is inclined, the waste material gets automatically pushed into the kiln (6), and the ash particles are collected through an exit port located at the rear end of the kiln (6). The shell and tube heat exchanger unit (9) that is connected to a water tank (11) and a pump (10) is of cross flow type to recover heat from the flue gases exiting in the kiln (6). Stainless steel is used for the construction of the shell of dimension 900 mm × 810 mm × 400 mm. Copper is used for the construction of the tube of diameter 12.7 mm and length 100 m. The tube is fabricated along with the fin made of aluminium.

[00030] FIG. 3 illustrates a schematic top view and front view of the internals of the rotary kiln (6), in accordance with the disclosed embodiments. The arrangement of the air supply tubes with holes in it for admitting air for combustion is shown. The typical feed rate of the MSW was fixed at 10 kg/hr, although it can be increased upto 100 kg/hr. The rpm of the sieve mesh (7) was optimized to 1. With higher rpm, the flame was put off by the whole mass of material that is circulated in the kiln (6). Feed rate was calculated as the product of speed of belt (in m/min) and kg/m of waste transported through the conveyor belt (2). The combustor was designed for 30-50% fill fraction. Air needed at stoichiometry (in kg/kg fuel) was calculated using the formula [11.521C+34.56H+4.32(S-O)]/100, and the equivalence ratio was fixed at 0.8.

The carbon conversion efficiency was high (94%) when a 1 cm × 1 cm sieve mesh (7) was used, as compared to 87% when a 2 cm × 2 cm mesh was used, corresponding to a feed containing 25% moisture with 45:35:10:10 fraction of organics: plastics: paper: dry leaves.

[00031] Moisture in the feedstock played a significant role in determining the rate of combustion, and in turn the throughput of the system. For example, the feed with 10% moisture got burnt completely (with 98% carbon conversion efficiency) in almost half the time, which was consumed by a 25% moisture feed (whose carbon conversion efficiency was 94%). The steam temperature in the former case was 112°C. With the installation of emission treatment units like filter and scrubber, the composition of CO and CO_2 in the exhaust gases reduced as compared to that when the emission treatment units were not employed.

[00032] Compared to Indian boiler emission norms, the composition of CO, CO_2, SO_2, NOx, TOC, HCl, HF, particulates were within limits. Maximum temperature of the exhaust gases was within 600°C, and average temperature was 230-280°C. This resulted in NOx levels in the exhaust within the allowed limits as per 2016 MSW boiler emission norms. The dioxins and furans were not directly measured, but their presence was monitored by bubbling the exhaust gases through a solvent bath. Dioxin and furan derivatives in <0.1 area% in GC/MS (gas chromatograph/mass spectrometer) were observed. The ash surface morphology and composition were measured using energy dispersive spectroscopy technique. A typical ash sample contained: F (2.8%), Na (0.97%), Mg (2.1%), Al (0.13%), Si (10%), P (1%), Cl (3.6%), K (8.15%), Ca (2%) and Ni (2.4%). The quality and composition of ash depends significantly on the type of feedstock.

[00033] Table 1 depicts the typical feed composition classified according to different grades that were employed in the experiments. Table 2 shows the proximate analysis, elemental analysis and calorific value.

Moisture (wt. %)	Mixture Composition (wt. %)				Grade	
	Organic	Plastic	Paper	Dry leaves		
10	22.5	47.5	10	10	1A	High grade
	47.5	22.5	10	10	1B	
	22.5	22.5	22.5	22.5	1C	
25	20	35	10	10	2A	Medium grade
	35	20	10	10	2B	
	18.75	18.75	18.75	18.75	2C	
40	10	40	5	5	3A	Low grade
	40	10	5	5	3B	
	15	15	15	15	3C	

TABLE-1

Grade	Mixture composition (wt. %)				Proximate analysis (wt. % db)				Ultimate analysis (wt. % db)					Calorific value (MJ/kg)
	Organic	Plastic	Paper	Dry leave	M	VM	A	FC	C	H	N	S	O	
-	100	0	0	0	14.7	68.9	11.8	4.6	37.4	11.7	3.4	0	35.7	13.4
-	0	100	0	0	0	91.4	0	8.6	85.8	0	0	0	14.2	45.8
-	0	0	100	0	8.6	78.2	7.4	5.8	39.5	5.7	2.0	0	45.4	14.9
-	0	0	0	100	13.8	67.1	7.8	11.3	43.1	6.5	6.2	0	36.4	15.8
1A	25	50	12.5	12.5	6.2	86.9	4.6	2.3	62.5	4.5	1.9	0	26.5	29.8
[redacted]														
1C	25	25	25	25	8.5	82.8	6.2	2.5	51.4	6.0	2.9	0	33.5	22.9

TABLE-2

[00034] The rotary kiln system (100) proposed herein is a unique and improved system comprising the rotary kiln (6) with the rotating sieve mesh (7) to segregate the inerts during combustion, and hence, sustain the flame. The efficient design to treat MSW containing bio-organics and bio-inorganics with moisture (up to 25%) without the use of any auxiliary fuel, and up to 40% with auxiliary fuel spray. The invention teaches better control over NOx and SOx by conducting combustion at low temperatures, which is also facilitated by the moisture present in the feedstock.

[00035] It will be appreciated that variations of the above-disclosed and other features and functions, or alternatives thereof, may be desirably combined into many other different systems or applications. Also, that various presently unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art which are also intended to be encompassed by the following claims.

CLAIMS

I/We CLAIM:

1. An improved rotary kiln (100) incinerator for municipal solid waste (MSW) incineration and recovering the heat energy along with emission treatment, comprising:

a rotary kiln (6) with steam jacket is configured with a sieve mesh (7) for receiving and processing the municipal solid waste (MSW) from a shedder unit (1) via a belt conveyor (2);

a heat exchanger unit (9) configured with the rotary kiln (6) for recovering the heat contained in the combustion gases and continuously produce steam in the kiln system (100) and the ash generated in the rotary kiln (6) is received at ash collecting tray (8).

a wet scrubber unit (12) and a filter unit (13) for controlling the toxic emission levels in the gas fuels and thereby control the toxic emission levels in the rotary kiln system (100) wherein an exhaust gas emission analyser unit (12) measures and monitors the exhaust gas emission levels in order to provide a safe and secure municipal solid waste (MSW) treatment into a heat energy in the kiln system (100).

2. The system as claimed in claim 1 wherein the rotary kiln (6) is a cylindrical drum unit made of aluminum material with a measurement of 450mm diameter and 650mm length wherein the rotating sieve mesh (7) with 400mm diameter and length comprising 1cm×1cm square opening for effective combustion of unsegregated feedstock is configured inside the rotary kiln (6).

3. The system as claimed in claim 1 wherein the rotary kiln (6) comprises:

a wheel (21) that is operatively configured (welded) with the sieve mesh (7);

at least two supporting gear units (23); and

a trimming gear (22) that is connected to a DC motor unit.

4. The system as claimed in claim 3 wherein the rotary kiln () comprises a forced draft fan (4) connected to a rotameter (5) for supplying air to the rotary kiln (6) for combustion of the MSW in the rotary kiln (6).

5. The system as claimed in claim 1 wherein the rotary kiln (6) is inclined where the waste material gets automatically pushed into the kiln (6) and the ash particles are collected through an exit port located at the rear end of the kiln (6).

6. The system as claimed in claim 1 wherein the shell and tube of the heat exchanger unit (9) is of cross flow type to recover heat from the flue gases exiting in the kiln (6).

7. The system as claimed in claim 1 wherein copper is used for the construction of the tube of diameter 12.7 mm and length 100 m which is fabricated from aluminium.

8. The system as claimed in claim 1 wherein the rotary kiln (6) with the rotating sieve mesh (7) segregates the inerts during combustion and sustain the flame.

1/3

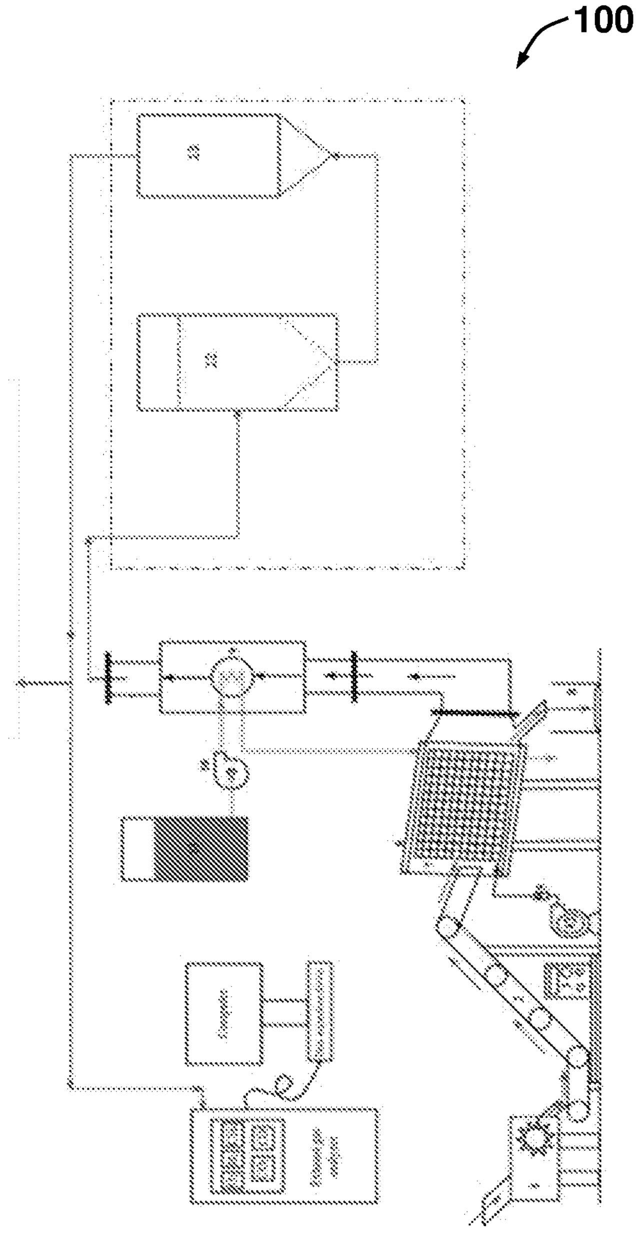

FIG.1

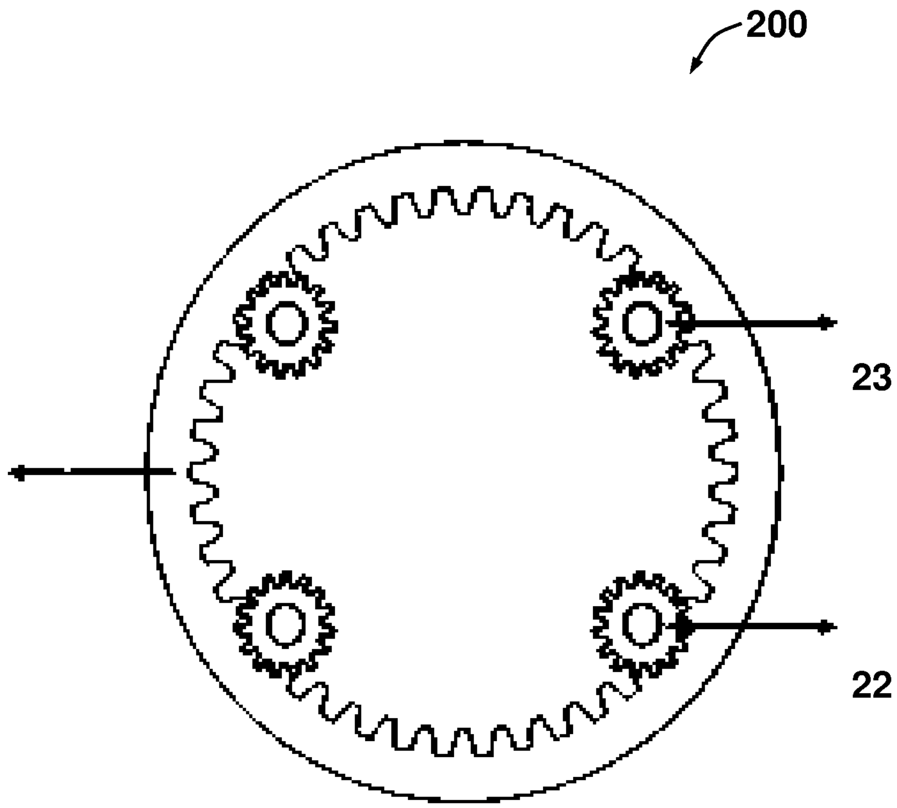

FIG.2

300

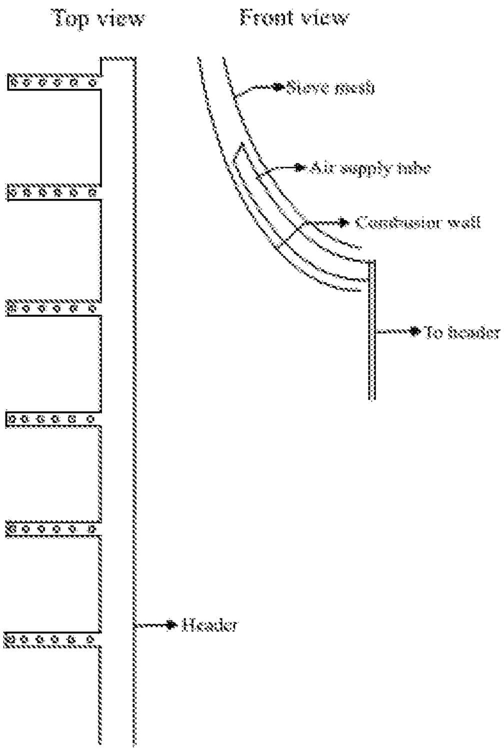
Top view
Front view
Sieve mesh
Air supply tube
Combustor wall
To header
Header

FIG.3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IN2021/050751

A. CLASSIFICATION OF SUBJECT MATTER
F23G5/20 Version=2021.01

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)

F23G5/20

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)

PatSeer, IPO Internal Database

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US3938449A (WATSON IND PROPERTIES) 17 Feb 1976; column 7, line 53; column 7, line 66 - column 8, line 5; fig 7, 11 & 15;	1,4,5
Y	US5207176A (ICI EXPLOSIVES USA INC [US]) 04 May 1993; claim 72; column 19, line 41-48;	1,4,5
Y	CN106500105A (JIANGXI DONGJIANG ENV PROT TECH CO LTD) 15 Mar 2017; abstract;	1,4,5
Y	GB1326872A (CIQUECO COMPAGNIE DES CONVOYEU) 15 Aug 1973; abstract; fig 3;	4,5
A	DE1526088A1 (SILVANO, Dr-Ing Silvano) 12 Feb 1970; abstract; fig 4;	1-8

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
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- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22-11-2021	22-11-2021

Name and mailing address of the ISA/	Authorized officer
Indian Patent Office Plot No.32, Sector 14,Dwarka,New Delhi-110075 Facsimile No.	Abinash Kumar Puhan Telephone No. +91-1125300200

INTERNATIONAL SEARCH REPORT
Information on patent family members

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