(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
22 August 2013 (22.08.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/122486 Al

(51) **International Patent Classification:**
F26B 17/10 (2006.01)

(21) **International Application Number:**
PCT/PL2012/0001 13

(22) **International Filing Date:**
25 October 2012 (25.10.2012)

(25) **Filing Language:** English

(26) **Publication Language:** English

(30) **Priority Data:**
P.398095 13 February 2012 (13.02.2012) PL

(71) **Applicant: AKADEMIA GORNICZO-HUTNICZA** [PL/PL]; im. Stanislawa, Staszica, Al. Mickiewicza 30, PL-30-059 Krakow (PL).

(72) **Inventors: DZIK, Tomasz;** ul. E.Heila 9/2, 30-654 Krakow (PL). **GRZEBIELUCH, Adam;** Wymyslow 31A, PL-32-200 Miechow (PL).

(74) **Agent: GUBALA, Jozef;** ul. Lea 53/84, PL-30-052 Krakow (PL).

(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, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, 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, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

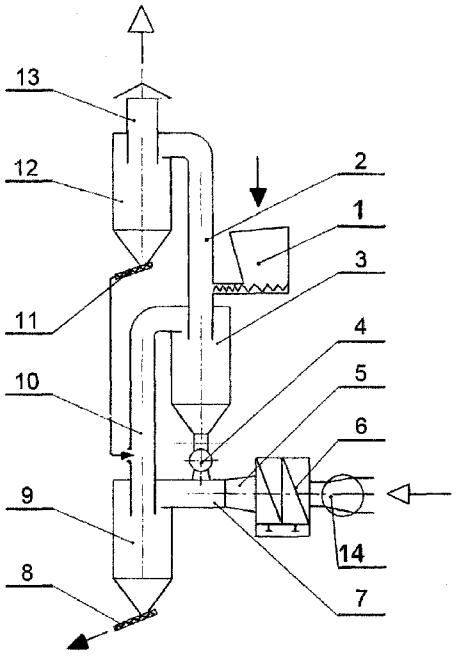
(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available):* ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

WO 2013/122486 A1

(54) Title: CYCLONE DRYER FOR PLANT BIOMASS



(57) Abstract: The cyclone dryer has three cyclones (9, 3, 12) connected in series. Heated air flows through an air duct (7), through the receiving cyclone (9), through a first outlet pipe (10), through the middle cyclone (3), through a second outlet pipe (2), and through the top cyclone (12), leaving the dryer through an exhaust duct (13). A first feeder (1) supplies biomass to the second outlet pipe (2) of the middle cyclone (3), while a second feeder (11) at the top cyclone (12) feeds the biomass into the first outlet pipe (10) of the receiving cyclone (9). A third feeder (4) transports the biomass precipitated in the middle cyclone (3) into the air duct (7). A fourth feeder (8) discharges the dried biomass from the receiving cyclone (9).

CYCLONE DRYER FOR PLANT BIOMASS

The invention relates to a cyclone dryer for plant biomass: chopped straw, oil sake, seaweed grown for energy purposes and other fibrous waste from agricultural production.

Combustion of biomass is considered better for environment than combustion of fossil fuels, mainly due to lower sulfur content and reduced amount of carbon dioxide, previously absorbed by plants. The efficiency of the combustion of biomass, in edition to homogenization and fragmentation, depends mainly to the degree of drying. Often used tumble dryers fired with liquid or gaseous fuels are characterized by very high - as far as the requirements for biomass are concerned - temperatures in burner zones, which imposes the need to cool exhaust gases by supplying additional air. There are also known fluid bed dryers for biomass, in which the receiving agent, which committees plant moisture from biomass which is entering a drying chamber, is air blown by fans and heaters located under the perforated bottoms of chambers. The air from the fluid bed is discharged by a discharge channel to a cyclone and to the atmosphere. Gas-tight screw feeders or cell feeders are used in these dryers. Such arrangements, among others, are shown in the description of the Polish patent PL 12825 1 and the utility model Ru 62261 .

A biomass dryer column known from the description of the international patent application WO2010052405 contains many coaxially positioned and vertically arranged cyclones with tapered cylindrical casings. In these cyclones agents flow in different manner than in the standard de-dusting system. Biomass pours down successively in coaxial channels between the outlet of the conical part of the upper cyclone and the inlet of the axis of the lid of the lower cyclone . Drying gas flows trough a channel having an inlet located within the axis of the upper cyclone , then the channel goes askew downwardly through the side surface of the cone and to the tangential inlet in the lid on the cylindrical part of the lower cyclone. Cold biomass and hot drying gas are fed into the upper cyclone and discharged from the lowest cyclone. The heat exchange in the case of the concurrent movement of the agents, however, are characterized by low efficiency.

The dryer according to the present invention, as in the above described embodiments, includes a pressure fan, an air heater, a biomass supply feeder, cyclones which are connected in series with gas outlet pipes, an exhauster which exhausts air to the atmosphere, and the gas-tight feeders of the biomass precipitated in cyclones. The flow of gas and particles in the cyclones is the same as in the de-dusting cyclones. The essence of the invention lies in the fact that the dryer has three cyclones, and that the cyclone receiving the dried biomass is connected by its outlet pipe to the inlet pipe of the middle cyclone, which in turn is connected by its outlet pipe to the upper cyclone ended with an exhauster. The biomass supply feeder is connected to the outlet pipe of the middle cyclone and the feeder of the upper cyclone is introduced into the outlet tube of the cyclone receiving biomass. The feeder of biomass precipitated in the middle cyclone is

introduced into an air duct located between the air heater and the receiving cyclone.

The drying process in the dryer according to the invention is realized in three cyclones connected in series. Moist and cold biomass is introduced into the outlet pipe behind the middle cyclone. Biomass is previously precipitated in the middle cyclone and is already substantially mid-dried and heated when it is introduced into the receiving cyclone. The receiving cyclone is supplied with air at highest temperature. The described system of biomass circulation provides high efficiency of drying.

Dryer according to the invention in the embodiment is shown in a scheme.

The dryer has three cyclones connected in series in the flow of air: a receiving cyclone **9** which receives dry biomass, a middle cyclone **3** and a top cyclone **12** having an outlet pipe ended with an exhauster **13** which exhausters gases into atmosphere or into a de-dusting system. The outlet pipe of the receiving cyclone **9** is supplied with air from a pressure fan **14** through an air heater **6,** an injector **5** and an air duct **7.** Its outlet pipe **10** is connected to the inlet pipe of the middle cyclone **3.** Wet biomass supply is realized by a screw supply feeder **1** connected to the outlet pipe **2** of the middle cyclone **3** and connected into the inlet pipe of the top cyclone **12.** Biomass precipitated in the top cyclone **12** is supplied with a screw feeder **11** into the outlet pipe **10** of the receiving cyclone 9. Biomass precipitated in the middle cyclone **3** is supplied by a cell feeder 4 into the air duct **7** located between the air heater 6 and the receiving cyclone 9.

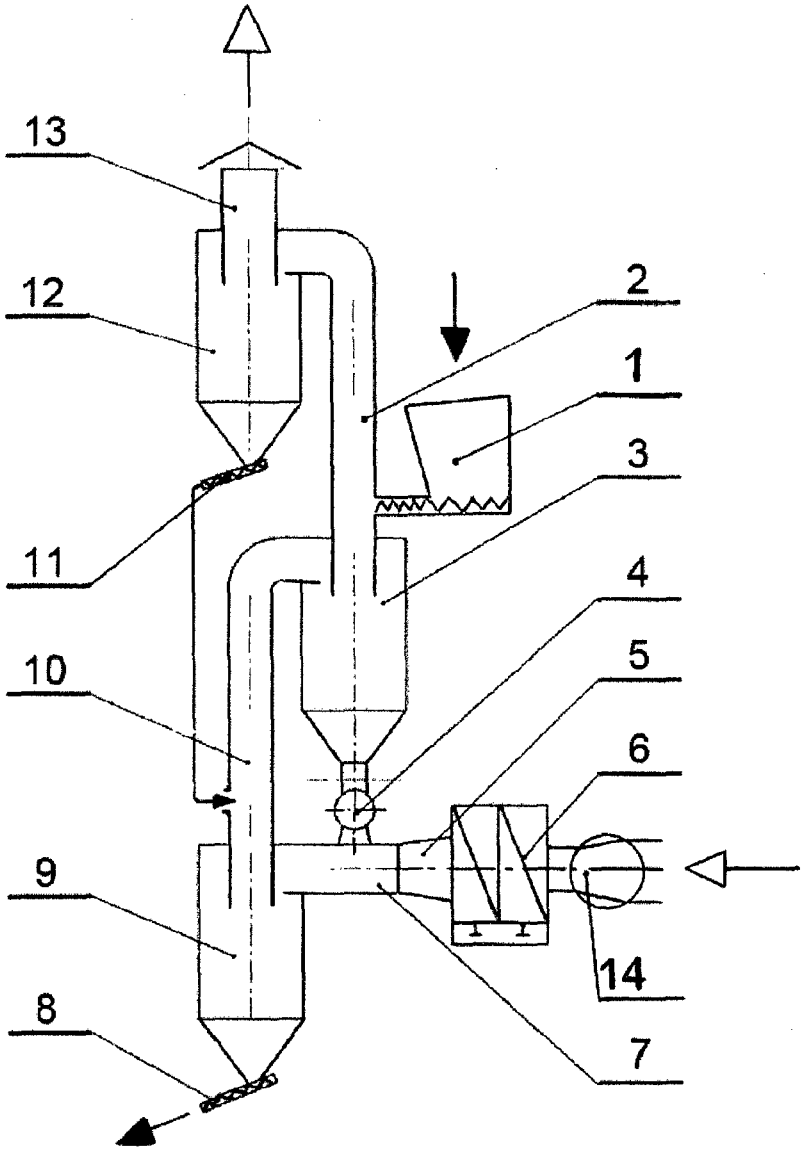
Wet biomass supplied to the dryer by the feeder **1** is lifted in a stream of hot air through the outlet pipe **2** into top cyclone **12.** After vortexing, precipitated

biomass in partly heated and partly dry condition is supplied by the feeder **11** into the outlet pipe **10.** A stream of air at higher temperature flows through the pipe **10.** Biomass is raised into the middle cyclone **3,** and after precipitation it is supplied by the cell feeder **4** into the air duct **7** which is located directly behind the heater **6.** An air stream at temperature 150 - 250°C blows through biomass, which is finally drying in the receiving cyclone **9.** Dried biomass is derived out by a feeder **8.** In each of the three stages of drying, which are set by the work of the cyclones, there are conditions for increasing the drying air temperature and in consequence for decreasing the humidity of the biomass —which ensures high efficiency of the process.

CLAIM

Cyclone dryer for plant biomass, having a pressure fan 14, an air heater 6, a supply feeder 1 of biomass, cyclones 9, 3, 12, connected in series by outlet pipes 10, 2 with an exhauster 13 exhausting air to the atmosphere, and gas-tight feeders 4, 11, 8 for biomass precipitated in the cyclones, characterized in that it has three cyclones 9, 3, 12 of which the cyclone 9 receiving dried biomass is connected by its outlet pipe 10 to the outlet pipe of the middle cyclone 3, which in turn is connected by its outlet pipe 2 to the top cyclone 12 with the exhauster 13, and said supply feeder 1, which supplies biomass is connected to the outlet pipe 2 of the middle cyclone 3, while the feeder 11 from the top cyclone 12 is connected into the outlet pipe 10 of the receiving cyclone 9, furthermore the feeder 4 which transports biomass precipitated in the middle cyclone 3 is connected into an air duct 7 situated between the air heater 6 and the receiving cyclone 9.

1/1



INTERNATIONAL SEARCH REPORT

International application No
PCT/PL2012/000113

A. CLASSIFICATION OF SUBJECT MATTER
INV. F26B17/10
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)
F26B

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)
EPO-Internal , WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 1 528 995 A (SINGER PHILIP A) 10 March 1925 (1925-03-10) page 1, line 9 - line 20; figure 1 page 1, line 54 - page 2, line 127	1
A	US 2 069 873 A (CHENAULT EARL A) 9 February 1937 (1937-02-09) page 1, column 1, line 1 - line 12; figure 5 page 1, column 2, line 19 - line 26 page 3, column 1, line 46 - column 2, line 51	1
A	US 3 998 583 A (HINTERKEUSER JAKOB ET AL) 21 December 1976 (1976-12-21) Title; figure 1 column 2, line 39 - line 60	1

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

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" documentwhich may throw doubts on priority claim(s) orwhich is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 February 2013	06/03/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Hauck, Gunther

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/PL2012/000113

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 1528995 A	10-03-1925	NONE	
US 2069873 A	09-02-1937	NONE	
US 3998583 A	21-12-1976	BE 832632 Al	16-12-1975
		DE 2440053 Al	11-03-1976
		DK 374975 A	22-02-1976
		FR 2282610 Al	19-03-1976
		GB 1513474 A	07-06-1978
		JP 51045364 A	17-04-1976
		US 3998583 A	21-12-1976
		ZA 7505371 A	28-07-1976