

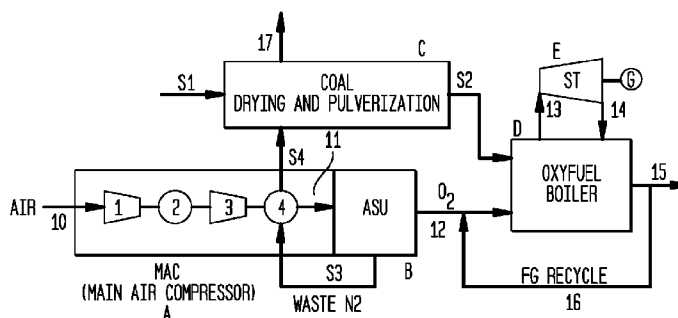


- (51) International Patent Classification:
F23K 1/00 (2006.01) *F23D 1/00* (2006.01)
F23L 15/00 (2006.01)
- (21) International Application Number:
PCT/US2017/015982
- (22) International Filing Date:
1 February 2017 (01.02.2017)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
62/311,080 21 March 2016 (21.03.2016) US
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- (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, 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, 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, ST, 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, KM, ML, MR, NE, SN, TD, TG).

Published:
— with international search report (Art. 21(3))

(54) Title: METHODS FOR COAL DRYING AND OXY-FUEL COMBUSTION THEREOF



(57) Abstract: A method for integrating an oxy-fuel boiler and an air separation unit, along with a supply of wet coal is disclosed. The integration applies the steps of feeding an air stream to an air separation unit thereby producing oxygen and nitrogen; feeding the oxygen to an oxy-fuel boiler; feeding the nitrogen to a supply of wet coal, thereby drying the wet coal; feeding the dry coal to the oxy-fuel boiler; and combusting the coal and oxygen in the oxy-fuel boiler.

WO 2017/164990 A1

METHODS FOR COAL DRYING AND OXY-FUEL COMBUSTION THEREOF

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0001] This invention was made with government support under Contract DE-FE0009448 awarded by the US Department of Energy. The government has certain rights in the invention.

BACKGROUND OF THE INVENTION

[0002] As the desire to use cleaner energy sources grows, the desire to use cleaner, more efficient power generation systems has grown as well. This has fueled greater technology development in this area such as for an oxy-fuel combustion boiler using pulverized coal as a fuel.

[0003] In conventional, low pressure, air fired coal boilers, raw coal with large amounts of moisture is first dried in direct contact with a stream of preheated air which is then used for the combustion of the pulverized coal. In advanced, oxy-fuel power generation designs, oxygen instead of air is used as an oxidant. Consequently using oxygen in place of air is not feasible as preheated oxygen in direct contact with coal can cause fires and explosions. As a result, an innovative coal drying process should be considered to reap the benefits of combusting partially dried coal rather than wet coal in oxy-fuel coal power generation systems.

[0004] Many of the elements of oxy-fuel combustion systems are similar to unit operations found in commercially utilized air based combustion boilers. A few differences are the air separation unit (ASU) which supplies oxygen to for the oxy-fuel combustion upfront of the fuel combustor and a carbon dioxide recirculation system which moderates the oxy-fuel combustion temperature to fit selected material temperature limitations. Another advantage of oxy-fuel

power generation is the carbon dioxide rich flue gas which can be used to produce an enhanced oil recovery (EOR) grade carbon dioxide as the byproduct of the power generation.

[0005] Possible examples of drying coal before its combustion with oxygen would be to use a mixture of previously dried carbon dioxide byproduct from the flue gas mixed with fresh dry oxygen. This has a negative impact of increased capital cost and energy penalties. Alternatively, expansion of pressurized, partially dried carbon dioxide which can be heated with a waste heat gas source will also increase capital cost and energy loss due to oxygen compression.

[0006] The methods of the present invention avoid these shortcomings by reducing specific coal and oxygen utilization as well as by increasing power generation efficiency and reducing the cost of electricity for related operations.

SUMMARY OF THE INVENTION

[0007] In a first embodiment of the invention, there is disclosed a method for integrating an oxy-fuel boiler and an air separation unit comprising the steps:

- a) Feeding an air stream to an air separation unit thereby producing oxygen and nitrogen;
- b) Feeding the oxygen to an oxy-fuel boiler;
- c) Feeding the nitrogen to a supply of wet coal, thereby drying the wet coal;
- d) Feeding the dry coal to the oxy-fuel boiler; and

e) Combusting the coal and oxygen in the oxy-fuel boiler.

In a second embodiment of the invention, there is disclosed a method for operating an oxy-fuel boiler comprising the steps of:

a) Producing oxygen and nitrogen in an air separation unit;

b) Feeding the nitrogen to a supply of wet coal, thereby drying the coal;
and

c) Feeding the oxygen and the coal to the oxyfuel boiler.

[0008] The carbon dioxide that is produced by the operation of the oxy-fuel boiler and the carbon dioxide is recycled to the oxygen feed to the oxy-fuel boiler.

[0009] The air stream is fed to the air separation unit after it has been cooled and compressed. This cooling and compression can be by one or more separate stages.

[0010] The nitrogen contacts the air stream prior to the air stream entering the air separation unit. The nitrogen will provide cooling to the air stream.

[0011] The nitrogen is heated prior to contacting the supply of wet coal by contact with the second compression stage where the air stream is at a warmer temperature than the incoming nitrogen stream.

[0012] The oxygen, coal and occasionally carbon dioxide will fuel the boiler in the oxy-fuel boiler which in turn produces steam for operating a steam turbine.

[0013] The air separation unit can be any conventional design but is

typically a cryogenic distillation unit.

[0014] In a third embodiment of the invention, there is disclosed a method for drying wet coal comprising the steps:

- a) Feeding an air stream to an air separation unit thereby producing oxygen and nitrogen; and
- b) Feeding the nitrogen to a supply of wet coal

[0015] The air stream is fed to the air separation unit after it has been cooled and compressed.

[0016] The nitrogen contacts the air stream prior to the air stream entering the air separation unit and will provide cooling of the air stream, particularly as it leaves the one or more compression stages.

[0017] The nitrogen is heated prior to contacting the supply of wet coal by contact with the second compression stage where the air stream is at a warmer temperature than the incoming nitrogen stream.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The figure is a schematic showing the integration of the oxy-fuel boiler with the air separation unit and coal supply.

DETAILED DESCRIPTION OF THE INVENTION

[0019] Turning to the figure, an advanced oxy-fuel combustion system using direct coal drying is shown. Waste nitrogen from the air separation unit is indirectly heated with compressed air and directed to the coal drying and pulverization unit.

[0020] Air is fed through line 10 into the main air compressor (MAC) A. The air will pass by way of line 11 through a first stage compressor 1; an interstage air cooler 2; a second stage air compressor 3 and an after compression air cooler with waste nitrogen 4. The air will typically be above 100°C after the second stage air compressor 3

[0021] The air separation unit is a conventional air separation unit B which can be for example, a cryogenic distillation unit which will cryogenically distill air to produce nitrogen and oxygen. The oxygen can be fed through line 12 to the oxy-fuel boiler D. The nitrogen which is typically at close to atmospheric pressure will be fed through line S3 to the after compression air cooler 4 in the main air compressor A to provide cooling to the air stream prior to its entry into the air separation unit B. The dry nitrogen will be heated in the after compression air cooler 4 and fed through line S4 to the coal drying and pulverization unit C.

[0022] The coal drying and pulverization unit C receives raw coal through feed line S1. The raw coal is contacted with the heated dry nitrogen feed into the coal drying and pulverization unit C. The heated dry nitrogen is typically at around 100°C and will remove moisture from the raw coal. Once the nitrogen passes through the coal, it is directed out of the coal drying and pulverization unit C through line 17. The dry coal is fed through line S2 to the oxy-fuel boiler D where it will be combusted with the oxygen and recycled carbon dioxide fed through line 12 from the air separation unit B.

[0023] The oxy-fuel boiler D will combust the dry coal using a mixture of carbon dioxide recycle and oxygen. This will produce steam which will be pressurized and fed through line 13 to a steam turbine E which will generate mechanical work which is usually translated into electrical energy. The electrical energy can be employed as part of the site operations. The water from the turbines can be returned via line 14 to the oxy-fuel boiler D where it

will be reheated, pressurized and fed to the steam turbine E as stream,

[0024] The stream 15 exiting the oxy-fuel boiler is a mixture of carbon dioxide and water and can include smaller amounts of oxygen, carbon monoxide, sulfur dioxide and nitrogen. This stream can be treated as necessary for environmental purposes and discharged to the atmosphere. A part of the carbon dioxide produced can be recycled through line 16 to the oxygen feed line 12 from the air separation unit B for entry as a fuel in the oxy-fuel boiler D.

[0025] The inventors envision that the integration as disclosed by the present invention could be applied to other combustion processes and fuels, as well as modifications of power generation plants that utilize compressed oxygen enriched air for example.

[0026] While this invention has been described with respect to particular embodiments thereof, it is apparent that numerous other forms and modifications of the invention will be obvious to those skilled in the art. The appended claims in this invention generally should be construed to cover all such obvious forms and modifications which are within the true spirit and scope of the invention.

Having thus described the invention, what we claim is:

1. A method for integrating an oxy-fuel boiler and an air separation unit comprising the steps:
 - a) Feeding an air stream to an air separation unit thereby producing oxygen and nitrogen;
 - b) Feeding the oxygen to an oxy-fuel boiler;
 - c) Feeding the nitrogen to a supply of wet coal, thereby drying the wet coal;
 - d) Feeding the dry coal to the oxy-fuel boiler; and
 - e) Combusting the coal and oxygen in the oxy-fuel boiler.
2. The method as claimed in claim 1 wherein carbon dioxide is produced by the operation of the oxy-fuel boiler and the carbon dioxide is recycled to the oxygen feed to the oxy-fuel boiler.
3. The method as claimed in claim 1 wherein an air stream is fed to the air separation unit after it has been cooled and compressed.
4. The method as claimed in claim 1 wherein the nitrogen contacts the air stream prior to the air stream entering the air separation unit.
5. The method as claimed in claim 4 wherein the nitrogen provides cooling to the air stream.
6. The method as claimed in claim 1 wherein the nitrogen is heated prior to contacting the supply of wet coal.

7. The method as claimed in claim 1 wherein the oxy-fuel boiler produces steam for operating a steam turbine.
8. A method for operating an oxy-fuel boiler comprising the steps of:
 - a) Producing oxygen and nitrogen in an air separation unit;
 - b) Feeding the nitrogen to a supply of wet coal, thereby drying the coal; and
 - c) Feeding the oxygen and the coal to the oxyfuel boiler.
9. The method as claimed in claim 8 wherein carbon dioxide is produced by the operation of the oxy-fuel boiler and the carbon dioxide is recycled to the oxygen feed to the oxy-fuel boiler.
10. The method as claimed in claim 8 wherein an air stream is fed to the air separation unit after it has been cooled and compressed.
11. The method as claimed in claim 8 wherein the nitrogen contacts the air stream prior to the air stream entering the air separation unit.
12. The method as claimed in claim 11 wherein the nitrogen provides cooling to the air stream.
13. The method as claimed in claim 8 wherein the nitrogen is heated prior to contacting the supply of wet coal.
14. The method as claimed in claim 8 wherein the oxy-fuel boiler produces steam for operating a steam turbine.

15. The method as claimed in claim 8 wherein the air separation unit is a cryogenic distillation unit.

16. A method for drying wet coal comprising the steps:

a) Feeding an air stream to an air separation unit thereby producing oxygen and nitrogen; and

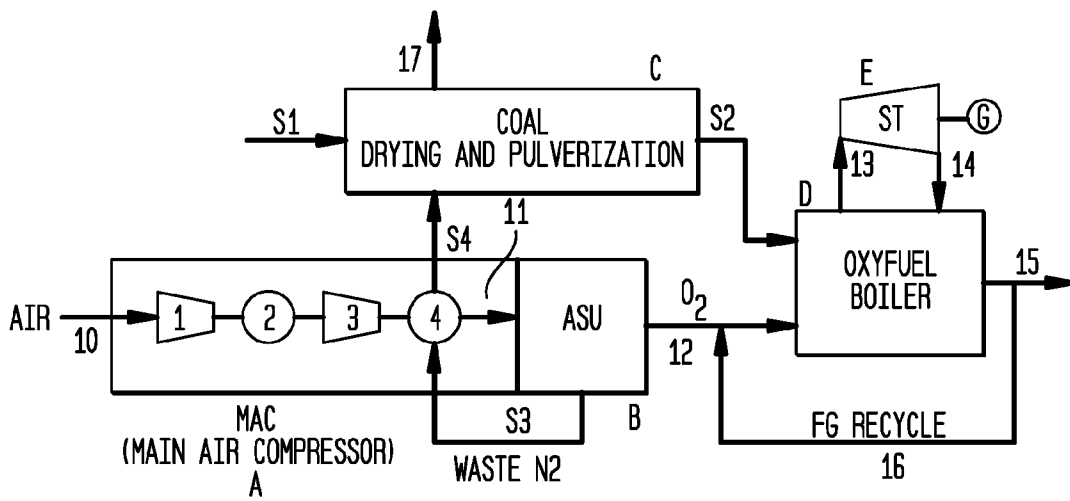
b) Feeding the nitrogen to a supply of wet coal.

17. The method as claimed in claim 16 wherein an air stream is fed to the air separation unit after it has been cooled and compressed.

18. The method as claimed in claim 16 wherein the nitrogen contacts the air stream prior to the air stream entering the air separation unit.

19. The method as claimed in claim 18 wherein the nitrogen provides cooling to the air stream.

20. The method as claimed in claim 16 wherein the nitrogen is heated prior to contacting the supply of wet coal.



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 17/15982

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - F23K 1/00, F23L 15/00, F23D 1/00 (2017.01)
CPC - F23C2202/20; F23L7/007; Y02E20/344; F25B9/00; F01K23/068

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)

See Search History Document

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

See Search History Document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History Document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2007/0119753 A1 (VARAGANI et al.) 31 May 2007 (31.07.2007) para [0025], [0038], [0052]-[0055], [0060], [0072]; figures 1 and 7	1-2, 6, 8-9, 13, 16 and 20 ----- 3-5, 7, 10-12, 14-15 and 17-19
Y	US 6,925,818 B1 (BROWN) 9 August 2005 (09.08.2005) col 1, ln 39-56; title	3, 10 and 17
Y	US 5,137,558 A (AGRAWAL) 11 August 1992 (11.08.1992) col 4, ln 9-14; abstract	4-5, 11-12 and 18-19
Y	US 2006/0123844 A1 (LE BOT et al.) 15 June 2006 (15.06.2006) para [0040]-[0047]	7 and 14
Y	US 5,049,173 A (CORMIER, SR. et al.) 17 September 1991 (17.09.1991) col 1, ln 14-16; col 2, ln 45-49	15
A	US 5,327,717 A (HAUK) 12 July 1994 (12.07.1994); the entire document	1, 8 and 16
A	US 2014/0238281 A1 (ISHII) 28 August 2014 (28.08.2014); the entire document	1, 8 and 16

Further documents are listed in the continuation of Box C.

* Special categories of cited documents:	"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
"A" document defining the general state of the art which is not considered to be of particular relevance	"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
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"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	

Date of the actual completion of the international search
20 March 2017

Date of mailing of the international search report
24 APR 2017

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