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April 11, 2017

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Under Secretary of Commerce for Intellectual Property
and Director of the United States Patent and Trademark Office



P. R. Grant
P. R. GRANT
Certifying Officer

PATENT ASSIGNMENT COVER SHEET

Electronic Version v1.1
 Stylesheet Version v1.2

EPAS ID: PAT4344422

SUBMISSION TYPE:	NEW ASSIGNMENT
NATURE OF CONVEYANCE:	ASSIGNMENT

CONVEYING PARTY DATA

Name	Execution Date
ERIC L WELLS	04/05/2016
ALBERT J BENNETT	04/05/2016

RECEIVING PARTY DATA

Name:	THE BABCOCK & WILCOX COMPANY
Street Address:	20 S VAN BUREN AVENUE
City:	BARBERTON
State/Country:	OHIO
Postal Code:	44203

PROPERTY NUMBERS Total: 1

Property Type	Number
Application Number:	15091211

CORRESPONDENCE DATA

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ATTORNEY DOCKET NUMBER:	CASE 7709
NAME OF SUBMITTER:	AMY M SAUS
SIGNATURE:	/amsaus/
DATE SIGNED:	03/30/2017

Total Attachments: 3

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ASSIGNMENT TO THE BABCOCK & WILCOX COMPANY

CASE 7709

THIS ASSIGNMENT made the 5th day of April, 2016, by Eric L. Wells residing at 9185 Hunters Chase Street NW, Massillon, Ohio 44646; and by Albert J. Bennett, residing at 12539 Hollow Ridge Drive, Doylestown, Ohio 44230; and by ~~Jeremy L. Remus, residing at 3211 W. Rangercrest Place, Sugar Land, Texas 77479~~; all citizens of the United States of America;

WITNESSETH: That

WHEREAS, we are the joint inventors of a certain new and useful improvement and invention in

**HIGH TEMPERATURE SUB-CRITICAL BOILER WITH STEAM COOLED
UPPER FURNACE AND START-UP METHODS**

for which we have prepared and executed an application for Letters Patent of the United States on the 5th day of April, 2016, and

WHEREAS, THE BABCOCK & WILCOX COMPANY, a Corporation organized under the laws of the state of Delaware, U.S.A., and having its principal office at 20 S. Van Buren Ave., Barberton, Ohio, U.S.A., is desirous of acquiring the entire right, title, and interest in and to said improvement and invention, and any and all Letters Patent which shall be granted therefor;

NOW, THEREFORE, To All Whom It May Concern, be it known that for and in consideration of the sum of One Dollar (\$1.00) to us in hand paid, and other good and valuable considerations, the receipt of which is hereby acknowledged, we, Eric L. Wells, Albert J. Bennett and ~~Jeremy L. Remus~~, have sold, assigned, transferred and set over, and by these presents do sell, assign, transfer and set over, unto said THE BABCOCK & WILCOX COMPANY, its successors and assigns, the entire right, title, and interest in and to the above-mentioned improvement, invention, and application for Letters Patent therefor, and in and to any and all Letters Patent of the United States which may hereinafter be granted therefor, and in and to any and all extensions, divisions, or reissues of said Letters Patent, the same to be held and enjoyed by said THE BABCOCK & WILCOX COMPANY, for its own use and behoof, and the use and behoof of its successors and assigns, to the full end of the term for which said Letters Patent may be granted, as fully and entirely as the same would have been held and enjoyed by us had this assignment and sale not been made;

ASSIGNMENT TO THE BABCOCK & WILCOX COMPANY

CASE 7709

AND, for the consideration aforesaid, we hereby covenant and agree with said THE BABCOCK & WILCOX COMPANY, its successors and assigns, that at the time of the execution and delivery of these presents, we are the joint and lawful owners of the entire right, title, and interest in and to the above-mentioned improvement, invention, and application for Letters Patent above mentioned, and that the same are unencumbered, and that we have good right and lawful authority to sell and convey the same in the manner herein set forth;

AND, for the consideration aforesaid, we hereby covenant and agree with said THE BABCOCK & WILCOX COMPANY, its successors and assigns, that we will, whenever its counsel or the counsel of its successors or assigns, learned in the law, shall advise that an amendment or division or any other proceeding in connection with said application, including interference proceedings, is lawful and desirable or that a reissue or extension of said Letters Patent is lawful and desirable, sign all papers and drawings, take all rightful oaths, and do all acts necessary or required to be done for the procurement of valid Letters Patent for said improvement and invention, or for the reissue or extension of same, without charge to said THE BABCOCK & WILCOX COMPANY, or its successors or assigns, but at its or their expense.

We hereby request the Honorable Commissioner of Patents and Trademarks of the United States to issue the Letters Patent in accordance with this instrument.

AND, for the consideration aforesaid, we have sold, assigned, transferred and set over, and by these presents do sell, assign, transfer and set over, unto said THE BABCOCK & WILCOX COMPANY, its successors, assigns, or nominees, the entire right, title, and interest in and to any and all Letters Patent or other form of protection which may be granted in countries foreign to the United States, and in and to any and all applications for Letters Patent or other form of protection which may be filed for said improvement and invention in countries foreign to the United States, including all rights to claim priority, and in and to the invention described in said applications; and we hereby authorize and empower said THE BABCOCK & WILCOX COMPANY, its successors, assigns, or nominees, to apply for Letters Patent, or other form of protection, on said improvement and invention, in its own name or in the name of its successors, assigns, or nominees, in any and all countries where it may desire to file

ASSIGNMENT TO THE BABCOCK & WILCOX COMPANY

CASE 7709

such applications and where such applications may be filed by another other than the inventors; and we hereby covenant and agree to sign all papers and drawings, take all rightful oaths, and do all acts necessary or required to be done for the procurement of valid Letters Patent, or other form of protection, for said improvement and invention in countries foreign to the United States, and for further investing or confirming the right and title thereto in said THE BABCOCK & WILCOX COMPANY, its successors, assigns, or nominees, without charge to said THE BABCOCK & WILCOX COMPANY, its successors, assigns, or nominees, but at its or their expense.

IN WITNESS WHEREOF, we have hereunto set our hands and seal on the day and year first above written.

Eric L. Wells
Eric L. Wells

Albert J. Bennett
Albert J. Bennett

Jeremy L. Remus

WITNESSES: [Signature]

[Signature]

STATE OF OHIO)
COUNTY OF Summit) ss.

On this, the 5th day of April, 2016, before me personally appeared, Eric L. Wells, Albert J. Bennett and ~~Jeremy L. Remus~~, me known and known to me to be the persons described in and who executed the foregoing instrument; and they acknowledged to me that they executed the same for the purpose therein stated.



MICHAEL J. SEYMOUR
NOTARY PUBLIC - OHIO
MY COMMISSION HAS NO EXPIRATION DATE
UNDER SECTION 147.03 R.C.

[Signature]

membrane walls, the use limit is about 1000°F, so the dry steam from the separator outlet **56** is sufficient to cool the membrane walls.

[0081] In **FIG. 6**, the firing rate indicates the relative amount of heat being generated by the boiler. The boiler is run at about 10% for four hours using oil before the boiler is ramped up to 100% capacity. This permits the formation of steam sufficient to fill the steam-cooled tubes. For the first two hours, the steam diversion path **100** is open, and afterwards is closed to permit steam to fill the walls of the convection pass. After four hours, the high-pressure turbine is fully loaded as well, and the fuel is switched to coal. The firing rate, steam flow, and throttle pressure are then increased to their steady-state operating values.

[0082] Advantageously, the supply of steam for start-up using this approach comes from the steam separator **54**. This allows the boiler **10** to be put in service without the use of auxiliary steam and/or an auxiliary steam boiler. It will again be appreciated that the disclosed approach for cooling membrane walls during start-up may be employed in a wide range of boilers besides the illustrative boiler **10** of **FIG. 1**.

[0083] The present disclosure has been described with reference to exemplary embodiments. Obviously, modifications and alterations will occur to others upon reading and understanding the preceding detailed description. It is intended that the present disclosure be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.

CLAIMS:

We claim:

1. A boiler comprising:
 - a furnace including burners and steam-cooled membrane walls, the steam-cooled membrane walls comprising pipes sealed by membrane;
 - a steam separator having a dry steam outlet;
 - a steam-cooled circuit connected to the dry steam outlet of the steam separator, the steam-cooled circuit including at least (i) a primary superheater comprising pipes without membrane and (ii) the steam-cooled membrane walls of the furnace, wherein the steam-cooled membrane walls of the furnace are located downstream of the primary superheater in the steam-cooled circuit; and
 - startup control circuitry configured to (i) reduce flow to the primary superheater and (ii) divert flow from the dry steam outlet of the steam separator to the steam-cooled membrane walls of the furnace.
2. The boiler of claim 1, wherein the startup control circuitry includes:
 - at least one diversion valve that when opened operatively connects the dry steam outlet of the steam separator to the steam-cooled membrane walls of the furnace; and
 - at least one reduction valve in the steam-cooled circuit that is operative to reduce flow through the primary superheater.
3. The boiler of claim 2, wherein the startup control circuitry further includes an electronic controller configured to set the startup control circuitry into one of:
 - a startup mode in which the at least one diversion valve is opened and the at least one reduction valve is operated to reduce flow through the primary superheater;
 - or
 - a normal operating mode in which the at least one diversion valve is closed and the at least one reduction valve is fully open.

4. The boiler of claim 1, wherein the startup control circuitry includes:
a valved diversion path connecting the dry steam outlet of the steam separator to the steam-cooled membrane walls of the furnace; and
at least one reduction valve in the steam-cooled circuit that is operative to reduce flow through the primary superheater.

5. The boiler of claim 4, wherein the startup control circuitry further includes an electronic controller configured to set the startup control circuitry into one of:
a startup mode in which the valved diversion path is open and the at least one reduction valve is operated to reduce flow through the primary superheater; or
a normal operating mode in which the valved diversion path is closed and the at least one reduction valve is fully open.

6. The boiler of claim 5, further comprising a secondary superheater located downstream of the steam-cooled membrane walls of the furnace in the steam-cooled circuit.

7. The boiler of any one of claims 1-6, wherein the furnace includes:
a steam-cooled upper furnace having the steam-cooled membrane walls;
and
a water-cooled lower furnace formed by water-cooled membrane walls that comprise pipes sealed by membrane, the water-cooled membrane walls not being included in the steam-cooled circuit connected to the dry steam outlet of the steam separator.

8. A boiler, comprising:

a furnace including at least one steam-cooled membrane wall, the at least one steam-cooled membrane wall comprising pipes sealed by membrane;

a steam separator having a dry steam outlet;

one or more primary superheaters comprising pipes without membrane;

a steam-cooled circuit running from the dry steam outlet to the one or more primary superheaters and subsequently to the at least one steam-cooled membrane wall of the furnace, and containing one or more reduction valves between the one or more primary superheaters and the at least one steam-cooled membrane wall of the furnace;

a diversion path running from the dry steam outlet through one or more diversion valves to a location upstream of the at least one steam-cooled membrane wall of the furnace and downstream of the one or more primary superheaters; and

control circuitry for switching dry steam flow from the steam separator through the steam-cooled circuit or the diversion path.

9. The boiler of claim 8, wherein the control circuitry includes an electronic controller configured to operate the one or more reduction valves and the one or more diversion valves.

10. The boiler of claim 8, further comprising a convection pass formed by steam-cooled convection pass membrane walls, the convection pass membrane walls being located upstream of the one or more primary superheaters in the steam-cooled circuit.

11. The boiler of claim 10, further comprising secondary superheaters comprising pipes without membrane, the secondary superheaters being located downstream of the at least one steam-cooled membrane wall of the furnace in the steam-cooled circuit.

12. The boiler of claims 11, wherein the furnace includes:

a steam-cooled upper furnace having an upper furnace that includes the at least one steam-cooled membrane wall; and

a water-cooled lower furnace formed by water-cooled membrane walls, the water-cooled membrane walls not being included in the steam-cooled circuit connected to the dry steam outlet of the steam separator.

13. A boiler start-up method for starting a boiler having a steam separator, steam-cooled membrane walls forming at least a portion of a furnace, and a primary superheater interposed in a steam-cooled circuit between a dry steam outlet of the steam separator and the steam-cooled membrane walls, the method comprising:

reducing dry steam flow through the steam-cooled circuit; and

diverting dry steam flow through a diversion path that runs from the dry steam outlet to a location upstream of the steam-cooled membrane walls of the furnace and downstream of the primary superheater, wherein the diversion path bypasses the primary superheater.

14. The boiler start-up method of claim 13, wherein the diverting comprises opening a diversion valve upstream of the primary superheater.

15. The boiler start-up method of claim 13, wherein the reducing comprises closing a reduction valve located in the steam-cooled circuit downstream of the primary superheater.

16. The boiler start-up method of claim 14, further comprising:

firing up the boiler using oil as fuel;

terminating the reducing and diverting responsive to a switch-over condition; and

after the terminating, switching over from using oil as fuel to using coal as fuel.

17. The boiler start-up method of claim 16, wherein the steam-cooled circuit further comprises steam-cooled convection pass membrane walls, the convection pass membrane walls being located upstream of the primary superheater in the steam-cooled circuit.

18. The boiler start-up method of claim 17, wherein the steam-cooled circuit further comprises secondary superheaters comprising pipes without membrane, the secondary superheaters being located downstream of the steam-cooled membrane walls of the furnace in the steam-cooled circuit.

19. The boiler start-up method of claim 14, wherein the reducing comprises closing a reduction valve located in the steam-cooled circuit downstream of the primary superheater.

20. The boiler start-up method of claim 19, further comprising:
firing up the boiler using oil as fuel;
terminating the reducing and diverting responsive to a switch-over condition; and
after the terminating, switching over from using oil as fuel to using coal as fuel.

**HIGH TEMPERATURE SUB-CRITICAL BOILER WITH STEAM COOLED UPPER
FURNACE AND START-UP METHODS**

ABSTRACT OF THE DISCLOSURE

A boiler is disclosed in which the furnace is divided into a lower furnace and an upper furnace. The lower furnace uses water-cooled membrane walls, while the upper furnace uses steam-cooled membrane walls that act as superheating surfaces. A steam-cooled circuit includes a steam separator, a primary superheater, and the steam-cooled membrane walls of the upper furnace. During start-up, a diversion path is opened that reduces dry steam flow through the primary superheater and increases dry steam flow through the steam-cooled membrane walls of the upper furnace. This protects the steam-cooled membrane walls from excessive thermal stresses during start-up.

DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION
(37 CFR §1.63)

Rev. 09/2012/13 (ptik)

Attorney Docket No. 7709

As below named inventor, I hereby declare that: My residence, post office address and citizenship are as stated below next to my name. I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject, **HIGH TEMPERATURE SUB-CRITICAL BOILER WITH STEAM COOLED UPPER FURNACE AND START-UP METHODS**, the specification of which:

Check one ☒ is attached hereto

☐ was filed on _____ as United States or PCT International application Serial No. _____ and was amended on _____ (if applicable).

The above-identified application was made or authorized to be made by me.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose to the United States Patent and Trademark Office (USPTO) all information known to me to be material to patentability as defined in 37 CFR §1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT International filing date of the continuation-in-part application.

I hereby claim foreign priority benefits under 35 USC §119(a)-(d) or (f) or §365(b) of any foreign application(s) for patent or inventor's certificate, or under §365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below any foreign application for patent or inventor's certificate, or PCT International application, having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)

(Number) _____ (Country) _____ (Day/Month/Year Filed) _____ Priority Claimed: Yes ☐ No ☐

I hereby claim the benefit under 35 USC §119(e) of any United States provisional applications:

(Application Serial No.) _____ (Month/Day/Year Filed) _____

I hereby claim the benefit under 35 USC §120 of any United States application(s), or under §365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 USC §112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR §1.56 which become available between the filing date of the prior application and the national or PCT International filing date of this application.

(Application Serial No.) _____ (Filing Date) _____ (Status--patented, pending, abandoned) _____

Address all telephone calls to **Michael J. Seymour** at telephone no. **(330) 860-6710**
Address all correspondence to **Babcock & Wilcox Power Generation Group, Inc.**
Patent Department - BVCB2K
20 South Van Buren Avenue
Barberton, OH 44203-0351

US PTO CUSTOMER NUMBER

41669 -
BWPGG

Authorization To Permit Access To Application by Participating Offices:

The undersigned hereby grants the USPTO authority to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the World Intellectual Property Office (WIPO), and any other intellectual property offices in which a foreign application claiming priority to the above-identified application is filed access to above-identified patent application. See 37 CFR §1.14(c) and (h).

In accordance with 37 CFR §1.14(h)(3), access will be provided to a copy of the above-identified with respect to: 1) the above-identified patent application-as-filed; 2) any foreign application to which the above-identified application claims priority under 35 USC 119(a)-(d) if a copy of the foreign application that satisfies the certified copy requirement of 37 CFR §1.55 has been filed in the above-identified patent application; and 3) any U.S. application from which benefit is sought in the above-identified application.

In accordance with 37 CFR §1.14(c), access may be provided to information concerning the date of filing the Authorization to Permit Access to Application by Participating Offices.

DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION
(37 CFR §1.63)

Rev. 06/2013 (sm)

Attorney Docket No. 7709

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under §1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of sole or first inventor

WELLS, ERIC L

Inventor's signature Eric L Wells

Date 4/5/16 Citizenship US

Residence MASSILLON, OHIO

Post office address 9185 Hunters Chase Street NW
Massillon, OH 44646-9560

Full name of second inventor, if any

BENNETT, ALBERT J

Inventor's signature Albert J Bennett

Date 4/5/2016 Citizenship US

Residence DOYLESTOWN, OH

Post office address 12539 Hollow Ridge Drive
Doylestown, OH 44230

Full name of third inventor, if any

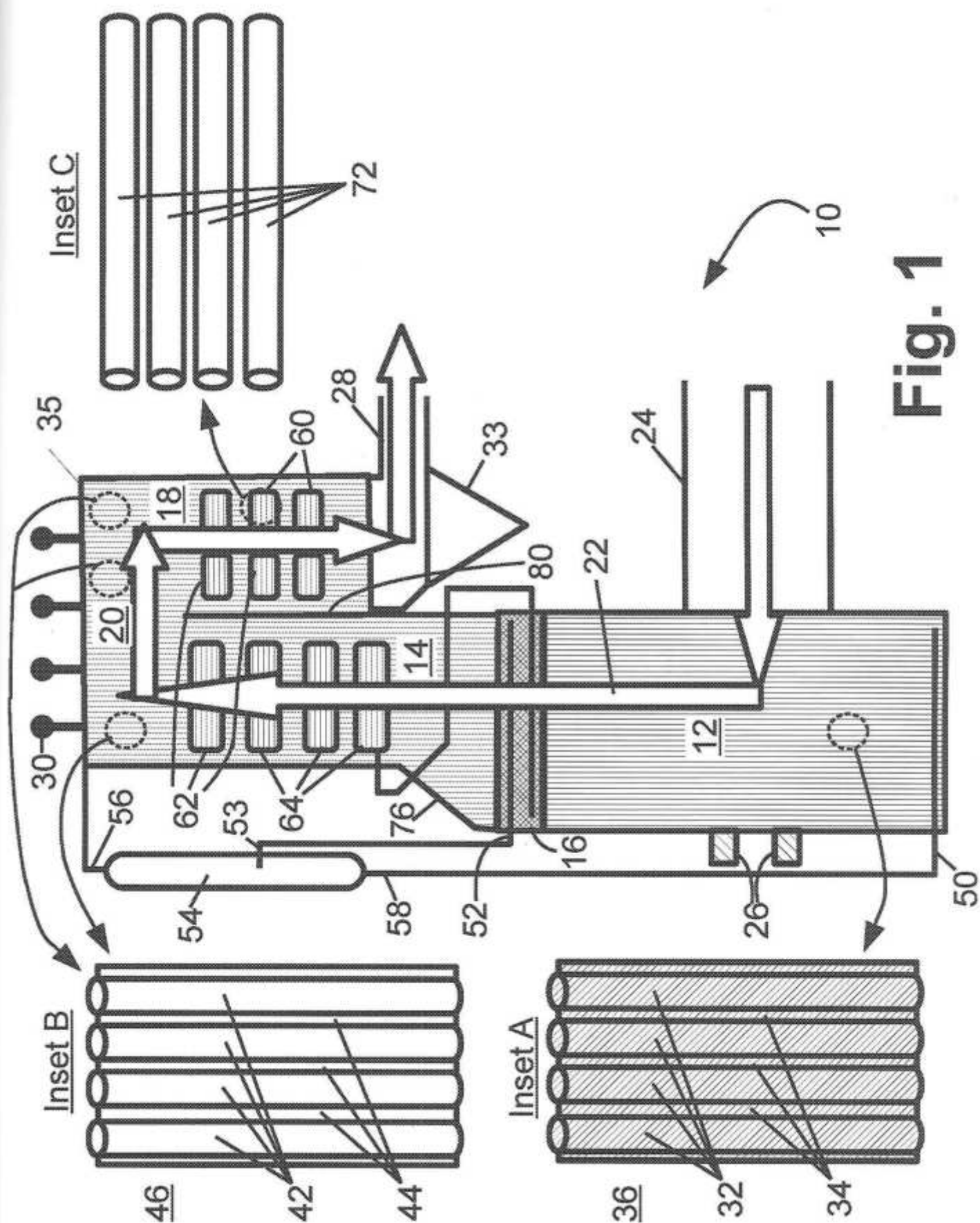
REMUS, JEREMY L

Inventor's signature _____

Date _____ Citizenship US

Residence SUGAR LAND, TEXAS

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Sugar Land, TX 77479



Section A-A

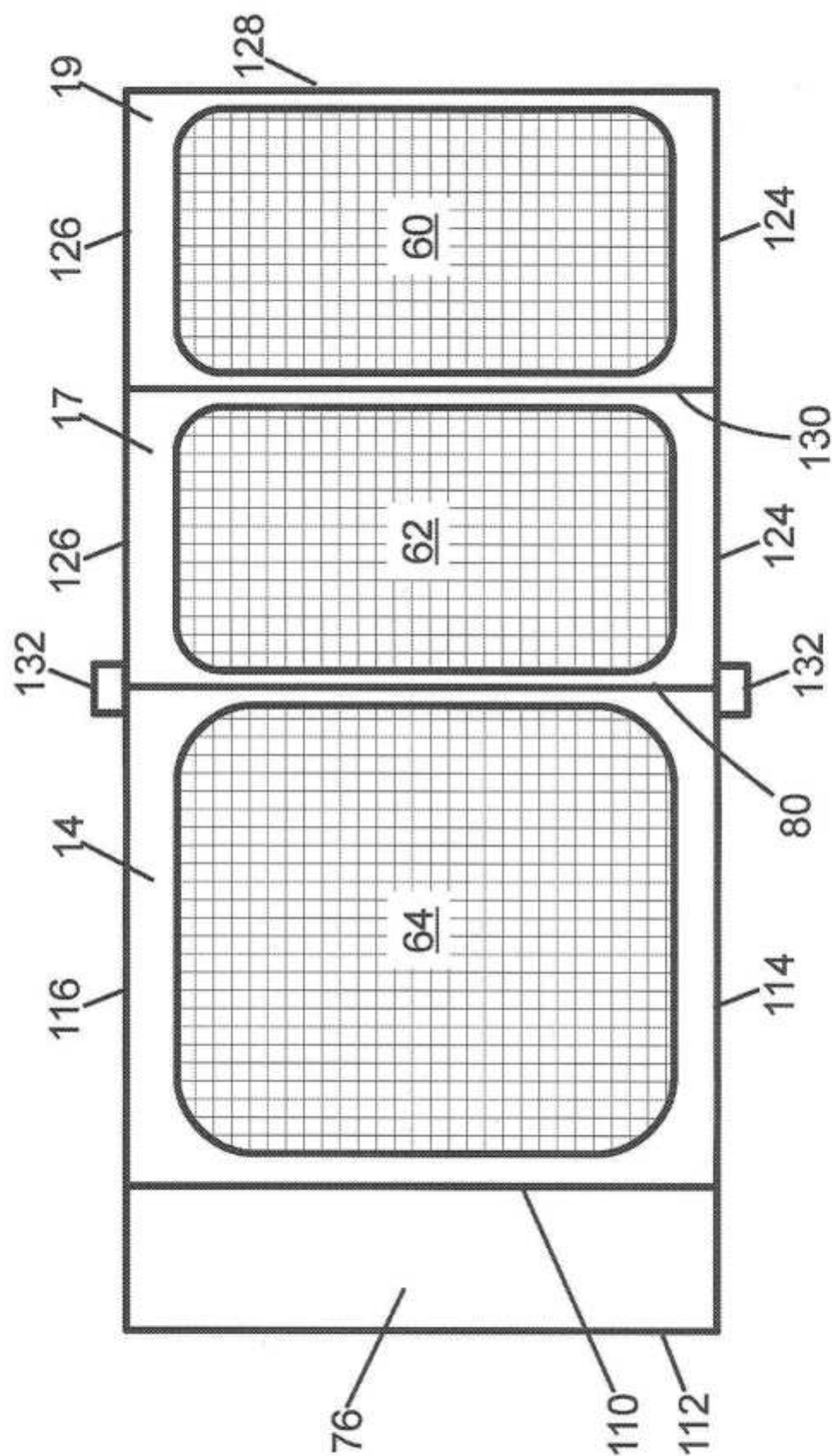
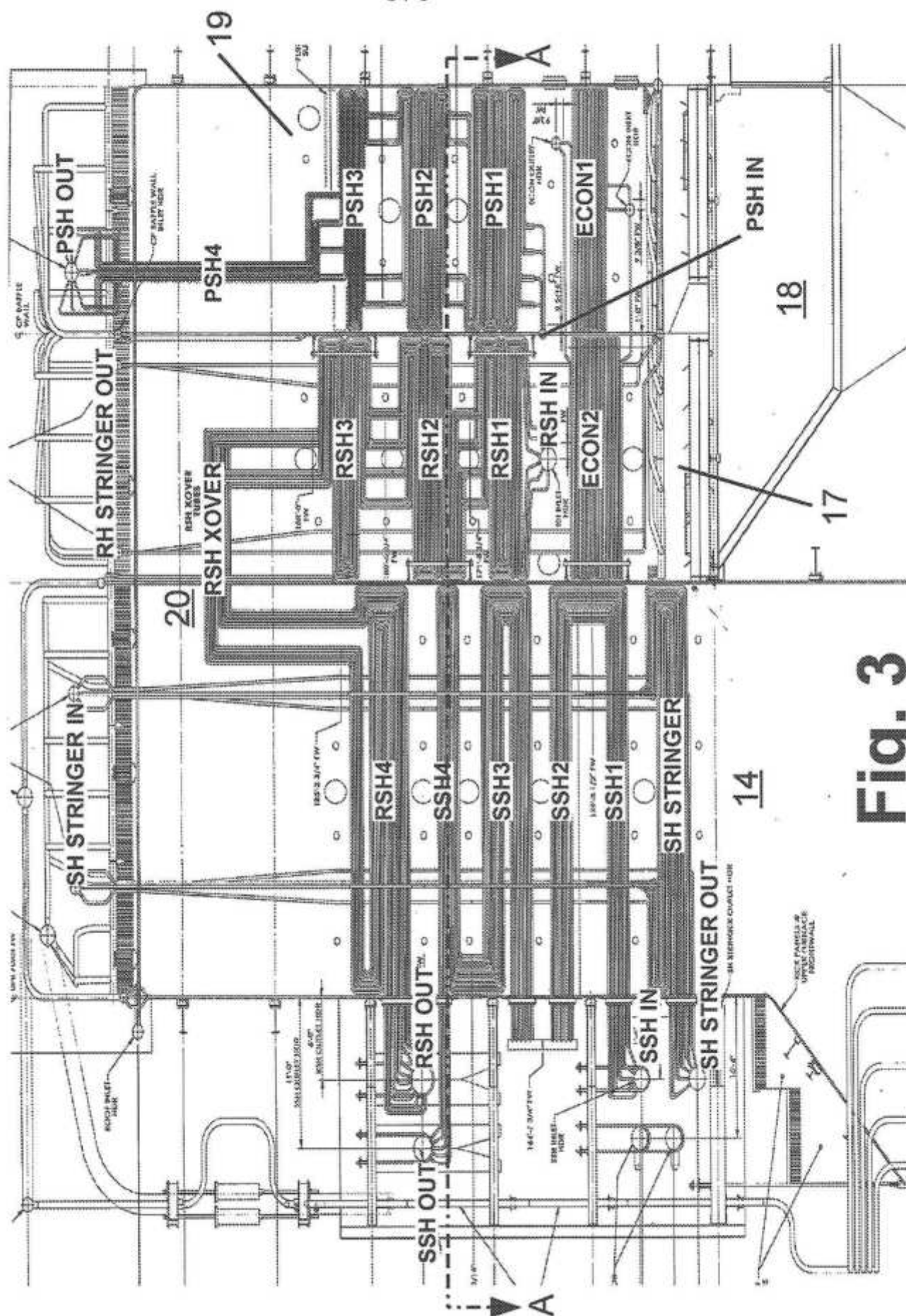


Fig. 2



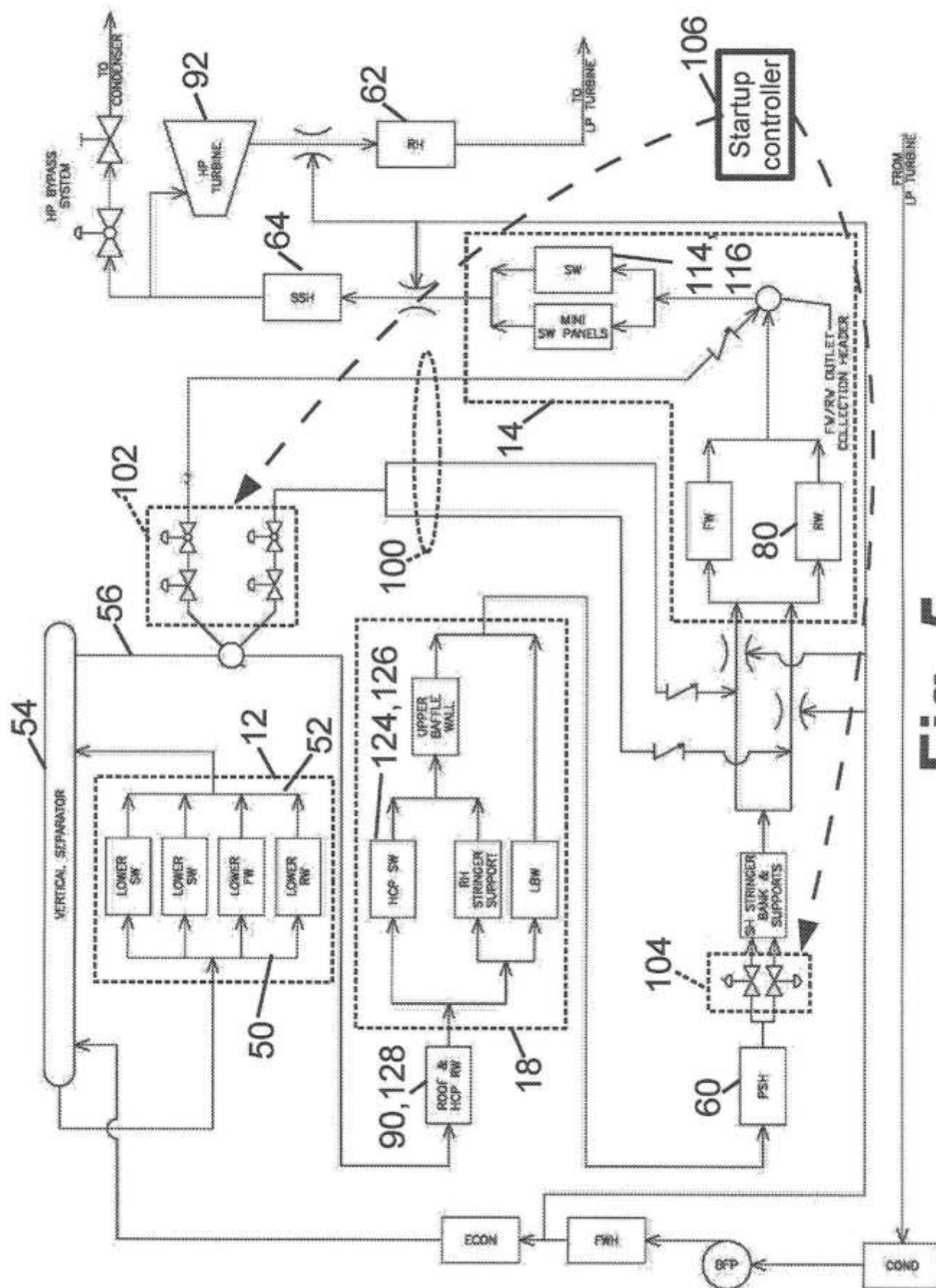


Fig. 5

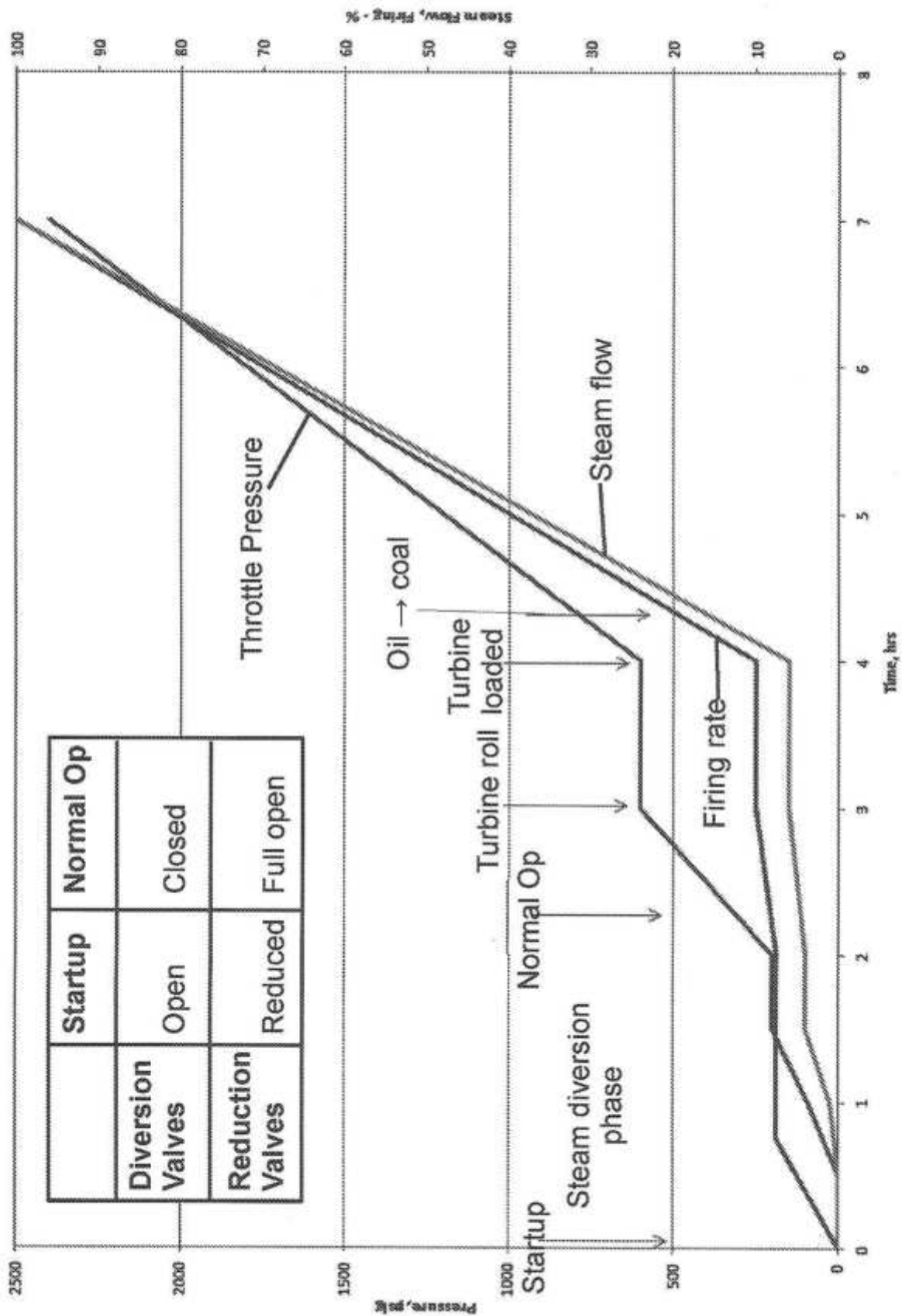


Fig. 6

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	Case 7709
		Application Number	
Title of Invention	HIGH TEMPERATURE SUB-CRITICAL BOILER WITH STEAM COOLED UPPER FURNACE AND START-UP METHODS		
The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76. This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.			

Secrecy Order 37 CFR 5.2:

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor	1				Remove
Legal Name					
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Eric	L	Wells		
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service					
City	Massillon	State/Province	OH	Country of Residence	US
Mailing Address of Inventor:					
Address 1	9185 Hunters Chase Street NW				
Address 2					
City	Massillon	State/Province	OH		
Postal Code	44646-9560	Country i	US		
Inventor	2				Remove
Legal Name					
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Albert	J	Bennett		
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service					
City	Doylestown	State/Province	OH	Country of Residence	US
Mailing Address of Inventor:					
Address 1	12539 Hollow Ridge Drive				
Address 2					
City	Doylestown	State/Province	OH		
Postal Code	44230	Country i	US		
Inventor	3				Remove
Legal Name					
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Jeremy	L	Remus		
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service					

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	Case 7709		
		Application Number			
Title of Invention	HIGH TEMPERATURE SUB-CRITICAL BOILER WITH STEAM COOLED UPPER FURNACE AND START-UP METHODS				
City	Sugar Land	State/Province	TX	Country of Residence	US
Mailing Address of Inventor:					
Address 1	3211 W. Rangercrest Place				
Address 2					
City	Sugar Land	State/Province	TX		
Postal Code	77479	Country	US		
All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the Add button.				Add	

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below. For further information see 37 CFR 1.33(a).	
☐ An Address is being provided for the correspondence information of this application.	
Customer Number	41669
Email Address	patent@babcock.com Add Email Remove Email

Application Information:

Title of the Invention	HIGH TEMPERATURE SUB-CRITICAL BOILER WITH STEAM COOLED UPPER FURNACE AND START-UP METHODS		
Attorney Docket Number	Case 7709	Small Entity Status Claimed	☐
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	6	Suggested Figure for Publication (if any)	1

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)
☐ Request Not to Publish. I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application has not and will not be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	Case 7709
		Application Number	
Title of Invention	HIGH TEMPERATURE SUB-CRITICAL BOILER WITH STEAM COOLED UPPER FURNACE AND START-UP METHODS		

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Please Select One:	☒ Customer Number	☐ US Patent Practitioner	☐ Limited Recognition (37 CFR 11.9)
Customer Number	41669		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.

When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status			Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the Add button.			Add

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)ⁱ the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Application Number	Country ⁱ	Filing Date (YYYY-MM-DD)	Access Code ⁱ (if applicable)	Remove
Additional Foreign Priority Data may be generated within this form by selecting the Add button.				Add

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	Case 7709
		Application Number	
Title of Invention	HIGH TEMPERATURE SUB-CRITICAL BOILER WITH STEAM COOLED UPPER FURNACE AND START-UP METHODS		

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐	This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013. NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.
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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	Case 7709
		Application Number	
Title of Invention	HIGH TEMPERATURE SUB-CRITICAL BOILER WITH STEAM COOLED UPPER FURNACE AND START-UP METHODS		

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ **A. Applicant DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ **B. Applicant DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

NOTE: Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	Case 7709
		Application Number	
Title of Invention	HIGH TEMPERATURE SUB-CRITICAL BOILER WITH STEAM COOLED UPPER FURNACE AND START-UP METHODS		

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Applicant 1

Remove

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

Clear

Assignee

Legal Representative under 35 U.S.C. 117

Joint Inventor

• Person to whom the inventor is obligated to assign.

Person who shows sufficient proprietary interest

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor:

If the Applicant is an Organization check here. ☒

Organization Name

The Babcock & Wilcox Company

Mailing Address Information For Applicant:

Address 1

20 S. Van Buren Avenue

Address 2

City

Barberton

State/Province

OH

Country

US

Postal Code

44203

Phone Number

Fax Number

Email Address

Additional Applicant Data may be generated within this form by selecting the Add button.

Add

Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	Case 7709
		Application Number	
Title of Invention	HIGH TEMPERATURE SUB-CRITICAL BOILER WITH STEAM COOLED UPPER FURNACE AND START-UP METHODS		

Assignee | 1

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

Remove

If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

Prefix	Given Name	Middle Name	Family Name	Suffix

Mailing Address Information For Assignee including Non-Applicant Assignee:

Address 1			
Address 2			
City		State/Province	
Country i		Postal Code	
Phone Number		Fax Number	
Email Address			

Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button.

Add

Signature:

Remove

NOTE: This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). However, if this Application Data Sheet is submitted with the **INITIAL** filing of the application and either box A or B is **not** checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a juristic entity (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/mjseymour/		Date (YYYY-MM-DD)	2016-04-05
First Name	Michael	Last Name	Seymour	Registration Number
				54436

Additional Signature may be generated within this form by selecting the Add button.

Add

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	Case 7709
		Application Number	
Title of Invention	HIGH TEMPERATURE SUB-CRITICAL BOILER WITH STEAM COOLED UPPER FURNACE AND START-UP METHODS		

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Señor Director

DIRECCION DE NUEVAS CREACIONES

Superintendencia de Industria y Comercio

E. S. D.

Referencia: Expediente No. NC2017/0003065

Asunto: Solicitud de patente para: ***“UNA UNIDAD DE EMPAQUE QUE TIENE SELLADO MEJORADO Y UN DISPOSITIVO INDICADOR PARA EL USUARIO, Y UN MÉTODO PARA FORMAR TAL UNIDAD DE EMPAQUE”***

Solicitante: THE BABCOCK & WILCOX COMPANY

Fecha de solicitud: 10 de enero de 2017

RESPUESTA A EXAMEN PRELIMINAR

Yo, ANDRÉS RINCÓN USCÁTEGUI, identificado como aparece al pie de mi firma, en mi condición de apoderado de la sociedad solicitante de la patente de la referencia, doy respuesta al Oficio No. 5053.

I. EN CUANTO AL ANÁLISIS DE PRIORIDAD

Presento, junto con la respuesta a este oficio, copia certificada del documento de la prioridad invocada.

II. EN CUANTO AL DOCUMENTO DE CESIÓN

Presento, junto con la respuesta a este oficio, copia del documento de cesión por parte de los inventores a favor de los solicitantes.

III. EN CUANTO A LAS OBJECIONES DE SUPUESTA FALTA DE CLARIDAD

1. El Examinador señala que las reivindicaciones de la 1 a la 10 no son claras, en resumen, por las siguientes razones:

– Los términos “un horno” (reiv. 1, 8), “quemadores” (reiv. 1), “pared(es) de membrana enfriadas con vapor” (reiv. 1, 8), “un separador de vapor” (reiv. 1), “una salida de vapor seco” (reiv. 1, 8), “un circuito enfriado con vapor” (reiv. 1, 8), “tubos sin membrana” (reiv. 1, 8), “tubos sellados por membrana” (reiv. 1, 8), “supercalentador (es) primario” (reiv. 1, 8, 10), “circuitos de control” (reiv. 1, 9), “una válvula de desvío” (reiv. 2, 3), “una válvula de reducción” (reiv. 2 a 5), “un controlador electrónico” (reiv. 3, 4, 9), “una vía de desvío” (reiv. 4, 8), “un supercalentador secundario” (reiv. 6), “un horno superior” (reiv. 7), “un horno inferior” (reiv. 7), “válvulas de desvío” (reiv. 9), “válvulas de reducción” (reiv. 9), “un paso de convección” son imprecisos y/o relativos, por lo cual no permiten distinguir la invención del estado de la técnica.

– Los términos “al menos” (reiv. 1 a 5, 8), “uno o varios (as)” (reiv. 8, 9), son imprecisos.

– La expresión “está configurada para acomodar al menos una parte del material de carbono”, en la reivindicación 5, corresponde a una característica funcional.

– Las frases “enfriadas con vapor” (reiv. 1, 4, 6, 7, 10), “enfriadas con agua” (reiv. 7), “configurados para (i) reducir el flujo al supercalentador primario y (ii) desviar el flujo de la salida de vapor seco del separador de vapor a las paredes de membrana enfriadas con vapor del horno” (reiv. 1), “cuando se abre, conecta operativamente la salida de vapor seco del separador de vapor con las paredes de membrana enfriadas con vapor del horno” (reiv. 2), “es operativa para reducir el flujo a través del supercalentador primario” (reiv. 2, 4), “configurado para regular los circuitos de control de puesta en marcha” (reiv. 3, 5), “un modo de puesta en marcha en el que al menos una válvula de desvío se abre y al menos una válvula de reducción se opera para reducir el flujo a través del supercalentador primario; o un modo operativo normal en donde al menos una válvula de desvío se cierra y al menos una válvula de reducción se abre por completo” (reiv. 3, 5), “para conmutar el flujo de vapor seco del separador de vapor a través del circuito enfriado con vapor o la vía de desvío” (reiv. 8), “configurado para operar una o varias válvulas de reducción y una o varias válvulas de desvío” (reiv. 9) corresponden a características funcionales, los cuales no definen la invención.

– Incluir entre paréntesis () los números de referencia de cada uno de los elementos que hacen parte de la invención de acuerdo con la numeración empleada en los dibujos.

2. Mi representado se reserva el derecho de modificar Los términos “un horno” (reiv. 1, 8), “quemadores” (reiv. 1), “pared(es) de membrana enfriadas con vapor” (reiv. 1, 8), “un separador de vapor” (reiv. 1), “una salida de vapor seco” (reiv. 1, 8), “un circuito enfriado con vapor” (reiv. 1, 8), “tubos sin membrana” (reiv. 1, 8), “tubos sellados por membrana” (reiv. 1, 8), “supercalentador (es) primario” (reiv. 1, 8, 10), “circuitos de control” (reiv. 1, 9), “una válvula de desvío” (reiv. 2, 3), “una válvula de reducción” (reiv. 2 a 5), “un controlador electrónico” (reiv. 3, 4, 9), “una vía de desvío” (reiv. 4, 8), “un supercalentador secundario” (reiv. 6), “un horno superior” (reiv. 7), “un horno inferior” (reiv. 7), “válvulas de desvío” (reiv. 9), “válvulas de reducción” (reiv. 9), “un paso de convección” para cuando se realice el examen de patentabilidad, en aras de no limitar indebidamente la invención.

3. Difiero respetuosamente de la opinión del Examinador en lo referente a que los términos “al menos” (reiv. 1 a 5, 8), “uno o varios (as)” (reiv. 8, 9) son imprecisos dado que los citados términos fijan un mínimo necesario para que la invención sea realizada exitosamente.

4. Difiero respetuosamente de la opinión del Examinador en lo referente al uso de la expresión “está configurada para acomodar al menos una parte del material de carbono”, en la reivindicación 5 dado que la Guía de Examen de Patentes permite el uso de características funcionales cuando buscan ilustrar o definir las características técnicas de la invención. Dicha frase busca brindar mayor información sobre el alcance de las características técnicas.

5. Difiero respetuosamente de la opinión del Examinador en lo referente al uso de las frases frases “enfriadas con vapor” (reiv. 1, 4, 6, 7, 10), “enfriadas con agua” (reiv. 7), “configurados para (i) reducir el flujo al supercalentador primario y (ii) desviar el flujo de la salida de vapor seco del separador de vapor a las paredes de membrana enfriadas con vapor del horno” (reiv. 1), “cuando se abre, conecta operativamente la salida de vapor seco del separador de vapor con las paredes de membrana enfriadas con vapor del horno” (reiv. 2), “es operativa para reducir el flujo a través del supercalentador primario” (reiv. 2, 4), “configurado para regular los circuitos de control de puesta en marcha” (reiv. 3, 5), “un modo de puesta en marcha en el que al menos una válvula de desvío se

abre y al menos una válvula de reducción se opera para reducir el flujo a través del supercalentador primario; o un modo operativo normal en donde al menos una válvula de desvío se cierra y al menos una válvula de reducción se abre por completo” (reiv. 3, 5), “para conmutar el flujo de vapor seco del separador de vapor a través del circuito enfriado con vapor o la vía de desvío” (reiv. 8), “configurado para operar una o varias válvulas de reducción y una o varias válvulas de desvío” (reiv. 9) no definen la invención. Es menester traer a colación, que de acuerdo con la Guía para Examen de Solicitudes de Patentes de Invención y Modelos de Utilidad empleada en Colombia, este tipo de expresiones sí son permitidas y aceptas, siempre y cuando la invención se encuentre definida por sus características estructurales. En este caso en concreto, las expresiones citadas con anterioridad que se usan para definir las características funcionales, sirven con un propósito ilustrativo, proveen un mejor entendimiento de las características técnicas de la invención y asimismo aclaran la reivindicación de la invención. Por todo lo anterior, considero refutable la objeción en cuestión.

5. Mi representado se reserva el derecho de incluir entre paréntesis () los números de referencia de cada uno de los elementos que hacen parte de la invención de acuerdo con la numeración empleada en los dibujos.

Por todo lo anterior, considero que el Capítulo Reivindicatorio Modificado adjunto cumple con todos los requisitos de claridad y concisión, ajustándose así a los lineamientos del Artículo 30 de la Decisión 486, ya que cualquier persona medianamente versada en la materia está en completa capacidad de reproducir la invención sin ambigüedad alguna.

IV. EN CUANTO AL PAGO DE TASA ADICIONAL POR EL NÚMERO DE REIVINDICACIONES

Mi representado se reserva el derecho de realizar el pago por reivindicaciones adicionales.

V. PETICIÓN

Teniendo en cuenta que la presente solicitud cumple con los requisitos de los Artículos 26 y 27 de la Decisión 486 de 2000 y considerando que se ha dado respuesta a cada una de las observaciones de la Dirección de Nuevas Creaciones con respecto a otros aspectos que tienen que ver con la

patentabilidad de la invención, solicito a su Despacho continuar con el trámite administrativo correspondiente.

VI. ANEXOS

- Copia certificada del documento de prioridad
- Cesión de inventores

Señor Director,

ANDRÉS RINCÓN USCÁTEGUI

C.C. 79.780.910 de Bogotá

T.P. 114.908



THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

March 17, 2017

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A FILING DATE UNDER 35 USC 111.

APPLICATION NUMBER: 15/091,211

FILING DATE: April 05, 2016

THE COUNTRY CODE AND NUMBER OF YOUR PRIORITY APPLICATION, TO BE USED FOR FILING ABROAD UNDER THE PARIS CONVENTION, IS US15/091,211

**By Authority of the
Under Secretary of Commerce for Intellectual Property
and Director of the United States Patent and Trademark Office**



[Signature]
SYLVIA HOLLEY
Certifying Officer

Electronic Acknowledgement Receipt

EFS ID:	25405089
Application Number:	15091211
International Application Number:	
Confirmation Number:	5352
Title of Invention:	HIGH TEMPERATURE SUB-CRITICAL BOILER WITH STEAM COOLED UPPER FURNACE AND START-UP METHODS
First Named Inventor/Applicant Name:	Eric L Wells
Customer Number:	41669
Filer:	Eric Marich/Amy Saus
Filer Authorized By:	Eric Marich
Attorney Docket Number:	
Receipt Date:	05-APR-2016
Filing Date:	
Time Stamp:	16:31:38
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	\$1600
RAM confirmation Number	3113
Deposit Account	501813
Authorized User	SAUS, AMY

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:
Charge any Additional Fees required under 37 CFR 1.16 (National application filing, search, and examination fees)

File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Application Data Sheet	Case_7709_ADS_aia0014.pdf	1835924 6490254e9eb04f64b8e15704ea2fb1de949f etc;	no	9
Warnings:					
Information:					
2	Oath or Declaration filed	Case_7709_Declaration_EXECUTED.pdf	762988 4f516a34352d27bcee15ac9849a4dc977b6e1d	no	2
Warnings:					
Information:					
3		Case_7709_Final.pdf	187954 41a0f6dc919acbf6b6b60ea89b89ce04b52d2	yes	27
	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Specification		1	21	
	Claims		22	26	
	Abstract		27	27	
Warnings:					
Information:					
4	Drawings-only black and white line drawings	Case_7709_Drawings.pdf	678386 be78437495bcb6c77000b7c409c35d2a8fb7774f	no	6
Warnings:					
Information:					
5	Fee Worksheet (SB06)	fee-info.pdf	34975 bee0043171aa55b16600c2a9e661718ce09201c	no	2
Warnings:					
Information:					
Total Files Size (in bytes):			3500227		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

HIGH TEMPERATURE SUB-CRITICAL BOILER WITH STEAM COOLED UPPER FURNACE AND START-UP METHODS

BACKGROUND

[0001] The present disclosure relates to the boiler arts, with illustrative embodiments including sub-critical boilers, sub-critical natural circulation boilers, coal-fired boilers, sub-critical coal-fired boilers, sub-critical natural circulation coal-fired boilers, and to methods of manufacturing and operating the same.

[0002] Small coal-fired boilers find application in diverse settings, such as where power requirements are relatively low (e.g. rural areas, underdeveloped regions), where coal is readily available, and so forth. Typical small coal-fired boilers for electric power generation employ a sub-critical natural circulation design. An example of such a boiler design is the Babcock & Wilcox Carolina-Type Radiant Boiler design. This design employs a furnace with membraned water-cooled furnace walls that feed one or more steam drums. Water passing through the furnace walls absorb heat energy, in effect cooling the tubes / pipes directly exposed to the combustion heat. The steam drum(s) feeds one or more primary superheaters located inside a convection pass, and one or more secondary pendant superheaters located inside the upper portion of the furnace. This superheated steam is used to run a high-pressure turbine. The steam exiting the high-pressure turbine is then sent through reheaters to increase the temperature again, so that the steam can then be used to run a low-pressure turbine.

[0003] Water-cooled pipes or tubes are designed to carry wet steam (i.e. a steam/water mixture, or equivalently, steam quality less than 100%). For a given operating pressure, the temperature of wet steam is thermodynamically limited to the boiling temperature of liquid water at the given operating pressure. In practice, water-cooled pipes are designed for an operating temperature of about 650°F-670°F, corresponding to an operating pressure of about 2200-2600 psig. In a sub-critical boiler, water-cooled pipes feed wet steam into the steam drum.

[0004] By contrast, steam-cooled pipes or tubes are designed to carry superheated steam having a steam quality of 100% (i.e., no liquid component). The temperature of superheated steam is not thermodynamically limited for a given pressure, and in

Carolina-Type designs the steam-cooled superheaters generally carry superheated steam at temperatures of about 1000°F-1050°F.

[0005] Because of the differences in temperature, water-cooled pipes can be made of lower cost carbon steel, whereas steam-cooled pipes are made of more costly steel compositions. A design such as the Carolina-Type Radiant Boiler advantageously leverages these factors by designing the entire furnace to be water-cooled, so that the membraned walls can use lower cost carbon steel pipes and connecting membranes. The higher alloy superheater components are located within the furnace and convection pass (i.e inside the walls of the boiler), and are not membraned. In such designs, the membraned water-cooled walls are generally cooler than the flue gas to which the steam-cooled superheaters are exposed, due to more efficient heat transfer to the steam/water mixture carried by the water-cooled pipes.

[0006] In certain applications, it is desirable to obtain steam at high temperatures after superheating and after reheating, e.g. about 1050°F after both cycles. This can be difficult in small designs, and further designs and methods are needed to obtain such high temperatures.

BRIEF DESCRIPTION

[0007] The present disclosure thus relates to small high pressure sub-critical boilers that can have natural circulation and achieve high superheater temperatures of about 1050°F. Generally, the lower furnace of such boilers uses water-cooled tubes/pipes, and the upper furnace uses steam-cooled tubes/pipes. Put another way, the upper furnace of the boiler is made of superheater tubes/pipes. The steam-cooled tubes of the upper furnace are typically near the end of the arrangements of superheating surfaces in the boiler. However, this can cause exposure to excessive thermal stresses during start-up. In the present disclosure, a diversion path is sued during start-up to bypass the other superheating surfaces and divert dry steam directly to the steam-cooled tubes in the upper furnace.

[0008] Disclosed in various embodiments herein is a boiler comprising: a furnace including burners and steam-cooled membrane walls, the steam-cooled membrane walls comprising pipes sealed by membrane; a steam separator having a dry steam

outlet; a steam-cooled circuit connected to the dry steam outlet of the steam separator, the steam-cooled circuit including at least (i) a primary superheater comprising pipes without membrane and (ii) the steam-cooled membrane walls of the furnace, wherein the steam-cooled membrane walls of the furnace are located downstream of the primary superheater in the steam-cooled circuit; and startup control circuitry configured to (i) bypass the primary superheater and (ii) divert flow from the dry steam outlet of the steam separator to the steam-cooled membrane walls of the furnace.

[0009] The startup control circuitry may include: at least one diversion valve that when opened operatively connects the dry steam outlet of the steam separator to the steam cooled membrane walls of the furnace; and at least one reduction valve in the steam cooled circuit that is operative to reduce flow through the primary superheater.

[0010] The startup control circuitry may further include an electronic controller configured to set the startup control circuitry into one of: a startup mode in which the at least one diversion valve is opened and the at least one reduction valve is operated to reduce flow through the primary superheater; or a normal operating mode in which the at least one diversion valve is closed and the at least one reduction valve is fully open.

[0011] In other embodiments, the startup control circuitry includes: a valved diversion path connecting the dry steam outlet of the steam separator to the steam cooled membrane walls of the furnace; and at least one reduction valve in the steam cooled circuit that is operative to reduce flow through the primary superheater. The startup control circuitry may further include an electronic controller configured to set the startup control circuitry into one of: a startup mode in which the valved diversion path is open and the at least one reduction valve is operated to reduce flow through the primary superheater; or a normal operating mode in which the valved diversion path is closed and the at least one reduction valve is fully open.

[0012] The boiler may further comprise a secondary superheater located downstream of the steam-cooled membrane walls of the furnace in the steam-cooled circuit.

[0013] The furnace may include: a steam-cooled upper furnace having the steam-cooled membrane walls; and a water-cooled lower furnace formed by water-cooled membrane walls that comprise pipes sealed by membrane, the water-cooled membrane

walls not being included in the steam-cooled circuit connected to the dry steam outlet of the steam separator.

[0014] Also disclosed in various embodiments herein is a boiler, comprising: a furnace including at least one steam-cooled membrane wall, the at least one steam-cooled membrane wall comprising pipes sealed by membrane; a steam separator having a dry steam outlet; one or more primary superheaters comprising pipes without membrane; a steam-cooled circuit running from the dry steam outlet to the one or more primary superheaters and subsequently to the at least one steam-cooled membrane wall of the furnace, and containing one or more reduction valves between the one or more primary superheaters and the at least one steam-cooled membrane wall of the furnace; a diversion path running from the dry steam outlet through one or more diversion valves to a location upstream of the at least one steam-cooled membrane wall of the furnace and downstream of the one or more primary superheaters; and control circuitry for switching dry steam flow from the steam separator through the steam-cooled circuit or the diversion path.

[0015] The control circuitry may include an electronic controller configured to operate the one or more reduction valves and the one or more diversion valves.

[0016] The boiler may further comprise a convection pass formed by steam cooled convection pass membrane walls, the convection pass membrane walls being located upstream of the one or more primary superheaters in the steam-cooled circuit.

[0017] The boiler can also further comprise secondary superheaters comprising pipes without membrane, the secondary superheaters being located downstream of the at least one steam-cooled membrane wall of the furnace in the steam-cooled circuit.

[0018] The furnace may include: a steam-cooled upper furnace having an upper furnace that includes the at least one steam-cooled membrane wall; and a water-cooled lower furnace formed by water-cooled membrane walls, the water-cooled membrane walls not being included in the steam-cooled circuit connected to the dry steam outlet of the steam separator.

[0019] Also disclosed herein are boiler start-up methods for starting a boiler having a steam separator, steam-cooled membrane walls forming at least a portion of a furnace, and a primary superheater interposed in a steam-cooled circuit between a dry steam

outlet of the steam separator and the steam cooled membrane walls, the methods comprising: reducing dry steam flow through the steam-cooled circuit; and diverting dry steam flow through a diversion path that runs from the dry steam outlet to a location upstream of the steam-cooled membrane walls of the furnace and downstream of the primary superheater, wherein the diversion path bypasses the primary superheater.

[0020] The diverting may comprise opening a diversion valve upstream of the primary superheater. The reducing may comprise closing a reduction valve located in the steam-cooled circuit downstream of the primary superheater.

[0021] The boiler start-up method may further comprise: firing up the boiler using oil as fuel; terminating the reducing and diverting responsive to a switch-over condition (e.g. time, temperature, pressure, combinations thereof); and after the terminating, switching over from using oil as fuel to using coal as fuel.

[0022] The steam-cooled circuit may further comprise steam cooled convection pass membrane walls, the convection pass membrane walls being located upstream of the primary superheater in the steam-cooled circuit. The steam-cooled circuit may also further comprise secondary superheaters comprising pipes without membrane, the secondary superheaters being located downstream of the steam-cooled membrane walls of the furnace in the steam-cooled circuit.

[0023] These and other non-limiting aspects and/or objects of the disclosure are more particularly described below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] The following is a brief description of the drawings, which are presented for the purposes of illustrating embodiments disclosed herein and not for the purposes of limiting the same.

[0025] **FIG. 1** diagrammatically shows a side-sectional view of an illustrative boiler. Insets A, B, and C illustrate portions of piping.

[0026] **FIG. 2** is a top cross-sectional view of the boiler of **FIG. 1** through the upper furnace along line A-A of **FIG. 3**.

[0027] **FIG. 3** diagrammatically shows a more detailed side-sectional view of a portion of the boiler of **FIG. 1** including an illustrative layout of superheaters.

[0028] FIG. 4 diagrammatically shows a cooling circuit of the boiler of FIG. 1 and FIG. 2.

[0029] FIG. 5 diagrammatically shows the cooling circuit of FIG. 4 with start-up control circuitry as described herein.

[0030] FIG. 6 diagrammatically plots a typical start-up sequence performed using the circuitry of FIG. 5. The inset table shows start-up circuitry valve settings for the start-up and normal operating modes. The x-axis is time in hours, and runs from 0 to 8 in intervals of 1. The left-hand y-axis is the pressure in psig, and runs from 0 to 2500 in intervals of 500. The right-hand y-axis is the steam flow and firing %, and runs from 0 to 100 in intervals of 10. There are three lines for throttle pressure, firing rate, and steam flow. The throttle pressure is read against the left-hand y-axis, and the firing rate and steam flow are read against the right-hand y-axis.

DETAILED DESCRIPTION

[0031] A more complete understanding of the processes and apparatuses disclosed herein can be obtained by reference to the accompanying drawings. These figures are merely schematic representations based on convenience and the ease of demonstrating the existing art and/or the present development, and are, therefore, not intended to indicate relative size and dimensions of the assemblies or components thereof.

[0032] Although specific terms are used in the following description for the sake of clarity, these terms are intended to refer only to the particular structure of the embodiments selected for illustration in the drawings, and are not intended to define or limit the scope of the disclosure. In the drawings and the following description below, it is to be understood that like numeric designations refer to components of like function.

[0033] The modifier "about" used in connection with a quantity is inclusive of the stated value and has the meaning dictated by the context (for example, it includes at least the degree of error associated with the measurement of the particular quantity). When used with a specific value, it should also be considered as disclosing that value. For example, the term "about 2" also discloses the value "2" and the range "from about 2 to about 4" also discloses the range "from 2 to 4."

[0034] It should be noted that many of the terms used herein are relative terms. For example, the terms "inlet" and "outlet" are relative to a direction of flow, and should not be construed as requiring a particular orientation or location of the structure. The terms "upstream" and "downstream" are relative to the direction in which a fluid flows through various components, i.e. the fluid flows through an upstream component prior to flowing through the downstream component. It should be noted that in a loop, a first component can be described as being both upstream of and downstream of a second component. Similarly, the terms "upper" and "lower" are relative to each other in location, i.e. an upper component is located at a higher elevation than a lower component.

[0035] The terms "horizontal" and "vertical" are used to indicate direction relative to an absolute reference, i.e. ground level. However, these terms should not be construed to require structures to be absolutely parallel or absolutely perpendicular to each other. For example, a first vertical structure and a second vertical structure are not necessarily parallel to each other.

[0036] The terms "top" and "bottom" or the terms "roof" and "floor" are used to refer to locations/surfaces where the top/roof is always higher than the bottom/floor relative to an absolute reference, i.e. the surface of the earth. The terms "upwards" and "downwards" are also relative to an absolute reference; an upwards flow is always against the gravity of the earth.

[0037] The term "plane" is used herein to refer generally to a common level, and should be construed as referring to a volume, not as a flat surface.

[0038] A fluid at a temperature that is above its saturation temperature at a given pressure is considered to be "superheated." The temperature of a superheated fluid can be lowered (i.e. transfer energy) without changing the phase of the fluid. As used herein, the term "wet steam" refers to a saturated steam/water mixture (i.e., steam with less than 100% quality where quality is percent steam content by mass). As used herein, the term "dry steam" refers to steam having a quality equal to or about 100% (i.e., no liquid water is present).

[0039] The terms "pipes" and "tubes" are used interchangeably herein to refer to a hollow cylindrical shape, as is commonly understood.

[0040] The term "natural circulation", as used herein, refers to the circulation of water through the boiler due to differences in density as the water is heated. Water circulation can occur without the need for a mechanical pump.

[0041] To the extent that explanations of certain terminology or principles of the boiler and/or steam generator arts may be necessary to understand the present disclosure, the reader is referred to *Steam/its generation and use*, 42nd Edition, edited by G.L. Tomei, Copyright 2015, The Babcock & Wilcox Company, ISBN 978-0-9634570-2-8, the text of which is hereby incorporated by reference as though fully set forth herein.

[0042] Higher wet steam pressures are not desired for many small boiler applications due to cost and safety issues (e.g. higher minimum pipe wall and membrane thicknesses). In a small boiler using only water-cooled furnace walls, it is difficult or impossible to achieve superheater and reheater outlet temperatures both at 1050°F for 150-300 MW net power generation, because it is not possible to provide sufficient superheater / reheater surface area for heat transfer to the dry steam to obtain such high temperatures.

[0043] One possible alternative is to employ a drumless once-through boiler design, such as one of the Babcock & Wilcox Universal Pressure boiler designs. However, these designs employ once-through steam generation. In a once-through design, the transition point from wet steam to superheated steam depends on operating conditions, rather than being defined using a steam separator (e.g. a steam drum). As a result, more expensive piping is typically used for all piping/tubing in such once-through designs for safety. This results in increased capital costs.

[0044] In the sub-critical boiler designs of the present disclosure, the furnace is divided into two sections: a lower furnace using water-cooled membrane walls that feeds into the steam separator, and an upper furnace using steam-cooled membrane walls that is fed (directly or indirectly) by the dry steam outlet of the steam separator. This approach advantageously enables lower cost carbon steel to be used for the lower furnace walls, with more expensive piping being used only in the upper steam-cooled furnace (including the convection path walls in some embodiments). Cost is lowered by retaining the steam separator. A higher steam output temperature is attainable because

the use of a steam-cooled upper furnace and convection pass walls provides additional surface area for heat transfer from combustion / flue gases to the dry steam within the steam-cooled walls, resulting in superheated steam of desired temperatures. Again, such high superheated steam temperatures cannot be obtained with conventional water-cooled walls in the upper furnace.

[0045] In some embodiments, further improvement is attained in such a design by reducing the cross-section of the upper steam-cooled furnace compared with the lower water-cooled furnace. This increases flue gas flow velocity in the upper steam-cooled furnace compared with the lower water-cooled furnace, which provides more efficient heat transfer in the high temperature gas path, and also reduces the amount of materials and manufacturing cost.

[0046] In Carolina-Type Radiant Boiler designs, the convection pass is spaced apart from the furnace by a horizontal convection pass whose horizontal length creates a spacing between the furnace and the convection pass. As a result, in the Carolina-Type Radiant Boiler design, the furnace includes a rear wall and the convection pass includes a front wall. In a folded design, these two walls are combined into one wall. In the present disclosure, a common membraned steam-cooled wall is used to separate the upper furnace up-pass and the adjacent convection pass. This eliminates the open pass between the furnace and the convection pass, providing improved compactness for the boiler and reduces the amount of materials and manufacturing cost.

[0047] These benefits set forth above are attained by replacing the conventional water-cooled furnace with a two-part design in which the upper furnace is steam-cooled. However, such a modification has certain potential disadvantages. Overall material cost is increased due to the higher-cost alloy used in the upper furnace, but this can be mitigated by approaches disclosed herein (e.g., reduced upper furnace cross-section, employing a common steam-cooled wall between the furnace and the convection pass). Another potential disadvantage is structural complications for the preferred top-supported arrangement. This potentially arises because the lower furnace pipes are preferably carbon steel to reduce cost, while the upper furnace pipes are higher cost alloys for compatibility with steam cooling. Such a difficulty is also encountered in some once-through super-critical furnaces that employ carbon steel pipes in a lower furnace

section to reduce cost. An example of such a design is the Babcock & Wilcox Spiral Wound Universal Pressure (SWUP) Boiler. In the SWUP once-through super-critical boiler design, the lower water-cooled furnace portion is top-supported via dedicated lower furnace support components that connect with the upper boiler support via an array of vertical tie rods and/or connections to the upper furnace water-cooled pipes. The resulting assembly is complicated as the lower furnace must be secured by installing its support components, followed by performing the pipe welding.

[0048] Such an approach employing dedicated lower furnace support components can also be employed in sub-critical boiler designs with an upper steam-cooled furnace and lower water-cooled furnace, as disclosed herein. However, in some embodiments disclosed herein, such dedicated support castings and concomitant complex pipe welding operations are eliminated, and in their place a transition section with integral transition piping is employed. The transition section contains both water pipes and steam pipes, and provides a location where these pipes can be run to headers. In the transition section, at least some transition pipes are designed to be vertically oriented pipes, and lower furnace support is achieved by tensile support via welds to these vertically oriented transition pipes. The transition section is designed to support twice the load of the lower furnace. The transition section can be made of a cast stainless steel material that is compatible with steam-cooling – it is therefore overdesigned for the water-cooled transition pipes, but the ability to maintain top support for the lower furnace outweighs the additional cost entailed by overdesigning these relatively short water-cooled transition pipes. The transition section also acts as a pressure seal between the lower furnace and the upper furnace.

[0049] Some illustrative embodiments of such sub-critical boilers are diagrammatically shown and described below. These are merely illustrative examples, and a given embodiment may include one, two, more, or all disclosed novel features described herein.

[0050] **FIG. 1** and **FIG. 2** show different views of an illustrative sub-critical natural circulation boiler of the present disclosure. **FIG. 1** is a side-sectional view of the entire boiler. **FIG. 2** is a top (plan) view that passes through the upper furnace of the boiler.

[0051] With reference to **FIG. 1**, a sub-critical boiler **10** is diagrammatically shown. The boiler **10** includes a lower furnace **12** which is water-cooled, an upper furnace **14** which is steam-cooled, and a transitional section **16** which in preferred embodiments is formed from a single-piece transition casting. The illustrative boiler **10** is a folded boiler design that further includes a convection pass **18** which is connected to the upper furnace **14** to form what might be considered a horizontal pass **20**. The walls of the lower furnace **12**, the transitional section **16**, the upper furnace **14**, and the convection pass **18** collectively define the boiler.

[0052] Combustion / flue gas **22** are diagrammatically indicated by arrows, and these gases flow through the boiler and heat the water / steam in the various walls of the boiler. More specifically, combustion air is blown into the lower furnace **12** through an air inlet **24**, where it is mixed with a combustible fuel such as coal, oil, or natural gas. In some preferred embodiments, the fuel is coal, which is pulverized by a pulverizer (not shown). A plurality of burners **26** combusts the fuel/air mixture, resulting in flue gas. The flue gas rises by natural convection through the up-pass formed by the lower furnace **12**, the transition section **16**, and the upper furnace **14**, then flows horizontally through the convection pass, which includes the convection pass **18** and finally exits through a flue gas outlet **28** for further downstream processing. Preferably, a hopper **33** is provided to capture ash or other contaminants in the exiting flue gas.

[0053] The sub-critical boiler **10** is top-supported to the building structure via suitable upper anchor points **30**. These are diagrammatically indicated in **FIG. 1**. The pipes of the upper furnace **14** and the convection pass **18** are vertically oriented and are directly supported from the anchor points **30**. The pipes of the lower furnace **12** are also vertically oriented and are indirectly supported via welds to the transition section **16**.

[0054] It is desirable to capture the heat energy present in the combustion / flue gas **22** for tasks such as driving an electrical power generation turbine (for example). To do so, the sub-critical boiler **10** includes cooling surfaces comprising pipes or tubes through which wet steam flows (these pipes or tubes are referred to herein as water-cooled) or through which superheated steam flows (these pipes or tubes are referred to herein as steam-cooled). More particularly, with reference to Inset A of **FIG. 1**, the lower furnace **12** includes water-cooled tubes **32** with membrane **34** disposed between and welded to

the tubes 32, so that the tubes 32 and membrane 34 collectively form a membrane wall 36, with the tubes 32 carrying flow of wet steam through the membrane wall 36. The membrane wall 36 forms the barrier that contains the flue gas 22, i.e. the membrane 34 is welded or otherwise connected to the tubes 32 to provide a seal against leakage of the flue gas 22. The water-cooled membrane wall 36 of the lower furnace 12 does not see highly elevated water temperatures; for example, if the sub-critical boiler 10 is designed for a maximum steam pressure of 2800 psig, then the saturated steam carried by the water-cooled tubes 32 is at about 685°F (corresponding to the boiling point of water at 2800 psig), though of course the combustion gas is at a much higher temperature.

[0055] The upper furnace 14 and convection pass 18 are analogously made of a steam-cooled membrane wall 46 comprising steam-cooled tubes 42 with membrane 44 disposed between and welded or otherwise connected to the tubes 42 (see Inset B of FIG. 1), with the tubes 42 and membrane 44 collectively forming the membrane wall 46. The tubes 42 carry a flow of superheated steam through the membrane wall 46. The steam-cooled membrane wall 46 carries steam at substantially higher steam temperatures than the water-cooled membrane wall 36. For example, the steam in the steam-cooled membrane walls 46 may be at a temperature of over 1000°F, e.g. up to 1050°F in some contemplated embodiments. It should be noted that the roof 35 of the furnace and the convection pass is also made of steam-cooled membrane wall. It should also be noted that the diameter of the tubes and the spacing between the tubes of the steam-cooled membrane walls may differ between the upper furnace and the convection pass.

[0056] The tubes 32 of the water-cooled membrane wall generally have a greater diameter than the tubes 42 of the steam-cooled membrane wall. In particular, embodiments, the inner diameter of the water-cooled tubes is at least 0.5 inches greater than the inner diameter of the steam-cooled tubes. The tubes of the water-cooled membrane wall have an inner diameter of about 1.5 inches to about 2.0 inches, while the tubes of the steam-cooled membrane wall have an inner diameter of about 1.0 inches to about 2.5 inches. The tubes of the water-cooled membrane wall have an outer diameter of about 2.0 inches to about 2.5 inches, while the tubes of the steam-

cooled membrane wall have an outer diameter of about 1.3 inches to about 2.3 inches. The tubes themselves may have a thickness of about 0.2 inches to about 0.5 inches.

[0057] In a typical steam flow circuit for the sub-critical boiler **10**, water is inputted to the lower ends of the water-cooled tubes **32** via a lower inlet header **50**. As the water travels upwards through these water-cooled tubes **32**, the water cools the tubes exposed to high-temperature flue gas in the lower furnace **12** and absorbs energy from the flue gas to become a steam-water mixture (i.e. wet steam) at subcritical pressure.

[0058] The wet steam exits the upper ends of the water-cooled tubes **32** and flows via a wet steam outlet header **52** into an inlet **53** of a steam separator **54**. The wet steam outlet header **52** is preferably welded to water-cooled transition pipes within the transition section **16**. Preferably, the wet steam outlet header **52** facilitates venting of the tubes **32** as appropriate during start up, shut down, or maintenance, etc.. Any type of steam separator may be used, e.g. employing cyclonic separation or so forth. In particular embodiments, a vertical steam separator is used, such as that described in U.S. Patent No. 6,336,429. A dry steam outlet **56** of the steam separator **54** at an upper end of the steam separator outputs substantially dry steam (i.e., steam with 100% quality). A drain or water outlet **58** near the lower end of the steam separator **54** collects water extracted from the wet steam for recycle back to the lower inlet header **50** feeding the lower furnace **12**.

[0059] The steam output from the dry steam outlet **56** flows to the convection pass **18** and then to the upper furnace **14**. To provide additional surface for heat transfer, one or more primary superheaters **60**, re-heaters **62**, and/or secondary superheaters **64** may be provided in the interior volume of the boiler, within the upper furnace **14** and the convection pass **18**. As illustrated here, one or more superheaters **60** disposed in the convection pass **18**; one or more re-heaters (or re-heating superheaters) **62** are disposed in the convection pass **18** and/or in the upper furnace **14**; and one or more secondary superheaters **64** are disposed in the upper furnace **14**. Again, the steam-cooled furnace walls **46** of the upper furnace **14** act as superheater surfaces as well. A more detailed illustrative steam circuit is described in later drawings. It is to be understood that the illustrative steam circuit is merely an example, and other steam

circuit configurations are contemplated, e.g. various superheater components may be omitted, and/or located elsewhere, etc.

[0060] Unlike the membrane walls **46** of the steam-cooled upper furnace **14** and the convection pass **18**, the superheaters **60**, **62**, **64** located within the boiler are formed from loose pipes/ tubes **72** without membranes joining the tubes together (see Inset C of **FIG. 1**). These superheaters **60**, **62**, **64** are disposed in the interior of the flue boiler, and desirably permit flue gas to pass through them, increasing the surface area through which heat transfer from the flue gas to the steam within the pipes can occur. The superheater pipes **72** are preferably made of an alloy steel material. In some embodiments, the superheater pipes **72** and the steam-cooled membrane wall **46** are made of the same alloy steel material, although this is not required.

[0061] As seen in **FIG. 1**, the superheaters **60**, **62**, **64** are surrounded by the steam-cooled membrane walls **46**. Said another way, the superheaters **60**, **62**, **64** are contained within the upper furnace **14** and/or in the convection pass **18** as shown in the illustrative boiler **10** of **FIG. 1**. The steam within the steam-cooled membrane walls **46** may be at the same or higher temperature than in the superheaters **60**, **62**, **64**. Due to the additional surface area available for heat transfer from the flue gas to the superheated steam within the various superheating surfaces **46**, **60**, **62**, **64**, the boiler **10** can achieve higher superheated steam temperatures than would be achievable with a conventional water-cooled sub-critical boiler whose furnace walls are entirely cooled by wet steam flowing through water-cooled pipes. However, the sub-critical boiler **10** retains the general layout of a sub-critical boiler, including employing the steam separator **54** disposed (in a steam flow sense) between the wet steam sub-circuit and the superheated steam sub-circuit, thus retaining advantages such as the operational flexibility of a sub-critical boiler design.

[0062] The illustrative sub-critical boiler **10** employs certain features that enhance compactness and efficiency. One feature is a reduced cross-sectional area for the combustion / flue gas flow **22** through the upper furnace **14** compared with the lower furnace **12**. The referenced cross-sectional area is the horizontal cross-section in the illustrative design in which the flue gas **22** flows vertically upward. In the illustrative boiler **10**, the reduction in cross-sectional area of the upper furnace **14** relative to the

lower furnace 12 is obtained via a "arch" surface 76, which is slanted as the upper furnace continues upward from the transition section 16, to reduce turbulence at the transition to higher flow velocity. This has at least two benefits. First, the reduced cross-sectional area of the upper furnace 14 reduces the amount of material (e.g. total surface area of membrane wall 46) which reduces capital cost. Second, the higher velocity of the flue gas flow 22 due to the reduced cross-sectional area increases the efficiency of heat transfer to the steam-cooled pipes 42, 72. The transition section 16 is located below the arch surface 76. The arch 76 is part of the upper furnace, and is also a steam-cooled membrane wall.

[0063] FIG. 2 is a cross-sectional plan (top) view of the boiler 10 through the upper furnace 14, and provides another view of the various components. The front wall 110 of the upper furnace is shown in solid line, as is the front wall 112 of the lower furnace. The area between these two walls is the arch 76. The upper furnace includes a first side wall 114 and a second side wall 116 opposite the first side wall, both of which are made of steam-cooled membrane walls 42. The fourth side of the upper furnace is defined by a common steam-cooled membrane wall 80. The convection pass is defined by a first side wall 124, a second side wall 126 opposite the first side wall, and a rear wall 128. A baffle wall 130 divides the convection pass into a front convection pass 17 and a rear convection pass 19. A primary superheater 60 is seen in the rear convection pass 19, while a reheater 62 is seen in the front convection pass 17 and a secondary superheater 64 is seen within the upper furnace 14.

[0064] Another feature that enhances the compactness and efficiency of this boiler design is the use of a common steam-cooled membrane wall 80. The common steam-cooled membrane wall 80 is both a "rear" wall of the upper furnace 14 and a "front" wall of the convection pass 18. The upper furnace 14 and the convection pass 18 thus share the common steam-cooled membrane wall 80, which comprises a single layer of pipes sealed by a single layer of membrane disposed between and connected to the single layer of pipes. The use of the common steam-cooled membrane wall 80 has numerous advantages. The usual open pass between the furnace and the convection pass is eliminated, providing a more compact design and reducing capital costs due to lower surface area. The common steam-cooled membrane wall 80 is advantageously heated

both by flue gas flowing upward through the upper furnace **14** and by flue gas flowing downward through the convection pass **18**.

[0065] One issue with employing the common steam-cooled membrane wall **80** is the large temperature variation between the flue gas temperature in the upper furnace **14**, on the one hand, and the flue gas temperature in the convection pass **18** on the other hand. This differential between the two flue gas temperatures will be felt by the common steam-cooled membrane wall **80**. Using transient modeling and finite element analysis to determine the resulting stress in the walls of the boiler, it was found that maximum thermal differential stress occurs during start-up, and more particularly occurs in a small area about the bottom of the common steam-cooled membrane wall **80** adjacent walls **114**, **124** on one side and walls **116**, **126** on the other. Intuitively, this can be understood since this bottommost part of the common steam-cooled membrane wall **80** is where there is the greatest temperature differential between the upward flue gas flow in the upper furnace **14** and the downward flue gas flow in the convection pass **18**. This stress can cause boiler bowing/tearing, and is accommodated by providing seals at the junction of the bottom of the common steam-cooled membrane wall **80**, the furnace side walls **114**, **116**, and the convection pass side walls **124**, **126**, as analysis showed that the overstressed area does not extend significantly up the common steam-cooled membrane wall **80**. These seals are illustrated in **FIG. 2** with reference numeral **132**.

[0066] It should be noted that the various improvements disclosed herein can be used to advantage individually or in various combinations, and/or in various types of boilers. For example, the disclosed common steam-cooled membrane wall **80** can also be used to advantage in a once-through boiler design having a convection pass, or in other types of boilers having two neighboring steam-cooled membrane walls.

[0067] With reference now to **FIGS. 2-4**, an illustrative steam-cooled circuit is described that may be used in the boiler **10** of **FIG. 1**. **FIG. 3** shows a side-sectional view of the upper furnace **14**, the convection pass **18**, and the horizontal pass **20** connecting them. Also shown are more detailed renderings of the primary superheaters **60**, reheaters **62**, and secondary superheaters **64**. In **FIG. 3** and **FIG. 4**, the primary superheaters **60** are labeled using the prefix "PSH"; the reheaters (i.e. re-heating superheaters) are labeled using the prefix "RSH"; and the secondary superheaters are

labeled using the prefix "SSH". Additionally, economizers are shown, indicated by the prefix "ECON". Inlet headers are indicated by the suffix "IN" while outlet headers are indicated by the suffix "OUT".

[0068] As shown in **FIG. 3**, there are four primary superheaters disposed in the rear convection pass **19**. Three of these employ horizontal tubes, and from lowest to highest elevation are indicated as PSH1, PSH2, and PSH3. The fourth primary superheater PSH4 is at the highest elevation and employs vertical pipes. Flow through the primary superheaters is in sequential order by number, upward through the convection pass, and the superheated steam exits at the PSH OUT header at the roof of the boiler.

[0069] Four reheaters RSH1, RSH2, RSH3, and RSH4 are also employed. Three of these (RSH1, RSH2, and RSH3) are disposed in the front convection pass **17**, while the fourth reheater RSH4 is disposed near the top of the upper furnace **14**. Cross-over piping labeled RSH XOVER conveys steam from RSH3 in the convection pass **18** to RSH4 in the upper furnace **14**. Steam flow is from a lower inlet header RSH IN, through the reheaters in sequential order, to an outlet header RSH OUT shown to the left of the upper furnace **14** in **FIG. 3**.

[0070] Four secondary superheaters SSH1, SSH2, SSH3, and SSH4 are disposed in the upper furnace **14** below the fourth re-heater RSH4. Superheated steam flows from the PSH OUT header to the SSH IN header shown to the left of the upper furnace **14**, then upwards successively through SSH1, SSH2, SSH3, and SSH4 and to the SSH OUT header again shown to the left of the upper furnace **14** above the SSH IN header.

[0071] The steam-cooled circuit further includes superheater stringers denoted SH STRINGER in **FIG. 3**, which are fed from SH STRINGER IN headers at the top of the upper furnace and subsequently flow to the SH STRINGER OUT outlet header. These stringers support the secondary superheaters. Similarly, reheater stringers are visible which support the reheaters in the front convection pass.

[0072] Referring now to **FIG. 4**, a more detailed illustration of the components that form the steam-cooled circuit and their interconnections is shown. The steam-cooled circuit starts at the dry steam outlet **56** of the steam separator **54**. Going downstream from the steam separator, dry steam running downstream first flows from the dry steam outlet **56** across the roof **90** of the boiler **10**. Dry steam also flows down the rear wall

128 of the convection pass **18**. The dry steam that flowed down the rear wall **128** then flows up the convection pass side walls **124**, **126** and the reheater stringer supports **91**, and then back down the upper baffle wall. The dry steam from the roof **90** of the boiler flows up the lower baffle wall.

[0073] The two dry superheated steam streams from the upper baffle wall and the lower baffle wall are then combined and flow into the primary superheaters **60** (i.e. PSH1, PSH2, PSH3, PSH4 in **FIG. 3**). Please note the superheated steam travels through all four primary superheaters; the steam is not divided so that only a portion flows through each primary superheater. The superheated steam travels upwards to the PSH OUT header (see **FIG. 3**). The superheated stream then travels downwards through the superheater stringers (labeled SH STRINGER) in the upper furnace. From there, the superheated stream travels upwards through the upper furnace front wall **110** and the common steam-cooled membrane wall **80** (acting as the upper furnace rear wall). The superheated steam then travels upwards through the upper furnace side walls **114**, **116**. Next, the superheated steam travels upwards through the secondary superheaters **64**. Again, the superheated steam passes through all four secondary superheaters (SSH1, SSH2, SSH3, and SSH4). After passing through the secondary superheaters, the superheated steam has a pressure of 2000 psig or greater, and in some cases 2500 psig or greater, such as about 2600 psig. The superheated steam also has a temperature of 1000°F or greater, such as about 1050°F. The superheated steam is then sent to a high-pressure turbine **92** where the heat energy is used for electrical power generation. The superheated steam loses both temperature and pressure within the high-pressure turbine **92**. The output from the high-pressure turbine is then sent back to the boiler **10** and sent through the reheaters **62**. After passing through the reheaters, the steam has a pressure of 500 psig or greater, such as about 600 psig, and also has a temperature of 1000°F or greater, such as about 1050°F. This superheated steam can then be used to run a low-pressure turbine.

[0074] Referring back to **FIG. 4**, water is returned from the low-pressure turbine. This water passes through a condenser (COND), a boiler feed pump (BFP), and a feedwater heater (FWH) before being sent to the economizer (ECON) to absorb residual heat energy from the flue gas exiting the convection pass. From there, the

heated water from the economizer is sent to the steam separator **54**. In the water-cooled circuit, water is sent from the steam separator to lower furnace inlet header **50**, which feeds the water-cooled membrane walls of the lower furnace **12**. Wet steam is collected from lower furnace outlet header **52** and sent to the steam separator **54** for separation into water and dry steam.

[0075] The steam-cooled circuit of **FIG. 3** and **FIG. 4** is merely an illustrative example, and in other embodiments the number and locations of superheaters may be different, as well as the arrangement of the various steam-cooled membrane wall and superheater components in the steam-cooled circuit. The illustrative furnace of **FIG. 1** with the illustrative steam-cooled steam circuit of **FIG. 3** and **FIG. 4** has been modeled using 3D solid modeling software, and was determined from this analysis to provide improved performance including a 1050°F/2600 psig superheater temperature/pressure and a 1050°F/600 psig reheater temperature/pressure, for a boiler designed to provide 150 MW to 300 MW of net power.

[0076] One potential issue with the furnace design of **FIG. 1** is that during start-up, there is no steam passing through the steam-cooled membrane walls of the upper furnace. When the boiler **10** is first fired, the hot flue gas flows across these steam-cooled membrane walls. During steady-state operation, the dry steam within the membrane walls would absorb heat energy, thus reducing the temperature of the pipes and membrane of the membrane wall, as well as reducing the temperature of the flue gas. During start-up, though, there is very little steam throughout the boiler. As a result, the thermal stresses on the steam-cooled membrane walls of the upper furnace are greater than during steady-state operation.

[0077] **FIG. 5** illustrates a steam circuit that provides a solution to this start-up thermal stressing problem, which leverages the dry steam output at the dry steam outlet **56** of the steam separator **54**. This dry steam is not yet superheated. As seen in **FIG. 5**, the start-up control circuitry of the steam circuit includes a valved diversion path **100** that connects the dry steam outlet **56** of the steam separator **54** more directly to the steam-cooled membrane walls of the upper furnace **14**. The valved diversion path **100** is valved with one or more diversion valves **102** (four are shown here). The diversion path **100** diverts flow from the dry steam outlet **56** of the steam separator **54** to the

steam-cooled membrane walls of the upper furnace **14**. The start-up circuitry further includes one or more reduction valves **104** (two are shown here) located in the steam-cooled circuit downstream of the primary superheaters **60**. The diversion path bypasses the primary superheaters **60**, providing dry steam more quickly to the steam-cooled membrane walls **46** of the upper furnace **14**. The diversion path runs from the dry steam outlet **56** to a location downstream of the primary superheaters **60** and upstream of the steam-cooled membrane walls **46**. A startup controller **106**, e.g. a computer or other electronic control device, operates the valves **102**, **104** to establish: (1) a start-up mode in which diversion valves **102** are opened to open the diversion path **100** and reduction valves **104** are closed (fully or partially as desired) to reduce flow through the partially bypassed primary superheaters **60** and convection pass **18**; or (2) a normal operating mode in which diversion valves **102** are closed to shut off the diversion path **100** and reduction valves **104** are open to allow full flow through the primary superheaters **60** and the convection pass **18**.

[0078] When the diversion valves **102** are open, and reduction valves **104** are partially closed, because the upper furnace walls provide the lowest path of resistance to flow,, the dry steam will tend to flow through the upper furnace walls instead of through the roof and convection pass. The presence of the dry steam in the upper furnace walls will protect the tubes of the upper furnace from excessive temperature differential, and will also cool the flue gas. As a result, the passage of flue gas through the convection pass **18** will not excessively stress the walls of the convection pass, even though dry steam is not present in large amounts in these steam-cooled walls during startup.

[0079] Heated flue gas also flows over the steam-cooled membrane walls of the convection pass **18**; however, the flue gas will have cooled substantially by this point, so the primary start-up thermal stresses arise in the upper furnace **14**.

[0080] With continuing reference to **FIG. 5** and with further reference to **FIG. 6**, a typical startup sequence is shown. The diversion valves **102** may in some embodiments be adjusted based on a thermocouple temperature reading at the outlet headers of the upper furnace walls, so that a temperature limit for the walls is not exceeded. For typical

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April 11, 2017

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Certifying Officer

PATENT ASSIGNMENT COVER SHEET

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 Stylesheet Version v1.2

EPAS ID: PAT4344460

SUBMISSION TYPE:	NEW ASSIGNMENT
NATURE OF CONVEYANCE:	ASSIGNMENT
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DATE SIGNED:	03/30/2017
Total Attachments: 3	
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ASSIGNMENT TO THE BABCOCK & WILCOX COMPANY

CASE 7709

THIS ASSIGNMENT made the 30th day of March, 2017, by ~~Erie L. Wells~~ residing at ~~9185 Hunters Chase Street NW, Massillon, Ohio 44646~~; and by ~~Albert J. Bennett~~ residing at ~~12539 Hollow Ridge Drive, Doylestown, Ohio 44230~~; and by ~~Jeremy L. Remus~~ residing at ~~4269 Woodhollow Drive, Mantua, OH 44255~~; all citizens of the United States of America;

WITNESSETH: That

WHEREAS, we are the joint inventors of a certain new and useful improvement and invention in

**HIGH TEMPERATURE SUB-CRITICAL BOILER WITH STEAM COOLED
UPPER FURNACE AND START-UP METHODS**

for which we have prepared and executed an application for Letters Patent of the United States on April 5, 2016, having U.S. Serial No. 15/091211, and

WHEREAS, THE BABCOCK & WILCOX COMPANY, a Corporation organized under the laws of the state of Delaware, U.S.A., and having its principal office at 20 S. Van Buren Ave., Barberton, Ohio, U.S.A., is desirous of acquiring the entire right, title, and interest in and to said improvement and invention, and any and all Letters Patent which shall be granted therefor;

NOW, THEREFORE, To All Whom It May Concern, be it known that for and in consideration of the sum of One Dollar (\$1.00) to us in hand paid, and other good and valuable considerations, the receipt of which is hereby acknowledged, we, ~~Erie L. Wells, Albert J. Bennett and Jeremy L. Remus~~, have sold, assigned, transferred and set over, and by these presents do sell, assign, transfer and set over, unto said THE BABCOCK & WILCOX COMPANY, its successors and assigns, the entire right, title, and interest in and to the above-mentioned improvement, invention, and application for Letters Patent therefor, and in and to any and all Letters Patent of the United States which may hereinafter be granted therefor, and in and to any and all extensions, divisions, or reissues of said Letters Patent, the same to be held and enjoyed by said THE BABCOCK & WILCOX COMPANY, for its own use and behoof, and the use and behoof of its successors and assigns, to the full end of the term for which said Letters Patent may be granted, as fully and entirely as the same would have been held and enjoyed by us had this assignment and sale not been made;

ASSIGNMENT TO THE BABCOCK & WILCOX COMPANY

CASE 7709

AND, for the consideration aforesaid, we hereby covenant and agree with said THE BABCOCK & WILCOX COMPANY, its successors and assigns, that at the time of the execution and delivery of these presents, we are the joint and lawful owners of the entire right, title, and interest in and to the above-mentioned improvement, invention, and application for Letters Patent above mentioned, and that the same are unencumbered, and that we have good right and lawful authority to sell and convey the same in the manner herein set forth;

AND, for the consideration aforesaid, we hereby covenant and agree with said THE BABCOCK & WILCOX COMPANY, its successors and assigns, that we will, whenever its counsel or the counsel of its successors or assigns, learned in the law, shall advise that an amendment or division or any other proceeding in connection with said application, including interference proceedings, is lawful and desirable or that a reissue or extension of said Letters Patent is lawful and desirable, sign all papers and drawings, take all rightful oaths, and do all acts necessary or required to be done for the procurement of valid Letters Patent for said improvement and invention, or for the reissue or extension of same, without charge to said THE BABCOCK & WILCOX COMPANY, or its successors or assigns, but at its or their expense.

We hereby request the Honorable Commissioner of Patents and Trademarks of the United States to issue the Letters Patent in accordance with this instrument.

AND, for the consideration aforesaid, we have sold, assigned, transferred and set over, and by these presents do sell, assign, transfer and set over, unto said THE BABCOCK & WILCOX COMPANY, its successors, assigns, or nominees, the entire right, title, and interest in and to any and all Letters Patent or other form of protection which may be granted in countries foreign to the United States, and in and to any and all applications for Letters Patent or other form of protection which may be filed for said improvement and invention in countries foreign to the United States, including all rights to claim priority, and in and to the invention described in said applications; and we hereby authorize and empower said THE BABCOCK & WILCOX COMPANY, its successors, assigns, or nominees, to apply for Letters Patent, or other form of protection, on said improvement and invention, in its own name or in the name of its successors, assigns, or nominees, in any and all countries where it may desire to file

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CASE 7709

such applications and where such applications may be filed by another other than the inventors; and we hereby covenant and agree to sign all papers and drawings, take all rightful oaths, and do all acts necessary or required to be done for the procurement of valid Letters Patent, or other form of protection, for said improvement and invention in countries foreign to the United States, and for further investing or confirming the right and title thereto in said THE BABCOCK & WILCOX COMPANY, its successors, assigns, or nominees, without charge to said THE BABCOCK & WILCOX COMPANY, its successors, assigns, or nominees, but at its or their expense.

IN WITNESS WHEREOF, we have hereunto set our hands and seal on the day and year first above written.

Eric L. Wells

Albert J. Bennett

Jeremy L. Remus

WITNESSES:

Daleigh Laskado

Amy M. Saus

STATE OF Ohio)
COUNTY OF Summit) ss.

On this, the 30th day of March, 2017, before me personally appeared Eric L. Wells, Albert J. Bennett and Jeremy L. Remus, me known and known to me to be the persons described in and who executed the foregoing instrument; and they acknowledged to me that they executed the same for the purpose therein stated.

SEAL



AMY M. SAUS
NOTARY PUBLIC
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RECORDED IN
STARK COUNTY
My Commission Expires
December 19, 2020