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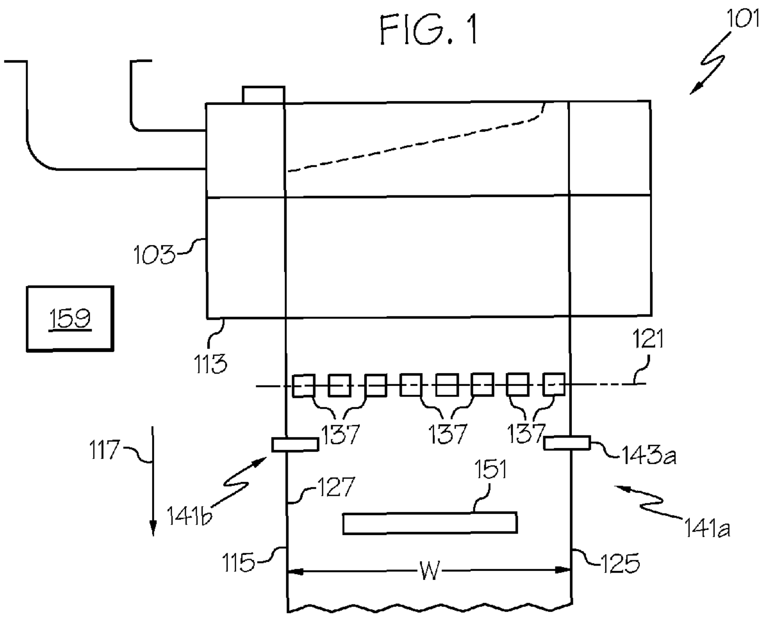
FIG. 1



(57) Abstract: Methods for producing a glass ribbon include the step of drawing a glass ribbon from a quantity of molten glass and detecting an instability in the glass ribbon. In response to the detected instability, the method can further include the step of automatically adjusting an operating variable for each of a plurality of stabilizing elements simultaneously with a controller to at least partially counter the detected instability.

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METHODS FOR PRODUCING A GLASS RIBBON

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of priority under 35 U.S.C. § 120 of U.S. Application Serial No. 14/334108 filed on July 17, 2014, the content of which is relied upon and incorporated herein by reference in its entirety.

FIELD

[0002] The present disclosure relates generally to methods for producing a glass ribbon and, more particularly, to methods for producing a glass ribbon including automatically adjusting an operating variable of a plurality of stabilizing elements simultaneously with a controller to at least partially counter the detected instability.

BACKGROUND

[0003] Methods of producing a glass ribbon are known to include the step of drawing a glass ribbon from a quantity of molten glass. During production, undesired instabilities may arise in the glass ribbon that may disrupt further production of high-quality glass ribbon until the instability is addressed.

SUMMARY

[0004] The following presents a simplified summary of the disclosure in order to provide a basic understanding of some example aspects described in the detailed description.

[0005] In a first example aspect, a method for producing a glass ribbon includes the step of drawing a glass ribbon from a quantity of molten glass in a draw direction. The glass ribbon includes a width extending along a profile axis perpendicular to the draw direction between a first edge and a second edge of the glass ribbon. The glass ribbon further includes a thickness extending between a first major surface and a second major surface of the glass ribbon. A plurality of thermal elements are positioned along the profile axis. Each thermal element includes an adjustable operating variable. The method further includes the step of providing the glass ribbon with a first predetermined temperature profile along the profile axis. The method further includes the step of automatically adjusting the adjustable operating variable of each thermal element simultaneously with a controller based on an input into the controller to automatically change the first temperature profile to a second temperature profile that is predetermined.

[0006] In one example of the first aspect, the first temperature profile of the step of providing the glass ribbon facilitates maintenance of a first thickness of the glass ribbon along the width of the glass ribbon, and the second temperature profile of the step of automatically adjusting facilitates maintenance of a second thickness of the glass ribbon along the width of the glass ribbon that is greater than the first thickness.

[0007] In another example of the first aspect, the input of the step of automatically adjusting represents an instability in the process of drawing the glass ribbon. For instance, in one example, the instability comprises a discontinuity of the glass ribbon.

[0008] In another example of the first aspect, the second temperature profile is higher in temperature than the first temperature profile.

[0009] In still another example of the first aspect, the controller is in communication with a plurality of predetermined temperature profiles and, during step of automatically adjusting, the controller selects the second temperature profile from the plurality of predetermined temperature profiles based on the input.

[0010] In yet another example of the first aspect, the plurality of thermal elements comprise a plurality of heating elements and the adjustable operating variable of each heating element comprises a heating parameter of the heating element.

[0011] In a second example aspect, a method for producing a glass ribbon comprises the steps of drawing a glass ribbon from a quantity of molten glass and detecting an instability in the glass ribbon. In response to the detected instability, the method further includes the step of automatically adjusting an operating variable for each of a plurality of stabilizing elements simultaneously with a controller to at least partially counter the detected instability.

[0012] In one example of the second aspect, during the step of drawing, the controller operates the stabilizing elements with a first operating profile. In another particular example, during the step of automatically adjusting, the first operating profile of the stabilizing elements is automatically switched by the controller to a second operating profile to at least partially counter the detected instability. In one example, the controller is in communication with a plurality of predetermined operating profiles and, during the step of automatically adjusting, the controller selects the second operating profile from the plurality of predetermined operating profiles based on the input. In another example, the first operating profile facilitates maintenance of a first thickness of the glass ribbon and the second operating profile facilitates maintenance of a second thickness of the glass ribbon that is predetermined and greater than the first thickness. In still another example, after the step of automatically adjusting, the method further includes the step of detecting a stability in the glass ribbon. In response to detecting the stability, the method further includes the step of automatically switching the second operating profile of the stabilizing elements back to the first operating profile with the controller.

[0013] In another example of the second aspect, the step of automatically adjusting at least partially counters the detected instability by adjusting the operating variable for each of the plurality of stabilizing elements to increase a thickness of the glass ribbon.

[0014] In yet another example of the second aspect, the instability detected during the step of detecting an instability comprises a discontinuity in the glass ribbon.

[0015] In still another example of the second aspect, the stabilizing elements each comprise a thermal element. In one example, the operating variable for each of the stabilizing elements comprises a heating parameter of the thermal element, and the step of automatically adjusting at least partially counters the detected instability by adjusting the heating parameter of the thermal element to increase a temperature of the glass ribbon.

[0016] In a further example of the second aspect, the stabilizing elements each comprise a pulling roll. In one example, the operating variable for each of the stabilizing elements comprises a contact status of the pulling roll with the glass ribbon, wherein during the step of automatically adjusting, the contact status of the pulling roll is automatically switched by the controller from an engaged position wherein the pulling roll contacts the glass ribbon to a disengaged position wherein the pulling roll is not in contact with the glass ribbon. In another example, the operating variable for each of the stabilizing elements comprises a pulling roll speed of the pulling roll.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] These and other features, aspects and advantages of the present disclosure are better understood when the following detailed description is read with reference to the accompanying drawings, in which:

[0018] **FIG. 1** schematically illustrates an example apparatus for producing a glass ribbon;

[0019] **FIG. 2** schematically illustrates a side view of the example apparatus of **FIG. 1**;

[0020] **FIG. 3** is a flow chart illustrating steps of a first example method for producing a glass ribbon using the example apparatus of **FIG. 1**; and

[0021] **FIG. 4** is a flow chart illustrating steps of a second example method for producing a glass ribbon using the example apparatus of **FIG. 1**.

DETAILED DESCRIPTION

[0022] Apparatus and methods will now be described more fully hereinafter with reference to the accompanying drawings in which example embodiments of the disclosure are shown. Whenever possible, the same reference numerals are used throughout the drawings to refer to the same or like parts. However, this disclosure may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein.

[0023] **FIGS. 1 and 2** illustrate an example apparatus **101** for producing a glass ribbon. The figures schematically illustrate an example fusion draw apparatus **101**, although up draw, slot draw or other glass forming techniques may be used with aspects of the disclosure in further examples. The illustrated fusion draw apparatus **101** comprises a forming wedge **103** with a pair of downwardly inclined forming surface portions **107**, **109** extending between opposed ends of the forming wedge **103** that converge to form a root **113**. Molten glass may be fed to the forming wedge **103** such that the molten glass flows along the inclined forming surface portions **107**, **109** and meets at the root **113**, producing a glass ribbon **115**. The glass ribbon **115** can be drawn from the root **113** in a downward draw direction **117** that is substantially vertical. The glass ribbon **115** can include a thickness **T** extending between a first major surface **131** and a second major surface **133** of the glass ribbon **115**. The glass ribbon **115** can further include a width **W** extending along a profile axis **121** between a first edge **125** and a second edge **127** of the glass ribbon **115**. The profile axis **121** may be orthogonal (i.e. perpendicular) to the draw direction **117**, as shown in **FIGS. 1 and 2**, or the profile axis **121** may be non-orthogonal (e.g. parallel) to the draw direction **117.** The profile axis **121** may be fixed relative to the forming wedge **103** such that the moving glass ribbon **115** passes through the profile axis **121** or the profile axis **121** may be fixed relative to the glass ribbon **115** such that the profile axis **121** travels with the glass ribbon **115**. Alternatively, the profile axis **115** may move relative to both the forming wedge **103** and the glass ribbon **115**.

[0024] The fusion draw apparatus **101** can comprise various elements that can be useful in achieving one or more target attributes and/or removing one or more instabilities in the glass ribbon **115**. Target attributes can comprise, for example, a thickness, temperature, or draw speed of the glass ribbon **115**. Meanwhile, instabilities can comprise, for example, vibrations in the glass ribbon, a crack in the glass ribbon, a full break (i.e. discontinuity) in the glass ribbon, or any other condition that inhibits processing of the high quality glass ribbon.

[0025] The fusion draw apparatus **101** can comprise a plurality of thermal elements **137** that each comprise an adjustable operating variable that may be adjusted to vary a parameter of the heat that is applied to or removed from the glass ribbon **115** by the corresponding thermal element **137**. For example, the plurality of thermal elements **137** may comprise a plurality of heating elements and the adjustable operating variable of each heating element can comprise a heating parameter of the corresponding heating element. For instance, each heating element may be an electric heating coil and the adjustable operating variable can comprise a current applied to the heating coil that may be adjusted to control the amount of heat radiated from the heating coil and applied to the glass ribbon **115**. Alternatively, the adjustable operating variable may be a distance between the glass ribbon **115** and the corresponding heating element or a location of the corresponding heating element along the major surfaces **131**, **133** of the glass ribbon **115**. As another example, in addition or alternatively, the plurality of thermal elements **137** may comprise a plurality of cooling elements and the adjustable operating variable of each cooling element can comprise a cooling parameter of the corresponding cooling element. For instance, each cooling element may be a fluid-cooled cooling coil and the adjustable operating variable can comprise the flow rate of cooling fluid that flows through the cooling element and may be adjusted to control the rate at which heat is removed from the glass ribbon **115**. Alternatively, the adjustable operating variable may be a distance between the glass ribbon **115** and the corresponding cooling element or a location of the corresponding cooling element along the major surfaces **131**, **133** of the glass ribbon **115**. In another embodiment the adjustable operating variable may be a temperature of the cooling fluid provided to the cooling element. In yet another embodiment, the operational variable may be the material of construction of the cooling element, thereby changing the emissivity of the radiation heat transfer. The plurality of thermal elements **137** may comprise a combination of heating and cooling elements and the adjustable operating variables of the thermal elements **137** may comprise a combination of heating and cooling parameters. Moreover, each thermal element **137** may comprise multiple adjustable operating variables.

[0026] The operating variables of the thermal elements **137** can be adjusted to control a temperature profile of the glass ribbon **115** along a profile axis of the glass ribbon **115**. For example, as shown in **FIG. 1**, the plurality of thermal elements **137** may be positioned along the profile axis **121** of the glass ribbon **115** such that the operating variables of the thermal elements **137** can be adjusted to control a temperature profile of the glass ribbon **115** along the profile axis **121**. The plurality of thermal elements **137** may be fixed relative to the profile axis **121** or the plurality of thermal elements **137** may move relative to the profile axis **121**. For instances wherein the profile axis **121** is moving relative to the forming wedge **103**, the plurality of thermal elements **137** can travel with the profile axis **121** or the plurality of thermal elements **137** can remain stationary relative to the forming wedge **103**. In some embodiments, the plurality of thermal elements **137** can move relative to both the profile axis **121** and the forming wedge **103**.

[0027] The operating variables of the thermal elements **137** can be adjusted to provide any number of temperature profiles along the profile axis **121.** For example, the operating variables of the thermal elements **137** can be adjusted to provide a first temperature profile along the profile axis **121**. As another example, the operating variables of the thermal elements **137** can be adjusted to provide a second temperature profile along the profile axis **121**. The operating variables of the thermal elements **137** may be adjusted to provide any number of temperature profiles along the profile axis **121** or any other profile axis of the glass ribbon **115**.

[0028] The ability to adjust the operating variables of the thermal elements **137** can be useful in achieving process stability and/or target attributes for the glass ribbon **115**. For example, if the glass ribbon **115** experiences an instability such as a crack in the glass ribbon **115**, the operating variables may be adjusted to raise the temperature profile to a higher temperature to prevent crack propagation in the glass ribbon **115**. In such examples, the average temperature of the temperature profile can be increased to prevent crack propagation in the glass ribbon **115**. For instance, the heat may be adjusted to a higher level by stepping up the heat output of each thermal element by the same amount or same percentage. As another example, the operating variables of the thermal elements **137** can also be adjusted to account for emissivity changes in the glass ribbon **115**. For instance, if a thickness of the glass ribbon **115** along the profile axis **121** is adjusted, the emissivity of the glass ribbon **115** along the profile axis **121** will also change. This change in emissivity will affect radiant heat transfer across the profile axis **121**. Thus, to maintain a temperature profile along the profile axis **121** during and after adjustment of the thickness, the operating variables of the thermal elements **137** can be adjusted to vary the amount of heat applied to the profile axis **121** and so as to account for the changes in emissivity.

[0029] The fusion draw apparatus **101** can further comprise a plurality of pulling roll assemblies **141*a***, **141*b*** that, in some examples, can each comprise an adjustable operating variable. For example, the pulling roll assembly **141*a*** may comprise a first pulling roll **143*a*** and a second pulling roll **143*b*** that are arranged on opposite sides of the glass ribbon **115** such that the glass ribbon **115** passes between the first pulling roll **143*a*** and a second pulling roll **143*b***. The adjustable operating variable of the pulling roll assembly **141*a*** may comprise a contact status between the first and second pulling rolls **143*a***, **143*b*** and the glass ribbon **115**. For example, the contact status can comprise a first "engaged position" wherein the first and second pulling rolls **143*a***, **143*b*** are spaced apart by an operating distance such that the first and second pulling rolls **143*a***, **143*b*** contact the first and second major surfaces **131**, **133** of the glass ribbon **115** to control the thickness of the glass ribbon **115** passing therebetween. In a further example, the contact status can comprise a second "engaged position" wherein the operating distance between the first and second pulling rolls **143*a***, **143*b*** is increased to allow for thickened edges of the glass ribbon **115** between the first and second pulling rolls **143*a***, **143*b***. In a further example, the contact status can comprise a "disengaged position" wherein the first and second pulling rolls **143*a***, **143*b*** are spaced apart such that they do not contact the first and second major surfaces **131**, **133** of the glass ribbon **115**. In the "disengaged position", the glass ribbon **115** will be unconstrained by the first and second pulling rolls **143*a***, **143*b***. Unconstrained operation may be desirable under certain situations to allow free movement of the glass ribbon to help at least partially counter an instability in the glass ribbon. On the other hand, when the operating distance between the first and second pulling rolls **143*a***, **143*b*** is narrowed such the first and second pulling rolls **143*a***, **143*b*** contact the first and second major surfaces **131**, **133** of the glass ribbon **115**, the glass ribbon **115** will be constrained by the first and second pulling rolls **143*a***, **143*b***. Thus, the contact status of the first and second pulling rolls **143*a***, **143*b*** may be adjusted to provide constraint to the glass ribbon **115** and, as set forth below, facilitate maintenance of the desired thickness **T** of the glass ribbon **115**.

[0030] The adjustable operating variable of the pulling roll assembly **141*a*** may alternatively or additionally comprise the pulling roll rotational speeds of the first and/or second pulling rolls **143*a***, **143*b***. When the first and second pulling rolls **143*a***, **143*b*** are oriented in the "engaged position", each pulling roll respectively engages the first and second major surfaces **131**, **133** of the glass ribbon **115**. In the engaged position, the pulling roll speeds of the first and/or second pulling rolls **143*a***, **143*b*** may be adjusted to control the drawing speed of the glass ribbon **115** in the draw direction 117 and the thickness **T** of the glass ribbon **115** along the width **W** of the glass ribbon **115**. For example, the pulling roll speeds of the first and second pulling rolls **143*a***, **143*b*** may be increased to increase the drawing speed of the glass ribbon **115** or decreased to decrease the drawing speed of the glass ribbon **115**. Decreasing the drawing speed of the glass ribbon **115** can be particularly helpful when an instability is detected in the glass ribbon **115**, as the reduced speed will slow down the draw of the glass ribbon off the root **113** to thereby increase the thickness **T** of the glass ribbon to help at least partially counter an instability in the glass ribbon. Indeed, increasing the thickness **T** of the glass ribbon can increase the stiffness and reduce the probability of crack propagation in the glass ribbon **115**. Once the instability is countered, the draw speed can be increased again to provide the desired thickness **T** during normal operating conditions. Thus, pulling roll speeds of the first and second pulling rolls **143*a***, **143*b*** may be adjusted to control the drawing speed of the glass ribbon **115** and facilitate maintenance of the thickness **T** of the glass ribbon **115** along the width **W** of the glass ribbon **115**.

[0031] The fusion draw apparatus **101** can further comprise one or more instability detectors configured to detect the presence of instabilities in the glass ribbon **115**. For example, as shown in **FIGS. 1 and 2**, the fusion draw apparatus **101** can comprise an instability detector **151**. An instability may be any condition of the glass ribbon **115** that disrupts the processing of the glass ribbon **115**. For example, as discussed above, an instability may comprise vibrations in the glass ribbon **115**, a crack in the glass ribbon **115**, a full break (i.e. discontinuity) in the glass ribbon **115**, or any other condition that inhibits processing of the high quality glass ribbon **115**. The instability detector **151** in the present example can comprise an ultrasonic sensor that monitors the distance **X** between the instability detector **151** and the glass ribbon **115**. The instability detector **151** can therefore detect if there are excessive vibrations in the glass ribbon **115** or if there is a discontinuity in the glass ribbon **115** by monitoring for changes in the distance **X**. The fusion draw apparatus **101** in other examples may comprise alternative or additional instability detectors. For example, the fusion draw apparatus **101** may comprise an optical sensor that similarly detects discontinuities in the glass ribbon **115**. As another example, the fusion draw apparatus **101** may comprise a torque sensor that measures a torque in one of the first and second pulling rolls **143*a***, **143*a*** to determine if there is glass ribbon present between and engaged with the first and second pulling rolls **143*a***, **143*a*** and/or whether there is a significant decrease in weight of the glass ribbon below the pulling rolls that may indicate a discontinuity of the glass ribbon below the pulling rolls.

[0032] The fusion draw apparatus **101** can further comprise one or more stabilizing elements that may be operated to at least partially counter a detected instability in the glass ribbon **115**. In the present example, the plurality of thermal elements **137** and the pulling roll assemblies **141*a***, **141*b*** can comprise the stabilizing elements. The operating variables of the stabilizing elements may be adjusted to at least partially counter a detected instability in the glass ribbon **115**. For example, the pulling roll speeds of the first and second pulling rolls **143*a***, **143*b*** of the pulling roll assembly **141*a*** may be decreased to thicken the glass ribbon **115**. Thickening the glass ribbon **115** can make the glass ribbon **115** more stiff and resistant to breakage, which can inhibit further instabilities and allow operators or other machinery to handle the glass ribbon **115** if needed to correct the instability. Moreover, decreasing the speed of the first and second pulling rolls **143*a***, **143*b*** will decrease the speed of the glass ribbon **115**, which can make it easier for operators or machinery to handle the glass ribbon **115** and correct the instability. As another example, if an instability is detected in the glass ribbon **115** while the first and second pulling rolls **143*a***, **143*b*** of the pulling roll assembly **141*a*** are engaged with the glass ribbon **115**, the operating distance between the first and second pulling rolls **143*a***, **143*b*** may be increased to also allow thickened edges of the glass ribbon **115** to pass through the pulling rolls, thereby stiffening the edges of the glass ribbon **115** to resist instabilities that may otherwise pass through the edges of the glass ribbon **115**. Moreover, the contact status of the first and second pulling rolls **143*a***, **143*b***

may be adjusted from the engaged position to a disengaged position, thus allowing the glass ribbon **115** to hang unconstrained during an instability and preventing the possibility of breakage due to restraint by the first and second pulling rolls **143*a***, **143*b***. As yet another example, if a crack in the glass ribbon **115** is detected while the glass ribbon **115** is provided with a first temperature profile at the profile axis **121**, the operating variables of the plurality of thermal elements **137** may be adjusted to provide the glass ribbon **115** with a second temperature profile at the profile axis **121** that is higher in temperature than the first temperature profile, thus mitigating the chance of crack propagation. Any one of the above-referenced example stabilizing adjustments may be performed to at least partially counter a detected instability in the glass ribbon **115**. In further examples, any combination of the above-referenced example stabilizing adjustments may be performed (e.g., simultaneously, sequentially, etc.) to at least partially counter a detected instability in the glass ribbon **115**.

[0033] Although the plurality of thermal elements **137** and the pulling roll assemblies **141*a***, **141*b*** constitute the stabilizing elements in the present example, the fusion draw apparatus **101** may comprise other types of stabilizing elements in other examples. For instance, the fusion draw apparatus **101** may comprise positioning elements such as, for example, air bearings that control the position of the glass ribbon **115** and help stabilize the glass ribbon **115**. In addition, there may be examples where only the thermal elements **137** or only the pulling roll assemblies **141*a***, **141*b*** are provided as stabilizing elements. The fusion draw apparatus may comprise any variety of stabilizing elements that may be operated to at least partially counter a detected instability in the glass ribbon **115** and comprise an adjustable operating variable.

[0034] The fusion draw apparatus **101** can further comprise a controller **159** configured to automatically adjust the adjustable operating variables discussed above based on one or more inputs provided to the controller **159**. Various methods for producing a glass ribbon may be accomplished with the controller **159**. For example, **FIG. 3** illustrates a flow diagram of a first example method **301** that controls the thermal elements **137** of the fusion draw apparatus **101**. This example method **301** may be used to adjust the operating variables of the thermal elements **137** to either accommodate for a detected instability in the glass ribbon **115** or to accommodate for a change in process conditions. The first example method **301** comprises a step **303** of drawing the glass ribbon **115** from a quantity of molten glass from the forming wedge **103** in the downward draw direction **117** such that the glass ribbon

115 includes the width **W** extending along the profile axis **121.** Step **303** further provides the glass ribbon **115** with the thickness **T** extending between the first and second major surfaces **131**, **133** of the glass ribbon **115**, and the plurality of thermal elements **137** positioned along the profile axis **121**.

[0035] The first example method **301** further comprises a step **305** of providing the glass ribbon **115** with a first temperature profile along the profile axis **121**. For example, the first temperature profile may be provided to facilitate drawing of the glass ribbon with desired characteristics under normal operating conditions. For example, the operating variables of the thermal elements **137** can be set to provide the glass ribbon **115** with a first temperature profile that is predetermined and facilitates maintenance of a first thickness **T** of the glass ribbon **115** along the width **W** of the glass ribbon **115**. The operating variables can either be set manually by an operator or automatically by the controller **159**.

[0036] The first example method **301** further comprises a step **307** of automatically adjusting the adjustable operating variables of the thermal elements **137** simultaneously with the controller **159** based on an input into the controller **159** to maintain the first temperature profile or automatically change the first temperature profile to a second temperature profile that is predetermined. For example, an input may be provided to the controller **159** indicating that a process condition such as, for example, a thickness of the glass ribbon **159**, has changed. Based on the input, the controller **159** may automatically adjust the operating variables of the thermal elements **137** to account for changes in emissivity in the glass ribbon **115** and maintain the first temperature profile. As another example, the controller **159** can be in communication with a plurality of predetermined temperature profiles that may be stored in a database. Based on the input provided to the controller **159**, the controller **159** can select one of the predetermined temperature profiles and automatically change the first temperature profile to the selected predetermined temperature profile. For instance, if an input **A** is provided to the controller **159**, the controller **159** may select one of the predetermined temperature profiles and automatically change the first temperature profile to the corresponding predetermined temperature profile. As an alternative example, if an input **B** is provided to the controller **159**, the controller **159** may select a different predetermined temperature profile and automatically change the first temperature profile to the corresponding predetermined temperature profile. The selected temperature profile will depend on what input is provided to the controller **159**. Each of the plurality of predetermined temperature profiles can be designed to counter various instability conditions detected in the fusion draw process and/or achieve target attributes for the glass ribbon **145**. For instance, one predetermined temperature profile may be designed to increase the average temperature of the temperature profile along the profile axis **121** of the glass ribbon **115** to mitigate propagation of a crack in the glass ribbon **145**. Moreover, another predetermined temperature profile may be designed to facilitate maintenance of a desired thickness **T**.

[0037] As mentioned above, the controller **159** can simultaneously adjust the adjustable operating variables of the thermal elements **137** based on the input provided to the controller **159**. For example, if an input is provided to the controller **159** that causes the controller **159** to select a second temperature profile that is higher in temperature than the first temperature profile, the heating parameters of each heating element may be adjusted simultaneously by the controller **159** to increase the amount of heat applied by each of the thermal elements **137** to the glass ribbon **115**. As another example, if an input is provided to the controller **159** that causes the controller **159** to select a second temperature profile that is lower in temperature than the first temperature profile, each heating element may be adjusted simultaneously by the controller **159** to decrease the amount of heat applied by each of the thermal elements **137** to the glass ribbon **115**.

[0038] In alternative examples, if the fusion draw apparatus **101** is provided with cooling elements, the controller **159** may simultaneously adjust the cooling parameters of each cooling element to control the amount of cooling applied to the glass ribbon **115**. The controller **159** can simultaneously adjust any combination of the adjustable operating variables of the thermal elements **137** described above to maintain the first temperature profile or to automatically change the first temperature profile to the second temperature profile in step **307**. Moreover, although the controller **159** can adjust these adjustable operating variables simultaneously, the adjustment of each variable need not always be simultaneous with the others. For instance, the controller **159** may begin adjustment of a first set of operating variables and after a set time, begin simultaneous adjustment of a second set operating variable. Indeed, some variables may not even need adjustment to automatically change the first temperature profile to the second temperature profile.

[0039] The input provided to the controller **159** in step **307** may be provided manually by an operator when, for example, target attributes in the glass ribbon **115** require a certain predetermined temperature profile along the profile axis **121** that is different from the temperature profile currently being provided. Alternatively, the input may be provided to the controller **159** by the instability detector **151** upon detection of an instability such as, for example, a discontinuity in the glass ribbon **115**. The input in some examples can represent the instability and cause the controller **159** to select a second temperature profile that is designed to at least partially counter the instability. However the input is provided, the controller **159** can simultaneously adjust the operating variables of the thermal elements **137** to maintain the first temperature profile or automatically change the first temperature profile to a predetermined temperature profile that corresponds with the input. This simultaneous adjustment can inhibit the occurrence of further instabilities that may otherwise occur if each of the operating variables were adjusted sequentially. Moreover, simultaneous adjustment of the operating variables can lead to faster process adjustments, which can reduce overall production times and cost. Thus, the fusion draw apparatus **101** and method **301** described above can provide a way to quickly adjust operating variables of the thermal elements **137** as desired while inhibiting unwanted instabilities.

[0040] Turning now to **FIG. 4**, a second example method **401** will now be described that can manage the plurality of stabilizing elements of the fusion draw apparatus **101** described above and thus accommodate for an instability detected in the glass ribbon **115**. The second example method **401** comprises a step **403** of drawing the glass ribbon **115** from a quantity of molten glass from the forming wedge **103** in the downward draw direction **117**. In such an example, the glass ribbon **115** includes the width **W** extending along the profile axis **121** and the thickness **T** extending between the first and second major surfaces **131**, **133** of the glass ribbon **115**. During the step **403**, the controller **159** can operate the plurality of stabilizing elements according to a first operating profile. The first operating profile can be designed to achieve target attributes in the glass ribbon **115**. Such target attributes may require a certain thickness or temperature profile along the profile axis **121** of the glass ribbon **115**. Accordingly, the first operating profile can be designed to facilitate maintenance of a first thickness and/or first temperature profile of the glass ribbon **115**. For example, the first operating profile may be designed to operate the thermal elements **137** such that the glass ribbon **115** is provided with a first temperature profile along the profile axis **121**. In another example, the first operating profile may be designed such that the first and second pulling rolls **143*a***, **143*b*** are engaged with the glass ribbon **115** and separated by a certain operating distance, thereby facilitating maintenance of the first predetermined thickness. In yet another example, the first operating profile may be designed such that the first and second pulling rolls **143*a***, **143*b*** are set to a first pulling roll speed, thereby facilitating maintenance of the first thickness. The first operating profile can be deigned to operate any of the stabilizing elements of the fusion draw apparatus **101** in any manner.

[0041] The second example method **401** next comprises the step **405** of detecting an instability in the glass ribbon **115**. For example, the instability may be detected using the instability detector **151** discussed above or any of the other instability detectors also described. Moreover, the instability may comprise any of the instabilities discussed above such as, for example, a discontinuity in the glass ribbon **115**. Once the instability is detected, an input may be provided to the controller **159** automatically by the instability detector **151** to indicate that the instability is present. The input by the instability detector **151** may be a physical, electronic signal sent to the controller **159** or the input may simply be the absence of such a signal. Moreover, the input may continue to be provided to the controller **159** until the instability is no longer present. In this manner, the instability detector **151** can operate as a stability detector as well, since the loss of the input indicates that the instability is no longer present.

[0042] In response to detecting the instability, the example method **401** can further comprise a step **407** of automatically adjusting the operating variables of the plurality of stabilizing elements simultaneously with the controller **159** to at least partially counter the detected instability. More specifically, upon receipt of the input from the instability detector **151** indicating that the instability is present, the first operating profile of the stabilizing elements can be automatically switched by the controller **159** to a second operating profile to at least partially counter the detected instability. For example, the controller **159** can be in communication with a plurality of predetermined operating profiles and based on the input provided to the controller **159**, the controller **159** will select one of the predetermined operating profiles and automatically adjust the operating variables of the plurality of stabilizing elements simultaneously to achieve the selected operating profile. For instance, if an input **A** is provided to the controller **159** that indicates a first type of instability, the controller **159** may select one of the predetermined operating profiles and automatically change the first operating profile to the corresponding predetermined operating profile. As an alternative example, if an input **B** is provided to the controller **159** corresponding to a second type of instability, the controller **159** may select a different predetermined operating profile and automatically change the first operating profile to the corresponding predetermined operating profile. The selected operating profile will depend on what input is provided to the controller **159**.

[0043] Each of the plurality of predetermined operating profiles can be designed to at least partially counter detected instabilities in various ways. For example, one predetermined operating profile can be designed to facilitate maintenance of a second thickness of the glass ribbon **115** that is predetermined and greater than the first thickness facilitated by the first operating profile in step **403**, thus stiffening the glass ribbon **115** and making the glass ribbon **115** more resistant to breakage. For instance, if engaged with the glass ribbon **115**, the operating distance between the first and second pulling rolls **143*a***, **143*b*** may be automatically increased by the controller **159** to allow for thickened edges of the glass ribbon **115** between the first and second pulling rolls **143*a***, **143*b***. Additionally or alternatively, the pulling roll speeds of the first and second pulling rolls **143*a***, **143*b*** may be decreased with the controller **159** to increase the thickness **T** of the glass ribbon **115** along the width **W** between the edges of the glass ribbon. As another example, one predetermined operating profile may be designed to facilitate a disengaged contact status of the first and second pulling rolls **143*a***, **143*b***. For instance, if the first and second pulling rolls **143*a***, **143*b*** are engaged with the major surfaces **131**, **133** of the glass ribbon **115** when the instability is detected, the operating distance between the first and second pulling rolls **143*a***, **143*b*** may be automatically increased by the controller **159** such that the contact status of the first and second pulling rolls **143*a***, **143*b*** automatically switches from an engaged status to a disengaged status. The disengaged status of the pulling rolls can allow the glass ribbon **115** to hang unconstrained and not in contact with the first and second pulling rolls **143*a***, **143*b*** during instability. As such, under certain circumstances breakage can be avoided that might otherwise occur by restraining the first and second pulling rolls **143*a***, **143*b***. As yet another example, one predetermined operating profile may be designed to facilitate maintenance of a second temperature profile of the glass ribbon **115** that is predetermined and higher in average temperature than the first temperature profile facilitated by the first operating profile in step **403**. The higher average second temperature profile may mitigate the risk of crack propagation in the glass ribbon **115**. For instance, the heating parameters of each thermal element **137** may be adjusted simultaneously by the controller **159** to increase the amount of heat applied by the thermal elements **137** to the glass ribbon **115** and provide the predetermined second temperature profile that has an average temperature that is greater than the average temperature of the first temperature profile. As still yet another example, one predetermined operating profile may be designed to facilitate a second pulling roll speed for the first and second pulling rolls **143*a***, **143*b*** that is predetermined and slower than the first pulling roll speed facilitated by the first operating profile in step **403**, thus making it easier for operators or draw machinery to handle the glass ribbon **115** and correct the instability. The predetermined operating profiles may be designed to operate any of the stabilizing elements of the fusion draw apparatus **101** in any manner to at least partially counter detected instabilities.

[0044] The controller **159** can simultaneously adjust any combination of the adjustable operating variables of the stabilizing elements of the fusion draw apparatus **101** to achieve the predetermined second profile in step **407**. Moreover, although the controller **159** can adjust these operating variables simultaneously, the adjustment of each variable need not always be simultaneous with the others. For instance, the controller **159** may begin adjustment of a first operating variable and after a set time, begin adjustment of a second operating variable while simultaneously still providing adjustment to the first operating variable. Indeed, some variables may not even need adjustment to automatically switch the operating profile of the stabilizing elements to the stabilizing profile in step **407**.

[0045] Eventually, the step **407** of automatically adjusting the operating variables of the plurality of stabilizing elements to at least partially counter the instability detected in step **405** may lead to a stabilization of the glass ribbon **115**. Accordingly, the example method **401** can further comprise the step **409** of detecting a stability in the glass ribbon **115**. As mentioned above, since the loss of the input provided by the instability detector **151** to the controller **159** can indicate that the instability detected in step **405** is no longer present, the instability detector **151** can also act as a stability detector. However, other embodiments of the fusion draw apparatus **101** may comprise a separate device configured to detect a stability in the glass ribbon **115** and provide a separate input to the controller **159** indicating that the stability is present.

[0046] In response to detecting the stability, the example method **401** can further comprise the step **411** of automatically switching the second operating profile of the stabilizing elements back to the first operating profile with the controller **159**. More specifically, upon loss of the input from the instability detector **151** indicating that the instability is present, the operating variables of the plurality of stabilizing elements can be adjusted simultaneously with the controller **159** to achieve the first operating profile. The stabilizing elements can continue to operate under the original first operating profile until an instability is detected again or the process is terminated.

[0047] The method **401** described above can allow for the simultaneous adjustment of operating variables of the stabilizing elements in response to a detected instability. This simultaneous adjustment can at least partially counter the detected instability and inhibit the occurrence of further instabilities that may otherwise occur if each of the operating variables were adjusted sequentially. Moreover, simultaneous adjustment of the operating variables can lead to faster process adjustments, which can reduce overall production times and cost. Furthermore, once the glass ribbon **115** has been stabilized, the method **401** can allow for the simultaneous adjustment of the operating variables of the stabilizing elements back to their original operating conditions.

[0048] It will be apparent to those skilled in the art that various modifications and variations can be made to the present disclosure without departing from the spirit and scope of the invention. Thus, it is intended that the present invention cover the modifications and variations of this disclosure provided they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. A method for producing a glass ribbon comprising:

(I) drawing a glass ribbon from a quantity of molten glass in a draw direction, wherein the glass ribbon includes a width extending along a profile axis perpendicular to the draw direction between a first edge and a second edge of the glass ribbon, the glass ribbon further includes a thickness extending between a first major surface and a second major surface of the glass ribbon, and a plurality of thermal elements positioned along the profile axis, wherein each thermal element includes an adjustable operating variable;

(II) providing the glass ribbon with a first temperature profile along the profile axis; and

(III) automatically adjusting the adjustable operating variable of each thermal element simultaneously with a controller based on an input into the controller to maintain the first temperature profile or automatically change the first temperature profile to a second temperature profile that is predetermined.

2. The method of claim 1, wherein step (III) adjusts the adjustable operating variable of each thermal element to automatically change the first temperature profile to a second temperature profile that is predetermined.

3. The method of claim 2, wherein the input of step (III) represents an instability in the process of drawing the glass ribbon.

4. The method of claim 3, wherein the instability comprises a discontinuity of the glass ribbon.

5. The method of claim 2, wherein the second temperature profile is higher in temperature than the first temperature profile.

6. The method of claim 2, wherein the controller is in communication with a plurality of predetermined temperature profiles and, during step (III), the controller selects the second temperature profile from the plurality of predetermined temperature profiles based on the input.

7. The method of claim 1, wherein the plurality of thermal elements comprise a plurality of heating elements and the adjustable operating variable of each heating element comprises a heating parameter of the heating element.

8. A method for producing a glass ribbon comprising:

(I) drawing a glass ribbon from a quantity of molten glass;

(II) detecting an instability in the glass ribbon; and in response to detecting the instability,

(III) automatically adjusting an operating variable for each of a plurality of stabilizing elements simultaneously with a controller to at least partially counter the detected instability.

9. The method of claim 8, wherein during step (I), the controller operates the stabilizing elements with a first operating profile.

10. The method of claim 9, wherein during step (III), the first operating profile of the stabilizing elements is automatically switched by the controller to a second operating profile to at least partially counter the detected instability.

11. The method of claim 10, wherein the controller is in communication with a plurality of predetermined operating profiles and, during step (III), the controller selects the second operating profile from the plurality of predetermined operating profiles based on the input.

12. The method of claim 10, wherein the first operating profile facilitates maintenance of a first thickness of the glass ribbon and the second operating profile facilitates maintenance of a second thickness of the glass ribbon that is predetermined and greater than the first thickness.

13. The method of claim 10, wherein after step (III), further comprising,

(IV) detecting a stability in the glass ribbon; and then in response to detecting the stability,

(V) automatically switching the second operating profile of the stabilizing elements back to the first operating profile with the controller.

14. The method of claim 8, wherein step (III) at least partially counters the detected instability by adjusting the operating variable for each of the plurality of stabilizing elements to increase a thickness of the glass ribbon.

15. The method of claim 8, wherein the instability detected during step (II) comprises a discontinuity in the glass ribbon.

16. The method of claim 8, wherein the stabilizing elements each comprise a thermal element.

17. The method of claim 16, wherein the operating variable for each of the stabilizing elements comprises a heating parameter of the thermal element, and step (III) at least partially counters the detected instability by adjusting the heating parameter of the thermal element to increase a temperature of the glass ribbon.

18. The method of claim 8, wherein the stabilizing elements each comprise a pulling roll.

19. The method of claim 18, wherein the operating variable for each of the stabilizing elements comprises a contact status of the pulling roll with the glass ribbon, wherein during step (III) the contact status of the pulling roll is automatically switched by the controller from an engaged position wherein the pulling roll contacts the glass ribbon to a disengaged position wherein the pulling roll is not in contact with the glass ribbon.

20. The method of claim 18, wherein the operating variable for each of the stabilizing elements comprises a pulling roll speed of the pulling roll.

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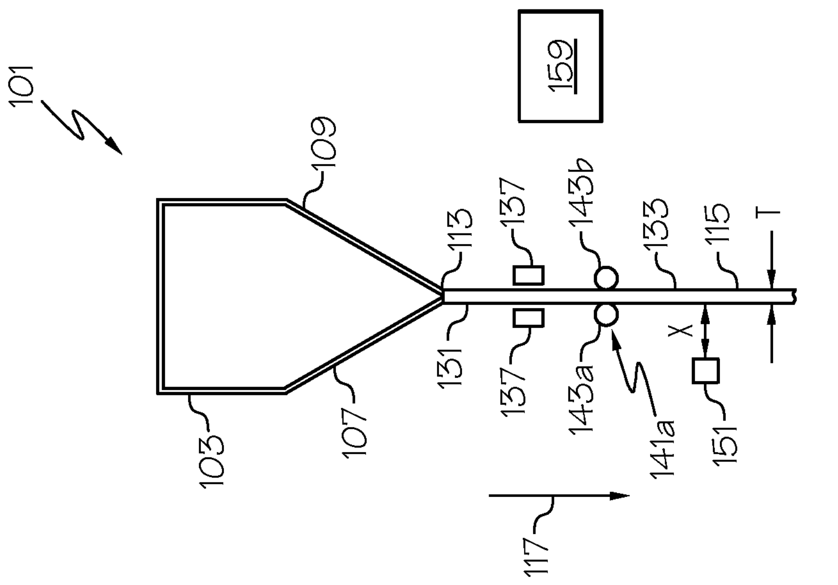
101
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137
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143b
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133
115
151
X
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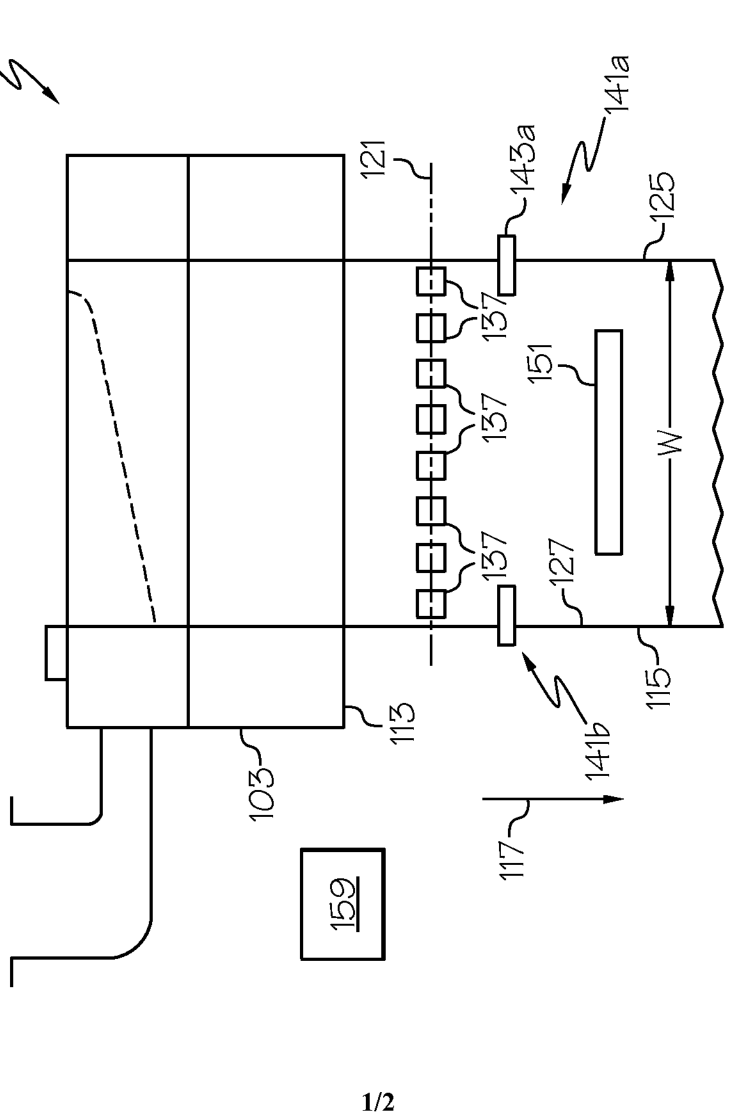
FIG. 2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159

FIG. 1

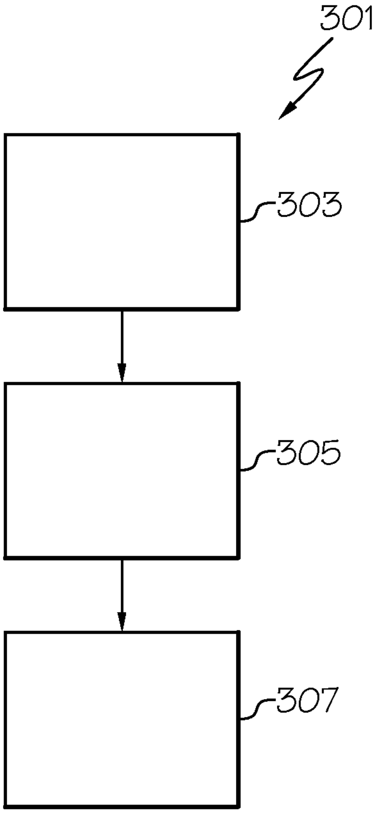

FIG. 3

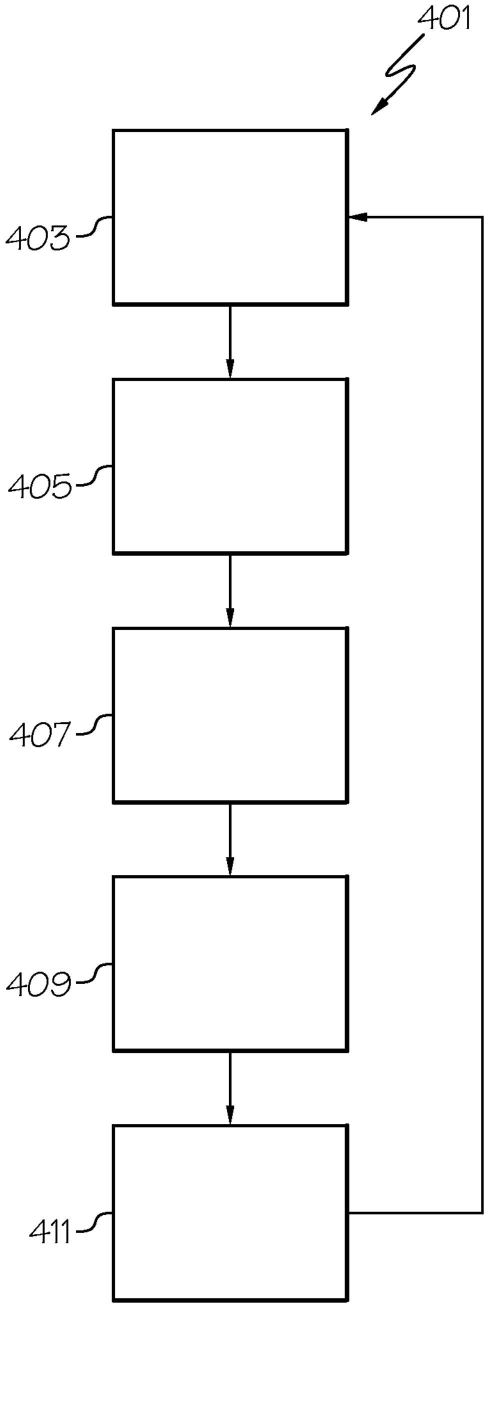

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/040471

A. CLASSIFICATION OF SUBJECT MATTER
INV. C03B17/06
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C03B

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

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

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	US 2013/074549 A1 (AHRENS JEFFREY H [US] ET AL) 28 March 2013 (2013-03-28) items W,223,313; sentences 21-25, paragraph 6; claims 1,3,16,26; figures 2-3 paragraphs [0027], [0034], [0035], [0039], [0046], [0047], [0054], [0055], [0096]; claim 17 sentences 5-6, paragraph 29 sentences 2-3, paragraph 30 sentences 6-14, paragraph 49 sentences 6-11, paragraph 51 ----- -/--	1-11,16, 17

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 September 2015	05/10/2015

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

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International application No
PCT/US2015/040471

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