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(54) **BURNER FIRING RATE DETERMINATION FOR MODULATING FURNACE**

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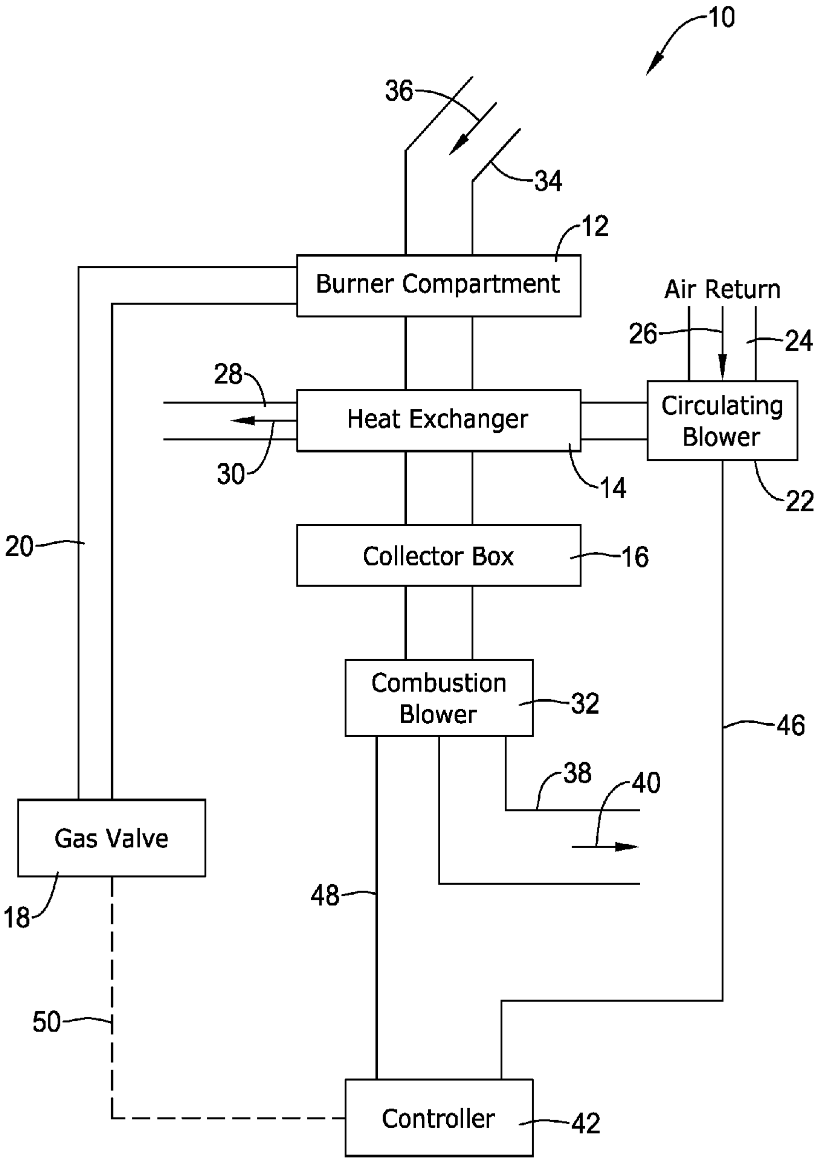
(57) **ABSTRACT**

A modulating furnace having a variable rate burner and a controller is operated at a first burner firing rate for a first period of time, and a higher burner firing rate once the first period of time has expired. In some instances, the burner may be operated only while the controller is receiving a call for heat from a thermostat or the like.



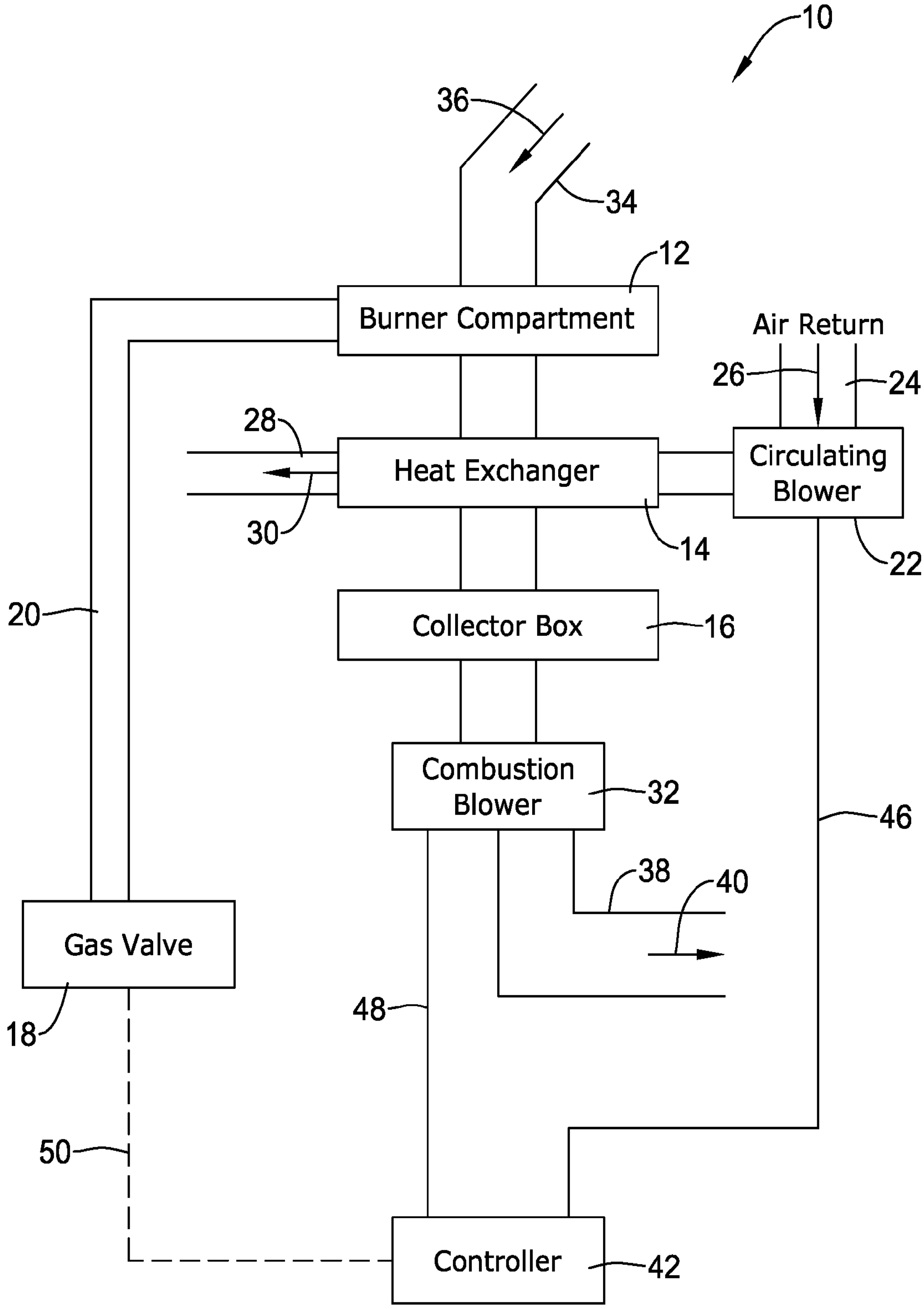

10
36
34
12
Burner Compartment
Air Return
26
24
28
Heat Exchanger
Circulating Blower
30
14
22
20
Collector Box
16
Combustion Blower
32
46
38
40
Gas Valve
18
48
50
Controller
42

Figure 1

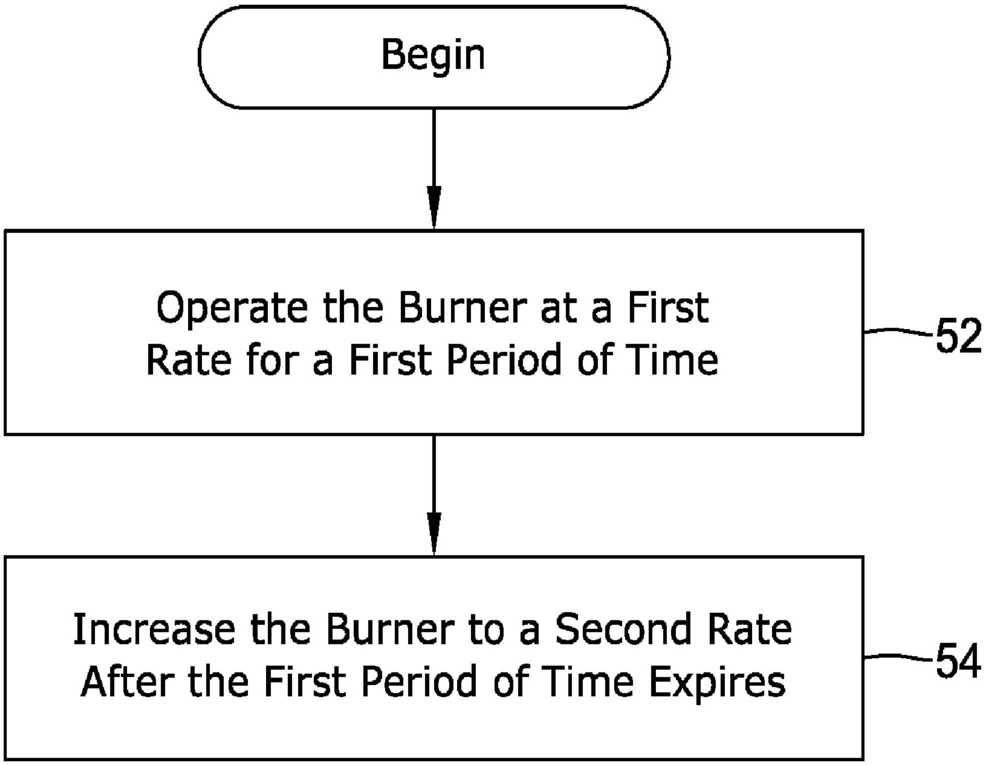

Begin
Operate the Burner at a First Rate for a First Period of Time
52
Increase the Burner to a Second Rate After the First Period of Time Expires
54

Figure 2

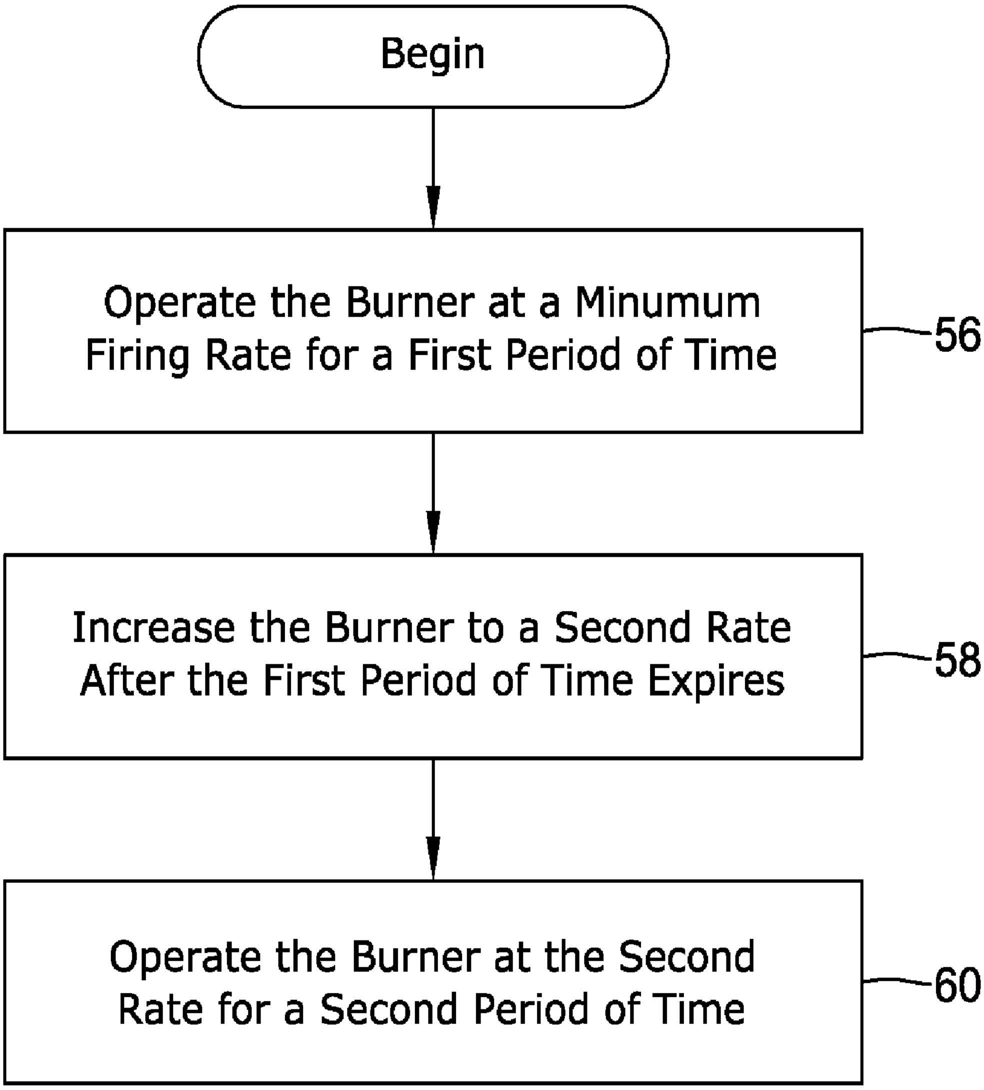

Begin
Operate the Burner at a Minumum Firing Rate for a First Period of Time
56
Increase the Burner to a Second Rate After the First Period of Time Expires
58
Operate the Burner at the Second Rate for a Second Period of Time
60

Figure 3

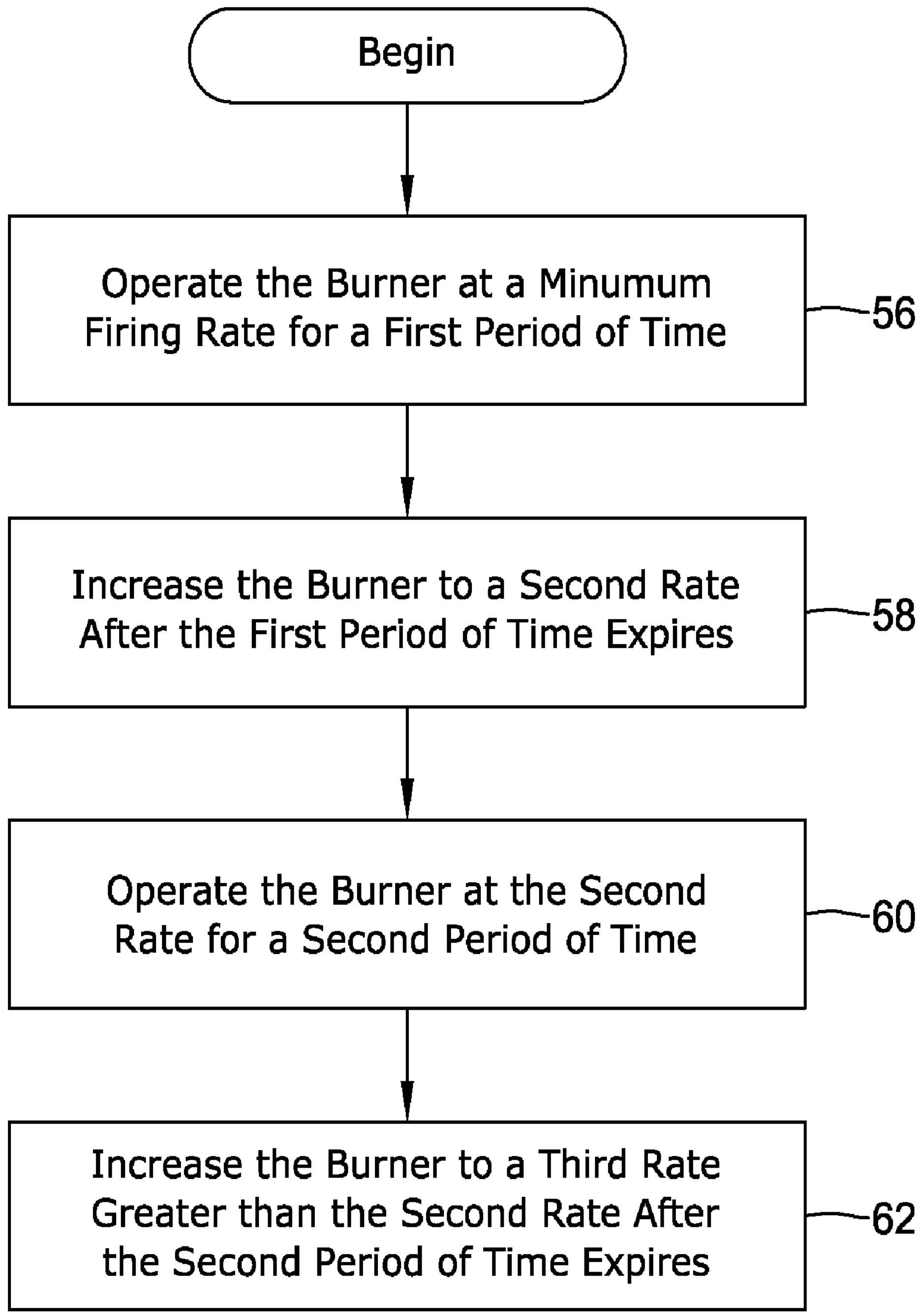

Begin
Operate the Burner at a Minumum Firing Rate for a First Period of Time
56
Increase the Burner to a Second Rate After the First Period of Time Expires
58
Operate the Burner at the Second Rate for a Second Period of Time
60
Increase the Burner to a Third Rate Greater than the Second Rate After the Second Period of Time Expires
62

Figure 4

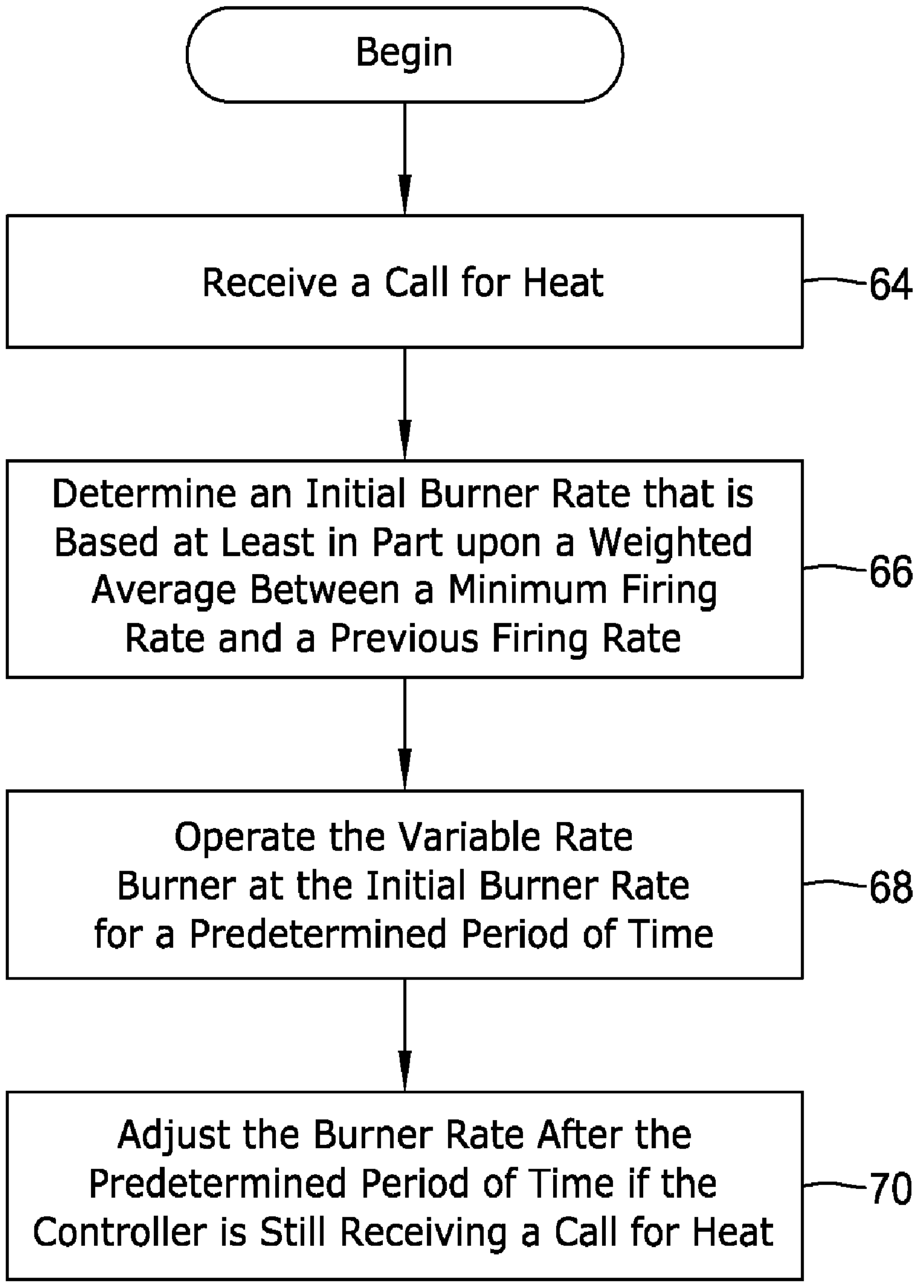

Begin
Receive a Call for Heat
64
Determine an Initial Burner Rate that is Based at Least in Part upon a Weighted Average Between a Minimum Firing Rate and a Previous Firing Rate
66
Operate the Variable Rate Burner at the Initial Burner Rate for a Predetermined Period of Time
68
Adjust the Burner Rate After the Predetermined Period of Time if the Controller is Still Receiving a Call for Heat
70

Figure 5

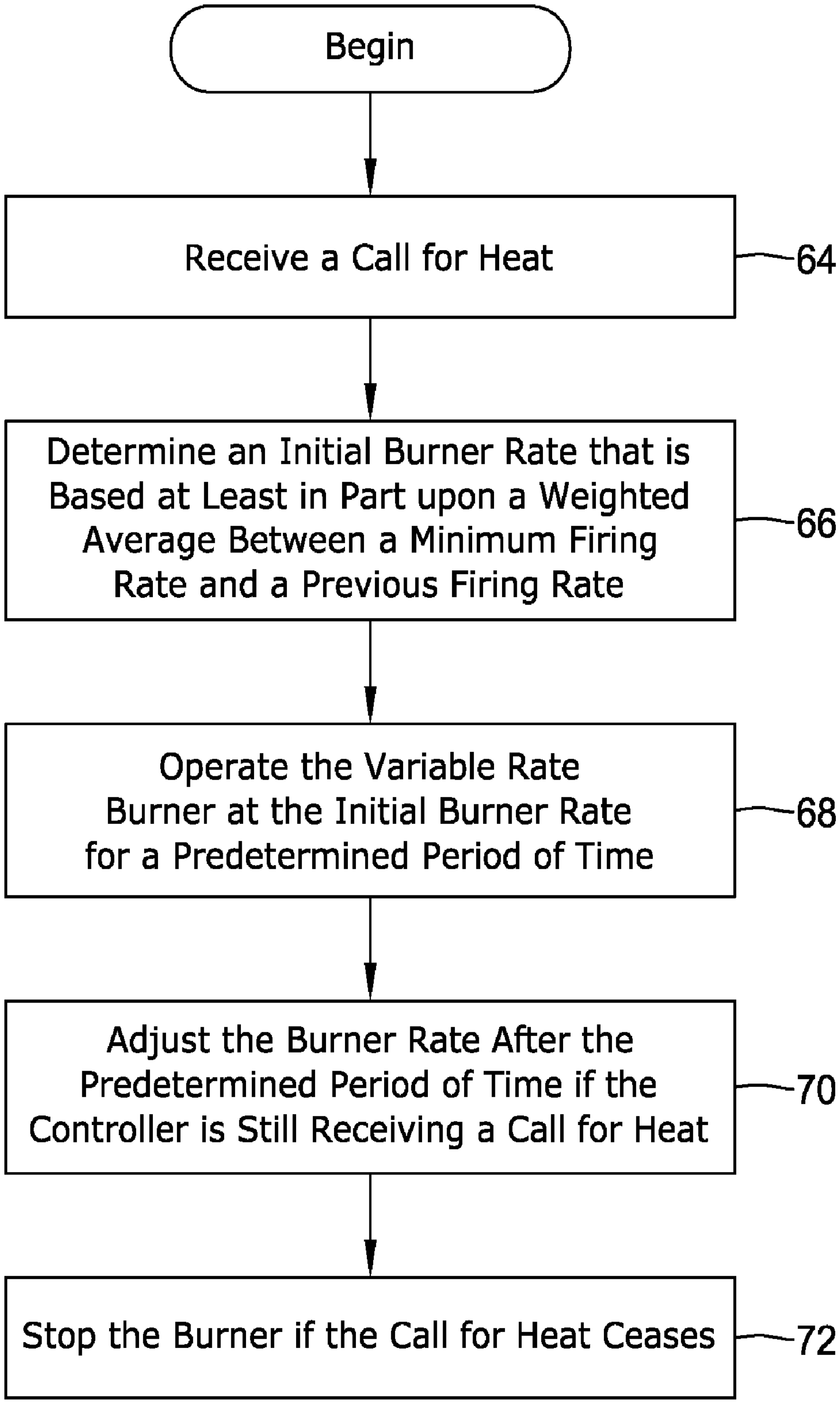

Begin
Receive a Call for Heat
64
Determine an Initial Burner Rate that is Based at Least in Part upon a Weighted Average Between a Minimum Firing Rate and a Previous Firing Rate
66
Operate the Variable Rate Burner at the Initial Burner Rate for a Predetermined Period of Time
68
Adjust the Burner Rate After the Predetermined Period of Time if the Controller is Still Receiving a Call for Heat
70
Stop the Burner if the Call for Heat Ceases
72

Figure 6

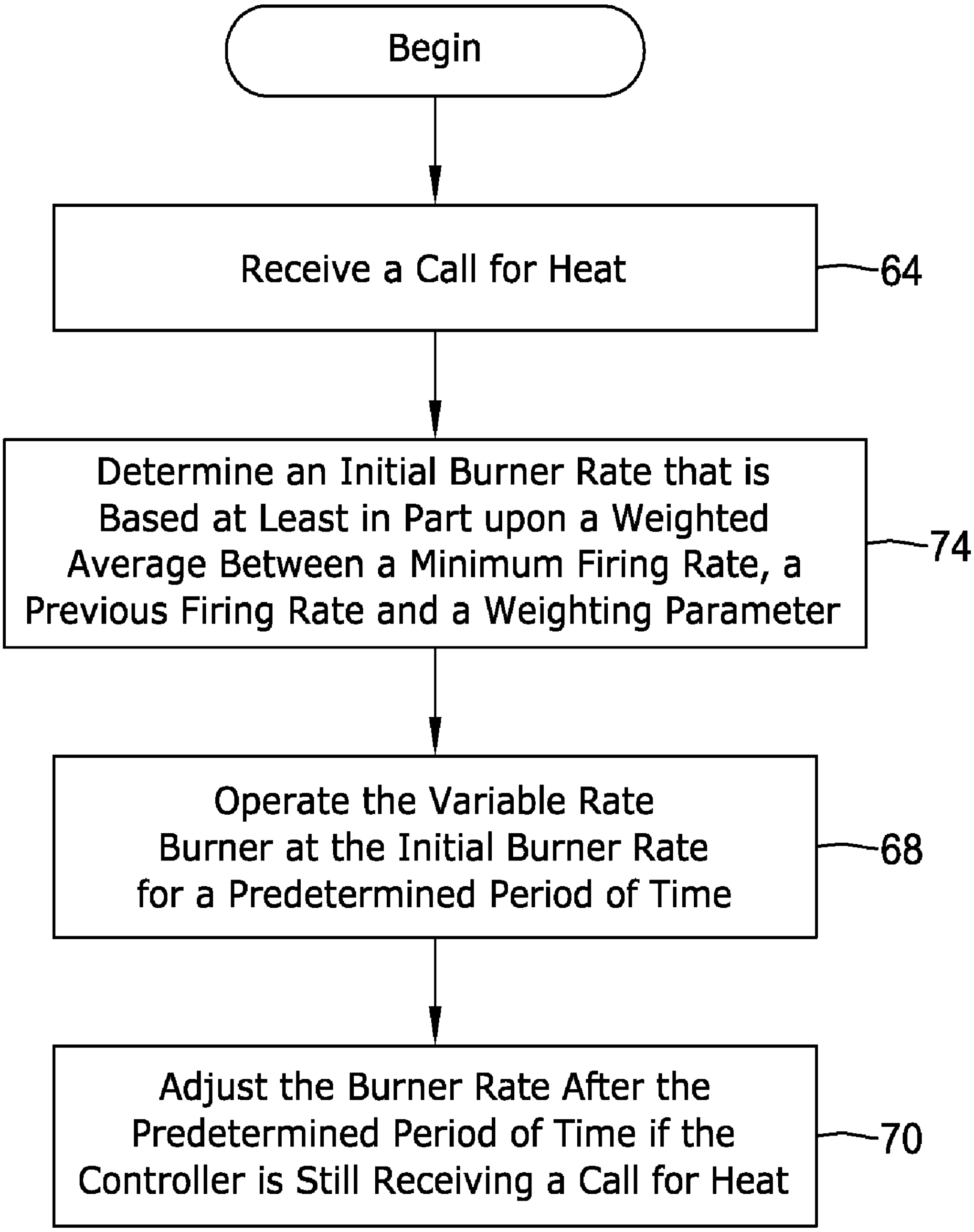

Begin
Receive a Call for Heat
64
Determine an Initial Burner Rate that is Based at Least in Part upon a Weighted Average Between a Minimum Firing Rate, a Previous Firing Rate and a Weighting Parameter
74
Operate the Variable Rate Burner at the Initial Burner Rate for a Predetermined Period of Time
68
Adjust the Burner Rate After the Predetermined Period of Time if the Controller is Still Receiving a Call for Heat
70

Figure 7

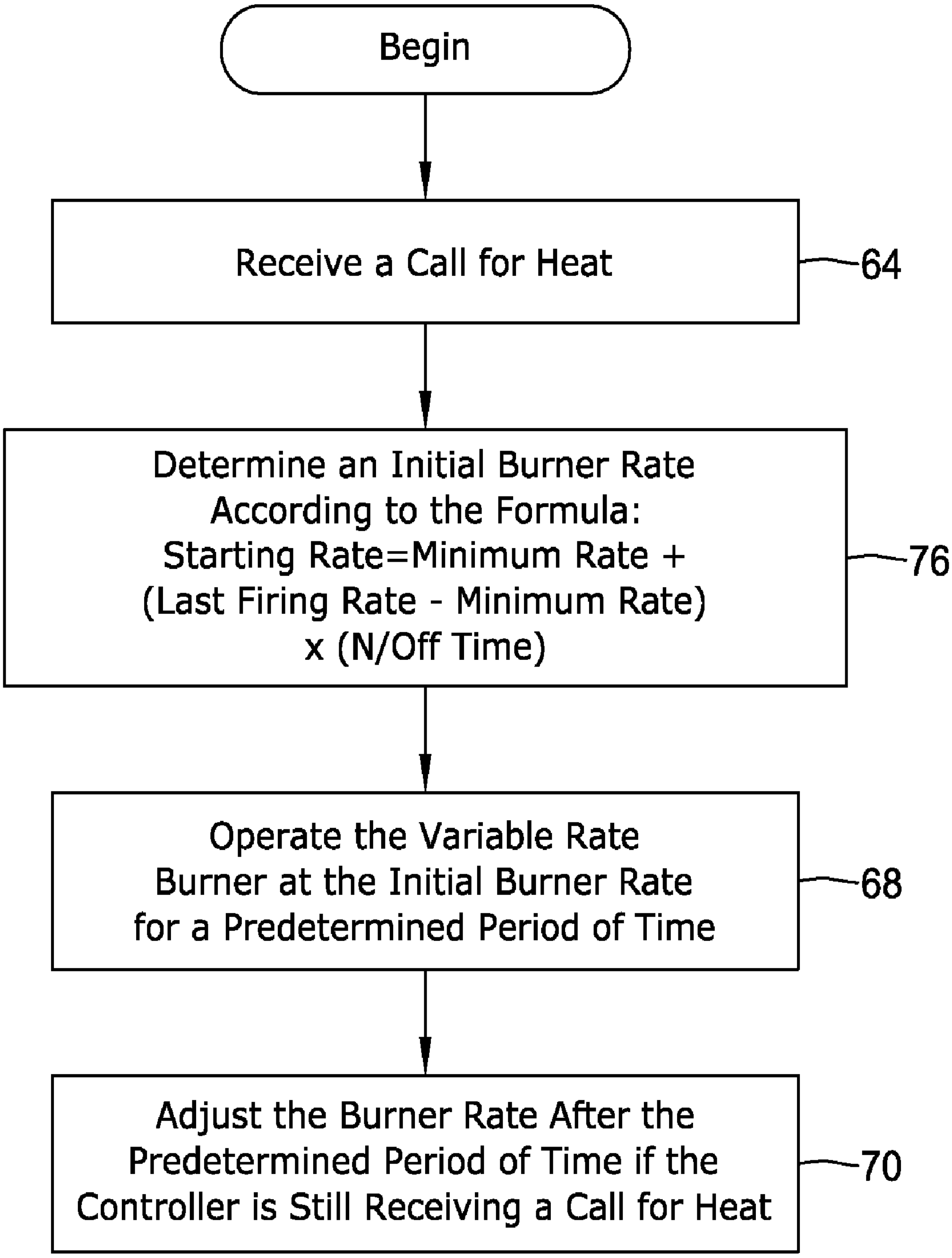

Begin
Receive a Call for Heat
64
Determine an Initial Burner Rate According to the Formula: Starting Rate=Minimum Rate + (Last Firing Rate - Minimum Rate) x (N/Off Time)
76
Operate the Variable Rate Burner at the Initial Burner Rate for a Predetermined Period of Time
68
Adjust the Burner Rate After the Predetermined Period of Time if the Controller is Still Receiving a Call for Heat
70

Figure 8

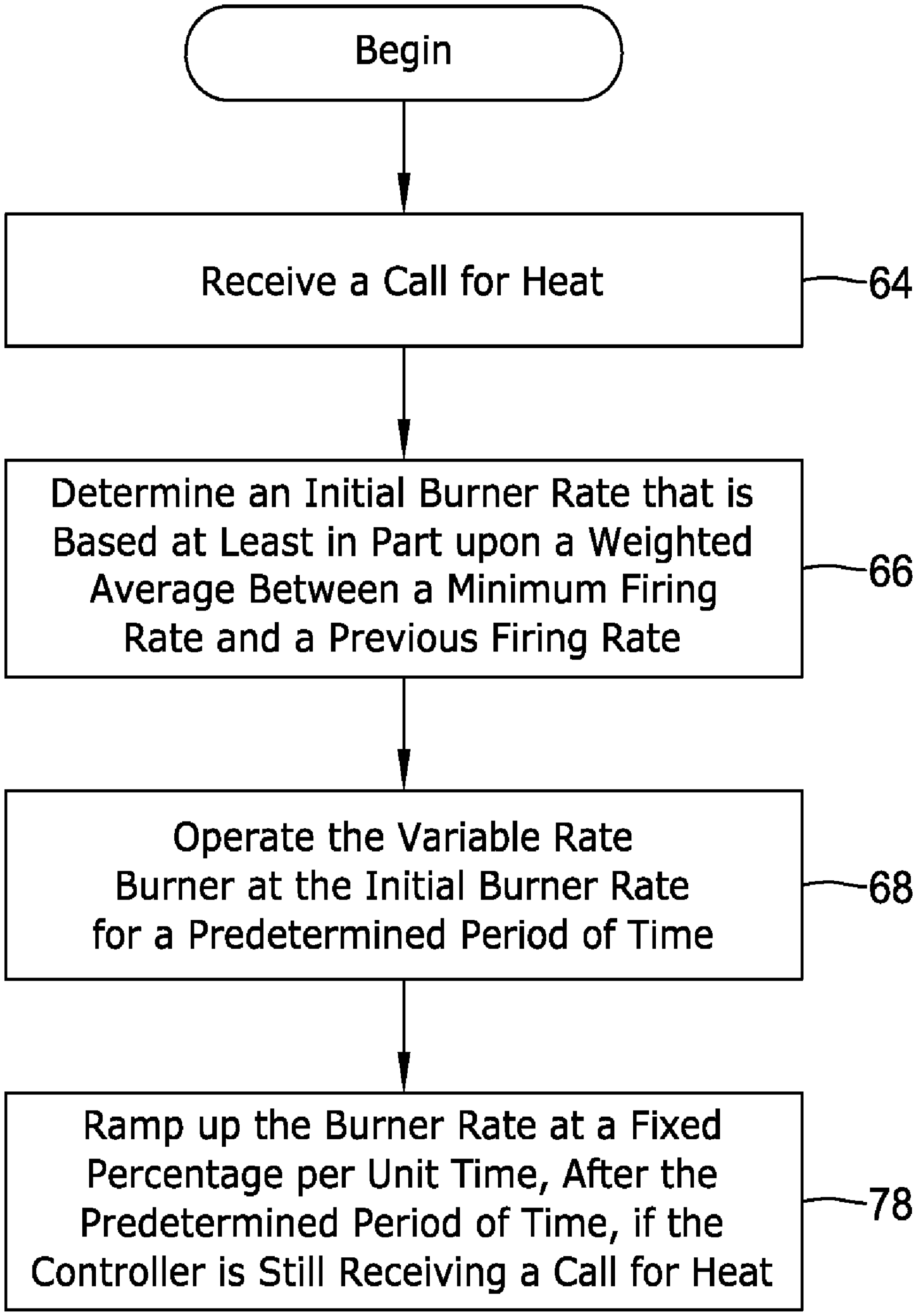

Begin
Receive a Call for Heat
64
Determine an Initial Burner Rate that is Based at Least in Part upon a Weighted Average Between a Minimum Firing Rate and a Previous Firing Rate
66
Operate the Variable Rate Burner at the Initial Burner Rate for a Predetermined Period of Time
68
Ramp up the Burner Rate at a Fixed Percentage per Unit Time, After the Predetermined Period of Time, if the Controller is Still Receiving a Call for Heat
78

Figure 9

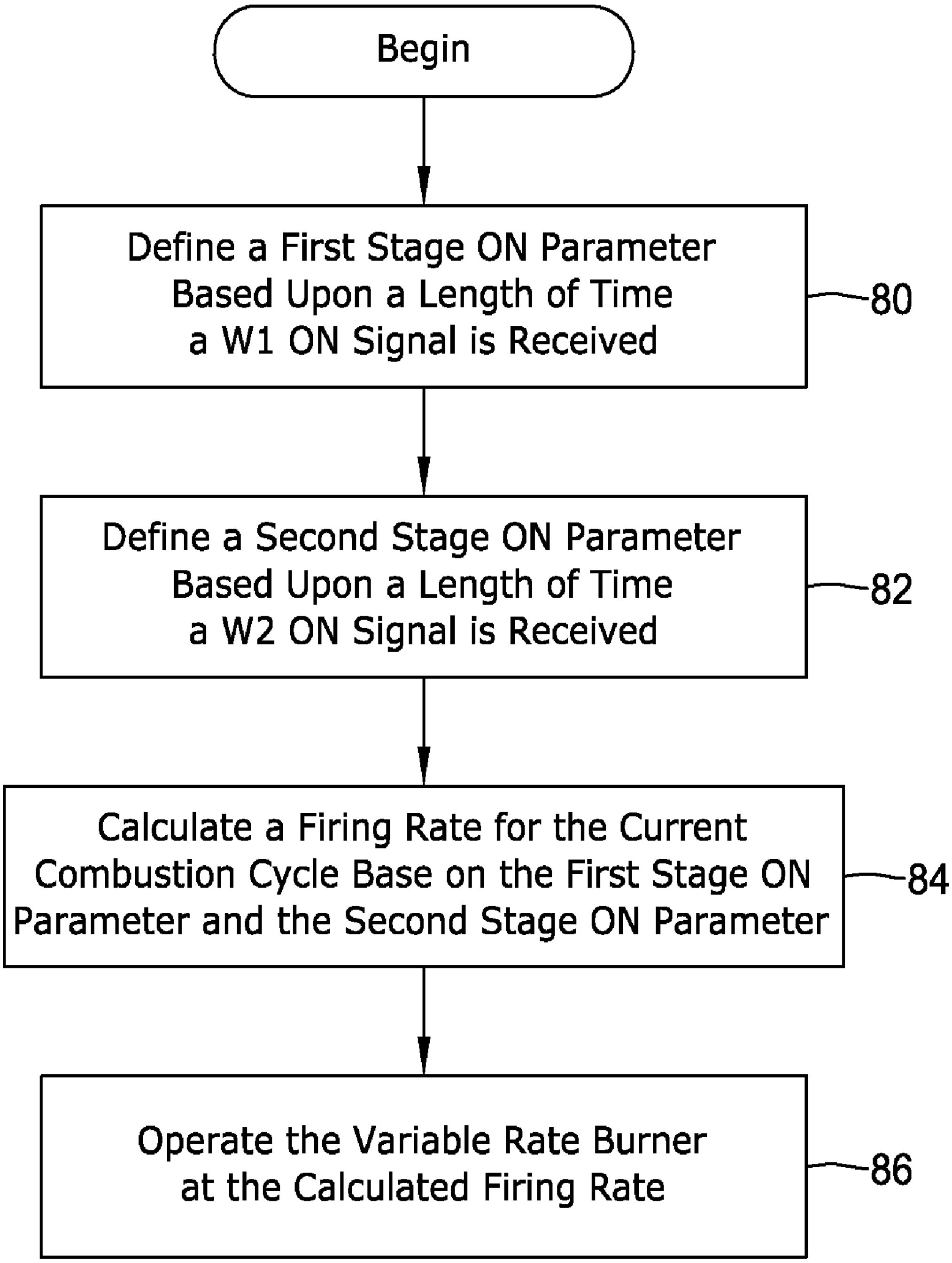

Begin
Define a First Stage ON Parameter Based Upon a Length of Time a W1 ON Signal is Received
80
Define a Second Stage ON Parameter Based Upon a Length of Time a W2 ON Signal is Received
82
Calculate a Firing Rate for the Current Combustion Cycle Base on the First Stage ON Parameter and the Second Stage ON Parameter
84
Operate the Variable Rate Burner at the Calculated Firing Rate
86

Figure 10

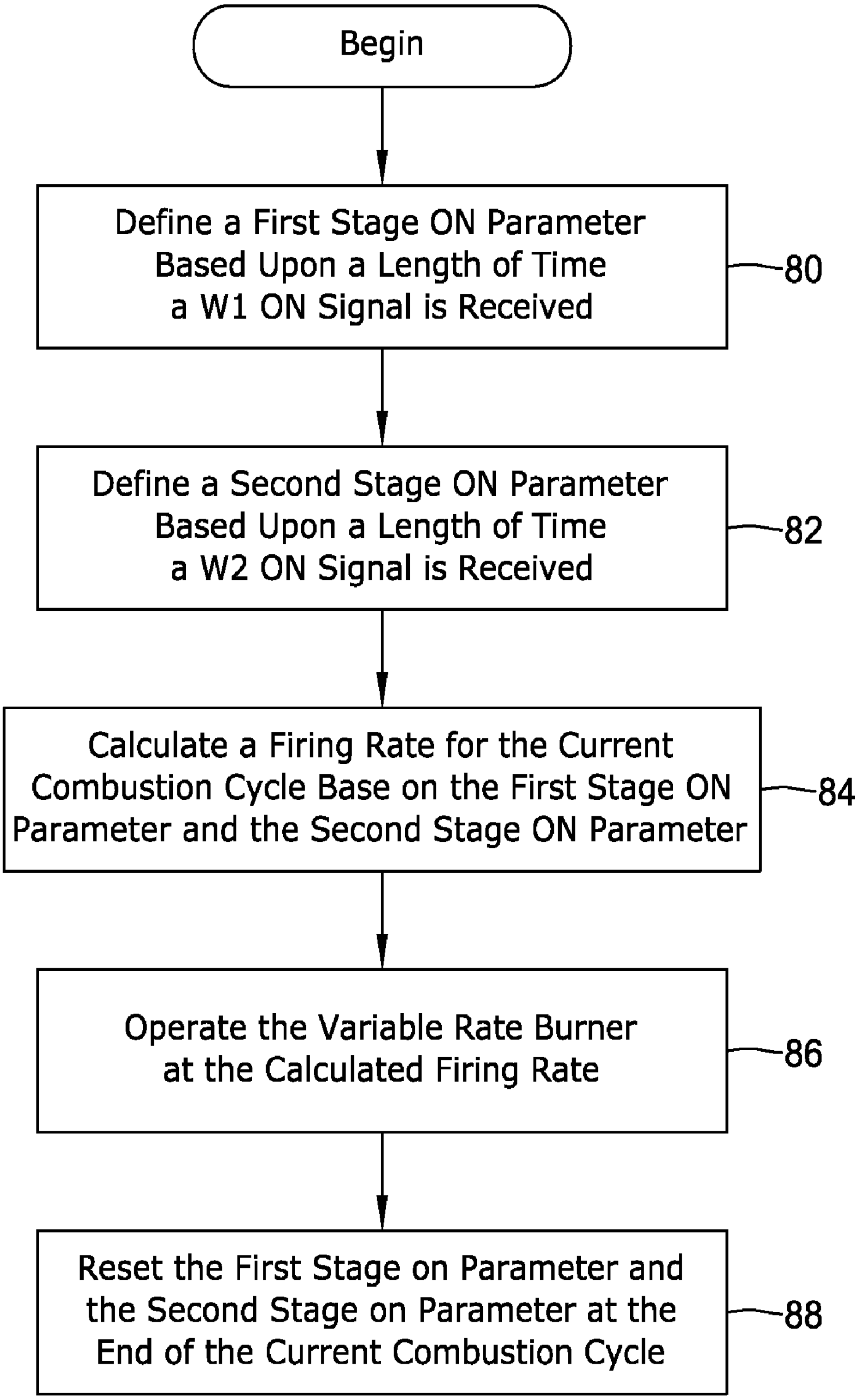

Begin
Define a First Stage ON Parameter Based Upon a Length of Time a W1 ON Signal is Received
80
Define a Second Stage ON Parameter Based Upon a Length of Time a W2 ON Signal is Received
82
Calculate a Firing Rate for the Current Combustion Cycle Base on the First Stage ON Parameter and the Second Stage ON Parameter
84
Operate the Variable Rate Burner at the Calculated Firing Rate
86
Reset the First Stage on Parameter and the Second Stage on Parameter at the End of the Current Combustion Cycle
88

Figure 11

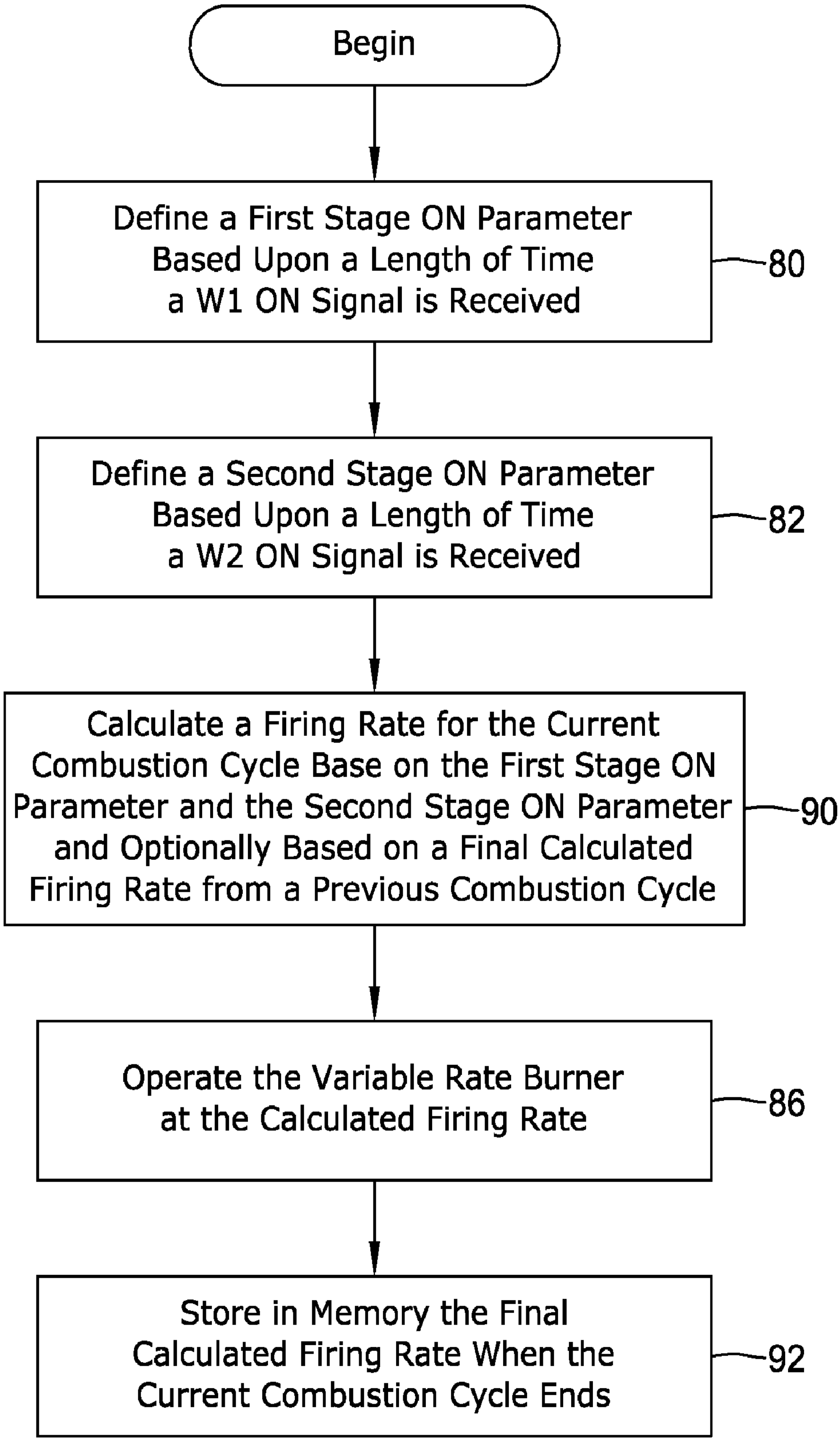

Begin
Define a First Stage ON Parameter Based Upon a Length of Time a W1 ON Signal is Received
80
Define a Second Stage ON Parameter Based Upon a Length of Time a W2 ON Signal is Received
82
Calculate a Firing Rate for the Current Combustion Cycle Base on the First Stage ON Parameter and the Second Stage ON Parameter and Optionally Based on a Final Calculated Firing Rate from a Previous Combustion Cycle
90
Operate the Variable Rate Burner at the Calculated Firing Rate
86
Store in Memory the Final Calculated Firing Rate When the Current Combustion Cycle Ends
92

Figure 12

BURNER FIRING RATE DETERMINATION FOR MODULATING FURNACE

TECHNICAL FIELD

[0001] The disclosure relates generally to furnaces such as modulating furnaces.

BACKGROUND

[0002] Many homes and other buildings rely upon furnaces to provide heat during cool and/or cold weather. Typically, a furnace employs a burner that burns a fuel such as natural gas, propane, oil or the like, and provides heated combustion gases to the interior of a heat exchanger. The combustion gases typically proceed through the heat exchanger, are collected by a collector box, and then are exhausted outside of the building via a vent or the like. In some cases, a combustion blower is provided to pull in combustion air into the burner, pull the combustion gases through the heat exchanger into the collector box, and to push the combustion gases out the vent. At the same time, a circulating blower typically forces return air from the building, and in some cases ventilation air from outside of the building, over or through the heat exchanger, thereby heating the air. The heated air is subsequently routed throughout the building via a duct system. A return duct is typically employed to return air from the building to the furnace to be re-heated and then re-circulated.

[0003] In order to provide improved energy efficiency and/or occupant comfort, some furnaces may be considered as having two or more stages, i.e., they can operate at two or more different burner firing rates, depending on how much heat is needed within the building. Some furnaces are known as modulating furnaces, because they can potentially operate at a number of different burner firing rates and/or across a range of burner firing rates. The burner firing rate of the furnace typically dictates the amount of gas and air that is required by the burner. The circulating blower may be regulated, in accordance with the burner firing rate, to maintain a desired discharge air temperature, i.e., the temperature of the heated air returning to the building. A need remains for improved methods of determining burner firing rates.

SUMMARY

[0004] The disclosure pertains generally to methods of operating modulating combustion appliances such as forced air furnaces. An illustrative but non-limiting example of the disclosure may be found in a method of operating a modulating furnace having a burner that is configured to operate at variable burner firing rates and a controller that is configured to accept a call for heat from a thermostat or the like. The call for heat may remain activate until the call is satisfied, at which time the call may be terminated by the thermostat or the like, resulting in a heating cycle. This may be repeated during operation of the modulating furnace.

[0005] In some instances, the burner may be operated at a first burner firing rate for a first period of time. After the first period of time has expired, the burner firing rate may be increased. In some instances, the burner firing rate may be increased in accordance with a predetermined function, such as a linear function, a piecewise linear function, a step-wise function that includes a single or multiple steps, an exponential function, any combination of these functions, or any other suitable function, as desired. In some instances, the burner may be operated only while the controller is receiving a call for heat from the thermostat or the like, but this is not required in all embodiments.

[0006] The initial burner firing rate for each heating cycle may be a fixed value, such as a predetermined minimum burner firing rate (e.g. 40%). Alternatively, the initial burner firing rate may vary for each heating cycle. When the initial burner firing rate may vary for each of the heating cycles, it is contemplated that the initial burner firing rate may be based, at least in part, on historical operating parameters of the modulating furnace. For example, the initial burner firing rate may be based, at least in part, on the "off" time of the burner during one or more previous heating cycles or over a previous period of time (e.g. 1 hour), the run-time of the burner during one or more previous heating cycles or over a previous period of time, and/or the burner firing rate that existed at the end of the previous heating cycle.

[0007] In some cases, the initial burner firing rate may be based, at least in part, on a weighed set or weighted average of one or more current and/or historical operating parameters of the modulating furnace. For example, the initial burner firing rate may be based, at least in part, on the average duty cycle of the modulating furnace during one or more previous heating cycles or over a predetermined period of time, a weighted set or weighted average of the burner firing rates over one or more previous heating cycles or over a predetermined period of time, a weighed set or weighted average of a predefined minimum burner firing rate and one or more previous burner firing rates. These, however, are merely illustrative.

[0008] Another illustrative but non-limiting example of the disclosure may be found in a method of operating a forced air furnace that includes a variable rate burner and a controller that is configured to accept signals from a two-stage thermostat. The controller may define a first stage ON parameter based at least in part on a length of time that a W1 (First Stage Heat) ON signal is received from the two-stage thermostat. A second stage ON parameter may be defined based at least in part on a length of time that a W2 (second Stage Heat) ON signal is received from the two-stage thermostat. A burner firing rate for a current heating cycle may be determined, relying at least in part on the first stage ON parameter and/or the second stage ON parameter. For example, the burner firing rate may be set to an initial burner firing rate for a period of time, after which the burner firing rate may be increased if the W2 (second Stage Heat) ON signal remains active. In some cases, the longer the W2 (second Stage Heat) ON signal remains active, the more the burner firing rate may be increased. The initial burner firing rate may be a fixed value, or may vary for each heating cycle, as described above.

[0009] The above summary is not intended to describe each disclosed embodiment or every implementation. The Figures, Description and Examples which follow more particularly exemplify these embodiments.

BRIEF DESCRIPTION

[0010] The disclosure may be more completely understood in consideration of the following detailed description of various embodiments in connection with the accompanying drawings, in which:

[0011] FIG. **1** is a schematic view of an illustrative but non-limiting furnace; and

[0012] FIGS. **2** through **12** are flow diagrams showing illustrative but non-limiting methods that may be carried out using the furnace of FIG. **1**.

[0013] While the invention is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit the invention to the particular embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention.

DESCRIPTION

[0014] The following description should be read with reference to the drawings, in which like elements in different drawings are numbered in like fashion. The drawings, which are not necessarily to scale, depict selected embodiments and are not intended to limit the scope of the invention. Although examples of construction, dimensions, and materials are illustrated for the various elements, those skilled in the art will recognize that many of the examples provided have suitable alternatives that may be utilized.

[0015] FIG. **1** is a schematic view of a furnace **10**, which may include additional components not described herein. The primary components of furnace **10** include a burner compartment **12**, a heat exchanger **14** and a collector box **16**. An electrically or pneumatically regulated gas valve **18** provides fuel such as natural gas or propane, from a source (not illustrated) to burner compartment **12** via a gas line **20**. Burner compartment **12** burns the fuel provided by gas valve **18**, and provides heated combustion products to heat exchanger **14**. The heated combustion products pass through heat exchanger **14** and exit into collector box **16**, and are ultimately exhausted to the exterior of the building or home in which furnace **10** is installed.

[0016] In the illustrative furnace, a circulating blower **22** accepts return air from the building or home's return ductwork **24** as indicated by arrow **26** and blows the return air through heat exchanger **14**, thereby heating the air. The heated air exits heat exchanger **14** and enters the building or home's conditioned air ductwork **28**, traveling in a direction indicated by arrow **30**. For enhanced thermal transfer and efficiency, the heated combustion products may pass through heat exchanger **14** in a first direction while circulating blower **22** forces air through heat exchanger **14** in a second direction. In some instances, for example, the heated combustion products may pass generally downwardly through heat exchanger **14** while the air blown through by circulating blower **22** may pass upwardly through heat exchanger **14**, but this is not required.

[0017] In some cases, as illustrated, a combustion blower **32** may be positioned downstream of collector box **16** and may pull combustion gases through heat exchanger **14** and collector box **16**. Combustion blower **32** may be considered as pulling combustion air into burner compartment **12** through combustion air source **34** to provide an oxygen source for supporting combustion within burner compartment **12**. The combustion air may move in a direction indicated by arrow **36**. Combustion products may then pass through heat exchanger **14**, into collector box **16**, and ultimately may be exhausted through the flue **38** in a direction indicated by arrow **40**.

[0018] Furnace **10** may include a controller **42** that can be configured to control various components of furnace **10**, including the ignition of fuel by an ignition element (not shown), the speed and operation times of combustion blower **32**, and the speed and operation times of circulating fan or blower **22**. In addition, controller **42** can be configured to monitor and/or control various other aspects of the system including any damper and/or diverter valves connected to the supply air ducts, any sensors used for detecting temperature and/or airflow, any sensors used for detecting filter capacity, and any shut-off valves used for shutting off the supply of gas to gas valve **18**. In the control of other gas-fired appliances such as water heaters, for example, controller **42** can be tasked to perform other functions such as water level and/or temperature detection, as desired.

[0019] In some embodiments, controller **42** can include an integral furnace controller (IFC) configured to communicate with one or more thermostats or the like (not shown) for receiving calls for heat, sometimes from various locations within the building or structure. It should be understood, however, that controller **42** may be configured to provide connectivity to a wide variety of platforms and/or standards, as desired.

[0020] Controller **42** may provide commands to circulating blower **22** via an electrical line **46**. In some cases, controller **42** may also regulate combustion blower **32** via signals sent via an electrical line **48**. In some instances, controller **42** may indirectly regulate the flow of gas through gas valve **18** by electrically commanding combustion blower **32** to increase or decrease its speed. The resulting change in combustion gas flow through one or more of burner compartment **12**, heat exchanger **14**, collector box **16** and combustion blower **32** may be detected and/or measured pneumatically as a pressure or as a pressure drop. The pressure signal may be used to pneumatically regulate gas valve **18**, although the pneumatic line(s) is (are) not illustrated in FIG. **1**. In some instances, it is contemplated that controller **42** may electrically control gas valve **18** by sending appropriate command signals via an optional electrical line **50**.

[0021] FIGS. **2** through **12** are flow diagrams showing illustrative but non-limiting methods that may be carried out using furnace **10** (FIG. **1**). In FIG. **2**, control begins at block **52**, at which controller **42** (FIG. **1**) operates burner **12** (FIG. **1**) at a first burner firing rate for a first period of time. The first period of time may, for example, be a selectable parameter that can be adjusted by an installer or the like. In some cases, this parameter may also be software settable via controller **42**. In some instances the first burner firing rate may be an initial burner firing rate. The initial burner firing rate may, for each heating cycle of the furnace **10**, be set to a fixed value such as a predetermined minimum burner firing rate (e.g. 40%). Alternatively, the initial burner firing rate may vary for each heating cycle.

[0022] When the initial burner firing rate may vary for each of the heating cycles, it is contemplated that the initial burner firing rate may be based, at least in part, on historical operating parameters of the furnace **10**. For example, the initial burner firing rate may be based, at least in part, on the "off" time of the burner during one or more previous heating cycles or over a previous period of time (e.g. 1 hour), the run-time of the burner during one or more previous heating cycles or over a previous period of time, and/or the burner firing rate that existed at the end of the previous heating cycle.

[0023] In some instances, the initial burner firing rate may be based, at least in part, on a weighed set or weighted average of one or more current and/or historical operating parameters of the furnace **10**. For example, the initial burner firing rate may be based, at least in part, on the average duty cycle of the furnace **10** during one or more previous heating cycles or over a predetermined period of time, a weighted set or weighted average of the burner firing rates over one or more previous heating cycles or over a predetermined period of time, a weighed set or weighted average of a predefined minimum burner firing rate and one or more previous burner firing rates. These, however, are merely illustrative.

[0024] At block **54**, controller **42** increases the firing rate of burner **12** after the first period of time has expired, such as to a second burner firing rate. The second burner firing rate may be determined in a step-wise fashion and/or may be ramped up, i.e., increasing the burner firing rate by a particular amount or percentage per unit time. In some instances, the burner firing rate may be increased in accordance with any predetermined function, such as a linear function, a piecewise linear function, a step-wise function that includes a single or multiple steps, an exponential function, any combination of these functions, or any other suitable function, as desired.

[0025] In some instances, burner **12** may be permitted to operate while controller **42** is receiving a call for heat (from a thermostat or similar device, not shown) but is stopped when the call for heat ceases. In some cases, for example, a call for heat may mean that controller **42** is receiving a call for heat from a single stage thermostat. In other cases, a call for heat may mean that controller **42** is receiving a W1 (first stage heat) ON signal and/or a W2 (second stage heat) ON signal from a two stage thermostat. These, however, are only illustrative, and it is contemplated that a call for heat may emanate from any suitable device.

[0026] Turning now to FIG. **3**, control begins at block **56**, where controller **42** (FIG. **1**) operates burner **12** (FIG. **1**) at a minimum burner firing rate for a first period of time. At block **58**, controller **42** increases burner **12** to a second burner firing rate after the first period of time has expired. The second burner firing rate may be determined in a step-wise fashion, by ramping the burner firing rate, or by any other suitable function, as desired. Controller **42** may operate burner **12** at the second rate for a second period of time, as shown at block **60**. The second period of time may be a user-determined parameter and/or an installation-specific setting that is determined and set by an installer. Alternatively, the second period of time may be determined by the controller, and in some cases, may be based on one or more historical operating parameters of the furnace.

[0027] Turning now to FIG. **4**, control begins at block **56**, where controller **42** (FIG. **1**) operates burner **12** (FIG. **1**) at a minimum burner firing rate for a first period of time. At block **58**, controller **42** increases burner **12** to a second burner firing rate after the first period of time has expired. Controller **42** may operate burner **12** at the second burner firing rate for a second period of time, as referenced at block **60**. Control passes to block **62**, where controller **42** increases burner **12** to a third burner firing rate after the second period of time has expired. The third burner firing rate may be greater than the second burner firing rate, but this is not required in all embodiments. In some cases, the third burner firing rate may be a maximum fire rate. In FIG. **5**, control begins at block **64**, where controller **42** (FIG. **1**) receives a call for heat from a thermostat or the like. Control passes to block **66**, where controller **42** determines an initial burner firing rate that is based at least in part on a weighted average between a minimum burner firing rate and a previous burner firing rate. This is only illustrative, and it is contemplated that any suitable method, including those discussed above, may be used to determine the initial burner firing rate. At block **68**, burner **12** (FIG. **1**) is operated at the initial burner firing rate for a predetermined period of time. Control passes to block **70**, where controller **42** adjusts the burner firing rate of burner **12** after the predetermined period of time expires if controller **42** is still receiving the call for heat.

[0028] In FIG. **6**, control begins at block **64**, where controller **42** (FIG. **1**) receives a call for heat from a thermostat or the like. Control passes to block **66**, where controller **42** determines an initial burner firing rate that is based at least in part on a weighted average between a minimum burner firing rate and a previous burner firing rate. Again, this is only illustrative, and it is contemplated that any suitable method, including those discussed above, may be used to determine the initial burner firing rate. At block **68**, burner **12** (FIG. **1**) is operated at the initial burner firing rate for a predetermined period of time. Control passes to block **70**, where controller **42** adjusts the burner firing rate of burner **12** after the predetermined period of time expires if controller **42** is still receiving a call for heat.

[0029] At block **72**, controller **42** stops burner **12** if the call for heat stops. While block **72** is shown in FIG. **6** at the end of the flow diagram, it will be appreciated that in some cases controller **42** can cease burner operation at any suitable point during the flow diagram. For example, if controller **42** recognizes that the call for heat has stopped even while controller **42** is in the process of carrying out the steps outlined in block **66**, block **68** and/or block **70**, controller **42** may immediately stop burner operation. If gas valve **18** (FIG. **1**) is electrically controlled, appropriate instructions may be sent via electrical line **50** (FIG. **1**) to cease burner operation. If gas valve **18** is pneumatically modulated, burner operation may be ceased by reducing the speed of combustion blower **32** (FIG. **1**) such that the resultant pressure drop within flue **38** will cause gas valve **18** to stop providing gas to the burner.

[0030] In FIG. **7**, control begins at block **64**, where controller **42** (FIG. **1**) receives a call for heat from a thermostat or the like. At block **74**, controller **42** determines an initial burner firing rate that is based at least in part on a weighted average between a minimum burner firing rate and a previous burner firing rate and is also based at least in part on a weighting parameter. In some cases, the weighting parameter may be a function of an Off time during a previous heating cycle, although this is not required. At block **68**, burner **12** (FIG. **1**) is operated at the initial burner firing rate for a predetermined period of time. Control passes to block **70**, where controller **42** adjusts the burner firing rate of burner **12** after the predetermined period of time expires if controller **42** is still receiving a call for heat.

[0031] In FIG. **8**, control begins at block **64**, where controller **42** (FIG. **1**) receives a call for heat from a thermostat or the like. At block **76**, controller **42** determines an initial burner firing rate according to the formula:

$$StartingRate = MinimumRate + \left(\begin{array}{c} LastFiringRate - \\ MinimumRate \end{array} \right) * \frac{N}{OffTime},$$

where StartingRate is the initial burner firing rate, MinimumRate is a minimum burner firing rate, LastFiringRate is the previous burner firing rate, OffTime represents how long the burner was off during a previous heating cycle, and N is a parameter that can be adjusted to further weight the StartingRate. In some cases, N may be selected to provide a StartingRate that is close to the minimum fire rate for a chosen OffTime. In an illustrative but non-limiting example, N may be set to five minutes. At block **68**, burner **12** (FIG. **1**) is operated at the initial burner firing rate for a predetermined period of time. Control passes to block **70**, where controller **42** adjusts the burner firing rate of burner **12** after the predetermined period of time expires if controller **42** is still receiving a call for heat.

[0032] In FIG. **9**, control begins at block **64**, where controller **42** (FIG. **1**) receives a call for heat from a thermostat or the like. Control passes to block **66**, where controller **42** determines an initial burner firing rate that is based at least in part on a weighted average between a minimum burner firing rate and a previous burner firing rate. At block **68**, burner **12** (FIG. **1**) is operated at the initial burner firing rate for a predetermined period of time. Control passes to block **78**, where controller **42** ramps up the burner firing rate of burner **12** at a fixed percentage at each of a number of time intervals if, after the predetermined period of time has expired, controller **42** is still receiving a call for heat.

[0033] Turning now to FIG. **10**, control begins at block **80**, where controller **42** (FIG. **1**) defines a first stage ON parameter that is based upon a length of time that a W1 (first stage heat) ON signal is received by controller **42**. In some cases, the first stage ON parameter tracks how long the W1 (first stage heat) ON signal is received during a current heating cycle, but this is not required. At block **82**, controller **42** (FIG. **1**) defines a second stage ON parameter that is based upon a length of time that a W2 (second stage heat) ON signal is received by controller **42**. In some cases, the second stage ON parameter tracks how long the W2 (second stage heat) ON signal is received during the current heating cycle, but this is not required.

[0034] At block **84**, controller **42** (FIG. **1**) calculates a burner firing rate for the current heating cycle that is based at least in part on the second stage ON parameter, and in some cases, on the first stage ON parameter. It will be appreciated that these parameters, i.e., how long a thermostat is calling for first stage heat, how long the thermostat is calling for second stage heat, and/or how long a thermostat is calling for first stage heat relative to how long the thermostat is calling for second stage heat, may provide controller **42** with information indicative of the current heat load on the building in which furnace **10** (FIG. **1**) is installed. Control passes to block **86**, where burner **12** (FIG. **1**) is operated at the calculated burner firing rate. It will be appreciated that the calculated burner firing rate may be recalculated as often as appropriate during a single heating cycle.

[0035] In some cases, the calculated burner firing rate may be calculated (with reference to block **84**) in accordance with the formula:

$$FiringRate = W1Rate + FiringRange * \left(\frac{W2OnTime}{FurnaceOnTime}\right),$$

where FiringRate is the calculated burner firing rate, W1Rate is a minimum burner firing rate or a burner firing rate calculated using a previous burner firing rate or the like, FiringRange is a parameter based upon a desired burner firing rate, W2OnTime is the amount of time that a W2 (second stage heat) ON signal is received during a current heating cycle, and FurnaceOnTime is a length of time the furnace is operating during the current heating cycle. In some cases, FiringRange may represent a difference between maximum burner firing rate and minimum burner firing rate, but this is not required.

[0036] Turning now to FIG. **11**, control begins at block **80**, where controller **42** (FIG. **1**) defines a first stage ON parameter that is based upon a length of time that a W1 (first stage heat) ON signal is received by controller **42**. At block **82**, controller **42** (FIG. **1**) defines a second stage ON parameter that is based upon a length of time that a W2 (second stage heat) ON signal is received by controller **42**. At block **84**, controller **42** (FIG. **1**) calculates a burner firing rate for the current heating cycle that is based at least in part on the first stage ON parameter and the second stage ON parameter.

[0037] Control passes to block **86**, where burner **12** (FIG. **1**) is operated at the calculated burner firing rate. It will be appreciated that the calculated burner firing rate may be recalculated as often as appropriate during a single heating cycle. At block **88**, controller **42** (FIG. **1**) resets the first stage ON parameter and the second stage ON parameter to zero at the end of the current heating cycle.

[0038] In FIG. **12**, control begins at block **80**, where controller **42** (FIG. **1**) defines a first stage ON parameter that is based upon a length of time that a W1 first stage heat) ON signal is received by controller **42**. At block **82**, controller **42** (FIG. **1**) defines a second stage ON parameter that is based upon a length of time that a W2 (second stage heat) ON signal is received by controller **42**. At block **90**, controller **42** (FIG. **1**) calculates a burner firing rate for the current heating cycle that is based at least in part on the first stage ON parameter and the second stage ON parameter, and may optionally also be based upon a final calculated burner firing rate from a previous heating cycle. It will be appreciated that the calculated burner firing rate may be recalculated as often as appropriate during a single heating cycle.

[0039] Control passes to block **86**, where burner **12** (FIG. **1**) is operated at the calculated burner firing rate. At block **92**, controller **42** (FIG. **1**) stores in memory the final calculated burner firing rate when the current heating cycle ends. This value may subsequently be used, as referenced in block **90**, in calculating a burner firing rate for a subsequent heating cycle.

[0040] The invention should not be considered limited to the particular examples described above, but rather should be understood to cover all aspects of the invention as set out in the attached claims. Various modifications, equivalent processes, as well as numerous structures to which the invention can be applicable will be readily apparent to those of skill in the art upon review of the instant specification.

We claim:

1. A method of operating a modulating furnace having a burner configured to operate at multiple burner firing rates and a controller configured to accept a call for heat, the method comprising the steps of:

operating the burner at a first rate for a first period of time; and

increasing the burner firing rate of the burner after the first period of time expires;

wherein the burner is operated while the controller is receiving a call for heat and is not operated when the call for heat ceases.

2. The method of claim **1**, wherein operating the burner at a first rate for a first period of time includes operating the burner at a minimum burner firing rate for a selectable period of time.

3. The method of claim **2**, wherein increasing the burner firing rate of the burner includes operating the burner at a second rate for a second period of time.

4. The method of claim **3**, further comprising increasing the burner to a third fire rate that is greater than the second rate after the second period of time ends.

5. The method of claim **4**, wherein the third fire rate is a maximum fire rate.

6. The method of claim **1**, wherein the call for heat includes a W1 (first stage heat) ON signal from a two-stage thermostat.

7. The method of claim **6**, wherein the call for heat further comprises a W2 (second stage heat) ON signal from the two-stage thermostat.

8. A method of operating a forced air furnace having a variable rate burner and a controller, the method comprising the steps of:

receiving a call for heat;

determining an initial burner firing rate that is based at least in part on a weighted average of one or more previous operating parameters of the forced air furnace;

operating the variable rate burner at the initial burner firing rate for a predetermined period of time; and

adjusting the burner firing rate after the predetermined period of time expires if the controller is still receiving a call for heat.

9. The method of claim **8**, further comprising stopping the burner if the call for heat ceases.

10. The method of claim **8**, wherein determining an initial burner firing rate comprises determining an initial burner firing rate based at least in part on a weighted average between a predetermined minimum burner firing rate and a previous burner firing rate.

11. The method of claim **10**, wherein the weighted average includes a weighting parameter, and wherein the weighting parameter is a function of an Off time of the forced air furnace during a previous heating cycle.

12. The method of claim **8**, wherein determining the initial burner firing rate comprises determining an initial burner firing rate according to the formula:

$$StartingRate = MinimumRate + \begin{pmatrix} LastFiringRate - \\ MinimumRate \end{pmatrix} * \frac{N}{OffTime},$$

where StartingRate is the initial burner firing rate,

MinimumRate is a predetermined minimum burner firing rate,

LastFiringRate is the burner firing rate at the end of a previous heating cycle,

OffTime represents how long the burner was off just prior to receiving the call for heat, and

N is a parameter that can be adjusted to further weight the StartingRate.

13. The method of claim **8**, wherein adjusting the burner firing rate after the predetermined period of time comprises ramping up the burner firing rate by a determined amount at each of one or more predetermined intervals.

14. A method of operating a forced air furnace comprising a variable burner firing rate burner and a controller, the controller configured to accept signals from a two-stage thermostat, the method comprising the steps of:

defining a second stage ON parameter based upon a length of time a W2 (second stage heat) ON signal is received;

calculating a burner firing rate for the current heating cycle based, at least in part, on the second stage ON parameter; and

operating the variable rate burner at the calculated burner firing rate.

15. The method of claim **14**, further comprising the step of defining a first stage ON parameter based upon a length of time a W1 (first stage heat) ON signal is received, and wherein the calculating step calculates the burner firing rate for the current heating cycle based, at least in part, on the first stage ON parameter and the second stage ON parameter, and wherein the first stage ON parameter is based upon a length of time the W1 (first stage heat) ON signal is on during the current heating cycle and the second stage ON parameter is based upon a length of time the W2 (second stage heat) ON signal is on during a current heating cycle.

16. The method of claim **15**, further comprising resetting the first stage ON parameter to zero at the end of the current heating cycle.

17. The method of claim **15**, further comprising resetting the second stage ON parameter to zero at the end of the current heating cycle.

18. The method of claim **14**, further comprising storing a final calculated burner firing rate when a previous heating cycle ends.

19. The method of claim **18**, wherein calculating the burner firing rate based on the first stage ON time and the second stage ON is also based at least in part on the stored calculated burner firing rate.

20. The method of claim **14**, wherein calculating the burner firing rate comprises calculating a burner firing rate according to the formula:

$$FiringRate = W1Rate + FiringRange * \left(\frac{W2OnTime}{FurnaceOnTime}\right),$$

where FiringRate is the calculated burner firing rate,

W1 Rate is a minimum burner firing rate or a burner firing rate calculated using a previous burner firing rate,

FiringRange is a parameter based upon a desired burner firing rate,

W2OnTime is the amount of time that a W2 (second stage heat) ON signal is received during a current heating cycle, and

FurnaceOnTime is a length of time the furnace is operating during the current heating cycle.

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