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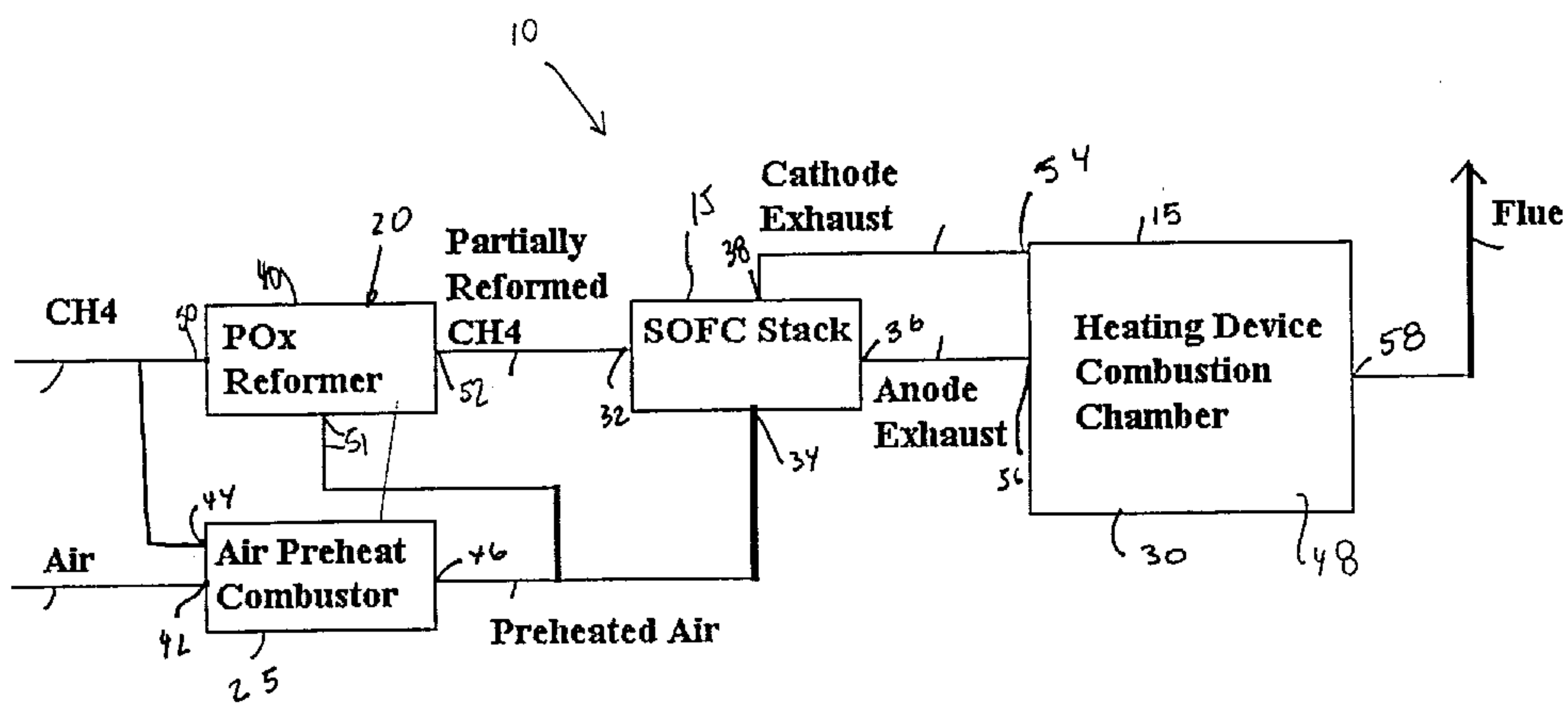
(54) **BRULEUR DE PILE A COMBUSTIBLE A OXYDE SOLIDE ET METHODE POUR PRODUIRE DE LA CHALEUR A L'AIDE DE CELUI-CI**

(54) **SOLID OXIDE FUEL CELL BURNER SYSTEM AND METHOD FOR GENERATING HEAT THEREFROM**



(57) A burner system comprising a solid oxide fuel cell (SOFC), a partial reformer, an air preheater and a heat energy recovery member. The reformer is associated with the SOFC and partially reforms fuel prior to introduction into the SOFC. The preheater is associated with the SOFC and preheats air for introduction into the reformer and the SOFC. The heat energy recovery member is associated with the exhaust of the SOFC and recovers heat energy from the exhaust of the solid oxide fuel cell.

ABSTRACT

A burner system comprising a solid oxide fuel cell (SOFC), a partial reformer, an air preheater and a heat energy recovery member. The reformer is associated with the SOFC and partially reforms fuel prior to introduction into the SOFC. The preheater is associated with the SOFC and preheats air for introduction into the reformer and the SOFC. The heat energy recovery member is associated with the exhaust of the SOFC and recovers heat energy from the exhaust of the solid oxide fuel cell.

TITLE OF THE INVENTION

SOLID OXIDE FUEL CELL BURNER SYSTEM AND METHOD FOR GENERATING HEAT THEREFROM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates in general to solid oxide fuel cells (SOFC's), and more particularly to a partial combustion integrated SOFC for use as an electrochemical burner.

2. Background Art

SOFC's have the potential to convert any heating device using a gas burner into a cogeneration system. To do so, heating performance must be unaffected in the combined system. Accordingly, the SOFC must maintain the duty cycle of the replaced burner if the heating performance is to be maintained. In addition, to maintain thermal efficiency, deviation from the air, fuel and heating rates as well as combustion product temperatures should be minimized. Fuel cell efficiency is not important in such applications, as heat is the primary product, while electric power is a byproduct. Indeed, energy not converted to electricity will be delivered as heat. However, the additional cost of the fuel cell system must be offset by the value of the electric power produced within the thermal system duty cycle.

Many of the characteristics attributable to an electrochemical burner are substantially different from those of a fuel cell power plant. In particular, fuel cell power plant designs allow for much longer start up times, with few required thermal cycles and a near 100% duty cycle. As electric power is the only product, high electrical efficiency is a requirement to compete on the basis of cost of electricity. In particular, such high efficiency designs incorporate recuperative air preheaters and fuel processors which boost electrical efficiency. The preheaters include heat exchangers which, for example, utilize stack heat to reform the fuel and to heat the fluid to desired elevated temperatures. Components such as these heaters, however, add to the cost and complexity of the system. Additionally, these components add substantial thermal mass to the system which makes frequent or rapid thermal cycling impractical.

Additionally, exhaust gas temperatures are much too low to enable efficient recovery of waste heat in a conventional heating system. An additional contributing factor which impedes the recovery of waste heat is the amount of excess air required to control temperature gradients in the fuel cell stacks. Conventional burners generally operate with an air to fuel ration near stoichiometric, while a fuel cell may require air flows of 5 or more times greater than stoichiometric.

SUMMARY OF THE INVENTION

The invention comprises a burner system which includes a SOFC, a means for partially reforming a fuel, means for preheating air, and means for recovering heat energy. The reforming means partially reforms a fuel prior to introduction of the fuel into the SOFC. The preheating means preheats the air prior to the introduction of air into the SOFC. The heat energy recovery means recovers energy from the exhaust of the SOFC. In such an embodiment, the partial reforming means sufficiently heats the fuel so as to eliminate the need for any fuel preheaters which are detrimental to the overall efficiency of the system.

In a preferred embodiment, the SOFC comprises a low temperature fuel cell stack or a monolithic cell, and the reforming means may comprise a POX reformer.

In another preferred embodiment, the air preheating means comprises means for providing a predetermined quantity of fuel to the preheating means. In such a preferred embodiment, the providing means directs between approximately 23% and 30% of the fuel supplied in the burner system to the preheating means.

It is also contemplated that the heat energy recovery means comprises at least one combustor, and, the air preheating means comprises an off-stoichiometric (fuel lean) combustor. Furthermore, the reforming means may include means for accepting a predetermined quantity of air exiting the air preheating means.

The invention further comprises a method for generating heat. The method comprises the steps of: preheating a predetermined quantity of air in the air preheater; reforming at least a portion of the fuel stream in the reformer; passing at least a portion of the fuel stream and the air through a SOFC; and combusting at least a portion of the exhaust of the SOFC.

In a preferred embodiment of the method, the step of preheating further includes the steps of: diverting a predetermined quantity of fuel to the preheater; and combusting the fuel in the preheater, to, in turn, preheat a predetermined quantity of air. In such a preferred embodiment, the step of combusting the fuel further comprises the step of combusting the fuel in an off-stoichiometric burner.

In another preferred embodiment, the step of reforming the fuel stream comprises the step of directing a predetermined quantity of preheated air from the preheater to the reformer.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 of the drawings is a schematic diagram showing the improved equipment configuration of the invention; and

Fig. 2 of the drawings is a graph showing the fuel fraction in the preheat burner in mol/mol against the preheat temperature change in degrees Kelvin.

DETAILED DESCRIPTION OF THE DRAWINGS

While this invention is susceptible of embodiment in many different forms, there is shown herein in the drawings and will be described in detail several specific embodiments, with the understanding that the present disclosure is to be considered as an exemplification of the principles of the invention and is not intended to limit the invention to the embodiments illustrated.

Burner system 10 is shown in Fig. 1 as comprising solid oxide fuel cell (SOFC) 15, means 20 for partially reforming fuel, means 25 for preheating air, and means 30 for recovering heat energy. As will be explained, SOFC 15 combines air from the preheating means and fuel from the reforming means to generate electricity and heat, and, subsequently exhausts the products to recovery means 30 which further captures some of the heat energy in the exhaust.

SOFC 15 is shown in Fig. 1 as comprising fuel inlet 32, air inlet 34, anode exhaust 36 and cathode exhaust 38. SOFC 15 may comprise any number of different SOFC constructions, including, but not limited to monolithic designs and low temperature stacks.

Partial reforming means 20 is shown in Fig. 1 as comprising POX reformer 40 having air inlet 51, fuel inlet 50 and exhaust 52. Fuel inlet 50 is associated with a fuel supply, and air inlet 51 is associated with exhaust 46 of preheat means 25. The POX reformer may comprise an off-stoichiometric (fuel rich) reformer, however other reformers are likewise contemplated. Use of such a partial reforming means to preheat the fuel eliminates the requirement for additional preheaters, which utilize, for example, steam to elevate the temperature of the fuel. In the present system, by utilizing the partial reforming means to heat the fuel, the additional costs and energy losses associated with the conventional heaters can be eliminated thereby improving overall performance and efficiency of the system.

Air preheat means 25 is shown in Fig. 1 as comprising air inlet 42, fuel inlet 44 and exhaust 46. Fuel inlet 44 is associated with the system fuel supply and air inlet 42 is associated with the system air supply. Air preheat means 25 may comprise an off-stoichiometric (fuel lean) combustor which increases the temperature of the air supply.

Heat recovery means 30, as shown in Fig. 1, comprises heating device combustion chamber 48. Heating device combustion chamber 48 includes cathode inlet 54 associated with cathode outlet 38 of SOFC 15, anode inlet 56 associated with anode outlet 36 of SOFC 15 and exhaust 58.

In operation, a fuel supply and an air supply are provided to burner system 10. In particular, the fuel supplied may comprise natural gas, such as methane (CH_4), although other fuels are likewise contemplated. In such an embodiment, the air supply comprises ambient air, however, for different fuels, different air mixtures may be required, having various constituents in various ratios.

The fuel supply is separated so that a predetermined portion is directed into air preheating means 25. The portion directed to the air preheating means will vary depending on the particular components and SOFC utilized. For a low temperature SOFC, approximately 23% to 30% of the fuel is directed to the air preheat means. As will be understood to those having ordinary skill in the art, higher preheat requirements may require approximately 35-40% or more of the fuel to be directed to the air preheat means.

As the fuel enters into air preheating means 25, it is mixed with air and partially combusted. Since the combustion is off-stoichiometric, the combustion reacts the fuel with only a portion of the air. Thus, air and the combustion exhaust gasses exit through exhaust 46 at a temperature greater than the air inlet temperature.

As the preheated air exits through exhaust 46, a portion of the air is directed into inlet 51 of POX reformer 40. The POX reformer accepts fuel from inlet 50 and the air from inlet 51 and partially reforms the fuel. The partially reformed fuel exits from POX reformer 40 through exhaust 52.

The fuel from exhaust 52 is directed into inlet 32 of SOFC 15. Similarly, the portion of the air from exhaust 46 of air preheat means 25 is then directed to inlet 34 of SOFC 15. Within the SOFC, the air and fuel react to generate electricity, as is known in the art. The exhaust from the cathode side of the SOFC is directed to cathode exhaust 38 and the exhaust from the anode side of the SOFC is directed to anode exhaust 36.

Next, the cathode exhaust is directed to inlet 54 of heating device combustion chamber 48, and, the anode exhaust is directed to inlet 56 of heating device combustion chamber 48. The two inlet streams further combust in chamber 48 and the remaining exhaust gasses exit through exhaust 58. Chamber 48 of heat recovery means 30 may comprise a substantially stoichiometric combustor.

In support of the above, analysis of one embodiment of the method was conducted. In such an embodiment, approximately 23% of the fuel was required for air preheat. In this analysis, a POX reformer having a phi of 4 (phi is the fuel/air equivalence ratio) and a preheat means having a phi of .21 were utilized. When such a POX reformer was used, it was observed that approximately 58% of the fuels stream 61 remained for reaction in SOFC 15. Utilization of the remaining fuel entering the SOFC was then limited to approximately 50%. Limitation of the fuel was carried out by the conventional technique of controlling stack current -- although other conventional limiting techniques can also be used. The remaining fuel resulted in an equivalent of 3.4 air stoichs relative to current. Stack heat is rejected by the mechanisms of partial internal reformation, conduction-radiation, and to the "excess air". In such an example, SOFC 15 operates in a temperature range from 600 °C to 800 °C so that it can take advantage of partial internal reformation as a part of the overall SOFC cooling strategy. In such an example, the gross electrical efficiency (neglecting fan and power conversion losses) is calculated to be approximately 20% for a cell operating with a voltage of 0.70V. Of course, other embodiments may have even lower utilization, where such applications have lower electrical and thermal requirements. Such lower utilization permits reduced SOFC sizes, and, in turn less expensive SOFC's.

The foregoing description and drawings merely explain and illustrate the invention and the invention is not limited thereto except insofar as the appended claims are so limited, as those skilled in the art who have the disclosure before them will be able to make modifications and variations therein without departing from the scope of the invention.

CLAIMS

What is claimed is:

1. A burner system comprising:

- a solid oxide fuel cell;
- means associated with the solid oxide fuel cell for partially reforming a fuel prior to introduction of the fuel into the solid oxide fuel cell;
- means associated with the solid oxide fuel cell for preheating air prior to introduction of the air into the solid oxide fuel cell; and
- means associated with the solid oxide fuel cell for recovering heat energy from the exhaust of the solid oxide fuel cell.

2. The burner system of claim 1 wherein the solid oxide fuel cell comprises a low temperature fuel cell stack.

3. The burner system of claim 1 wherein the solid oxide fuel cell comprises a monolithic cell.

4. The burner system of claim 1 wherein the partial reforming means comprises a POX reformer.

5. The burner system of claim 1 wherein the fuel comprises natural gas.

6. The burner system of claim 1 wherein the air preheating means includes means for providing a predetermined quantity of fuel to the preheating means.

7. The burner system of claim 6 wherein the providing means directs between approximately 23% and 30% of the fuel supplied in the burner system to the preheating means.

8. The burner system of claim 1 wherein the recovering means comprises at least one combustor.

9. The burner system of claim 1 wherein the air preheating means comprises an off-stoichiometric combustor.

10. The burner system of claim 1 wherein the recovery means comprises a substantially stoichiometric combustor.

11. The burner system of claim 1 wherein the reforming means includes means for accepting a predetermined quantity of air exiting the preheating means.

12. A method for generating heat comprising the steps of:
- preheating a predetermined quantity of air in a preheater;
- partially reforming a fuel stream in a reformer;
- passing at least a portion of the fuel stream and the air through a solid oxide fuel cell; and
- combusting at least a portion of the exhaust of the solid oxide fuel cell.

13. The method according to claim 12 wherein the step of preheating comprises the steps of
- diverting a predetermined quantity of fuel to the preheater; and
- combusting the fuel in the preheater, to in turn, preheat a predetermined quantity of air.

14. The method according to claim 13 wherein the step of combusting the fuel comprises the step of combusting the fuel in an off-stoichiometric burner.

15. The method according to claim 12 wherein the step of reforming at least a portion of a fuel stream comprises the step of:
- directing a predetermined quantity of preheated air from the preheater to the reformer.

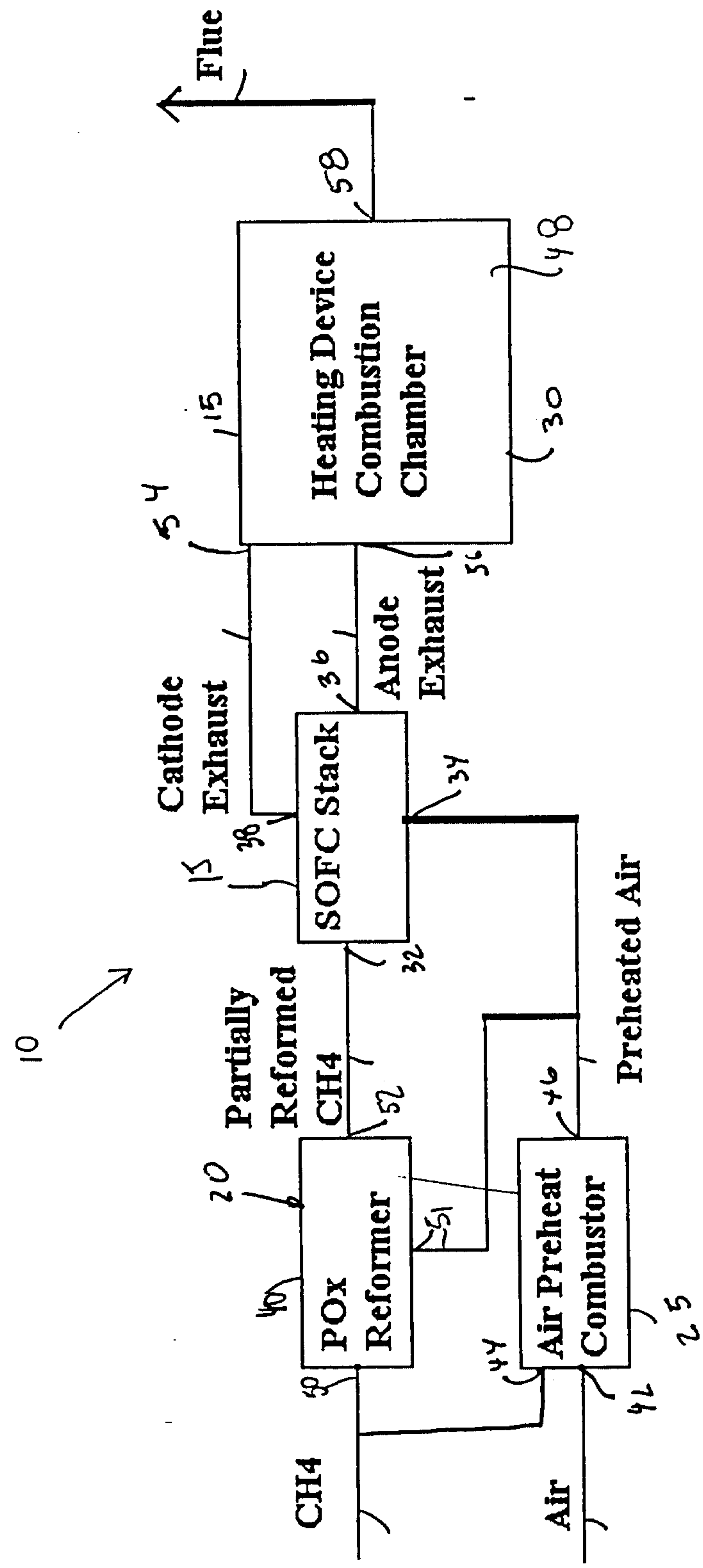

Flue
Heating Device
Combustion
Chamber
Cathode
Exhaust
Anode
Exhaust
SOFC Stack
Preheated Air
Partially
Reformed
CH4
POx
Reformer
Air Preheat
Combustor
CH4
Air
10
15
20
25
30
32
34
36
38
40
42
44
46
48
50
51
52
54
56
58

Fig. 1

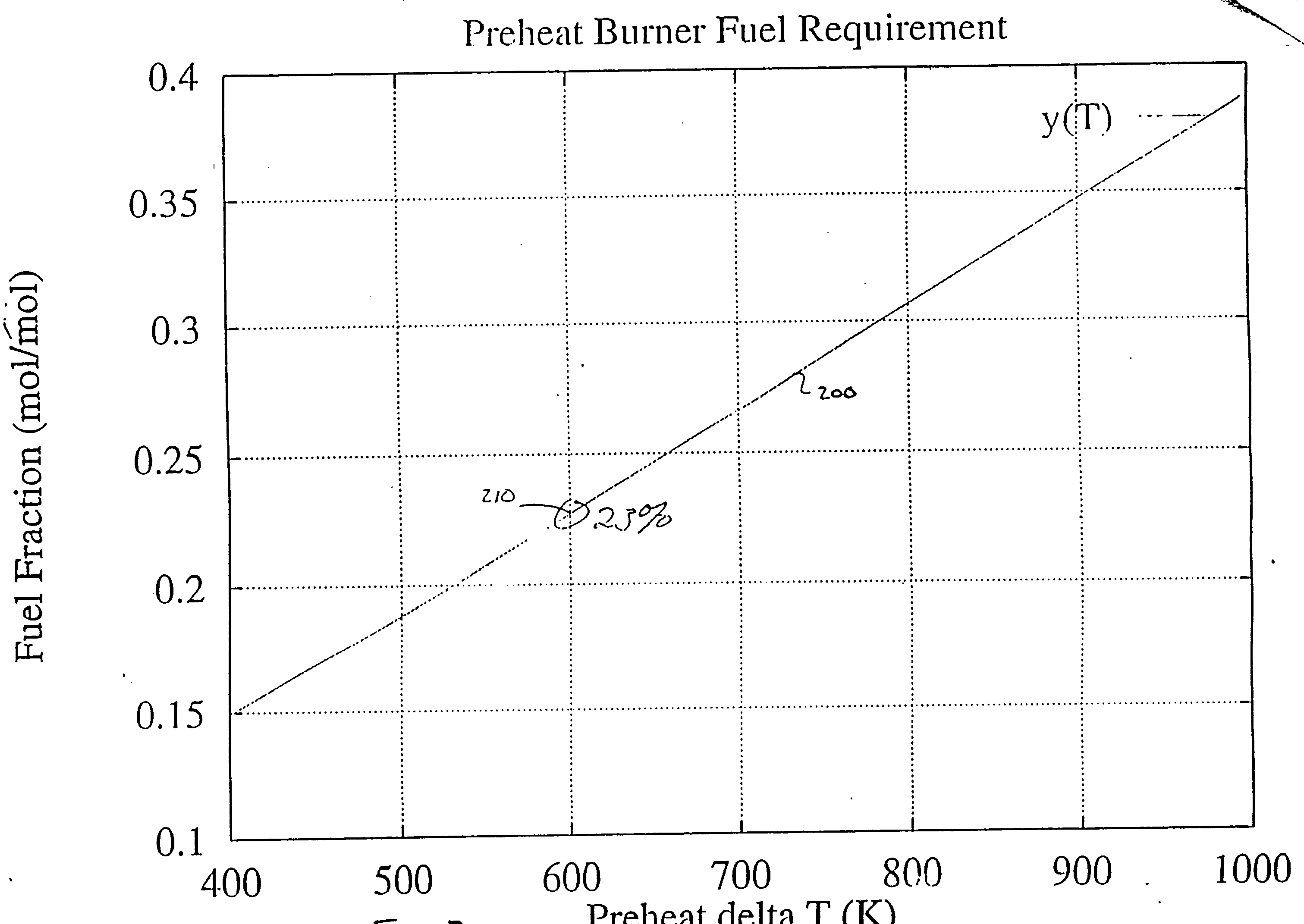
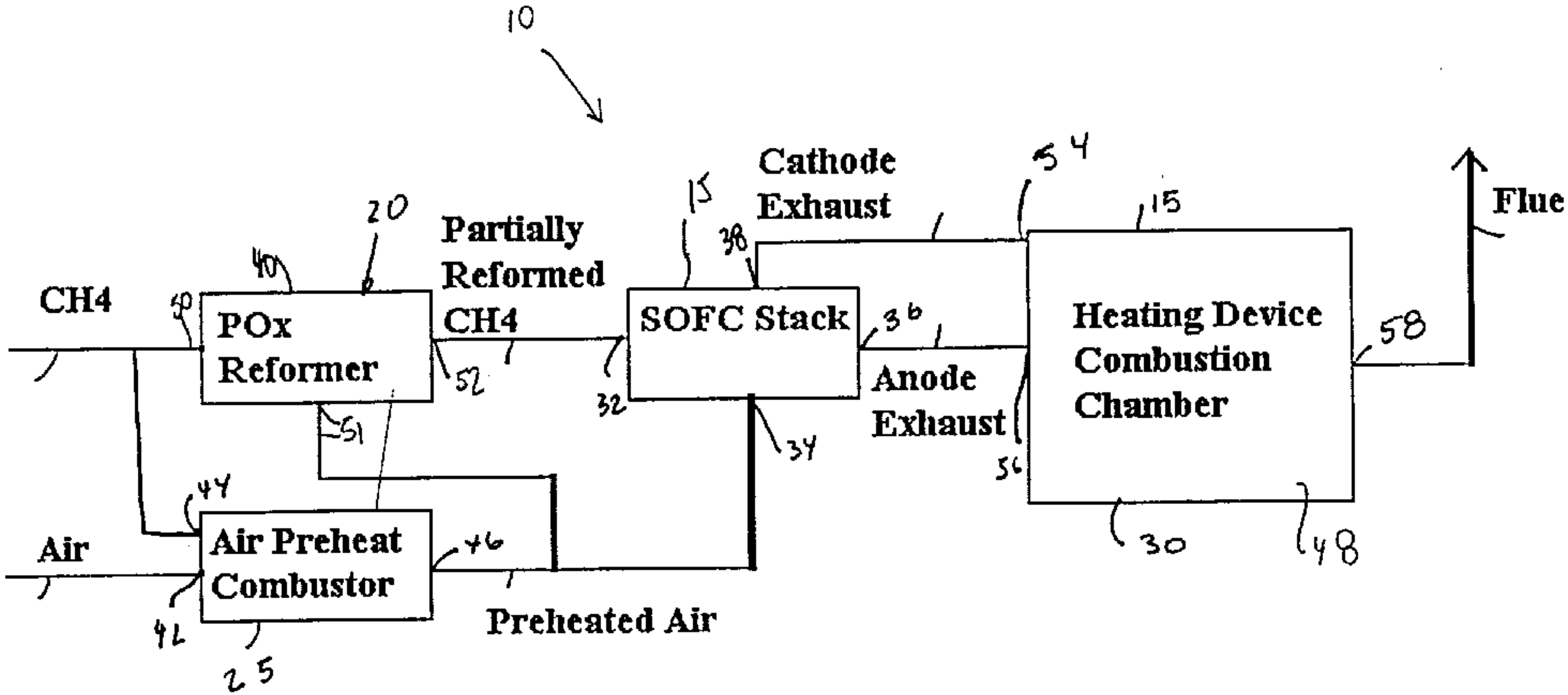

Preheat Burner Fuel Requirement
Fuel Fraction (mol/mol)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
400
500
600
700
800
900
1000
Preheat delta T (K)
y(T)
200
210
25%

FIG. 2


10
CH4
POx
Reformer
20
40
50
Partially
Reformed
CH4
52
51
SOFC Stack
15
38
36
32
34
Cathode
Exhaust
54
Anode
Exhaust
56
Heating Device
Combustion
Chamber
15
58
30
48
Flue
Air
Air Preheat
Combustor
44
42
46
25
Preheated Air