

RADIANT BURNER FOR NOXIOUS GAS INCINERATION

FIELD OF THE INVENTION

The present invention relates to a radiant burner and method.

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BACKGROUND

Radiant burners are known and are typically used for treating an effluent gas stream from a manufacturing processing tool used in, for example, the semiconductor or flat panel display manufacturing industry. During such manufacturing, residual perfluorinated compounds (PFCs) and other compounds exist in the effluent gas stream pumped from the process tool. PFCs are difficult to remove from the effluent gas and their release into the environment is undesirable because they are known to have relatively high greenhouse activity.

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Known radiant burners use combustion to remove the PFCs and other compounds from the effluent gas stream. Typically, the effluent gas stream is a nitrogen stream containing PFCs and other compounds. A fuel gas is mixed with the effluent gas stream and that gas stream mixture is conveyed into a combustion chamber that is laterally surrounded by the exit surface of a foraminous gas burner. Fuel gas and air are simultaneously supplied to the foraminous burner to affect flameless combustion at the exit surface, with the amount of air passing through the foraminous burner being sufficient to consume not only the fuel gas supply to the burner, but also all the combustibles in the gas stream mixture injected into the combustion chamber.

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Although techniques exist for processing the effluent gas stream, they each have their own shortcomings. Accordingly, it is desired to provide an improved technique for processing an effluent gas stream.

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SUMMARY

According to a first aspect, there is provided a radiant burner for treating an effluent gas stream from a manufacturing process tool, the radiant burner comprising: a sintered metal fibre sleeve through which combustion materials
5 pass for combustion proximate to an inner combustion surface of the sintered metal fibre sleeve; and an insulating sleeve surrounding the sintered metal fibre sleeve and through which the combustion materials pass.

The first aspect recognizes that in order to improve the energy efficiency of the processing or abatement of the effluent stream, it may be desirable for the
10 radiant burner to be extinguished during periods of processing tool inactivity, which typically occurs during idle steps of the processing. However, the first aspect also recognizes that these idle steps may be frequent and of short duration, and that such rapid cycling can lead to premature failure of existing
15 radiant burner sleeves or liners due to cracking.

Accordingly, a radiant burner may be provided. The radiant burner may treat or abate an effluent gas stream emitted or exhausted from a manufacturing processing tool. The radiant burner may comprise a metal fibre sleeve which
20 may be sintered. The combustion materials may pass through the metal fibre sleeve in order to combust proximate or adjacent to an inner combustion surface of the metal fibre sleeve. The radiant burner may also comprise an insulating sleeve. The insulating sleeve may surround or at least partially encompass the metal fibre sleeve. The combustion materials may also pass
25 through the insulating sleeve to reach the metal fibre sleeve. In this way, a radiant burner is provided which does not crack due to rapid cycling caused by frequent idle steps during which the burner is extinguished. Also, by providing an insulating sleeve, the temperature within the radiant burner and the temperature of an outer surface of the radiant burner remain comparable
30 with existing ceramic burners. This enables the radiant burner to be substituted in place of existing ceramic burners as a line-replaceable unit

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which does not suffer from cracking during such frequent and short-duration periods of process tool inactivity.

In one embodiment, the sintered metal fibre sleeve has a porosity of 80-90%.

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In one embodiment, the sintered metal fibre sleeve has an air permeability of 150-300 cc/min/cm².

In one embodiment, the sintered metal fibre sleeve has a density of 690-1110 kg/m³.

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In one embodiment, the insulating sleeve is a ceramic fibre blanket.

In one embodiment, the insulating sleeve has a density of 100-150 Kg/m³.

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In one embodiment, the insulating sleeve has a density which provides a 40-60 Pa pressure drop as the combustion materials pass therethrough.

In one embodiment, the sintered metal fibre sleeve is retained concentrically within the insulating sleeve.

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In one embodiment, the radiant burner comprises a support operable to retain the sintered metal fibre sleeve and the insulating sleeve.

In one embodiment, the insulating sleeve is retained concentrically within the support.

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In one embodiment, the sintered metal fibre sleeve comprises a pleat extending circumferentially. Providing a pleat helps to accommodate changes in size of the sintered metal fibre sleeve at different temperatures.

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In one embodiment, the radiant burner comprises a temperature sensor thermally coupled with the sintered metal fibre sleeve and operable to provide an indication of a temperature of the sintered metal fibre sleeve. Accordingly, an indication of the temperature of the metal fibre sleeve may be provided in order that the operating temperature of the radiant burner can be established.

In one embodiment, the temperature sensor is thermally coupled with the sintered metal fibre sleeve on an outer surface. Accordingly, the temperature sensor may be provided outside of a combustion chamber defined by the metal fibre sleeve in order to protect the temperature sensor from materials within the combustion chamber.

In one embodiment, the radiant burner comprises a source operable to supply the combustion materials in one of a plurality of mix ratios selected in response to the temperature. Hence, the mix ratio of the combustion materials may be varied in response to the temperature in order to optimize the operating conditions and/or temperature of the radiant burner.

In one embodiment, the source is operable to supply the combustion materials in a substantially stoichiometric mix ratio when the temperature of the sintered metal fibre sleeve fails to exceed an operating temperature. Accordingly, a stoichiometric or fuel-rich mix ratio may be provided in order to improve the warm-up time of the radiant burner.

In one embodiment, the source is operable to supply the combustion materials in a substantially lean mix ratio when the temperature of the sintered metal fibre sleeve exceeds an operating temperature. Accordingly, once a suitable operating condition has been reached, the fuel content may be reduced.

According to a second aspect, there is provided a method of operating a radiant burner for treating an effluent gas stream from a manufacturing

process tool, the method comprising: determining a temperature of an outer surface of a sintered metal fibre sleeve of the radiant burner through which combustion materials pass for combustion proximate to an inner combustion surface of the sintered metal fibre sleeve; and supplying the combustion
5 materials in one of a plurality of mix ratios selected in response to the temperature.

In one embodiment, the supplying comprises supplying the combustion materials in a substantially stoichiometric mix ratio when the temperature of
10 the sintered metal fibre sleeve fails to exceed an operating temperature.

In one embodiment, the supplying comprises supplying the combustion materials in a substantially lean mix ratio when the temperature of the sintered metal fibre sleeve exceeds an operating temperature.

15 In one embodiment, the supplying comprises supplying the combustion materials in the substantially stoichiometric mix ratio for a selected time period.

20 In one embodiment, the supplying comprises supplying the combustion materials in the substantially lean mix ratio upon expiry of the selected time period.

In embodiments, the radiant burner comprises the features of the first aspect.
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Further particular and preferred aspects are set out in the accompanying independent and dependent claims. Features of the dependent claims may be combined with features of the independent claims as appropriate, and in combinations other than those explicitly set out in the claims.

30 Where an apparatus feature is described as being operable to provide a function, it will be appreciated that this includes an apparatus feature which

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provides that function or which is adapted or configured to provide that function.

BRIEF DESCRIPTION OF THE DRAWINGS

- 5 Embodiments of the present invention will now be described further, with reference to the accompanying drawings, in which:
Figure 1 illustrates a radiant burner according to one embodiment; and
Figure 2 illustrates in more detail the arrangement of the foraminous burner liner shown in Figure 1.

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DESCRIPTION OF THE EMBODIMENTS

- Before discussing the embodiments in any more detail, first an overview will be provided. Embodiments provide a radiant burner which is particularly suited to operate in a so-called “green mode”, where the burner is
15 extinguished during periods of processing tool inactivity (for example, during idle steps), these periods may be frequent and of short duration. The radiant burner liner has a sintered metal fibre sleeve which is surrounded by an insulating sleeve, which replaces a typical ceramic radiant burner liner. The combination of the sintered metal fibre sleeve and the insulating sleeve
20 provides a radiant burner which operates under almost identical conditions and with improved efficiency compared with existing radiant burners, but which is able to resist shocks due to thermal cycling. Also, in order to improve the warm-up time of the radiant burner from cold, the mix of the combustion materials may be adjusted to make the mixture rich before reverting to lean
25 conditions during normal operation.

Radiant Burner - General Configuration and Operation

- Figure 1 illustrates a radiant burner, generally 8, according to one embodiment. The radiant burner 8 treats an effluent gas stream pumped from
30 a manufacturing process tool such as a semiconductor or flat panel display process tool, typically by means of a vacuum-pumping system. The effluent stream is received at inlets 10. The effluent stream is conveyed from the inlet

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10 to a nozzle 12 which injects the effluent stream into a cylindrical combustion chamber 14. In this embodiment, the radiant burner 8 comprises four inlets 10 arranged circumferentially, each conveying an effluent gas stream pumped from a respective tool by a respective vacuum-pumping
5 system. Alternatively, the effluent stream from a single process tool may be split into a plurality of streams, each one of which is conveyed to a respective inlet. Each nozzle 12 is located within a respective bore 16 formed in a ceramic top plate 18 which defines an upper or inlet surface of the combustion chamber 14. The combustion chamber 14 has side walls defined by an exit
10 surface 21 of a foraminous burner element 20, which is illustrated schematically and shown in more detail in Figure 2. The burner element 20 is cylindrical and is retained within a cylindrical outer shell 24.

A plenum volume 22 is defined between an entry surface of the burner
15 element 20 and the cylindrical outer shell 24. A mixture of fuel gas, such as natural gas or a hydrocarbon, and air is introduced into the plenum volume 22 via inlet nozzles. The mixture of fuel gas and air passes from the entry surface 23 of the burner element to the exit surface 21 of the burner element for combustion within the combustion chamber 14.

20 The nominal ratio of the mixture of fuel gas and air is varied to vary the nominal temperature within the combustion chamber 14 to that which is appropriate for the effluent gas stream to be treated. Also, the rate at which the mixture of fuel gas and air is introduced into the plenum volume 22 is
25 adjusted so that the mixture will burn without visible flame at the exit surface 21 of the burner element 20. The exhaust 15 of the combustion chamber 40 is open to enable the combustion products to be output from the radiant burner 8.

30 Accordingly, it can be seen that the effluent gas received through the inlets 10 and provided by the nozzles 12 to the combustion chamber 14 is combusted within the combustion chamber 14 which is heated by a mixture of fuel gas

and air which combusts near the exit surface 21 of the burner element. Such combustion causes heating of the chamber 14 and provides combustion products, such as oxygen, typically with a nominal range of 7.5 % to 10.5 %, depending on the fuel air mixture (CH_4 , C_3H_8 , C_4H_{10}) and the surface firing rate of the burner, to the combustion chamber 14. The heat and combustion products react with the effluent gas stream within the combustion chamber 14 to clean the effluent gas stream. For example, SiH_4 and NH_3 may be provided within the effluent gas stream, which reacts with O_2 within the combustion chamber to generate SiO_2 , N_2 , H_2O , NO_x . Similarly, N_2 , CH_4 , C_2F_6 may be provided within the effluent gas stream, which reacts with O_2 within the combustion chamber to generate CO_2 , HF , H_2O .

Foraminous Burner Liner Arrangement

Turning now to the arrangement of the foraminous burner liner 20, its construction is shown in more detail in Figure 2. In this arrangement, the foraminous burner liner 20 is constructed by rolling and seam welding a sintered metal fibre sheet 100 to a perforated screen 110, retained between flanges 120A, 120B.

The sintered metal fibre sheet 100 may be any suitable sintered metal fibre, such as SFF1-35, or SFFE-30 supplied by the FiberTech Company of South Korea alternatively S-mat or D-mat supplied by Micron Fiber-Tech Company of USA. Typically, such sintered metal fibre has a porosity of between 80% and 90%, an air permeability of 150-300 cc/min/cm², and a sheet density of around 694 to 1111 kg/m³.

Referring now to Table 1, it has been found that a foraminous burner liner having the sintered metal fibre sheet welded to the perforated support 110 operates under identical conditions to existing ceramic foraminous burner liners. In this example, a 152.4 mm (6 inch) internal diameter by 304.8 mm (12 inch) axial length foraminous burner liner having the sintered metal fibre sheet (and another example with a ceramic fibre blanket mentioned below)

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with a surface area of 145,931 mm² (226 inch²) was fired using 36 slm of natural gas in 610 slm of air, which provided a surface burning rate of approximately 80 kW/m² (50,000 BTU/hr/ft²) and a residual oxygen concentration of 9% (as measured when no effluent stream is present).

- 5 Combustion emissions were measured in the presence of a simulated effluent stream of 200 l/min of nitrogen. As can be seen the combustion emissions (sintered metal fibre sheet/sintered metal fibre sheet + ceramic fibre blanket) when the effluent stream was then introduced are better than existing burners (ceramic).

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Species	Concentration (ppm)		
	ceramic	sintered metal fibre sheet	sintered metal fibre sheet + ceramic fibre blanket
CO	22	18	7
NO	3	3	3
NO ₂	2	1	1

Table 1

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However, the warm-up time from cold for such an arrangement can be approximately 15 minutes. This can be shortened to less than 10 seconds by lighting off under stoichiometric conditions, before reverting to lean conditions after a short period such as, for example, 10 seconds.

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In addition, the steady state temperature of the outer face 105 of the sintered metal fibre sheet 100 is higher than that of a ceramic foraminous burner liner (at 120-140 °C compared to less than 50 °C). This temperature climbs much more slowly than the combustion chamber 14 and so whilst it may not be possible to use this parameter to directly control the rich start, the outer face 105 temperature may be used beneficially to inhibit the rich start function.

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Constructing a three component structure, comprising a mechanical outer support such as, for example, the perforated screen 100 and the flanges 120A, 120B, a gas permeable ceramic fibre blanket 130 and the sintered metal fibre sheet 100, results in improved performance, as shown in Tables 2 and 3. In this example, a 152.4 mm (6 inch) internal diameter by 152.4 mm (6 inch) axial length foraminous burner liner having the sintered metal fibre sheet welded to the perforated support (and another example with the ceramic fibre blanket) having a surface area of 72,965 mm² (113 inch²) was fired using 19 slm of natural gas in 310 slm of air, which provided a residual oxygen concentration of 9% (as measured when no effluent stream is present). Nitrogen trifluoride abatement was measured as part of a simulated effluent stream with 200 l/min of nitrogen. As can be seen the combustion emissions (bare metal/insulated metal) when the effluent stream was then introduced are better than existing burners (ceramic).

NF3 in (SLM)	NF3 out (ppm)		
	ceramic	sintered metal fibre sheet + perforated support	sintered metal fibre sheet + perforated support + ceramic fibre blanket
0.25	69	57	38
0.5	108	96	59
0.75	158	173	91
1.00	183	208	110
1.25	219	202	116
1.50	215	192	126
1.75	201	205	121
2.00	219	275	122

Table 2

NF3 in (SLM)	NF3 destruction efficiency (%)		
	ceramic	sintered metal fibre sheet + perforated support	sintered metal fibre sheet + perforated support + ceramic fibre blanket
0.25	86.3	88.7	92.4
0.5	89.3	90.4	94.1
0.75	89.4	88.5	94.0
1.00	90.9	89.6	94.5
1.25	91.2	91.9	95.4
1.50	92.8	93.6	95.8
1.75	94.2	94.1	96.5
2.00	94.5	93.1	96.9

Table 3

The ceramic fibre blanket 130 is chosen so as to have a minimal pressure drop at the surface flow rates equivalent to the surface firing rates mentioned above. Typically somewhere between 6 and 12 mm, and preferably 10 mm, of commercially available blanket material such as Isofrax 1260 (calcium silicate) of 128 kg/m³ density or Saffil (alumina) have acceptable performance, in the range of 40-60 Pa pressure drop at 0.1 m/s face velocity with a linear pressure-flow relationship. Both of these materials are available from Unifrax Limited.

As shown in Figure 2, a thermocouple 140 is provided which thermally couples with the outer surface 105 of the sintered metal fibre sheet 100. The thermocouple 140 or other temperature sensor measures the temperature of the sintered metal fibre sheet 100. When the thermocouple 140 indicates that the temperature of the sintered metal fibre sheet 100 is below a threshold value (which indicates that the operating temperature of the combustion

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chamber 14 is lower than the operating temperature), the ratio of fuel to air is increased. The ratio of fuel to air is decreased when the temperature reported by the thermocouple 140 exceeds the threshold value, which indicates that the operating temperature of the combustion chamber 14 exceeds the
5 operating temperature.

It will be appreciated that whilst in this embodiment a perforated screen 110 and metal flanges 120A, 120B are used to provide mechanical support, other arrangements for retaining the sintered metal fibre sheet 100 and the ceramic
10 fibre blanket 130 may be provided.

Although not illustrated in Figure 2, a circumferential pleat may be provided within the sintered metal fibre sheet 100 to accommodate changes in the length of the sintered metal fibre sheet 100 at different temperatures.
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Although illustrative embodiments of the invention have been disclosed in detail herein, with reference to the accompanying drawings, it is understood that the invention is not limited to the precise embodiment and that various changes and modifications can be effected therein by one skilled in the art
20 without departing from the scope of the invention as defined by the appended claims and their equivalents.

List of Reference Signs

	8	radiant burner
	10	inlets
5	12	nozzle
	14	combustion chamber
	15	exhaust
	16	bore
	18	ceramic top plate
10	20	foraminous burner element
	21	exit surface
	22	plenum volume
	23	entry surface
	24	outer shell
15	100	sintered metal fibre sheet
	105	outer face
	110	perforated screen
	120A, 120B	flanges
	130	ceramic fibre blanket
20	140	thermocouple

CLAIMS

1. A radiant burner for treating an effluent gas stream from a manufacturing process tool, said radiant burner comprising:
5 a sintered metal fibre sleeve through which combustion materials pass for combustion proximate to an inner combustion surface of said sintered metal fibre sleeve; and
10 an insulating sleeve surrounding said sintered metal fibre sleeve and through which said combustion materials pass.
2. The radiant burner of claim 1, wherein said sintered metal fibre sleeve has at least one of a porosity of 80-90%, an air permeability of 150-300
15 cc/min/cm² and a density of 690-1110 kg/m³.
3. The radiant burner of claim 1 or 2, wherein said insulating sleeve is a ceramic fibre blanket.
- 20 4. The radiant burner of any preceding claim, wherein said insulating sleeve has at least one of a density of 100-150 Kg/m³ and a density which provides a 40-60 Pa pressure drop as said combustion materials pass therethrough.
- 25 5. The radiant burner of any preceding claim, wherein said sintered metal fibre sleeve is retained concentrically within said insulating sleeve.
6. The radiant burner of any preceding claim, comprising a support operable to retain said sintered metal fibre sleeve and said insulating
30 sleeve.

7. The radiant burner of any preceding claim, wherein said insulating sleeve is retained concentrically within said support.
8. The radiant burner of any preceding claim, wherein said sintered metal fibre sleeve comprises a pleat extending circumferentially.
9. The radiant burner of any preceding claim, comprising a temperature sensor thermally coupled with said sintered metal fibre sleeve and operable to provide an indication of a temperature of said sintered metal fibre sleeve.
10. The radiant burner of any preceding claim, wherein said temperature sensor is thermally coupled with said sintered metal fibre sleeve on an outer surface.
11. The radiant burner of claim 10, comprising a source operable to supply said combustion materials in one of a plurality of mix ratios selected in response to said temperature.
12. The radiant burner of claim 11, wherein said source is operable to supply said combustion materials in a substantially stoichiometric mix ratio when said temperature of said sintered metal fibre sleeve fails to exceed an operating temperature.
13. The radiant burner of claim 11 or 12, wherein said source is operable to supply said combustion materials in a substantially lean mix ratio when said temperature of said sintered metal fibre sleeve exceeds an operating temperature.
14. A method of operating a radiant burner for treating an effluent gas stream from a manufacturing process tool, said method comprising:

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determining a temperature of an outer surface of a sintered metal fibre sleeve of said radiant burner through which combustion materials pass for combustion proximate to an inner combustion surface of said sintered metal fibre sleeve; and

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supplying said combustion materials in one of a plurality of mix ratios selected in response to said temperature.

10 15. The method of claim 14, wherein said supplying comprises supplying said combustion materials in a substantially stoichiometric mix ratio when said temperature of said sintered metal fibre sleeve fails to exceed an operating temperature.

15 16. The method of claim 14 or 15, wherein said supplying comprises supplying said combustion materials in a substantially lean mix ratio when said temperature of said sintered metal fibre sleeve exceeds an operating temperature.

20 17. The method of any one of claims 14 to 16, wherein said supplying comprises supplying said combustion materials in said substantially stoichiometric mix ratio for a selected time period.

25 18. The method of any one of claims 14 to 17, wherein said supplying comprises supplying said combustion materials in said substantially lean mix ratio upon expiry of said selected time period.

19. A radiant burner as hereinbefore described with reference to the accompanying drawings.

30 20. A method as hereinbefore described with reference to the accompanying drawings.