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(54) Method for the combustion of fuel by stepped fuel feed and burner for use with it.

(57) To lower NO_x production in a stepped fuel feed combustion method, secondary fuel (15) is injected into a combustion chamber as a jet through an internal recirculation zone of the primary combustion zone (6) to a secondary combustion zone (8). The stoichiometry of the system up to and including the secondary combustion zone is preferably 0.70 to 0.90. A burner adapted for such a method is also disclosed, which has a duct for secondary fuel (15) concentrically within an inner annular duct (13) for primary fuel and an outer annular duct (14) for primary air.

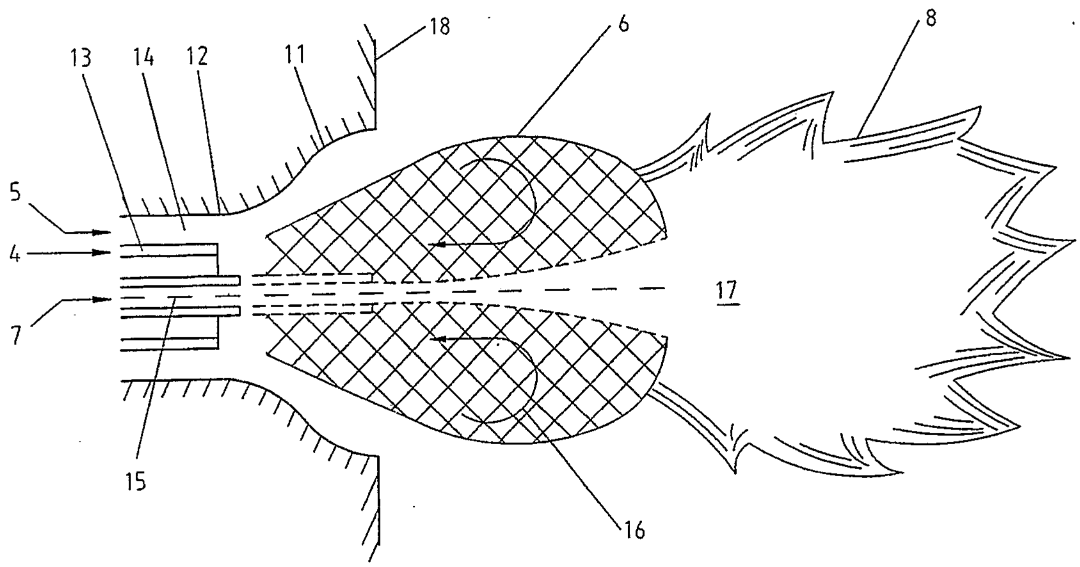

FIG. 3

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METHOD FOR THE COMBUSTION OF FUEL BY STEPPED FUEL FEED AND BURNER FOR USE WITH IT

The invention relates to a method for the combustion of fuel with a low NO_x content in the combustion gases by means of stepped fuel feed.

Stepped fuel feed is a known type of operation which uses at least one burner of a type comprising a duct (hereinafter a quarl) widening out to a combustion chamber, near the throat of which two concentric annular ducts open out, through the inner of which a first part of the fuel (hereinafter primary fuel) is fed, and through the outer of which swirling combustion air is fed. The primary fuel and the combustion air is allowed to combust in the combustion chamber in a primary combustion zone, whereby an internal recirculation zone (IRZ) is formed. A second part of the fuel (hereinafter secondary fuel) is fed to the combustion chamber near the primary combustion zone, and the secondary fuel is allowed to combust under sub-stoichiometric conditions in a secondary combustion zone downstream from the primary combustion zone, whereby the NO_x formed in the primary combustion zone is reduced, at least in part. Finally, tertiary combustion air is fed in near the secondary combustion zone, whereby the residual fuel is allowed to burn out in the product of combustion formed in the secondary combustion zone in a burn-out zone downstream from the secondary combustion zone. At the same time the invention relates to a burner to be used with the method.

This type of burner is known in current practice as a 'swirl stabilized burner'. A characteristic of such a burner is that during operation the internal recirculation zone is set up, in which the products of combustion of the primary combustion zone are recirculated.

K. Leikert, K.D. Rennert and W. Schreiber in "Test data of a multiple staged-mixing burner using fuel staging" published in the proceedings of the IFRF 8th Members Conference, Noordwijkerhout May 28-30, 1986 disclosed how the secondary fuel may be fed by means of a number of passages through the wall of the combustion chamber.

Leikert and Rennart, with G. Buttner, are named as inventors of GB-A-2146113, wherein there is disclosed the concentric introduction through annular ducts of, successively from the centre, primary fuel, primary air, secondary fuel and tertiary air. The central void inside the innermost annulus (i.e. inside the primary fuel duct) is in communication with a zone described as a return flow zone.

R. Waibel and D. Nickeson in "Staged fuel burners for NO_x control" also published in the above mentioned proceedings, show how the secondary fuel may be fed into each burner and that feed be integrated into the burner design. However, the fuel feed takes place outside the feed of the combustion air, the primary fuel being fed into the throat with the aid of a distribution head arranged as an annulus at the combustion chamber. Within the scope of the present application such an arrangement is deemed to be identical to fuel feed by means of the inner annulus.

In US-A-4265615 there is disclosed a can-type combustor divided by a restriction into a primary and secondary zone. In this burner construction primary fuel is injected from an annular duct with annular air inlets both radially inside and outside it. Secondary fuel is injected from a central duct, and is intended to pass through the primary zone to the secondary zone where it will be ignited by tertiary air fed into that zone. All the fuel flows and air flows through the burner are swirled and directed so as to maintain the primary and secondary fuels separate in the primary zone.

An inconvenience of the known methods and constructions is that the mixture of the secondary fuel and the products of combustion from the primary combustion zone is poor, whereby results are difficult to optimise.

The burner construction and method of the invention is differentiated from GB-A-2146113 (which because of its constructional and operational similarities is regarded as the closest prior art) by the fact that the secondary fuel is fed through at least one duct concentric with or almost concentric with the two annuli, through which duct the secondary fuel is injected into the combustion chamber. This has various advantages. There is no need for extra passages through the wall of the combustion chamber for feeding the secondary fuel. The manner of feeding the secondary fuel makes for a particularly simple and compact design of the burner. Further the secondary fuel may be fed at a lower speed at a distance from the wall of the combustion chamber. This means that less high temperature corrosion occurs in the steel pipes in that wall. Also it restricts deposition of thick slag on the wall of the combustion chamber more to its burner part than with the state of the art.

The secondary fuel is injected into the combustion chamber at such a speed that the fuel penetrates as a jet through the internal recirculation zone to the downstream end of the internal recirculation zone, and there mixes with the products of combustion of the primary combustion zone. Preferably the secondary fuel is fed to the combustion chamber at a speed of at least 30 m/sec. This further optimises the method in accordance with the invention. The secondary fuel is then preferably between 10 and 30% of the fuel and the stoichiometry in the secondary combustion zone is between 0.60 and 1.0, and more preferably between 0.70 and 0.90.

In another aspect the invention is also embodied in a burner of a type comprising a quarl widening out to a combustion chamber and a pair of concentric annular ducts opening out near the throat of the quarl, the inner annulus being intended for feeding fuel, and the outer annulus being intended for feeding combustion air and being provided with means of setting the combustion air swirling. As stated above, in current practice such a burner is known as a 'swirl stabilized burner'. In accordance with the invention the burner is provided with at least one duct concentric with or almost concentric with the two annuli intended for feeding secondary fuel during operation. Further optimization of the method in accordance with the invention is achieved in that the duct concentric with the two annuli opens out within the burner at a position lying from near the throat of the quarl to the end of the quarl flush in operation with the inner wall of a combustion chamber.

Embodiments of the invention will be illustrated by reference to the drawings wherein:

Fig. 1 shows fuel staged burning for a prior art stove;

Fig. 2 shows a prior art burner;

Fig. 3 shows fuel staged burning embodying the invention;

Fig. 4 shows results obtained from the invention.

Fig. 1 and Fig. 2 show fuel staged burning in accordance with the prior art, a burner 2 in the wall 3 of the stove. Primary fuel 4 and combustion air 5 are fed and combusted in a primary combustion zone 6. This combustion gives off NO_x.

At the same time a secondary fuel 7 is fed and, after mixing in the products of combustion from the primary combustion zone, is combusted under substoichiometric conditioning in a secondary combustion zone reburn zone 8. This reduces, at least partially, the NO_x formed in the primary combustion zone. In principle this reduction takes place in accordance with the equation:

$2\,NO + CH \text{ -----> } N_2 + CO + OH$

The products of combustion from the secondary combustion zone contain still combustible constituents. These are burned out in a burnout zone 10 by tertiary air 9.

The burner used with this known method is often a swirl stabilized burner, whereby (see Fig. 2) two concentric annular ducts (annuli) 13 and 14 for feeding the first part of the fuel (primary fuel) 4 and the combustion air 5 open out into the throat 12 of a quarl 11. The combustion air is fed by swirling (not shown). With this type of burner, an internal recirculation 16 takes place in the primary combustion zone 6.

An embodiment of the invention is shown in Fig. 3. Here the secondary fuel 7 is fed through a duct 15 concentric with, or nearly so, and within the ducts 13 and 14. This fuel is fed at such a speed that a jet penetrates the internal recirculation zone 16 and mixes, particularly at its downstream end 17, with the products of combustion from the primary combustion zone, whereupon combustion takes place in the secondary combustion zone 8. As indicated by a broken line in Fig. 3, the duct 15 may open out into the burner at any position in a range bordered by the throat 12 and by the inner wall 18 of the combustion chamber.

The invention may be used for all kinds of fuel such as pulverized coal, oil, residues and gas.

The results of this operation in terms of NO_x content in the exhaust gases depend, among other things, on the type of fuel and the position of feeding the tertiary combustion air. However, it has been found that the effect of the stoichiometry and the quantity of secondary fuel, under otherwise identical conditions, is determined by a parameter, namely the stoichiometry in the secondary combustion zone (by which is to be understood the stoichiometry of all fuel and air fed up to and including the secondary combustion zone).

Fig. 4 shows a characteristic of the invention established on this basis. The stoichiometry in the secondary combustion zone is preferably between 0.70 and 0.90. The quantity of secondary fuel used in preferably as small as possible, yet for practical reasons remains in the range 10 to 30%.

Claims

1. A method for stepped fuel feed combustion in a combustion chamber for reduced NO_x content including feeding primary fuel (4) and air (5) into the chamber from respectively inner (13) and outer (14) concentric annular ducts of a burner to combust in the chamber in a primary combustion zone (6), secondary fuel (15) being added to complete combustion of combustion products from the primary zone (6) with further air in the same chamber under substoichiometric conditions in a secondary combustion zone (8)

   characterised in that the primary fuel (4) and air (5) are fed through a divergent throat (12) of a quarl (11) and in that the secondary fuel is fed to the chamber from a duct (7) within the inner (4) of the annular ducts (4,5) to penetrate as a jet through the primary combustion zone (6) to the secondary combustion zone (8).

2. Method according to Claim 1, wherein the secondary fuel is fed to the combustion chamber at a speed of at least 30 m/sec.

3. Method according to Claim 1 or Claim 2, wherein the secondary fuel is between 10 and 30% of the total fuel.

4. Method according to any one of Claims 1 to 3, wherein the stoichiometry in the secondary combustion zone is between 0.6 and 1.0.

5. Method according to Claim 4 wherein the stoichiometry is between 0.7 and 0.9.

6. A stepped fuel feed combustion method using at least one burner comprising a quarl opening out to a combustion chamber near the throat of which quarl two concentric annular ducts open out, comprising feeding primary fuel through the inner of said concentric annular ducts and feeding primary air through the outer of said concentric annular ducts while imposing a swirl upon said air, combusting said primary fuel and primary air in said combustion chamber in a primary combustion zone in which an internal recirculation zone is formed, and injecting secondary fuel into the combustion chamber from a duct radially inside of said inner concentric annular duct such as to penetrate through said internal recirculation zone as a jet and to combust with products of combustion from the primary combustion zone under sub-stoichiometric conditions in a secondary combustion zone downstream of said primary zone, and burning out any residual fuel of the primary and secondary fuel by feeding further air.

7. Burner for use with the method in accordance with andy one of Claims 1 to 6 comprising a quarl (11) widening out (12) to a combustion chamber and a pair of concentric annular ducts (13,14) opening out near the throat of the quarl (11), the inner (13) being intended for feeding fuel, and the outer (14) being intended for feeding primary combustion air and being provided with means of setting the combustion air swirling, the burner being provided with at least one duct (15) within and concentric with or almost concentric with the two annuli and intended for feeding secondary fuel during operation.

8. Burner according to Claim 7, wherein the innermost duct (15) opens out within the burner in a position which lies between the throat (12) of the widening duct (11) to the end of the widening duct flush during operation with the inner wall (18) of the combustion chamber.

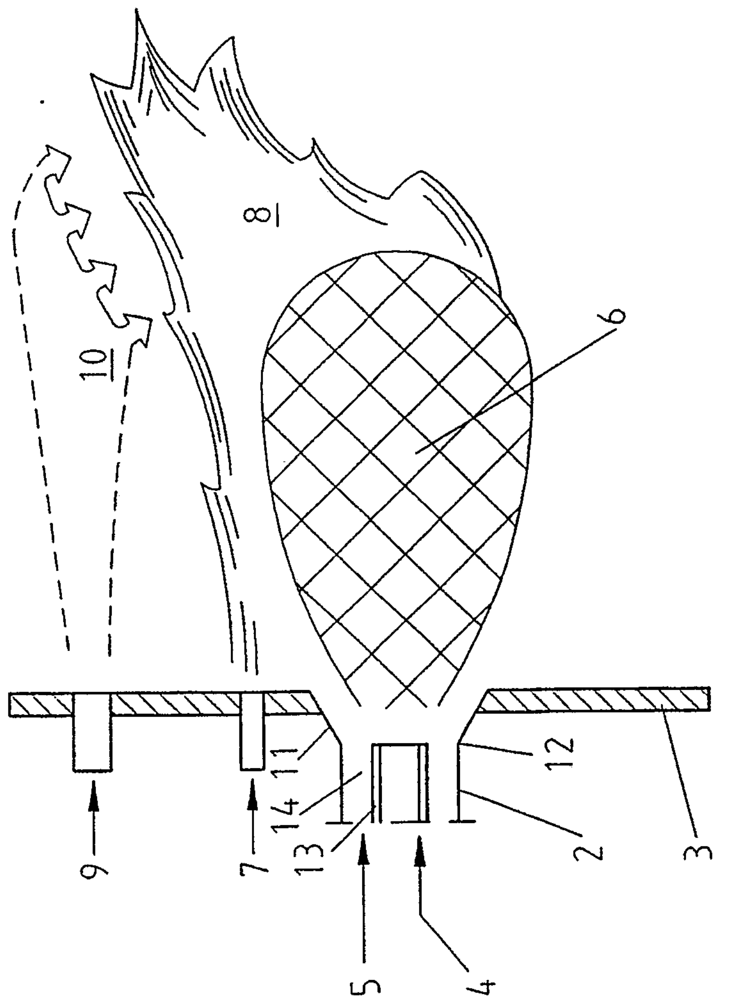

FIG. 2

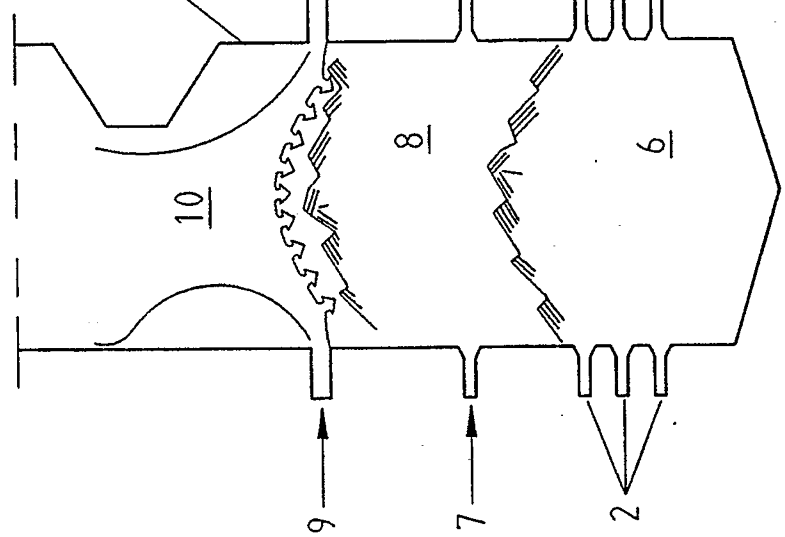

FIG. 1

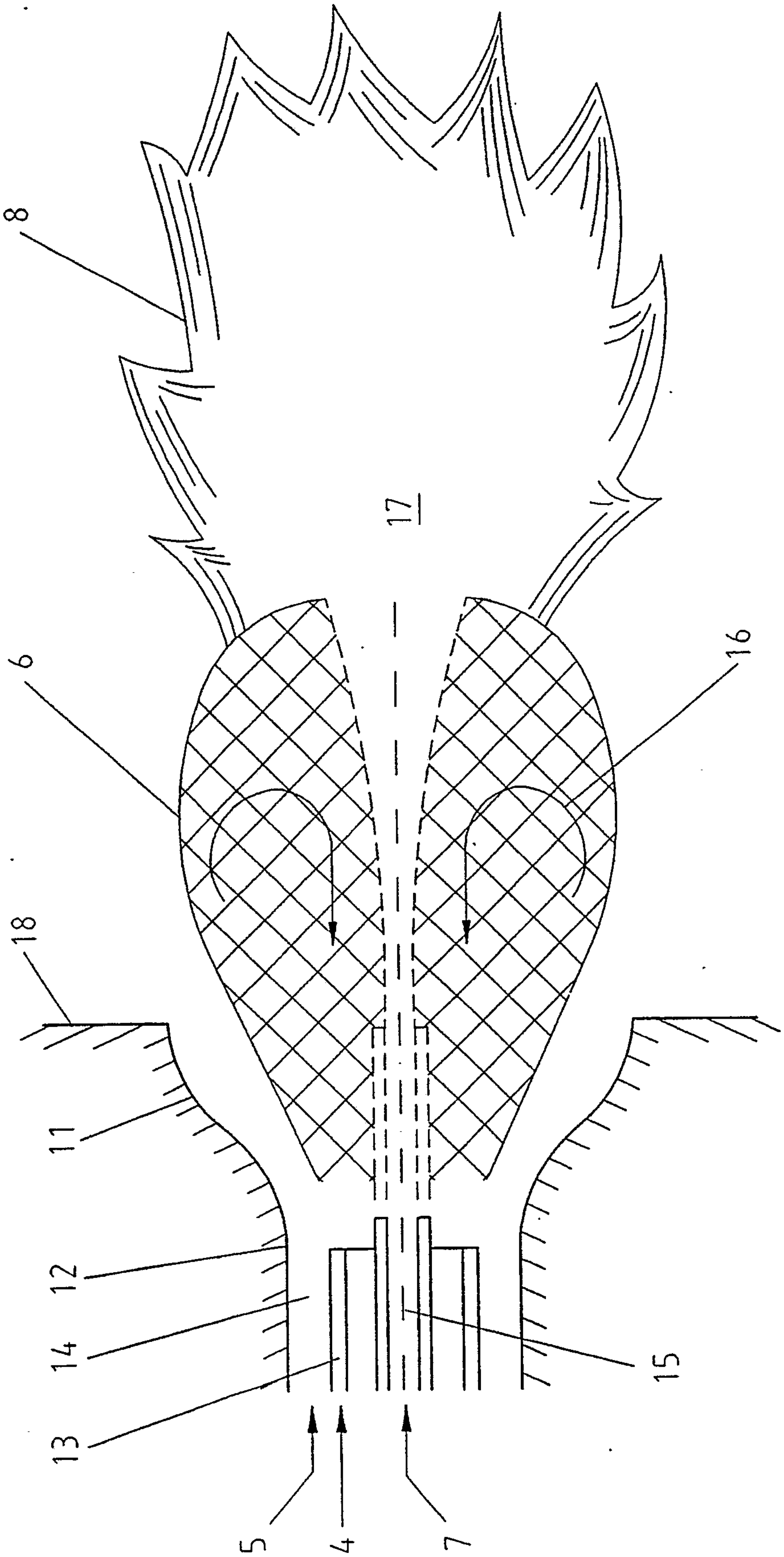

FIG. 3

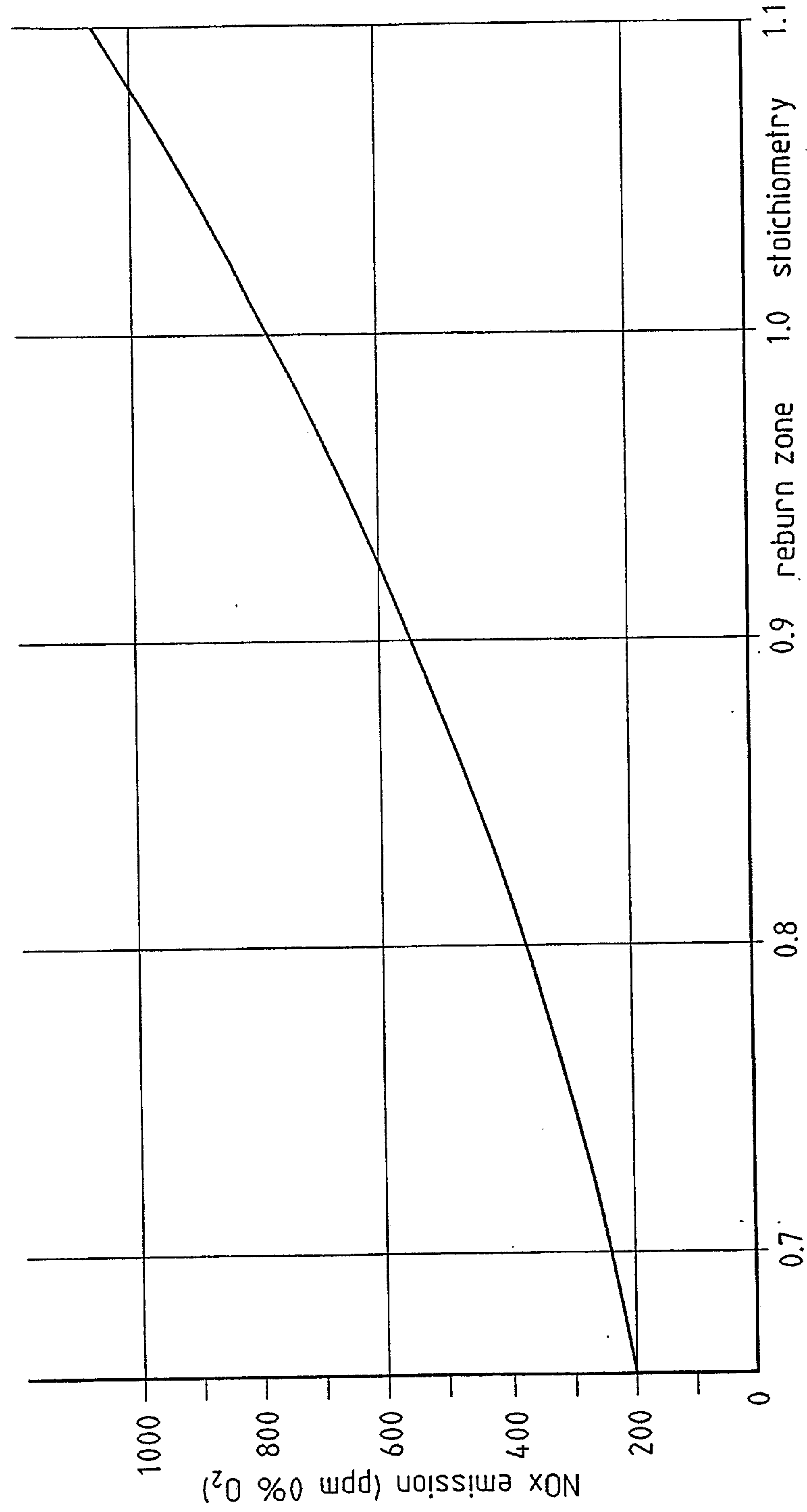
NOx emission (ppm 0% O_2)
1000
800
600
400
200
0
0.7
0.8
0.9
1.0
1.1
reburn zone stoichiometry

FIG. 4