

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
21 December 2000 (21.12.2000)

PCT

(10) International Publication Number
WO 00/77450 A1

(51) International Patent Classification⁷: F23D 14/12,
F24C 15/24, C03C 13/00

(21) International Application Number: PCT/GB00/02075

(22) International Filing Date: 30 May 2000 (30.05.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
9913681.4 11 June 1999 (11.06.1999) GB

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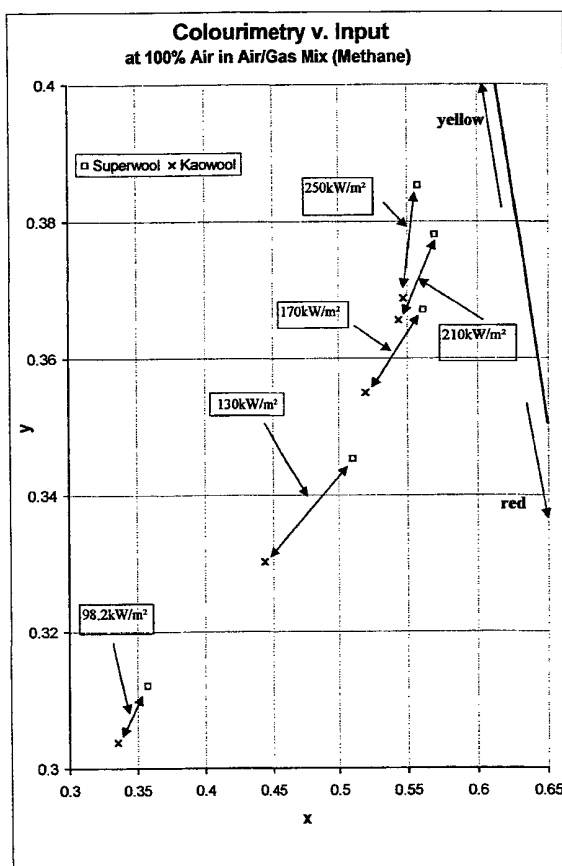
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(81) Designated States (national): AE, AG, AL, AM, AT, AU,
AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE,
DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU,
ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS,
LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO,
NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR,
TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States (regional): ARIPO patent (GH, GM,
KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian
patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European
patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE,

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(54) Title: SURFACE COMBUSTION RADIANT HEATERS AND HEATING PLAQUES



(57) Abstract: A surface combustion radiant heating plaque is described formed from an inorganic bonded fibrous material, in which the material comprises fibres which are alkaline earth silicate fibres. Such a plaque has a higher luminance and stronger colour than conventional plaques with broadly similar combustion properties.

WO 00/77450 A1



IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Published:

— *With international search report.*

SURFACE COMBUSTION RADIANT HEATERS AND HEATING PLAQUES

This invention relates to surface combustion radiant heaters and heating plaques.

Surface combustion radiant heaters comprise a plaque mounted on a burner box. A gas/air mixture supplied to the burner box passes through a plurality of ports in the plaque and burns at the outer surface of the plaque. The burning gases raise the temperature of the outer surface of the plaque so that it radiates heat and light. Plaques of this type are described, for example, in UK Patent No. 1436842. UK Patent No. 1436842 describes the benefits of using as the material of the plaque an open structure of bonded refractory ceramic fibre, the continuous service temperature of fibre and bonding agent being at least 1000°C. Reference to UK Patent No. 1436842 may be had in the event of any further explanation of the manufacture of plaques being required.

Such surface combustion radiant heaters are used in a variety of applications including industrial heating and domestic heating. For domestic heating the visual appearance of plaques may be modified by surface decoration. Typically the plaques are made from an inorganic bonded fibrous material. The fibres used are usually alumino-silicate fibres.

An alternative type of plaque uses a body of non-fibrous dense ceramic (e.g. cordierite or mullite) or a body of low density ceramic (e.g. amorphous silica) and such plaques frequently have a higher luminance than fibrous plaques. Surface combustion burner plaques can fail however if the flame can pass back through the ports to the burner box behind the plaque ("lightback"). Fibrous plaques however, because of their lower thermal conductivity, are less susceptible to failure through lightback and so permit higher throughputs of gas.

It has been a long felt need to provide fibrous surface combustion burner plaques which have a higher luminance than conventional fibrous plaques and which have a luminance comparable with, or better than, non-fibrous plaques.

The applicants have found that plaques of superior luminance and appearance may be obtained by replacing alumino-silicate fibres with alkaline earth silicate fibres.

Accordingly the present invention provides a surface combustion radiant heating plaque formed from an inorganic bonded fibrous material in which the fibres are alkaline earth silicate fibres.

Alkaline earth silicate fibres are described for example in WO87/05007, WO89/12032, WO93/15028, WO94/15883, WO96/02478, WO97/16386 and WO97/49643.

In a preferred embodiment the fibres are calcium magnesium silicate fibres.

In a further preferred embodiment the alkaline earth silicate fibres have a composition comprising CaO, SiO₂, MgO, optionally ZrO₂, optionally less than 0.75mol% Al₂O₃, any incidental impurities amounting to less than 2mol% in total, in which the amount of CaO is less than the sum of the amount of MgO and twice the amount of ZrO₂ and in which the SiO₂ excess (defined as the amount of SiO₂ calculated as remaining after the above named constituents are crystallised as silicates) exceeds 21.8mol%. Such fibres are described in WO94/15883 and reference to this patent should be made for any further explanation of the term "SiO₂ excess" required.

Still more preferably the fibres may have a composition comprising in weight percent:-

SiO ₂	<70%
ZrO ₂	<10%
CaO	11-20%
MgO	8-16%
impurities	<1%

An advantageous range of compositions comprise in weight percent:-

SiO ₂	64 ± 1%
CaO	17 ± 1%
MgO	13.5 ± 1%
ZrO ₂	5 ± 1%
impurities	< 1%.

An alternative calcium magnesium silicate fibre is one in which the amount of MgO in mol% is greater than the amount of CaO in mol % and which comprises:-

SiO ₂	>64.25 wt%
CaO	>18 wt%
MgO	< 17 wt%

and which preferably comprises

SiO ₂	65 ± 0.5 wt%
CaO	20 ± 0.5 wt%
MgO	15 ± 0.5 wt%.

The plaques may be formed by vacuum casting the fibre, a filler, and optionally a flux to fuse the fibres. A starch for green body handling strength may be used.

Typically the slurry may comprise:-

Fibre	65 ± 20%
Filler	25 ± 20%
Flux	0-20%

Advantageously the plaque may be formed from a slurry comprising in weight percent of the stated ingredients:-

Fibre	70-77.5%
Filler	19.5-29.5%
Flux	0.5-1.7%

The invention also extends to surface combustion radiant heaters comprising a surface combustion radiant heating plaque formed from an inorganic bonded fibrous material in which the fibres are alkaline earth silicate fibres.

The invention is illustrated by way of example in the following description with reference to the drawings in which:-

Fig. 1 is a graph comparing radiant output v. input for a plaque in accordance with the invention and a comparison conventional plaque;

Fig. 2 is a graph comparing radiant output v. fuel/gas stoichiometry for a plaque in accordance with the invention and a comparison conventional plaque

Fig. 3 is a graph comparing radiant efficiency v. port loading for a plaque in accordance with the invention and a comparison conventional plaque;

Fig. 4 is a graph comparing true NO_x output v. port loading for a plaque in accordance with the invention and a comparison conventional plaque;

Fig. 5 is a graph comparing true NO_x output v. air/fuel stoichiometry for a plaque in accordance with the invention and a comparison conventional plaque;

Fig 6 is a graph comparing CO/CO₂ ratio v. input for a plaque in accordance with the invention and a comparison conventional plaque;

Fig. 7 is a graph comparing CO/CO₂ ratio v. air/fuel stoichiometry for a plaque in accordance with the invention and a comparison conventional plaque;

Fig. 8 is a graph comparing luminance v. input for a plaque in accordance with the invention and a comparison conventional plaque;

Fig. 9 is a chromaticity diagram comparing colour v. input for a plaque in accordance with the invention and a comparison conventional plaque;

Fig. 10 is a more detailed chromaticity diagram than in Fig.9 comparing colour v. input for a plaque in accordance with the invention and a comparison conventional plaque.

A pair of plaques of identical port diameters, radiant areas and size were made.

The burning area and average port dimensions of the plaques were measured using a VIEW 1200 non-contact co-ordinate measuring machine to ensure comparability of the data but the two plaques tested were identical as far as measured and so normalisation of data was not required. The plaques had a total burning area of 11212 mm², with 909 ports of port diameter 1.44mm making up a total port area of 1481mm². The burning area is defined as the area over which the plaque is lit, that is to say the area of a boundary encompassing all of the ports at which gas is burned.

The first plaque (A) was made in accordance with the present invention using Superwool 612™ refractory ceramic fibre which is available from Thermal Ceramics de France SA or Thermal Ceramics Limited. Superwool 612™ has a nominal composition (by weight) of SiO₂ 64%, CaO 17%, MgO 13.5%, ZrO₂ 5%, and impurities < 0.5%, and is usable at temperatures in excess of 1200°C and up to 1250°C.

The second plaque (B) was made for comparison purposes from Kaowool™ fibre which has a composition approximately 46% Al₂O₃, 54% SiO₂.

The plaques were formed by vacuum deposition from a slurry. The compositions used in making the slurry were as follows (weight percent):-

Inventive plaque (A)

Superwool 612™ (blown fibre)	73.7%
Filler	24.6%
Boron phosphate	1.23%
Cationic starch	0.52%

Comparison plaque (B)

Kaowool Fibre	66.35%
Filler	22.12%
Boron phosphate	11.06%
Cationic starch	0.47%

The filler used was Speswhite clay but other fillers such as talc may be used. Boron phosphate was used as a flux but other fluxes (e.g. borax) may be used. The amount of boron phosphate is less than in the conventional mix since it was found that the flux (which acts as a sintering agent to cross-link the fibres) reacts more strongly with alkaline earth metal silicate fibres than with conventional alumino-silicate fibres and at conventional levels a higher shrinkage than desirable resulted. Comparative tests at various levels of boron phosphate were done (keeping the fibre/filler ratio constant) and the results are indicated in Table 1 below:-

% of boron phosphate	Shrinkage %
0	1.0
10	1.45
40	2.75
50	2.96
75	4.31

The level used in plaque (A) was chosen as a compromise to give sufficient hardness with low shrinkage but the invention is not limited to this low level. Higher levels may be appropriate in some circumstances.

The slurries were prepared by adding successively the fibre, the filler, the boron phosphate and then the cationic starch to water while agitating. The materials were added at a rate of approximately 60kg of fibre plus filler plus boron phosphate in total to a cubic metre of water.

The slurries were vacuum formed onto a perforated expanded copper grid having aperture size of a nominal 0.5mm as measured by travelling microscope. The former had retractable pins to produce the ports in the finished plaque. The resultant green shape was dried and then fired in air at about 1050°C for about 40 minutes, sufficient to bond the fibres.

Combustion properties were measured on both plaques using methane as the combustible gas, which has a calorific value of 38000 J/l. In the Drawings the symbol \square represents the plaque (A) according to the invention and the symbol \times represents the conventional comparison plaque (B).

Table 2 and Figs. 1- 3 show that radiant output and efficiency of the plaques were very similar over a range of inputs and at different gas mixture stoichiometries. In Table 2 the column headed input represents the calorific value of the gas supplied divided by the burning area of the plaque (the area which contains ports); port loading represents the calorific value of the gas supplied divided by the area of the ports; stoichiometry represents the percentage amount of air required for complete combustion - 100 representing complete combustion, percentages below this indicating a fuel rich mixture and percentages above indicating an air rich (also known as fuel lean) mixture; total output represents the radiant heat output of the plaque; relative output represents the output per unit area of burning area of plaque; and efficiency is the ratio of radiant heat output to the input. The deficiency between the amount of radiant heat and the heat input

is accounted for partly by heating of the combustion gases (which results in convective heat) and partly by loss of energy in light emission, sound, latent heat, and other forms of energy.

Table 2					
Part 1 - Conventional plaque (Kaowool™)					
Input (kW/m²)	Port Loading (kW/m²)	Stoichiometry (%)	Total Radiant Output (W)	Relative Radiant Output (kW/m²)	Radiant Efficiency (%)
98.2	743.6	100	336.9	30.0	30.6
130	984.4	80	428.0	38.2	29.4
130	984.4	90	470.5	42.0	32.3
130	984.4	100	455.9	40.7	31.3
130	984.4	110	415.2	37.0	28.5
130	984.4	120	348.3	31.1	23.9
170	1287.4	100	579.2	51.7	30.4
210	1590.3	100	666.7	59.5	28.3
250	1893.2	100	731.5	65.2	26.1
Part -2 Plaque according to invention (Superwool™)					
Input (kW/m²)	Port Loading (kW/m²)	Stoichiometry (%)	Total Radiant Output (W)	Relative Radiant Output (kW/m²)	Radiant Efficiency (%)
98.2	743.6	100	334.5	29.8	30.4
130	984.4	80	430.0	38.4	29.5
130	984.4	90	472.3	42.1	32.4
130	984.4	100	459.3	41.0	31.5
130	984.4	110	419.8	37.4	28.8
130	984.4	120	361.5	32.2	24.8
170	1287.4	100	581.3	51.8	30.5
210	1590.3	100	659.9	58.9	28.0
250	1893.2	100	721.5	64.4	25.7

Table 3 and Figs. 4-7 show that the production of combustion products are broadly comparable between the plaques. In this table the columns headed input, port loading, and stoichiometry are as in Table 2; true NO_x represents a measured value for nitrogen oxides which is corrected for dilution by calculation; CO represents the amount of carbon monoxide measured in volume percent; CO₂ represents the amount of carbon dioxide measured in volume percent; and ratio CO/CO₂ is their ratio.

Table 3						
Part 1 - Conventional plaque (Kaowool™)						
Input (kW/m ²)	Port Loading (kW/m ²)	Stoichiometry (%)	True NO _x (ppm)	CO (%)	CO ₂ (%)	Ratio CO/CO ₂
98.2	743.6	100	3.30	0.0123	1.03	1.19×10 ⁻²
130	984.4	80	10.28	0.0041	1.44	2.85×10 ⁻³
130	984.4	90	8.40	0.0050	1.46	3.42×10 ⁻³
130	984.4	100	5.42	0.0053	1.48	3.58×10 ⁻³
130	984.4	110	3.12	0.0128	1.42	9.01×10 ⁻³
130	984.4	120	2.08	0.0209	1.36	1.54×10 ⁻²
170	1287.4	100	7.73	0.0037	1.77	2.09×10 ⁻³
210	1590.3	100	8.18	0.0040	2.19	1.83×10 ⁻³
250	1893.2	100	10.81	0.0039	2.40	1.63×10 ⁻³
Part -2 Plaque according to invention (Superwool™)						
Input (kW/m ²)	Port Loading (kW/m ²)	Stoichiometry (%)	True NO _x (ppm)	CO (%)	CO ₂ (%)	Ratio CO/CO ₂
98.2	743.6	100	3.60	0.0118	1.18	1.00×10 ⁻²
130	984.4	80	11.34	0.0050	1.58	3.16×10 ⁻³
130	984.4	90	8.53	0.0059	1.57	3.76×10 ⁻³
130	984.4	100	5.11	0.0061	1.42	4.30×10 ⁻³
130	984.4	110	3.48	0.0109	1.49	7.32×10 ⁻³
130	984.4	120	2.46	0.0170	1.42	1.20×10 ⁻²
170	1287.4	100	7.33	0.0045	1.80	2.50×10 ⁻³
210	1590.3	100	9.43	0.0038	2.13	1.78×10 ⁻³
250	1893.2	100	10.37	0.0043	2.41	1.78×10 ⁻³

However Table 4 and Figs. 8-10 shows that there are real differences in the brightness and colour of the plaques. In Table 4 the columns headed input, port loading, and stoichiometry are as in Table 2; luminance is the light output in candelas per square metre of the burning area; co-ordinates x and y are chromaticity co-ordinates indicative of colour. An explanation of colour co-ordinates may be found at pages 84-87 of "Colour physics for industry", Ed. Roderick McDonald, published 1987 by the society of Dyers and Colourists. In the present case, because we are concerned with light output rather than reflected light, complications such as requiring standard observing conditions and a standard light source are removed. The chromaticity co-ordinates were measured using a Bentham Spectrophotometer TM 300 series monochromator which measures the light output at a stepped series of frequencies and has software to calculate the x and y chromaticity co-ordinates directly. The spectrophotometer was calibrated with a lamp of the integrating sphere design traceable to National Physical Laboratory standards.

Table 4					
Part 1 - Conventional plaque (Kaowool™)					
Input (kW/m²)	Port Loading	Stoichiometry (%)	Luminance (cd/m²)	Colour x	Colour y
98.2	743.6	100	11.20	0.3355	0.3038
130	984.4	100	19.87	0.4435	0.3302
170	1287.4	100	42.51	0.5197	0.3550
210	1590.3	100	71.52	0.5439	0.3656
250	1893.2	100	90.03	0.5471	0.3688
Part -2 Plaque according to invention (Superwool™)					
Input (kW/m²)	Port Loading	Stoichiometry (%)	Luminance (cd/m²)	Colour x	Colour y
98.2	743.6	100	12.48	0.3577	0.3121
130	984.4	100	33.04	0.5105	0.3453
170	1287.4	100	94.71	0.5615	0.3671
210	1590.3	100	183.4	0.5699	0.3781
250	1893.2	100	236.2	0.5577	0.3853

The plaque in accordance with the invention was significantly brighter at the inputs tested (see Fig. 8) and also exhibited much more intense colour at equivalent input levels (see Figs. 9 and 10).

Referring to Fig. 8 it can be seen that although at low inputs the plaque in accordance with the invention is comparable with a conventional plaque, at higher inputs the inventive plaque has a considerably higher luminance (over twice as high at an input of 250 kW/m²). The plaque has a luminance in excess of 75cd/m² when supplied with a 100% stoichiometry air/methane mixture at an input of 170 kW/m² and has a luminance in excess of 200cd/m² when supplied with a 100% stoichiometry air/methane mixture at an input of 250 kW/m². This is well in excess of a conventional plaque.

A plaque which has a luminance in excess of 90cd/m² when supplied with a 100% stoichiometry air/methane mixture at an input of 170 kW/m² and has a luminance in excess of 220cd/m² when supplied with a 100% stoichiometry air/methane mixture at an input of 250 kW/m² is dramatically better than conventional fibrous plaques. Most non-fibrous plaques cannot provide an input of 250 kW/m² when supplied with a 100% stoichiometry air/methane mixture as failure through lightback occurs at such high inputs. A plaque in accordance with this invention could go to inputs as high as 400 kW/m² and maintain radiant mode.

Referring to Fig. 9 a chromaticity diagram is shown as to CIE 1931. A curved boundary with one straight edge is shown. Towards the edge of the area indicated by this boundary lay intense colours whereas towards the centre lay pale colours and white. As one moves along the curved boundary the colours change from red through yellow and green to blue. (This curve is called the spectrum locus). Fig. 10 is a more detailed view showing linked pairs of points representing a conventional plaque and a plaque in accordance with the invention at various inputs (shown unlinked in Fig. 9). The pairs of points plotted on this graph show that at all inputs the inventive plaque has a stronger colour than the conventional plaque, lying further from the centre of the area indicated and towards the spectrum locus.

Since the overall radiant output of the two plaques is similar, as measured using a broad-band thermopile, it appears that the emissivity in the visual part of the spectrum is greater for the inventive plaque than a conventional plaque.

At the same time, the plaques in accordance with the present invention emit a more yellow light than the conventional plaques. As the eye is most sensitive in the yellow region of the spectrum a strong yellow colour looks brighter and warmer than an orange or red colour.

The present invention therefore provides a surface combustion radiant heating plaque having a higher luminance and stronger colour than conventional plaques with broadly similar combustion properties. Such plaques are particularly useful in domestic heating but may be used in any application where conventional plaques are used.

CLAIMS

1. A surface combustion radiant heating plaque formed from an inorganic bonded fibrous material, characterised in that the material comprises fibres which are alkaline earth silicate fibres.
2. A surface combustion radiant heating plaque as claimed in claim 1 in which the fibres are calcium magnesium silicate fibres.
3. A surface combustion radiant heating plaque as claimed in claim 1 or claim 2 in which the alkaline earth silicate fibres have a composition comprising CaO, SiO₂, MgO, optionally ZrO₂, optionally less than 0.75mol% Al₂O₃, any incidental impurities amounting to less than 2mol% in total, in which the amount of CaO is less than the sum of the amount of MgO and twice the amount of ZrO₂ and in which the SiO₂ excess (defined as the amount of SiO₂ calculated as remaining after the above named constituents are crystallised as silicates) exceeds 21.8mol%.
4. A surface combustion radiant heating plaque as claimed in any preceding claim in which the fibres have a composition comprising in weight percent:-

SiO ₂	<70%
ZrO ₂	<10%
CaO	11-20%
MgO	8-16%
impurities	<1%

5. A surface combustion radiant heating plaque as claimed in any preceding claim in which the fibres have a composition comprising in weight percent:-

SiO ₂	64 ± 1%
CaO	17 ± 1%
MgO	13.5 ± 1%
ZrO ₂	5 ± 1%
impurities	< 1%

6. A method of making a surface combustion radiant heating plaque as claimed in any preceding claim in which the plaque is formed by vacuum casting from a slurry which comprises in weight percent of the stated ingredients:-

Alkaline earth silicate fibre	65 ± 20%
Filler	25 ± 20%
Flux	0-20%

7. A method of making a surface combustion radiant heating plaque as claimed in claim 6 in which the slurry comprises in weight percent of the stated ingredients:-

Alkaline earth silicate fibre	70-77.5%
Filler	19.5-29.5%
Flux	0.5-1.7%

8. A surface combustion radiant heater comprising a surface combustion radiant heating plaque as claimed in, or as made by the method of, any preceding claim.

9. A surface combustion radiant heater as claimed in claim 8, the plaque having a luminance in excess of 75cd/m^2 when supplied with a 100% stoichiometry air/methane mixture at an input of 170 kW/m^2 and having a luminance in excess of 200cd/m^2 when supplied with a 100% stoichiometry air/methane mixture at an input of 250 kW/m^2 .

- 10 A surface combustion radiant heater as claimed in claim 9, the plaque having a luminance in excess of 90cd/m^2 when supplied with a 100% stoichiometry air/methane mixture at an input of 170 kW/m^2 and having a luminance in excess of 220cd/m^2 when supplied with a 100% stoichiometry air/methane mixture at an input of 250 kW/m^2 .

**Figure 1 : Radiant Output v. Input
at 100% Air in Air/Gas mix (Methane)**

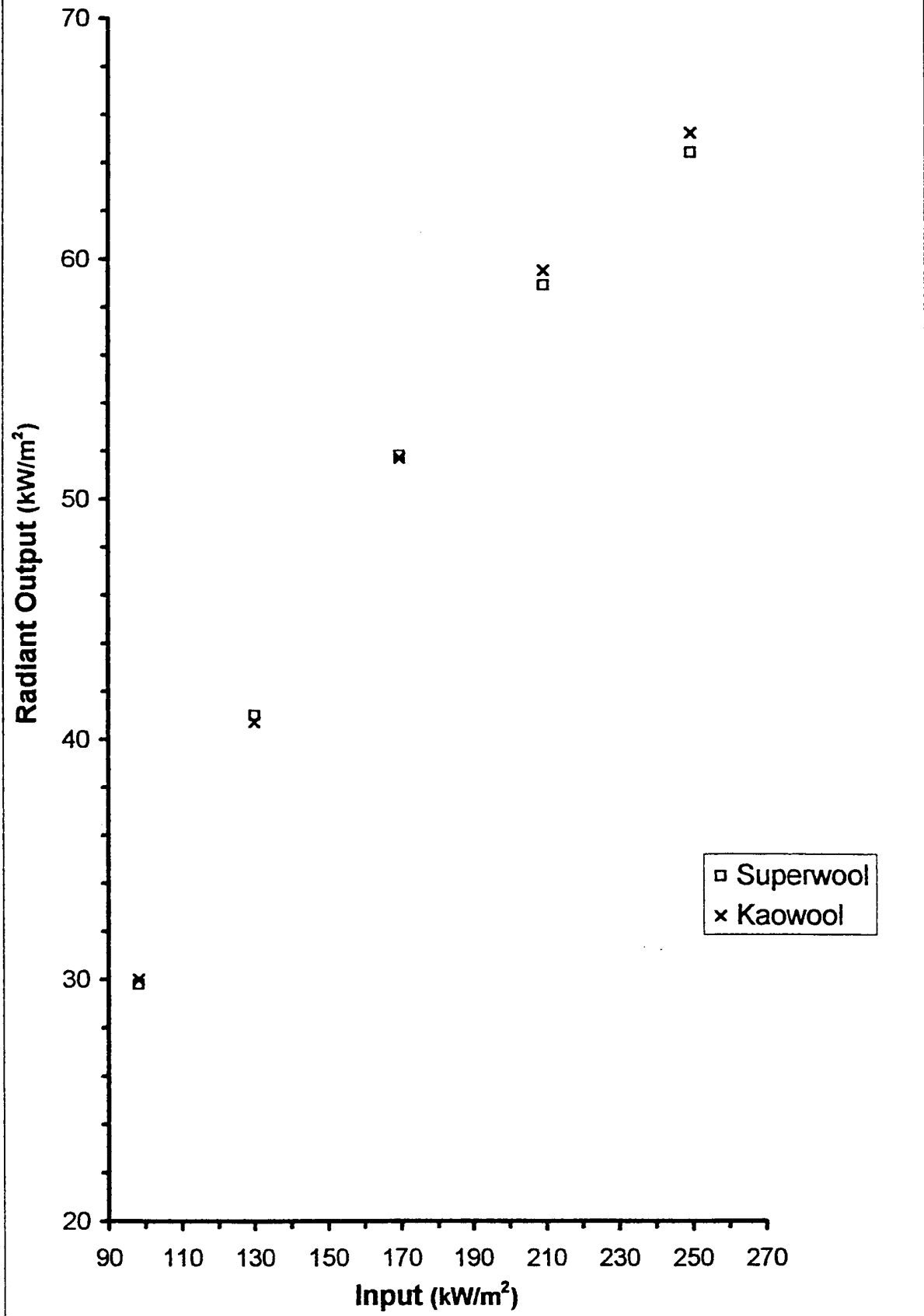
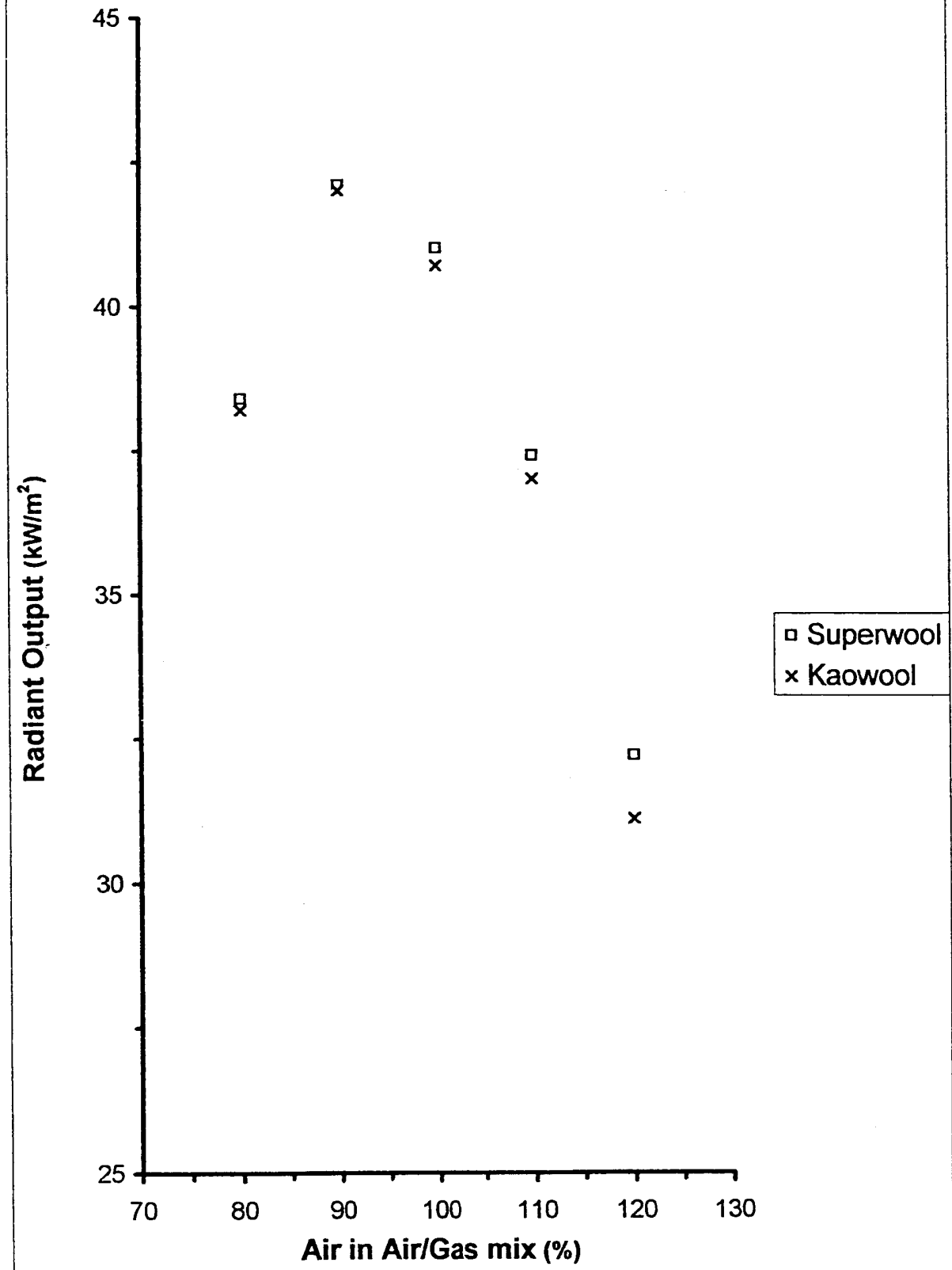
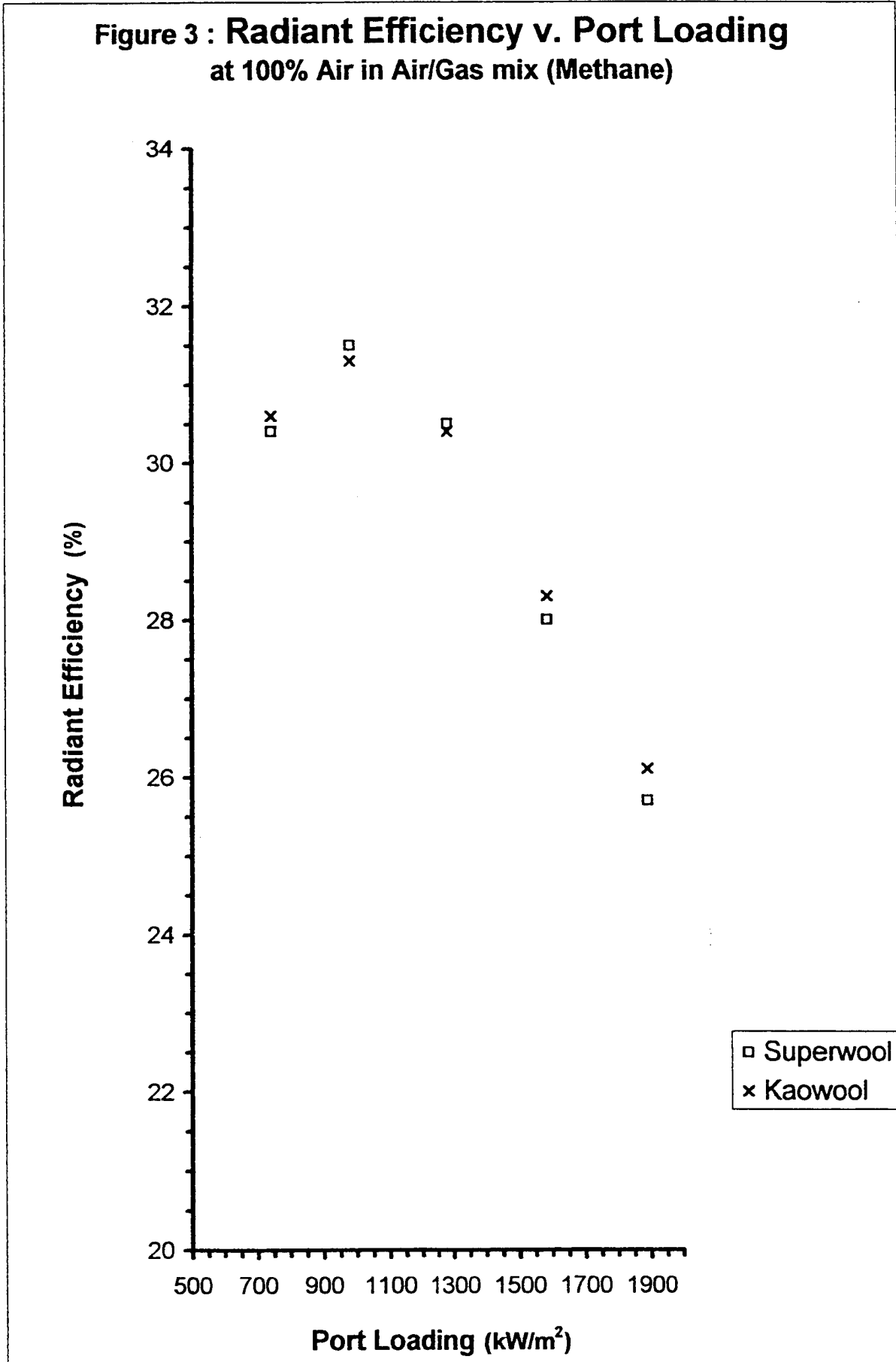
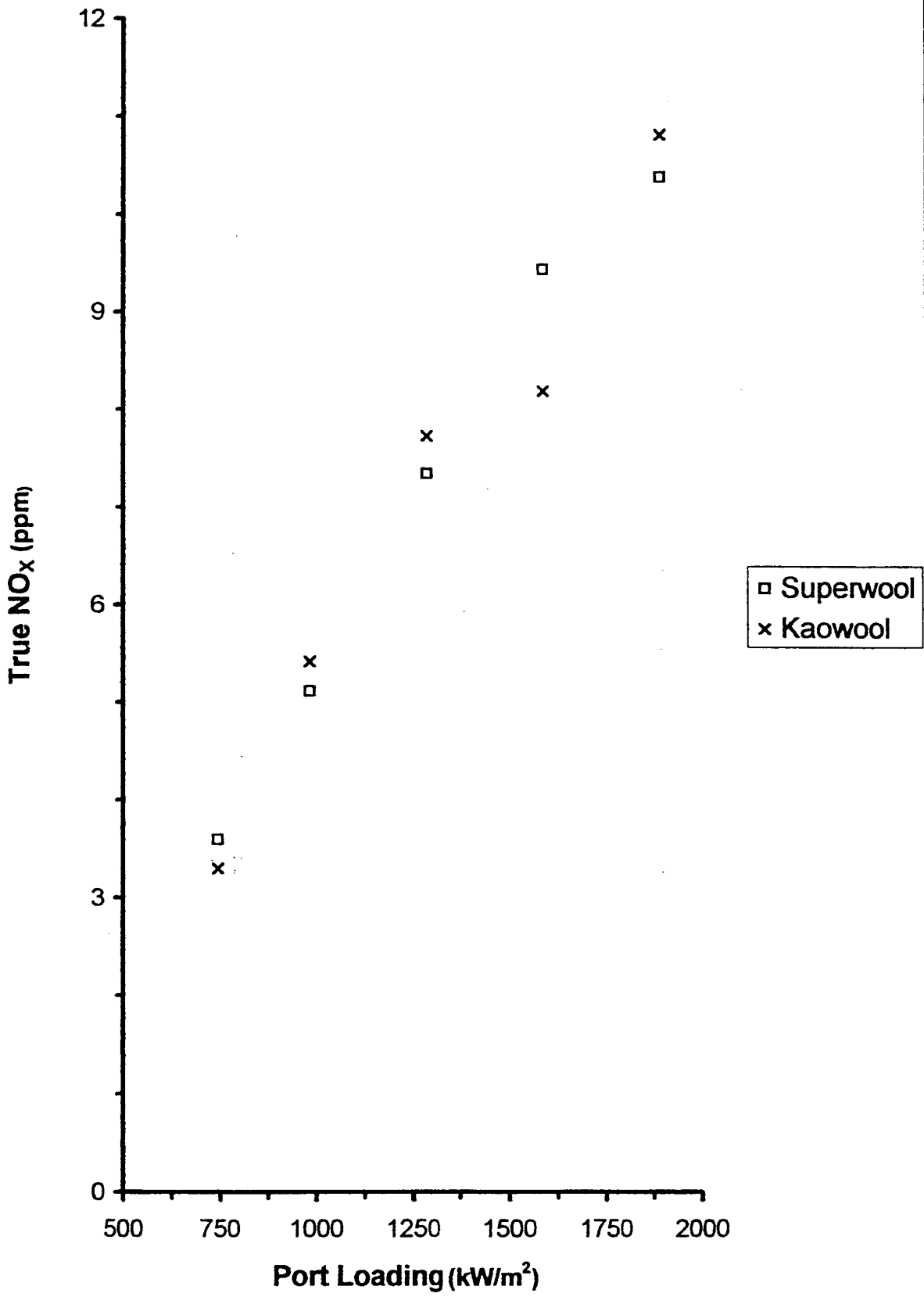


Figure 2 : Radiant Output v. Air in Air/Gas Mix
at 130 kW/m² Input (Methane)

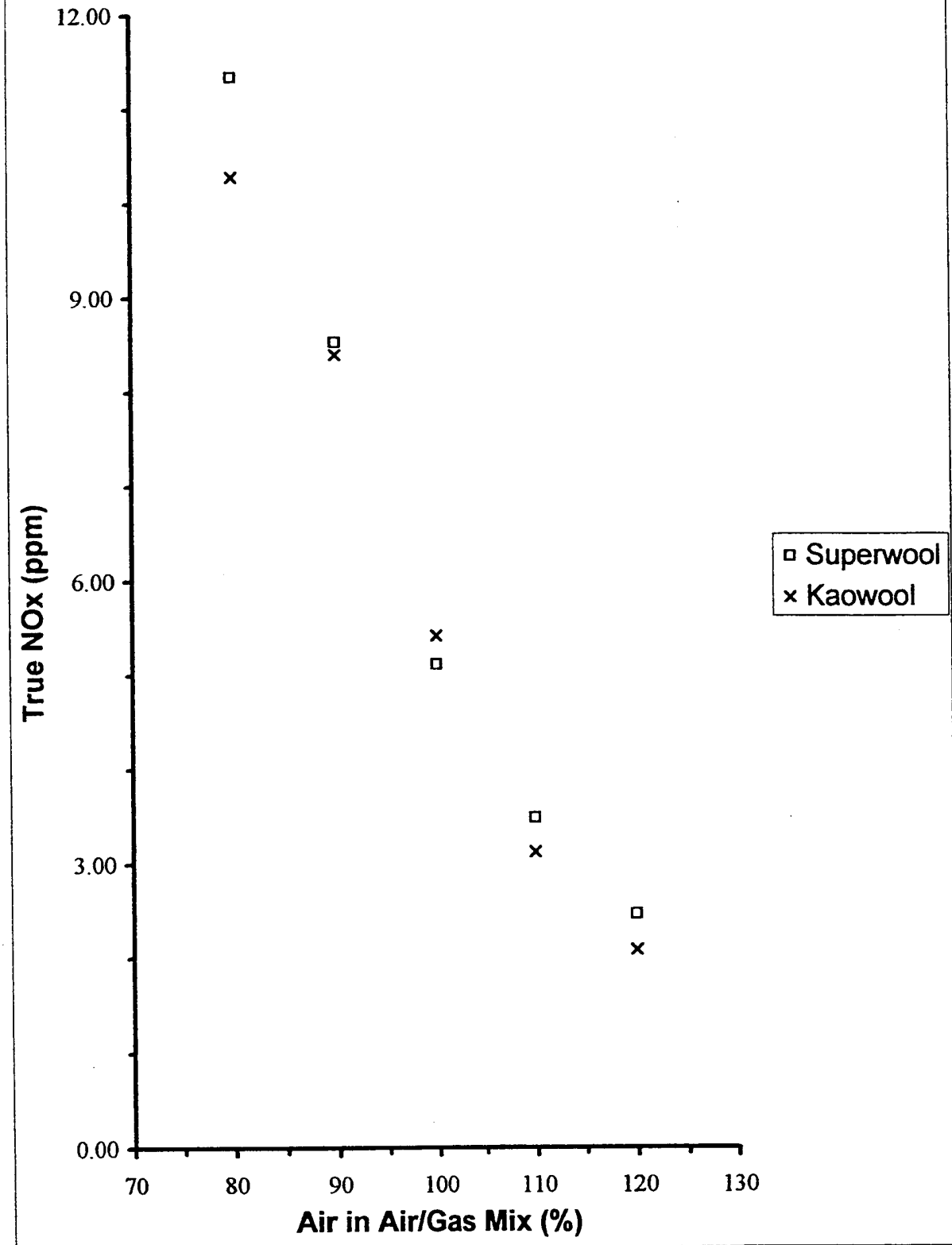




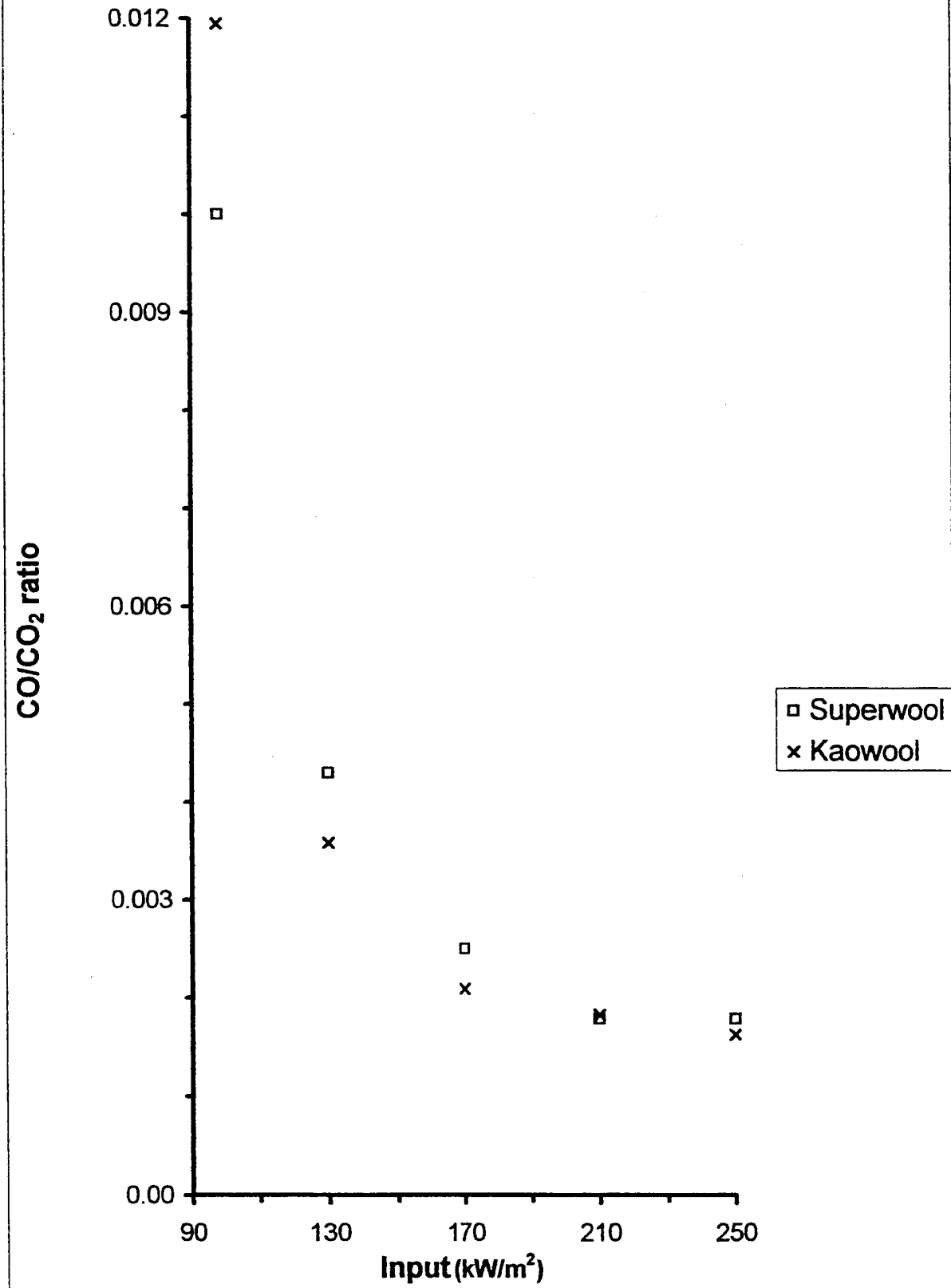
**Figure 4 : True NO_x v. Port Loading
at 100% Air in Air/Gas mix (Methane)**

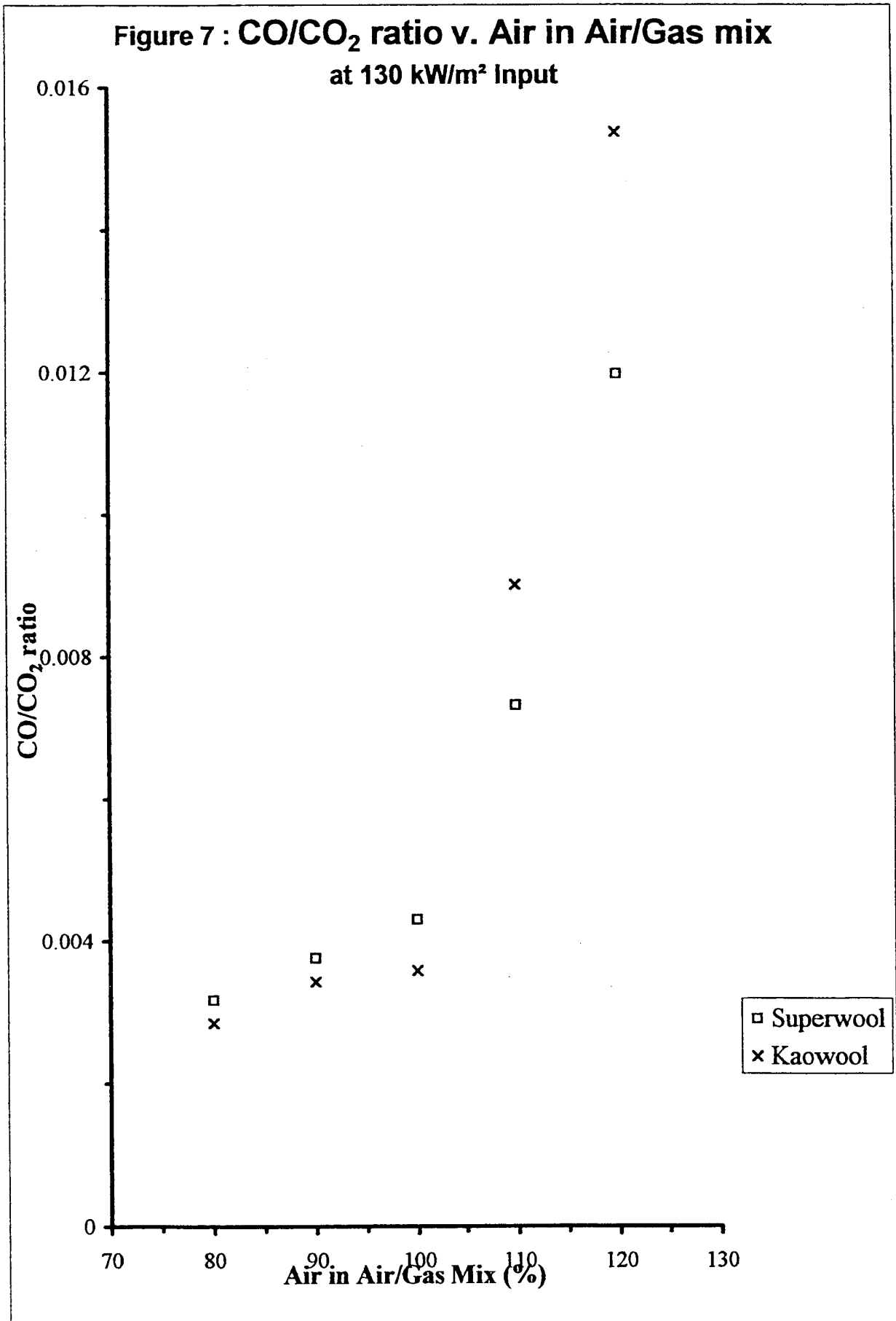


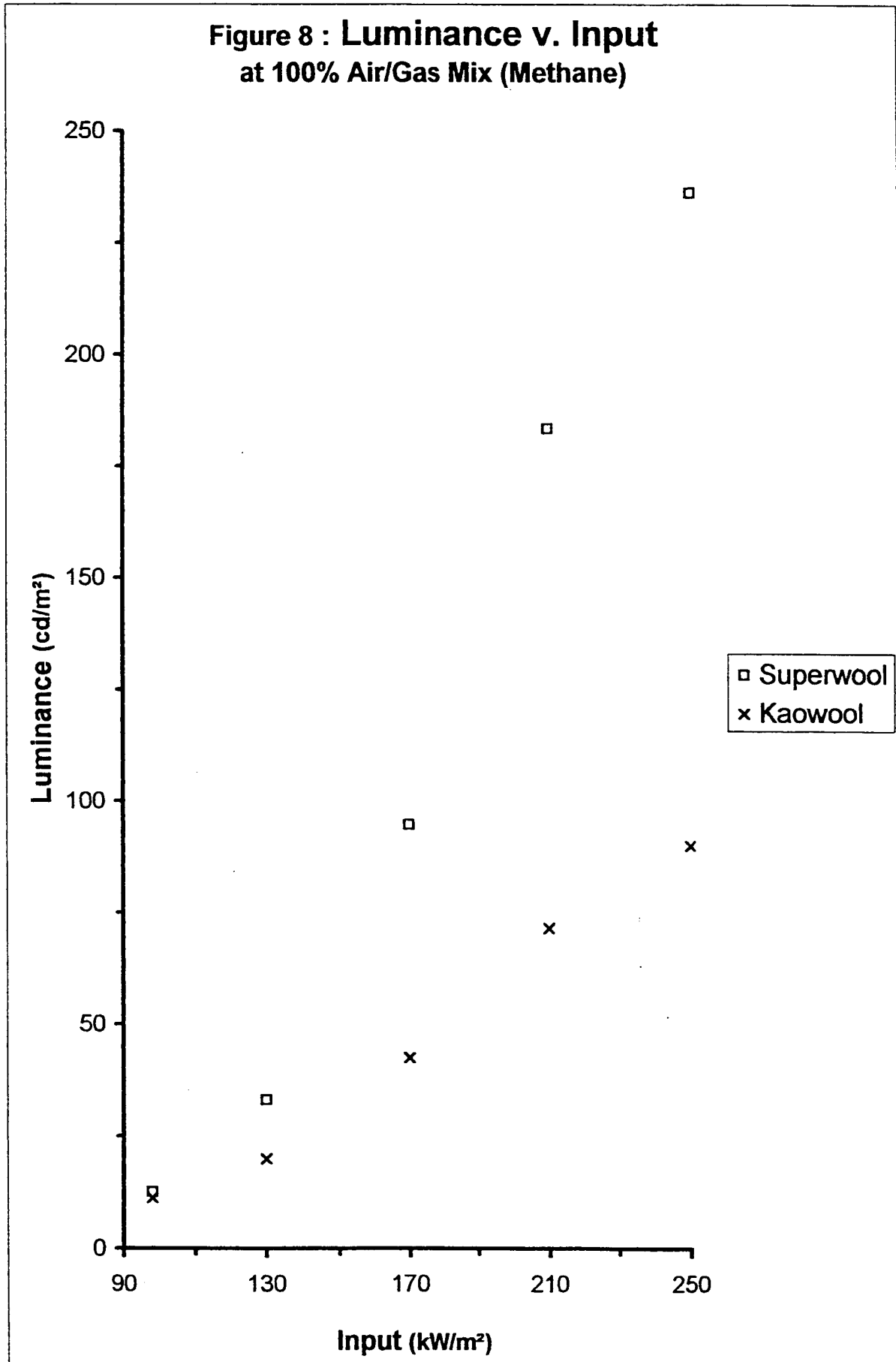
**Figure 5 : True NOx v. Air in Air/Gas Mix
(Methane)
at 130 kW/m² Input**



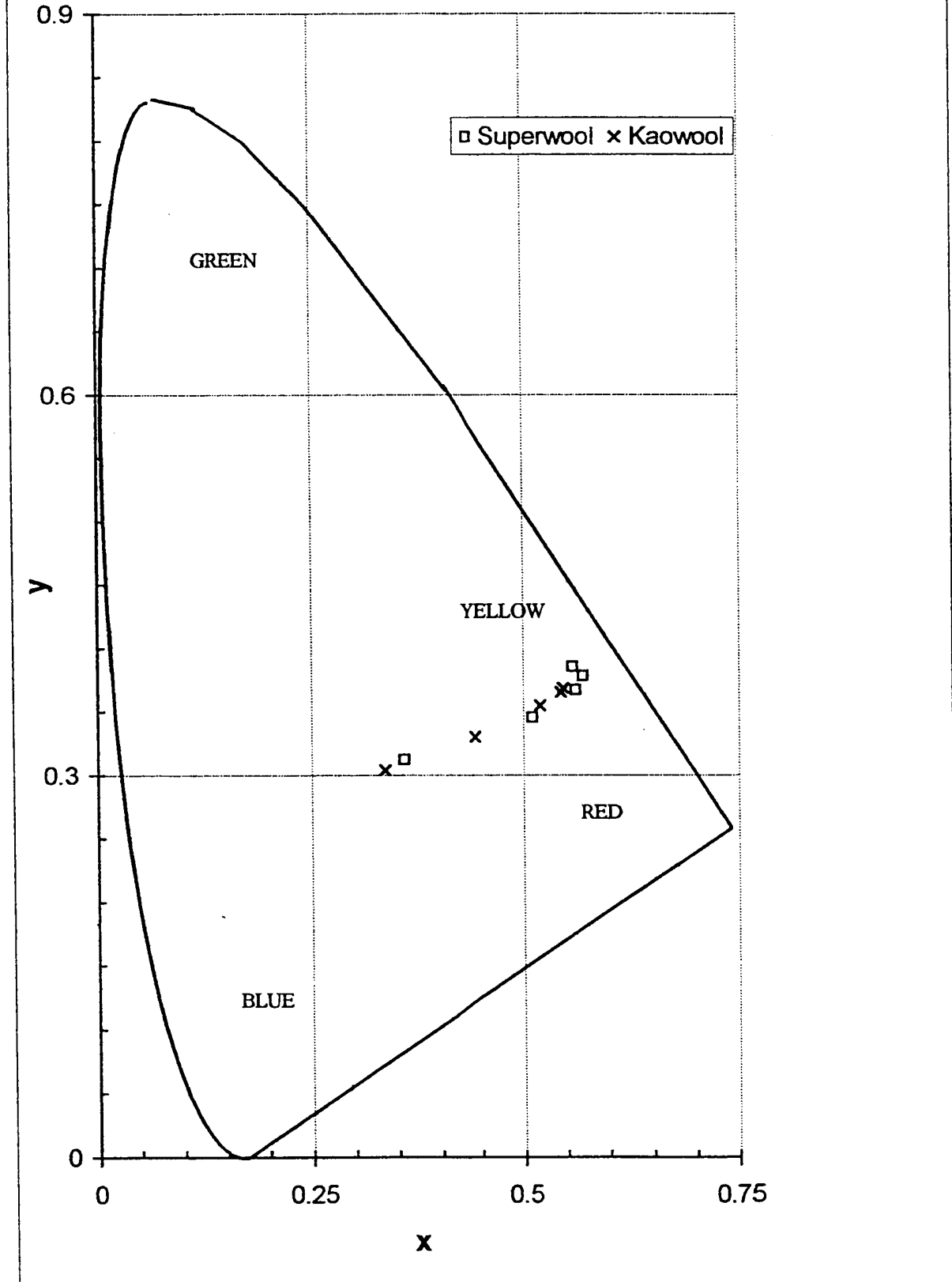
**Figure 6 : CO/CO₂ Ratio v. Input
at 100% Air in Air/Gas mix (Methane)**



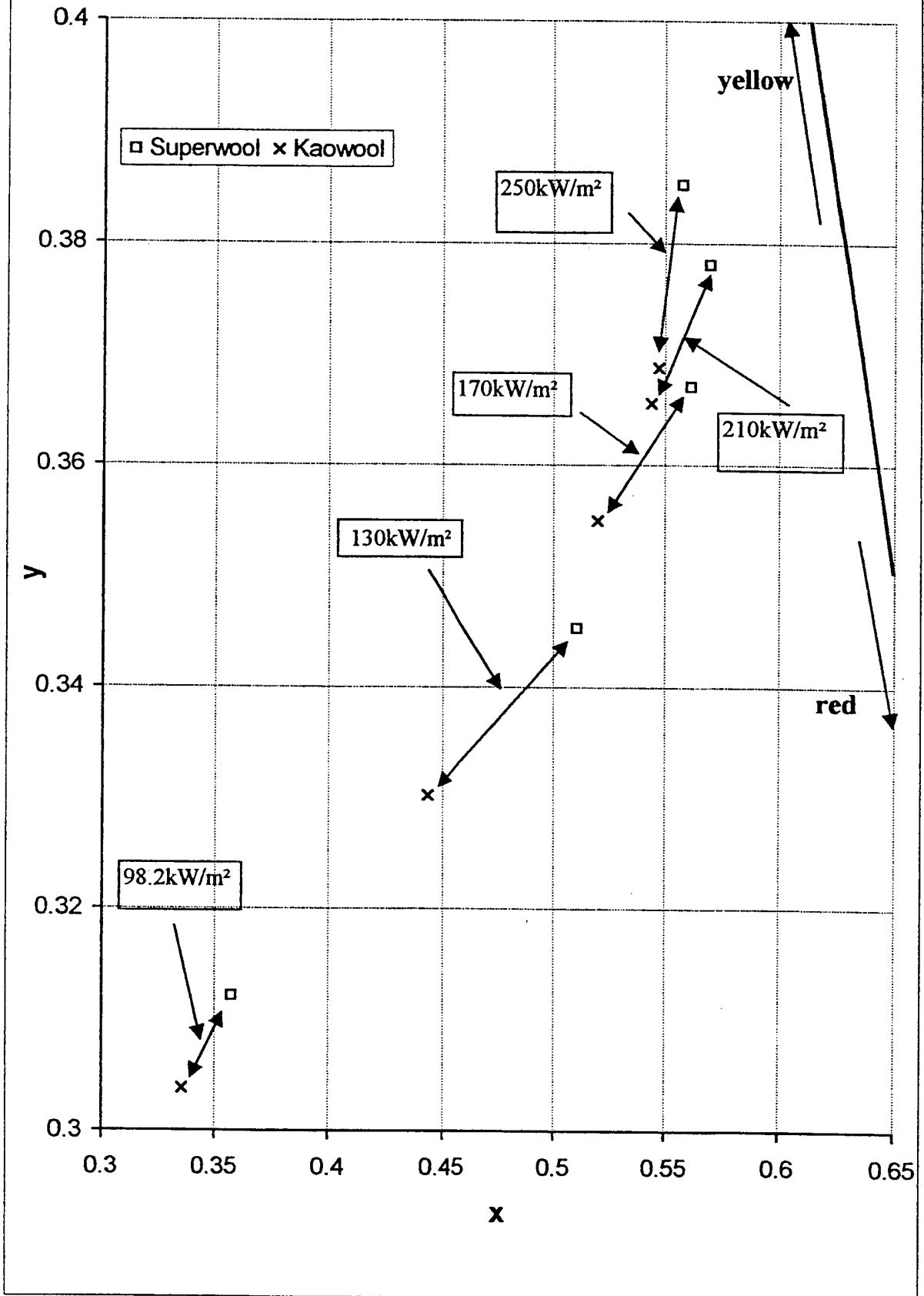




**Figure 9 : Colourimetry v. Input
at 100% Air in Air/Gas mix**



**Figure 10 : Colourimetry v. Input
at 100% Air in Air/Gas Mix (Methane)**



INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 00/02075

A. CLASSIFICATION OF SUBJECT MATTER
 IPC 7 F23D14/12 F24C15/24 C03C13/00

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 F23D F24C C03C

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 5 447 666 A (LAFONTAINE ROBERT D) 5 September 1995 (1995-09-05) column 5, line 24 - line 53 ---	1,2,8 6
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Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

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Date of the actual completion of the international search

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