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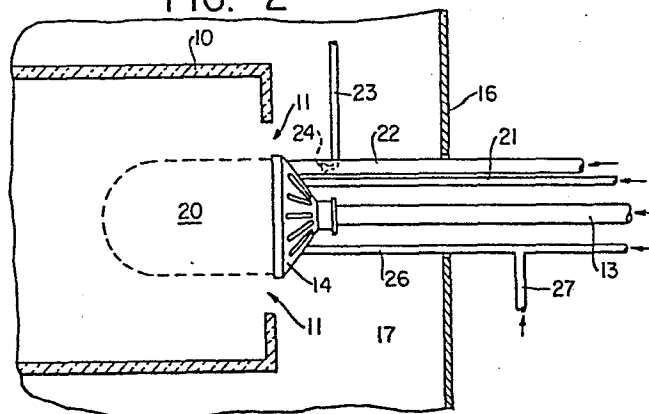
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54 Catalyst system for delivering catalytic material to a selected portion of a combustion chamber.

57 A catalyst delivering system for delivering catalytic material to a high temperature zone (20, 44) of a combustion chamber (10, 41) in which oil, gas or other carbon fuel is burning.

FIG. 2



CATALYST SYSTEM FOR DELIVERING CATALYTIC
MATERIAL TO A SELECTED PORTION OF A
COMBUSTION CHAMBER

Prior patents have suggested the continuous introduction of catalytic material into combustion chambers along with air or fuel or mixtures of air and fuel (see U.S. Patents 2,460,700 to Lyons; 3,862,819 to Wentworth; 4,014,637 to Schena and 4,214,615 to Boyer and see British Patents Nos. 1,381,936 and 1,191,464).

The catalytic introduction techniques suggested prior hereto have not provided satisfactory catalyzation in the combustion chamber.

According to the present invention there is provided a system for delivery of a catalytic material to a combustion chamber having a high temperature flame zone therein characterised in that the system comprises:

- a) admixing said catalytic material with a fluid medium;
- b) introducing substantially all of said catalytic material as admixed into the flame zone.

The present invention provides a system whereby the introduction of a catalytic material into a high temperature zone of the combustion chamber during combustion can be continuously metered. Catalytic material, which materials may include one or more platinum group metals, can be introduced directly into the high temperature zone of the chamber.

It is a feature of the invention that the catalytic material is selected so that upon its entry into the high temperature zone of the chamber elemental platinum group metal or other catalyst is made available in a short period of time to the combustion process by decomposition or disassociation of material or otherwise.

It is a further feature that the catalytic material may be conveyed to the high temperature zone by various vehicles such as air, fuel, steam or an emulsion.

Embodiments of the present invention will now be described by way of example, with reference to the accompanying drawings in which:-

Fig. 1 is a perspective view of the combustion chamber;

Fig. 2 is a partial elevational view of the combustion chamber including an air manifold;

5 Fig. 3 is a view of the combustion air and fuel supply systems; and

Fig. 4 is an enlarged view of an air or steam atomization fuel nozzle.

10 Fig. 5 is a plan view of a boiler having a flame zone in the combustion chamber;

Fig. 6 is a plan view of the boiler of Fig. 5 with a smaller flame zone shown;

Fig. 7(a)-(d) shows the temperature gradient along lines A-A, B-B, C-C and D-D of Figs. 5 and 6;

15 Fig. 8 is a graph plotting efficiency and steam rate;

Fig. 9 is a graph plotting pounds of steam per gallon of fuel oil versus gallons of fuel consumed per day;

20 Fig. 10 is a graph plotting excess oxygen versus pounds of steam per gallon of fuel oil; and

Fig. 11 is a graph plotting pounds of steam per gallon of fuel oil versus percentage boiler efficiency

Referring to Fig. 1, rectilinear combustion unit 8 includes rectangular chamber opening 11 into which fuel injector gun unit 12 is projected. Injector gun unit 12 includes fuel line 13 and diffuser head 14.

25 Turning to Figs. 2 and 3, combustion chamber 10 is shown surrounded by air manifold housing 16. The area between the chamber 10 and housing 16 serves as an air manifold 17. Combustion air is forced by fan 18 along normal air intake duct 19 into manifold 17 and from
30 manifold 17 air enters the combustion chamber 10 through opening 11.

Catalytic materials used include dihydrogen platinum hexachloride and other platinum compounds which decompose at temperatures lower than the temperatures found in the high temperature flame zone 20 of chamber 10 (see dotted line Fig. 2). Normally, 2600°F. to 3500°F. is the range of temperature found in the combustion chamber of a medium sized commercial steam generating boiler. Temperatures vary depending on the load placed on the chamber (See Figs. 7(a)-(d)).

Various techniques for introducing the catalytic material into flame zone 20 are shown. Referring to Figs. 2 and 3, catalytic material may be conveyed directly, without mixture blending or union with any other material, through catalyst material line 21 to head 14 from which discharge point the material is carried into flame zone 20 by fuel, steam or other fluids flowing into the zone 20. Secondly, liquid catalytic material may be introduced into auxiliary air line 22 using catalytic material feed line 23 and nozzle 24. Catalytic air fed through line 22 may be directed and used to atomize the fuel just prior to its entry into the flame zone. Thirdly, catalytic material can be introduced into steam line 26 through catalytic supply line 27.

Fourthly, the catalytic material can be introduced into the fuel by mixing the material with the fuel by introducing it through catalytic intake line 28 into feed fuel line 29. Alternatively, the catalytic material may be mixed with fuel in mixer 31, to form an emulsion of catalytic material and fuel may be heated by heater 32 and introduced through fuel line 13 into zone 20.

Finally, turning to Fig. 3 catalytic material can be introduced into air duct 19 via nozzle 31 fed by catalytic material conduit 32.

With reference to Fig. 4, steam flowing in steam line 26 divides to thereafter flow in steam ports 33. Fuel from line 13 flows through fuel feed slots 34. As the fuel enters the steam lines 33, the fuel and steam mix, forming an emulsion. The fuel/steam mixture is atomized into small droplets upon exiting the nozzle. Because part of the steam forms an emulsion with the oil, atomized oil droplets contain small droplets of water. Exposure to the flame causes boiling of the water droplets which explode (microexplosions), shattering the oil droplets into many smaller droplets and vapors. Inclusion of catalyst with the steam thus affords a near optimal distribution of air/fuel/catalyst throughout the burning zone and, in particular, in the high temperature zone 20, causing rapid dissociation and, hence, activation of the precious metal atoms throughout the flame. An emulsion of fuel and steam may be formed at a remote location and, with added or included catalyst, the emulsion can then be transported to the site of the combustion unit 8 for introduction into the chamber.

Air may be substituted for steam to atomize the oil in the fuel nozzle identical or similar to that of Fig. 14. The benefits of catalyst injection are identical except that of the emulsion are, of course, excluded, i.e., with air atomization, no emulsion occurs, whereas emulsion does occur with steam atomization. The application of the present invention to oil, gas and coal fired boilers requires selecting and controlling the point of introduction, direction of flow of the catalyst-carrying fluid introduced to meet the requirement that substantially all the catalyst admixed with the carrier fluid be introduced into the flame zone.

Turning to Fig. 5, there is shown boiler 40 which includes chamber 41, burner diffuser head 42, air intake

manifold 43 and flame zone 44 shown in dashed lines. Tube section 46 is heated by the flow of gases from, around and through the flame zone 44 to exhaust stack 47. The boiler of Fig. 5 is being fired at high load with low excess air creating a flame zone 44 which has a size and shape to substantially fill chamber 41 so that the normal intake of air entering the chamber 41 (see arrows 45) is introduced into the flame zone 44. Thus, catalyst material being supplied via normal intake air will be introduced into the flame zone 44.

In Fig. 6, the same boiler 40 as shown in Fig. 5 is being operated at reduced load. Under these conditions, a substantial portion of the normal intake air carrying catalyst material will bypass flame zone (arrow 47).

Example

A platinum catalyst was introduced into a commercial boiler combustion chamber fed by a steam-fuel diffuser by installing an auxiliary air lance which lance delivered catalyst containing air to the diffuser head. Substantially all of the catalyst was introduced into the high temperature flame zone. Alternatively, catalyst was introduced via the steam to the diffuser. The boiler was also run for periods of time without use of a catalyst.

It was observed that boiler efficiency increased when the catalyst was used (See Fig. 8). It was also discovered that smoke and soot build-up and emissions were improved. The boiler was successfully run with low excess air (2.5%O₂, 10% excess air) without increasing soot or smoke emissions (see following Tables 1 and 2)).

Table 1

Firing rate	Normal Operation		Low Excess Air*	
	<u>gph</u>	<u>lbs. steam/hr./grph</u>	<u>lbs. steam/hr./grp</u>	<u>% Increase</u>
5	117	125	132	5.6
	135	126	133	5.6
	150		134	

* unacceptable operation due to Heavy Smoke and Particulate Emissions at 3.% O₂

Table 2

Firing Rate	Normal Operation		Catalyst On*	
	<u>gph</u>	<u>lbs. steam/hr./gph</u>	<u>lbs. steam/hr./gph</u>	<u>% Increase</u>
15	117.	125	138	10.4
	135.	126	139	10.3
	150.		140	

* Light Smoke at 1.5% O₂

A 10.% improvement in steam output per gallon of oil fired was demonstrated and highlighted in the following Tables 3 and 4.

Table 3

Percent Fan Capacity	Percent Excess Air	Oil gph	(Dry) CO ₂ %	(Dry) O ₂ %	Steam lbs. hr.	Stack Temp ² °F	Boiler 1,3 Efficiency
59		117.	10.9	6.7			85./84.
41			10.9	6.7	15,100./14,600	416	86.1
38			11.3	6.4	16,500./16,000.	414	87.
35	30		12.3/12.4	5./5.1	17,300.	411	87.8
34	15.7		14.	3.	16,000.	408	87.5
34	21.3		13.4	3.7/3.8			88.1
34	8.		15.1	1.5	17,000.	417	87.3
35	24.		13.	4.2		413	88.4
30/32*	4.5/5.		15.	.9/1.			
53		135.	10.3	7.5/7.7	16,500.	441	84.3
48			10.8	7.1/7.	16,900.	439	84.8
43			11.9	5.7	18,700	430	86.
35	12.3/11.7		14.6	2.4/2.3		409	88.2
38	19.4/18.6		13.7	3.6/3.4	18,300./18,400.	415	87.5
33*	6.3/5.7		15.3	1.3/1.2			88.3
	9.		14.9	1.8	18,000./18,200.	410	88/88.3
	15.7		14.	3.		421	87.5
60		150.	10.3	7.6	17,400.	452	83.9
45	19.		13.6	3.5	21,500.	429	87.1
40	11.		14.5/14.6	2.2	20,000/21,500	425	87.6
38	8.3/7.5		15.2	1.7/1.6	20,500	418	88.1
	21.3		13.3	3.8		421	86.7
35*	4.5		15.7	0.9	20,800		88.2

* Boiler Smoke observed at stack and optical monitor swinging between 5. and 20% opacity.

- NOTE: 1. ENERAC instrument in boiler exhaust.
 2. Stack temperature obtained from inplace thermocouple (T/C) at boiler exhaust.
 3. ENERAC T/C reading typically 30°F below stack T/C.

Table 4

Percent Fan Capacity	Percent Excess Air	Oil gph	CO ₂ %	O ₂ %	Steam lbs hr.	Stack Temp °F	% Boiler Efficiency+
33	27.5	117	13.1	4.7	15,500	404	88.
41	60.		9.1	8.1	14,600	420	85.6
59			6.9	11.9		439	80.7
33**	12.5	135	14.4	2.5	18,000	410	88.6
38*	22.		13.1	3.9		416	87.9
43	37.5		11.6	5.9		422	86.7
48	46.3		10.7	6.9		427	85.9
53	65.		9.6	8.6		435	84.7
58			8.5	9.8		442	83.2
33***	6.5	150	15.7	1.3	20,000	399	84.4
40	14.		14.1	2.8		418	88
60			9.	9.3		443	83.5

Notes

+ ENERAC instrument in boiler exhaust

* Heavy smoke without catalyst injection

** Heavy soot/particulate emissions without catalyst

*** Erratic steam output due to inability to match steam load/pressure requirements with #3 boiler on baseload and #1 boiler on swing load

A portion of the improvement was due to the reduction in excess air afforded by the catalyst. This is also illustrated in Fig. 9, which includes over four months of data from operations preceding the catalyst tests. Additional illustration of the improvements in boiler efficiency and steam generation rate are given in Figures 10 and 11. At very high excess air (6%O₂ Fig. 10) the effects of the reduction in flame temperatures and excessive stack gas losses dominate the steam generation rate and, hence, boiler efficiency.

The amounts of catalytic material used are illustrated by the following use of platinum-containing catalytic material:

Injection Rates: .035gph solution=.035*.4 grams Pt/hour; thus, at 150gph oil or 1188.9 lbs/hour,

$$\frac{\text{Catalyst Rate}}{\text{oil rate}} = \frac{.035*.4}{1188.9*454} \frac{\text{grams}}{\text{gram oil}}$$

$$= .026*10^{-6} \text{ by weight } (.026\text{ppmw})$$

Assuming #6 oil is 88% Carbon by weight, then

$$\frac{\text{Catalyst Rate}}{\text{Carbon Rate}} = \frac{.026*12.011}{.88*195.09} \frac{\text{Moles Pt}}{\text{Moles C}} *10^{-6}$$

$$= 1.82*10^{-9} \text{ atoms Pt/atom C}$$

Range of rates tested were:

	<u>ppmw</u>	<u>atoms/atom</u>
	.0045	3.12*10 ⁻¹⁰
	.119	8.32*10 ⁻⁹
Preferred:	.026	1.82*10 ⁻⁹

Catalysts useful in the practice of the present invention include chloro platinic acid; (H₂PtCl₆.6H₂O); platinum tetrachloride (PtCl₄); ruthenium chloride (RuCl₃.H₂O); ruthenium oxide

($\text{RuO}_2 \cdot \text{H}_2\text{O}$); palladium nitrate ($\text{Pd}(\text{NO}_3)_2$);
palladium sulfate ($\text{PdSO}_4 \cdot 2\text{H}_2\text{O}$) and rhodium nitrate
($\text{Rh}(\text{NO}_3)_3 \cdot 2\text{H}_2\text{O}$). Magnesium oxide (MgO) and
manganese oxide (MnO) may also be used.

5 The catalyst introduction method selected for any
particular combustion chamber including external and
internal combustion systems depends on the combustion
chamber design and the size and shape of the flame zone
therein to be catalyzed.

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CLAIMS:

1. A system for delivery of a catalytic material to a combustion chamber (10,41) having a high temperature flame zone (20,44) therein characterised in that the system comprises
 - 5 a) admixing said catalytic material with a fluid medium;
 - b) introducing substantially all of said catalytic material as admixed into the flame zone (20,44).
- 10 2. A system as claimed in claim 1 in which the catalytic material is mixed with steam which steam and catalytic material are caused to atomize the fuel just prior to its entry into the flame zone (20,44).
- 15 3. A system as claimed in claim 1 in which the catalytic material is mixed with air which air and catalytic material are caused to atomize the fuel just prior to its entry into the flame zone (20,44).
4. A system as claimed in claim 3 in which the catalytic material is mixed with a stream of air prior to the air and catalytic material entering the flame zone (20,44).
- 20 5. A system as claimed in claim 4, in which the stream of air is normal chamber intake air.
6. A system as claimed in claim 4, in which the stream of air is a stream of air apart from the normal intake air.
- 25 7. A system as claimed in claim 1 in which the catalytic material is pumped as a liquid into the flame zone (20,44).
8. A system as claimed in claim 1 in which the catalytic material is mixed with the fuel prior to the mixture of fuel and catalytic material entering the flame zone (20,44).

9. A system as claimed in any preceding claim, in which the catalytic material includes a platinum group metal or compound thereof.

10. In a system for delivery of a catalyst material
5 to a combustion chamber (10,41) having a high temperature flame zone (20,44) which zone varies in size and volume as the amounts of combustible materials fed to the chamber are varied, said system being characterised in that the system comprises

- 10 1) determining the size and volume of the zone (20,44) in the chamber (10,41);
- 2) introducing catalyst material into the chamber (10,41);
- 3) controlling such introduction so that
15 substantially all of the catalyst material is fed directly into the said zone (20,44).

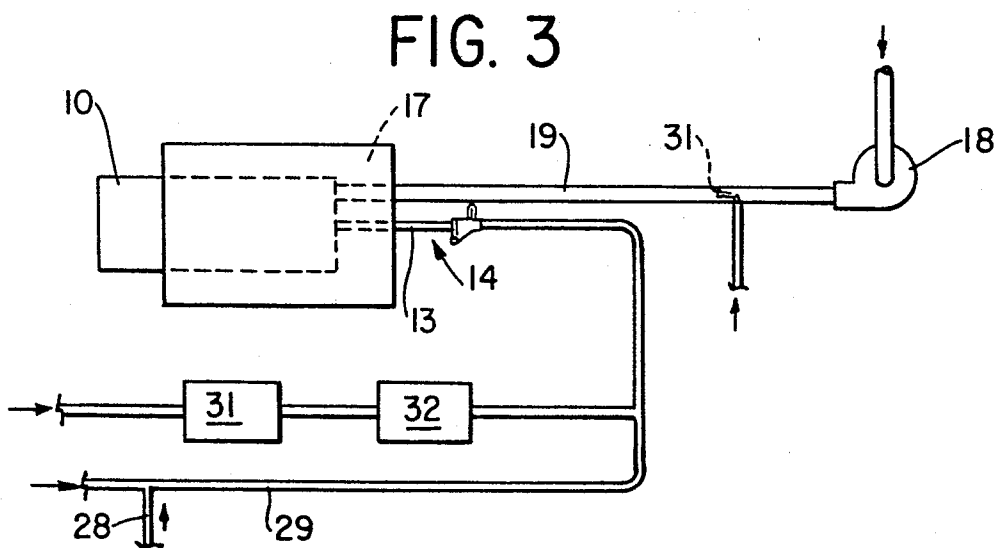
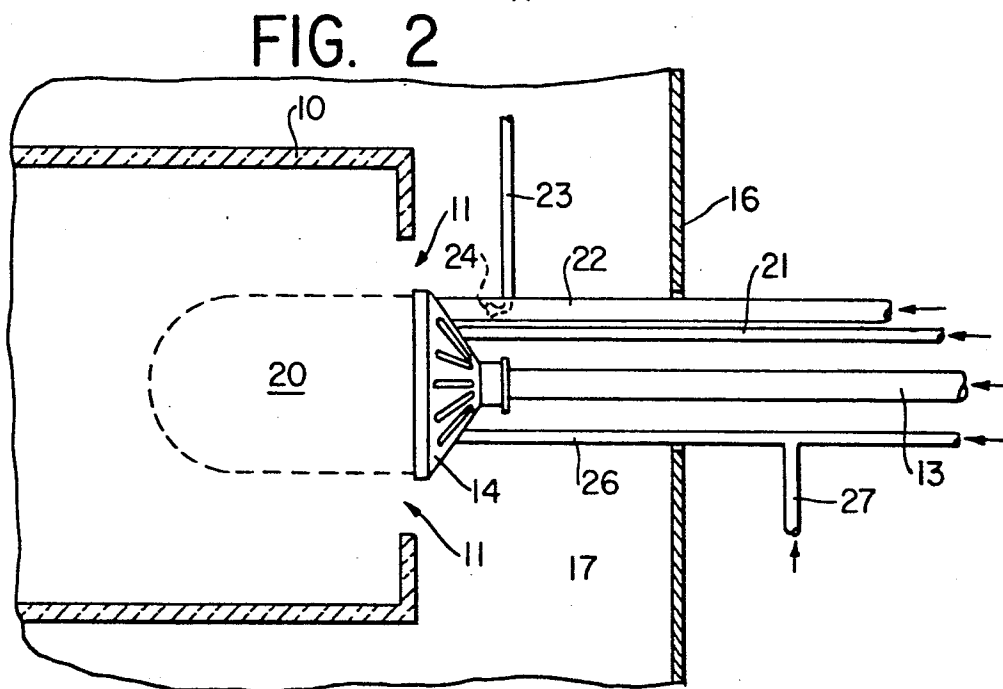
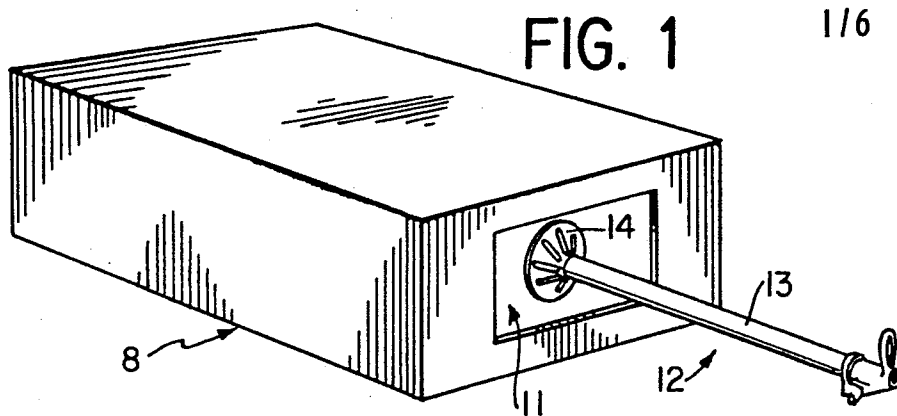


FIG. 4

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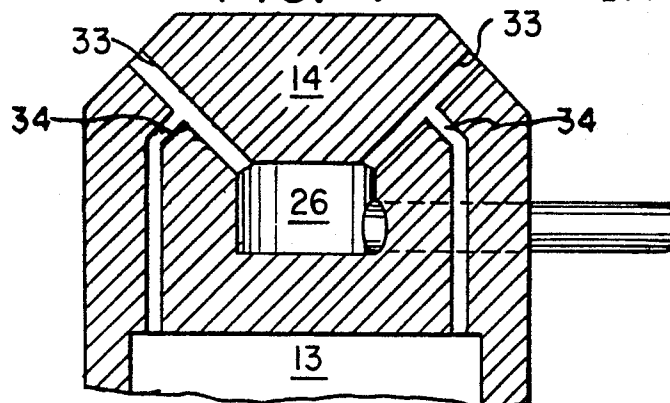


FIG. 5

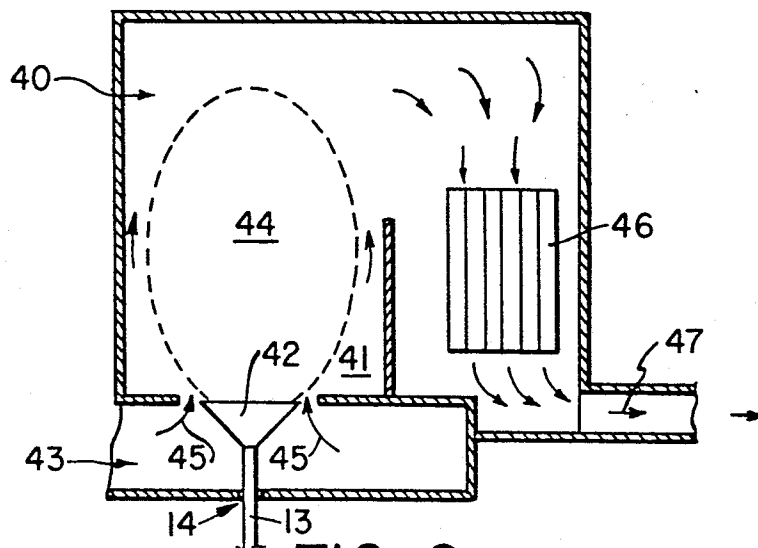
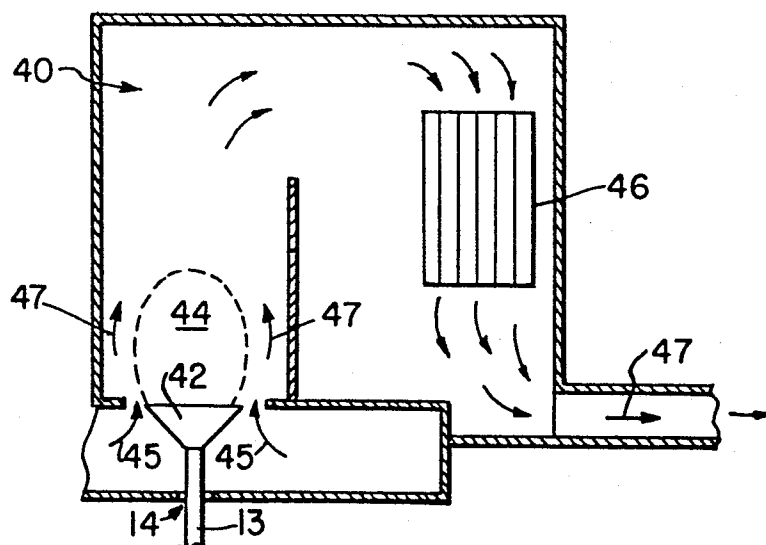


FIG. 6



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FIG. 7a

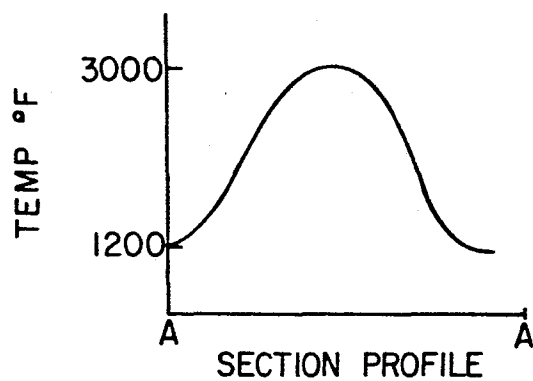


FIG. 7b

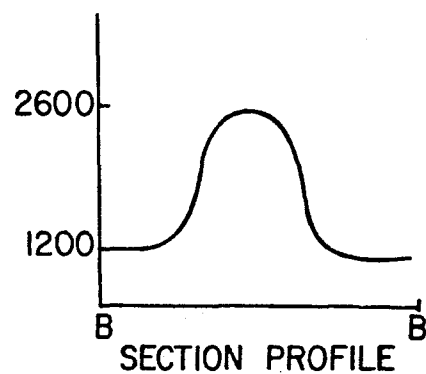


FIG. 7c

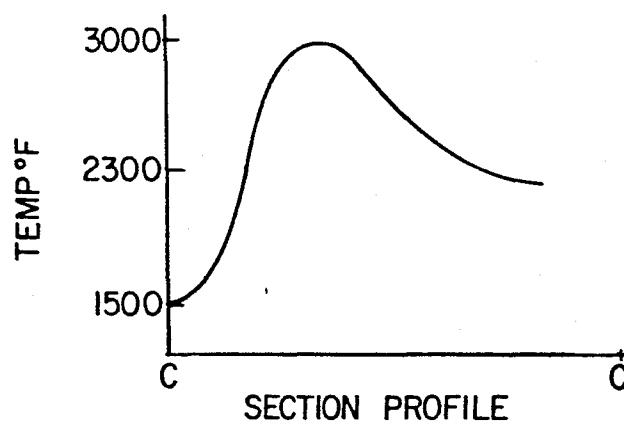
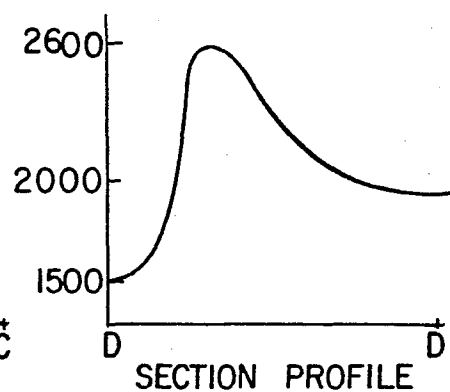


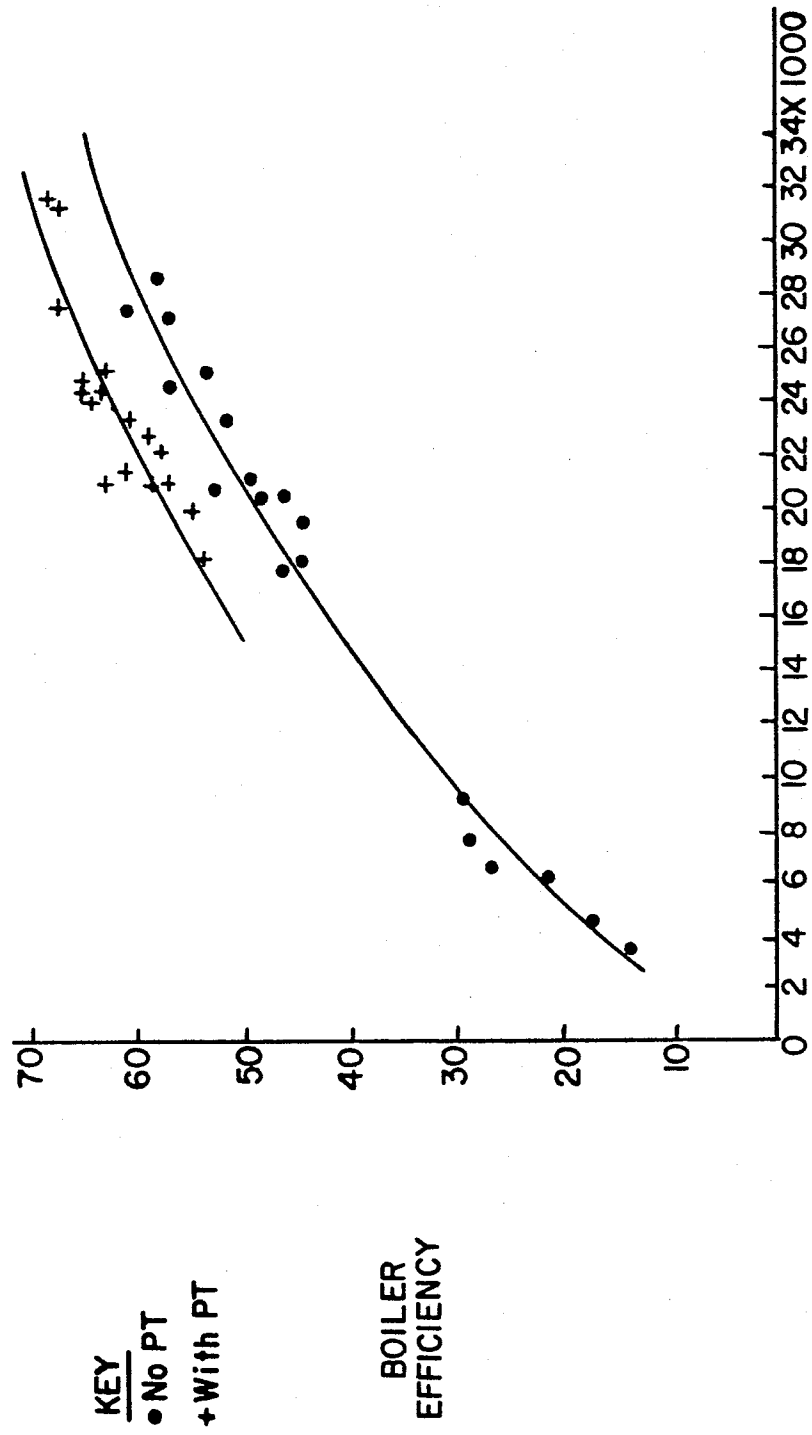
FIG. 7d



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FIG. 8

EFF VS. STEAM RATE



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FIG. 9
STEAM VS. FUEL

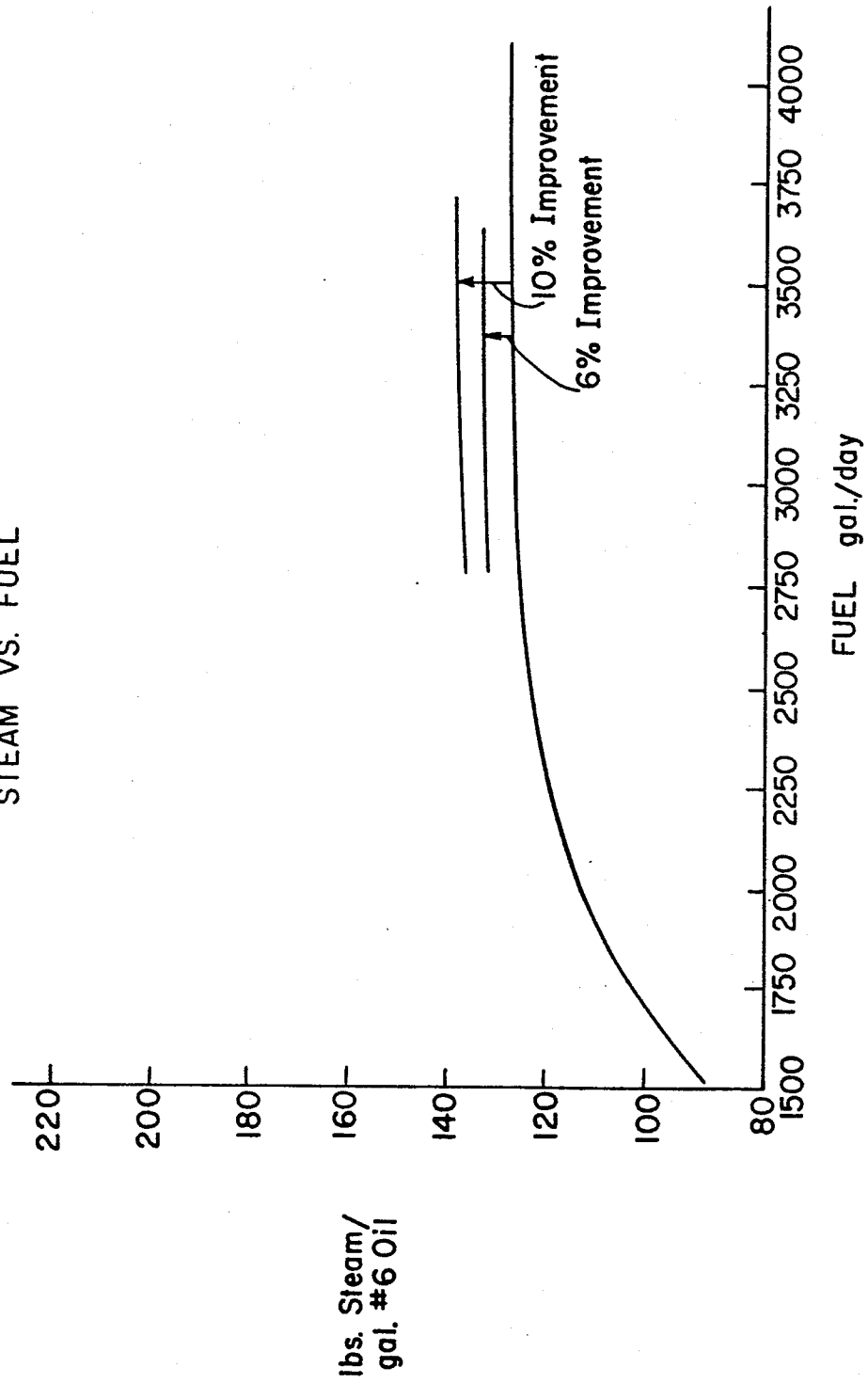


FIG. 10

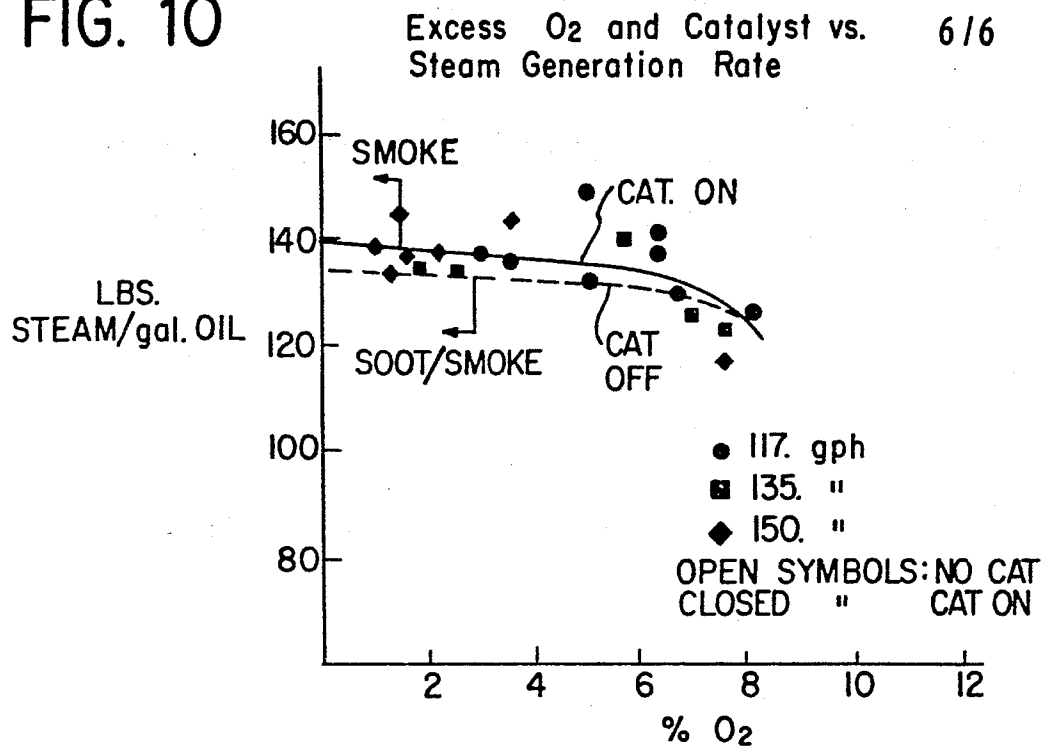


FIG. 11

Effect of Catalyst on Steam Generation Rate

