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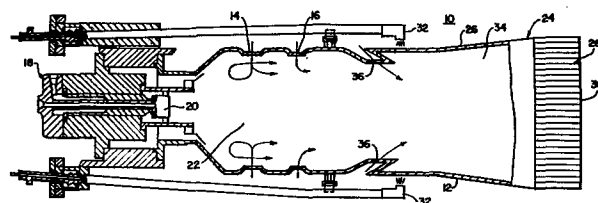
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54 **Turbine combustor having more uniform mixing of fuel and air for improved downstream combustion.**

57 A combustor (10) for a structure with a land based combustion turbine, comprises a generally tubular sidewall (12) having a downstream-mixing zone (34) where a mixture of fuel and air is developed for downstream combustion, said tubular structure further having an upstream primary zone (22) into which air is admitted through sidewall openings to develop an axial airflow for mixing with downstream injection fuel, means (32) for spraying fuel in the form of small rapidly evaporable droplets generally radially inwardly of the tubular structure through said sidewall (12) at a location between said primary zone (22) and said mixing zone (34) for mixing with the primary air flow, a catalyst (28) is disposed in the combustor tubular structure at the outlet of said mixing zone (34), a plurality of circumferentially disposed air scoops (36) are located in upstream proximity to said fuel spraying means (32) and directed downstream to produce said booster air streams.



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TURBINE COMBUSTOR HAVING MORE UNIFORM  
MIXING OF FUEL AND AIR FOR IMPROVED  
DOWNSTREAM COMBUSTION

The present invention relates to combustors employed in land based combustion turbines and more particularly to catalytic combustors in which substantially uniform mixing of fuel and air across the combustor mixing zone is needed prior to entry of the mix into the catalytic combustion zone.

Premixing of fuel and air in premix combustors is needed to provide long combustor life, high combustor efficiency and low emissions through proper combustion operating temperatures and proper reaction. Catalytic combustors provide a practical commercial alternative for low pollutant, and especially low NO<sub>x</sub>, combustion turbine operation for electric power plants and other land based applications; proper catalytic combustion especially requires substantial uniformity in the premixing of fuel and air within the combustor mixing zone.

In view of certain operating compressor-discharge-pressure levels in most engine designs, some preheating of fuel is needed for proper catalytic combustion. A catalytic combustor may be provided with a generally tubular envelope having a primary combustion zone followed in sequence first by a secondary fuel injection and mixing zone and finally by a catalyst zone. The primary combustion zone operates for example during startup when operating temperatures do not adequately support

catalytic combustion. During the catalytic combustion phase of operation, secondary fuel is injected into the mixing zone where it mixes with air for delivery to the flow channels through the catalyst zone.

5           Typically, the secondary fuel injectors are disposed circumferentially about the mixing zone and they may inject fuel radially inwardly at a right angle or other preferred angle into the combustor mixing zone. Further, the fuel must be preferably completely vaporized  
10 before entering the catalyst which requires that the fuel nozzle produce very small droplets which can evaporate rapidly. Small droplets can be obtained by using a very high fuel nozzle pressure drop (pressure atomization), by using a small amount of high energy atomizing air (air  
15 assist), or by using a relatively large amount of low energy atomizing air (air blast). In all cases, the momentum of the resulting fuel spray is quite high. In fact the momentum of the fuel spray with respect to the momentum of the cross flowing air inside the combustor is  
20 high enough that the fuel tends to penetrate to the center (axis) of the combustor. This action produces a fuel rich core, i.e. the fuel/air ratio profile has a single center peak shape across a reference diameter of a cross section of the combustor mixing zone.

25           The fuel/air ratio is highest at the axis in the fuel injection plane or region, and it decreases in the radially outward direction. As the mix flows downstream through the mixing zone, additional mixing action causes the fuel/air ratio profile to flatten somewhat. In gen-  
30 eral, however, the fuel penetration in the injection region is such that there is too much axial fuel concentration to permit available downstream mixing to produce a substantially uniform fuel/air ratio distribution at the catalyst entry plane.

35           In accordance with the present invention, improved operation is obtained in combustors and especially catalytic combustors through structure which assists

deflection of injected fuel in the axial direction to produce more uniform mixing of fuel and air in a mixing zone located immediately upstream from the zone where combustion occurs. Preferably, the structure includes circumferentially distributed holes in the combustor wall upstream from the fuel injectors such that entering air streams are angled downstream. The entering air streams have high velocity due to the pressure drop across the combustor wall and accordingly greatly assist the internal gas flow in axially deflecting the injected fuel and producing a substantially uniform fuel/air ratio profile at the catalyst entry plane.

Figure 1 shows an elevational view of a catalytic combustor having portions thereof cut away and being arranged in accordance with the principles of the invention.

Figure 2 shows a schematic diagram of a catalytic combustor like that of Figure 1 with operating features of the invention illustrated in greater detail.

Figure 3 shows a diagram like that of Figure 2 but representing an alternative embodiment in which external air scoops are employed.

Figure 4 shows test results obtained with use of the present invention as compared to results obtained with a prior art reference.

Figure 5 shows a diagram of a prior art combustor configuration used in obtaining comparative test results.

More particularly, a catalytic combustor 10 is shown in Figure 1 for a land based combustion turbine which is typically used in electric power and other industrial plants.

The combustor 10 includes a generally tubular sidewall 12 having successive circumferential rows of holes 14, 16 for entry of air used in the combustion process. At a head end 18 of the combustor 10, a primary fuel nozzle 20 admits fuel for burning in a primary zone

22 to generate the energy needed for startup until operating conditions support catalytic combustion. In addition, the primary nozzle 20 supplies some fuel for primary combustion during catalytic operation to provide any  
5 preheating needed to keep the gas temperature at a catalyst entry plane 24 at the value needed (i.e. approximately 1800 - 1950°F) for efficient catalytic combustion. The overall combustor operation involves amounts of primary fuel combustion such that NOx production is well  
10 below prescribed environmental limits.

An outlet end 26 of the combustor wall 12 is outwardly flared and coupled to a conventional catalyst element 28 having a honeycomb structure. In turn, the catalyst region outlet 30 is coupled to a transition duct  
15 (not shown) which directs the hot gases to the turbine (not shown).

Secondary fuel is injected into the combustor 10 during the catalytic combustion phase of operation by a set of circumferentially spaced nozzles 32 at the downstream end of the primary combustor zone 22. Air may or may not enter the combustor 10 at the nozzle locations. A combustor mixing region 34 between the primary zone and the catalyst element 28 provides for mixing of the secondary fuel and air prior to its entry into the catalyst  
20 region 28. The region 34 is referred to as a mixing zone, and combustion is avoided and does not occur in this zone since flashback can damage the combustor and/or catalyst 28. As more fully described in connection with Figures 2 and 4, a circumferential row of air holes 36 immediately  
25 upstream of the secondary fuel injections in the combustor sidewall are angled to admit air in the downstream direction to produce uniform mixing of the secondary fuel and air in the mixing zone 34.  
30

As shown in the enlarged view of Figure 2,  
35 internal angular scoops 37 are provided for producing an angled air stream flow 39 through the holes 36 so as to assist in deflecting the secondary fuel to produce a

substantially uniform fuel/air mixture for the catalyst 28. As shown in Figure 2, the angled air stream 39 significantly assists internal crossflow air 41 in deflecting the fuel spray produced by the secondary fuel nozzles 32.

5 In Figure 3, an alternate embodiment is illustrated in which external scoops 33 produce similar fuel-air mixing action.

Generally, the fuel/air distribution is controlled and the center peaked fuel/air mix situation is  
10 avoided by taking advantage of the pressure drop across the combustor wall or liner 12. This pressure drop is typically high enough that the velocity of the air entering the combustor 10 through holes is much higher than that of the air already flowing inside the combustor 10.  
15 Therefore, the momentum flux (momentum per unit area per unit time) of the entering air is much higher. With plunged holes or scoops located just upstream of the fuel spray and angled downstream, the high velocity of the air admitted through the holes provides a basis for avoiding  
20 the nonuniform center peaked fuel/air mix situation. In fact, the angle of the holes can be varied to control the fuel/air mix profile entering the catalyst region 28.

With the provision of angled air admission as described, sidewall injection of fuel for catalytic combustors is capable of giving the needed even fuel/air  
25 mixture approaching the catalyst.

As shown by test results in Figure 4, the catalyst outlet temperature, which reflects the catalyst entry fuel/air ratio profile, shows a relatively even distribution 44 (i.e. a generally flattened shape) for an embodiment of the invention as compared to the center peaked distribution for the prior art. Figure 5 shows the configuration used for the prior art in the test while Figure 5 shows the invention configuration used in the test. The  
35 provision of angled air streams in the invention configuration is the principal reason for the improvement. The improved mixing is believed to occur as a result of deflec-

tion of the fuel spray by the angled air stream to a more advantageous mix location and/or possibly as a result of air boosted turbulent kinetic energy in the region where the secondary fuel spray enters the combustor.

5           The following are the conditions applicable to the test of Figure 4:

COMPARISON OF CATALYST OUTLET TEMPERATURE  
PROFILES FROM FULL SCALE TESTS

| 10 |                                    | <u>Prior Art</u>            | <u>Invention As<br/>Tested in a<br/>Laboratory</u> |
|----|------------------------------------|-----------------------------|----------------------------------------------------|
|    | AIR INLET TEMP.:                   | 757°F                       | 701°F                                              |
|    | AIR INLET PRESS.:                  | 100.1 psig                  | 151.6 psig                                         |
|    | CATALYST APPROACH                  |                             |                                                    |
| 15 | VELOCITY:                          | 73.6 fps<br>(feet per sec.) | 79.4 fps<br>(feet per sec.)                        |
|    | PRESSURE DROP:<br>(CATALYST)       | 3.47%                       | 3.85%                                              |
|    | FUEL/AIR RATIO:                    | 0.0139                      | 0.0136                                             |
| 20 | ATOMIZING AIR                      |                             |                                                    |
|    | PRESS. DROP,<br>(SECONDARY NOZZ.:) | 73.5 psid                   | 185.3 psid                                         |

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CLAIMS:

1. A combustor for a land based combustion turbine, comprising: a generally tubular structure with a sidewall and having a downstream mixing zone where a mixture of fuel and air is developed for downstream combustion, said sidewall further having sidewall-openings and an upstream primary zone into which air is admitted through said sidewall-openings to develop an axial airflow for mixing with downstream secondary injection fuel, fuel spraying means for spraying secondary fuel in the form of relatively small rapidly evaporable droplets directed generally radially inwardly through said sidewall at a location between said primary zone and said mixing zone for mixing with the primary air flow, and air stream directing means for directing booster air streams on the sprayed fuel at a predetermined angle to the axis of the tubular structure to boost the mixing of fuel and air for improved uniformity of the fuel/air mixture at an outlet of mixing zone, said booster air streams having a higher velocity than that of a crossflow air from the primary zone.

2. A combustor as in claim 1 wherein a catalyst is disposed in the combustor sidewall at the outlet of said mixing zone.

3. A combustor as in claim 2 wherein a head end region of said combustor includes a primary fuel nozzle which supplies fuel for combustion in said primary zone to supplement the catalytic combustion under limited predetermined operating conditions.



4. A combustor as in claim 2 wherein said air stream directing means comprise a plurality of circumferentially disposed and spaced air scoops located in upstream proximity to said fuel spraying means and pointing in downstream direction to produce said booster air streams.

5. A combustor as in claim 4 wherein said scoops are located substantially externally of said combustor sidewall.

10 6. A combustor as in claim 4 including means to vary said predetermined angle of said booster air streams.

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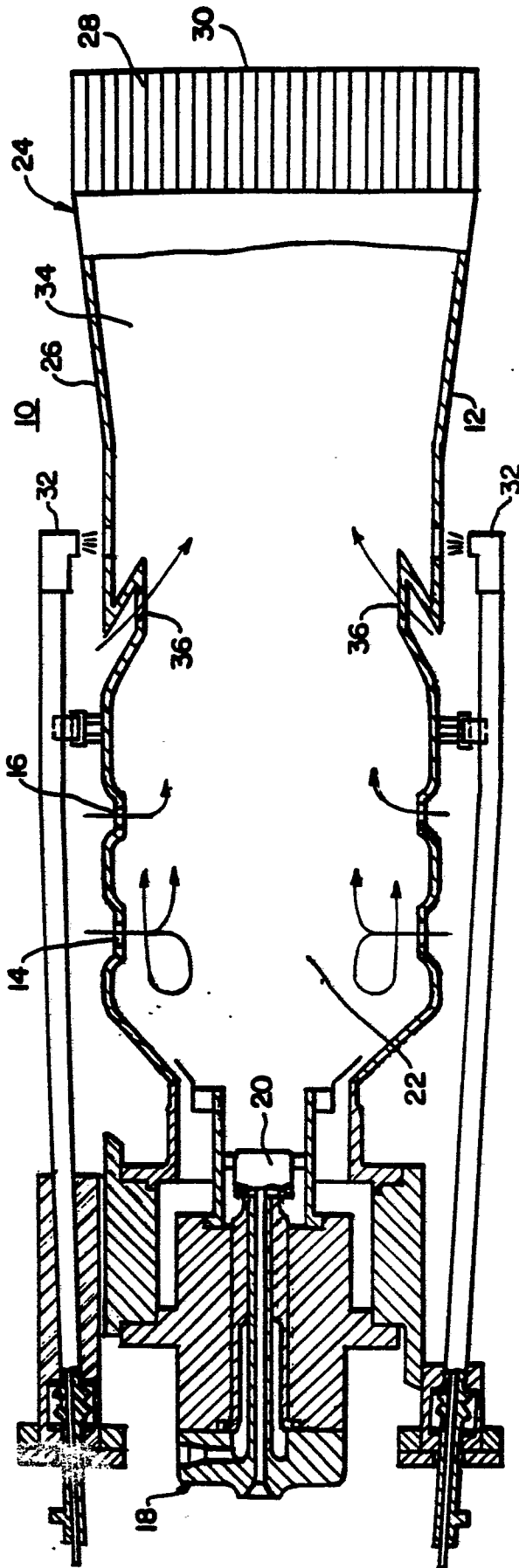
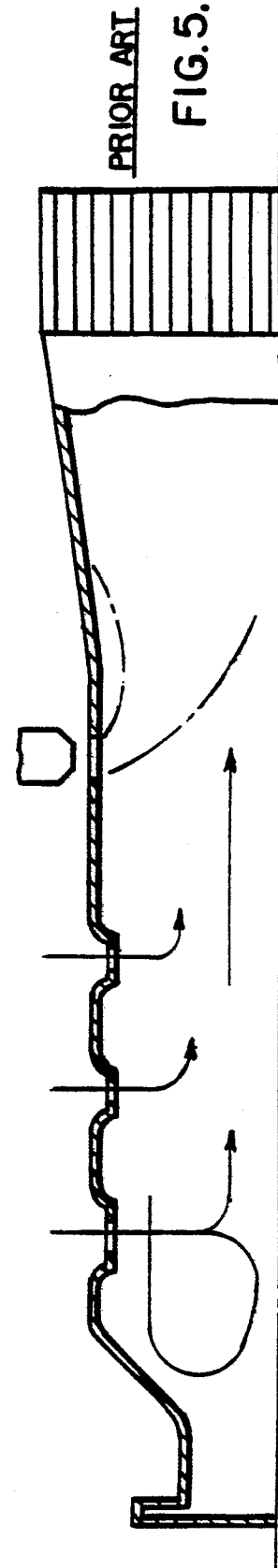


FIG. 1.



PRIOR ART

FIG. 5.

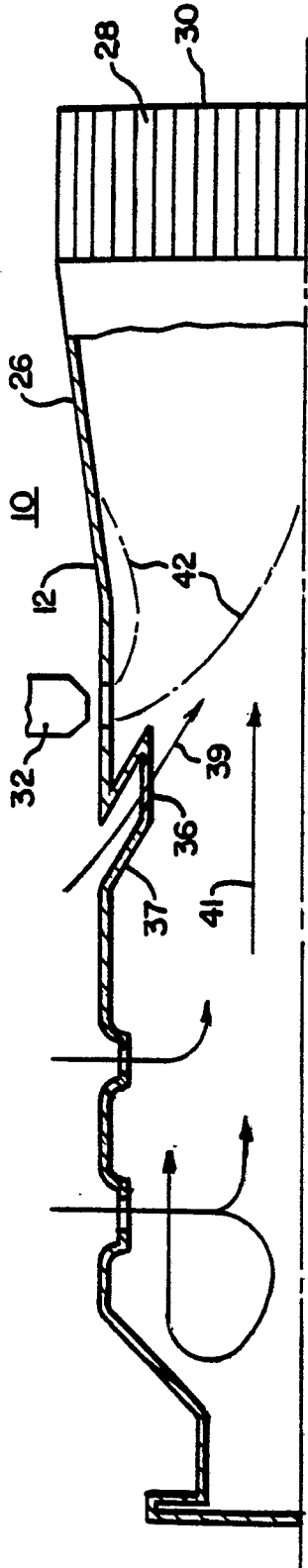


FIG. 2.

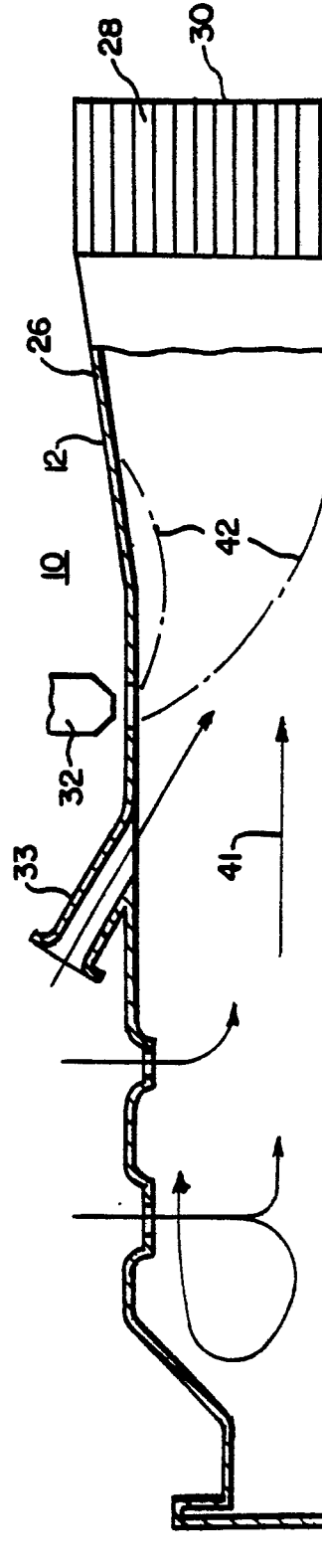


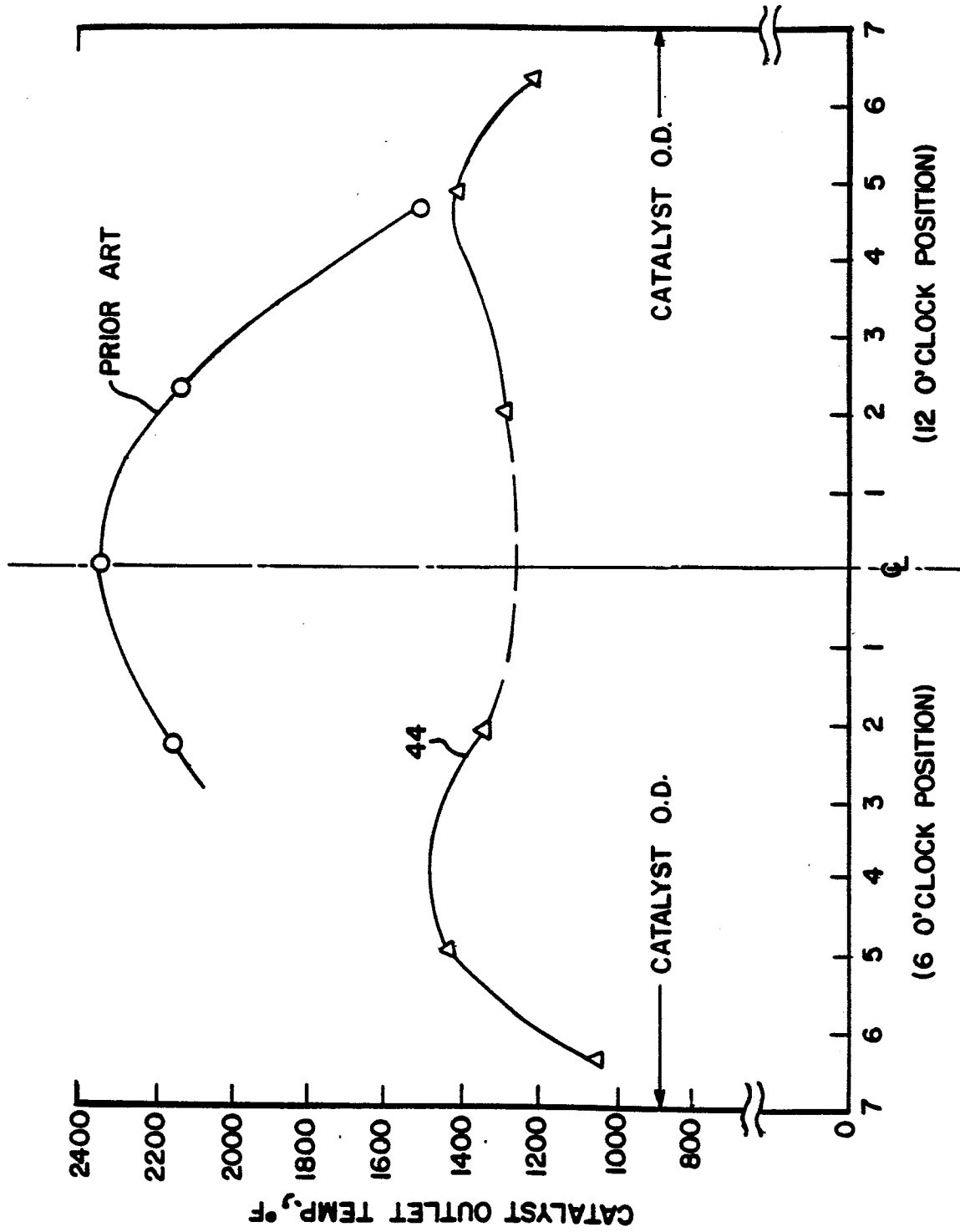
FIG. 3.

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FIG. 4.





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| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                     |                                                |                                                                      |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|------------------------------------------------|----------------------------------------------------------------------|
| Category                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Citation of document with indication, where appropriate, of relevant passages       | Relevant to claim                              | CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)                       |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <u>US - A - 3 937 008</u> (MARKOWSKI et al.)<br>* Fig. 1,4,5,12, numerals 56, 104 * | 1,3                                            | F 23 R 3/06                                                          |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <u>US - A - 3 934 409</u> (QUILLEVERE et al.)<br>* Fig. 1,2, numerals 26,31 *       | 1                                              |                                                                      |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <u>GB - A - 1 575 427</u> (ENGELHARD MINERALS & CHEMICALS CORP.)<br>* Fig. 2 *      | 1-3                                            |                                                                      |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <u>US - A - 2 579 614</u> (RAY)<br>* Totality *                                     | 1                                              | TECHNICAL FIELDS SEARCHED (Int. Cl. 3)<br>F 23 R 3/00<br>F 02 C 7/00 |
| The present search report has been drawn up for all claims                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                     |                                                |                                                                      |
| Place of search<br>VIENNA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                     | Date of completion of the search<br>17-11-1983 | Examiner<br>PIPPAN                                                   |
| <b>CATEGORY OF CITED DOCUMENTS</b><br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document<br>T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>& : member of the same patent family, corresponding document |                                                                                     |                                                |                                                                      |