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(71) Applicant
Michael George Berry,
Kingswood House, Kits Coty, Nr Aylesford, Maidstone, Kent ME2Q 7EL

(72) Inventor
Michael George Berry

(74) Agent and/or Address for Service
M. G. Berry,
Kingswood House, Kits Coty, Nr Aylesford, Maidstone, Kent ME2Q 7EL

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GB 1482826	**GB 1261366**

(58) Field of search
B1W

(54) Exhaust catalytic combustor

(57) An exhaust combustor is used to boost the waste exhaust gas of an engine to a pre-designed state enabling further use (eg in a heat exchanger or inert gas plant). Connected to the engine exhaust it has an outer shell 21, causing the waste gases to pass through a particulate filter 29 and flash arrestor 31 prior to being injected with fuel 32 and admixed in static mixer 33. Normal exhaust temperature (or burner 28 for rapid warm-up) initiates the oxidisation or combustion process within a highly selective catalyst 34 which utilizes precious metal to gain maximum combustion efficiency at a prefered operating range of 1100–1450°C. Where required, air is supplied at 30 for combustion and 35 for increased mass to gain engineered thermal/mass balance.

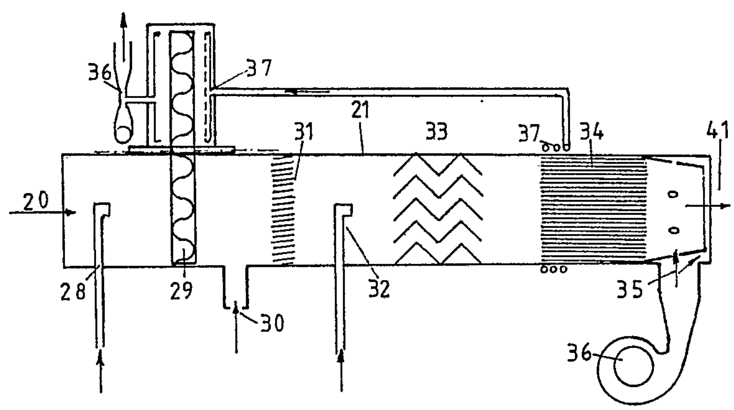

FIG 3

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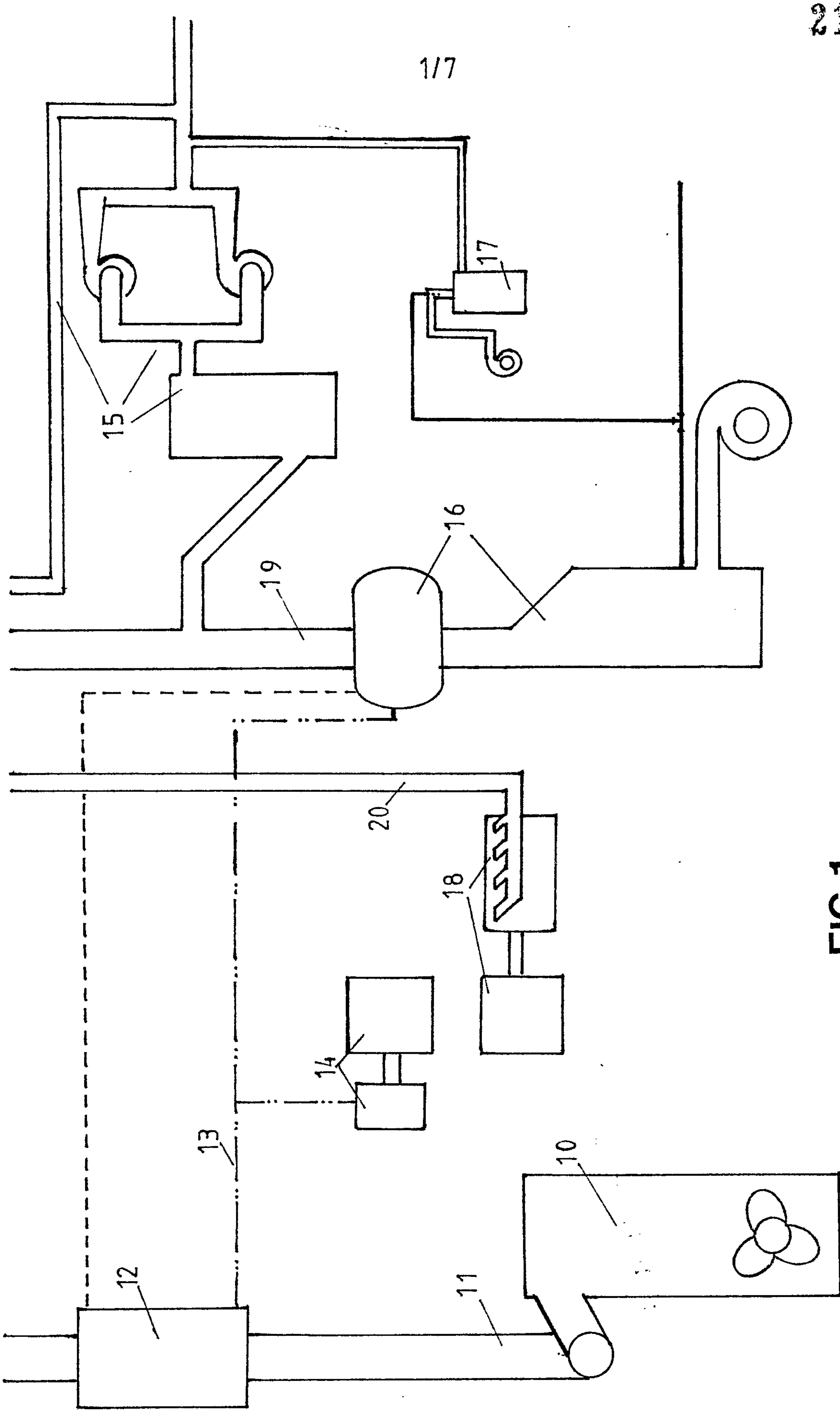

FIG 1

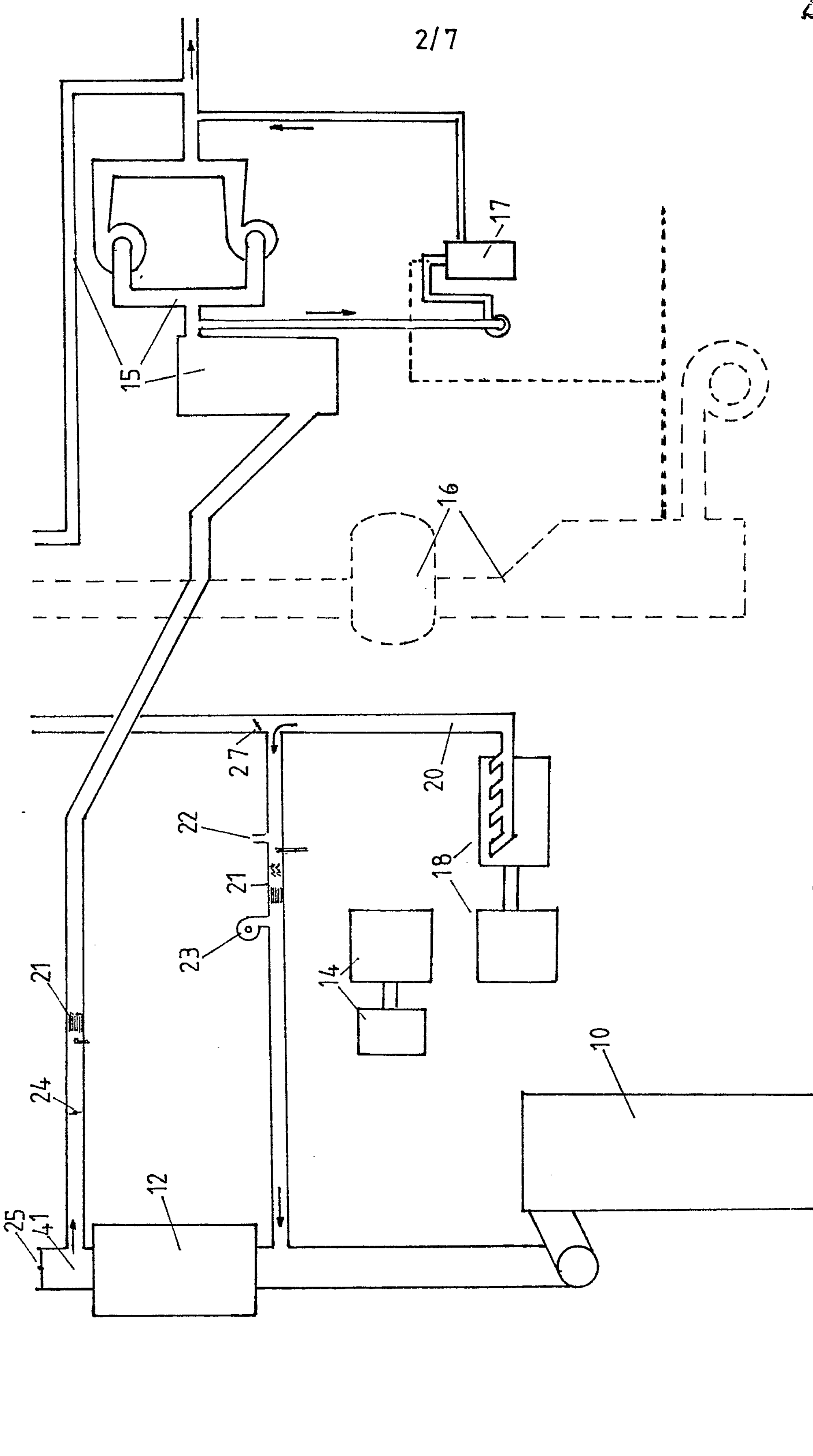

FIG 2

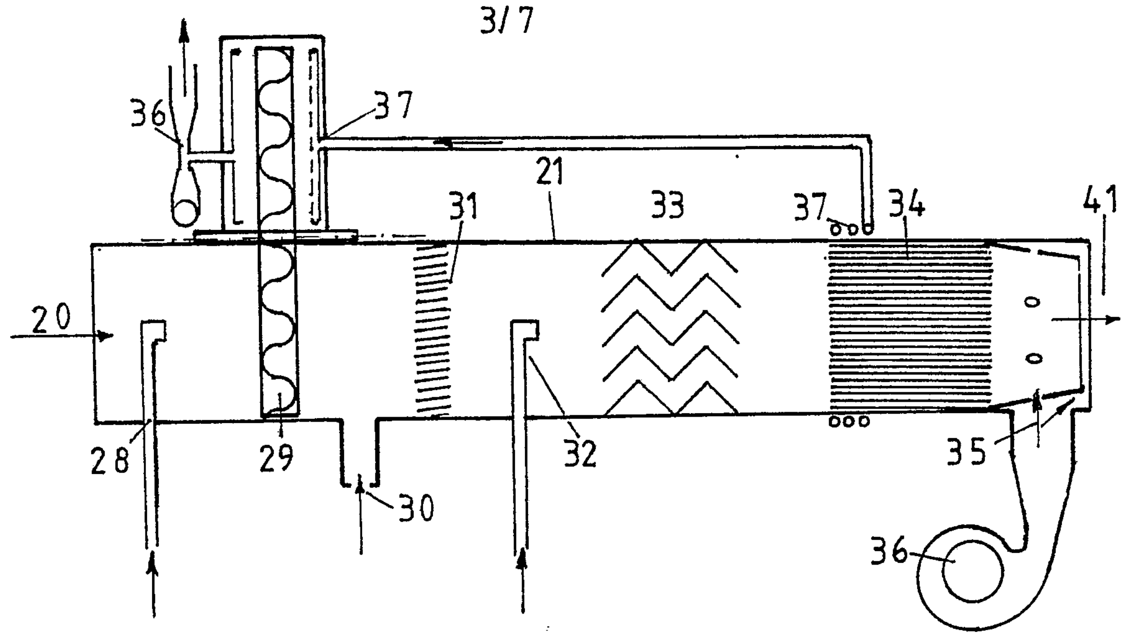

FIG 3

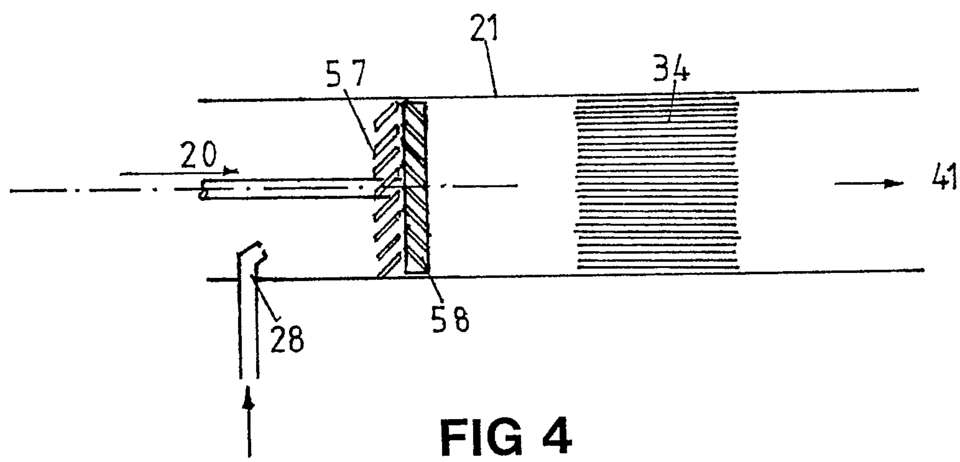

FIG 4

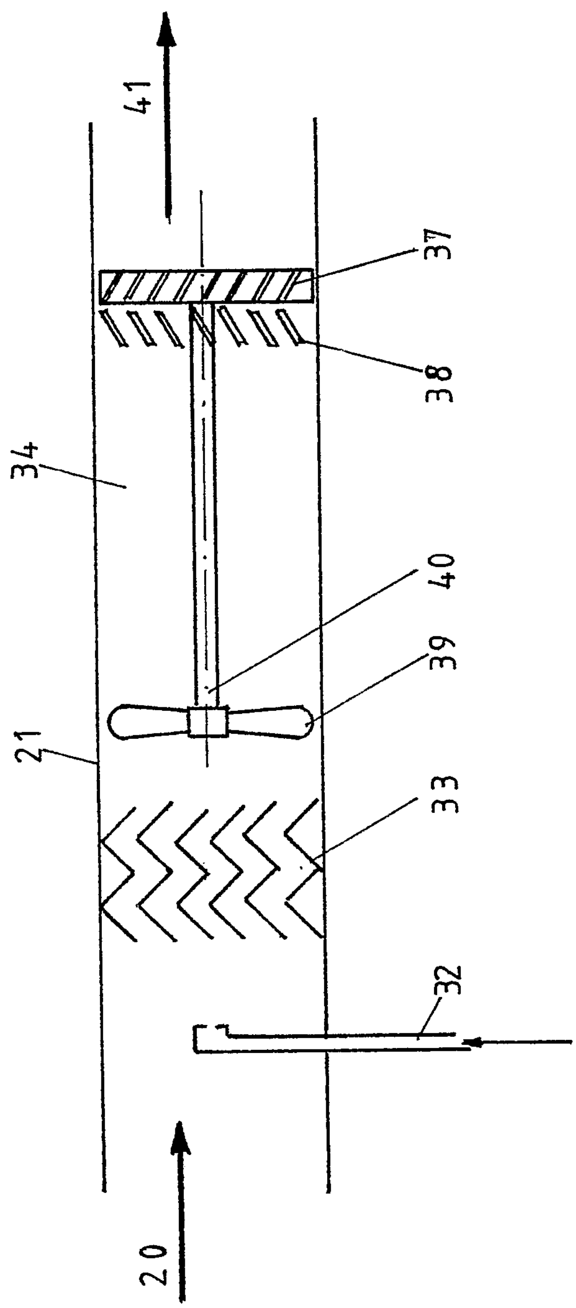

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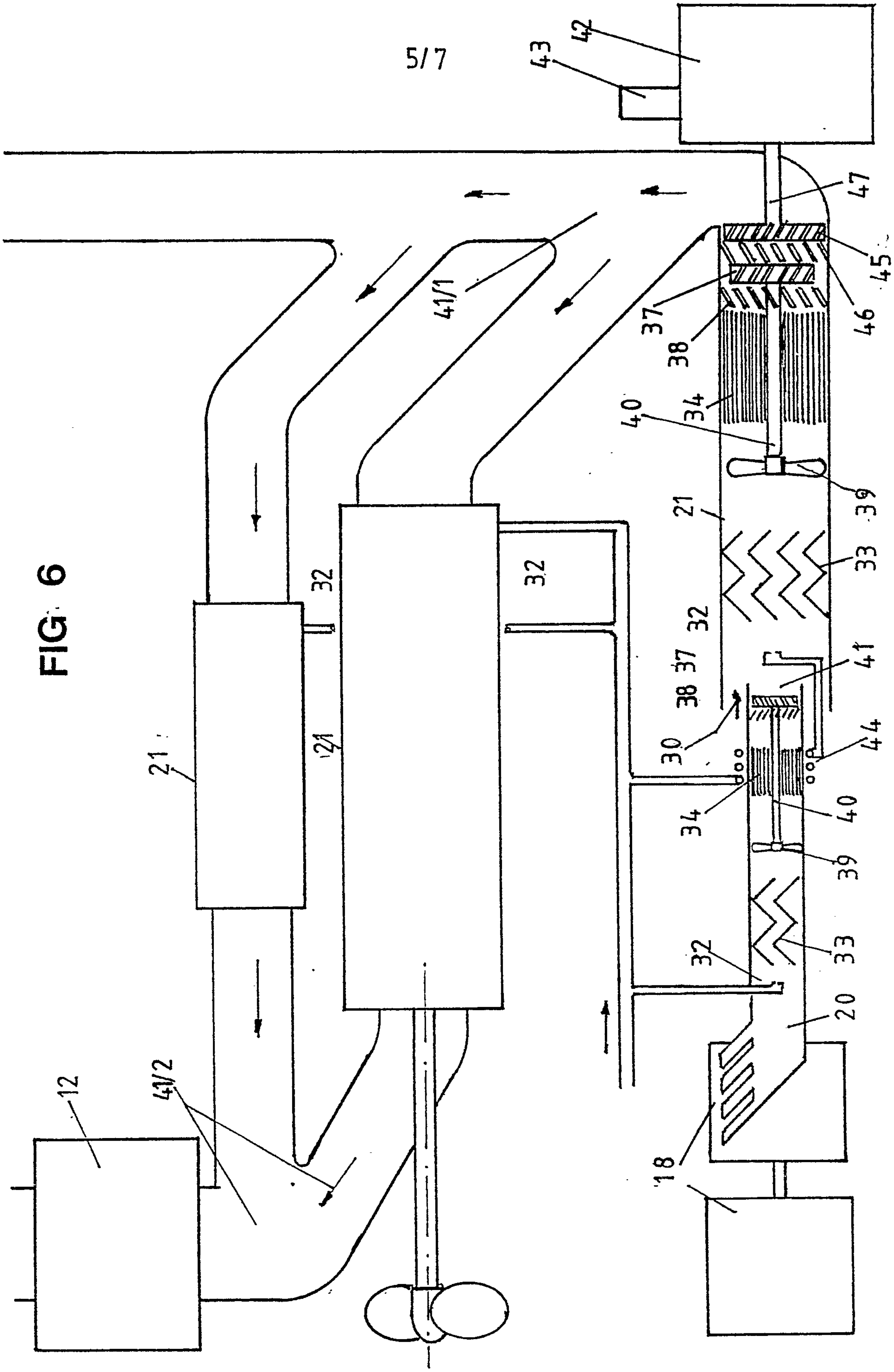
FIG 6



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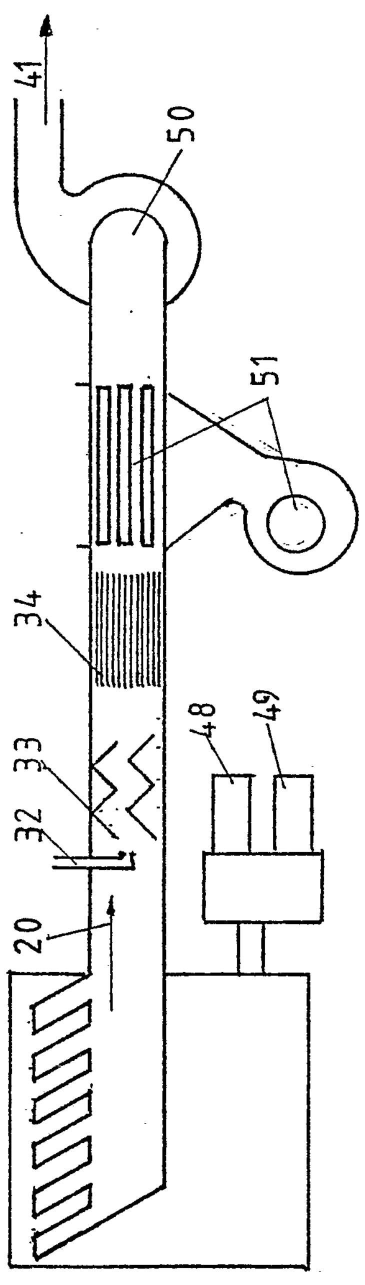
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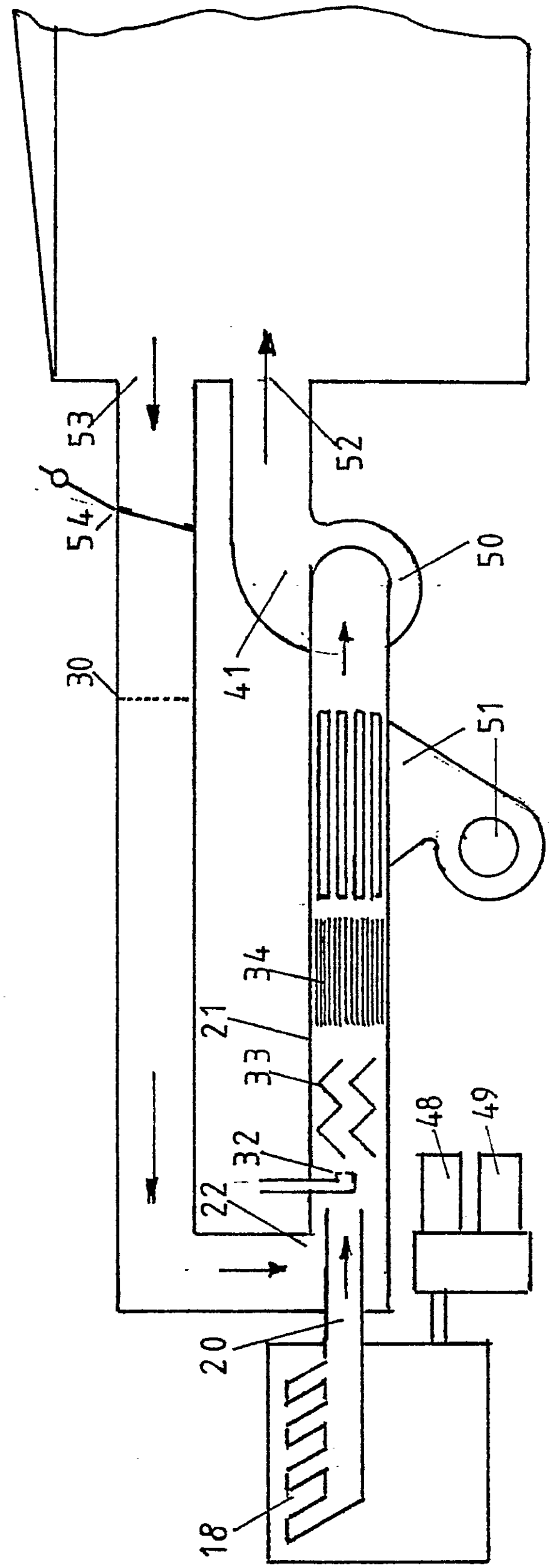
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FIG 8

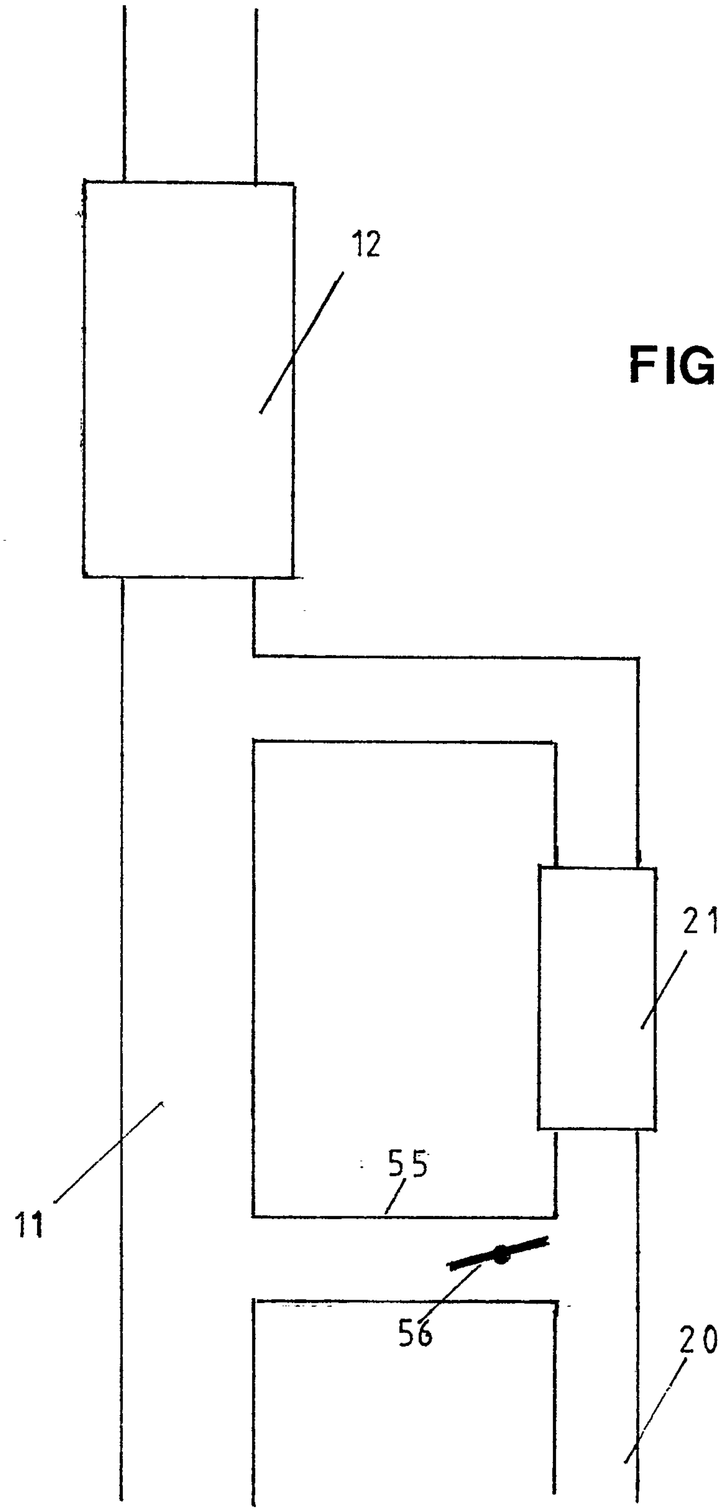

FIG 9

SPECIFICATION

Exhaust catalytic combustion

This invention relates to the use of catalysts to deliberately oxidise injected fuel under controlled conditions to enhance the existing values of an engine's exhaust gas.

The use of catalysts are well known. They have been demonstrated as being able to form the basis of boiler and gas turbine combustion systems. They have been used to remove pollutants from exhaust gas streams and where feasable, any temperature increase has been utilized as per normal engineering practice (eg through heat exchanges).

The recovery of heat from exhaust systems through waste heat boilers or economisers is also common practice. However, there are certain situations where the normal useful energy of an engine exhaust is insufficient to meet local requirements and additional separate energy sources has to be gained.

This additional energy requirement where there are existing engine exhaust occurs in many industrial plants. However, this invention is easily related to marine tanker vessels because of their specific operational needs.

The propellar of the marine tanker shown as an example in figure 1 is driven through the water while underway by the vessels main diesel engine 10. The engine exhaust 11 is passed through an economiser 12 to provide steam 13 for general services and to drive a turbo-electrical generator 14. Being a tanker the vessel requires a tank inert gas system 15, but due to the long warm up period and large quantities of fuel used in the auxilary boiler 16, a small oil-fixed inert gas generator 17 is used to top-up the inert gas system 15.

In port the vessel's main engine 10 and turbo-generator 14 are shut-down. To provide electrical power a diesel generator 18 is started. The diesel generator 18 exhaust 20 is insufficient (both in heat and volume) to power the economiser and steam 13 is provided by the auxiliary boiler 16.

The auxilary boiler 16 exhaust 19 is used to inert the vessel's tanks (not shown). During this inerting the boiler 16 must be controlled to ensure that the oxygen content of the exhaust gas 19 is 5% or less by volume.

Though figures vary from vessel to vessel according to design and size, the heat exchange surface area of the main engine economiser 12 is normally larger than the auxilary boiler 16 tube surface area. In general terms economiser 12 use extended surface tubes to gain efficient heat transfer at low (300°C or less) inlet temperatures. Their design (by classification rules), must conform to the same pressures etc. required by the auxilary boiler 16. This permits temperatures of 500°C and even higher to be used giving increased water/steam flows.

Where an inert gas system is fitted, the proportions are again generally similar (ie the larger the vessel, the greater the pumping/cargo discharge rate, the more powerful the main engines) and the main engine exhaust is roughly equal to the volumetric through-put of the inert gas system.

According to the present invention, there is provided an exhaust catalytic conbustor comprising:

a) An outer shell with means to connect to an engine exhaust.

b) A pilot burner fueled by an injector to cause rapid warm-up and permit purging operations.

c) A filter to trap particulate matter where certain engine combustion efficiencies are less than the normally expected.

d) A flash-back arrestor where the exhaust gas is liable to become explosive when fuel is added.

e) An injector(s) to provide fuel proportionally to the additional requirements.

f) An air inlet to provide additional air for combustion on low oxygen exhausts.

g) A static mixer to blend exhaust, fuel and any additional air.

h) A highly selective catalyst utilising precious metal to gain maximum combustion efficiency.

i) A secondary inlet to balance mass and thermal outlet value to external requirements.

j) A mean to overcome system pressure head losses.

All being designed for the purpose of increasing the thermal capacity of an engine exhaust gas.

Specific embodiments of the invention will now be described by way of examples with reference to the accompanying drawings in which:

Figure 1 schematically depicts an existing marine tanker operational power layout;

Figure 2 schematically depicts the same vessel utilizing exhaust catalytic combustors;

Figure 3 details an exhaust catalytic combustor suitable for an exhaust gas from an engine with poor combustion characteristic (ie large particulate mass of unburnt hydrocarbons and the incombustable elements remaining from the original fuel);

Figure 4 details an exhaust catalytic combustor suitable for a standard engine exhaust (ie well maintained fuel injectors/planed maintenance etc.);

Figure 5 details an exhaust catalytic combustor complete with a turbo-blower/expansion turbine;

Figure 6 details exhaust catalytic combustors on a vessel specifically designed for their use;

Figure 7 depicts a portable inert gas generating exhaust catalytic combustor;

Figure 8 details an exhaust catalytic combustor in gas recycle mode;

Figure 9 demonstrates the use of an exhaust catalytic combustor to assist a vessel during reduced operating conditions.

Refering to Figure 2 with the vessel in port, the main engine 10 and turbo-generator 14 is shut down and the diesel generator 18 started. Valve 27 is closed and the exhaust gas 20 is passed through the exhaust catalytic combustor 21 (instead of to atmosphere as shown in Figure 1). The exhaust gas 20 temperature (300/400°C) causes the catalytic to be heated to the point where injected fuel can be oxidised. The volume of fuel injected is controlled to equalise or better the thermal operating requirement of the economiser 12. Normally there would be sufficient free oxygen in the exhaust 20 to gain the thermal energy required. Should there be any oxygen deficiency, this is catered for by the addition of combustion air at inlet 22.

Dependent on economiser 12 design provision is made for the addition of ambient air either through the combustion inlet 22 as excess air or through the secondary air 23 inlet to conform with the economiser's normal volumetric through-put. This is to prevent any excessive temperatures or hot spots occuring in the economiser 12 and to ensure sufficient gas 41 volume for inert gas operation.

Having provided the operational steam requirements the exhaust gas 41 must pass to the inert gas system through valve 24. When there is a possibility of gas being drown down from atmosphere, an additional valve 25 installed in the exhaust stack must be made to close.

Should the addition of excess air 22 or secondary 23 have caused an increased of oxygen above the 5% by volume required for inerting operations, then the exhaust gas 41 must pass through a second exhaust catalytic combustor 21 where sufficient fuel necessary to reduce the oxygen content is injected and oxidised. By this means the vessel's auxilary boiler 16 is not required, the diesel generator exhaust 20 temperature and reduced oxygen features are inhance to gain the necessary operational steam power and an exhaust gas sufficiently low in oxygen content to inert the tanks.

The honeycomb configuration of catalyst used in this example permits rapid warm-up to operating temperatures (within 5 minutes). Consequently the second exhaust catalytic 21 combustor can be used on a start-stop basis during the discharge or for topping-up duties utilizing the main engine when the vessel is underway.

To ensure the minimum amount of fuel being used to achieve each individual operational requirement valves 24 and 25 can be made automatic. For instance when topping-up the system, the smaller capacity inert gas generator fan can be used with valve to atmosphere 25 fully open and inert gas inlet valve partially closed to permit only that volume required to be oxidised in the exhaust catalytic combustor 21.

It should be noted that the configuration of exhaust catalytic combustor 21 will vary according to their specific requirements. They could be identical, though in practice it may for instance be necessary to preheat the second catalytic combustor 21 sited at the inert gas inlet due to the cooling of the gases through the economiser 12.

There are numerous configurations in which the present invention can utilize and inhance the existing features of an engine exhaust. With reference to Figure 3, exhaust gases with heavy particulate from poor combustion or from fuel with relatively high percentages of contaminants can be used with special care.

The engine exhaust gas enters the exhaust catalytic combustor 21 via an engine exhaust connection (not shown). If necessary the gases and complete exhaust catalytic combustor 21 is preheated to the required catalytic operating temperature required by the specific fuel used. The heat being created by the injection and ignition of fuel at the pilot burner 28. This pilot burner 28 is also used where the purging of the exhaust catalytic combustor 21 can be achieved through heating (ie the burning off of particulate matter from all internal surfaces).

The gases then pass through a filter 29 designed to trap the particulate matter. The example shown rotates across the gas stream allowing the reverse flow heated jet stream 37 to back flush the particles from the filter. In this example, the jet stream is heated by being coiled around the external surface of the exhaust catalytic combustor, beneath the lagging (not shown). Though an external heat source for this cleaning jet 37 is equally suitable provided the exhaust gases are not unduly cooled.

The particulate matter removed from the filter 28 being educted at 36 through the front of the casing. The casing encompasses the rotating filter thereby retaining the exhuast gases within the unit 21. Alternate filter both fixed, which require periodic cleaning and sliding filters allowing alternate surface cleaning in situ, are equally suitable.

Where additional combustion air is needed to meet the designed requirement (eg due to low exhaust oxygen content), this air can be induced into the exhaust stream before the exhaust catalytic combustor or as shown as 30 in Figure 3. Any combustion air inlet must be controlled (eg an orifice plate) to ensure that catalyst is not cooled below the catalytic combustion point of the designated fuel for that unit.

To any possibility of flash-back the exhaust gas/combustion air then pass through a flame arrestor 31 prior to the injection of fuel. This can be fabricated from wire or a sintered honeycomb with its channels slanted at 15° to the flow as shown.

Once the catalyst is heated to the required catalytic combustion temperature, the volume of fuel injected at 32 is controlled to bring the total exhaust catalytic combustor 21 up to its operating temperature.

The engine exhaust gas, fuel and combustion air in this example are blended in a static mixer unit 33 to gain a homogeneous gaseous state prior to entering the catalyst 34.

The specific catalyst 34 shown in all examples is a ceramic honeycomb support with a multiplicity of straight parallel flow channels. It is coated to provide a high total surface area capable of withstanding the operating temperatures and has a catalytic material containing a precious metal or metal designed to gain the maximum combustion efficiency.

The catalyst 34 shown in Figure 3 is supported in a basket designed to withstand the maximum operation temperatures and is fixed to ensure that all fuel charged gases pass through it. Where the exhaust gases are extremely aggressive, the catalyst 34 can be designed for cleaning in a similar fashion to the filter 29 (ie by rotation or sliding with heated jets cleaning unexposed areas). Alternatively increased operating temperatures or the use of lighter fraction fuel such as Methonel through the pilot burner 28 (or injector 32) can be utilized to burn any particulate matter from the catalytic 34 surfaces.

Alternative catalyst in the form of :

i) precious metal (or metals) coated wire or tubes;

ii) precious metal (or metals) coated pellets (in the form of a fluidised bed) could also be used.

Operating temperature vary from 50°C to 1540°C according to requirements. The lower (50°C) is dependant on the fuel used. The upper 1540°C point is set to ensure all operations remain below temperatures conductive to the formation of oxides of nitrogen (NOx). With the preferred operating range being 1100 -1450°C after gaining the catalytic ignition temperature for the specific fuel.

This example (Figure 3) demonstrates the use of secondary or dilution air entering 35, causing either cooling of the exhaust gases or increasing the total volume to gain any mass/thermal requirement at 41 outlet. To overcome system pressure differential this dilution or cooling air inlet 35 is informed according to eductor principles with the air being fed under pressure by fan 36 as shown. In some instances the existing force draft fan can be utilized or another alternative is to use a fan direct in line. This enhance diesel exhaust 20 being then suitable to requirement (not shown).

Figure 4 demonstrates an exhaust catalytic combustor 21 on a standard engine exhaust. The engine exhaust has sufficient temperature (ie normal operating condition) together with the free oxygen necessary for the convertion of fuel through the catalyst 34. System pressure resistance being overcome by the engine's own combustion pressure. According to the present invention, the engine exhaust gases pass through the exhaust catalytic combustor 21 until the fuel catalytic ignition temperature is reached.

Fuel equal to the final operating range is feed under control through injector 32. In this example the injector 32 is installed prior to the exhaust turbine stator 57 and roter 58 of the engine's turbo charger, to assist in the vaporisation and mixing of the fuel with the exhaust stream.

This fuel charged exhaust mixture is then passed through a catalyst 34 which is similar in all respects to that described in Figure 3. The enhanced or boosted exhaust stream 41 being then passed to an external unit (eg heat exchanger), where the original exhaust energy features, plus the additions from the exhaust catalytic combustor can be utilized.

Figure 5 demonstrates a self contained exhaust catalytic combustor that uses a turbo blower/expansion turbine to overcome internal and external pressure (to flow) resistances. The catalytic operational principles are the same as previously described against Figure 4.

The engine exhaust gases 20 enter the exhaust catalytic combustor after warm-up fuel is injected at 32 and is vaporised due to the exhaust gas temperature. This admixture then passes through a static mixer 33 to ensure a reasonably homogeneous mix and eliminate any fuel in droplet form.

The fuel charged gas passes the (now wind milling) blower 39, into the catalyst 34 (previously described) honeycomb structure where the fuel element ignites. The expanding gases being guided by the stator blades 38 onto the turbine element 37 causing it to rotate and drive the blower element 39 via the shaft 40. Thus overcoming pressure losses and enabling the design of specific pressure and volume for gas at 41.

Where as the previous examples cover designs enabling the energy in existing engine exhaust 20 to be improved and utilized, figure 6 is used as an example of how exhaust catalytic combustor can be economise on fuel requirements for future plants.

Though there are similar requirements for land-based industrial plants (eg in the middle east), a marine vessel is again used as an example in Figure 6.

There is always an initial need for electrical power to gain lights and start essential pumps (eg lubricating pumps) prior to starting any major engine (or plant).

According to the present invention this initial power requirement is provided by an engine driven electrical generator 18. Once electrical power and general services are established. Fuel is injected into the now heated exhaust catalytic combustor 21 fitted to the generator 18 engine exhaust 20.

The exhaust catalytic combustor 21 would be of the type described against Figure 5, with the turbo charger 39 expansion turbine 38,37,40 blowing the exhaust gased 41 through a much larger exhaust catalytic combustor driving the general services generator 42. By this means the main problem of pre-heating the combustion air and catalyst is overcome.

Having heated the catalyst 34 in the second exhaust catalytic combustor 21 (driving the Service Generator 42) an electric driven motor 43 brings this service generator up to speed. Additional combustion air 30 is drawn into the unit together with the exhaust gases 41 and injected fuel 32. To assist in the vaporisation, the fuel is preheated by being coiled at 44.

This mass then passes through a static mixer element 33 before being combusted as previously described across the catalyst 34. The resultant expanding gases drives the turbine 37 and 45. Turbine 37 drives the blower element 39 through shaft 40. The services electrical windings 42 are driven through shaft 47 by the larger turbine 45 (46 being turbine 45's stator blades). This generates the total electrical power requirement for the vessel.

The exhaust gases 41/1 from the services generator 42 are then utilized to start the main engine exhaust catalytic combustor 21 in a similar fashion to that previously described for the services generator.

The exhaust gases 41/2 from the main engine exhaust catalytic combustor passed through an economiser 12 to gain all steam power and heat require for the vessel while underway. When in port the services generator 42 exhaust gases 41/1 can be boosted by an exhaust catalytic combustor

21 (as previously described) to energise the same economiser 12.

The purpose of this method of plant operation being to utilize the 99% combustion efficiency and speed of response (time taken to reach operating temperatures) of catalysts from the exhaust of a relatively small engine. Further, because a catalyst can operate within the confines of a (reduced oxygen) exhaust unprecedented fuel economize can be gained. In addition, by using exhaust catalytic combustor the exhaust temperature can be controlled through external units (eg economisers, piping etc.) to reduce the possibility of corrosive attack from the condensing of elements from the original fuel. With the final exhaust to atmosphere being cleaner by pollution standard than present day operations (ie reduced hydrocarbon and oxides of nitrogen emissions).

There are various other uses for the exhaust catalytic combustor. Figure 7 details a portable inert gas generator, which (as opposed to existing units) has the capacity to be independent of externally supplied electrical power, pneumatic air, water and fuel.

The engine 18 (in this example a diesel) is started, its exhaust heats the exhaust catalytic combustor 21 and catalytic combustion takes place as previously described. The engine power is used to drive a hydraulic pump 48 and/or a pneumatic compressor 49 which provide power to the inert gas supply fan 50 and exhaust gas heat exchanger (air to air cooling) 51. This pneumatic/hydraulic power also being used to control external valves and equipment (not shown).

Figure 8 shows a similar inert gas generator that has an engine with less than the required volume of gas in its exhaust. Though in this example it is used to demonstrate the recycling of inert gas through the exhaust catalytic combustor, it could equally increase the heat energy in another duty.

The engine 18 (again diesel in this example) is started, catalytic combustion of the exhaust gas 20 is realised and is cooled by the heat exchanger 51 as previously described. The fan 50 designed to overcome total system resistance causes the exhaust gas 41 to enter the tank 52 where it is mixed with the air/hydrocarbons (present but below the lower explosive limit). The tank outlet 53 is fed back through the non-return valve 54 and flashback arrestor 30 to the inlet 22 of the exhaust catalytic combustor 21. Recycling continues until such time that the total tank contents are sufficiently reduced in oxygen content (or final total temperature increases when recycling heat energy without the heat exchange).

The final example of an exhaust catalytic combustor in Fig. 9 is used to demonstrate its use in both full and partial exhaust gas streams. Again an economiser 12 on board a vessel is used. Assuming an exhaust catalytic combustor 21 has been fitted to a diesel generator exhaust 20. It could be used in port instead of the ship's boiler to produce steam as previously described. However, many vessels at present are on reduced speed, this obviously reduces the thermal mass to the economiser 12 while underway.

Under these circumstances there is a need to boost the thermal capacity of the main engine exhaust 11. Due to the size of the unit involved, it would be uneconomic to pass the total main engine exhaust 11 through an exhaust catalytic combustor. However the required thermal capacity could be gained from a small percentage of the main engine exhaust 11 (say 10%) being passed through the diesel generator exhaust catalytic combustor 21 via duct 55 and valve 56. Having received a thermal boost as previously, the exhaust from the unit would be admixed to the main engine exhaust and passed through the economiser 12.

Because their use is normal practice in both marine and industrial engineering, diesel engines have been used in all examples. However, the exhaust catalytic combustor could equally enhance the waste gas product of any combustion process, including boiler plant, gas turbines and petrol engines.

CLAIMS

1. An exhaust catalytic combustor comprising an outer shell with means to connect to an engine exhaust, a pilot burner fueled by an injector to cause rapid warm-up and permit purging operations, a filter to trap particulate matter, a flash arrestor, an injector(s) to provide fuel proportional to combustion requirements, air inlet to provide additional combustion air on low oxygen content exhausts, a static mixer to blend exhaust, fuel and any additional air, a highly selective catalyst utilizing precious metal to gain maximum combustion efficiency, a secondary inlet to balance mass and thermal outlet valve to external requirements, and a means to overcome system pressure head losses. All being designed for the purpose of increasing the thermal capacity of an engine exhaust gas.

2. An exhaust catalytic combustor as claimed in Claim 1, where in the original oxygen content of the engine exhaust gas is further reduced to less than 5% by volume to suit inert gas plant operations.

3. An exhaust catalytic combustor as claimed in Claim 1 or Claim 2, wherein the pilot burner, and/or filter, and/or flash arrestor, and/or combustion air inlet, and/or static secondary mass balance inlet is considered unnecessary for a specific duty.

4. An exhaust catalytic combustor as claimed in any preceding claim, wherein a turbo charger or expansion turbine, driven by the catalytically expanded gas, is used to overcome system pressure against flow resistance.

5. An exhaust catalytic combustor as claimed in Claim 4, wherein the gases produced from catalytic combustion are caused to recycle through any part of the exhaust catalytic combustor.

6. An exhaust catalytic combustor as claimed in Claim 4 wherein the exhaust catalytic combustor is designed for a specific task as a total plant and the engine is sized to meet catalytic combustion re-

quirements.

7. An exhaust catalytic combustor as claimed in Claim 4 wherein the exhaust catalytic combustor is designed as self-contained portable unit that can be fitted in turn to more than one engine.

8. An exhaust catalytic combustor as claimed in Claim 4 wherein the engine exhaust combustion air, fuel supply or the secondary inlet volumes can be adjusted to give different flows.

9. An exhaust catalytic combustor as claimed in Claim 4 wherein there is more than one pilot burner of filter or flash arrestor or fuel injector or combustion air inlet or static mixers or catalyst or secondary inlet.

10. An exhaust catalytic combustor as claimed in Claim 4, wherein the exhaust catalytic combustor's turbo chargers exhaust turbine, offers a larger turbine blade area than that required to overcome system resistance and is used to drive a unit external to the exhaust catalytic combustor.

11. An exhaust catalytic combustor as claimed in Claim 4, wherein only part of the engine exhaust passes through the catalyst with the remaining (or part of the remaining) gases being passed around the periphery of the catalyst to perform other duties (eg boundry cooling or additional expansion).

12. An exhaust catalytic combustor as claimed in Claim 4, wherein the catalytic combustion of fuel forms part of a pollutant emissions control system (eg reduction of hydrocarbon/oxides of nitrogen).

13. An exhaust catalytic combustor as claimed in claim 4, wherein any particulate matter impringing on the catalyst surfaces are purged/burnt-off using lighter fracture fuel such as methanol.

14. An exhaust catalytic combustor as claimed in Claim 4, wherein any particulate matter impringing on the internal surfaces is purged using a high pressure jet.

15. An exhaust catalytic combustor substantially as described herein with reference to Figure 1 - 9 of the accompanying drawings.

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