

EXHAUST MANIFOLD WITH INTEGRAL CATALYTIC CONVERTER

BACKGROUND OF THE INVENTION

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TECHNICAL FIELD:

This invention relates to methods and apparatus for removing pollutants from the exhaust emissions of internal combustion engines and, more particularly, to a pollutant
10 reducing exhaust manifold for an internal combustion engine comprising, a plurality of header pipes connected to and receiving exhaust gases from respective ones of a plurality of exhaust ports of the engine; a catalytic chamber having inlet(s) connected to receive exhaust gases from the plurality of header pipes and an outlet therefrom connected to an exhaust system; and, a catalytic converter structure having a catalyst disposed on a
15 supporting substrate disposed in the catalytic chamber between the inlet(s) and the outlet so that all exhaust gases from the engine must pass through the catalytic converter structure.

BACKGROUND ART:

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For many years, the exhaust systems of automobiles and other vehicles powered by internal combustion engines have remained substantially unchanged. There is an exhaust manifold that collects the exhaust gases emitted from the exhaust ports of the engine and outputs them into an exhaust pipe which conducts the gases to the rear of the
25 automobile. Typically, a muffler is disposed in-line with the exhaust pipe to muffle the sounds of the gases to an acceptable level. More recently (after 1974 in the United States of America), modern exhaust systems have included a catalytic converter to remove emitted pollutants from the exhaust gases. A typical prior art exhaust system of such design is depicted in Figure 1. The exhaust manifold 10 is bolted or clamped to the engine
30 (not shown) with the flanges 12. The catalytic converter 14 is positioned in-line in the

exhaust pipe 16, typically some two to ten feet from the manifold 10. The muffler 18 is typically located at the rear of exhaust system.

The above-described placement of the catalytic converter 14 creates several
5 problems completely contrary to the intent thereof which is to reduce pollutants. Once it is operational, it works fairly well for its intended purpose. Because of its placement, however, it does not work as well as it could and, moreover, until it attains its operating temperature, it does not work at all. A catalytic converter is nothing more than a catalyst disposed on a substrate. When hot enough, the catalyst causes the unburned pollutants to be further
10 oxidized. Until that time, the pollutants pass through unaffected. Since it is placed well down the exhaust pipe 16, when the engine is started the catalytic converter 14 is cold. And, it takes time for heat to build up in the catalytic converter 14 to a sufficient level that it begins to work. Unfortunately, starting is the time when the most pollutants are produced since a choke or similar mechanism typically increases the fuel-to-air ratio to enhance the
15 combustion process in a cold engine. Thus, the partially burned fuel products pass virtually unhindered into the atmosphere. When one considers the number of engines started in a cold condition in a major city on any normal day, it can be seen that there are a lot of unburned pollutants poured into the atmosphere each and every day.

20 It has been suggested to add a heating element to the catalytic converter to get it to operating temperature more quickly; but, that is a stop-gap measure that is not overly effective. Typically, a operator expects his/her vehicle to start immediately when the ignition key is turned and will object if he/she must wait until the catalytic converter warms up before the engine will start. Like the bell or other alarm that warns that the seatbelt is
25 not fastened, if a car will not start until the catalytic converter reaches temperature, based on human nature and prior experience many drivers will simply have their vehicles modified to bypass that feature, thereby eliminating the results intended to be attained thereby.

Wherefore, it is an object of the present invention to provide a catalytic converter which begins effective operation virtually immediately.

It is another object of the present invention to provide a catalytic converter which is
5 highly effective in eliminating pollutants from exhaust gases.

Other objects and benefits of this invention will become apparent from the description which follows hereinafter when read in conjunction with the drawing figures which accompany it.

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DISCLOSURE OF THE INVENTION

The foregoing objects have been achieved in an exhaust manifold for an internal combustion engine having a plurality of header pipes connected to and receiving exhaust
15 gases from respective ones of a plurality of exhaust ports of the engine and a single chamber inlet(s) connected to the plurality of header pipes and an outlet connected to an exhaust system, by the improvement of the present invention for reducing pollutants emitted by the engine comprising disposing a catalytic chamber between the inlet(s) and outlet thereof and disposing a catalytic converter structure having a catalyst disposed on a
20 supporting substrate in the catalytic chamber between the inlet(s) and the outlet so that all exhaust gases from the engine must pass through the catalytic converter structure.

Preferably, the plurality of header pipes and the catalytic chamber are of a structural fiber reinforced ceramic matrix composite (FRCMC) material comprising fibers of
25 a generic fiber system disposed throughout a pre-ceramic resin in its ceramic state. The preferred pre-ceramic resin comprises either a polymer-derived ceramic resin such as silicon-carboxyl or alumina silicate resins or a cementatous resin that has been modified to emulate polymer composite processing techniques such as monoaluminum phosphate (a.k.a. monoaluminophosphate) resin; and, the preferred generic fiber system comprises



alumina, Altex, Nextel 312, Nextel 440, Nextel 510, Nextel 550, silicon nitride, silicon carbide, HPZ, graphite, carbon, and peat

The preferred supporting catalyst substrate is an open cell silicon carbide foam,
5 silicon carboxyl foam, oxide ceramic foam, or similar ceramic foam material.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a simplified drawing of the components of a prior art exhaust system
10 employing a catalytic converter.

Figure 2 is a simplified, partially cutaway drawing of an exhaust manifold according
to the present invention incorporating a catalytic converter therein.

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BEST MODES FOR CARRYING OUT THE INVENTION

In a co-pending application entitled FIBER REINFORCED CERAMIC MATRIX
COMPOSITE INTERNAL COMBUSTION ENGINE EXHAUST MANIFOLD, serial number
20 _____, filed on even date herewith, an improved structural fiber
reinforced ceramic matrix composite material is disclosed having high breakage resistance,
high temperature resistance, corrosion resistance, low heat rejection, and "tailorable"
thermal expansion characteristics which makes it particularly suited for an exhaust
manifold material for an internal combustion engine. This co-pending application referred
25 to a method of forming fiber reinforced ceramic matrix composite (FRCMC) automotive
parts using a resin transfer molding (RTM) technique as disclosed in a second co-pending
application entitled METHODS AND APPARATUS FOR MAKING CERAMIC MATRIX
COMPOSITE LINED AUTOMOTIVE PARTS AND FIBER REINFORCED CERAMIC
MATRIX COMPOSITE AUTOMOTIVE PARTS, serial number _____, also filed
30 on even date herewith. The general RTM method described in the aforementioned second

co-pending application included the first step is to form a shaped preform from the generic fiber system that is to be used. This is then inserted into a preform mold and the mold sealed. In the preferred approach, the generic fiber system occupies from 30% up to about 60% of the internal volume of the mold. As an alternative, but not preferred, approach, the mold can be filled with generic fiber chop to the same packing density by volume. A pre-ceramic polymer resin is then forced through the fibers to fill the remaining internal volume of the mold. The preferred resin is the previously described pre-ceramic polymer, silicon-carboxyl resin sold by Allied Signal under the trade name Blackglas. This is because of its low viscosity which allows it to be forced through and saturate a high volume density of the generic fiber preform. The tighter the fiber density, the stronger the part will be. Thus, to use a resin of higher viscosity, the packing density of the fibers would have to be greatly reduced, resulting in a corresponding reduction in the strength of the part.

The resin impregnated preform within the mold is then heated to a level and for a time sufficient to polymerize the resin saturating the fiber preform. The preform is then like a bisque-ware in ceramics such that it does not have its full strength as yet, but can be handled. The polymer preform is removed from the mold and then fired at a temperature and for a time as set forth by the manufacturer of the resin so as to ceramitize the polymer. The part or liner in its basic form is thus formed as a ceramic matrix composite having preferably about 50-60% by volume of fiber content therein.

The firing process which turns the polymer to ceramic causes the formation of pores due to outgassing which takes place during the firing process. The resultant ceramic part is about 70% solid and 30% outgas-formed pores. In this regard, it is much like the monolithic ceramics previously used to line automotive parts. The fiber reinforced ceramic matrix composite parts are, of course, much stronger than the monolithic parts because of the high fiber content. The same technique, however, can be used to make the parts even stronger. The ceramic preform is immersed in liquid Blackglas resin (or an equivalent). The water-like viscosity of the resin causes it to fill the 30% pores in the part. The part is then fired once again for the time and at the temperature indicated by the manufacturer of

the resin. This causes the resin within the 30% pores to be turned to ceramic. But, the firing process causes 30% of the 30% volume to be outgassed. So, the part is once again immersed in the liquid resin and fired for a third time. This process can be repeated until the pore removal has achieved a desired level. The resultant part is about 95%-98% ceramic and fibers with no out-gassed pores to speak of. Thus, it is of maximum strength.

The aforementioned first co-pending application describes a specific method for fabrication of a FRCMC exhaust manifold using the above-described RTM method which including the following steps:

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1. Lay-up either a pair of half-manifolds (upper and lower halves) to be joined at a later step or a total manifold from woven cloth matting of fibers such as, but are not limited to, alumina, Altex, Nextel 312, Nextel 440, Nextel 510, Nextel 550, silicon nitride, silicon carbide, HPZ, graphite, carbon, and peat.

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2. The half manifolds or total manifold then have a fiber interface coating applied as per industry best practices. The assignee of this application, Northrop Corporation, currently has a number of patents on the application of interface coatings, the teachings of which are incorporated herein by reference. Also, Allied-Signal or Sinterials are commercial companies which will apply an interface coating as a purchased service.

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3. The half-manifolds or total manifold are then saturated with the resin, in this example being Blackglas resin. This step may also include squeezing the mixture of polymer-derived ceramic resin and interface material-coated fibers of a generic fiber system under pressure into a mold to form the manifold shaped structure.

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4. The resin-saturated half-manifolds or total manifold is then heated as per the following cycle:

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- A) Ramp from ambient to 150°F at 2.7°/minute
- B) Hold at 150°F for 30 minutes

- C) Ramp at 1.7°/minute to 300°F
- D) Hold at 300°F for 60 minutes
- E) Cool at 1.2°/minute until temperature is below 140°F.

5 It should be noted that there are a variety of heat-up cycle definitions which will create usable hardware and the foregoing is by way of one example only and not intended to be exclusive.

5. If half-manifolds were made, they are snapped or fitted together along
10 mating edges at this point to form a total manifold. The two pieces now fitted together are dipped in Blackglas resin for a minimum of five minutes. The part is then removed from the resin and heated as per the previous ramp-up rate to hold the edges together.

6. The polymer composite manifold is then pyrolyzed. In this regard, fabrication
15 of a sealable container, such as a stainless steel box, capable of withstanding 1900°F is required for the pyrolysis cycle in a standard furnace. In the alternative, an inert gas furnace could be used if available. The box should have two tubing connections, one on the bottom and one on the top to allow the box to be flooded with an inert gas. In this example, the manifold is placed in the box, the box placed in a standard furnace, stainless
20 steel tubing is connected to the lower connector on the box and to a supply of high purity argon. Any equivalent inert gas could, of course, be used. The argon is allowed to flow into the box, and out the top vent at a rate of 5-10 standard cubic feet per hour for the entire heat cycle, thus assuring the manifold is totally enveloped in an inert environment. The furnace is closed and fired on the following basis:

- 25 A) Ramp to 300°F at 223°/hour
- B) Ramp to 900°F at 43°/hour
- C) Ramp to 1400°F at 20°/hour
- D) Ramp to 1600°F at 50°/hour
- E) Hold at 1600°F for 4 hours
- 30 F) Ramp to 77°F at -125°/hour

Again, there are a variety of heating schedules other than this one, given by way of example only, which will yield usable hardware.

5 7. Upon cooling, the manifold is removed from the furnace and box and submerged in a bath of Blackglas resin for enough time to allow all air to be removed from the manifold (typically 5 minutes or more). A vacuum infiltration may also be used for this step. This fills any outgassed pores in the FRCMC manifold with the resin.

10 8. Steps 6 and 7 are then repeated until the remaining outgassed pores are below a desired level which imparts the maximum strength to the final FRCMC manifold. Typically, it is preferred that this cycle be repeated five times. The manifold is then ready for use.

15 The present invention is particularly intended for use with the above-described manifold design, as a catalytic converter substrate can be co-cured with the manifold itself. Additionally in the ceramic manifold invention, an expendable mandrel is employed to form the inner contours of the FRCMC exhaust manifold structure and, as described therein, by employing the present invention herein described the expendable mandrel can
20 be eliminated and be replaced by the catalytic converter substrate material which acts as an internal tool during the forming process of the FRCMC manifold structure.

As depicted in Figure 2, in the present invention the catalytic converter substrate material 14' is incorporated directly into the exhaust manifold 10'. The header pipes 22,
25 chamber 24, and single connecting pipe 28 all contain the catalytic substrate and therefore, act as the catalytic converter chamber. The outlet 30 is the outlet of the manifold 10' to which the standard exhaust pipe 16 of Figure 1 is connected. Thus, all the hot exhaust gases from the engine immediately impinge on and pass through the catalytic substrate 26 to be cleaned thereby. Not only are the gases hotter than in a conventional
30 prior art catalytic converter, but, additionally, the catalytic substrate 26 of this invention

achieves sufficient operating temperature almost immediately because of the heat insulating/containment effect of the outer FRCMC structure that is inherently low thermal conductivity and low specific heat capacity.

5 While any structure capable of withstanding the temperatures involved may be employed for the manifold 10' of this invention, the all-ceramic structure as described in the aforementioned first co-pending application is preferred. Thus, it is preferred that the header pipes 22, the chamber 24, the connecting pipe 28, and the outlet 30 be of a fiber reinforced ceramic matrix composite (FRCMC) material comprising a pre-ceramic resin
10 having fibers of a generic fiber system disposed throughout.

 The preferred FRCMC material used in the present invention includes either polymer derived ceramic resins commercially available such as silicon-carboxyl resin (sold by Allied-Signal under the trade name Blackglas), alumina silicate resin (sold by Applied
15 Polaramics under the product designation CO₂) or cementitious resins that have been modified to emulate polymer composite processing techniques such as monoaluminum phosphate (also known as monoaluminum phosphate) resin combined with a generic fiber system such as, but are not limited to, alumina, Altex, Nextel 312, Nextel 440, Nextel 510, Nextel 550, silicon nitride, silicon carbide, HPZ, graphite, carbon, and peat. To add
20 toughness qualities to the material, the fiber system is first coated to a few microns thickness with an interface material such as carbon, silicon nitride, silicon carbide, silicon carboxide, boron nitride or multiple layers of one or more of these interfacial materials. The interface material prevents the resin from adhering directly to the fibers of the fiber system. Thus, after the resin has been converted to a ceramic as per the resin
25 manufacturer's recommended cure cycle, there is a weak interface between the ceramic matrix and the fibers thereby imparting the desired qualities to the final component. Additionally, while any type of structure capable of withstanding the temperatures involved can be employed for the catalytic converter substrate 26, a high temperature resistant foam structure such as a silicon carbide, silicon carboxyl, or an equivalent oxide ceramic foam is
30 preferred due to its high surface area to volume ratio and low specific heat capacity.



Wherefore, having thus described the present invention, what is claimed is:

1. A pollutant reducing exhaust manifold for an internal combustion engine
5 comprising:
 - a) a plurality of header pipes connected to and receiving exhaust gases from respective ones of a plurality of exhaust ports of the engine;
 - b) a catalytic chamber having at least one inlet connected to receive exhaust gases from said plurality of header pipes and an outlet therefrom connected to an
10 exhaust pipe; and,
 - c) a catalytic converter structure having a catalyst disposed on a supporting substrate disposed in said catalytic chamber between said at least one inlet and said outlet so that all exhaust gases from the engine must pass through said catalytic converter structure.
- 15 2. The pollutant-reducing exhaust manifold of claim 1 wherein:
said plurality of header pipes and said catalytic chamber are of a structural fiber reinforced ceramic matrix composite material comprising fibers disposed throughout a pre-ceramic resin in its ceramic state.
- 20 3. The pollutant-reducing exhaust manifold of claim 2 wherein:
 - a) said pre-ceramic resin constitutes at least one of silicon-carboxyl resin, alumina silicate, and monoaluminum phosphate resin; and,
 - b) said fibers constitute at least one of alumina, Altex, Nextel 312,
25 Nextel 440, Nextel 510, Nextel 550, silicon nitride, silicon carbide, HPZ, graphite, carbon, and peat.
4. The pollutant-reducing exhaust manifold of claim 1 wherein:
said catalyst supporting substrate is a high temperature resistant foam
30 material.





5. The pollutant-reducing exhaust manifold of claim 4 wherein:
said foam material constitutes at least one of silicon carbide, silicon
carboxyl, and oxide ceramic.

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6. A method of maximizing the elimination of unburned pollutants from an
internal combustion engine exhaust comprising the steps of:

- a) receiving hot exhaust gases from a plurality of exhaust ports of the
engine;
- 10 b) immediately directing all the hot exhaust gases into a chamber
connected to the exhaust ports and containing a catalyst on a substrate; and,
- c) directing all the hot exhaust gases over the catalyst and out a single
outlet of the chamber into an exhaust system.

15 7. In an exhaust manifold for an internal combustion engine having a plurality
of header pipes connected to and receiving exhaust gases from respective ones of a
plurality of exhaust ports of the engine and a single chamber connected to the plurality of
header pipes and an outlet connected to an exhaust system, the improvement for reducing
pollutants emitted by the engine comprising:

20 disposing a catalytic converter structure having a catalyst disposed on a
supporting substrate in said catalytic chamber between said header pipes and said outlet
so that all exhaust gases from the engine must pass through said catalytic converter
structure.

25 8. The improvement to an exhaust manifold of claim 7 wherein:
the plurality of header pipes and said catalytic chamber are of a structural
fiber reinforced ceramic matrix composite material comprising fibers disposed throughout a
pre-ceramic resin in its ceramic state.

30 9. The improvement to an exhaust manifold of claim 8 wherein:



- a) said pre-ceramic resin constitutes at least one of silicon-carboxyl resin, alumina silicate resin, and cementatous resins modified to emulate polymer composite processing techniques including monoaluminum phosphate resin; and,
- b) said fibers constitute at least one of alumina, Altex, Nextel 312, Nextel 440, Nextel 510, Nextel 550, silicon nitride, silicon carbide, HPZ, graphite, carbon, and peat.

10. The improvement to an exhaust manifold of claim 7 wherein:
said supporting substrate is a ceramic foam material.
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11. The improvement to an exhaust manifold of claim 10 wherein:
said foam material constitutes at least one of silicon carbide, silicon carboxyl, and oxide ceramic.



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