

May 7, 1963

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REACTION MILIEU AND AFTERBURNER INCORPORATING SAME

Filed Feb. 6, 1961

2 Sheets-Sheet 1

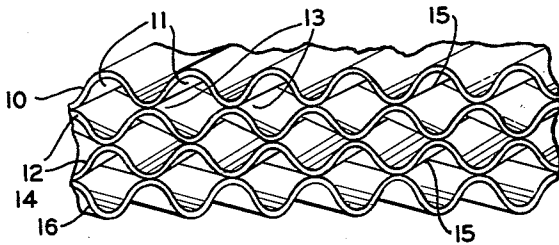


FIG. 1

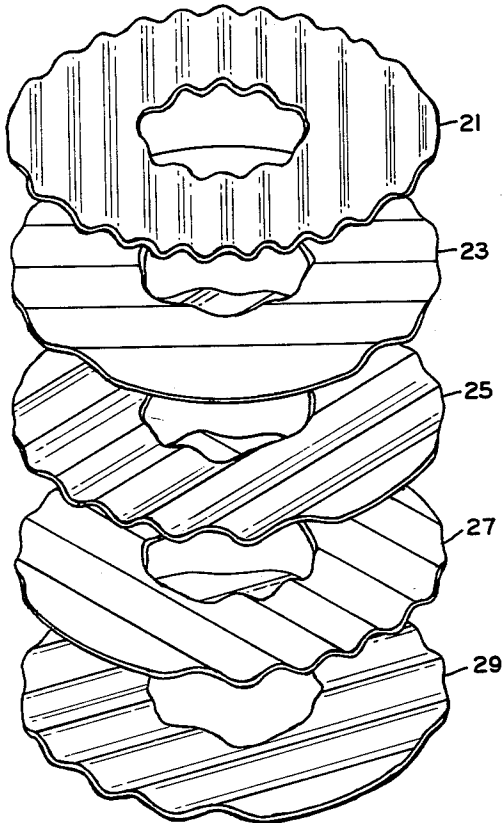


FIG. 2

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2 Sheets-Sheet 2

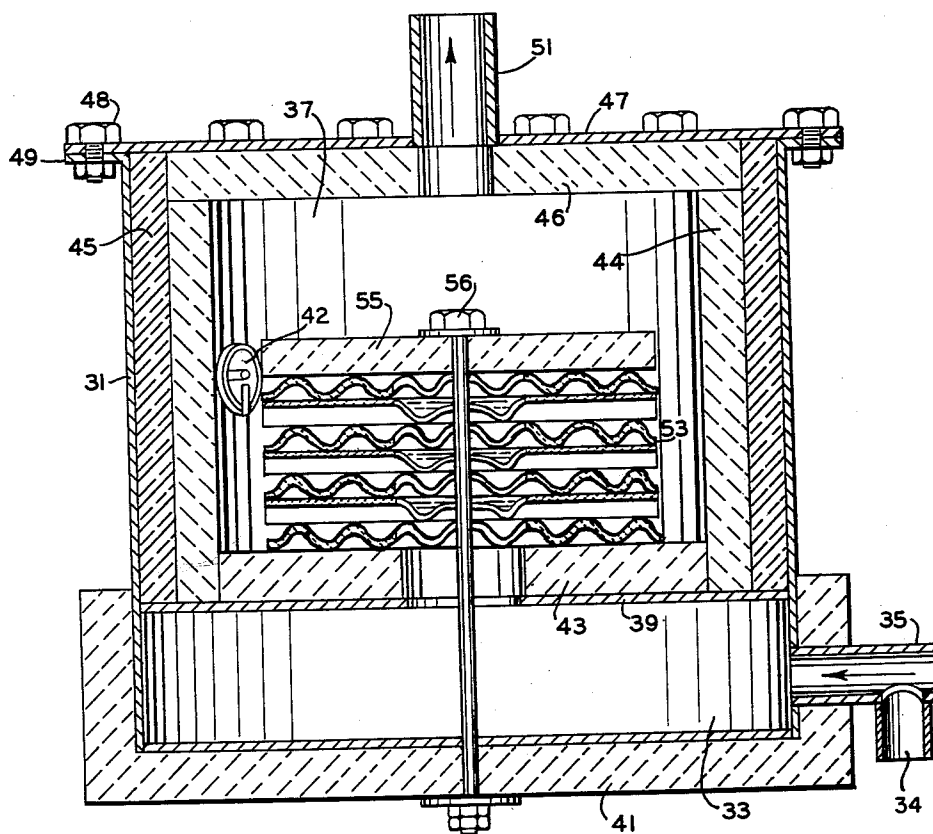


FIG. 3

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REACTION MILIEU AND AFTERBURNER INCORPORATING SAME

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6 Claims. (Cl. 60—30)

This invention relates to a new and novel structure for defining a reaction milieu and to an article of manufacture comprising the said structure in combination with a casing and associated ducts to provide an afterburner for the exhaust of internal combustion engines.

The incineration or burning of the residual combustibles present in the exhaust gases from internal combustion engines, particularly those from automobiles, is a desirable means of eliminating atmospheric pollution. It is rather surprising that ordinarily automobile exhaust gases still contain sufficient amounts of combustible substances so that, under conditions of elevated temperature (of the order of about 1200° to 1400° F.) and with the addition of some additional air (typically of the order of magnitude of about 10 to 15 volume percent), the residual combustibles will burn exothermically. This is analogous in some ways with the incineration of solid refuse and it is considered that that term is very appropriate.

While the incineration of automobile exhaust gases is feasible from the thermodynamic consideration, the prior art apparently has not included a commercially practicable device meeting the requirements of cost, space and efficiency. As a result of experiments in attempting to devise a practicable means for initiating and maintaining the incinerative combustion of automobile exhaust gases, the conclusion has been reached that one of the major difficulties heretofore encountered lies in providing a suitable container for the flame. For example, when the reaction is initiated in structures having a simple configuration consisting of a multiplicity of small passageways in line with the direction of flow, it appears that a large number of factors inherent in the automobile exhaust gas system conspire to prevent maintenance of the flame in the structure. Such a structure is in fact rather like certain types of flame-arrestors, but slight fluctuations in pressure or localized conditions of pressure or temperature appear to result in either enlargement of the flame front beyond the structure (with resulting collapse) or collapse before the structure. Whatever the actual reasons may be, such a structure does not continuously envelop and hold a stable flame, particularly in view of the pulsating nature of automobile exhaust gases and the variability of composition thereof.

It is an object of this invention to provide a structure having a multiplicity of extensively interconnected passageways, for continuous chemical reactions.

Another object of the invention is to provide a refractory structure for continuous gaseous chemical reactions involving high temperatures.

A further object is to provide a simple refractory structure capable of maintaining the sustained homogeneous incineration of automobile exhaust.

Another object of the invention is to provide an efficient refractory flame-containing structure of relatively small dimensions.

A still further object of the invention is to provide an automobile exhaust afterburner.

Other objects of the invention will become evident from the disclosure hereinafter made.

It has been found that stabilization of a reaction zone in a reactor for gaseous reactants may be achieved by

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extensive interconnection of passages of flow of the burning gas in a structure composed of corrugated sheets which contact each other only at their ridges. By extensive interconnection is meant that the interconnecting passageways are approximately equal in cross-sectional area to the passageways of flow themselves. The structure of the invention thus is such that the passageways have continuous walls only along one-half their diameter.

It has further been found that virtually ideal extensive interconnection of passageways as the term is used herein is provided by stacking corrugated sheets of material in superimposed array, with the axes of the corrugations of consecutive sheets in non-parallel arrangement. As the simplest such arrangement successive corrugated sheets are oriented with the corrugations at right angles to those of the contiguous corrugated sheets. However, from a practical standpoint this angle may vary from about 20° to about 160°, although angles of about 45° to about 135° are preferred. Furthermore, a more or less random arrangement can be made if desired, since the main consideration is the provision of passages by the contact of the ridges of adjacent sheets.

In order to provide the highly refractory structure which is required e.g. for combustion of exhaust gases, the corrugated sheets must comprise either refractory materials such as ceramics or be convertible thereto. The sheets can be adhered one to another at the contact points, either by use of a binding cement or by sintering together at points of contact if desired. Alternatively they may be stacked and held together by external means.

As will be described in greater detail below, the structures may be classified generically as reaction milieus, since they can be used for chemical reactions involving gases, thus defining reaction zones for chemical reactions, e.g. exothermic or catalytic. The structures of the invention have particular utility as flame holders, as in gas burners and automobile exhaust-gas afterburners.

The heat resistance required of the ceramic or refractory material to be used in the structures is of course dependent upon temperature conditions expected in a particular use. Thus, while for purposes of use in automobile exhaust gas afterburners, resistance to temperatures of about 1600° F. to perhaps 2000° F. is sought, the more readily available materials tend to limit the useful upper temperature limit of the structure of about 1800° F. Materials which are unstable, or melt lower than the temperatures named are therefore unacceptable for construction of an automobile exhaust gas afterburner, but may be useful in chemical processes where maximum temperatures are lower. Also, for some purposes resistance to even higher temperatures may be imperative. Under such circumstances it is possible to employ refractory metals or more heat-resistant ceramic ingredients. In general, in selecting additives, it is desirable to avoid the use of large amounts of ingredients which may flux the higher melting refractories with the formation of low melting phases. It will be apparent to one skilled in the ceramic art that the numerous refractory ceramic materials available will enable choice of desirable and useful materials. The known and available ceramic compositions are readily adaptable to use in the structures of the invention.

Representative sinterable ceramic materials useful for making corrugated sheets for the purposes of this invention when relatively high temperatures are encountered include such substances as alumina, silicon carbide, beryllia, titania, zirconia, cordierite, mullite, petalite and the like, as well as metal powders such as tungsten, molybdenum, tantalum and the like.

Formation of the structures of the invention as illus-

trated in the drawings is readily accomplished according to the following procedure.

A raw material mix comprising the desired finely divided sinterable particles and, if desired, plasticizing ingredients (such as, for example, organic polymeric resins) and/or volatile viscosity adjusting media, is formed into a thin film or sheet material. Such film may be formed as thin as desired, e.g. a mil or so, as by knife coating on a temporary support, extrusion or the like as long as it possesses sufficient body when free of any viscosity adjusting fluids to retain its integrity during and after corrugation. Very thin, delicate films are hard to handle, whereas films thicker than about 0.125 inch tend to be too bulky for convenient corrugation as described herebelow. Best results are obtained by avoiding extremes; and the advantages of the structures of the invention with respect to strength and structure retention without fragility or fracture problems become particularly apparent when using films about 2 to 50 mils thick. Advantageously, thin films contribute to the thermal shock resistance of the fired structures, permitting them to withstand a multitude of rapid and severe fluctuations in temperature without fracture.

In the step of corrugation itself, it may be desirable to support the plasticized green ceramic film on a thin sheet of metal foil, for example, aluminum foil, preferably of a thickness on the same order of magnitude as the film to be corrugated (but usually not greater than about 0.01 inch), or to sandwich the green ceramic film between two such metal foil sheets as it is passed between the corrugating rolls, suitably at room or elevated temperatures. The foil advantageously serves as a carrier to distribute corrugation stresses uniformly, aiding in obviating cracking or rupture of the films. Also, in the case of those films plasticized with ingredients which impart an elastic memory property to the film, at least one sheet of metal foil corrugated with the film is desirably left in position for a short time so as to maintain the corrugation in the film and prevent reversion to a flat sheet.

Corrugation of the flexible films may be accomplished using standard corrugating equipment, and without undue pressure at low temperatures. Usually corrugations of uniform periodicity are formed, for example, corrugations of repetitive and uniform wave shape, amplitude, and frequency. The corrugations most frequently employed are those of standard curved ridges and grooves; however, other wave shapes or configurations may be useful. As a minimum requirement the amplitude of corrugations (that is, the elevation distance between the peak of a ridge and the lowermost portion of an adjacent groove) is at least as great as the thickness of the film that is corrugated, which means that the elevation distance between the peak of a ridge on one side of a corrugated film and the peak of a ridge on the opposite side of the film is at least twice as great as the thickness of the film itself. However, the flame-containing structures of this invention, and particularly the preferred structures in which the sheets are about 2 to 50 mils thick, generally have corrugations with amplitudes at least about five to ten times greater than the thickness of the film and up to about twenty to thirty times this thickness. It is an important feature of the structures of the invention that contact is provided at the points where ridges of adjacent sheets intersect. It will be understood that the term "point" is not employed in the mathematical sense, but in the practical sense that contact is not continuous along the ridges but involves only very small isolated areas. Adhesion at the points of contact where the ridges of adjacent sheets intersect may be provided or contact may be maintained by means urging the sheets together with sufficient force to maintain structural relationship but not sufficient to result in mechanical damage. Mechanical means for this purpose are readily provided, as by engagement with portions of a housing for the structures, or bolts, encircling framework, clamps and the like. The

mechanical effect of this pointwise adhesion is that the structures are less sensitive to thermal stress since expansion and contraction in any direction does not result in abrasive action and can be absorbed by the corrugated surfaces between points of adhesion.

While the sinterable flexible plasticized corrugated films are in the green unfired state, they are cut and fabricated into assemblies and structures such as illustrated in the drawings and described in the present specification or alternatively part of the final shaping operations can be deferred until after assembly of the corrugated members. At the points of contact between successive corrugated pieces adhesion may be provided by employing the basic raw material mix from which the sinterable film or sheet material was formed, diluted with suitable solvents or fluids to adjust viscosity, and then painted over the ridges of the corrugations as a glue medium. The solvent of the applied glue media may tend to solvate portions of the adjacent corrugated members before volatilizing into the air. In any event, once the structure is dried, a temporary bond is formed at the points of contact which, after the structure is fired to sintering temperatures, turns into a strong and rigid weld. The extensively interconnected passageways are then bounded by successively adhered corrugated sheets. Alternatively, if desired, for some purposes, other temporary adhesives such as water glass may be employed which effect slight fluxing of the ceramic material on firing. Of course where the sheets are not to be cemented they can be stacked and held together mechanically.

In the green unfired state, the assemblies of corrugated sheets can easily be cut or sawed to shape or trimmed as desired for the fabrication of the structures or they can be cemented together by the methods described above for the adhesion of successive sheets. By such procedures, orientation of the extensively interconnected passageways in any manner which may be desirable in the final structure is readily achieved.

The completed green, unfired assembly is allowed to dry in air at temperatures up to about 150° C. so as substantially to remove volatile solvents or organic fluids from its joints without affecting any thermoplastic binders or effecting any sintering of particles. Then the structures are fired using temperatures suitable for a sintering of the particular sinterable ingredients in the structure, as well understood in the ceramic art.

Hereinabove has been generally described the manner of obtaining a multiplicity of extensively interconnected passageways in the reaction milieu structures of the invention. The invention is further described by reference to the accompanying drawings wherein:

FIGURE 1 is a side elevation of part of a structure possessing extensively interconnected passageways as hereinabove described.

FIGURE 2 shows an exploded view of a refractory annular flame-containing structure of the invention consisting of only five sheets.

FIGURE 3 shows an exhaust-gas afterburner incorporating a refractory annular flame-containing structure of the invention.

Referring to the drawings, in FIGURE 1 it will be seen that successive sheets 10, 12, 14 and 16 are arranged with the corrugations of each sheet substantially at right angles to one another to produce passageways as at 11 interconnected as at 13. In this figure it will be seen that the corrugations of sheets 10 and 14 are parallel and at approximately right angles to the corrugations of sheets 12 and 16 which are also parallel. The substantially point contact of the ridges of the corrugations can also be noted as at 15.

FIGURE 2 shows an exploded view of an annular flame-containing structure consisting of five sheets: 21, 23, 25, 27 and 29. In this figure it will be apparent that none of the sheets are parallel with respect to the corrugations. It would of course be within the scope of

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the invention to have alternate sheets parallel in this respect. The external and internal curved "faces" of the cylindrical structure formed by the stacked sheets will obviously be of different area and this is a valuable feature of the invention. The faces in which the passages terminate in the structures of the invention consist generally of the open portions of the interconnected passages and accordingly present a peculiar pattern produced by the thin edges of the component sheets.

FIGURE 3 shows a refractory annular flame-containing structure of the invention positioned in a suitable container to provide an afterburner for automobile exhaust fumes. The mild steel casing 31 is divided into a plenum section 33 having inlet 35 and a burner section 37 separated by annular partition 39. Plenum section 33 is externally insulated by the refractory insulating covering 41 which is suitably made of fire clay. Burner section 37 is lined with a refractory in three pieces, viz. annular base plate lining 43 resting on and concentric with the partition 39, cylindrical wall lining 44 concentric with the casing and insulated from the vertical walls thereof by a packed fibrous insulation material 45 and annular top plate lining 46 resting on the cylindrical wall lining 44. The refractory top plate is held in position by casing cover plate 47 having a centrally located outlet 51 and fastened to the steel casing by bolts 48 through flange 49 of the casing. Concentrically located in the burner section and resting on base plate 39 is annular flame-container 53 which is held in position by superposed refractory plate 55 and bolt 56 which extends downwardly to the exterior of the steel casing. Other methods of positioning and retaining the flame-containing structure are equally suitable, as, for example by spring pressure from above. It is only necessary in this particular afterburner that the central hole in the flame holder be closed at the upper end so that gases entering at the lower end are forced to pass radially outwardly through the flame container. The corrugations of the sheets of the flame-container 53 are drawn out of proportion. The sheets are also shown in exaggerated thickness as the delineation of the scale of edges and sections which are of the order of 2-50 mils in thickness is not practicable. The central opening in the flame container is shown as the portion of the sheets not sectioned.

Not shown in this drawing are thermocouples used for test purposes to establish the thermal gradients. The thermocouples are, of course, not necessary for ordinary use. Supplementary air is conveniently introduced upstream in the exhaust line through port 34 so that adequate mixing occurs in the plenum chamber. As ignition means a sparking plug 42 is used in chamber 37, preferably mounted in the annular space between the flame holder 53 and the lining 44. Alternatively preheating of the exhaust gases may be used as by direct flame from an auxiliary burner.

The annular overall cylindrical shape of the representative flame-containing structure of the invention shown in exploded form in FIGURE 2 is to be considered as one embodiment of the invention. The general and overall configurations of these structures can be widely varied. Thus, the annular cylindrical form can be employed. For example, segments may be made on planes cutting parallel to the central axis of the cylinder radially at any angle or along chords of the circular area or in planes not parallel to the axis and at right angles or otherwise thereto giving elliptical outlines or portions thereof. Such segments offer the advantage that they provide a convenient means for providing flame-containing structures having predetermined different areas of the faces for inflow or combustible mixtures and outflow of exhaust gas. Such segments may further be cemented to one another, preferably in the unfired state, as hereinafter explained, to produce more complicated shapes such as spherical, parabolic or hyperbolic. For cylindrical annuli of large

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radius, a number of smaller annuli can be cut into segments with sides at angles representing radii of the larger structure and then assembled. The outer and inner surface will not be regularly circular but this procedure may often prove more convenient than construction of the larger structure. Sheets of square shape may also be employed to build structures of box-like external configuration.

One characteristic feature of the flame-containing structures of the invention which have central openings is that inlet and outlet faces possess different areas. It will be apparent that this feature is particularly advantageous, when reaction such as combustion results in enlarged volumes of outgases.

An extremely useful feature of these structures is their radiative ability, which, coupled with their other features, presents great advantages. It will be seen that the outer surfaces of these structures present such an apparent enclosure of the inner structure owing to the numerous curved surfaces that from a given point external and removed from the outer surface only relatively few of the passageways can be seen in cross-section as holes. It follows that heat is radiated to that external point from all the other visible structure. The structure operates to transmit the heat from the internal flame not only by conduction but very strongly by radiation.

The high radiative ability of structures of the invention can be employed in reverberatory furnaces. Since the structures present very little resistance to flow of gases, they may be used to provide radiative surface where the use of flue openings has heretofore been necessary. When composed of or coated with thermoluminescent materials, e.g. thoria, these structures provide an intense source of brilliant light.

These structures further provide excellent supports for catalysts, particularly for gas phase reactions at elevated temperatures. The extensive interconnection of the passageways assures turbulent flow and good contact of gas with the catalyst-coated surfaces.

It is thus apparent that the cylindrical annular structures of the invention possess a most useful and unprecedented combination of properties; namely, internal flame stabilization, low resistance to gas flow, high radiative ability and adaptability in form.

The following specific examples are set forth to show the production of use of representative structure of the invention.

Example 1

Two refractory annular flame-containing structures designated M-31 and M-28 having respectively 7 and $4\frac{1}{2}$ corrugations per inch are fabricated from flexible polymer-bonded sheets consisting essentially of ceramic particles which will combine during firing to approximately the composition of cordierite, and containing a few percent by weight of cellulose fibers to enhance the green strength of the sheets.

The sheets are corrugated to the stated respective frequency by passage between mating corrugating rollers and are then cut into annular discs having central holes 2 inches in diameter and 6 inches in outer diameter. These discs are assembled in stacks, one stack being made of the sheets having 7 corrugations per inch and the other stack being made of sheets having $4\frac{1}{2}$ corrugations per inch. Successive discs are superimposed with corrugations at right angles. A slurry of the same ceramic particles with small additions of a phosphate flux and polyvinyl alcohol as a binder is used as a temporary adhesive where corrugations touch. The sheets are stacked to a total height of about 3.6 and 6 inches respectively. The two green shapes thus produced are dried, and subsequently fired at about 1350°C . for about $2\frac{1}{2}$ hours. The ceramic particles in the temporary binder become an integral part of the structure on firing and hold it together.

The flame-containing structure designated M-28 is mounted in an afterburner casing as shown in FIGURE 3 in which the plenum section is about 11 inches in diameter and about 12 inches high and the burning section (within the insulation and refractory) is 8 inches in diameter and 10 inches high (exclusive of base and closing plates). Thermocouples are positioned so there is one in the central hole, three located radially in the flame-containing structure and one in the space peripheral to the structure to measure temperatures during operation.

Exhaust gases from a small test engine (output up to about 2.5 standard cubic feet per minute) are passed through the afterburner. Homogeneous combustion is started by preheating the afterburner and shape with an auxiliary heater so that a temperature of 1400° F. is reached at the central part of the structure. At an input rate to the afterburner of about one standard cubic foot per minute and the addition of about 0.25 s.c.f.m. of supplementary air plus a fraction (about one seventh) of the amount of raw gasoline entering the engine added to the exhaust gases upstream from the plenum chamber, combustion continues within the flame container as shown by the temperature readings.

Structure M-28 is removed and the structure designated M-31 is mounted in the casing and operated as above. The entrance gases contain about 7% carbon monoxide and about 225 parts per million of hydrocarbons as hexane (determined by infra-red absorption spectrometry). The exit gases after burning containing substantially 0.0 percent carbon monoxide and no hydrocarbons as determined by this method. The flame is maintained in the shape within limits of gas flow of about 0.5 to 1 s.c.f.m. In view of the elevated temperature necessary for perpetuation of combustion extremely low flow rates are not feasible in this instance.

Increased shielding of the flame-containing structure to lessen losses due to external radiation of heat is found to be desirable in some applications. This is effected in one embodiment by mounting the annular flame-containing structure within a cylindrical insulated casing and providing concentric inner passageways to effect utilization of the sensible heat of the burned exhaust gases, and of the heat radiated inwardly from the structure, to preheat the secondary air and the entering exhaust gases. A centrally located tube extends along the long axis of the cylinder to form the exit passageway for the incinerated exhaust gases. Thus tube is surrounded by a passageway for secondary air which is added to the incoming exhaust gases, and is in turn surrounded by the ceramic structure. Exhaust gases to be burned enter an annular inlet plenum chamber at one end, from which they pass through a mixing throat and mix with the preheated secondary air. The mixed gases enter the flame-containing structure through the inlet annular passageway surrounding the passageway for secondary air, the exterior "wall" of this inlet passageway being formed by the interior face of the ceramic structure. This wall radiates heat to the other wall thus further heating the secondary air. After burning in the flame-containing structure, the burned gases pass outwardly to the space between the ceramic shape and the cylindrical shell and enter the central exhaust passageway by means of a plenum chamber and ports in the central exhaust passageway at the end opposite the inlet end. A spark plug is fitted at a convenient point in the casing to provide for initial ignition.

An afterburner as above described is constructed having a cylindrical flame-containing structure consisting essentially of corrugated aluminum oxide sheets having 9 corrugations per inch with a central opening of 4 inches internal diameter and 7.5 inches in external diameter, and 9 inches long. This device is attached to the exhaust manifold of a six-cylinder automobile engine of 223 cu. in. displacement and 31.5 H.P. (AMA rating). When the exhaust gases are first ignited by sparking in the outermost annular space with the engine choked to

give a rich mixture, the temperature gradually rises and the flame moves back (up stream) into a flame-containing shape and is maintained there. The carbon monoxide content of the admitted gases is reduced from between 3.5 and 6.5 percent by volume to values below 1.0 percent by volume. Under some conditions this value is even reduced below 0.25 percent. The pressure drop across the afterburner is below 5 cm. of mercury.

Another embodiment of the invention is found to provide a useful burner for air and gas mixture and can be employed, for example, in a furnace. A refractory block, for example, of clay, about 3" x 4" x 8", is provided which has a cavity about 1½" x 3" x 3" deep in one of the 3" x 8" faces. A hole is bored to connect the cavity with an end of the block, and a suitable gas-air inlet connector is cemented into the bore. A flame-containing structure of the invention having the form of a segment of one of the above annular shapes is cemented into the cavity using fire clay or furnace cement. The structure is cut along radii 30° apart so that the cut faces are not parallel and consequently the inner concave surface area is smaller than the outer convex surface area. A generally wedge-shaped segment 3 inches long, about 1 inch thick (between the inner and outer curved surfaces) and about 2 inches wide at the outer curved surface is thus prepared from an annular structure as described above consisting substantially of cordierite after firing.

The cordierite segment is mounted so that it is embedded to about one-half its height in the cavity of the fire brick and the exposed sides are covered with sheets of cordierite, such as those employed in construction of the shape, or fire clay, etc., so that burned gases emerge only from the convex face. A gas-air mixture is provided as above and the burner is ignited. The flame burns entirely within the cordierite segment and radiates heat very effectively. Greater surface for radiation of heat can be provided by a shorter radius of curvature of the convex surface or by otherwise altering the geometry of the shape.

In another embodiment of the invention, a chemical reaction is carried out in the structure. This can be illustrated by a catalytic process, specifically the catalytic conversion of carbon monoxide to carbon dioxide with platinum. This method is usefully employed to remove the carbon monoxide from automobile exhaust gases. The conversion is effected in the presence of platinum at temperatures above about 450° F.

A cylindrical stainless steel casing about 10 inches in diameter and 29 inches long is constructed with an outlet connection at one end and a cover plate having an inlet and catalyst mounting means at the other. The outer surface of the casing is provided with cooling fins. A structure according to the invention is made composed of stacked, corrugated, somewhat porous alumina disks, about 27 inches long and 5¾ inches in diameter, and with a central passageway 2 inches in diameter, the sheets being adhered to each other at the point of contact. This structure is treated by soaking it in about 5% aluminum nitrate solution, followed by immersing it in 20% aqueous ammonia and then heating to about 950° F. This sequence is repeated 12 times, to impregnate the ceramic with a suitable aluminum oxide base for the platinum catalyst. The structure is then soaked in 0.03 M chloroplatinic acid solution and heated to form metallic platinum. These steps can be carried out on the fired, corrugated ceramic disks before assembling them, if desired, but it is more convenient to assemble the structure first. The catalytic structure is mounted on the cover plate of the casing with the central hole positioned in line with and connecting to the inlet opening. A plug is provided in the central passageway at about 5½ inches from the inlet end and the distal end of the passageway closed by a flat fire clay disc of the same diameter as the catalytic structure. The unit is then assembled in the casing with a circumferential annular partition which

also serves as a support for the catalytic shape in the casing being located about 12 inches from the inlet end. About two inches of head space remains at the outlet end. The catalytic structure is mounted by means of suitable locating studs within the casing. The combination of the plug in the passageway and the annular support effectively makes the one catalytic structure into three sequential portions, so that the flow through the unit is first radially outward through the catalytic structure, then radially inward and finally radially outward and then to the outlet. The unit is employed as an afterburner on an internal combustion engine. It is mounted in the exhaust gas stream about 8 inches from the manifold; about 15% of secondary air is mixed with the exhaust gases before they enter the inlet of the afterburner. When the temperature in the catalytic structure reaches about 475° F., catalytic and exothermic conversion of CO to CO₂ starts. Since no preheater is provided it is found that racing the engine substantially reduces the time necessary to start reacting. The reaction becomes progressively more efficient as the entire catalytic shape heats. The engine is run through cycles of idling, acceleration, cruising and deceleration for a prolonged period (equivalent to over 6,000 miles). The carbon monoxide is consistently reduced from the range of about 3 to 5 percent by volume to no more than a few tenths of one percent and on parts of the cycle is usually less than 0.1 percent. The pressure drop through the catalytic structure is very low. The catalytic oxidation of carbon monoxide to the dioxide is thus seen to be carried out very efficiently in the milieu provided by the ceramic shape of the invention.

What is claimed is:

1. A milieu for gaseous reactions consisting of an assemblage of stacked superimposed refractory corrugated sheets, the axes of the corrugations of adjacent consecutive sheets being non-parallel and the said sheets being held in contact to each other only at the intersection of the ridges of said adjacent sheets, the edges of said corrugated sheets being aligned and collectively forming at least two faces, at least one of the said faces being an inlet into said milieu for unreacted gases and the remainder of said faces being an outlet for reacted gases; and means for introducing gases into said milieu via said inlet.

2. A flame container for gaseous combustion consisting of an assemblage of stacked superimposed refractory corrugated sheets, the axes of the corrugations of adjacent consecutive sheets being non-parallel and the said sheets being in contact with and adhered to each other only at the intersection of the ridges of said adjacent sheets, the edges of said corrugated sheets being aligned and collectively forming at least two faces, at least one of said faces being an inlet into said flame container for unreacted gases and the remainder of said faces being an outlet for reacted gases; and means for introducing gases into said flame container via said inlet.

3. A flame container of generally cylindrical form consisting of an assemblage of stacked superimposed refractory corrugated discs provided with a central aperture, the axes of the corrugations of consecutive discs being non-parallel and the said discs being urged together and contacting each other only at the intersections of the ridges of adjacent sheets, the edges of said discs and of said cen-

tral apertures being aligned and collectively forming an exterior face and an interior face, respectively, of said assemblage; the interior face being an inlet into said flame container for unreacted gases and the exterior face of said assemblage being an outlet for reacted gases and a means comprising the passageway defined by the said interior face for introducing gases into said flame container.

4. A flame container of generally cylindrical form consisting of an assemblage of stacked superimposed refractory corrugated discs provided with a central aperture, the axes of the corrugations of consecutive discs being non-parallel and the said discs being adhered together and contacting each other only at the intersections of the ridges of adjacent sheets, the edges of said discs and of said central apertures being aligned and collectively forming an exterior face and an interior face, respectively, of said assemblage; the interior face being an inlet into said flame container for unreacted gases and the exterior face of said assemblage being an outlet for reacted gases and a means including the passageway defined by the said interior face for introducing gases into said flame container.

5. An afterburner for automobile exhaust gases having a combustion-supporting content of oxygen comprising, in combination,

A. a casing provided with an inlet for said exhaust gases and an outlet for said gases after combustion thereof,

B. means for initiating combustion of the said exhaust gases and,

C. a flame-container, positioned within said casing so as to be traversed by said gases after initiation of combustion, consisting of an assemblage of stacked superimposed refractory corrugated sheets, the axes of the corrugations of adjacent consecutive sheets being non-parallel and the said sheets being in contact with each other only at the intersections of the ridges of adjacent sheets.

6. An afterburner for automobile exhaust gases having a combustion-supporting content of oxygen comprising, in combination,

A. a casing provided with inlet and outlet means for said exhaust gases,

B. means for initiating combustion of the said exhaust gases and,

C. a flame-container, positioned within said casing so as to be traversed by said gases after initiation of combustion, consisting of an assemblage of stacked superimposed refractory corrugated sheets, the axes of the corrugations of adjacent consecutive sheets being non-parallel and the said sheets being adhered in contact with each other only at the intersections of the ridges of adjacent sheets.

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