June 26, 1962 E. J. HOUDRY 3,041,149

CATALYTIC MUFFLER

Filed Aug. 7, 1958 2 Sheets-Sheet 1

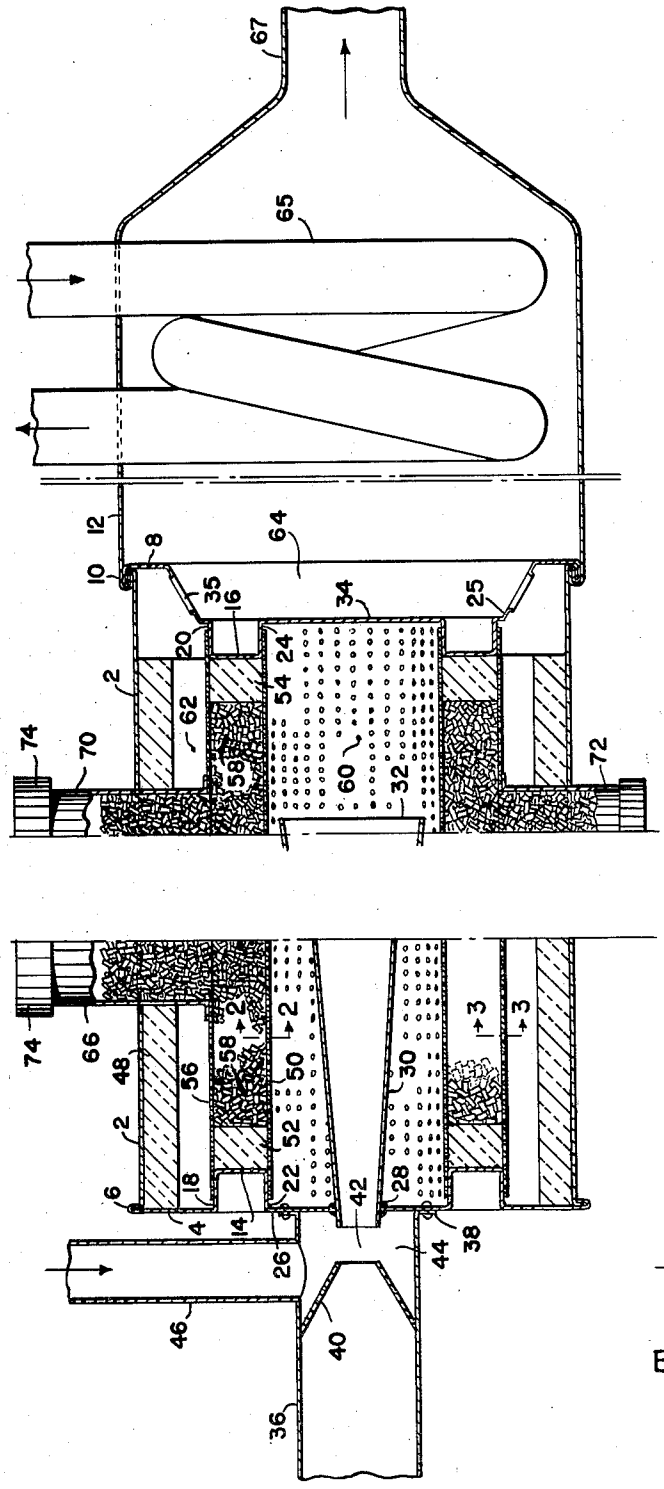


FIG. 1.

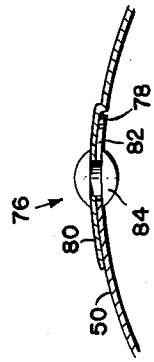


FIG. 2.

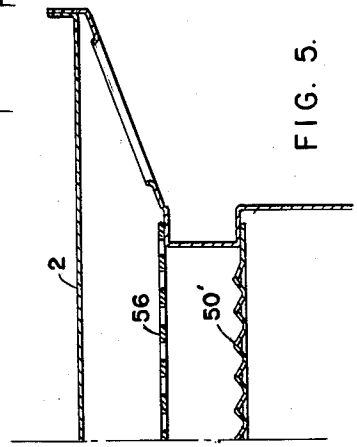


FIG. 5.

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CATALYTIC MUFFLER

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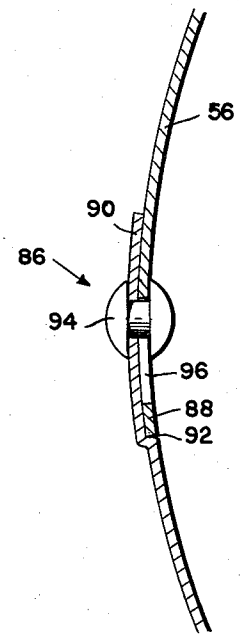


FIG. 3A.

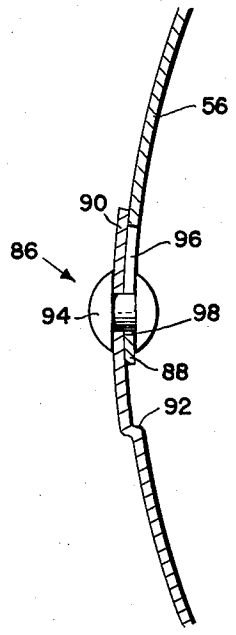


FIG. 3.

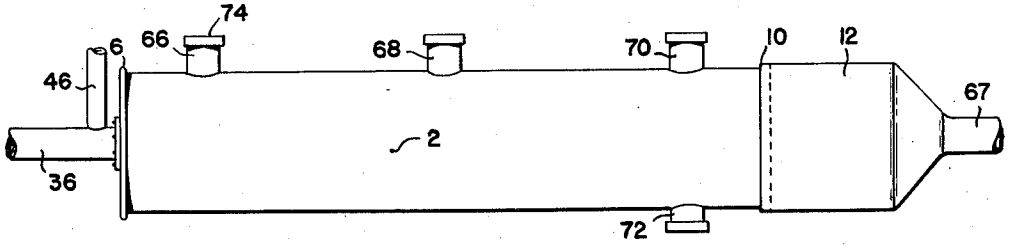


FIG. 4.

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CATALYTIC MUFFLER

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Filed Aug. 7, 1958, Ser. No. 753,845
7 Claims. (Cl. 23—288)

This invention relates to catalytic mufflers of the type designed to receive exhaust gases from an internal combustion engine and effect oxidation of the unburned constituents thereof. The term "muffler" is used not so much for its acoustic properties as for the fact that it is located in the position of an ordinary muffler between the exhaust manifold of an engine and the tailpipe. In general, the apparatus of the type herein referred to does have the acoustic properties of suppressing noise to a considerable degree though it may be augmented by additional muffling means to further reduce noise.

While the present invention has other uses, as will be apparent hereafter, it relates primarily to catalytic mufflers for use on passenger automobiles and trucks particularly when they utilize leaded gasolines. The general characteristics required for such a muffler are set forth in my application, Serial No. 737,424, filed May 23, 1958. In general, they involve the use of catalysts in the form of small pellets with the bed of such catalyst so arranged as to receive the exhaust gases mixed with added air and presenting to such gases a properly determined inlet area and thickness of bed in the direction of flow. When the various requirements are properly chosen, oxidation of hydrocarbons as well as carbon monoxide in the exhaust gases is effected to a substantially complete extent with the result that only innocuous products escape from the muffler. Furthermore, with proper design as set forth in said applications, conditions for quick starting and proper operation under the various extremes of driving conditions are secured. In a muffler of this type, the temperature of the catalyst bed under normal operating conditions varies between 1,000° and 1,200° F. While the requirements for proper operation may be achieved by many shapes and arrangements of catalytic beds and containers therefore, modern automobiles and the necessity for maintaining low the costs of catalytic mufflers impose certain practical restrictions. For example, passenger automobiles are presently being designed with less and less clearance of the ground and space, particularly in the vertical direction, available for a catalytic muffler is substantially reduced. The high temperatures of operation of a catalyst bed furthermore require heat insulation for comfort and safety, still further reducing the space available for a catalytic bed and gas flows to and from the same. Costly materials and features of construction must also be avoided.

It is, accordingly, one object of the present invention to provide for simplicity of construction at minimum cost and at the same time provide a catalytic muffler construction which occupies a minimum of space.

Another object of the invention is to avoid certain difficulties which arise particularly due to the wide variations in temperature inherently involved. While these difficulties are involved in other muffler constructions, explanation will be facilitated by applying the discussion to a catalytic muffler design which is particularly satisfactory in the light of the requirements of simplicity and space saving already mentioned. The most desirable form of the muffler involves providing an annular bed of catalyst to the interior of which the gases are introduced and from the exterior of which they are exhausted, the catalyst bed being bounded interiorly and exteriorly by perforated retaining screens and at

its ends by radial plate members. The screens referred to are desirably cylindrical, though this does not imply that they are necessarily circular cylinders. In fact, to minimize vertical height, and still provide the necessary volume and cross-sectional areas with respect to flow, the cylindrical boundaries are desirably elliptical in cross-section, using the term "elliptical" to include such sections as may be derived from horizontally elongated rectangles with some general rounding of corners and/or their faces. Irrespective of details of the configuration of the annular space, problems arise as follows:

The annular catalytic bed is necessarily, from a practical standpoint, bounded or confined by metallic walls. Whatever metals may be used, their linear thermal coefficients of expansion are considerably in excess of the corresponding linear coefficients of expansion of the catalytic material of the bed. When the automobile is not in use the muffler will, of course, attain the ambient atmospheric temperatures. In use, the bed temperature will rise to the order of 1,200° F. and this will also be true to at least a partial degree of the metal enclosures. Let us assume, now, some typical figures for a catalytic muffler for leaded gasoline applicable to an average passenger automobile. Assuming a circular cylindrical configuration, the inner envelope of the bed may have a diameter of 4 inches, the outer envelope a diameter of 6.4 inches, and the annular bed may have a length of about 30 inches. At atmospheric temperature, the volume of the bed space would, therefore, be 587.5 cubic inches. Let it be assumed that this annular space is filled with catalyst. Assuming stainless steel as the material used for the metal enclosure, if the temperature rises to 1,200° F., the volume of the catalyst space would increase to about 606.5 cubic inches due to metal expansion, this representing an increase in volume of 19 cubic inches.

Meanwhile, the actual mass of the catalyst will increase by its volumetric expansion only about 5 cubic inches, the difference representing a void of 14 cubic inches. The catalyst is a granular solid material, and under the conditions of the rise of temperature just mentioned and vibration due to operation of the automobile, the catalytic mass will act much like a liquid to settle down to a minimum volume having its center of mass as low as possible. The void of 14 cubic inches would thus occur at the uppermost portion of the catalyst chamber. Unfortunately, however, this action, similar to that of a liquid, is not reversible, and under subsequent contraction of volume of the catalyst chamber the granules will not flow back and rise to fill the chamber, but rather will act as a substantially rigid mass with resulting crushing of the catalyst or permanent bulging of the enveloping metal. The result would be either immediate destruction of the housing or the setting up of stresses which would ultimately lead to destruction. Furthermore, the remaining void would have a highly destructive effect on the catalyst and also lead to improper operation. The gases flow at considerable velocity and this would lead to "fluidization" of the top layer of catalyst producing attrition between its granules leading to loss of the catalyst. Furthermore, in an annular arrangement, the space referred to would leave at the top of the bed a minimum length of path through the bed so that an undue proportion of the gases would traverse this path leaving other portions of the catalyst relatively ineffective. This deterioration of operation could be cured by feeding new catalyst into the chamber from supply containers, but this solution would not cure the trouble arising from compacting of the catalyst bed and consequent bulging or straining of the bounding walls. A further object of the present invention is, accordingly, to provide a solution to the problem arising from expansion and settling of the catalyst. In brief,

this is accomplished by design of the catalytic muffler to maintain substantially constant the geometric shape of the catalyst bed, permitting, while maintaining the shape, only such volumetric expansion as is characteristic of the catalyst itself. This end is achieved by providing for an effective expansion of the catalyst chamber to a volumetric extent corresponding to the change of volume of the catalyst while maintaining geometric similarity of volumetric shape throughout the ranges of temperature changes involved.

Furthermore, in accordance with the invention, the foregoing results are achieved without undue heat losses which might result if attempts were made to solve the problems by cooling of the metal boundary walls.

Still other objects relate to the securing of shorter starting times and higher temperature levels of the catalyst, thereby securing optimum performance characteristics.

The foregoing and other objects of the invention particularly relating to advantageous details of construction will become apparent from the following description, read in conjunction with the accompanying drawings, in which:

FIGURE 1 is a vertical axial section through a preferred form of catalytic muffler provided in accordance with the invention;

FIGURE 2 is a fragmentary section taken on the plane indicated at 2—2 in FIGURE 1;

FIGURES 3 and 3A are sections taken on the plane indicated at 3—3 in FIGURE 1 but showing aspects of this section under different operating conditions;

FIGURE 4 is a side elevation of the muffler shown in the preceding figures; and

FIGURE 5 is a fragmentary axial section illustrating an alternative embodiment of the invention.

Referring first to FIGURE 1, there is indicated at 2 the cylindrical outer metallic wall of the muffler. This wall may be a circular cylinder where such shape is permitted by space limitation requirements, or, where vertical space particularly is not available, the cylinder may be of elliptical or other oval configuration having a vertical dimension less than its horizontal dimension in cross-section. For simplicity of description in avoiding numerous references to such variation, the following description will be in terms of circular cylindrical surfaces, but with the understanding that the surfaces so referred to are not necessarily circular in cross-section but may be generally concentric oval or elliptical surfaces. The reference to "cylindrical" surfaces is also not to be strictly construed since conical or bulging surfaces may be provided if desired. It will be evident, however, as the description proceeds, that the same basic principles apply with such obvious modifications of detailed dimensioning as would be entailed by departures from circular cylinders.

At its left hand end the wall 2 has secured thereto an end wall member 4 by means of a rolled or other joint 6. At its right hand end it is secured to a wall 8 and also to a sheet metal housing 12 by means of a joint such as the rolled joint 10. The sheet metal wall 4 is provided with an annular indentation 14 and the wall 8 is provided with an annular indentation 16 to provide a pair of outer shoulders of annular form indicated at 18 and 20 and a pair of inner shoulders of annular form indicated at 22 and 24. The right hand wall 8 is formed with an inwardly directed conical portion 25. The central portion 26 of the wall 4 is provided with a central opening into which is welded at 28 the divergent diffuser element 30 of a Venturi arrangement, this diffuser element desirably opening at 32 in the right hand portion of the muffler body. The purpose of this is not only to save axial space but to effect by radiation from the catalyst bed preheating of the gases during their passage through the diffuser. The central portion of the right hand wall 8 is closed as indicated at 34.

It may here be pointed out that in an average type of muffler for use in connection with passenger automobiles, the spacing between the walls 4 and 8 may be of the order of 30 inches.

There is indicated at 36 the combustion gas exhaust pipe connected to the exhaust manifold of the engine. This is secured by a flange 38 to the central portion 26 of the end wall 4 by welding or bolting. The pipe 36 is provided with converging wall elements 40 providing a nozzle spaced from the diffuser 30 at 42 and arranged to provide a jet of gases into the diffuser to carry air thereinto by ejector action from the annular space 44 connected by a tube 46 to the atmosphere, the air being drawn into the tube 46 from any desired location. This arrangement provides for the additional air required for the oxidation of the unburned constituents of the engine exhaust gases.

Bounding the internal surface of the wall 2 is a cylindrical heat insulator 48 which may be of any conventional composition.

An internal bounding wall for the catalyst bed is provided by a screen member 50 of cylindrical shape, this screen member being desirably provided by sheet metal having perforations therein which are smaller than the catalyst pellets so as to retain them. The screen member 50 is held in central position by the annular shoulders 22 and 24. At its ends and abutting the depressed portions 14 and 16 of the walls 4 and 8 it mounts annular heat insulating elements 52 and 54. An outer boundary for the catalyst bed is provided by a screen member 56, also desirably formed of sheet metal having perforations sufficiently small to prevent escape of the catalyst pellets. The screen member 56 is held in annularly centered position by the shoulders 18 and 20.

The catalyst mass is indicated at 58 and fills the annular space between the screen members 50 and 56. This catalyst may be of the type described in my prior applications referred to above and from the mechanical standpoint may, for example, consist of particles in the form of short cylinders which typically may have a diameter of 1.5 millimeters having somewhat random lengths of the same or larger dimensions. These catalyst particles are filled into the space between the screen members 50 and 56 at random and the initial filling is desirably effected with attendant vibration so as to compact the particle mass and secure a maximum filling of the space with the catalyst. The path of the exhaust gases, admixed with air in the Venturi, is from the space 60 within the screen member 50, through the screen member 50, the catalyst bed, and the screen member 56, thence into the annular space 62 outside the screen member 56 and through openings 35 in the conical portion 25 of wall 8 into the interior of the member 12, where the hot gases may be directed over the air heating coil 65, with final exhaust to the tailpipe 67. The provision of a heating coil 65 is in accordance with the disclosure of my application, Serial No. 457,500, filed September 21, 1954, now abandoned.

As the operation of the catalyst proceeds, some is eventually lost by reason of attrition due to vibration producing a dust which escapes through the screen member 56 with gradual reduction of the amount of catalyst in the catalyst chamber provided between the screen members 50 and 56. It is highly desirable to keep the catalyst chamber full, and to this end there are connected to the screen member 56 a plurality of catalyst supply chambers indicated at 66, 68 and 70 which communicate with large openings in the screen member and extend outwardly through the insulation 48 and the wall 2 at the top thereof and are provided with screw or other suitable caps indicated at 74. These chambers are filled with additional catalyst which, as catalyst is lost from the catalyst chamber, will pass thereinto to maintain the same filled, being distributed therein by reason of vibration. The caps 74 may be removed from time to time to ascertain whether any additional catalyst should be added. It may be here noted that the purpose of this addition is not to fill upper voids such as were referred to in the beginning of this specification as possibly resulting from differential expansions. As will shortly appear,

the design is so made as to prevent the formation of such volumetric voids.

At the bottom of the muffler there is desirably provided in communication with the catalyst chamber an outlet tube 72, normally capped, through which the catalyst may be removed when its useful life has terminated and refilling of the muffler is required.

Reference may now be made to those aspects of the invention relating to the prevention of troubles due to differential expansions as outlined above.

As illustrated in FIGURE 2, the inner screen member 50 is not a continuous cylinder but is provided with an expansion joint 76 involving its overlapping edges 78 and 80. The inner overlapping edge 78 is provided along its length with a plurality of circumferentially elongated slots 82 which slidably receive the shanks of rivets 84 which are secured in or which loosely fit circular openings in the overlapping edge portion 80. A range of relative movement of the edge portions is thus provided, with the overlap 80 of sufficient extent to close the slots throughout the range of movement. When the muffler is cold, the rivets project through the right hand ends of the slots 82 under the confinement by the shoulders 22 and 24 which determine the cylindrical surface aspect of the screen member 50. As the temperature rises, the attendant circumferential expansion of the screen member 50 causes the overlapping edges to increase their overlap, and this is permitted by the relative movements of the rivets 84 in their receiving slots 82, so that at the highest operating temperature conditions will exist as illustrated in FIGURE 2. Thus, despite the changes of temperature, the screen 50, which as a whole tends to expand by spring action, will present a substantially constant circumference to the catalyst bed, the circumference being determined by the shoulders 22 and 24.

Referring, now, to FIGURES 3 and 3A these show expansion joints 86 for the outer screen member 56. In the case of this screen member, since it is anchored at its top and bottom by the tubes 66, 68, 70 and 72, it is desirable to provide an expansion joint on each side, and one of these will be described with the understanding that the other is identical.

In the case of each of these joints there are provided the overlapping longitudinally extending edges 88 and 90. As illustrated, the edge 90 is diverted slightly outwardly to provide a shoulder 92. Rivets 94 spaced along the overlapping edges are secured to the overlapping edge 90 and pass through corresponding circumferentially elongated slots 96 in the overlapping edge 88, the overlapping edge 90 being of sufficient length to close these slots in all positions assumed during operation. The elements forming the screen member 56 are so shaped that by spring action when the muffler is cold they tend to contract about the shoulders 18 and 20 with the result that edges tend to increase their overlaps as indicated in FIGURE 3. This overlap is limited by the shoulders 18 and 20 but there exists at 98 some clearance between the rivet 94 and the lower end of the slot 96 in the case of each rivet. The reason for providing this clearance is that as operation of the engine is started the innermost portion of the catalyst first becomes hot while the outer portion adjacent to the screen member is relatively cold. Some volumetric expansion of the catalyst bed then takes place resulting in an increase of its outer diameter which may not be compensated by the increase of circumference of the members forming the screen member 56. The clearance at 98 permits this expansion to take place against the spring action of the screen member avoiding any undue compression on the catalyst bed. However, in a short time, the screen member 56 will become heated and the metal will expand at a circumferential rate considerably exceeding the rate of expansion of the outer circumference of the catalyst bed. When this condition is attained, the overlapping edges 88 and 90 will move so that the relative movements between the rivets 94 and slots 96 will cause the rivets to approach the upper ends of the slots 96. Nevertheless, the screen members 56 will tend to approach by spring actions the shoulders 18 and 20, or, rather, bind upon the catalyst bed which may have slightly expanded to prevent actual contact of the screen member with these shoulders. Finally, to limit this spring action, the end of the overlapping edge 88 will ultimately abut the shoulder 22 whereupon the screen member 56 effectively becomes a rigid cylinder thereafter expanding at the rate determined by its own linear coefficient of expansion. This condition, however, is desirably attained only when the temperature reaches its approximate maximum, and accordingly the expansion then resulting is so slight as to make negligible difference of the expansion rates of the catalyst bed and the screen member 56 so as not to enlarge the catalyst space appreciably over the enlargement of the catalyst bed itself due to its own expansion.

The axial expansion of the catalyst bed is readily accommodated by the flexibility of the end walls 4 and 8 which are insulated at 52 and 54 from the catalyst bed so that they are subjected to a relatively small rise of temperature, and this, in particular, prevents any great increase of the spaces between the shoulders 18 and 22 and between the shoulders 20 and 24. The longitudinal spacing between the inner faces of the insulators 52 and 54 will, of course, be changed to the extent of expansion of the wall 2 in an axial direction. However, this wall remains quite cool due to the insulation 48, and for practical purposes it may be said that the axial length of the enclosure changes only to a degree corresponding to the change of axial length of the catalyst bed due to its own expansion.

It will be noted that the screen members 50 and 56 have lengths substantially less than the spacings between the portions of walls 4 and 8 which they might abut. They are accordingly free to expand longitudinally without changing the volume of the catalyst space.

In the foregoing description it has been assumed that ordinary steel has been used for the metal elements of the container and that this steel, as would ordinarily be the case, has expansion coefficients considerably exceeding corresponding coefficients of the catalyst bed. Such ordinary steel is desirably porcelainized for corrosion resistance. What has been described so far, permits such use of ordinary steel with complete attainment of the objective of the invention which pertains to the maintenance of the geometric shape of the catalyst bed while permitting a proportional increase in linear dimensions in accordance with the thermal expansion of the bed. With ordinary steel, however, this is attended by substantial movements of the expansion joints in the screen members 50 and 56 which will produce some relative sliding movements between these screen members and the catalyst particles, and may produce some shearing action particularly at the openings in the screen members the edges of which may have some cutting action on the catalyst. While this action does not appear to have any major deteriorating effect, it may be substantially completely avoided by the adoption of additional precautions by way of dimensioning and choice of metals so that the relative movements of the edges of the joints may be reduced to a minimum. Expedients to achieve this end will now be described, and it will appear from the following that by the use of such expedients there may even be eliminated the necessity for use of the expansion joints.

For example, if the insulation 48 is omitted (and for purpose of keeping the muffler from radiating too much heat to the automobile floor insulation is provided exterior to the wall 2), and it is assumed that the temperatures of the screen members 50 and 56 and of the wall 2 continuously approximate, during operating conditions, the catalyst bed temperature, the screen member 50 might be made of stainless steel having a linear coefficient of expansion of 18×10^{-6} per degree centigrade, and the screen

member 56 and wall member 2 may be made of a steel such as that containing 0.13% chromium and 2% nickel having a coefficient of expansion of 9.99×10^{-6}, and without insulation at 52 and 54, and with the typical volumetric increase of the catalyst bed of the order of 1% between atmospheric temperature and the temperature of normal catalyst operation. The volume of the catalyst bed for the typical muffler dimensions given above would approximately equal the volume of the catalyst space through the range of temperature involved, the greater increase of diameter of the screen member 50 relative to the increase in diameter of the screen member 56, taking also into account the change in axial dimension of the catalyst space effecting the compensation. The foregoing assumes the same temperature for all of the metal parts, but taking into account the fact that the screen member 50 might have a higher temperature than the screen member 56 and this, in turn, a higher temperature than the wall 2, the same compensating aspects would be involved by a proper choice of the coefficients of expansion of the different metals forming these various elements. The major aspect of this is, of course, that the coefficient of expansion of the screen member 50 should be greater than the coefficient of expansion of the screen member 56.

Another solution to the same problem permits compensation by using primarily ordinary steel having a coefficient of expansion of about 12×10^{-6} for the screen member 56 and the wall 2, if stainless steel having a coefficient of expansion of 18×10^{-6} is used for screen member 50 provided the diameter of the screen member 56 is properly chosen. For example, with the metals just indicated, and the other dimensions of the muffler as given above, the diameter of the screen member 56 could be chosen as 5.1 inches, here again the same temperatures being assumed for the two screen members and the wall 2.

A third solution to the problem would involve the construction illustrated in FIGURE 1 including the insulation 48 within the wall 2 to maintain this wall at a low temperature while wall member 56 was constructed of ordinary steel, preferably porcelainized, with the screen member 50 constructed of stainless steel of the type indicated. In this case, compensation would be effected by the maintenance of the wall 2 at relatively low temperature.

FIGURE 5 shows still another solution in which the inner screen member 50', corresponding to 50, is corrugated at least longitudinally, and preferably both longitudinally and circumferentially but of ordinary steel, the corrugations, by adding extra metal over a given projected area, in effect increasing the overall coefficient of expansion, for example, to that corresponding to an ordinary cylinder of stainless steel.

While the foregoing methods of compensation may be used without the expansion joints heretofore described, it is desirable to use the expansion joints to take care of the transient conditions particularly involved in starting up inasmuch as they may vary considerably from time to time, producing unpredictable relative temperature variations of the parts of the muffler. However, by utilizing the compensations involved in various actual or effective coefficients of expansion of the metal parts, the relative movements in the expansion joints may be minimized and thereby minimize destructive action on the catalyst particles.

It will be evident from the foregoing that there are attained the various objects of the invention above mentioned. The muffler comprises a minimum number of parts readily assembled and accordingly the cost is a minimum. The chamber provided at 12 may not only contain a heater such as indicated at 65 but may contain acoustic muffling devices to minimize noise.

It will be evident that various changes in details may be made without departing from the invention as defined in the following claims.

What is claimed is:

1. A catalytic muffler for the oxidation of combustible materials in engine exhaust gases comprising radially spaced inner and outer annular members provided with openings for flow of gases, means closing the ends of the annular space between said members, catalyst particles within said annular space, means for leading exhaust gases and excess oxygen to the interior of said inner member, and means for leading products of oxidation by the catalyst from the exterior of said outer member, said inner annular member having an effective coefficient of expansion greater than the effective coefficient of expansion of said outer annular member, said effective coefficients of expansion of said members being such that as the container expands from a cold, non-operating condition to operating temperatures, the volumetric thermal expansion of said annular space is substantially equal to the volumetric thermal expansion of said catalyst particles within said annular space.

2. A catalytic muffler according to claim 1 in which the greater effective coefficient of expansion of said inner annular member is provided by corrugations.

3. A catalytic muffler according to claim 1 in which said different coefficients of expansion are achieved by the use of different materials for said annular members.

4. A catalytic muffler according to claim 1 in which said inner and outer annular members are provided with longitudinally extending expansion joints to permit circumferential expansion in combination with means maintaining approximately constant the confining circumferences of said members.

5. A catalytic muffler according to claim 2 in which said inner and outer annular members are provided with longitudinally extending expansion joints to permit circumferential expansion in combination with means maintaining approximately constant the confining circumferences of said members.

6. A catalytic muffler according to claim 3 in which said inner and outer annular members are provided with longitudinally extending expansion joints to permit circumferential expansion in combination with means maintaining approximately constant the confining circumferences of said members.

7. A catalytic muffler for the oxidation of combustible materials in engine exhaust gases comprising a container comprising radially spaced inner and outer members defining an annular space therebetween and provided with openings for flow of gases and means closing the ends of the annular space between said members, catalyst particles substantially filling the annular space of said container, the volumetric thermal expansion of the annular space of said container from a cold, non-operating condition to operating temperatures being substantially equal to the volumetric thermal expansion of the mass of catalyst particles in the annular space of said container, means for leading exhaust gases and excess oxygen to the interior of said inner member and means for leading products of oxidation by the catalyst from the exterior of said outer member.

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