Title: SUBSTRATE RETAINER FOR EXHAUST PROCESSOR

Abstract: An exhaust processor (10) having a central axis (32, 40), an outer shell (12), a substrate (14), and a substrate support (22) is disclosed. The outer shell (12) has an internal surface (30) defining an interior region. The substrate (14) has a first end (34), a second end (36), and an outer surface (38) extending between the first and second ends (34, 36). The substrate (14) is positioned in the interior region of the outer shell (12) so that the outer surface (38) of the substrate (14) is displaced from the internal surface (30) of the outer shell (12) by a distance. The substrate support (22) includes an intumescent material (62) and a wire mesh (60) coupled to the intumescent material (62) and is positioned to lie between the outer shell (12) and the substrate (14). The intumescent material (62) includes a first portion adjacent to the first end (34) of the substrate (14) and a second portion adjacent to the second end (36) of the substrate (14).
SUBSTRATE RETAINER FOR EXHAUST PROCESSOR

Background and Summary of the Invention

This invention relates to catalytic converters used in exhaust systems for motor vehicles and, more particularly, to components of catalytic converters which retain a monolithic substrate within a sheet metal container.

Catalytic converters generally, and the use of intumescent mat supports and wire mesh supports for retaining substrates within an outer shell of a catalytic converter, are discussed in Usleman et al., U.S. Patent No. 5,293,743 and Sickels et al., U.S. Patent No. 5,829,132 both of which are assigned to the assignee of the present invention and are incorporated herein by this reference.

Catalytic converters typically include a sheet metal shell surrounding a monolithic honey-combed ceramic substrate which catalyzes reactions with gasses in engine exhaust to reduce undesired emissions. The substrate is typically supported and retained in a central position within the metal shell. Two types of supports are normally used to retain the substrate. The first is a corrugated knitted wire mesh, normally made of stainless steel wire. The corrugated knitted wire mesh is effective at retaining the substrate as long as the gas temperatures in the exhaust do not get too high. The second type of support normally used is an intumescent mat support. Flakes of vermiculite are blended with ceramic fibers and a binder to form the intumescent mat. At a temperature of 300-400 degrees centigrade, the flakes of vermiculite expand to increase pressure exerted on the substrate by the intumescent mat and thereby compensates for the expansion of the sheet metal container as it heats up.

A problem that can develop with the support of substrates is that in some driving conditions, such as towing a heavy load up a steep grade, the exhaust gas temperatures can increase to over 1000 degrees centigrade. Wire mesh supports cannot survive at these temperatures resulting in loss of retention of the substrate. Therefore, catalytic converters using only corrugated wire mesh supports are subject to failure when operated at high temperatures.

Conversely, under other driving conditions, such as low speed “in city” driving, the temperature of the exhaust reaching a catalytic converter may never reach 300-400 degrees centigrade. An intumescent mat often needs to be exposed to
temperatures of at least 500-600 degrees centigrade for the initial expansion of the mat to take place. Because the mat support never reaches its initial expansion temperature, the retention on the substrate is lost as the outer shell expands more quickly than the substrate. Thus, catalytic converters using only intumescent mat supports are subject to failure during low temperature operation.

Bailey et al., U.S. Patent No. 4,269,807, discloses a small band of intumescent mat embedded in the mesh to provide a sealing function. Bailey et al. is entitled “Catalytic Converter Mounting Arrangement for Reducing Bypass Leakage” and in the claims limits the band of intumescent material to having an axial length substantially less than the axial length of the catalyst element or substrate. Bailey et al. combines a wire mesh for retention of the substrate and a small band of intumescent mat for reducing bypass leakage.

The substrate retainer for a catalytic converter of the present invention combines both a wire mesh support and an intumescent mat support. The corrugated wire mesh support is embedded within an intumescent mat support. Under low temperature operating conditions, before the intumescent mat support has expanded, the substrate is retained principally by the corrugated wire mesh support. If temperatures get high enough to cause the corrugated wire mesh support to loose its retention, then the temperature is high enough to expand the intumescent mat support. At that point, the substrate is retained principally by the intumescent mat support.

In the present invention, both the mesh support and intumescent mat support extend the full length of the substrate and they both contribute to the retention of the substrate.

According to the present invention, an exhaust processor having a central axis includes an outer shell having an external surface facing away from the central axis and an internal surface facing toward the central axis and defining an interior region. The exhaust processor also includes a substrate having a first end and a second end spaced apart from the first end along the central axis, and an outer surface extending between the first end and the second end. The substrate is positioned in the interior region of the outer shell so that the outer surface of the substrate is displaced from the internal surface of the outer shell by a distance. A substrate support including an intumescent material and a wire mesh coupled to the
intumescent material is positioned to lie between the outer shell and the substrate. The intumescent material includes a first portion adjacent to the first end of the substrate and a second portion adjacent to the second end of the substrate. The wire mesh may be corrugated to define troughs and ridges defining an uncompressed amplitude therebetween, the intumescent material will have a first surface and a spaced apart oppositely facing second surface defining an uncompressed thickness therebetween, and the uncompressed amplitude may be substantially equal to the uncompressed thickness.

In accordance with another aspect of the invention a substrate retainer is provided for an exhaust processor having an outer shell including an external surface facing away from a central axis and an internal surface facing toward the central axis and defining an interior region and a substrate including a first end, a second end spaced apart from the first end along the central axis, and an outer surface extending between the first end and the second end so that the substrate is positioned in the interior region of the outer shell so that the outer surface of the substrate is spaced apart from the internal surface of the outer shell by a distance. The substrate retainer includes an intumescent material and a wire mesh coupled to the intumescent material. The intumescent material has a first portion and a second portion spaced apart from the first portion. The substrate support is designed and arranged to be positioned between the outer shell and the substrate so that the first portion is positioned adjacent to the first end of the substrate and the second portion is positioned adjacent to the second end of the substrate.

Additional features and advantages of the present invention will become apparent to those skilled in the art upon consideration of the following detailed description of preferred embodiments exemplifying the best mode of carrying out the invention as presently perceived.

**Brief Description of the Drawings**

In describing the invention, reference will be made to the drawings in which:

Fig. 1 is a cross-sectional view of a exhaust aftretreatment device having an internal catalyst substrate (ceramic or metal) extending through an interior of
an outer shell and supported by a substrate retainer having corrugated wire mesh support embedded in an intumescent mat support;

Fig. 2 is a cross-sectional view taken along line 2-2 of Fig. 1;

Fig. 3 is a cross-sectional view of the substrate retainer having the corrugated wire mesh support embedded in the intumescent mat support showing ridges and troughs of the corrugated wire mesh support extending to the surfaces of the mat support;

Fig. 4 is a top view of the substrate retainer with portions of the mat broken away to expose corrugated wire mesh support showing the corrugated wire mesh support formed into a sheet which can be bent and shaped to extend circumferentially around the substrate as shown in Figs. 1 and 2, solid angled lines are added to represent the ridges of the corrugated wire mesh support;

Fig. 5 is a detailed perspective view of the portion of the sheet of corrugated wire mesh support enclosed in circle 5 of Fig. 4 showing the individual strands of wire forming the corrugated wire mesh support; and

Fig. 6 is a cross-sectional view, similar to Fig. 3, of an alternative substrate retainer showing a thin layer of mat support extending beyond the ridges and troughs of the corrugated wire mesh support.

20 **Detailed Description of the Drawings**

Referring to Fig. 1 there is shown a catalytic converter, a type of exhaust aftertreatment device or exhaust processor, 10 for use in an automotive exhaust system. Exhaust aftertreatment device 10 includes an outer shell 12, a monolithic substrate 14, two frusto-conical shields 16, two cones 18, insulation 20, and a retaining element 22. Shell 12 has an inlet end 24, an outlet end 26, an external surface 28, an internal surface 30, and a longitudinal axis 32. Substrate 14 includes an inlet end 34, an outlet end 36, an outer surface 38, a longitudinal axis 40, and an axial length 42 defined by the distance between inlet end 34 and outlet end 36.

Substrate 14 and shell 12 are cylindrical. It should be understood that shell 12 and substrate 14 may take on any shape. In the illustrated embodiment, internal surface 30 of shell 12 and outer surface 38 of substrate 14 are conformably shaped so that retaining element 22 is of a uniform thickness to fill the uniform gap
between outer surface 38 of substrate 14 and internal surface 30 of shell 12. In alternative embodiments, the retaining element may have a non-uniform thickness wherein the thickness corresponds with the gap between the outer surface 38 of substrate 14 and internal surface 30 of a nonconformably shaped shell 12.

Substrate 14 is positioned within shell 12 so that longitudinal axis 32 of shell 12 and longitudinal axis 40 of substrate 14 are coincident or coaxial, as shown, for example, in Fig. 1. In the illustrated embodiment, both shell 12 and substrate 14 are cylindrical and thus, outer surface 38 of substrate 14 is uniformly displaced from internal surface 30 of shell 12 by a distance 43. In alternative embodiments in which shell 12 and substrate 14 are not cylindrical, but wherein the internal surface 30 of shell 12 and outer surface 38 of substrate 14 are conformably shaped, shell 12 and substrate 14 may be oriented to maintain a uniform distance 43 between outer surface 38 and internal surface 30.

Each frusto-conical shield 16 includes a substrate-engaging end 44 and an exhaust component-receiving end 46. Shell 12 has a length 33 greater than axial length 42 of substrate 14 and substrate 14 is centered longitudinally and axially within shell 12 as shown, for example, in Fig. 1. Substrate-engaging end 44 of each shield 16 engages one of inlet end 34 and outlet end 36 of substrate 14, as shown in Fig. 1. Exhaust component-receiving end 46 of each shield 16 extends longitudinally beyond one of inlet end 24 and outlet end 26 of shell 12.

Each cone 18 includes a first end 48, a second end 50, and a side wall 52 having an external surface 54 and an internal surface 56. Internal surface 56 of cone 18 is connected at first end 48 to outside wall 58 of shield 16 near exhaust component-receiving end 46. Each cone 18 is also connected at second end 50 to internal surface 30 of shell 12 near one of inlet end 24 and outlet end 26 as shown, for example, in Fig. 1.

Insulation 20 extends between internal surface 56 of each cone 18 and outside wall 58 of each frusto-conical shield 16 to insulate cone 18 from shield 16. Insulation 20 also aids in reducing blow-by gases if a hole is somehow formed in shield 16. Shield 16, cone 18, and insulation 20 together aid in maintaining substrate 14 longitudinally centered within shell 12.
Retaining element 22 supports substrate 14 within shell 12 to maintain substrate 14 axially centered within shell 12 relative to longitudinal axes 32, 40 as shown, for example, in Figs. 1 and 2. Retaining element 22 includes a wire mesh support 60 and an intumescent mat support 62. Wire mesh support 60 is embedded within intumescent mat support 62.

Intumescent mat support 62 is a commonly used material produced by a number of manufacturers (e.g. 3M, Unifrax, and Ibiden). It consists of a homogeneous blend of ceramic fibers and intumescent (heat expanding) vermiculite. Typically, the ceramic fibers and vermiculite are bound together with a latex binder to aid in handling the mat support 62.

Illustratively, wire mesh support 60 is made from multiple strands 64 of stainless steel wire which are knitted or woven together to form a sheet 66 as shown for example in Figs. 4 and 5. The sheet 66 is corrugated to provide resiliency to wire mesh support 60. The wire mesh material which forms wire mesh support 60 is manufactured by a number of companies (e.g. Metrix, ACS, and Converter Support Systems).

Corrugated mesh sheet 66 is formed in a rectangular shape having a first edge 59, a second edge 61 spaced apart from and extending substantially parallel to first edge 59, a third edge 63 substantially perpendicular to, and extending between, first edge 59 and second edge 61, and a fourth edge 65 spaced apart from and extending substantially parallel to third edge 63 as shown in Fig. 4. Sheet 66 has a length 67 defined by the distance between first edge 59 and second edge 61. Sheet 66 also has a width 69 defined by the distance between third edge 63 and fourth edge 65. Length 67 is substantially equal to the circumference of the cylindrical substrate 14 and width 69 is substantially equal to the axial length 42 of substrate 14. Thus, sheet 66 is designed to wrap around substrate 14 to encase substrate 14 over substantially its entire axial length 42 as shown, for example, in Figs. 1 and 2.

Corrugated wire mesh sheet 66 has a sinusoidally shaped cross-section. Other cross-sections providing resiliency to wire mesh sheet 66 are within the scope of the invention. As shown in Fig. 5, ridges 68 and troughs 70 extend substantially parallel to each other similar to crests and troughs of wave fronts. In Fig. 4, solid lines represent ridges 68 of corrugated wire mesh support 60. However, ridges 68 and
troughs 70 are neither parallel nor perpendicular to first edge 59 and second edge 61 of sheet 66. It has been found that if ridges 68 and troughs 70 extend parallel to first edge 59, then corrugated wire support 60 is not sufficiently resilient to support substrate 14 within shell 12. It has also been found that if ridges 68 and troughs 70 are perpendicular to first edge 59 and second edge 61, it is difficult to bend sheet 66 around substrate 14. An acute angle 71 is defined between ridges 68 and troughs 70 and first edge 59 or second edge 61 which measures approximately thirty degrees (30°). It should be understood that acute angle 71 may vary depending on the diameter of the strands 64 forming the wire mesh support 60, the number of ridges 68 and troughs 70 per inch, and the desired stiffness of the mesh support 60.

Ridges 68 and troughs 70 of corrugated wire mesh support 60 define an uncompressed amplitude 72 therebetween as shown, for example, in Fig. 3. Prior to assembly of exhaust aftertreatment device 10, uncompressed amplitude 72 between ridges 68 and troughs 70 is greater than distance 43 between outer surface 38 of substrate 14 and internal surface 30 of shell 12 in the assembled exhaust aftertreatment device 10. In preferred embodiments, uncompressed amplitude 72 of corrugated mesh support 60 is six millimeters (6 mm) for a exhaust aftertreatment device 10 that will have a distance 43 of four millimeters (4 mm) between outer surface 38 of substrate 14 and internal surface 30 of shell 12.

Prior to assembly of exhaust aftertreatment device 10, retaining element 22 is formed by embedding or coupling sheet 66 of wire mesh support 60 within intumescent mat support 62. Intumescent mat support 60 has an uncompressed thickness 76 equal to, or slightly less than, uncompressed amplitude 72 between ridges 68 and troughs 70 of wire mesh support 60, as shown, for example, in Fig. 3. Thus, ridges 68 and troughs 70 extend through or beyond the surface of intumescent mat support 62 as shown, for example, in Fig. 3 and the middle of Fig. 4. It will be understood that the relative uncompressed thicknesses 76, 72 of mat support 62 and mesh support 60 will be similar allowing for mesh support 60 to be totally or substantially embedded within mat support 62 within the scope of the invention.

During assembly of exhaust aftertreatment device 10, retaining element 22 including sheet 66 of wire mesh support 60 embedded in intumescent mat support 62 is wrapped around substrate 14. First edge 59 and second edge 61 of corrugated
mesh support 60 are joined together by spot welds 78 as shown, for example in Fig. 2, or by some other appropriate joining method such as soldering. Third edge 63 of wire mesh support 60 is positioned adjacent one of outlet end 36 and inlet end 34 of substrate 14 and fourth edge 65 of wire mesh 60 is positioned adjacent the other of inlet end 34 and outlet end 36 of substrate 14. Thus, retaining element 22 extends substantially the entire axial length 42 of substrate 14. Shell 12 is then wrapped around the retaining element 22 compressing retaining element 22 between the outer surface 38 of substrate 14 and the internal surface 30 of the shell 12.

This compression by shell 12, compresses both intumescent mat support 62 and wire mesh support 60 creating a compressed thickness of intumescent mat support 62 and a compressed amplitude of wire mesh support 60 which are substantially equal to distance 43 between shell 12 and substrate 14 as shown, for example, in Figs. 1 and 2. Thus, retaining element 22 is compressed between outer surface 38 of substrate 14 and internal surface 30 of shell 12 to create a stored force in wire mesh support 60. Troughs 70 extending through intumescent mat support 62 engage substrate 14 while ridges 68 extending through intumescent mat support 62 engage internal surface 30 of shell 12 to support substrate 14 in its desired location with respect to shell 12 as shown, for example, in Figs. 1 and 2.

Typically, shell 12 has a higher coefficient of expansion than substrate 14, but is insulated from substrate 14 by intumescent material 62 and insulation 20. Thus, as the temperature of shell 12 increases the distance 43 between shell 12 and substrate 14 increases.

Wire mesh support 60 of retaining element 22 supports substrate 14 when the vehicle in which exhaust aftertreatment device 10 is installed is operated under low temperature conditions. During low temperature operation, as the distance 43 between shell 12 and substrate 14 increases, the stored force in wire mesh support 60 is sufficient to support substrate 14 within shell 12. As the temperature of operation rises, wire mesh support 60 begins to change its bonding structure causing the stored force imposed by wire mesh support 60 between substrate 14 and shell 12 to be reduced. Prior to reaching an operating temperature at which the stored force is reduced to the point that wire mesh support 60 can no longer support substrate 14 within shell 12, the vermiculite particles in intumescent mat support 62 begin to expand.
and exert a force between substrate 14 and the shell 12. Thus, the wire mesh support 60 and intumescent mat support 62 cooperate to support substrate 14 within shell 12 through a range of temperature conditions.

In an alternative embodiment of retaining element 122, uncompressed amplitude 172 between troughs 170 and ridges 168 is slightly less than uncompressed thickness 176 of intumescent mat support 162 as shown, for example, in Fig. 6. In retaining element 122 a thin sheet 180 of intumescent mat material extends beyond ridges 168 and troughs 170 of wire mesh support 160. Thus, when retaining element 122 is initially compressed between substrate 14 and shell 12, it will be understood that both intumescent mat support 162 and wire mesh support 160 are compressed but thin sheet 180 of intumescent material engages both the outer surface 38 of substrate 14 and the internal surface 30 of shell 12. Thin sheet 180 is initially compressed between the ridges 168 and troughs 170 and shell 12 and substrate 14, respectively. It is believed that in use, vibration and temperature changes eventually cause ridges 168 and troughs 170 of wire mesh support 160 to extend through surface of intumescent mat support 162. In use, retaining element 122 operates similarly to retaining element 22 to support substrate 14 within shell 12 under varying operating conditions.

The disclosed exhaust aftertreatment device 10 incorporating a retaining element 22 combining a wire mesh support 60 and an intumescent mat support 62 exhibits the advantages inherent in an exhaust aftertreatment device incorporating only an intumescent mat support. Intumescent mat support 62 acts to insulate shell 12 thermally from substrate 14. Since shell 12 does not get as hot as substrate 14, there is no need for additional shielding often required in exhaust aftertreatment devices not using intumescent mat supports. Intumescent mat support 60 also acts to seal the space between shell 12 and substrate 14 to help eliminate gas blowby.

Although the invention has been described in detail with reference to a certain preferred embodiment, variations and modifications exist within the scope and spirit of the present invention as described and defined in the following claims.
What is claimed is:

1. An exhaust processor having a central axis, the exhaust processor comprising:

   an outer shell including an external surface facing away from the central axis and an internal surface facing toward the central axis and defining an interior region,

   a substrate including a first end and a second end spaced apart from the first end along the central axis, an outer surface extending between the first end and the second end, the substrate positioned in the interior region of the outer shell so that the outer surface of the substrate is spaced apart from the internal surface of the outer shell by a distance, and

   a substrate support positioned between the outer shell and the substrate, the substrate support including an intumescent material and a wire mesh coupled to the intumescent material, the intumescent material including a first portion positioned adjacent to the first end of the substrate and a second portion positioned adjacent to the second end of the substrate.

2. The apparatus of claim 1 wherein the wire mesh is corrugated to define troughs and ridges defining an uncompressed amplitude therebetween, the intumescent material has a first surface and a spaced apart oppositely facing second surface, the first surface and the second surface defining an uncompressed thickness, and the uncompressed amplitude being substantially equal to the uncompressed thickness.

3. The apparatus of claim 2 wherein the ridges of the wire mesh extend through the first surface of the intumescent material and engage the internal surface of the outer shell.

4. The apparatus of claim 2 wherein the troughs of the wire mesh extend through the second surface of the intumescent material and engage the outer surface of the substrate.
5. The apparatus of claim 3 wherein the troughs of the wire mesh extend through the second surface of the intumescent material and engage the outer surface of the substrate.

6. The apparatus of claim 2 wherein the substrate support is compressed between the internal surface of the outer shell and the outer surface of the substrate.

7. The apparatus of claim 6 wherein the wire mesh has a compressed amplitude that is substantially equal to the distance.

8. The apparatus of claim 7 wherein the ratio of the uncompressed amplitude to the compressed amplitude is 2:1 or less.

9. The apparatus of claim 7 wherein the ratio of the uncompressed amplitude to the compressed amplitude is approximately 3:2.

10. The apparatus of claim 1 wherein a portion of the wire mesh is embedded in the intumescent material.

11. The apparatus of claim 10 wherein the intumescent material extends between the first portion and the second portion.

12. The apparatus of claim 11 wherein the wire mesh is corrugated to define troughs and ridges defining an uncompressed amplitude therebetween, the intumescent material has a first surface and a spaced apart oppositely facing second surface, the first surface and the second surface defining an uncompressed thickness, and the uncompressed amplitude being substantially equal to the uncompressed thickness.

13. The apparatus of claim 12 wherein the wire mesh has a compressed amplitude that is substantially equal to the distance.

14. A substrate retainer for an exhaust processor having an outer shell including an external surface facing away from a central axis and an internal surface facing toward the central axis and defining an interior region and a substrate including a first end and a second end spaced apart from the first end along the central axis, an outer surface extending between the first end and the second end, the substrate positioned in the interior region of the outer shell so that the outer surface of the substrate is spaced apart from the internal surface of the outer shell by a distance, the substrate retainer comprising:
an intumescent material having a first portion and a second portion spaced apart from the first portion,
a wire mesh coupled to the intumescent material, and
wherein the substrate support is designed and arranged to be positioned between the outer shell and the substrate so that the first portion is positioned adjacent to the first end of the substrate and the second portion is positioned adjacent to the second end of the substrate.

15. The apparatus of claim 14 wherein the wire mesh is embedded in the intumescent material.

16. The apparatus of claim 15 wherein the wire mesh is corrugated to define troughs and ridges defining an uncompressed amplitude therebetween, the intumescent material has a first surface and a spaced apart oppositely facing second surface, the first surface and the second surface defining an uncompressed thickness, and the uncompressed amplitude being substantially equal to the uncompressed thickness.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) :B01D 53/88, 53/94
US CL :422/179, 180, 177
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
U.S. : 422/179, 180, 177

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
APS, DERWENT, EPO, JPO search terms: intumescent, pad, mat, sheet, wire, mesh

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>US 3,876,384 A (SANTIAGO et al) 08 April 1975, see entire document.</td>
<td>1,2,6,10,14-15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6-9, 16</td>
</tr>
<tr>
<td>Y</td>
<td>US 5,686,039 A (MERRY) 11 November 1997, see col. 7, line 66-69, 19</td>
<td>1,2,6,10, 14-15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3-5, 7-9, 11-13</td>
</tr>
<tr>
<td>X</td>
<td>US 4,043,761 A (GAYSERT et al) 23 August 1977, see fig. 1.</td>
<td>1,2,6,14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6-9</td>
</tr>
<tr>
<td>Y</td>
<td>US 5,008,086 A (MERRY) 16 April 1991, figs. 1-2</td>
<td>1-16</td>
</tr>
</tbody>
</table>

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents:
**A** document defining the general state of the art which is not considered to be of particular relevance
**E** earlier document published on or after the international filing date
**L** document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
**O** document referring to an oral disclosure, use, exhibition or other means
**P** document published prior to the international filing date but later than the priority date claimed

Date of the actual completion of the international search
18 SEPTEMBER 2000

Date of mailing of the international search report
22 SEP 2000

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231
Facsimile No. (703) 305-3243

Authorized officer
SUSAN K. OHORODNIK
Telephone No. (703) 308-0651

Form PCT/ISA/210 (second sheet) (July 1998)*
<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>US 5,449,500 A (ZETTEL) 12 September 1995, see entire document.</td>
<td>1-16</td>
</tr>
</tbody>
</table>