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(54) **Exhaust gas cooler and exhaust gas recirculation system for internal combustion engine**

Abgaskühlsystem und Abgasrückführungssystem für Verbrennungsmotor

Refroidisseur de gaz d'échappement et système de recirculation de gaz d'échappement pour moteur à combustion interne

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(73) Proprietor: **TOYOTA JIDOSHA KABUSHIKI KAISHA**
**Toyota-shi, Aichi-ken, 471-8571 (JP)**

(72) Inventors:
- **Yamada, Satoshi**
  **Toyota-shi, Aichi-ken 471-8571 (JP)**
- **Ota, Atsushi**
  **Toyota-shi, Aichi-ken 471-8571 (JP)**

(74) Representative: **Winter, Brandl, Fürniss, Hübner, Röss, Kaiser, Polte - Partnerschaft mbB**
**Patent- und Rechtsanwaltskanzlei**
**Bavariaring 10**
**80336 München (DE)**

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## Description

**[0001]** The present invention relates to an exhaust gas cooler and an exhaust gas recirculation system for an internal combustion engine, and particularly relates to an exhaust gas cooler and an exhaust gas recirculation system for an internal combustion engine that cool exhaust gas recirculated from an exhaust passage side of a water-cooled engine to an intake passage side with coolant.

**[0002]** With more complex demand for exhaust gas purification performance of an internal combustion engine for vehicles, internal combustion engines with an Exhaust Gas Recirculation system (i.e. EGR system) that recirculates exhaust gas for effectively reducing NOx have gained popularity. For example, in an internal combustion engine (hereinafter referred to as an engine) which allows lean burning of fuel with respect to an amount of air to increase an amount of EGR, an EGR cooler or an exhaust gas cooler that cools recirculated exhaust gas is commonly used.

**[0003]** In the exhaust gas cooler, the EGR gas flows through a tube in a shell and is cooled by heat exchange between coolant that is guided between the shell and the tube and the EGR gas that flows through the tube before the EGR gas is recirculated to the intake. In other words, the exhaust gas cooler is a heat exchanger.

**[0004]** In conventional exhaust gas coolers and exhaust gas recirculation systems for internal combustion engines, that includes the conventional exhaust gas coolers, connecting pipe that forms part of an EGR gas passage is inserted in a coolant outlet passage that is formed inward from an end of a cylinder head in a water-cooled engine to direct the coolant from the water-cooled engine to flow toward a radiator. Generally, exhaust gas coolers are directly connected to a water jacket provided at the end of the cylinder head (e.g. see JP-A-2007-224784).

**[0005]** In another type of conventional exhaust gas coolers and exhaust gas recirculation systems for an internal combustion engine, the internal combustion engine includes a heat exchange mechanism, in which the water jacket of the water-cooled engine has an opening on a rear side, and the coolant outlet passage and the EGR gas passage from the engine toward the radiator are formed in a housing that closes the opening separately from the cylinder head (e.g. JP-A-2007-292012).

**[0006]** However, in conventional exhaust gas coolers and exhaust gas recirculation systems for the internal combustion engine as described above, the connection pipe that forms part of the EGR gas passage is inserted in a portion of the coolant outlet passage formed in the cylinder head such that a flange binding portion that attaches the exhaust manifold side of an EGR pipe to the cylinder head with a flange and the casing of an EGR valve that attaches the intake manifold side of the EGR pipe to the cylinder head are both formed with a recessed portion that houses one end of the connection pipe. Both ends of the connection pipe are inserted to inner bottom wall surfaces of the recessed portions of the flange binding portion and the casing of the EGR valve. However, a problem with the above-described configuration is that the structure to support the EGR gas passage on both side walls at the ends of the cylinder head that forms a coolant outlet as well as a problem of difficulty in assembling and securing the connection pipe to the cylinder head.

**[0007]** In addition, due to large differences in temperature between the cylinder head, which is cooled by the coolant and the connection pipe through which high temperature EGR gas (approximately 700°C, for example) flows, an accordion portion is provided in the connection pipe to compensate for a difference in heat expansion caused by the temperature difference, even when the connection pipe is made of stainless steel that has a small linear expansion coefficient. Consequently, it is difficult to increase the heat exchange area to improve exhaust gas cooling efficiency by constructing the connection pipe or an exhaust gas recirculation pipe from a plurality of tubes or planular tubes that are arranged in parallel.

**[0008]** Meanwhile, in the conventional exhaust gas cooler and the exhaust gas recirculation system disclosed in JP-A-2007-292012, it is difficult to form both the coolant outlet passage and the EGR gas passage in a manner to achieve specified exhaust gas cooling efficiency. This not only increases the cost of the exhaust gas cooler but also reduces its durability because heat stress in a high stress amplitude (level of stress variation) acts near the connections of the exhaust gas recirculation pipe the housing main body.

**[0009]** DE 10 2006 020 639 A1 provides a heat exchanger for an internal combustion engine, comprising a cooling core inserted into a cooling channel. The core has an elastically deformable bellows connected with a cooling pipeline at one end. The bellows is in contact with a housing at another end directly or over a sealing unit in an inserted condition of the core. The bellows is fixed at the housing using a detachable fastening unit, and compensates elongation of the core in the case of thermal expansion.

**[0010]** DE 10 2005 037 156 A1 discloses a heat exchanger for vehicles including a housing for exhaust gas recirculation pipes and coolant passages which are attached to the housing by a tube plate. The tube plate comprises a retaining plate and a bead.

**[0011]** EP 0 930 429 A2 provides a heat exchanger for vehicles with exhaust gas recirculation pipes and coolant passages inside a housing. The exhaust gas recirculation pipes are supported by a tube plate.

**[0012]** The present invention provides an internal combustion engine comprising an exhaust gas cooler as defined in claim 1 or any one of the dependant claims 2 to 9. Further, the invention provides an exhaust gas recirculation system for such an internal combustion engine, as defined in claim 10. The exhaust gas cooler and the exhaust gas recirculation system are provided at low cost, have a simple configuration, are high durable, and allow easy assembly and attachment of an exhaust gas

recirculation pipe to a housing.

**[0013]** The exhaust gas cooler is attached to the internal combustion engine that includes: a coolant outlet passage through which coolant guided into a water jacket flows out toward a radiator; and an exhaust gas recirculation passage that recirculates a part of exhaust gas from an exhaust passage to an intake passage, and cools the exhaust gas by heat exchange between the exhaust gas that flows through the exhaust gas recirculation passage and the coolant that flows through the coolant outlet passage. The exhaust gas cooler includes: a housing that is attached to an end of the internal combustion engine and forms the coolant outlet passage; an exhaust gas recirculation pipe that forms a part of the exhaust gas recirculation passage of the internal combustion engine in its inner peripheral side and that is supported by the housing to contact the coolant in the coolant exhaust passage in its outer peripheral side; and an expansion joint that is interposed between the housing and the exhaust gas recirculation pipe that fixes the exhaust gas recirculation pipe to the housing and is deformed to compensate for expansion and contraction when the exhaust gas recirculation pipe expands or contracts with respect to the housing.

**[0014]** In the exhaust gas cooler configured as described above, the exhaust gas recirculation pipe is supported by the housing so as to contact the coolant on the inside of the coolant outlet passage. When the exhaust gas recirculation tube, through which the high-temperature recirculated exhaust gas flows, expands with respect to the housing due to a difference in heat expansion, the expansion joint that is interposed between the housing and the exhaust gas recirculation pipe elastically contracts to compensate for the expansion of the exhaust gas recirculation pipe. When the exhaust gas recirculation pipe is cooled and contracts with respect to the housing, the expansion joint elastically expands between the housing and the exhaust gas recirculation pipe so as to compensate for the contraction of the exhaust gas recirculation pipe. Therefore, with a simple configuration in which the exhaust gas recirculation pipe runs through and is fixed to the housing, the exhaust gas cooler with superior cooling efficiency can easily be achieved in which piping and attachment is facilitated although the exhaust gas recirculation pipe is directly connected to the water jacket. The exhaust gas cooler also has high durability such that it prevents high heat stress caused by the difference in heat expansion between the exhaust gas recirculation pipe and the housing.

**[0015]** In addition, in the above exhaust gas cooler, it is possible that the exhaust gas recirculation pipe has a plurality of tubular portions that are spaced apart from each other in a direction perpendicular to an axial direction of the exhaust gas recirculation pipe and that the plurality of tubular portions are integrally secured to the expansion joint. It is possible with this configuration to provide the exhaust gas cooler with the superior cooling efficiency that has a sufficient heat transfer area for heat exchange.

**[0016]** It is possible in the above exhaust gas cooler that the plurality of tubular portions is arranged in parallel with each other. With this configuration, the attachment of the exhaust gas recirculation pipe to the housing is facilitated, and forces in an expansion/contraction direction act equally in the same direction on the expansion joint to which the plurality of tubular portions are secured. Thus, the durability of the expansion joint is improved. Here, the plurality of tubular portions may be cylindrical. The plurality of tubular portions may have the same diameter, or at least one of them may have a different diameter from the others. Further, the plurality of tubular portions may have a planular tubular shape. The plurality of tubular portions may have the same shape, or at least one of them may have a different shape from the others.

**[0017]** In the above exhaust gas cooler, it is possible that the expansion joint has: a retaining plate that expands in a radial direction of the exhaust gas recirculation pipe at an end of the exhaust gas recirculation pipe; and an annular indented portion that is integrally formed with the retaining plate and whose cross section curves to make an indented pattern in the expansion/contraction direction around the end of the exhaust gas recirculation pipe. The expansion joint can easily be made with this configuration.

**[0018]** In the above exhaust gas cooler, it is also possible that, together with the exhaust gas recirculation pipe, the expansion joint forms a part of the exhaust gas recirculation passage and has a cylindrical portion that is supported by the housing. With this configuration, the expansion joint can have a small diameter and only needs a small number of components.

**[0019]** In the above exhaust gas cooler, it is possible that the cylindrical portion of the expansion joint has an annular indented portion that makes an indented pattern in a radial direction and is formed throughout a region in a circumferential direction of the expansion joint. This configuration not only allows deformation of the expansion joint in the expansion/contraction direction of the exhaust gas recirculation pipe but also facilitates fixation and sealing of the expansion joint to the housing.

**[0020]** In the above exhaust gas cooler, it is more possible that the annular indented portion forms an accordion portion and that a part of the annular indented portion is pressure-welded to an inner peripheral annular groove or an inner peripheral annular projection of a support hole that is formed in the housing. With this configuration, the expansion joint can sufficiently compensate for the expansion/contraction of the exhaust gas recirculation pipe with respect to the housing, and any combination of materials that may differ from each other can be selected for the housing and the exhaust gas recirculation pipe.

**[0021]** Meanwhile, the exhaust gas recirculation system of the internal combustion engine according to the present invention includes the exhaust gas cooler in the above configuration. It is possible in the exhaust gas recirculation system that the water jacket has an opening

in an end of the cylinder head of the internal combustion engine and that the housing of the exhaust gas cooler is fixed to the end of the cylinder head.

**[0022]** The exhaust gas recirculation system in the above configuration improves the efficiency to cool the recirculated exhaust gas by utilizing the exhaust gas cooler in which the coolant passage in the housing is directly connected to the water jacket. Also, the assembly of the exhaust gas recirculation system of the internal combustion engine is facilitated by simplifying the attachment of the exhaust gas cooler and the arrangement of the exhaust gas recirculation pipe. Further, the durability of the exhaust gas recirculation system of the internal combustion engine can be improved by installing the exhaust gas cooler with high durability.

**[0023]** According to the present invention, with a simple configuration in which the exhaust gas recirculation pipe runs through the housing, it is possible to obtain the exhaust gas cooler that has the superior cooling efficiency and facilitates piping and attachment although the exhaust gas cooler is directly connected to the water jacket. The exhaust gas cooler also has high durability such that it prevents the high heat stress caused by the difference in heat expansion between the exhaust gas recirculation pipe and the housing.

**[0024]** It is possible with the exhaust gas cooler as described above to improve the efficiency to cool the recirculated exhaust gas and to provide the exhaust gas recirculation system of the internal combustion engine that has the high durability and can facilitate the attachment of the exhaust gas cooler and the arrangement of the exhaust gas recirculation pipe.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0025]** The features, advantages, and technical and industrial significance of this invention will be described in the following detailed description of example embodiments of the invention with reference to the accompanying drawings, in which like numerals denote like elements, and wherein:

FIG. 1 is a cross sectional view that shows a general configuration of an exhaust gas cooler according to a first embodiment of the present invention;

FIG. 2A is a partial side view of a housing that shows a fixing portion where a portion of an exhaust gas recirculation pipe in the exhaust gas cooler is attached to the housing according to the first embodiment of the present invention, and FIG. 2B is a cross sectional view of the fixing portion where the exhaust gas recirculation pipe is attached to the housing;

FIG. 3A shows the configuration of main components of an exhaust gas recirculation system in an internal combustion engine according to the first embodiment of the present invention and shows the exhaust gas cooler attached to one end of a cylinder head, and FIG 3B is a cross sectional view taken along the line B3-B3 of FIG. 3A;

FIG. 4A is a rear end view of the cylinder head in the exhaust gas recirculation system of the internal combustion engine according to the first embodiment of the present invention, and FIG. 4B is a front view of the exhaust gas cooler that is seen from a rear end surface side of the cylinder head;

FIG. 5 is a side view of the exhaust gas cooler according to the first embodiment of the present invention that is seen in the arrow V direction of FIG. 1;

FIG 6A is a partial side view of a housing that shows a fixing portion of an exhaust gas recirculation pipe in the exhaust gas cooler to the housing according to a second embodiment of the present invention, and FIG. 6B is a cross sectional view of the fixing portion of the exhaust gas recirculation pipe to the housing;

FIG. 7A is a partial side view of a housing that shows a fixing portion of an exhaust gas recirculation pipe in an exhaust gas cooler attached to the housing according to an unclaimed third embodiment, and FIG. 7B is a cross sectional view taken along the arrow B7-B7 of FIG. 7A;

FIG. 8A is a cross sectional view that is seen from a side of an expansion joint of the exhaust gas cooler according to the unclaimed third embodiment, and FIG. 8B is a partially enlarged cross sectional view of a portion that shows a protrusive shape before the expansion joint is welded to be fixed;

FIG. 9A is a partial side view of th housing that shows a fixing portion of an exhaust gas cooler to a housing for an expansion joint according to a fourth embodiment of the present invention, and FIG. 9B is a cross sectional view of the fixing portion of an exhaust gas recirculation pipe to the housing; and

FIG 10A illustrates pressure welding of the expansion joint in the exhaust gas cooler according to the fourth embodiment of the present invention, and FIG 10B is a cross sectional view of a pressure-welded portion of the expansion joint to the housing after the pressure welding.

## DETAILED DESCRIPTION OF EMBODIMENTS

**[0026]** Example embodiments of the present invention will be described below with reference to the drawings. In particular, FIG 1 to FIG. 5 show an exhaust gas cooler and an exhaust gas recirculation system (i.e. EGR system) for an internal combustion engine according to a first embodiment of the present invention.

**[0027]** The exhaust gas cooler of this embodiment shown in FIG 1 and FIG. 2 is included as a part of an exhaust gas recirculation system (i.e. EGR system) 20 of a multi-cylinder internal combustion engine 10 such as the one shown in FIG. 3.

**[0028]** More specifically, the engine 10 that is shown in FIGS. 3A and 3B includes: a cylinder block 11 in which a plurality of cylinders 11 a are formed; a cylinder head

12 that is fastened to an upper portion of the cylinder block 11 that closes top end of each cylinder 11a; an intake manifold 13 that is attached to an intake port 12a of the cylinder head 12; and an exhaust manifold 14 that is attached to an exhaust port 12b of the cylinder head 12 (see FIG. 4A). Although not shown in detail, a crankcase is attached to an upper portion of the cylinder head 12 of the engine 10.

**[0029]** A water jacket 16, which serves as a coolant passage is formed in the cylinder block 11 and the cylinder head 12. One end 16a of this water jacket 16 is connected to a discharge port of a water pump 18 that is attached to the engine 10. Meanwhile, the other end 16b of the water jacket 16 extends in a bottom wall portion 12c of the cylinder head 12 in a lateral direction of the cylinder head 12 and in a longitudinal direction of the cylinder head 12, and opens in a rear surface 12d of the cylinder 12. As shown in FIG. 3B, a plurality of tubular wall portions 12g through which ignition plugs as well as stem portions of intake valves and exhaust valves run and a plurality of inward projections (not shown) that house components of a valve train mechanism are provided inward of the bottom wall portion 12c of the cylinder head 12. The water jacket 16 surrounds the peripheries of the tubular walls 12g and the like and extends in the longitudinal direction of the cylinder head 12.

**[0030]** The engine 10 is also connected to a thermostat (not shown) and a radiator 17 that cools coolant that has flowed through the water jacket 16. The other end 16b of the water jacket 16 has a generally rectangular opening 16e through which the coolant introduced into the water jacket 16 flows to the radiator 17.

**[0031]** The engine 10 further includes the EGR system 20 that allows a part of the exhaust gas from the engine 10 from the exhaust manifold 14 to the intake manifold 13 for recirculation. Thus, some of the exhaust gas is recirculated from the exhaust passage 14a side to the intake passage 13a by the EGR system 20.

**[0032]** The EGR system 20 has an exhaust gas recirculation passage (EGR) gas passage 21 that communicates between the exhaust passage 14a of the exhaust manifold 14 and the intake passage 13 of the intake manifold 13a. An electromagnetic exhaust gas recirculation valve (EGR valve) 22 that adjusts the amount of exhaust gas recirculated and an EGR cooler 23 that cools the exhaust gas that is recirculated through the EGR gas passage 21 are provided in the middle of this EGR gas passage 21.

**[0033]** The EGR gas passage 21 is the exhaust gas recirculation passage that recirculates a portion of the exhaust gas from the exhaust gas passage 14a to the intake passage 13a of the engine 10, and a section of the EGR gas passage 21 serves as a cooling passage for recirculated exhaust gas in the EGR cooler 23.

**[0034]** The EGR valve 22 may be switched between an open state where the EGR gas passage 21 communicates with the intake passage 13a and a closed state where a communication between the EGR gas passage 21 and the intake passage 13a is restricted or, for example, shut off.

**[0035]** The EGR cooler 23 is a heat exchanger that exchanges heat between the coolant from the water jacket 16 and the EGR gas from the exhaust gas passage 14a, thereby cooling the EGR gas.

**[0036]** More specifically, the housing 31 of the EGR cooler 23 is made of die-cast aluminum alloy, for example, and has a large recess that is approximately the same width as the water jacket 16 in a height direction and a lateral direction (a right-left direction in FIG. 4A) of the cylinder head 12 such that an end of the housing 31 that faces the cylinder head 12 has an opening that corresponds to an opening 16e of the water jacket 16 on the other end. That is, the recess has approximately the same height and width as the opening 16e of the water jacket. Accordingly, together with the opening 16e of the water jacket 16 on the other end, the housing 31 forms a coolant outlet passage 32 having a relatively large volume, that is formed in a generally box shape and through which the coolant flows from the water jacket 16 to the radiator 17. In addition, the housing 31 is attached to the cylinder head 12 at a flange portion 31f along the outer periphery of the housing 31 by a plurality of fastening bolts (not shown) that are inserted in a plurality of bolt holes 31i (see FIG. 4B). A flat machined surface 12f and a plurality of fastening bolt holes 12j to fasten/fix the EGR system 20 to the cylinder head 12 are formed on the rear end surface 12d of the cylinder head 12 around the opening 16e of the water jacket 16.

**[0037]** As shown in FIG. 1, an outlet pipe portion 31p is integrally formed on the other end of the housing 31. This outlet pipe portion 31p forms an outlet passage hole 32e as a downstream end of the coolant outlet passage 32 in the inner peripheral side of the coolant outlet passage 32 and is coupled to an end 41a of a radiator hose 41 in the outer peripheral side thereof (see FIG. 3A).

**[0038]** An EGR pipe 33 in a generally box shape through which the EGR gas flows is attached to the housing 31 in the longitudinal direction of the coolant outlet passage 32.

**[0039]** The EGR pipe 33 is constructed from a material with a small linear expansion coefficient with respect to the housing 31, such as a pipe made of stainless steel. The EGR pipe 33 extends in a vertical direction of FIG. 1 that is generally perpendicular to the horizontal direction (a direction from right to left) of FIG. 1 and FIG. 2B, which is a flow direction of the coolant in the coolant outlet passage 32. A gas passage formed within the EGR pipe 33 forms part of the EGR gas passage 21 in the engine 10, and is supported by the housing 31 at both ends in the axial direction of the EGR pipe 33 so as to contact the coolant in the coolant outlet passage 32.

**[0040]** A passage portion 21 a of the EGR gas passage 21 that is disposed closer than the gas passage 34 to the exhaust gas passage 14a is formed by an EGR pipe 36 that is provided in the exhaust side between the exhaust manifold 14 and the housing 31. A passage portion

21b of the EGR gas passage 21 that is disposed closer than the gas passage 34 to the intake passage 13a is formed by an EGR pipe 37 that is provided in the intake side between the intake manifold 13 and the housing 31. The passage portion 21b is opened/closed by the EGR valve 22, which is provided between the intake manifold 13 and the housing 31. In addition, as shown in FIG. 5, the housing 31 is formed with a plurality of bolt holes 31j to fasten flange portions (not shown) of those EGR pipes 36 and 37.

**[0041]** Meanwhile, a pair of expansion joints 35 are provided between the housing 31 and at least one end of the EGR pipe 33 such as either one of both ends 33a and 33b so that the pair of expansion joints 35 are provided on opposite ends of the EGR pipe 33. The pair of expansion joints 35 may be, for example, made of the same material as the EGR pipe 33 or a different material from the EGR pipe 33 that has a suitable elastic property and may be joined to the EGR pipe 33.

**[0042]** As shown in FIG. 2B, each of the expansion joints 35 includes: a generally disc-shaped retaining plate 35a that is secured to the end 33a or 33b of the EGR pipe 33 and that extends in a radial direction of the EGR pipe 33; an annular indented portion 35b that is in the retaining plate 35a and has a generally cylindrical shape with a short axial length, and whose cross section curves to make an indented pattern in the radial direction of the EGR pipe 33 around the end 33a or 33b of the EGR pipe 33; and an annular secured portion 35c that is secured to a generally circular support hole 31h of the housing 31 in an airtight manner by metal electrode inert gas (MIG) welding or by laser welding.

**[0043]** When the EGR pipe 33 expands or contracts with respect to the housing 31 due to a difference in thermal expansion with the housing 31, the annular indented portions 35b of the expansion joints 35 are portions that may deform in an expansion or contraction direction of the EGR pipe 33 (a direction that corresponds to the axial direction of the EGR pipe 33 in this embodiment) in response to the expansion or contraction.

**[0044]** The retaining plate 35a and the annular indented portion 35b of each of the expansion joints 35 form a part of the EGR gas passage 21 together with the EGR pipe 33, and constitute a cylindrical portion 35d that has a bottom in one end thereof and is supported by the support hole 31h of the housing 31. The annular indented portion 35b forms the indented pattern in the radial direction of the cylindrical portion 35d, and is formed throughout a region of the cylindrical portion 35d in its circumferential direction. In addition, the annular indented portion 35b has at least one fold, an accordion shape in the cross section that curves in a wavelike manner, and an annular bulge shape in its projecting side.

**[0045]** Furthermore, the EGR pipe 33 includes a plurality of tubular portions 33t that are spaced apart from each other in a direction perpendicular to the axial direction of the EGR pipe 33. The plural tubular portions 33t are integrally secured at each of the ends 33a and 33b to the generally disc-shaped retaining plates 35a of the paired expansion joints 35 when the tubular portions 33t are arranged in parallel and are spaced apart from each other at equal distances.

**[0046]** In the EGR system 20 of this embodiment, the opening in the end surface 12d of the cylinder head 12 is formed in the water jacket 16, and the housing 31 of the EGR cooler 23 is fixed to the end surface 12d of the cylinder head 12. Accordingly, the coolant outlet passage 32 is formed in direct connect with the downstream end of the water jacket 16, both ends of the EGR pipe 33 having the plurality of tubular portions 33t are fixed to the housing 31 via the expansion joints 35 that also function as collecting pipes such that the EGR pipe 33 is located within the coolant outlet passage 32. The plurality of tubular portions 33t may be cylindrical and have the same diameter, or may have cylindrical tubular portions, at least one of which has a different diameter from the others.

**[0047]** In the EGR cooler 23 and the EGR system 20 of this embodiment, the EGR valve 22 opens when the engine 10 is running. Also, when the high-temperature EGR gas flows through the EGR pipe 33, the EGR pipe 33 expands with respect to the housing 31 due to the difference in thermal expansion.

**[0048]** At this time, the expansion joints 35, which are interposed between the housing 31 and the EGR pipe 33, are compressed and contracted in the axial direction so as to compensate for the expansion of the EGR pipe 33.

**[0049]** Meanwhile, when the EGR valve 22 is closed, and the EGR pipe 33 is cooled by the coolant in the coolant outlet passage 32 and contracted with respect to the housing 31, the expansion joints 35 are elastically recovered to extend between the housing 31 and the EGR pipe 33 so as to compensate for the contraction of the EGR pipe 33.

**[0050]** Accordingly, with a simple configuration in which the EGR pipe 33 runs through and is fixed to the housing 31 via the expansion joints 35 that have a function as fixing members, the EGR cooler 23 has superior cooling efficiency and can easily arrange the EGR pipes 36 and 37, and attach the housing 31 to the cylinder head 12, while the coolant passage of the EGR cooler 23 is directly connected to the water jacket 16. The superior durability of the EGR cooler 23 also prevents the high heat stress caused by the difference in heat expansion between the EGR pipe 33 and the housing 31.

**[0051]** In addition, the EGR pipe 33 includes the plurality of tubular portions 33t that are spaced apart from each other in the direction perpendicular to the axial direction, and the plurality of tubular portions 33t are integrally secured to the expansion joints 35 that function as the collecting pipes. Thus, the superior cooling efficiency of the EGR cooler 23 with the can be achieved that ensures a sufficient heat transmission area for heat exchange while achieving the simple arrangement of the EGR pipes 36 and 37.

**[0052]** Furthermore, in this embodiment, because the plurality of tubular portions 33t of the EGR pipe 33 are arranged in parallel with each other, it is possible to facilitate attachment of the EGR pipe 33 to the housing 31. Also, because forces in a contracting direction act equally in the same direction on the expansion joints 35 to which the plurality of tubular portions 33t are secured, the durability of the expansion joint 35 is also improved.

**[0053]** Together with the EGR pipe 33, the expansion joint 35 forms a part of the EGR gas passage 21 and has the cylindrical portion 35b that is supported by the housing 31. Thus, the expansion joint 35 can have a small diameter, and only the small number of components is required for the housing 31. In addition, because the cylindrical portion 35d makes the indented pattern in the radial direction and has the annular indented portion 35d that is formed throughout the region in the circumferential direction, the cylindrical portion 35d accomodates deformation of the expansion joint 35 in the contracting direction of the EGR pipe 33, and also facilitates temporary fixing, fixing, sealing, or the like of the expansion joint 35 to the housing 31.

**[0054]** In this embodiment, the efficiency in cooling the EGR gas may be improved by utilizing the EGR cooler 23 that is directly connected to the coolant passage in the housing 31 to the water jacket 16. The assembly of the EGR system 20 in the engine 10 is simplified by facilitating the attachment of the EGR cooler 23 and the arrangement of the exhaust recirculation pipe. In addition, the durability of the EGR system 20 may be improved by installing the EGR cooler 23 with high durability.

**[0055]** As described above, in this embodiment, with a simple configuration in which the EGR pipe 33 runs through the housing 31, the EGR cooler 23 with superior cooling efficiency is obtained that facilitates the arrangement of pipes and the attachment to the water jacket 16 even though the EGR cooler 23 is directly connected to the water jacket 16. The durability of the EGR cooler 23 is sufficient high to prevent high stress caused by the difference in heat expansion between the EGR pipe 33 and the housing 31.

**[0056]** The EGR cooler 23 as described above improves the efficiency of cooling the EGR gas, and the EGR system 20 with high durability that facilitates the attachment of the EGR cooler 23 and the arrangement of the EGR pipe may be provided by having such the EGR cooler 23.

**[0057]** FIG. 6A and FIG. 6B show the configuration of an exhaust gas cooler according to a second embodiment of the present invention. Each embodiment which will be described below is installed in an EGR system (exhaust gas recirculation system for the internal combustion engine) that is similar to one in the above first embodiment. Thus, the same or like components are given the same reference numerals as those in FIG. 1 to FIG. 5, and only differences of each embodiment from the first embodiment will be described below.

**[0058]** As shown in FIG. 6A and FIG. 6B, an EGR pipe 43 through which the EGR gas flows is installed in the housing 31 of the EGR cooler 23 in this embodiment.

**[0059]** The EGR pipe 43 extends in a direction perpendicular to the horizontal direction in FIG. 6A and FIG. 6B, which is the flow direction in the coolant outlet passage 32. A gas passage 44 is formed within the EGR pipe 43 is part of the EGR gas passage 21 in the engine, and is supported at both ends in the axial direction by the housing 31 so as to contact the coolant in the coolant outlet passage 32.

**[0060]** A pair of expansion joints 45 is provided between the housing 31 and at least one of the ends 43a, 43b of the EGR pipe 43 so as to fix the EGR pipe 43 to the housing 31. The pair of expansion joints 45 are made of the same material as the EGR pipe 43.

**[0061]** The EGR pipe 43 includes a plurality of planular tubular portions 43t of various widths that are spaced apart from each other in a direction perpendicular to the axial direction of the EGR pipe 43. The plural tubular portions 43t are arranged in parallel and spaced apart form each other at equal distances. In addition, the plural tubular portions 43t are integrally secured at each of the ends 43a and 43b to the pair of expansion joints 45. The plurality of tubular portions 43t here are planular tubular portions. The plurality of tubular portions 43t may be in the same shape, or at least one of the tubular portions 43t may have a different shape from the others.

**[0062]** Each of the expansion joints 45 has: a generally disc-shaped retaining plate 45a that is secured to the end 43a or 43b of the EGR pipe 43 so as to stretch out in a radial direction of the EGR pipe 43; an annular indented portion 45b is formed in the retaining plate 45a and has a generally cylindrical shape with cross section curves that form an indented pattern in the radial direction of the EGR pipe 43; and an annular secured portion 45c that is secured to a support hole 31h of the housing 31 in an airtight manner by welding, for example. When the EGR pipe 43 expands or contracts with respect to the housing 31 due to the difference in thermal expansion with the housing 31, the annular indented portions 45b of the paired expansion joints 45 are each adapted to function as an expansion joint that can be deformed in an expansion/contraction direction of the EGR pipe 43 in response to the expansion/contraction.

**[0063]** The retaining plate 45a and the annular indented portion 45b of each of the expansion joints 45 form a part of the EGR gas passage 21 together with the EGR pipe 43, and constitute a cylindrical portion 45d that is supported by the support hole 31h of the housing 31. The annular indented portion 45b makes an indented pattern in the radial direction of the cylindrical portion 45d, and is formed throughout a region of the cylindrical portion 45d in its circumferential direction. In addition, the annular indented portion 45b has at least one fold, an accordion shape in the cross section that curves in a wavelike manner, and an annular bulge shape in its projecting side.

**[0064]** The passage portion 21a of the EGR gas pas-

sage 21 that is disposed closer than the gas passage 44 to the exhaust gas passage 14a is formed by the EGR pipe 36. A passage portion 21b of the EGR gas passage 21 that is disposed closer than the gas passage 44 to the intake passage 13a is formed by the EGR pipe 37. The passage portion 21b is opened/closed by the EGR valve 22.

**[0065]** Thus, the same effects as those in the first embodiment can be achieved in this embodiment. In addition, because the EGR pipe 43 of this embodiment has the plurality of planular tubular portions 43t in various widths, it is possible to achieve the EGR cooler 23 with the further superior cooling efficiency. By including such the EGR cooler 23, the EGR system 20 with the further improved efficiency to cool the EGR gas can be provided.

**[0066]** FIG. 7 shows the configuration of main components of an exhaust gas cooler according to a third embodiment, and FIG. 8 shows a cross sectional shape of an expansion joint.

**[0067]** As shown in FIG. 7A and FIG. 7B, in this embodiment, an EGR pipe 53 through which the EGR gas flows is installed in a housing 51 of the EGR cooler 23 in the longitudinal direction (horizontal direction in FIG. 7B) of the generally box-shaped coolant outlet passage 32, and extends in a direction perpendicular to the flow direction of the coolant in the coolant outlet passage 32.

**[0068]** A gas passage 54 is formed within the EGR pipe 53 as a part of the EGR gas passage 21 of the engine 10, and is supported at both ends in its axial direction by the housing 51 so as to contact the coolant in the coolant outlet passage 32.

**[0069]** The EGR pipe 53 includes a plurality of planular tubular portions 53t in the same widths that are spaced apart from each other in a direction perpendicular to the axial direction of the EGR pipe 53. The plural tubular portions 53t are arranged in parallel and spaced apart from each other at equal distances. In addition, the plural tubular portions 53t are integrally secured at each of the ends 53a and 53b to the pair of expansion joints 55. The plurality of tubular portions 53t here are planular tubular portions. The plurality of tubular portions 53t may be in the same shape, or at least one of the tubular portions 53t may have a different shape from the others.

**[0070]** The overall shape of the housing 51 in this embodiment is similar to that of the housing 31 in the first embodiment. However, the housing 51 has a generally oval-shaped support hole 51h on both sidewalls, and a pair of generally oval-shaped support plates 56 is fixed to the housing 51 so as to close the support holes 51h.

**[0071]** The pair of expansion joints 55 that is secured to the housing 51 and each end 53a and 53b of the EGR pipe 53 is fixed to the pair of support plates 56 in advance and, together with the EGR pipe 53 and the pair of support plates 56, adapted to be inserted in the housing 51. When the pair of support plates 56 is fixed to the housing 51 in a manner that the support plates 56 close the support holes 51h of the housing 51, the EGR pipe 53 is supported via the pair of expansion joints 55 and the pair of support plates 56 that are supported in the housing 51. The pair of expansion joints 55 here is made of the same material as the EGR pipe 53, for example. The pair of support plates 56 is made of the same material as the housing 51.

**[0072]** Each of the expansion joints 55 has: a generally oval-shaped retaining plate 55a that is secured to the end 53a or 53b of the EGR pipe 53 and extends in the radial direction of the EGR pipe 53; an annular indentation 55b in the generally elliptical shape around either one of the ends 53a and 53b of the EGR pipe 53, that is integrally formed with the retaining plate 55a; and an annular secured portion 55c that is secured to the support plate 56, which is attached to the support hole 51h of the housing 51, in an airtight manner by projection welding (a type of resistance welding), for example. When the EGR pipe 53 expands or contracts with respect to the housing 51 due to the difference in thermal expansion with the housing 51, the annular indented portions 55b of the paired expansion joints 55 are each adapted to function as an expansion/contraction compensating portion that can be deformed in the expansion/contraction direction of the EGR pipe 53 in response to the expansion/contraction.

**[0073]** FIG. 8A shows a cross sectional shape of the expansion joint 55 before projection welding, and this expansion joint 55 has an annular projection portion 55w that is shown in a partially enlarged cross section in FIG. 8B. This annual projection portion 55w of the expansion joint 55 is adapted to be welded to the support plate 56 by resistance heat and flattened when the annual projection portion 55w abuts against the support plate 56 and applied with a specified electric current.

**[0074]** The passage portion 21a of the EGR gas passage 21 that is in the side of the exhaust gas passage 14a of the gas passage 54 is formed by the EGR pipe 36 in the exhaust side that is fixed to one of the paired support plates 56. The passage portion 21b of the EGR gas passage 21 is disposed in the side of the intake passage 13a side of the gas passage 54 and is formed by the EGR pipe 37. The passage portion 21b is opened/closed by the EGR valve 22 that is fixed to the other of the paired support plates 56. A plurality of boltholes 56j (see FIG. 7B) for fastening the flange portions (not shown) of the EGR pipes 36 and 37 are formed in either the housing 51 or the paired support plates 56.

**[0075]** Also in this embodiment, with a simple configuration in which the EGR pipe 53 runs through the housing 51, the EGR cooler 23 with superior cooling efficiency may be obtained that facilitates the arrangement and the attachment of pipes although the EGR cooler 23 is directly connected to the water jacket 16. The EGR cooler 23 also has the high durability that prevents high heat stress caused by the difference in heat expansion between the EGR pipe 53 and the housing 51. Accordingly, the same effects as those in the first embodiment may be achieved. Furthermore, in this embodiment, because the pair of expansion joints 55 each includes the annular indentation 55b in the generally elliptic shape around ei-

ther one of the ends 53a and 53b of the EGR pipe 53, that is, the annular indentation 55b is integrally formed with the retaining plate 55a having cross section curves to make an indented pattern in an expansion/contraction direction around the end of the EGR pipe 53, the expansion joints 55 may be advantageously and easily produced.

**[0076]** FIG. 9 shows the configuration of main components of an exhaust gas cooler according to a fourth embodiment of the present invention, and FIG. 10 shows a process of pressure-welding an expansion joint of the exhaust gas cooler to a housing. Because this embodiment has the same configuration as that of the second embodiment with the exception of the method of fixing the expansion joint to the housing, the same or similar components as those of the third embodiment are given the same reference numerals that are shown in FIG. 6A and FIG. 6B, and only the differences from the first and second embodiments will be described below.

**[0077]** As shown in FIG. 9A and FIG. 9B, in this embodiment, the EGR pipe 43 through is installed in a housing 61 of the EGR cooler 23 in the longitudinal direction of the generally box-shaped coolant outlet passage 32.

**[0078]** A pair of expansion joints 65 in a cylindrical shape is provided on opposite sides of the housing 61 and at least one of the ends 43a and 43b of the EGR pipe 43 to attach the EGR pipe 43 to the housing 61.

**[0079]** Each of the expansion joints 65 is made of the same material as the EGR pipe 43, for example. In addition, each of the expansion joints 65 has: a generally disc-shaped retaining plate 65a that is secured to either one of the ends 43a and 43b of the EGR pipe 43, and extends in the radial direction of the EGR pipe 43; an annular indented portion 65b that is integrally formed with the retaining plate 65a and in a generally cylindrical shape, and whose cross section curves to make the indented pattern in the radial direction of the EGR pipe 43 around the end 43a or 43b of the EGR pipe 43; and an annular pressure-welded portion 65c (annular secured portion) that forms a part of the indented portion 65b and is pressure-welded to an inner peripheral groove 61g of a generally circular support hole 61h of the housing 61 by pressure welding. When the EGR pipe 43 expands or contracts with respect to the housing 61 due to the difference in thermal expansion with the housing 61, the annular indented portions 65b of the paired expansion joints 65 serve as an expansion/contraction compensating portion that may be deformed in the expansion/contraction direction of the EGR pipe 43 in response to the expansion/contraction. The retaining plate 65a and the annular indented portion 65b constitute a cylindrical portion 65d in the generally cylindrical shape.

**[0080]** As shown in FIG. 10A, the inner peripheral groove 61g in the support hole 61h of the housing 61 has a rectangular cross section. In the expansion joint 65, only a part of the annular indented portion 65b is shaped as an outer peripheral annular groove before pressure welding. Then, as also shown in FIG. 10A, when the expansion joint 65 before pressure welding, which is disposed inward of the support hole 61h of the housing 61, is pressed by a tool 71T of a pressure welder to radiate outward from the inner peripheral side of the cylindrical portion 65d, the cylindrical portion 65d of the expansion joint 65 is deformed when pressure-welded to the inner peripheral wall of the support hole 61h of the housing 61 as shown in FIG. 10B.

**[0081]** The same effects as those in the first embodiment can also be obtained in this embodiment. In this embodiment, the annular pressure-welded portion 65c of each of the expansion joints 65 is pressure-welded to the inner peripheral groove 61g in the support hole 61h of the housing 61. Accordingly, the expansion joints 65 may be formed in a shape that is well suited to compensate the expansion/contraction. Also, various combinations of materials may be selected as appropriate for the housing 61 and the expansion joint 65 in comparison with a case of welding.

**[0082]** In this embodiment, the inner peripheral groove 61g is formed in the support hole 61h of the housing 61, and the annular pressure-welded portion 65c in the annular projecting shape is pressure-welded to a portion proximate to the inner peripheral groove 61g of the housing 61 in the outer periphery of the expansion joint 65. However, an annular inner projection may be formed in the support hole 61h of the housing 61, and a pressure-welded groove of an annular recess may be pressure-welded to a portion near the annular inner projection of the housing 61 in the outer periphery of the expansion joint 65.

**[0083]** In each of the above embodiments, the materials of the EGR pipe, the expansion joint, and the housing may be made from different materials with large differences in linear expansion coefficient, or may be the same material. The EGR pipe through which the high-temperature EGR gas flows and the expansion joint that is attached to the EGR pipe are preferably made of the same material or materials with the similar linear expansion coefficients or properties. However, the combinations of the materials can freely be selected by providing the expansion joint in a portion of the EGR pipe that is fixed to the housing and further by employing the pressure welding, etc. For example, not only the combination of stainless steel and aluminum but also the combination of stainless steel and stainless steel can be selected. In addition, the combination of improved aluminum alloys may also be selected.

**[0084]** As described above, with a simple configuration in which the EGR pipe runs through the housing, the present invention provides an exhaust gas cooler with superior cooling efficiency that facilitates the arrangement and the attachment of pipes although the exhaust gas cooler is directly connected to the water jacket. The durability of the exhaust gas cooler may be improved by preventing high heat stress caused by the difference in heat expansion between the EGR pipe and the housing. The present invention also provides a highly-durable

EGR system for the internal combustion engine that can facilitate the attachment of the exhaust gas cooler and the arrangement of the EGR pipe and that improves the efficiency to cool the recirculated exhaust gas by including such an exhaust gas cooler. The present invention thus is useful for any type of exhaust gas coolers and EGR systems for internal combustion engines that cools the recirculated exhaust gas using the coolant of the internal combustion engine.

## Claims

**1.** An internal combustion engine; comprising
a coolant outlet passage (32), through which a coolant introduced into a water jacket (16) flows from the water jacket (16) toward a radiator;
an exhaust gas recirculation pipe (21) through which a portion of the exhaust gas flowing through an exhaust gas passage (14a) is recirculated to an intake passage (13a),
an exhaust gas cooler (23) that is installed in the internal combustion engine (10) to cool exhaust gas through heat exchange between the exhaust gas flowing through the exhaust gas recirculation passage (21) and the coolant flowing through the coolant outlet passage (32),
wherein the exhaust gas cooler (23) comprises
a housing (31, 51, 61) that comprises a support hole (31 h, 61 h), and is configured to be attached to an end of the internal combustion engine (10) and to form the coolant outlet passage (32);
an exhaust gas recirculation pipe (33, 43, 53) that is configured to form a part of the exhaust gas recirculation passage (21) of the internal combustion engine (10) in an inner peripheral side thereof and to be supported by the housing (31, 51, 61) in an outer peripheral side thereof so as to contact the coolant in the coolant outlet passage (32); further comprising:

an expansion joint (35, 45, 55, 65) comprising a generally disc-shaped retaining plate (35a, 45a, 55a, 65a) that expands in a radial direction of the exhaust gas recirculation pipe (33, 43, 53) and is secured to an end of the exhaust gas recirculation pipe; and an annular indented portion (35b, 45b, 55b, 65b) that is integrally formed with the retaining plate (35a, 45a, 55a, 65a), is arranged inside of the support hole (31 h, 61 h) of the housing (31, 51, 61), has cross section curves to make an indented pattern in an expansion/contraction direction around the end of the exhaust gas recirculation pipe (33, 43, 53), and has an annular secured portion (35c) that is arranged within the support hole (31 h) and is secured to the generally circular support hole (31 h) by welding in an airtight manner, wherein the retaining plate and the annular indented portion of the expansion joint form a part of the exhaust gas recirculation passage together with the exhaust gas recirculation pipe, and constitute a cylindrical portion (35d) that has a bottom in one end thereof and is supported by the support hole (31 h) of the housing (31), the annular indented portion (35b) having at least one fold, an accordion shape in the cross section that curves in a wavelike manner, and an annular bulge shape in its projecting side,
wherein the expansion joint (35, 45, 55, 65) is configured to be interposed between the exhaust gas recirculation pipe (33, 43, 53) and the housing (31, 51, 61) to attach the exhaust gas recirculation pipe (33, 43, 53) to the housing (31, 51, 61),
wherein
the expansion joint elastically deforms to compensate for expansion/contraction of the exhaust gas recirculation pipe (33, 43, 53) when the exhaust gas recirculation pipe (33, 43, 53) expands or contracts with respect to the housing (31, 51, 61).

**2.** The internal combustion engine according to claim 1, wherein
the exhaust gas recirculation pipe (33, 43, 53) is formed as plural tubular portions (33t, 43t, 53t) that are spaced apart from each other in a direction perpendicular to an axial direction of the exhaust gas recirculation pipe (33, 43, 53) and in that the plural tubular portions (33t, 43t, 53t) are secured to the expansion joint (35, 45, 55, 65).

**3.** The internal combustion engine according to claim 2, wherein
the plural tubular portions (33t, 43t, 53t) are arranged in parallel with each other.

**4.** The internal combustion engine according to claim 2 or 3, wherein
the plural tubular portions (33t) are cylindrical and have the same diameter.

**5.** The internal combustion engine according to claim 2 or 3, wherein
the plural tubular portions are cylindrical and that at least one of the plural tubular portions has a different diameter from the others.

**6.** The internal combustion engine according to claim 2 or 3, wherein
the plural tubular portions are planular tubular portions and in the same shape.

**7.** The internal combustion engine according to claim 2 or 3, wherein

the plural tubular portions (43t, 53t) are planular tubular portions and that at least one of the plural tubular portions (43t, 53t) has a different shape from the others.

**8.** The internal combustion engine according to claim 7, wherein
the cylindrical portion (35d, 45d, 65d) of the expansion joint (35, 45, 65) has an annular indented portion (35b, 45b, 65b) that makes an indented pattern in a radial direction and is formed throughout a region in a circumferential direction.

**9.** The internal combustion engine according to claim 8, wherein
the annular indented portion (65b) has an accordion shape and that a part of the annular indented portion (65b) is pressure-welded to an inner peripheral annular groove (61 g) or an inner peripheral annular projection of a support hole that is formed in the housing (61).

**10.** The internal combustion engine according to any one of claims 1 through 9, wherein the water jacket (16) has an opening in an end of a cylinder head (12) of the internal combustion engine (10), and the housing (31, 51, 61) of the exhaust gas cooler is fixed to the end of the cylinder head (12).

**Patentansprüche**

**1.** Brennkraftmaschine, mit
einem Kühlmittelauslassdurchgang (32), durch welchen ein in einem Wassermantel (16) eingeleitetes Kühlmittel von dem Wassermantel (16) in Richtung eines Kühlers strömt;
einem Abgasrezirkulationsrohr (21), durch welchen ein Anteil des durch einen Abgasdurchgang (14a) strömenden Abgases zu einem Ansaugdurchgang (13a) rezirkuliert wird,
einem Abgaskühler (23), der in der Brennkraftmaschine (10) installiert ist, um Abgas durch Wärmeaustausch zwischen dem durch den Abgasrezirkulationsdurchgang (21) strömenden Abgas und dem durch den Kühlmittelauslassdurchgang (32) strömenden Kühlmittel zu kühlen,
wobei der Abgaskühler (23) aufweist
ein Gehäuse (31, 51, 61), das eine Stützausnehmung (31 h, 61 h) aufweist und ausgebildet ist, um an ein Ende der Brennkraftmaschine (10) angebracht zu sein und den Kühlmittelauslassdurchgang (32) auszubilden,
ein Abgasrezirkulationsrohr (33, 43, 53), das ausgebildet ist, um einen Teil des Abgasrezirkulationsdurchgangs (21) der Brennkraftmaschine (10) in einer Innenumfangsseite davon auszubilden und um durch das Gehäuse (31, 51, 61) in einer Außenumfangsseite davon so gestützt werden, um in Kontakt mit dem Kühlmittel in dem Kühlmittelauslassdurchgang (32) zu gelangen, ferner aufweisend:

eine Dehnungsverbindung (35, 45, 55, 65) mit einer im Allgemeinen scheibenförmigen Stützplatte (35a, 45a, 55a, 65a), die sich in einer Radialrichtung des Abgasrezirkulationsrohrs (33, 43, 53) erstreckt und an ein Ende des Abgasrezirkulationsrohrs befestigt ist; und
einen ringförmigen Einrückungsabschnitt (35b, 45b, 55b, 65b), der einstückig mit der Stützplatte (35a, 45a, 55a, 65a) ausgebildet ist, innerhalb der Stützausnehmung (31 h, 61 h) des Gehäuses (31, 51, 61) angeordnet ist, Querschnittskurven aufweist, um ein eingerücktes Muster in einer Expansions-/ Kontraktionsrichtung um das Ende des Abgasrezirkulationsrohres (33, 43, 53) auszubilden, und einen ringförmigen befestigten Abschnitt (35c) hat, der innerhalb der Stützausnehmung (31 h) angeordnet ist und an die im Allgemeinen kreisförmige Stützausnehmung (31 h) durch Schweißen in einer luftdichten Weise befestigt ist, wobei die Stützplatte und der ringförmige Einrückungsabschnitt der Dehnungsverbindung einen Teil des Abgarezirkulationsdurchgangs zusammen mit dem Abgasrezirkulationsrohr ausbilden und einen zylindrischen Abschnitt (35d), der an seinem einen Ende einen Boden aufweist und durch die Stützausnehmung (31h) des Gehäuses (31) gestützt ist, ausbilden, wobei der ringförmige Einrückungsabschnitt (35b) zumindest eine Falte, mit einer Faltform im Querschnitt, die in wellenförmiger Weise gebogen ist, und einem ringförmige Ausbuchtungsform in dessen Projektionsseite aufweist,
wobei die Dehnungsverbindung (35, 45, 55, 65) so ausgebildet ist, um zwischen dem Abgasrezirkulationsrohr (33,43, 53) und dem Gehäuse (31, 51, 61) angeordnet zu sein, um das Abgasrezirkulationsrohr (33, 43, 53) an das Gehäuse (31, 51, 61) zu befestigen, wobei
die Dehnungsverbindung sich elastisch verformt, um eine Expansion/ Kontraktion des Abgasrezirkulationsrohres (33, 43, 53) zu kompensieren, wenn sich das Abgasrezirkulationsrohr (33, 43 ,53) bezüglich des Gehäuses (31, 51, 61) expandiert und kontrahiert.

**2.** Brennkraftmaschine nach Anspruch 1, wobei das Abgasrezirkulationsrohr (33, 43, 53) als eine Mehrzahl rohrförmiger Abschnitte (33t, 43t, 53t) ausgebildet ist, die in einer Richtung senkrecht zu einer Axialrichtung des Abgasrezirkulationsrohres (33, 43, 53) voneinander beabstandet sind und in welchen die Mehrzahl rohrförmiger Abschnitte (33t, 43t, 53t) an die Dehnungsverbindung (35, 45, 55, 65) be-

festigt ist.

3. Brennkraftmaschine nach Anspruch 2, wobei die Mehrzahl rohrförmiger Abschnitte (33t, 43t, 53t) parallel zur einander angeordnet sind.

4. Brennkraftmaschine nach Anspruch 2 oder 3, wobei die Mehrzahl rohrförmiger Abschnitte (33t) zylindrisch sind und den gleichen Durchmesser aufweisen.

5. Brennkraftmaschine nach Anspruch 2 oder 3, wobei die Mehrzahl rohrförmiger Abschnitte zylindrisch sind und zumindest einer der Mehrzahl rohrförmiger Abschnitte einen anderen Durchmesser als die anderen hat.

6. Brennkraftmaschine nach Anspruch 2 oder 3, wobei die Mehrzahl rohrförmiger Abschnitte planare rohrförmige Abschnitte sind und dieselbe Form aufweisen.

7. Brennkraftmaschine nach Anspruch 2 oder 3, wobei die Mehrzahl rohrförmiger Abschnitte (43t, 53t) planare rohrförmige Abschnitte sind und zumindest einer der Mehrzahl rohrförmiger Abschnitte (43t, 53t) eine andere Form als die Anderen aufweist.

8. Brennkraftmaschine nach Anspruch 7, wobei der zylindrische Abschnitt (35d, 45d, 65d) der Dehnungsverbindung (35, 45, 65) einen ringförmigen Einrückungsabschnitt (35b, 45b, 65b) aufweist, der ein Einrückungsmuster in einer Radialrichtung ausbildet und über einen Bereich in einer Umfangsrichtung ausgebildet ist.

9. Brennkraftmaschine nach Anspruch 8, wobei der ringförmige Einrückungsabschnitt (65b) einen Faltabschnitt hat und ein Teil des ringförmigen Einrückungsabschnitts (65b) an eine Innenumfangs-Ringnut (61 d) oder einen Ringumfangs-Ringvorsprung einer Stützaufnehmung pressgeschweißt ist, welche in dem Gehäuse (61) ausgebildet ist.

10. Brennkraftmaschine nach einem der Ansprüche 1 bis 9, wobei der Wassermantel (16) in einem Ende eines Zylinderkopfes (12) der Brennkraftmaschine (10) eine Öffnung aufweist und das Gehäuse (31, 51, 61) des Abgaskühlers an das Ende des Zylinderkopfes (12) befestigt ist.

**Revendications**

1. Moteur à combustion interne, comprenant :

   un passage de sortie de réfrigérant (32), à travers lequel un réfrigérant introduit dans une chemise d'eau (16) s'écoule de la chemise d'eau (16) vers un radiateur ;
   un tuyau de recirculation de gaz d'échappement (21) à travers lequel une partie du gaz d'échappement s'écoulant à travers un passage de gaz d'échappement (14a) est recirculée vers un passage d'admission (13a),
   un refroidisseur de gaz d'échappement (23) qui est installé dans le moteur à combustion (10) pour refroidir le gaz d'échappement par l'échange de chaleur entre le gaz d'échappement s'écoulant à travers le passage de recirculation de gaz d'échappement (21) et le réfrigérant s'écoulant à travers le passage de sortie de réfrigérant (32),
   dans lequel le refroidisseur de gaz d'échappement (23) comprend :

      un boîtier (31, 51, 61) qui comprend un trou de support (31h, 61h), et est configuré pour être fixé à une extrémité du moteur à combustion interne (10) et pour former le passage de sortie de réfrigérant (32) ;
      un tuyau de recirculation de gaz d'échappement (33, 43, 53) qui est configuré pour former une partie du passage de recirculation de gaz d'échappement (21) du moteur à combustion interne (10) dans son côté périphérique interne et être supporté par le boîtier (31, 51, 61) dans son côté périphérique externe afin d'être en contact avec le réfrigérant dans le passage de sortie de réfrigérant (32) ; comprenant en outre :

   un joint de dilatation (35, 45, 55, 65) comprenant une plaque de retenue (35a, 45a, 55a, 65a) généralement en forme de disque qui se dilate dans une direction radiale du tuyau de recirculation de gaz d'échappement (33, 43, 53) et est fixé à une extrémité de tuyau de recirculation de gaz d'échappement ; et une partie dentelée annulaire (35b, 45b, 55b, 65b) qui est formée de manière solidaire avec la plaque de retenue (35a, 45a, 55a, 65a), est agencée à l'intérieur du trou de support (31h, 61h) du boîtier (31, 51, 61), a des courbes transversales pour réaliser un modèle dentelé dans une direction de dilatation/contraction autour de l'extrémité du tuyau de recirculation de gaz d'échappement (33, 43, 53) et a une partie fixée annulaire (35c) qui est agencée à l'intérieur du trou de support (31h) et est fixée au trou de support (31h) généralement circulaire par soudage de manière étanche à l'air, dans lequel la plaque de retenue et la partie dentelée annulaire du joint de dilatation forment une partie du passage de recirculation de gaz d'échappement conjointement avec le tuyau de recirculation de gaz d'échappement et consti-

tuent une partie cylindrique (35d) qui a un fond dans l'une de ses extrémités et est supportée par le trou de support (31h) du boîtier (31), la partie dentelée annulaire (35b) ayant au moins un pli, une forme d'accordéon dans la section transversale qui s'incurve à la manière d'une vague, et une forme de renflement annulaire dans son côté en saillie,
dans lequel le joint de dilatation (35, 45, 55, 65) est configuré pour être intercalé entre le tuyau de recirculation de gaz d'échappement (33, 43, 53) et le boîtier (31, 51, 61) pour fixer le tuyau de recirculation de gaz d'échappement (33, 43, 53) au boîtier (31, 51, 61), dans lequel :

le joint de dilatation se déforme élastiquement pour compenser la dilatation/contraction du tuyau de recirculation de gaz d'échappement (33, 43, 53) lorsque le tuyau de recirculation de gaz d'échappement (33, 43, 53) se dilate ou se contracte par rapport au boîtier (31, 51, 61).

**2.** Moteur à combustion interne selon la revendication 1, dans lequel :

le tuyau de recirculation de gaz d'échappement (33, 43, 53) est formé sous la forme de plusieurs parties tubulaires (33t, 43t, 53t) qui sont espacées les unes des autres dans une direction perpendiculaire à une direction axiale du tuyau de recirculation de gaz d'échappement (33, 43, 53) et en ce que la pluralité de parties tubulaires (33t, 43t, 53t) sont fixées au joint de dilatation (35, 45, 55, 65).

**3.** Moteur à combustion interne selon la revendication 2, dans lequel :

la pluralité de parties tubulaires (33t, 43t, 53t) sont agencées parallèlement entre elles.

**4.** Moteur à combustion interne selon la revendication 2 ou 3, dans lequel :

la pluralité de parties tubulaires (33t) sont cylindriques et ont le même diamètre.

**5.** Moteur à combustion interne selon la revendication 2 ou 3, dans lequel :

la pluralité de parties tubulaires sont cylindriques et en ce qu'au moins l'une de la pluralité de parties tubulaires a un diamètre différent des autres.

**6.** Moteur à combustion interne selon la revendication 2 ou 3, dans lequel :

la pluralité de parties tubulaires sont des parties tubulaires planes et de la même forme.

**7.** Moteur à combustion interne selon la revendication 2 ou 3, dans lequel :

la pluralité de parties tubulaires (43t, 53t) sont des parties tubulaires planes et au moins l'une de la pluralité de parties tubulaires (43t, 53t) a une forme différente des autres.

**8.** Moteur à combustion interne selon la revendication 7, dans lequel :

la partie cylindrique (35d, 45d, 65d) du joint de dilatation (35, 45, 65) a une partie dentelée annulaire (35b, 45b, 65b) qui réalise un modèle dentelé dans une direction radiale et est formée tout le long d'une région dans une direction circonférentielle.

**9.** Moteur à combustion interne selon la revendication 8, dans lequel :

la partie dentelée annulaire (65b) a une forme d'accordéon et en ce qu'une partie de la partie dentelée annulaire (65b) est soudée sous pression sur une rainure annulaire périphérique interne (61g) ou une saillie annulaire périphérique interne d'un trou de support qui est formée dans le boîtier (61).

**10.** Moteur à combustion interne selon l'une quelconque des revendications 1 à 9, dans lequel la chemise d'eau (16) a une ouverture dans une extrémité d'une culasse (12) du moteur à combustion interne (10), et le boîtier (31, 51, 61) du refroidisseur de gaz d'échappement est fixé sur l'extrémité de la culasse (12).

FIG. 1

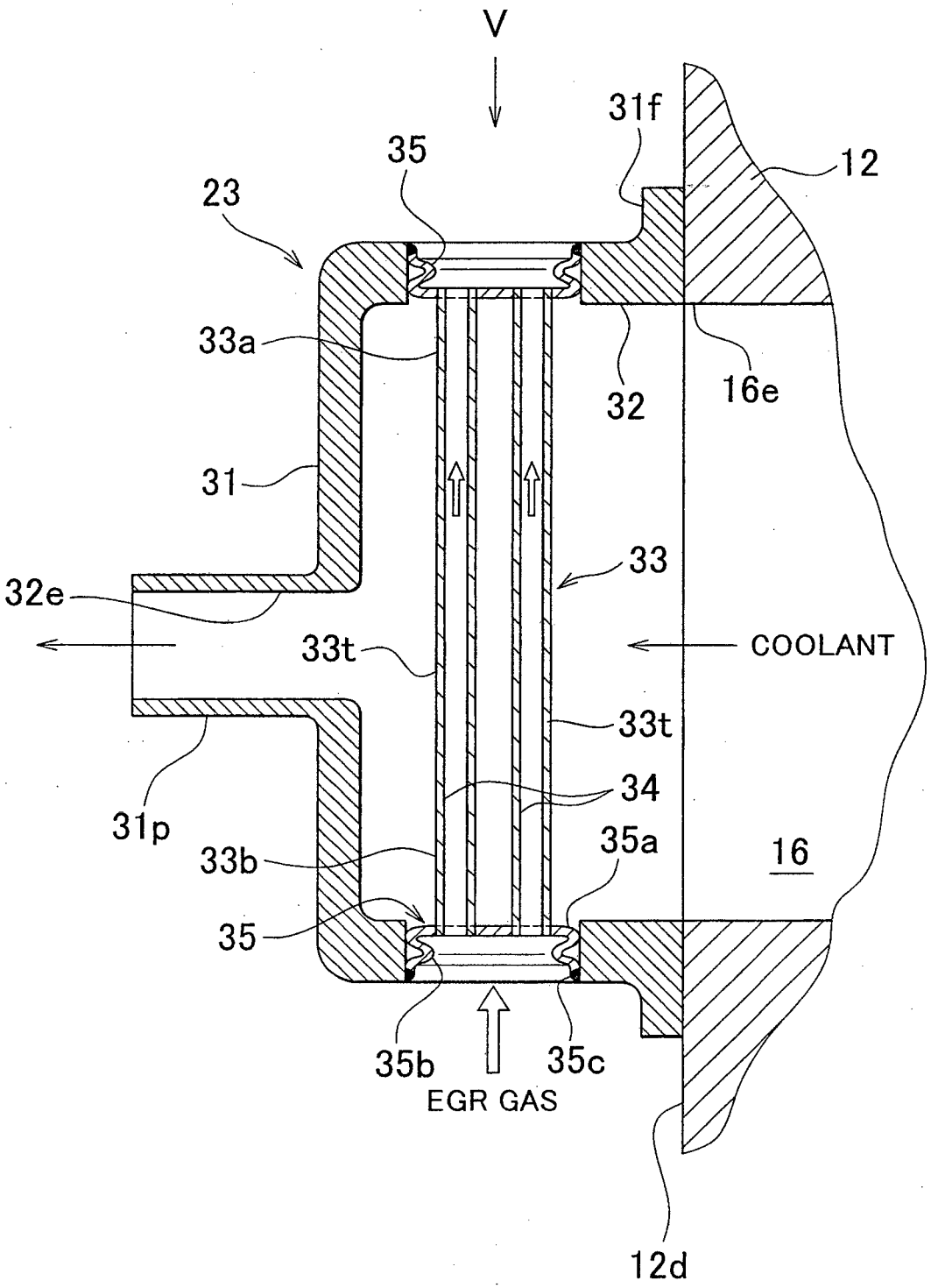

V
31f
35
12
23
33a
32
16e
31
33
32e
33t
COOLANT
33t
34
31p
35a
33b
16
35
35b
35c
EGR GAS
12d

FIG. 2A

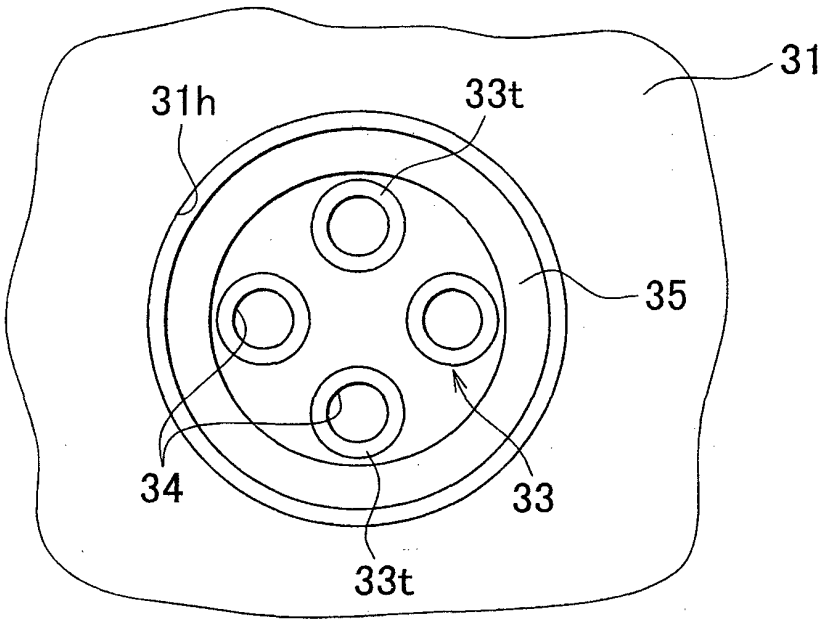

31
31h
33t
35
34
33
33t

FIG. 2B

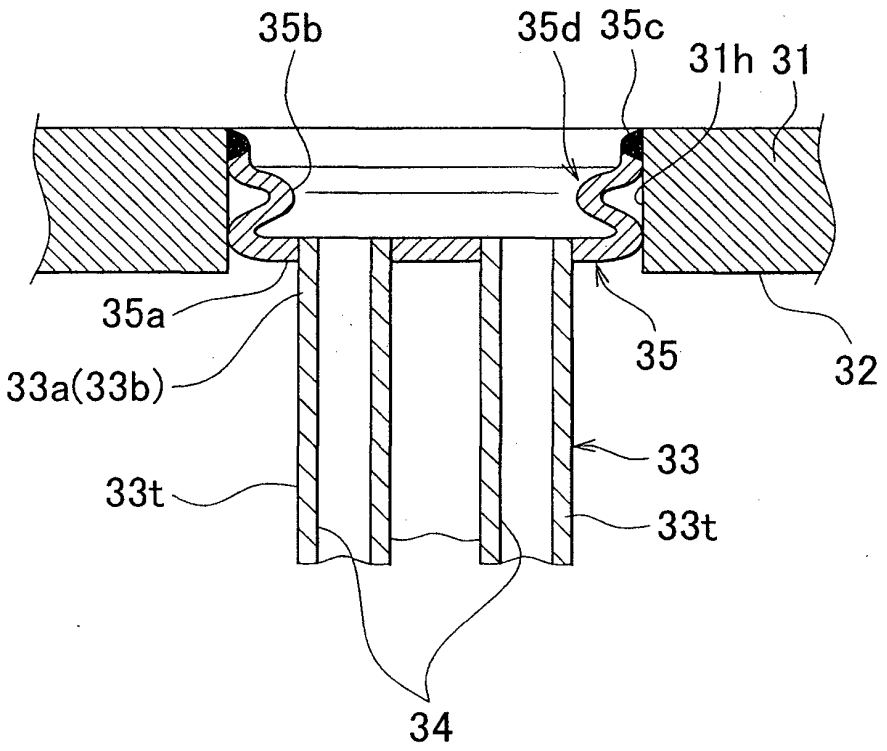

35b
35d
35c
31h
31
35a
33a(33b)
35
32
33
33t
33t
34

FIG. 3A

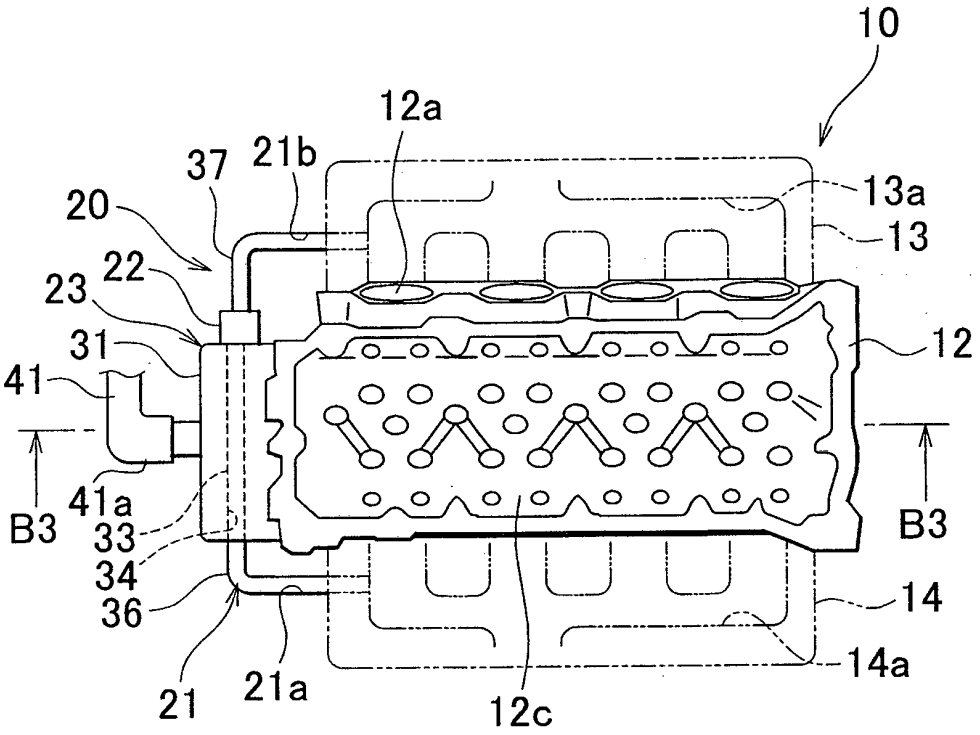

10
12a
37
21b
20
22
23
31
41
13a
13
12
B3
41a
33
34
36
21
21a
12c
14
14a
B3

FIG. 3B

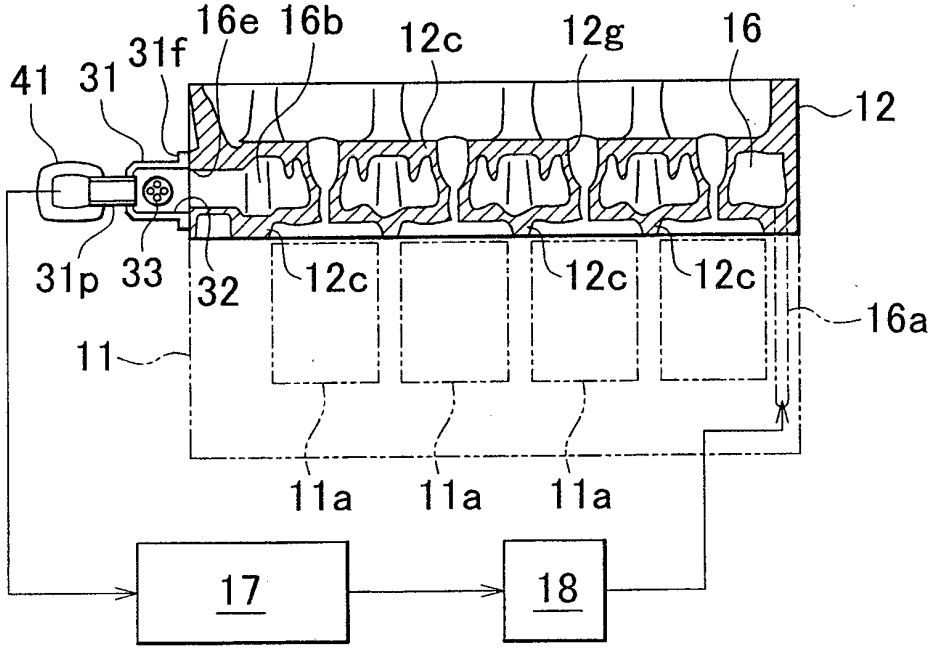

16e
16b
12c
12g
16
41
31
31f
12
31p
33
32
12c
12c
12c
16a
11
11a
11a
11a
17
18

FIG. 4A

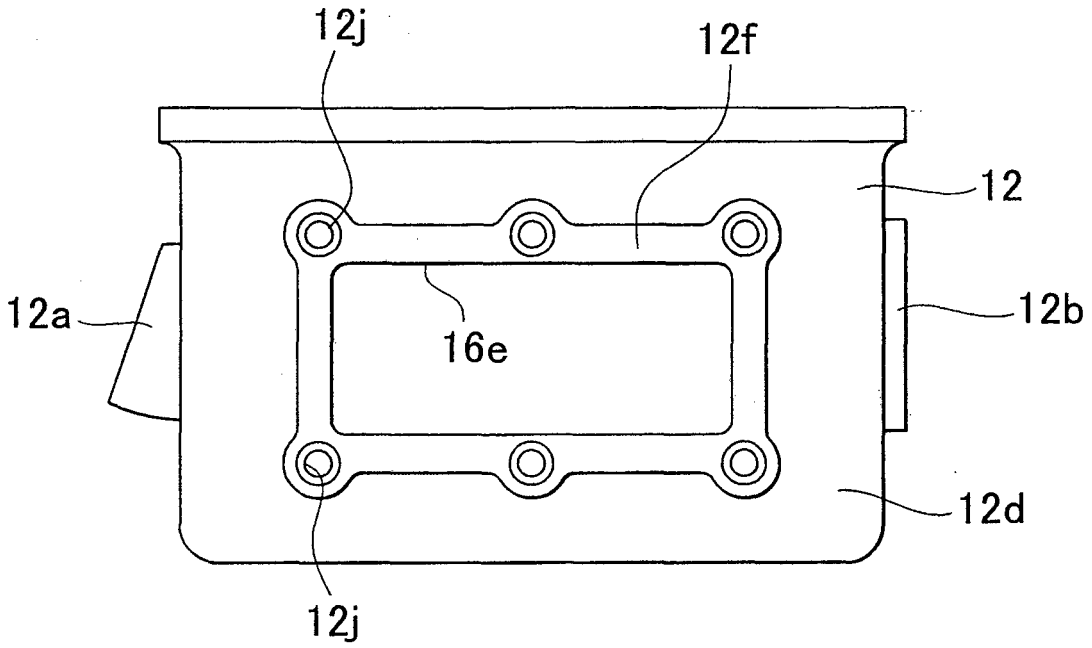



FIG. 4B

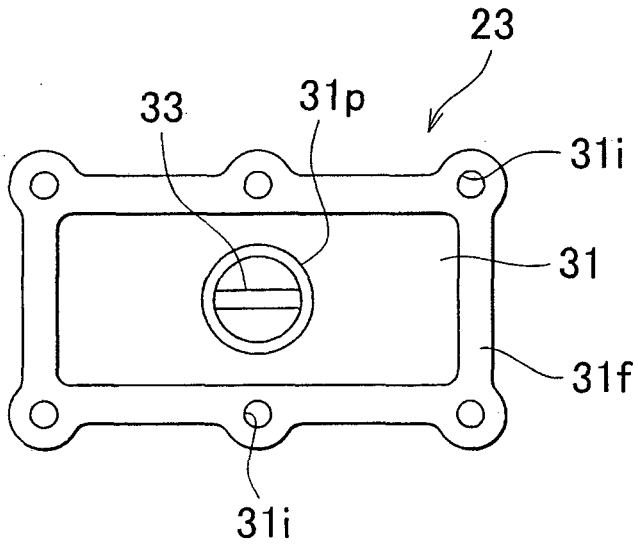


FIG. 5

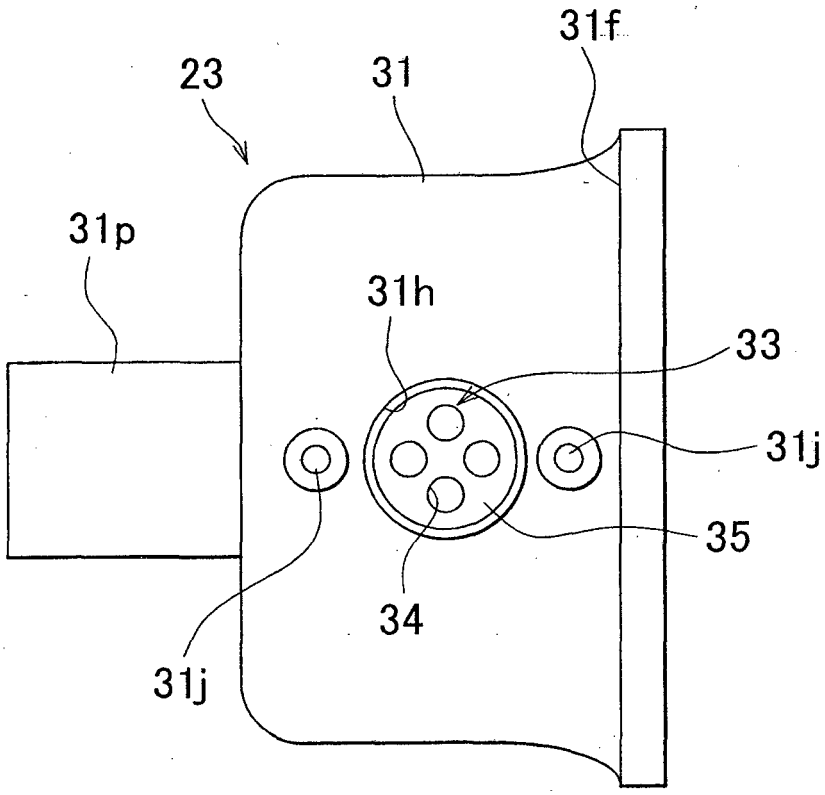


FIG. 6A

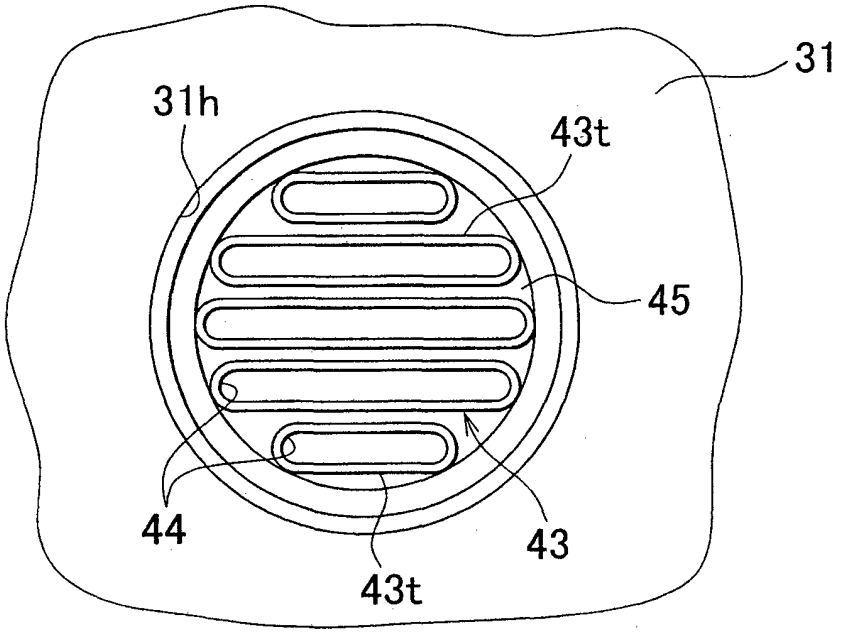

31
31h
43t
45
44
43
43t

FIG. 6B

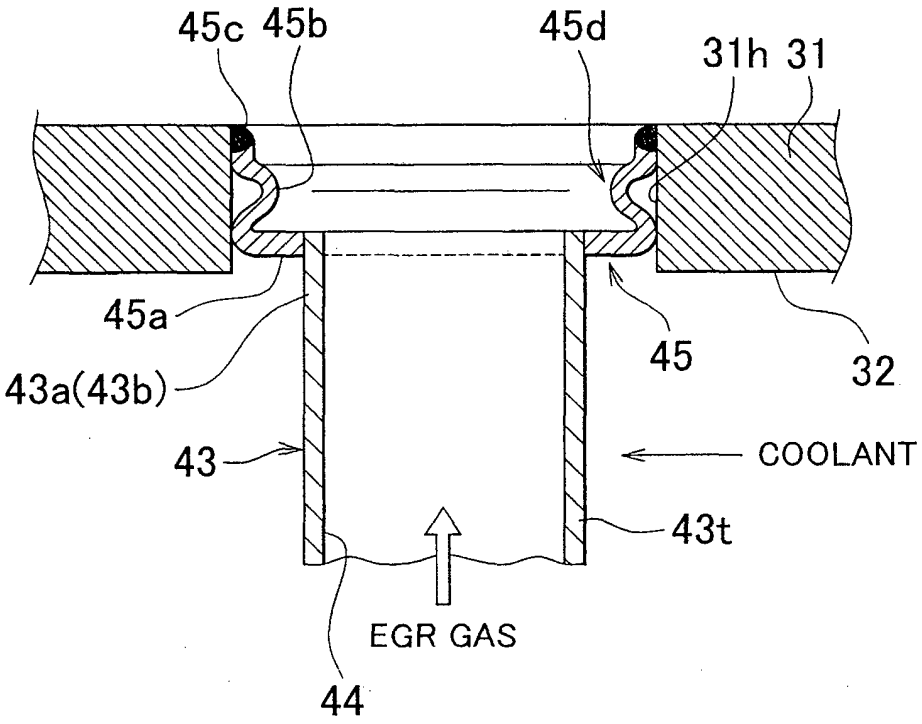

45c
45b
45d
31h
31
45a
43a(43b)
43
45
32
COOLANT
43t
EGR GAS
44

FIG. 7A

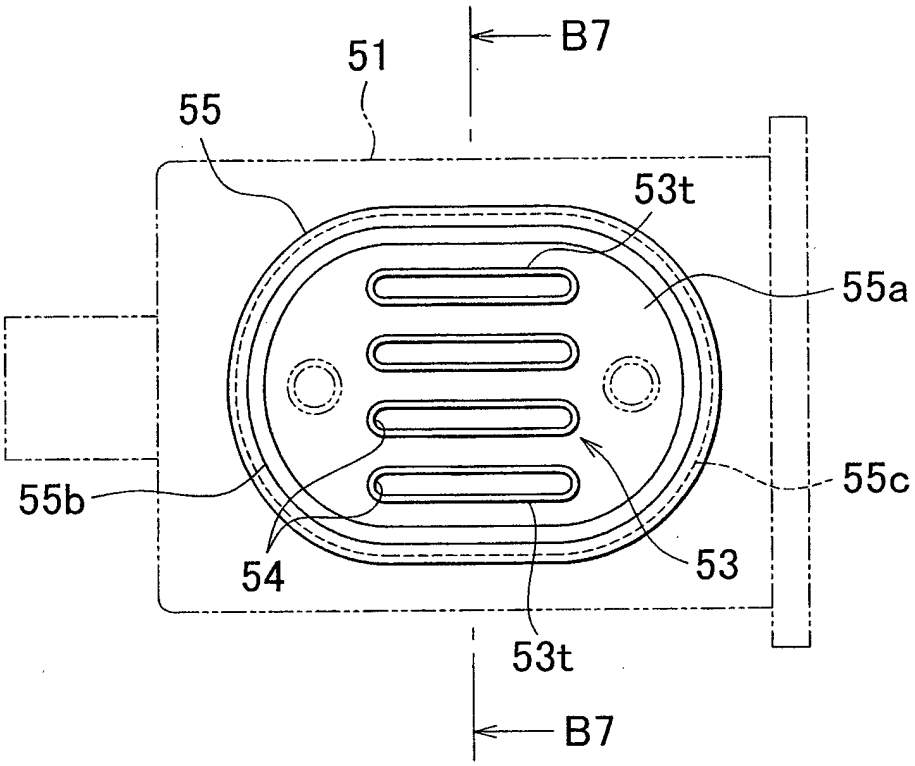

B7
51
55
53t
55a
55b
55c
54
53
53t
B7

FIG. 7B

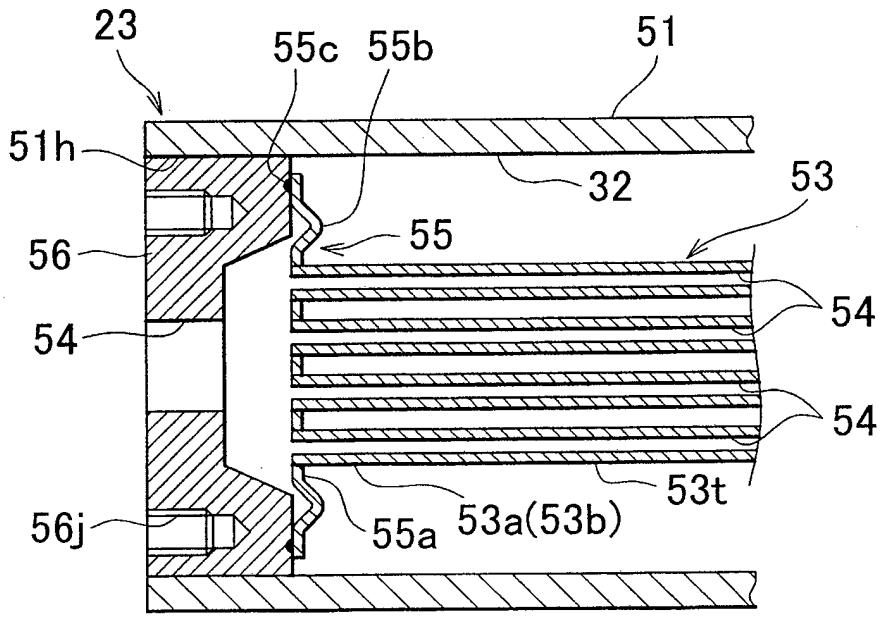

23
55c
55b
51
51h
32
53
55
56
54
54
54
53t
56j
55a
53a(53b)

FIG. 8A

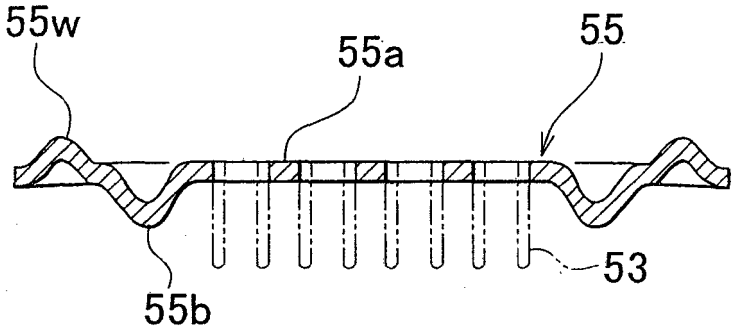



FIG. 8B

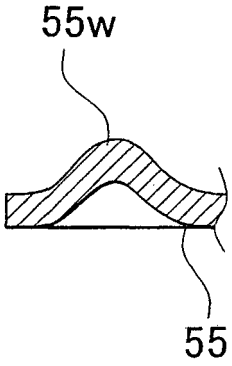


FIG. 9A

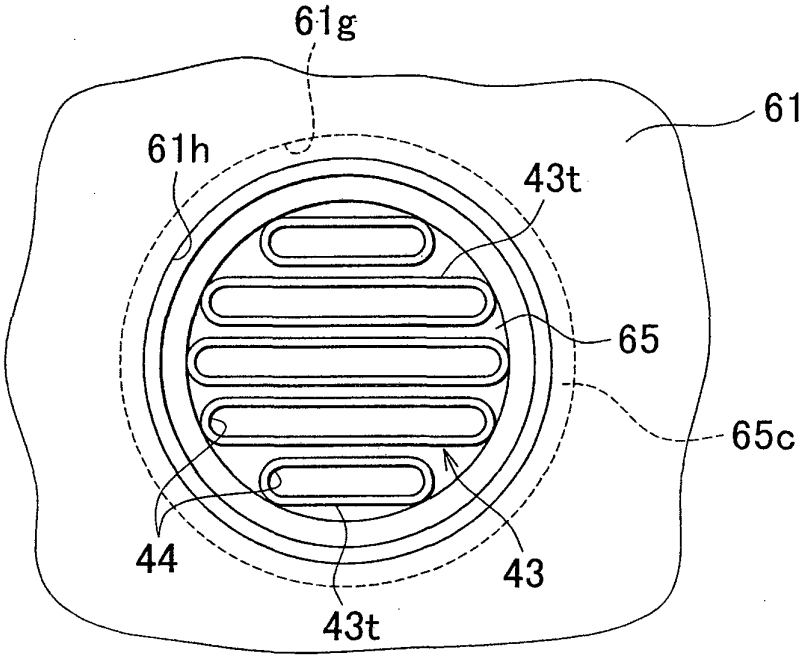

61g
61
61h
43t
65
65c
44
43
43t

FIG. 9B

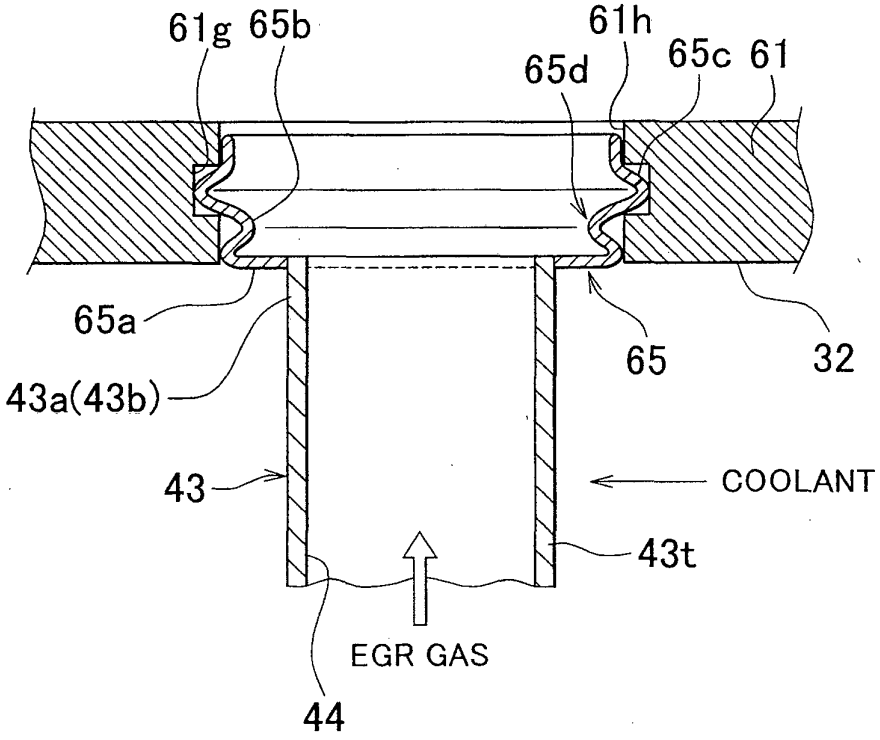

61g
65b
61h
65d
65c
61
65a
43a(43b)
65
32
43
COOLANT
43t
EGR GAS
44

FIG. 10A

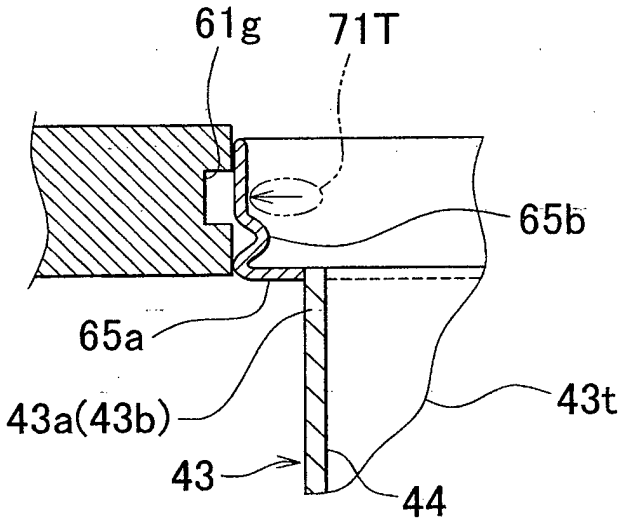
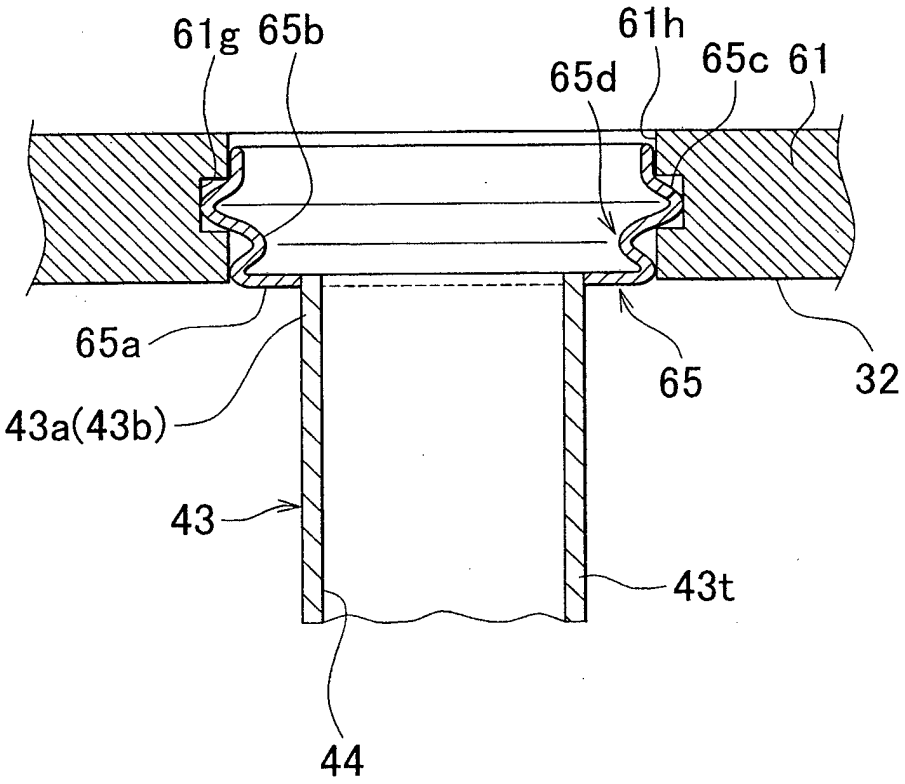



FIG. 10B



## REFERENCES CITED IN THE DESCRIPTION

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