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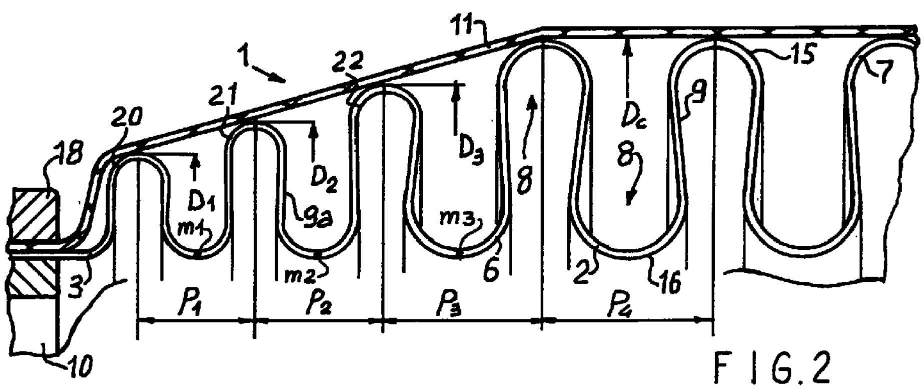
(54) Flexible undulated-walled conduit for decoupling vehicle engine exhaust pipes

(57) A flexible undulated-walled decoupling conduit (1) for a vehicle engine exhaust system; the conduit being defined by a flexible continuous-walled tubular element (2), and being made of stainless steel sheet (5), which is folded to form a closed conduit and deformed axially to form a number of circular undulations (7) enabling the conduit to flex; the tubular element (2) being covered externally or internally with a woven stainless steel wire sheath (11, 17); the tubular element, according to the invention, having, at each end (3, 4), a group of at least three undulations (20, 21, 22) of increasing inside and/or outside diameters (D_1, D_2, D_3) so as to decrease gradually in height towards the respective end of the tubular element; the undulations (20, 21, 22) in each group being separated by spacings (p_1, p_2, p_3) differing from one another and from the constant spacing of the intermediate undulations (6a); and the undulations so formed conferring greater rigidity to the ends of the flexible conduit in the event of lateral bending stress, so as to achieve substantially uniform stress along the meridians of the undulations (7).



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Description

The present invention relates to a flexible conduit for decoupling internal combustion engine exhaust pipes, and more specifically to a flexible undulated-walled tubular metal conduit interposed between the exhaust manifold of a vehicle engine and the catalytic muffler fitted to the exhaust pipe.

As is known, vehicle engines, particularly when accelerating rapidly, are subject to severe axial and transverse vibration with respect to the longitudinal axis of the exhaust pipe. As transverse vibration in particular subjects the exhaust pipe to severe lateral bending stress, which may result in premature fatigue failure of certain exhaust system components, the engine exhaust manifold and the exhaust pipe fitted to the vehicle body are connected by means of an intermediate decoupling element to prevent vibration being transmitted from the engine to the rest of the exhaust pipe.

One known decoupling element, interposed between the exhaust manifold of a vehicle engine and the catalytic muffler fitted to the exhaust pipe, comprises a bellows type flexible tubular element made of sheet steel, and which is deformed axially to form a series of circular undulations of constant diameter, is welded at the ends to two collars, in turn welded directly to the manifold at one end and to the catalytic muffler at the other, and is normally fitted with a protective steel wire outer sheath.

Though fairly effective in damping axial vibration, the above flexible tubular element adapts poorly to transverse vibration, which tends to offset the ends of the flexible tubular element and so form a bend which is sharpest at the end undulations of the flexible tubular element, thus subjecting the end undulations to severe bending stress concentrated along the meridian.

It is an object of the present invention to provide a flexible decoupling element for connecting a vehicle engine exhaust manifold to a catalytic muffler fitted to the exhaust pipe, and which is designed to eliminate the drawbacks typically associated with similar known elements, and, in addition to effectively sealing engine exhaust, damping vibration and attenuating noise inside and outside the vehicle, is also bendable substantially uniformly along the whole of its length.

According to the present invention, there is provided a flexible undulated-walled conduit for decoupling vehicle engine exhaust pipes, and which is interposed between the engine manifold and a catalytic muffler, and comprises a flexible tubular element made of sheet metal and deformed axially to form a series of adjacent circumferential undulations;

characterized in that said tubular element comprises, at each end, a group of at least three undulations having varying diameters differing from a constant diameter of intermediate undulations between said groups; said at least three undulations being so formed that the meridian bending stress of said at least three undulations is substantially equivalent.

According to a further characteristic of the invention, the undulations in each end group have spacings differing from one another and from the constant spacing of the intermediate undulations.

The undulations in the two end groups are therefore of heights decreasing gradually, towards said ends of the tubular element, with respect to the height of the intermediate undulations; which geometric characteristic has surprisingly been found to provide, under equal stress, for more uniform bending of the tubular element as compared with known elements featuring equally spaced undulations all of the same height. In the event of misalignment of the connected pipes, the conduit according to the invention assumes the form of a widely curving S to prevent overstressing the ends; which effect is dependent on each end group comprising at least three, as opposed to only one or two, undulations of reduced height.

A preferred non-limiting embodiment of the invention will be described by way of example with reference to the accompanying drawings, in which:

- Figure 1 shows a partial axial section of the flexible conduit according to the teachings of the present invention;
- Figure 2 shows a larger-scale detail of one end of the Figure 1 flexible conduit according to the invention;
- Figure 3 shows an example of a wire mesh sheath;
- Figures 4 and 5 show larger-scale views of a variation of the tubular element, in which the end undulations have varying inside diameters and varying inside and outside diameters respectively.

Number 1 in Figure 1 indicates a partially sectioned flexible decoupling conduit in accordance with the invention, which is interposed between a known vehicle engine exhaust manifold and a catalytic muffler or, more generally speaking, an exhaust pipe (none shown in the accompanying drawings).

Conduit 1 comprises a tubular element 2 deformed axially to form a bellows, and terminating at the ends with two cylindrical end portions 3 and 4.

Tubular element 2 is made from an appropriately thick strip 5 of sheet metal, preferably stainless steel with a high resistance to mechanical and thermal fatigue. Strip 5 is first folded and welded longitudinally into a cylinder to form a closed conduit, and is then hot-formed, by applying axial pressure, to form a lateral wall 6 having a number of circumferential undulations 7, which alternate with corresponding cavities 8 and have initially flat radial lateral walls 9.

A further, follow-up, forming operation is also performed to impart an inclined converging shape to the lateral walls, or sides, 9 of each undulation, so that, in radial section, the undulations are substantially omega-shaped.

The follow-up forming operation is preferably performed starting from the third undulation from each end, so that the first two undulations adjacent to each end portion 3, 4 of tubular element 2 have substantially parallel sides 9a, while the other undulations have the characteristic omega shape.

Tubular element 2 may also be double-walled by superimposing two strips 5 of the same or different thicknesses prior to the operations described above.

Two cylindrical annular sleeves 10 are force fitted with a small amount of interference inside end portions 3 and 4 of tubular element 2, and define strengthening and reinforcing elements for strengthening and reinforcing end portions 3, 4 of tubular element 2, and for simplifying connection of the tubular element to the manifold at one end and to the catalytic muffler at the other.

Tubular element 2 is fitted inside and/or outside with at least one known woven tubular metal sheath 11 (Figure 1 shows an outer sheath 11 only). Metal sheath 11 is roughly equal in length to the total length of tubular element 2, and, at end portions 3 and 4, is deformed locally so as to adhere externally to the end portions.

Used inside or outside tubular element 2, metal sheath 11 may be formed by braiding two groups 12, 14 of parallel wires interwoven at an angle of 90° to 120° as shown in Figure 1. A braided sheath is substantially rigid and compact, is bendable by only small angles, and is therefore preferably used as a cylindrical sheath for protecting and covering outer surface 15 or inner surface 16 of tubular element 2, by cooperating more effectively with the crests of undulations 7.

Alternatively, sheath 11 may be made of stainless steel wires interwoven to form a wire mesh 17, as shown schematically in Figure 3. A wire mesh sheath is extremely flexible, may be bent or drawn easily in any direction, and may be used singly or in multiple layers to improve the damping effect. In particular, a wire mesh sheath may be inserted to advantage inside the cavities 8 between adjacent undulations 7, as described in a co-pending patent application by the present Applicant.

The radially superimposed ends of sleeves 10, tubular element 2 and metal sheath 11 are gripped inside respective cylindrical collars 18, which are hot force fitted onto the ends and welded frontally with respective continuous circular weld beads 19 to prevent any gas from escaping between the various components.

An undulated conduit as described above is highly flexible, particularly axially. However, in the event tubular element 2 is subjected to lateral stress, e.g. transverse vibration with respect to the longitudinal axis of the conduit, such as to radially offset end portions 3 and 4, tubular element 2 flexes laterally to assume a roughly Z shape in which maximum bending is concentrated at the first undulations adjacent to each end portion, while the central portion 6a of the conduit remains substantially straight.

This therefore seriously increases the likelihood of fatigue failure of tubular element 2, particularly at the first undulations adjacent to the end portions.

According to the present invention, this has surprisingly been found to be avoidable by forming the first undulations - in particular, at least the first three undulations 20, 21, 22 adjacent to each end portion of tubular element 2 - with different spacings and of such diameters that, in radial section, the heights H (Figure 5) of the first undulations decrease towards the respective adjacent end portion 3, 4.

In the non-limiting example shown in Figures 1 and 2, undulations 20, 21, 22 are each separated from the next by a different spacing p_1, p_2, p_3 differing from the spacing p_4 of the following undulations 6a, and have respective outside diameters D_1, D_2, D_3 increasing towards the opposite end but smaller than the outside diameters D_c of undulations 6a of constant height. In the Figure 4 variation, the same effect is achieved by forming all the undulations with constant outside diameters D_c, and forming end undulations 20, 21, 22 with respective inside diameters d_1, d_2, d_3 increasing towards the respective adjacent end portion 3, 4.

In a further variation shown in Figure 5, end undulations 20, 21, 22 are formed with varying inside and outside diameters.

In all the above cases, the invention provides for considerably increasing the rigidity of the end portions of tubular element 2, so that, when tubular element 2 is subjected to lateral bending stress, end portions 3 and 4 are connected by more widely curving bends to the central portion. As such, in the event of misalignment of end portions 3, 4, the conduit substantially assumes the form of an S, so that bending stress is reduced and distributed substantially evenly along any meridian of the conduit to substantially achieve the following equation:

$$S_{m1} = S_{m2} = S_{m3} \quad (1)$$

where S_{mi}, where i=1, 2, 3, is the meridian stress measured at points m1, m2 and m3 (as shown in Figure 2).

The favourable and unexpected performance of conduit according to the present invention was comparison tested, under the same test conditions, with that of similar known types having undulations all of the same inside and outside diameters. In all the tests, the dynamic performance and mechanical resistance to fatigue of the conduit according to the invention were found to be decidedly superior.

The minimum number of three undulations of decreasing height at each end was found to be a determining factor in achieving the above results, which are not obtained with only one or two undulations of reduced height.

Though the same (or probably even better) results would be obtained by increasing the number of undulations of reduced height (to, say, four or more), more than three undulations are difficult to produce at reasonable cost using current manufacturing techniques.

Claims

1. A flexible undulated-walled conduit (1) for decoupling vehicle engine exhaust pipes, and which is interposed between the engine manifold and a catalytic muffler, and comprises a flexible tubular element (2) made of metal sheet (5) and deformed axially to form a series of adjacent circumferential undulations (7);
characterized in that said tubular element (2) comprises, at each end (3, 4), a group of at least three undulations (20, 21, 22) having varying diameters (D_1, D_2, D_3) differing from a constant diameter (D_c) of intermediate undulations (6a) between said groups; said at least three undulations (20, 21, 22) being so formed that the meridian bending stress (S_1, S_2, S_3) of said at least three undulations (20, 21, 22) is substantially equivalent.

2. A flexible conduit as claimed in Claim 1, characterized in that the undulations (20, 21, 22) in each of said two end groups are separated axially by varying spacings (p_1, p_2, p_3) differing from the axial spacing (p_4) of the intermediate undulations between said groups.

3. A flexible conduit as claimed in Claim 2, characterized in that said varying diameters are the outside diameters (D_1, D_2, D_3) of said at least three undulations (20, 21, 22), and vary gradually from a minimum value (D_1) of a first undulation (20) adjacent to the respective said end (3, 4), to a maximum value (D_3) of at least a third undulation (22).

4. A flexible conduit as claimed in Claim 1 or 2, characterized in that said varying diameters are the inside diameters (d_1, d_2, d_3) of said at least three undulations (20, 21, 22).

5. A flexible conduit as claimed in Claim 1 or 2, characterized in that said varying diameters are both the outside diameters (D_1, D_2, D_3) and inside diameters (d_1, d_2, d_3) of said at least three undulations (20, 21, 22).

6. A flexible conduit as claimed in one of the foregoing Claims, characterized in that the undulations (20, 21, 22) in the two end groups decrease gradually in height (H) towards said ends (3, 4) of the tubular element and with respect to the height of the intermediate undulations.

7. A flexible conduit as claimed in one of the foregoing Claims, characterized in that the undulations (22, 6a) of said tubular element (2) between the second and the last-but-one undulations (21) are further deformed axially to impart an inclined converging shape to the sides (9) of the undulations; the sides (9a) of each of the first two undulations (20, 21) adjacent to each end (3, 4) of said tubular element (2) being maintained substantially parallel.

8. A flexible conduit as claimed in one of the foregoing Claims, characterized in that a woven wire sheath (11, 17) is applied to externally and/or internally cover a lateral surface (15, 16) of said tubular element (2).

9. A flexible conduit as claimed in Claim 8, characterized in that said sheath (11) is a braided sheath comprising interwoven groups (12, 14) of parallel wires.

10. A flexible conduit as claimed in Claim 8, characterized in that said sheath is a wire mesh sheath (17).

11. A flexible conduit as claimed in Claim 10, characterized in that said wire mesh sheath (17) is inserted inside the cavities (8) between adjacent undulations (7) of said tubular element (2).

12. A flexible conduit as claimed in Claim 8, characterized in that a braided sheath (11) cooperates to cover an inner surface (16) of said flexible conduit, and a wire mesh sheath (17) cooperates to cover an outer surface (15) of said flexible conduit (1).

13. A flexible conduit as claimed in one of the foregoing Claims, characterized in that said tubular element (2) is made from a single metal sheet (5).

14. A flexible conduit as claimed in one of the foregoing Claims from 1 to 13, characterized in that said tubular element (2) is made from at least two superimposed metal sheets of equal thickness.

15. A flexible conduit as claimed in one of the foregoing Claims from 1 to 13, characterized in that said tubular element (2) is made from at least two superimposed metal sheets of different thicknesses.

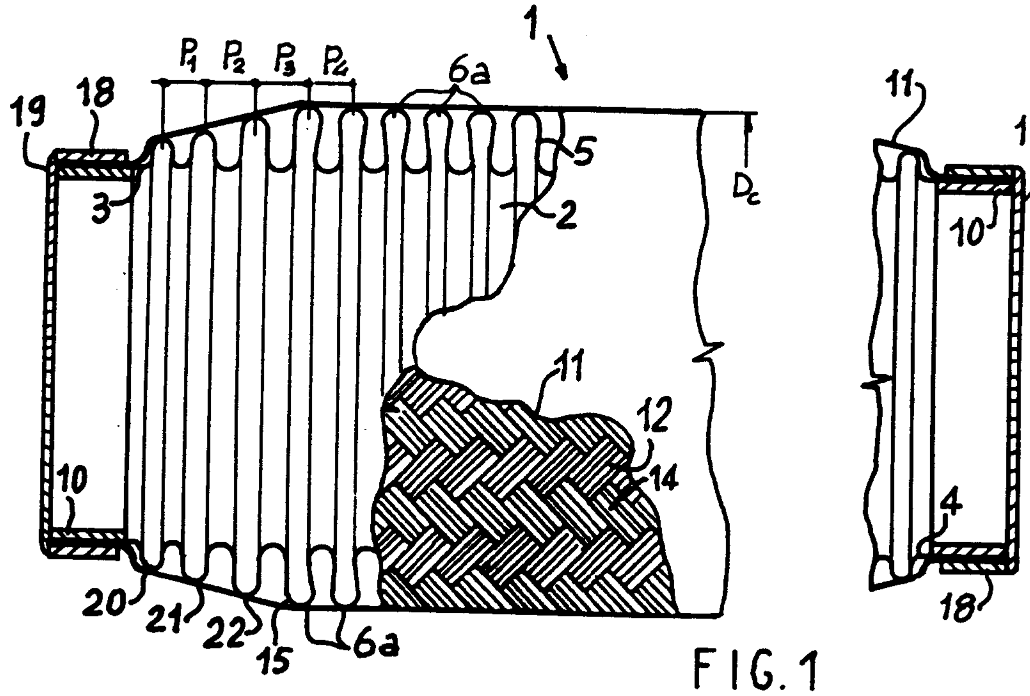


FIG. 1

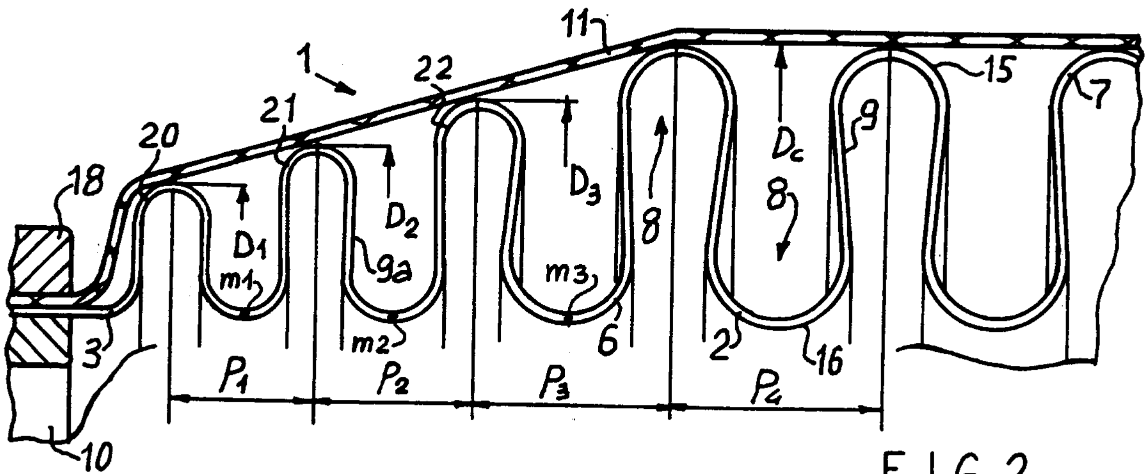


FIG. 2

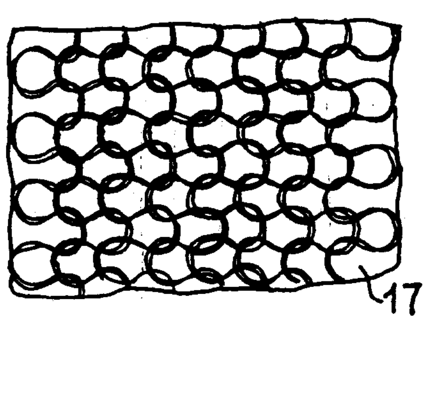


FIG. 3

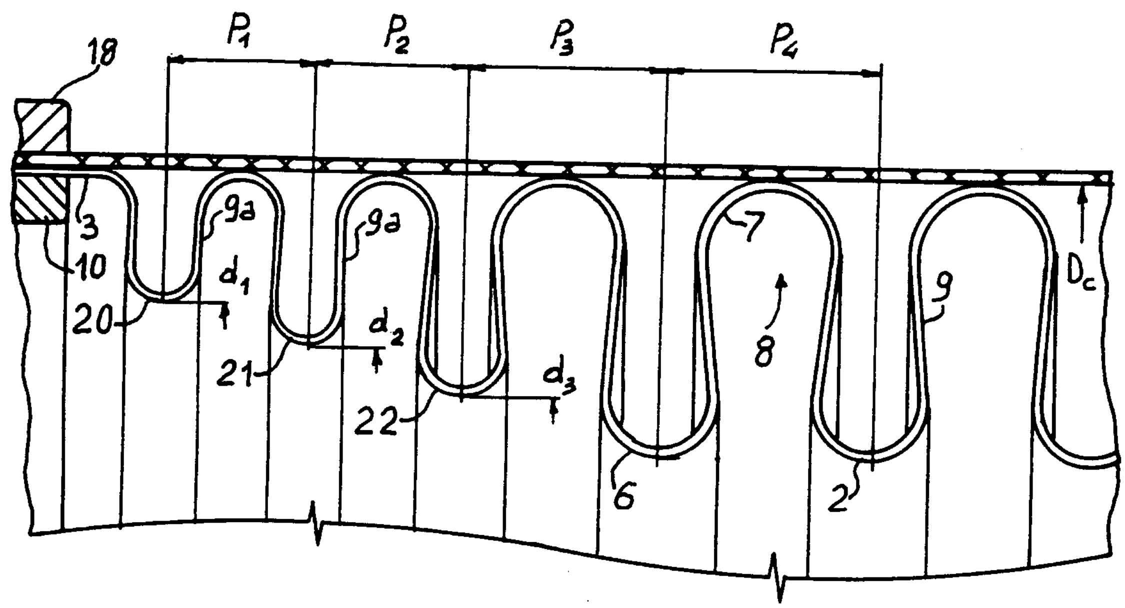
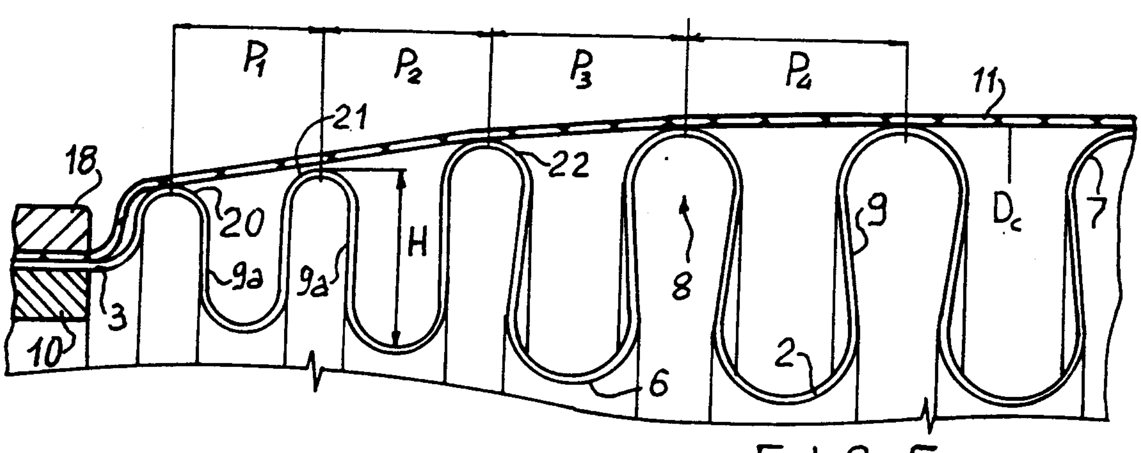

18
P1
P2
P3
P4
3
10
20
21
22
9a
9a
d1
d2
d3
7
8
9
Dc
6
2

FIG.4


P1
P2
P3
P4
11
21
22
18
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H
9a
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3
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8
9
Dc
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FIG.5

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EUROPEAN SEARCH REPORT

Application Number
EP 98 11 2403

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	16 October 1998	Friden, C

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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TECHNICAL FIELDS SEARCHED (Int.Cl.6)

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