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(54) **MULTISTAGE MOTOR-COMPRESSOR FOR THE COMPRESSION OF A FLUID**

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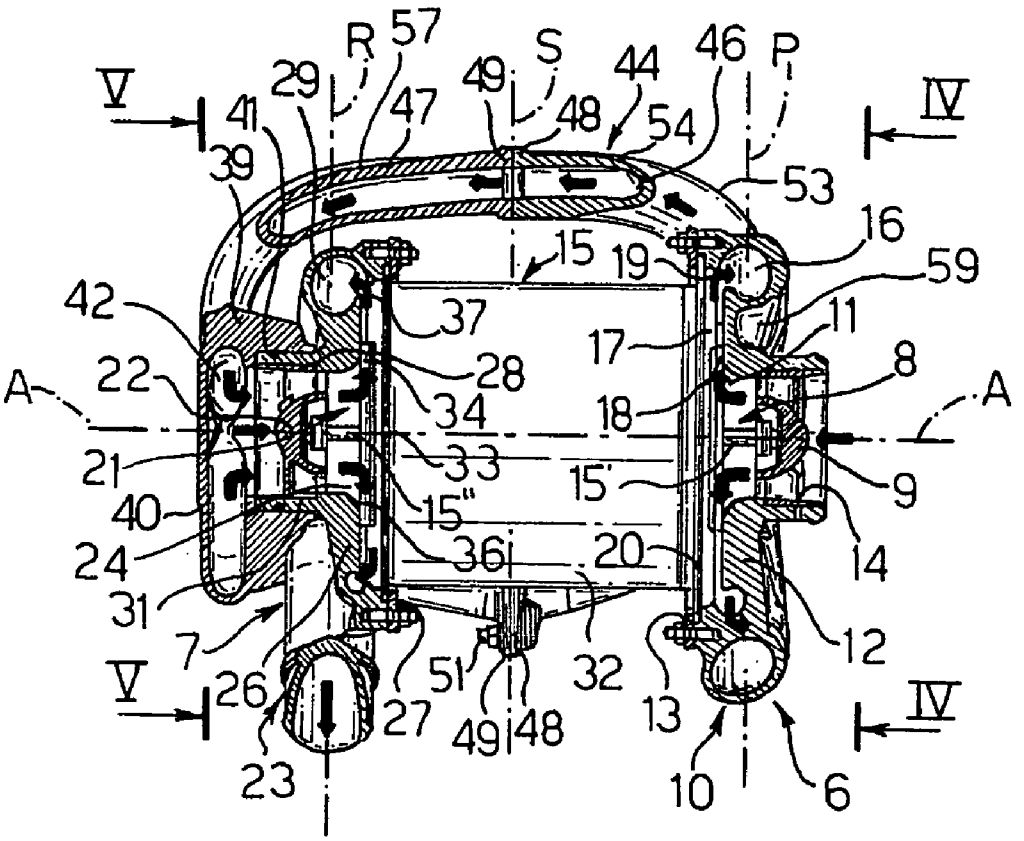
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(57) **ABSTRACT**

A motor-compressor is provided that includes a first compression stage with a primary impeller and at least one delivery duct, a second compression stage with a secondary impeller spinning in a predetermined direction of rotation, and at least one transfer duct placed so as to put the delivery duct in communication with a fluid conveyor for the second stage. The transfer duct is shaped in a way to create a fluid flow entering the conveyor with a substantially helical course and a direction of rotation opposite to the direction of rotation of the secondary impeller.



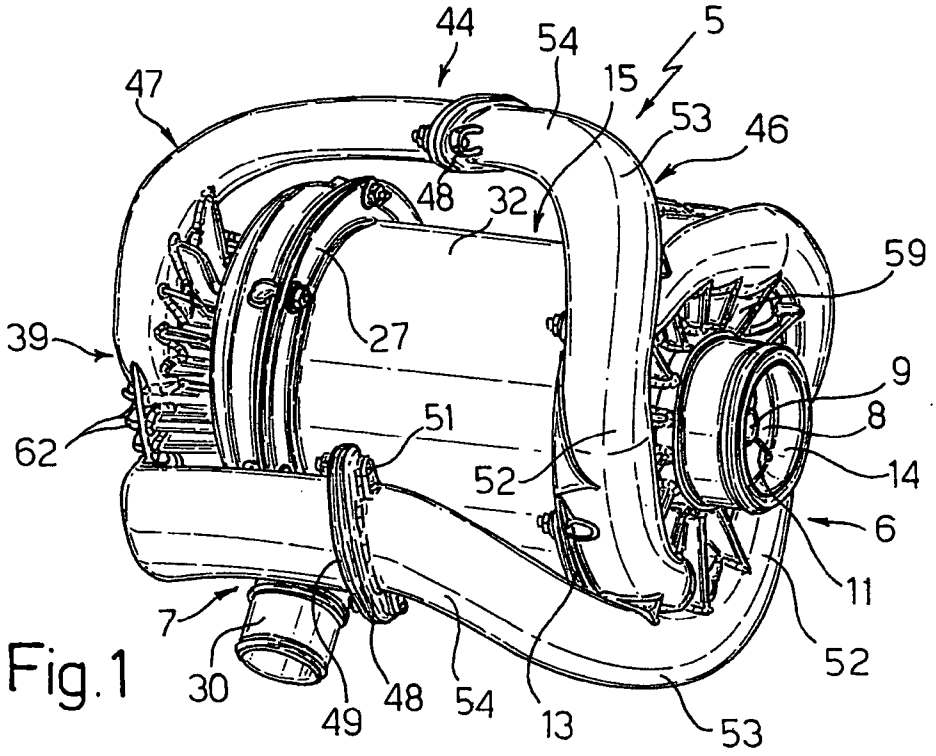

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Fig.1

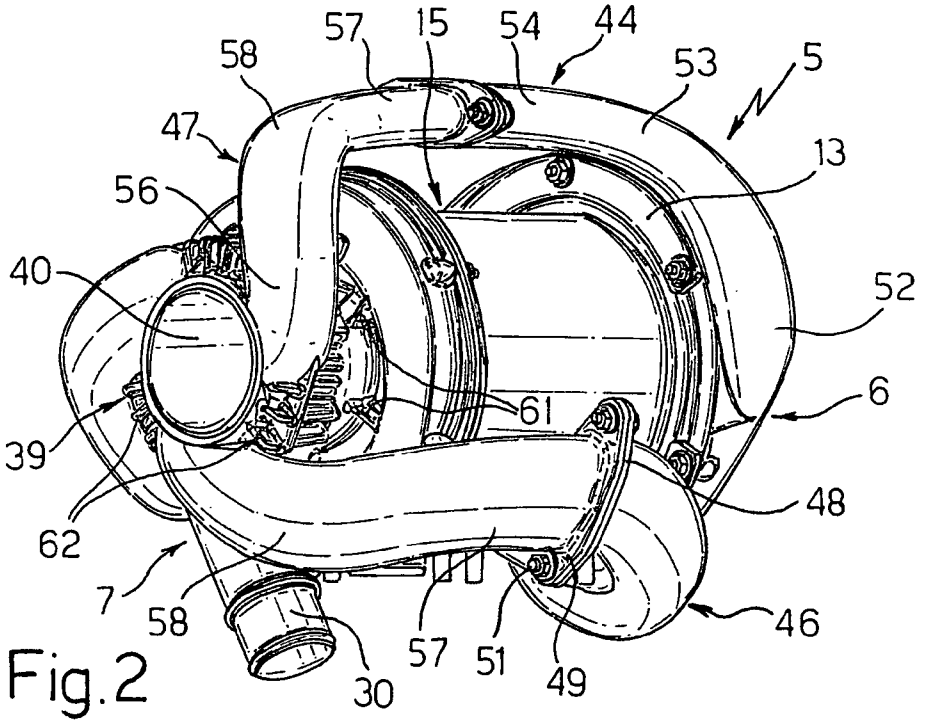

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Fig.2

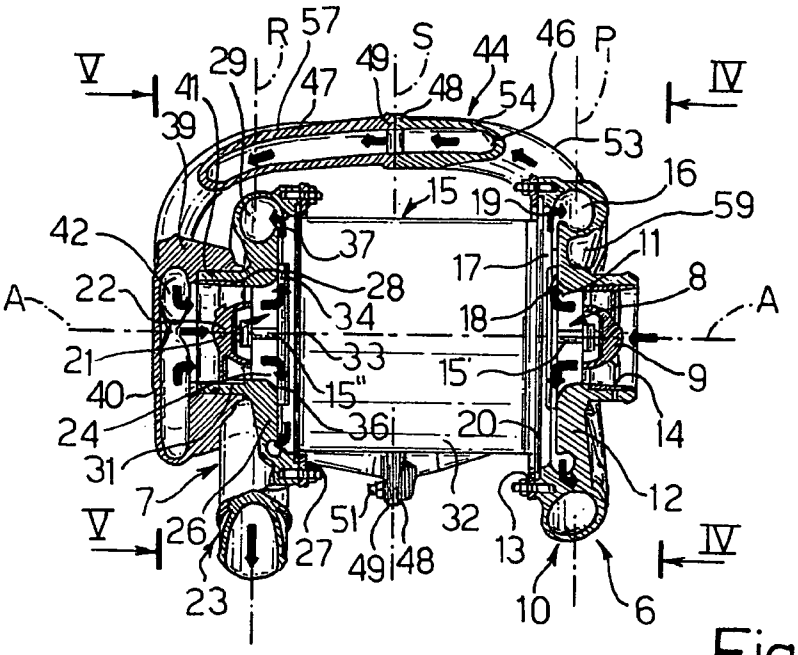


Fig.3

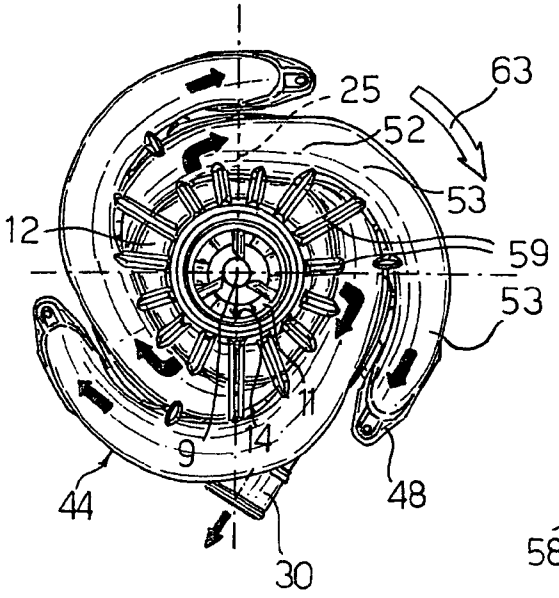


Fig.4

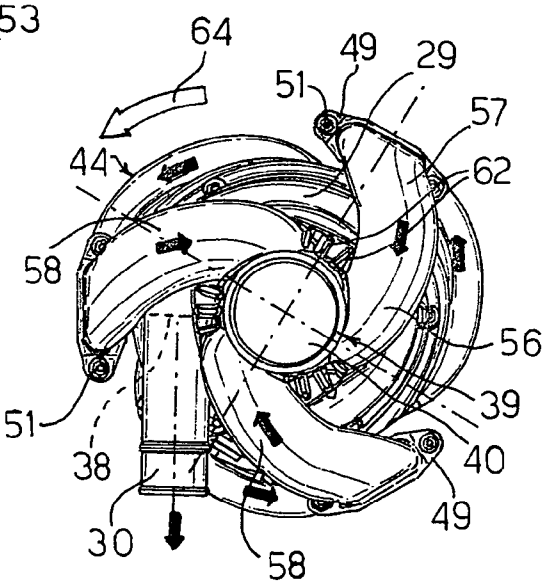


Fig.5

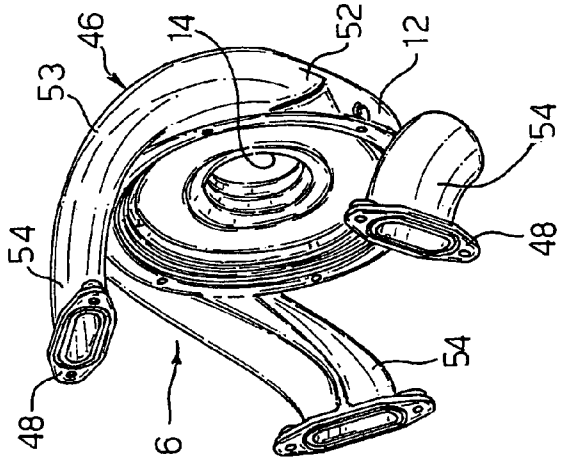


Fig.6

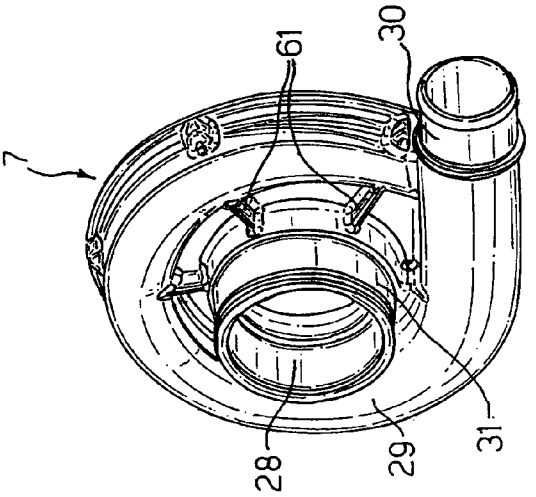


Fig.7

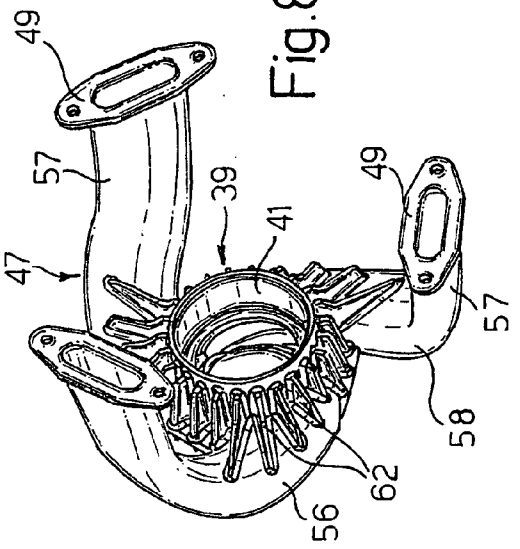


Fig.8

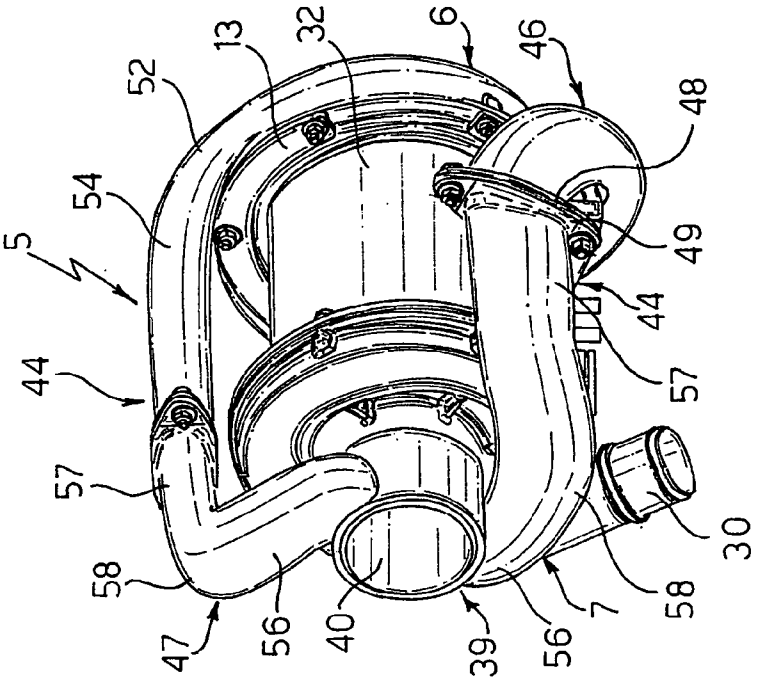


Fig.10

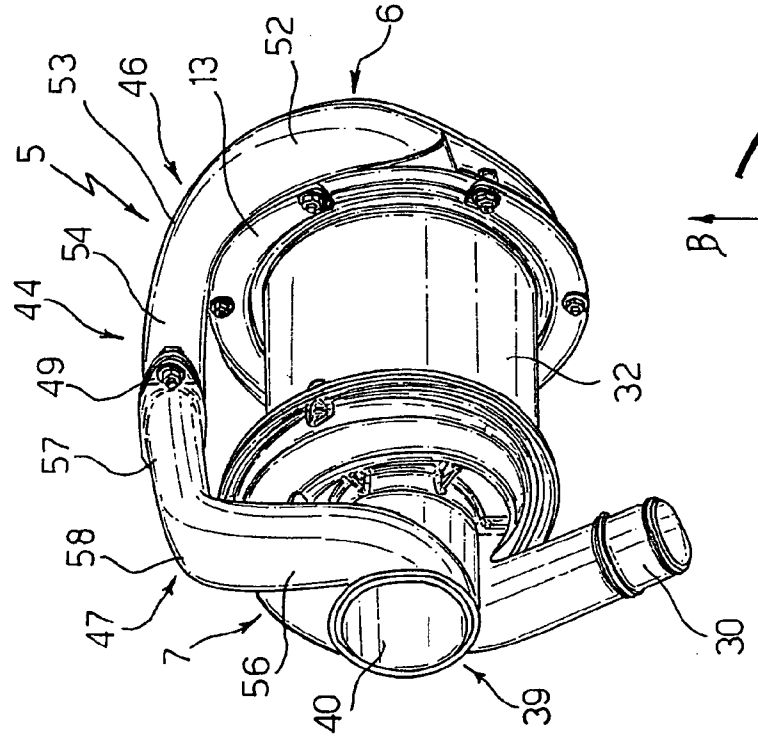


Fig.9

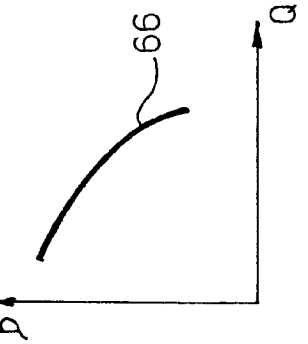


Fig.11

MULTISTAGE MOTOR-COMPRESSOR FOR THE COMPRESSION OF A FLUID

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims benefit under 35 U.S.C. §119(a) of Italian Patent Application No. T)2005A 000558, filed Aug. 5, 2005 and European Patent Application No. 06101557.4, filed Feb. 10, 2006, the entire contents of both of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] This disclosure refers to a multistage motor-compressor for the compression of a fluid, for motor vehicles for example. In particular, the disclosure refers to a two-stage motor-compressor for the supply of pressurized air to fuel cell systems.

[0004] 2. Description of Related Art

[0005] Motor-compressors of the above-stated type are well known, in which the first-stage scroll is connected to a tangential first section of a transfer duct, while a second axial or radial section of the transfer duct is connected to a fluid conveyor for the second-stage scroll. In the case where the second section is axial, the fluid flow entering the conveyor undergoes abrupt changes of direction, giving rise to a drop in flow pressure, high operational power consumption and reduced efficiency for the motor-compressor.

[0006] In the case in which the second section of the transfer duct is radial, it is normally shaped to create a helical flow with the same direction of rotation as that of the second-stage impeller. This radial connection has the drawback of reduced efficiency and a low compression ratio at high flow rates.

[0007] Multistage motor-compressors are also known, in which the impellers are arranged in series on the same output side of the driving electric motor's shaft. Since the two impellers are cantilever mounted on the shaft, the latter is subject to stress, which reduces the operating speed.

BRIEF SUMMARY OF THE INVENTION

[0008] The object of the disclosure is that of embodying a two-stage motor-compressor, which is highly reliable, eliminating the drawbacks and increasing the performance of motor-compressors of known art.

[0009] According to the disclosure, this object is achieved by a multistage motor-compressor for the compression of a fluid.

[0010] According to a variant of the disclosure, the impellers of the two stages are fixed on two opposite ends of the shaft of a common driving electric motor, for which the motor-compressor is able to operate at high speeds.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0011] For a better understanding of the disclosure, a preferred embodiment is described herein, provided by way of example with the aid of the enclosed drawings, in which:

[0012] FIG. **1** is a right-hand perspective view of a two-stage motor-compressor according to a first variant of the disclosure,

[0013] FIG. **2** is a left-hand perspective view of the motor-compressor in FIG. **1**,

[0014] FIG. **3** is a diametrical section of the motor-compressor in FIG. **1**,

[0015] FIG. **4** is a view along line IV-IV in FIG. **3**,

[0016] FIG. **5** is a view along line V-V in FIG. **3**,

[0017] FIG. **6** is a left-hand perspective view of part of the motor-compressor in FIG. **1**,

[0018] FIG. **7** is a left-hand perspective view of another part of the motor-compressor in FIG. **1**,

[0019] FIG. **8** is a right-hand perspective view of a further part of the motor-compressor in FIG. **1**,

[0020] FIGS. **9** and **10** are two due perspective views similar to that in FIG. **2**, regarding two variants of the motor-compressor, and

[0021] FIG. **11** is a graph of the motor-compressor's compression ratio.

DETAILED DESCRIPTION OF THE INVENTION

[0022] With reference to FIGS. **1** and **2**, reference **5** generically indicates a multistage motor-compressor for the compression of a fluid, for motor vehicles for example. In particular, the motor-compressor **5** is of the type with two stages **6** and **7**, low pressure and high pressure respectively, and is suitable for the supply of pressurized air in a fuel cell system or for supplying air to internal combustion engines, or for any system in which compressed air is required.

[0023] The low-pressure stage **6** comprises a low-pressure impeller, which henceforth will be called the primary impeller **8** (FIG. **3**). The primary impeller **8** rotates around an axis A and is preceded by a fixed ogival portion **9**, placed inside a low-pressure scroll, which henceforth will be called the primary scroll **10**. The primary impeller **8** is fixed on one end **15'** of a shaft of an electric motor **15**. The primary impeller **8** also comprises a series of substantially radial, shaped blades **11**, of known type.

[0024] The primary scroll **10** is composed of a shaped casing **12**, connected in a removable manner, via bolts and at least one half-ring **13**, to a fixed plate **20** carried on an external casing **32** of the motor **15**, which has a substantially cylindrical shape. The shaped casing **12** has a central air-inlet opening **14** to the low-pressure stage **6**. The primary scroll **10** also has at least one curved, fluid-delivery duct **16**, which has a substantially spiral shape placed substantially on plane P perpendicular to axis A.

[0025] According to the variant in FIGS. **1-8**, the primary scroll **10** is equipped with three curved ducts **16** arranged at 120° to each other, for the purpose of having a balanced load on the primary scroll **10**. The fixed plate **20** of the motor **15**, together with the shaped casing **12** of the primary scroll **10**, form an annular chamber **17** in communication with the curved ducts **16**. On one side, the annular chamber **17** is in communication with the central opening **14**, through an annular inlet opening **18** facing towards axis A, while on the

other side it is in communication with the curved ducts **16** through corresponding outlet openings **19**, facing towards the outside of the annular chamber **17**.

[**0026**] The shaped blades **11** of the impeller **8** are suitable for conveying incoming air from the central opening **14** to the curved ducts **16**. The axial direction of the airflow to be compressed is optimized by the ogival portion **9**. In order to convey compressed air from the impeller **8**, each curved duct **16** has an increasing section from the outlet opening **19** of the annular chamber **17** to the outlet opening **25**, which is defined by the terminal radial section of the curved duct **16**. The spiral shape of the curved duct **16** induces a fluid flow that turns in the same direction of rotation as the impeller **8**.

[**0027**] The high-pressure stage **7** of the motor-compressor **5** comprises a high-pressure impeller, which henceforth will be called the secondary impeller **21** (FIG. **3**), rotating around its axis. This axis can advantageously coincide with axis A of the primary impeller **8**. The secondary impeller **21** is fixed on the end **15"** of the shaft of the motor **15** opposite from that of the primary impeller **8**, thereby providing a balanced load on the shaft of the motor **15** such that the group of impellers **8** and **21** can be spun at high speed.

[**0028**] The secondary impeller **21** is equipped with its own ogival portion **22**, suitable for optimizing the direction of the axial flow. The ogival portion **22** is placed inside a high-pressure scroll, which henceforth will be called the secondary scroll **23**. The secondary impeller **21** also comprises a series of substantially radial, shaped blades **24**.

[**0029**] The secondary scroll **23** is composed of a shaped casing **26** connected in a removable manner, via bolts and at least one half-ring **27**, to another fixed plate **33**, carried on the external casing **32** of the motor **15**. The shaped casing **26** of the secondary scroll **23** has a sleeve **31** with a central air-inlet opening **28** to the high-pressure stage **7**.

[**0030**] In addition, the secondary scroll **23** has at least one curved duct **29**, substantially placed on another plane R perpendicular to axis A. The secondary scroll **23** (see also FIG. **7**) advantageously has just one curved duct **29**, which also has a substantially spiral course and terminates with a straight section **30**. The spiral of the curved duct **29** is such as to generate a fluid flow that also turns in the same direction as the secondary impeller **21**.

[**0031**] The fixed plate **33** together with the shaped casing **26** forms an annular chamber **34**, one side of which is in communication with the central opening **28**, through an annular inlet opening **36** facing towards axis A. On the other side, the annular chamber **34** is in communication with the curved duct **29**, through an opening **37** facing towards the outside, which forms the inlet opening of the curved duct **29**. The shaped blades **24** of the impeller **21** are suitable for conveying incoming air from the central opening **28** to the annular chamber **34**.

[**0032**] In order to convey compressed air entering through the central opening **28** in the annular chamber **34**, the curved duct **29** has an increasing section from the portion adjacent to its inlet opening **37** to a corresponding outlet opening **38** (FIG. **5**) defined by the terminal radial section of the curved duct **29**, which is equal to that of the straight section **30**.

[**0033**] The motor-compressor **5** also comprises a conveyor **39** with an outer wall **40** and a central opening **41** (FIG. **3**), in which the sleeve **31** of the secondary scroll **23** engages in a sealed manner. The conveyor **39** is also provided with three inlet openings **42** associated with the three outlet openings **25** of the curved ducts **16** of the primary scroll **10**. The three inlet openings **42** are also arranged at 120° to each other. A corresponding transfer duct, generically indicated by reference **44**, is placed between each outlet opening **25** of the primary scroll **10** and the corresponding inlet opening **42** of the conveyor **39**.

[**0034**] According to the disclosure, each transfer duct **44** is shaped so as to create a flow entering the conveyor **39** with a substantially helical course and a direction of rotation opposite to the direction of rotation of the secondary impeller **21**. In particular, each transfer duct **44** comprises a first section **52** (FIGS. **1**, **4** and **6**) connected to the corresponding curved duct **16** and substantially tangential to the primary impeller **8**, a second section **56** (FIGS. **2**, **5** and **8**) connected to the corresponding opening **42** of the conveyor **39** and substantially tangential to the secondary impeller **21**, and a longitudinal intermediate section **54** and **57**.

[**0035**] The second tangential section **56** of the transfer duct **44** and the corresponding opening **42** of the conveyor **39** are positioned in a manner to generate the said helical course of the flow, with an opposite direction of rotation to that of the impeller **21**. Furthermore, each transfer duct **44** comprises a first connector section **53**, substantially helical in form and placed between the first tangential section **52** and the intermediate section **54** and **57**. Each transfer duct also comprises a second curved connector section **58** placed between the second tangential section **56** and the intermediate section **54** and **57**.

[**0036**] The transfer ducts **44** are advantageously placed on the outside of the casing **32** and are each formed by two segments **46** and **47** (FIGS. **1** and **2**), connected in a removable manner to the primary scroll **10** and the conveyor **39** respectively. The two segments **46** and **47** terminate with corresponding flanges **48** and **49**, which mate together on a plane S (FIG. **3**) perpendicular to axis A, and are connected to each other in a sealed and removable manner, for example by bolts **51**.

[**0037**] The segment **46** of each transfer duct **44** comprises the said first section **52**, the corresponding substantially helical connection section **53**, and a straight portion **54**, which forms a portion **54** of the intermediate section **54** and **57**. In turn, the segment **47** of each transfer duct **44** comprises the said second section **56**, the curved connection section **58** and another straight portion **57** of the intermediate section **54** and **57**.

[**0038**] All of the ducts **16**, **29** and **44** of the motor-compressor **5** are outwardly sealed to support the pressurized fluid, via toroidal gaskets for example, pastes or in any other known manner. The shaped casing **12** of the primary scroll **10** is provided with a series of cooling ribs or fins **59**. Similarly, the shaped casing **26** of the secondary scroll **23** and the conveyor **39** are provided with corresponding series of cooling ribs or fins **61** and **62**. The fins **59**, **61** and **62** serve to increase the heat-exchange surface area with the external environment, to cool the compressed fluid efficiently, increasing the density and therefore increasing the efficiency of the motor-compressor **5**. The transfer ducts **44** have an elliptic section to contain the radial bulk of the motor-compressor **5**.

[0039] In the illustrated embodiment, the two impellers **8** and **21** are coaxial and are driven by a single electric motor **15**. In FIGS. **4** and **5**, the arrows **63** and **64** represent the direction of rotation of the motor **15**, while the black arrows on the transfer ducts **44** represent the flow of fluid. FIG. **4** clearly shows that the direction of rotation of the flow in the segments **46** is consistent with that of the motor **15** (arrow **63**), while FIG. **5** shows that the direction of rotation of the flow in the sections **57** of the segments **47** is opposite to that of the motor **15** (arrow **64**).

[0040] According to the variant in FIG. **9**, the motor-compressor **5** comprises just one delivery duct **16** and just one transfer duct **44** to the conveyor **39**. According to the variant in FIG. **10**, the motor-compressor **5** comprises two delivery ducts **16** and two transfer ducts **44**, placed diametrically opposite each other. Thus, the two variants have a number of outlets **25** for the scroll **10** and inlets **42** to the conveyor **39** equal to the number of transfer ducts **44**. The shape of the transfer ducts **44** in FIGS. **9** and **10** is identical to that of the transfer ducts **44** in FIG. **2**. In FIGS. **9** and **10** parts that are the same or similar to those in FIG. **2** are indicated with the same reference numbers, and so the two variants will not be described any further.

[0041] FIG. **11** shows a curve **66** of the compression ratio □ as a function of flow Q of the motor-compressor **5**. In the case of transfer ducts **44** able to generate a helical flow that is totally consistent with the rotation of the motor **15**, a predetermined compression curve **66** is obtained. If instead the second section **56** of each transfer duct **44** provokes an opposite helical flow to that of the motor **15**, the outcome is a displacement of the curve **66** to the right in FIG. **11**, which indicates that a greater compression ratio is achieved at high flow-rates.

[0042] The functioning of the motor-compressor **5** is as follows.

[0043] By making the two impellers **8** and **21** rotate in the direction of the arrows **63** and **64** (FIGS. **4** and **5**), the fluid entering from the central opening **14** of the casing **12** (see also FIG. **3**) is propelled by the blades **11** into the curved ducts **16** of the scroll **10**, undergoing a first compression. Exiting from the outlet openings **25** of the curved ducts **16**, the fluid flow, indicated in FIGS. **3-5** by black arrows on the various ducts, is channelled into the transfer ducts **44** and is introduced, through the inlet openings **42**, into the conveyor **39** with a helical motion that turns in the opposite direction to the direction of rotation of the motor **15**. The conveyor **39** then channels the fluid flow, via the central opening **28** of the sleeve **31**, to the inlet opening **37** of the secondary scroll **23**, where it undergoes a second compression imparted by the secondary impeller **21** and then passes into the curved duct **29** of the secondary scroll **23**. Finally, the pressurized fluid is conveyed to where utilized by the straight section **30**.

[0044] From what has been seen above, the advantages of the motor-compressor **5** according to the disclosure with respect to motor-compressors of known art are evident. In particular, the transfer ducts **44** avoid energy loss in the flow and improve the efficiency of the motor-compressor **5**. Furthermore, the fixing of the two impellers **8** and **21** on the two ends **15'** and **15"** of the shaft of the common motor **15** renders operation of the impellers **8** and **21** well balanced, avoiding the generation of vibration and thereby allowing an increase in the speed of rotation.

[0045] It is intended that various modifications and refinements can be made to the above-described motor-compressor **5** without departing from the scope of the claims. For example, each transfer duct **44** could be in a single piece, and be connected to the scroll **10** and to the conveyor **39** in a removable manner, via a bolted flange for example. In addition, the two impellers **8** and **21** could be spun by independent electric motors and the respective axes A could be parallel, oblique or coplanar, but with a predetermined angle formed between them. In this case as well, the two impellers **8** and **21** are preferably rotated by a common electric motor, possibly via at least one drive transmission group, of known type.

What is claimed is:

1. A multistage motor-compressor for compression of a fluid, comprising:

a first compression stage having a primary impeller and at least one delivery duct,

a second compression stage having a secondary impeller spinning in a first direction of rotation and a fluid conveyor, and

at least one transfer duct placing said at least one delivery duct in communication with said fluid conveyor, said at least one transfer duct being shaped in a way to create a fluid flow entering said fluid conveyor with a substantially helical course and with a direction of rotation opposite to said first direction of rotation.

2. The motor-compressor according to claim 1, wherein said second compression stage comprises at least one axial inlet duct for said fluid flow, said fluid conveyor having an inlet opening for said fluid flow, said inlet opening being in communication with said at least one transfer duct and with said at least one axial inlet duct.

3. The motor-compressor according to claim 2, wherein said at least one delivery duct comprises a pair of diametrically opposed delivery ducts, said fluid conveyor comprising a pair of diametrically opposed inlet openings, each inlet opening of said pair of inlet openings being in communication with a respective delivery duct of said pair of delivery ducts via a separate transfer duct.

4. The motor-compressor according to claim 2, wherein said at least one delivery duct comprises three delivery ducts set at 120° to each other, said fluid conveyor comprising three inlet openings set at 120° to each other, each inlet opening of said three inlet openings being in communication with a respective delivery duct of said three delivery ducts via a separate transfer duct.

5. The motor-compressor according to claim 3, wherein said primary and secondary impellers are driven by a driving device inside a casing, said separate transfer ducts being placed on an outside of said casing.

6. The motor-compressor according to claim 3, wherein each of said separate transfer ducts comprises:

a first section connected to said respective delivery duct and substantially tangential to said primary impeller,

a second section connected to said fluid conveyor and substantially tangential to said secondary impeller, and

a longitudinal intermediate section.

7. The motor-compressor according to claim 6, wherein each of said separate transfer ducts further comprises

a substantially helical section placed between said first tangential section and said intermediate section, and

a curved section placed between said second tangential section and said intermediate section.

8. The motor-compressor according to claim 7, wherein each of said separate transfer ducts is subdivided into two segments, each segment of said two segments comprising a portion of said intermediate section and a flange for connection with the other segment of said two segments.

9. The motor-compressor according to claim 3, wherein said separate transfer ducts are each shaped in a way to create said fluid flow exiting from said delivery ducts with a substantially helical course and with a third direction of rotation concordant with a direction of rotation of said primary impeller.

10. The motor-compressor according to claim 5, wherein said driving device comprise a first electric motor for driving said primary impeller and a second electric motor for driving said secondary impeller.

11. The motor-compressor according to one of the claims **5**, wherein said driving device comprises a common electric motor for said primary and secondary impellers.

12. The motor-compressor according to claim 11, wherein said primary and secondary impellers are coaxial.

13. The motor-compressor according to claim 12, wherein said primary and secondary impellers are fixed on two opposite ends of a shaft of said common electric motor.

14. The motor-compressor according to claim 11, wherein said primary and secondary impellers spin around two axes that are coplanar and which form a predetermined angle.

15. The motor-compressor according to claim 11, further comprising a drive transmission group placed between said common electric motor and said primary impeller and/or said secondary impeller.

* * * * *