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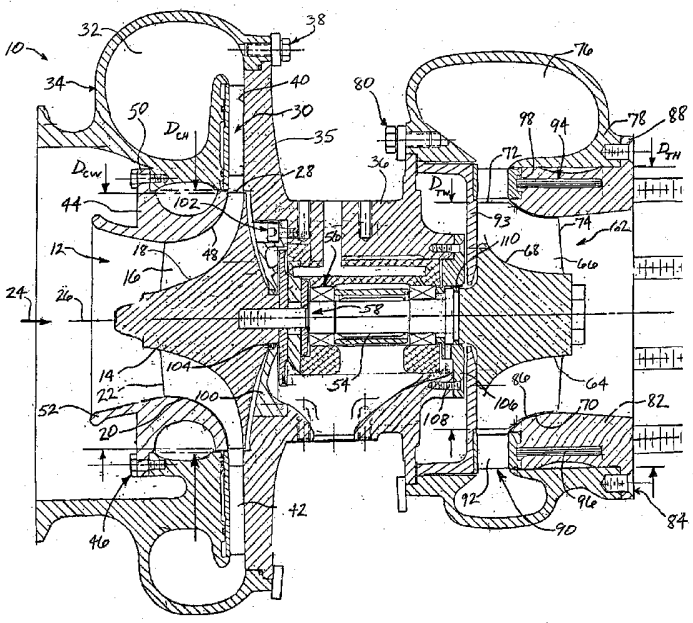
(54) **Title:** TURBOCHARGER WITH REMOVEABLE WHEEL SHROUDS AND/OR REMOVABLE SEALS



(57) **Abstract:** A turbocharger includes compressor and/or turbine end housing(s) and removable compressor and/or turbine shroud portion(s) configured in relation to the compressor and/or turbine wheel(s) such that either or both of the wheels can be removed, after removal of the respective shroud portion(s), without having to remove the respective end housing(s). Additionally or alternatively, a turbocharger includes removable and replaceable compressor and/or turbine seal(s) supported by removable compressor and/or turbine seal plate(s).

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TURBOCHARGER WITH REMOVABLE WHEEL SHROUDS AND/OR REMOVABLE SEALS

BACKGROUND OF THE INVENTION

The present invention relates to turbochargers.

Turbochargers are used in a variety of applications for boosting the performance of internal combustion engines, including IC engines of substantial power and size such as marine engines used for powering maritime vessels. In these higher-power applications, the turbochargers can be quite large and heavy, as well as expensive. The relatively high cost of such large turbochargers provides an economic incentive to service (e.g., repair and/or replace) individual components of the turbocharger, as opposed to replacing the entire turbocharger when it deteriorates or fails.

The substantial size and weight of the turbochargers, however, tend to make them difficult to service. For instance, a common type of turbocharger design includes removable compressor and turbine end housings surrounding the compressor and turbine wheels. If one of the wheels requires replacing, for example as a result of foreign object damage or fatigue, it is necessary to first unbolt the corresponding end housing from the rest of the turbocharger housing and remove it, before the wheel can be accessed and removed. The end housing in many cases is too large and heavy for an individual worker to handle, and hence an overhead hoist or the like is required. However, the cramped quarters in which many of these turbochargers are installed can make the use of such equipment awkward or impossible. Furthermore, the removal of the heavy end housing can pose a risk of causing further damage to components of the turbocharger.

An additional unfavorable aspect of many existing turbocharger designs relates to the seals that isolate the interior of the center housing, in which the bearing assembly is contained, from the compressor and turbine flow paths.

For example, in some turbochargers the turbine seal is an integral machined part of the center housing.

When the turbine seal fails, the entire center housing must be replaced, at substantial cost. This operation furthermore necessitates the use of a hoist or the like, with the attendant difficulties already mentioned.

BRIEF SUMMARY OF THE INVENTION

The present invention in a first aspect addresses the above needs and achieves other advantages, by providing a turbocharger that allows either or both of the compressor and turbine wheels to be removed without having to remove the respective end housings. In accordance with one embodiment of the invention, the turbocharger comprises:

a centrifugal compressor comprising a compressor wheel having an outermost peripheral surface defining a maximum outer diameter of the compressor wheel, the compressor wheel including a plurality of arcuate compressor blades each extending generally radially outward from a root to a tip of the blade;

a centrifugal turbine comprising a turbine wheel having an outermost peripheral surface defining a maximum outer diameter of the turbine wheel, the turbine wheel including a plurality of arcuate turbine blades each extending generally radially outward from a root to a tip of the blade;

a rotatable shaft having a first end on which the compressor wheel is mounted and an opposite second end on which the turbine wheel is mounted, the shaft being supported in a bearing assembly; and

a housing containing the bearing assembly and the compressor and turbine wheels, the housing including a compressor end housing defining a volute surrounding the compressor wheel for receiving air compressed by the compressor wheel, the compressor end housing having a radially inner surface defining a minimum inside diameter of the compressor end housing, said minimum inside diameter being greater than the maximum outer diameter of the compressor wheel, and the housing further

comprising a compressor shroud portion removably fastened by an fastening arrangement to the compressor end housing and defining an inner shroud surface proximate the tips of the compressor blades. The compressor shroud portion is configured to be removable upon release of the fastening arrangement such that the compressor wheel is removable from the housing while the compressor end housing is still in place.

In another embodiment of the invention, the turbocharger includes a turbine end housing defining a volute surrounding the turbine wheel for receiving exhaust gas and supplying the exhaust gas to the turbine wheel, the turbine end housing having a radially inner surface defining a minimum inside diameter of the turbine end housing, said minimum inside diameter being greater than the maximum outer diameter of the turbine wheel, and the housing further comprising a turbine shroud portion removably fastened by a fastening arrangement to the turbine end housing and defining an inner shroud surface proximate the tips of the turbine blades. The turbine shroud portion is configured to be removable upon release of the fastening arrangement such that the turbine wheel is removable from the housing while the turbine end housing is still in place.

In accordance with a second aspect of the invention, a turbocharger is provided, at one or both of the compressor and turbine ends of the shaft, with a seal plate removably fastened to a center housing of the turbocharger and supporting a seal. Removal of the or each seal plate allows the seal(s) to be replaced without having to replace the costly center housing.

The invention also encompasses turbochargers combining the first and second aspects in various ways.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

Having thus described the invention in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

FIG. 1 is a sectioned side view of a turbocharger in accordance with one embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The present inventions now will be described more fully hereinafter with reference to the accompanying drawings, in which some but not all embodiments of the inventions are shown. Indeed, these inventions may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Like numbers refer to like elements throughout.

With reference to FIG. 1, a turbocharger **10** representing an embodiment combining the above-noted first and second aspects of the invention is schematically illustrated. The turbocharger **10** includes a centrifugal compressor **12** having a compressor wheel **14** that supports a plurality of compressor blades **16** each of which extends generally radially outwardly from a root **18** to a tip **20** of the blade. Each blade has a leading edge **22** that is encountered by inlet air (indicated by arrow **24**) that flows in a generally axial direction (i.e., generally parallel to the longitudinal axis **26** of the turbocharger). Each blade has a trailing edge **28** that is located proximate to, and in some embodiment defines, a maximum outer diameter D_{CW} of the compressor wheel **14**. The rotation of the compressor wheel causes the blades **16** to compress the air flowing between the blades and the compressed air is discharged in a generally radially outward direction into a diffuser passage **30**.

The diffuser passage **30** diffuses the flow of compressed air and leads the air into a volute **32** that surrounds the compressor wheel. The volute **32** is defined by a compressor end housing **34**. The compressor end housing **34** is joined to a backplate **35** that, in the illustrated embodiment, is integrally formed on one end of a center housing **36** of the turbocharger. The compressor end housing **34** can comprise a separate piece from the backplate and be fastened to the backplate by a suitable fastening arrangement **38** as shown. The diffuser passage **30** in the illustrated embodiment is defined between the compressor end housing **34** and a surface **40** of the backplate **35**. A guide vane assembly **42** resides in the diffuser passage **30** and functions to facilitate the diffusion of the air (and, in some cases, can also remove swirl from the flow) before it enters the volute **32**.

The compressor end housing **34** has a minimum inside diameter D_{CH} that is slightly greater than the maximum outer diameter D_{CW} of the compressor wheel **14**, for reasons explained below. Although the backplate **35** is shown as being integral with the center housing **36**, alternatively the backplate **35** can be separately formed from the center housing and can be affixed to the center housing in any suitable fashion.

The turbocharger also includes a compressor shroud portion **44** that is removably fastened by a fastening arrangement **46** to the compressor end housing **34**. The compressor shroud portion **44** is a generally ring-shaped structure having a radially inner shroud surface **48** that is proximate the tips **20** of the compressor blades **16**. The compressor flow path is defined between the shroud surface **48** and the hub of the compressor wheel **14**. In the illustrated embodiment, the compressor shroud portion **44** defines a generally radially outwardly extending flange **50** and the compressor end housing **34** has a portion configured to abut the flange **50**. The flange and the end housing have holes that receive threaded fasteners of the fastening arrangement **46** to attach the shroud portion to the end housing. The shroud portion **44** also can include a tubular portion **52** at its upstream end (relative to the generally axial direction of flow **24**) that defines an inlet into the compressor. Any suitable fastening arrangement that is releasable can be used for fastening the compressor shroud portion **44** to the end housing, including threaded fasteners as shown, a clamping mechanism for clamping together respective portions of the shroud portion and end housing, or other types of releasable fastening arrangements.

The compressor wheel **14** is mounted on one end of a shaft **54** that extends through the interior space of the center housing **36**. The shaft is rotatably supported by a bearing assembly **56** mounted in the center housing. The compressor wheel is mounted to the shaft by a mounting arrangement **58** in such a manner that the compressor wheel can be detached from the shaft **54** from the compressor side of the center housing. For instance, the shaft can be attached to a threaded stud that passes through a center bore of the compressor wheel and receives a threaded nut to secure the wheel to the stud; however, alternative mounting arrangements for securing the wheel to the shaft can be

used, and the invention is not limited in this respect. The important point is that by releasing the mounting arrangement **58**, the wheel can be detached from the shaft.

Based on the above description, it will be understood that the provision of the unique compressor end housing **34** and shroud portion **44** enables the compressor wheel **14** to be removed without having to remove the end housing **34**. More specifically, releasing the fastening arrangement **46** allows the shroud portion **44** to be removed (to the left in FIG. 1). Then, releasing of the mounting arrangement **58** allows the compressor wheel **14** to be removed from the turbocharger because the maximum diameter of the wheel D_{CW} is less than the minimum inside diameter D_{CH} of the compressor end housing **34**. Particularly in turbochargers of substantial size where the end housing can be quite heavy, this ability of the turbocharger provides a significant advantage in ease of servicing of the turbocharger.

The turbocharger **10** also includes a turbine **62** having a turbine wheel **64** that supports a plurality of turbine blades **66** each of which extends generally radially outwardly from a root **68** to a tip **70** of the blade. Each blade has a leading edge **72** that is encountered by inlet air flowing in a generally radially inward direction (i.e., generally perpendicular to the longitudinal axis **26** of the turbocharger) and that is located proximate to, and in some embodiment defines, a maximum outer diameter D_{TW} of the turbine wheel **64**. Each blade has a trailing edge **74** that extends generally radially.

A volute **76** that surrounds the turbine wheel and receives exhaust gas from the exhaust stream discharged by an engine (not shown). The volute **76** is defined by a turbine end housing **78**. The turbine end housing **78** is joined to the opposite end of a center housing **36** from the compressor **12**, and can comprise a separate piece from the center housing and be fastened to the center housing by a suitable fastening arrangement **80** as shown. The turbine end housing **78** has a minimum inside diameter D_{TH} that is greater than the maximum outer diameter D_{TW} of the turbine wheel **64**, for reasons explained below.

The turbocharger also includes a turbine shroud portion **82** that is removably fastened by a fastening arrangement **84** to the turbine end housing **78**. The turbine shroud

portion **82** is a generally ring-shaped structure having a radially inner shroud surface **86** that is proximate the tips **70** of the turbine blades **66**. The turbine flow path is defined between the shroud surface **86** and the hub of the turbine wheel **64**. In the illustrated embodiment, the turbine shroud portion **82** defines a generally radially outwardly extending flange **88** and the turbine end housing **78** has a portion configured to abut the flange **88**. The flange and the end housing have holes that receive threaded fasteners to attach the shroud portion to the end housing.

The turbine also includes a nozzle ring **90** that supports vanes **92** for regulating the exhaust gas flow from the volute **76** into the turbine wheel **64**, and for more-efficiently directing the exhaust gas flow into the turbine wheel relative to a nozzleless turbine stage. The nozzle ring essentially comprises a pair of axially spaced rings having the vanes **92** connected therebetween and spaced apart about the circumference of the ring. The nozzle ring **90** is retained between the shroud portion **82** and the turbine heat shield **93**. The heat shield can define a radially outwardly facing step at a diameter corresponding to an inside diameter of the nozzle ring such that the step locates the nozzle ring coaxially with respect to the turbocharger axis **26**. The nozzle ring is removably connected to the turbine shroud portion **82** by a suitable arrangement **94**. For example, as shown, the arrangement **94** can comprise a generally tubular deformable element **96** (e.g., a metal tube or column) that fits into an annular channel formed in the shroud portion and that is axially compressed into the channel by advancing the nozzle ring and shroud portion toward each other such that the element buckles in the channel. One end of the deformable element **96** projects out from the shroud portion and fits into a groove **98** in the nozzle ring. The element **96** exerts a biasing force axially against the nozzle ring to load the nozzle ring against the heat shield **93**, preventing or at least substantially reducing any tendency of the nozzle ring to experience looseness or vibration.

The turbine wheel **64** is mounted on the opposite end of the shaft **54** from the compressor wheel, and can be either separately formed from and then joined to the shaft (e.g., by a fastener or by welding or the like) or can be integrally formed with the shaft as one piece. When the mounting arrangement **58** securing the compressor wheel to the

shaft is released, the turbine wheel **64** and shaft **54** are free to be withdrawn from the turbocharger housing as a unit.

Based on the above description, it will be understood that the provision of the unique turbine end housing **78** and shroud portion **82** enables the turbine wheel **64** to be removed without having to remove the end housing **78**. More specifically, releasing the fastening arrangement **84** allows the shroud portion **82** to be removed (to the right in FIG. 1). Then, releasing of the mounting arrangement **58** securing the compressor wheel to the shaft allows the turbine wheel **64** and shaft **54** to be removed from the turbocharger because the maximum diameter of the wheel D_{TW} is less than the minimum inside diameter D_{TH} of the turbine end housing **78**. Particularly in turbochargers of substantial size where the end housing can be quite heavy, this ability of the turbocharger provides a significant advantage in ease of servicing of the turbocharger.

Next, the second aspect of the invention will be explained. Generally, there is a need to seal the interior of the center housing **36**, where the bearing assembly **56** resides, from the compressor and turbine flow paths. To this end, the turbocharger **10** includes seal arrangements that advantageously are removable and replaceable at modest cost. More particularly, on the compressor side, the turbocharger includes a compressor seal plate **100** that is disposed between the compressor wheel **14** and the center housing **36**, and is fastened to the center housing in a removable fashion by a suitable fastening arrangement **102** such as threaded fasteners or the like. The compressor seal plate **100** is a generally annular structure defining a radially inner surface encircling and coaxial with the turbocharger longitudinal axis **26**, and the radially inner surface bears against a seal ring **104** such as a piston ring or the like. The seal ring **104** bears against a rotating surface of the compressor rotor assembly as shown, thus substantially isolating the compressor flow path from the interior of the center housing.

Advantageously, once the compressor wheel **14** has been removed as previously described, the seal plate **100** can be removed by releasing the fastening arrangement **102**, and the seal ring **104** can be replaced with a new one if necessary.

A similar removable seal arrangement is provided on the turbine side. More specifically, the turbocharger includes a turbine seal plate **106** that is disposed between the turbine wheel **64** and the center housing **36**, and is fastened to the center housing in a removable fashion by a suitable fastening arrangement **108** such as threaded fasteners or the like. The turbine seal plate **106** is a generally annular structure defining a radially inner surface encircling and coaxial with the turbocharger longitudinal axis **26**, and the radially inner surface bears against a seal ring **110** such as a piston ring or the like. The seal ring **110** bears against a rotating surface of the turbine rotor assembly as shown, thus substantially isolating the turbine flow path from the interior of the center housing.

Advantageously, once the turbine wheel **64** has been removed as previously described, the seal plate **106** can be removed by releasing the fastening arrangement **108**, and the seal ring **110** can be replaced with a new one if necessary.

As noted, although the turbocharger **10** as illustrated incorporates both the first aspect of the invention relating to the removable shroud portions **44, 82**, as well as the second aspect of the invention relating to the removable seal plates **100, 106** and seals **104, 110**, in alternative embodiments (not illustrated), a turbocharger can include only the turbine end or compressor end removable shrouds of the first aspect, or only turbine end or compressor end seals of the second aspect.

The invention in its various aspects facilitates maintenance and service work on turbochargers by making it easier and less-costly to remove and replace the compressor and/or turbine wheels, and to remove and replace the compressor and/or turbine seals.

Many modifications and other embodiments of the inventions set forth herein will come to mind to one skilled in the art to which these inventions pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the inventions are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

WHAT IS CLAIMED IS:

1. A turbocharger, comprising:

a centrifugal compressor comprising a compressor wheel having a maximum outer diameter, the compressor wheel including a plurality of compressor blades each extending generally radially outward from a root to a tip of the blade;

a centrifugal turbine comprising a turbine wheel having a maximum outer diameter, the turbine wheel including a plurality of turbine blades each extending generally radially outward from a root to a tip of the blade;

a rotatable shaft having a first end on which the compressor wheel is mounted and an opposite second end on which the turbine wheel is mounted, the shaft being supported in a bearing assembly; and

a housing containing the bearing assembly and the compressor and turbine wheels, the housing including a compressor end housing defining a volute surrounding the compressor wheel for receiving air compressed by the compressor wheel, the compressor end housing having a radially inner surface defining a minimum inside diameter of the compressor end housing, said minimum inside diameter being greater than the maximum outer diameter of the compressor wheel, and the housing further comprising a compressor shroud portion removably fastened by an fastening arrangement to the compressor end housing and defining an inner shroud surface proximate the tips of the compressor blades, the compressor shroud portion being configured to be removable upon release of the fastening arrangement such that the compressor wheel is removable from the housing while the compressor end housing is still in place.

2. The turbocharger of claim 1, wherein the housing includes a center housing that defines a cavity containing the bearing assembly, and further comprising a compressor seal plate that seals against a removable compressor seal that seals against a rotating surface to substantially isolate the cavity of the center housing from the compressor, wherein the compressor seal plate is removably fastened to the center housing by a fastening arrangement, whereby the compressor seal plate and removable compressor seal are removable and replaceable.

3. The turbocharger of claim 1, wherein the housing includes a turbine end housing defining a volute surrounding the turbine wheel for receiving exhaust gas and supplying the exhaust gas to the turbine wheel, the turbine end housing having a radially inner surface defining a minimum inside diameter of the turbine end housing, said minimum inside diameter being greater than the maximum outer diameter of the turbine wheel, and the housing further comprising a turbine shroud portion removably fastened by a fastening arrangement to the turbine end housing and defining an inner shroud surface proximate the tips of the turbine blades, the turbine shroud portion being configured to be removable upon release of the fastening arrangement such that the turbine wheel is removable from the housing while the turbine end housing is still in place.

4. The turbocharger of claim 3, wherein the housing includes a center housing that defines a cavity containing the bearing assembly, and further comprising a turbine seal plate that seals against a removable turbine seal that seals against a rotating surface to substantially isolate the cavity of the center housing from the turbine, wherein the turbine seal plate is removably fastened to the center housing by a fastening arrangement, whereby the turbine seal plate and removable turbine seal are removable and replaceable.

5. The turbocharger of claim 3, wherein the housing includes a center housing containing the bearing assembly, and wherein the turbine end housing is separately formed from the center housing and is fastened to the center housing by a releasable fastening arrangement.

6. The turbocharger of claim 1, wherein the housing includes a center housing containing the bearing assembly, and wherein the compressor end housing is separately formed from the center housing and is fastened to the center housing by a releasable fastening arrangement.

7. The turbocharger of claim 1, wherein the housing includes a center housing to which the compressor end housing is joined such that a diffuser passage is defined between the center housing and the compressor end housing, the diffuser passage leading

generally radially outwardly from the compressor wheel into the volute defined by the compressor end housing.

8. A turbocharger, comprising:

a centrifugal compressor comprising a compressor wheel having a maximum outer diameter, the compressor wheel including a plurality of compressor blades each extending generally radially outward from a root to a tip of the blade;

a centrifugal turbine comprising a turbine wheel having a maximum outer diameter, the turbine wheel including a plurality of turbine blades each extending generally radially outward from a root to a tip of the blade;

a rotatable shaft having a first end on which the compressor wheel is mounted and an opposite second end on which the turbine wheel is mounted, the shaft being supported in a bearing assembly; and

a housing containing the bearing assembly and the compressor and turbine wheels, the housing including a turbine end housing defining a volute surrounding the turbine wheel for receiving exhaust gas and supplying the exhaust gas to the turbine wheel, the turbine end housing having a radially inner surface defining a minimum inside diameter of the turbine end housing, said minimum inside diameter being greater than the maximum outer diameter of the turbine wheel, and the housing further comprising a turbine shroud portion removably fastened by a fastening arrangement to the turbine end housing and defining an inner shroud surface proximate the tips of the turbine blades, the turbine shroud portion being configured to be removable upon release of the fastening arrangement such that the turbine wheel is removable from the housing while the turbine end housing is still in place.

9. The turbocharger of claim 8, wherein the housing includes a center housing containing the bearing assembly and joined to the turbine end housing, and further comprising a turbine seal plate that seals against a removable turbine seal that seals against a rotating surface to substantially isolate the cavity of the center housing from the turbine, wherein the turbine seal plate is removably fastened to the center housing by a fastening arrangement, whereby the turbine seal plate and removable turbine seal are removable and replaceable.

10. The turbocharger of claim 9, the housing including a compressor end housing defining a volute surrounding the compressor wheel for receiving air compressed by the compressor wheel, the compressor end housing having a radially inner surface defining a minimum inside diameter of the compressor end housing, said minimum inside diameter being greater than a maximum outer diameter of the compressor wheel, and the housing further comprising a compressor shroud portion removably fastened by an fastening arrangement to the compressor end housing and defining an inner shroud surface proximate the tips of the compressor blades, the compressor shroud portion being configured to be removable upon release of the fastening arrangement such that the compressor wheel is removable from the housing while the compressor end housing is still in place.

11. The turbocharger of claim 8, wherein the turbine seal comprises a seal ring.

12. A turbocharger, comprising:

a centrifugal compressor comprising a compressor wheel including a plurality of compressor blades;

a centrifugal turbine comprising a turbine wheel including a plurality of turbine blades;

a rotatable shaft having a first end on which the compressor wheel is mounted and an opposite second end on which the turbine wheel is mounted, the shaft being supported in a bearing assembly; and

a housing containing the compressor and turbine wheels and including a center housing that defines a cavity containing the bearing assembly, and further comprising a turbine seal plate that seals against a removable turbine seal that seals against a rotating surface to substantially isolate the cavity of the center housing from the turbine, wherein the turbine seal plate is removably fastened to the center housing by a fastening arrangement, whereby the turbine seal plate and removable turbine seal are removable and replaceable.

13. The turbocharger of claim 12, wherein the turbine seal comprises a seal ring.

14. The turbocharger of claim 12, further comprising a compressor seal plate that seals against a removable compressor seal that seals against a rotating surface to substantially isolate the cavity of the center housing from the compressor, wherein the compressor seal plate is removably fastened to the center housing by a fastening arrangement, whereby the compressor seal plate and removable compressor seal are removable and replaceable.

15. The turbocharger of claim 14, wherein the compressor seal comprises a seal ring.

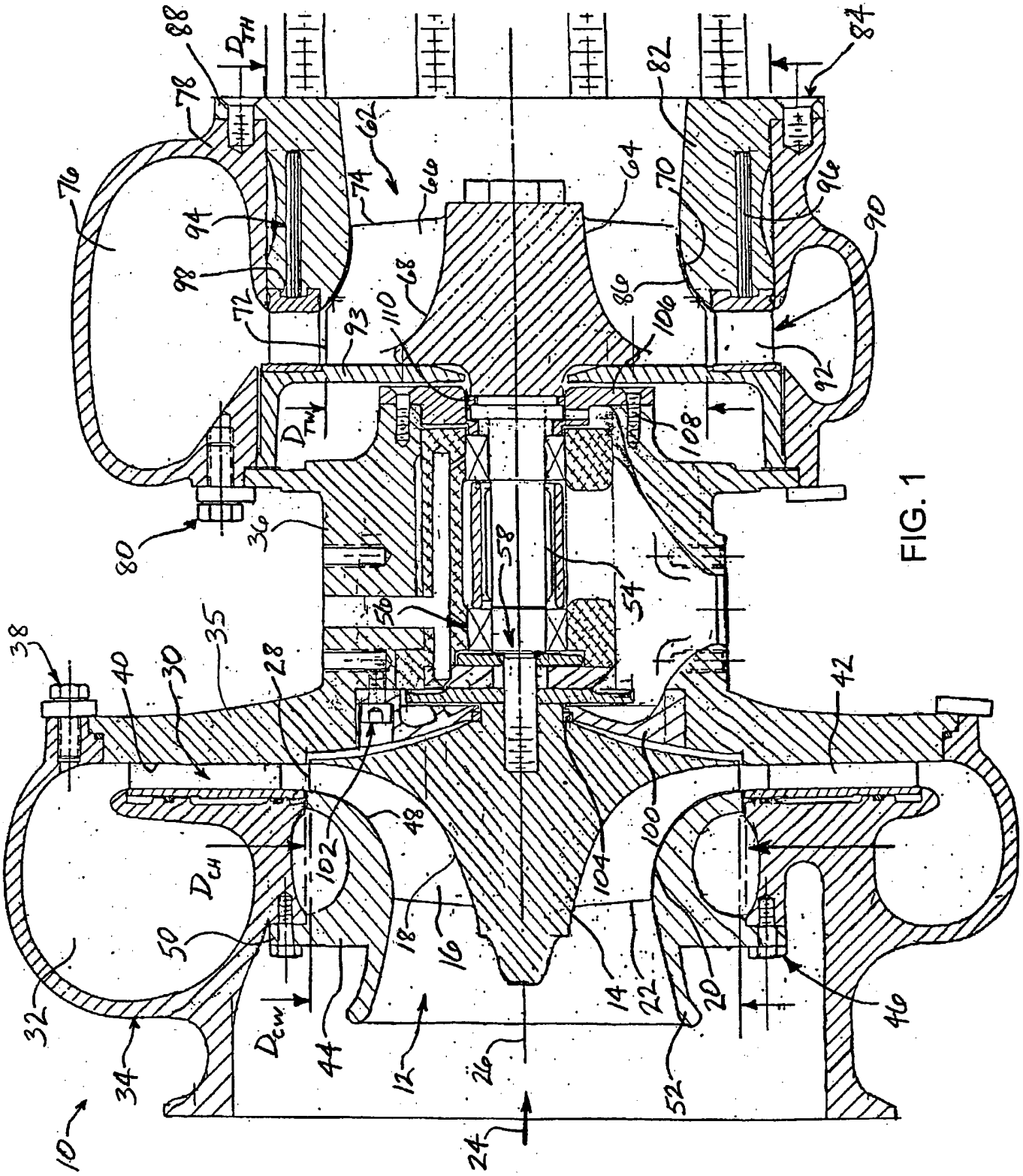
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FIG. 1