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(54) **COMPRESSOR TRAIN FOR CHEMICAL PLANT**

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(58) **Field of Classification Search**
CPC F01K 7/22; F01K 7/165
See application file for complete search history.

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(57) **ABSTRACT**

A compressor train for a chemical plant includes a compression unit configured to compress a process gas of the chemical plant by being driven, a motor configured to drive the compression unit, a steam turbine rotated by steam generated in association with treatment of the process gas of the chemical plant and configured to assist in rotation of the motor, a steam introduction line through which the steam flows toward the steam turbine, and a main trip and throttle valve disposed on the steam introduction line and configured to regulate a flow rate of the steam to the steam turbine.

4 Claims, 3 Drawing Sheets

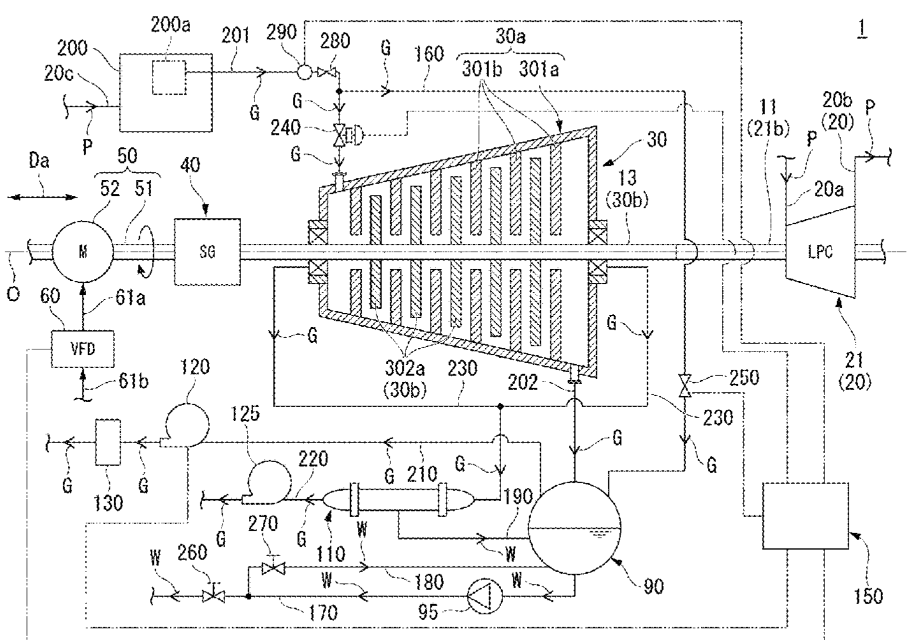
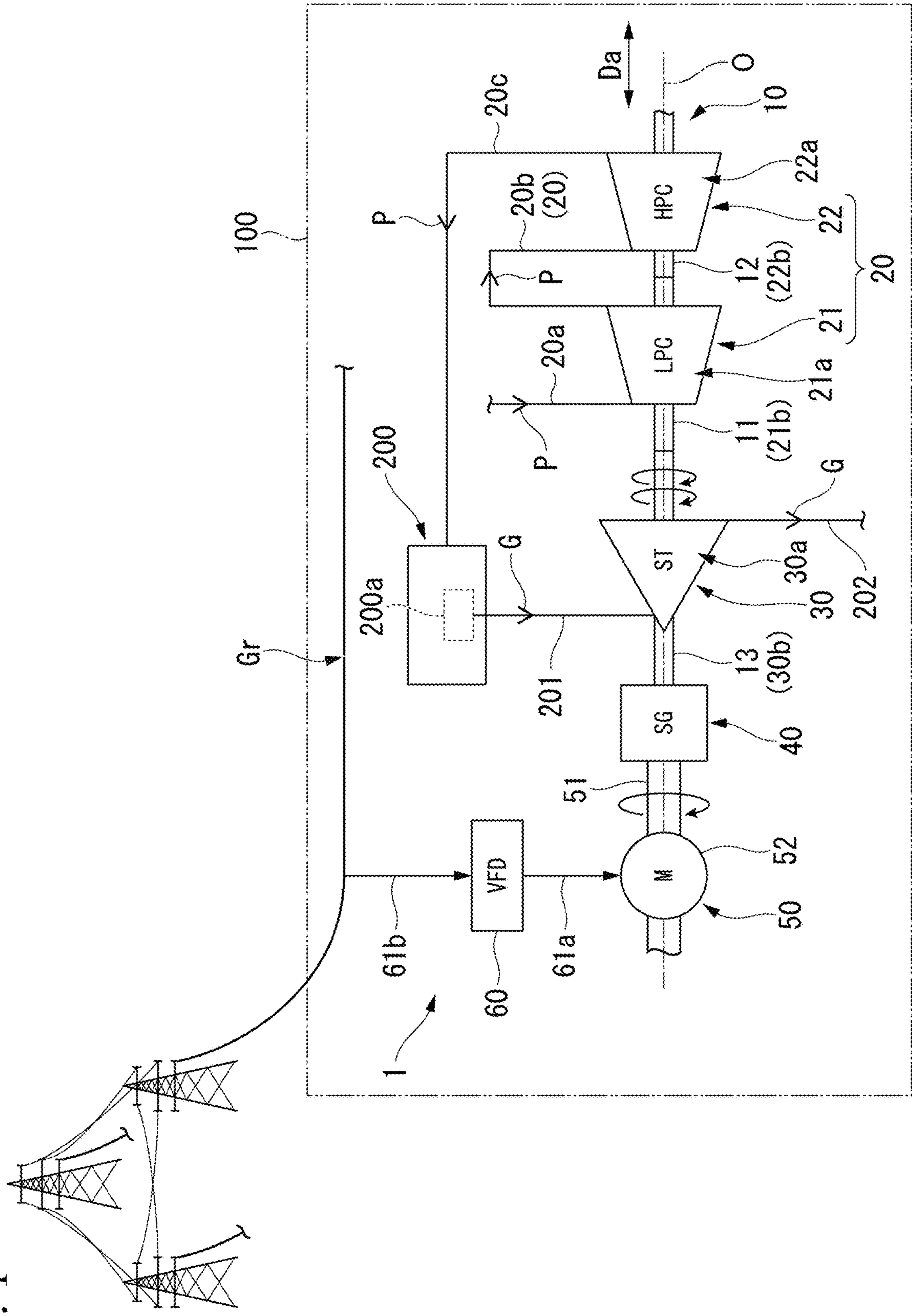


FIG. 1


100
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(20)
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22a
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21
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11
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202
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60
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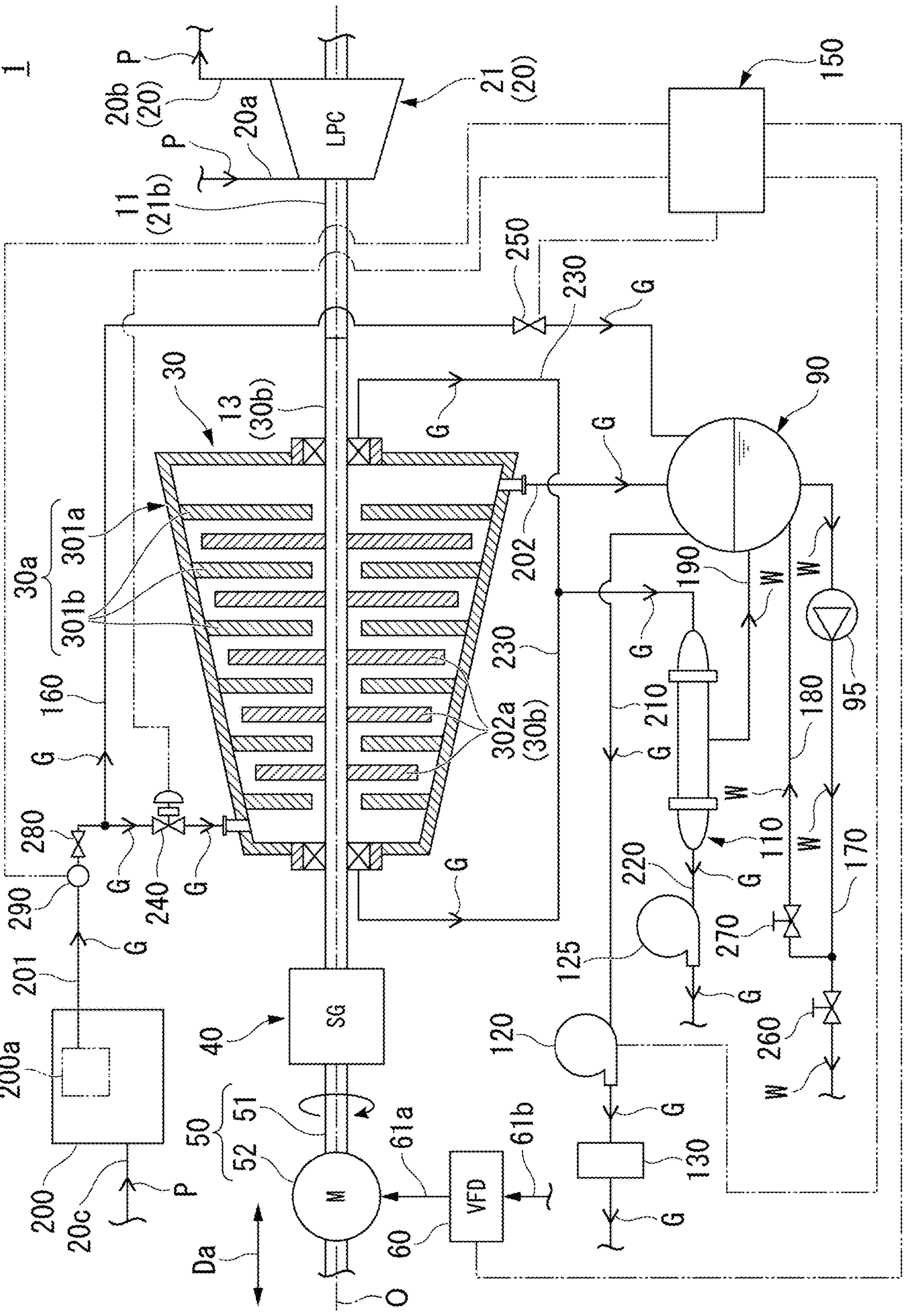
FIG. 2


1
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11 (21b)
13 (30b)
20a
20b (20)
20c
21 (20)
30
30a
301a
301b
302a (30b)
40
50
51
52
60
61a
61b
90
95
110
120
125
130
150
160
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190
200
200a
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210
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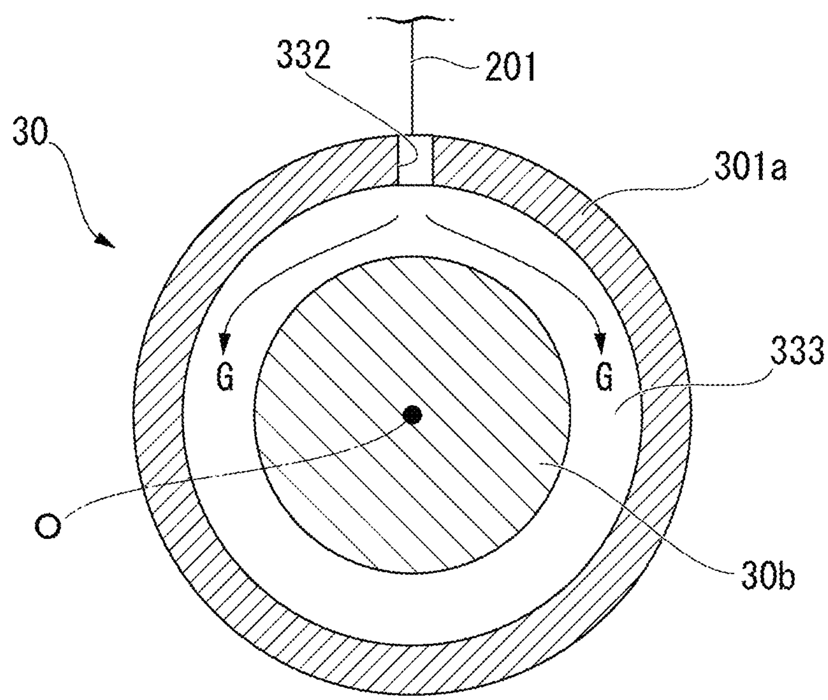
FIG. 3



COMPRESSOR TRAIN FOR CHEMICAL PLANT

BACKGROUND OF THE INVENTION

Field of the Invention

The present disclosure relates to a compressor train for a chemical plant.

Priority is claimed on Japanese Patent Application No. 2023-186483, filed on Oct. 31, 2023, the content of which is incorporated herein by reference.

Description of Related Art

For example, Patent Document 1 discloses a compressor system for producing ammonia used in an ammonia plant as a chemical plant for generating ammonia. The compressor system for producing ammonia includes a compressor on a low pressure side and a compressor on a high pressure side (hereinafter, referred to as a compression unit), and a driving machine (steam turbine) that drives the compression unit.

It is common to use the power of a steam turbine (driving machine) to drive the compression unit. In addition, a configuration in which an electric motor (motor) is used in combination is also proposed in order to supplement the power of the driving machine.

PRIOR ART DOCUMENTS

Patent Document

[Patent Document 1] Japanese Unexamined Patent Application, First Publication No. 2000-154020

SUMMARY OF THE INVENTION

Problems to be Solved by the Invention

However, in addition to the above-described configuration, it is also considered a configuration in which the compression unit is mainly driven by the electric motor, and the power of the electric motor is assisted by the steam turbine. In that case, precise control such as steam flow rate is no longer required for the steam turbine. Therefore, there is a problem that the configuration of the steam turbine in the plant in the related art is over-specified, which leads to an increase in operating costs and maintenance costs.

An object of the present disclosure is to provide a compressor train for a chemical plant with a simpler configuration.

Means for Solving the Problems

A compressor train for a chemical plant according to the present disclosure includes a compression unit configured to compress a process gas of the chemical plant by being driven, a motor configured to drive the compression unit, a steam turbine rotated by steam generated in association with treatment of the process gas of the chemical plant and configured to assist in rotation of the motor, a connection line through which the steam flows, and a main trip and throttle valve disposed on the connection line and configured to block or cause the steam to flow into the steam turbine.

Effects of the Invention

According to the present disclosure, it is possible to provide a compressor train for a chemical plant with a simpler configuration.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic view showing a configuration of a compressor train for a chemical plant according to an embodiment of the present disclosure.

FIG. **2** is a diagram showing a main part (system) of the compressor train for a chemical plant according to the embodiment of the present disclosure.

FIG. **3** is a cross-sectional view showing a configuration of a steam turbine according to the embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE INVENTION

Hereinafter, a compressor train for a chemical plant according to the embodiment of the present disclosure will be described with reference to the accompanying drawings.

(Compressor Train for Chemical Plant)

The compressor train for a chemical plant compresses the process gas generated in the chemical plant and supplies the compressed process gas to a reactor disposed in the chemical plant.

In a case where the chemical plant is an ammonia plant, the reactor may be exemplified by an ammonia converter that generates ammonia by a chemical reaction under high temperature and high pressure, and the process gas may be exemplified by a gas containing hydrogen as a main component. The chemical plant in the present embodiment is an ammonia plant that produces ammonia.

As shown in FIG. **1**, an ammonia plant **100** is provided with a compressor train **1** for a chemical plant, an ammonia converter **200**, a gas introduction line **20***a*, a gas exhaust line **20***c*, a first power purchase cable **61***a*, and a second power purchase cable **61***b*.

The compressor train **1** for a chemical plant is provided with a compression unit **20**, a steam turbine **30**, a speed increasing gear **40**, a motor **50**, a frequency conversion unit **60**, a condenser **90**, a condensate pump **95**, a grand condenser **110**, a vacuum pump **120**, a vapor fan **125**, a drain separator **130**, a steam introduction line **201**, a steam exhaust line **202**, a connection line **160**, a drainage line **170**, a circulation line **180**, a condensate recovery line **190**, a first suction line **210**, a second suction line **220**, a leak steam line **230**, a governing valve **240**, a dump valve **250**, a first opening and closing valve **260**, a second opening and closing valve **270**, and a main trip and throttle valve **280**.

(Compression Unit)

The compression unit **20** compresses the process gas P supplied from the outside used in the ammonia plant **100** and supplies the compressed process gas P to the ammonia converter **200**.

The compression unit **20** includes a low pressure stage compressor **21** (low pressure compressor: LPC), a high pressure stage compressor **22** (high pressure compressor: HPC), and an intermediate line **20***b*.

The low pressure stage compressor **21** is a rotary machine that increases the process gas P supplied from the outside to a predetermined first pressure value. The low pressure stage compressor **21** includes a first casing **21***a* and a first rotor **21***b*.

The first casing **21***a* is a member constituting an outer shell of the low pressure stage compressor **21**. The first casing **21***a* is supported by a compressor support portion (not shown) fixed to the ground, a frame, or the like, and causes the process gas P to flow inside.

The first casing **21***a* has a casing main body (not shown), an inlet port (not shown) for inhaling the process gas P, which is formed in the casing main body, and a discharge port (not shown) for discharging the process gas P, which is formed in the casing main body.

The first rotor **21***b* includes a first rotation shaft **11**, and a plurality of stages of impellers (not shown) that are fixed to the first rotation shaft **11** and form a flow path for compressing the process gas P together with an inner surface of the casing main body of the first casing **21***a*.

The first rotation shaft **11** is a driving shaft that forms a columnar shape extending in the axial direction Da (left-right direction in FIG. **1**) and is rotatable about the axis O extending in the horizontal direction. Hereinafter, a direction where the axis O extends is referred to as an "axial direction Da". The first rotation shaft **11** is made of a metal or the like. The casing main body of the first casing **21***a* is fixed to the first rotation shaft **11** in a non-rotatable manner, for example, via a bearing device, a sealing device, or the like.

The impeller is accommodated in the casing main body of the first casing **21***a*. The impellers are arranged on the first rotation shaft **11** to be aligned in the axial direction Da and rotate about the axis O integrally with the first rotation shaft **11**.

A flow of the process gas P introduced into the low pressure stage compressor **21** will be described below. The gas introduction line **20***a*, which is a pipe for introducing the process gas P before compression, is connected to an inlet port of the first casing **21***a* in the low pressure stage compressor, and the process gas P is introduced from a process gas treatment device (not shown) outside the compression unit **20** in the ammonia plant **100** through the gas introduction line **20***a*.

The process gas P introduced into the inside of the first casing **21***a* via the inlet port is sequentially compressed by the impeller of the first rotor **21***b* that rotates at a high speed inside the first casing **21***a*. The process gas P compressed to a first pressure value by the impeller of the last stage is discharged to the outside of the low pressure stage compressor **21** via the discharge port of the first casing **21***a*.

The high pressure stage compressor **22** is a rotary machine that increases the pressure of the process gas P compressed by the low pressure stage compressor **21** to a second pressure value higher than the first pressure value. The high pressure stage compressor **22** and the low pressure stage compressor **21** are connected to each other by an intermediate line **20***b* which is a pipe for causing the process gas P to flow.

That is, the process gas P compressed by the low pressure stage compressor **21** is introduced into the high pressure stage compressor **22** via the intermediate line **20***b*. For example, the second pressure value in the present embodiment is a pressure (atmospheric pressure) required for the chemical reaction in the ammonia converter **200**.

The high pressure stage compressor **22** is disposed on one side (right side in FIG. **1**) in the axial direction Da than the low pressure stage compressor **21**. The high pressure stage compressor **22** includes a second casing **22***a* and a second rotor **22***b*.

The second casing **22***a* is a member constituting an outer shell of the high pressure stage compressor **22**. The second casing **22***a* is supported by a compressor support portion (not shown) fixed to the ground, a frame, or the like, and causes the process gas P to flow inside.

The second casing **22***a* has a casing main body (not shown), an inlet port (not shown) for inhaling the process gas P, which is formed in the casing main body, and a discharge port (not shown) for discharging the process gas P, which is formed in the casing main body.

The second rotor **22***b* includes a second rotation shaft **12**, and a plurality of stages of impellers (not shown) that are fixed to the second rotation shaft **12** and form a flow path for compressing the process gas P together with an inner surface of the casing main body of the second casing **22***a*.

The second rotation shaft **12** is a driving shaft that forms a columnar shape extending in the axial direction Da and is rotatable about the axis O. The second rotation shaft **12** is made of a metal or the like. The casing main body of the second casing **22***a* is fixed to the second rotation shaft **12** in a non-rotatable manner, for example, via a bearing device, a sealing device, or the like.

The impeller is accommodated in the casing main body of the second casing **22***a*. The impellers are arranged on the second rotation shaft **12** to be aligned in the axial direction Da and rotate about the axis O integrally with the second rotation shaft **12**.

Here, an end portion of the first rotor **21***b* of the low pressure stage compressor **21** on one side in the axial direction Da of the first rotation shaft **11** and an end portion of the second rotor **22***b* of the high pressure stage compressor **22** on the other side in the axial direction Da the second rotation shaft **12** are integrally connected to each other. Specifically, the first rotation shaft **11** and the second rotation shaft **12** are elastically connected to each other by a coupling or the like (not shown) having flexibility.

The first rotation shaft **11** and the second rotation shaft **12** are connected to each other such that the centers of both are aligned. That is, the center line of the first rotation shaft **11** and the center line of the second rotation shaft **12** are on the same straight line. That is, the first rotation shaft **11** and the second rotation shaft **12** share the axis O as the center line.

The two-stage compressor mechanism (multi-stage compressor) includes the low pressure stage compressor **21** and the high pressure stage compressor **22**.

A flow of the process gas P introduced into the high pressure stage compressor **22** will be described below. The process gas P introduced into the inside of the second casing **22***a* via the inlet port of the second casing **22***a* is compressed by the second rotor **22***b* that rotates at a high speed inside the second casing **22***a*.

The process gas P compressed to the second pressure value by the impeller of the last stage is discharged to the outside of the high pressure stage compressor **22** via the discharge port of the second casing **22***a*. The gas exhaust line **20***c*, which is a pipe for discharging the process gas P after compression, is connected to the discharge port, and the process gas P is supplied to the ammonia converter **200** outside the compression unit **20** via the gas exhaust line **20***c*.

The process gas P (H2) introduced into the ammonia converter **200** through the compression unit **20** is used for a chemical reaction with nitrogen (N2) in the ammonia converter **200** in the presence of a catalyst. In this chemical reaction, ammonia (NH3) is generated in the ammonia converter **200**.

The ammonia converter **200** is provided with a boiler **200***a* as a heat exchanger that generates steam G by using heat generated in the chemical reaction. The steam G generated in the boiler **200***a* of the ammonia converter **200** is introduced into the steam turbine **30** as an operating fluid of the steam turbine **30**.

(Motor)

The motor (M) **50** is a rotary machine as an electric motor that drives the compression unit **20**. The motor **50** is applied with a voltage from the outside and is rotated at a rotation speed based on the magnitude of the applied voltage. The motor **50** includes an output shaft **51** and a motor main body **52**.

The output shaft **51** is a columnar member (motor shaft) made of metal or the like, which extends in the axial direction Da and is rotatable about the axis O. An end portion of the output shaft **51** on one side in the axial direction Da is connected to the speed increasing gear **40**. Specifically, the end portion of the output shaft **51** on one side in the axial direction Da is fixed to a pinion gear of a gear coupling of the speed increasing gear **40**.

Here, the output shaft **51** and the rotation shaft **10** are spaced apart from each other in the horizontal direction, and the center line of the rotation shaft **10** and the center line of the output shaft **51** are on the same straight line. That is, the output shaft **51** and the rotation shaft **10** share the axis O as the center line.

The motor main body **52** has, for example, a motor stator (not shown) as a stator and a motor rotor (not shown) as a rotor and integrally fixed to the output shaft **51**.

The motor stator is electrically connected to a device outside the motor **50**. When a current flows through the coil included in the motor stator, an electromagnetic force for rotating the motor rotor in a circumferential direction of the output shaft **51** with the axis O as a reference (center) is generated.

Therefore, when the power is input from the outside to the motor stator of the motor main body **52**, the output shaft **51** is rotated. When the output shaft **51** is rotated, the speed increasing gear **40** that connects the output shaft **51** and the turbine rotation shaft **13** increases the rotation speed of the turbine rotation shaft **13** to a speed higher than the rotation speed of the motor **50**.

(Speed Increasing Gear)

The speed increasing gear **40** (step-up gear: SG) is a gear device (gear box) that connects the rotation shaft **10** and the motor **50** to each other and can increase the rotation speed of the rotation shaft **10** to a speed higher than the rotation speed of the motor **50**.

That is, the speed increasing gear **40** is interposed between the compression unit **20** and the motor **50** and can increase the rotation speed of the first rotation shaft **11** and the second rotation shaft **12** in the compression unit **20** and the rotation speed of the turbine rotation shaft **13** of the steam turbine **30** to a speed higher than the rotation speed of the motor **50**.

The speed increasing gear **40** in the present embodiment has, for example, a gear coupling, which is a type of flexible shaft coupling, including a plurality of pinion gears arranged in the axial direction Da.

The pinion gear of the gear coupling is fixed such that an end portion of the rotation shaft **13** on the other side in the axial direction Da of the rotation shaft **10** and a part of the motor **50** are covered from the outside. The speed increasing gear **40** connects the rotation shaft **10** and the motor **50** at a predetermined gear ratio.

(Steam Turbine)

The steam turbine (ST) **30** is a rotary machine that assists in driving the compression unit **20** by using the steam G generated in association with the treatment of the process gas P of the ammonia plant **100**. The steam G generated in the boiler **200***a* of the ammonia converter **200** is introduced into the steam turbine **30** in the present embodiment via the steam introduction line **201**.

As shown in FIG. **2**, the steam turbine **30** includes a turbine stator **30***a* (stator) and a turbine rotor **30***b* (rotor).

The turbine stator **30***a* includes a turbine casing **301***a* that causes steam G to flow inside, and a plurality of stages of stator blades **301***b* that extend from an inner surface of the turbine casing **301***a* toward an inner side and rectify a flow of the steam G as the operating fluid.

The turbine casing **301***a* constitutes an outer shell of the steam turbine **30**. The turbine casing **301***a* includes a turbine casing main body **330**, a steam inlet portion **331** for introducing the steam G, which is formed in the turbine casing main body, and a steam outlet portion (not shown) for exhausting the steam G, which is formed in the turbine casing main body. The stator blade **301***b* extends from the inner surface of the turbine casing main body toward an inner side. The stator blade **301***b* rectifies a flow of the steam G as the operating fluid inside the turbine casing main body.

Here, as shown in FIG. **3**, on the most one side (that is, the upstream side) of the turbine casing **301***a* in the direction of the axis O, an inflow flow path **332** through which the steam G flows and a guide flow path **333** are formed on the upstream side of the first stage stator blade **301***b*. The inflow flow path **332** has an annular shape centered on the axis O. That is, when viewed from the direction of the axis O, the turbine rotor **30***b* (described below) is disposed on the inner peripheral side of the inflow flow path **332**, and the first stage stator blade **301***b* is disposed on the outer peripheral side.

The guide flow path **333** is a flow path that communicates the steam inlet portion **331** with the inflow flow path **332**. The guide flow path extends in a radial direction with respect to the axis O, for example. In addition, one guide flow path **333** is disposed at only one location in the circumferential direction with respect to the axis O.

The turbine rotor **30***b* includes a turbine rotation shaft **13**, and a plurality of stages of rotor blades **302***a* that are fixed to the turbine rotation shaft **13** and rotate about the axis O together with the turbine rotation shaft **13** when the rectified steam G collides with the stator blade **301***b* of the turbine stator **30***a*.

The rotor blade **302***a* is accommodated in the turbine casing main body. The rotor blade **302***a* is integrally formed with the turbine rotation shaft **13** and extends from an outer surface of the turbine rotation shaft **13** toward an outer side. The rotor blade **302***a* receives pressure from the steam G inside the turbine casing main body as a rotational force that rotates the turbine rotation shaft **13**.

The turbine rotor **30***b* forms a flow path of the steam G together with the inner surface of the turbine casing main body in the turbine casing **301***a* and the surface of the stator blade **301***b*. The stator blade **301***b* and the rotor blade **302***a* are alternately disposed in the axial direction Da.

A flow of the steam G introduced into the steam turbine **30** will be described below. The steam G introduced into the turbine casing main body via the steam inlet portion connected to the steam introduction line **201** is rectified by the stator blade **301***b* and collides with the rear stage rotor blade **302***a* to rotate the rotor blade **302***a* about the axis O. The steam G collided with the rotor blade **302***a* is rectified again by the rear stage stator blade **301***b* and then collides with the rear stage rotor blade **302***a*.

The steam G introduced into the inside of the turbine stator **30***a* continues to rotate the turbine rotor **30***b* by repeating rectification by the stator blade **301***b* and collision with the rotor blade **302***a*. That is, the steam G introduced into the steam turbine **30** continues to rotate the turbine rotation shaft **13** of the turbine rotor **30***b*.

The steam G introduced into the inside of the turbine stator **30***a* continues to rotate the turbine rotor **30***b* by repeating rectification by the stator blade and collision with the rotor blade. That is, the steam G introduced into the steam turbine **30** continues to rotate the turbine rotation shaft **13** of the turbine rotor **30***b*.

Here, an end portion of the turbine rotation shaft **13** of the turbine rotor **30***b* on one side in the axial direction Da and an end portion of the first rotation shaft **11** of the first rotor **21***b* on the other side in the axial direction Da are integrally connected to each other. Specifically, the turbine rotation shaft **13** and the first rotation shaft **11** are elastically connected to each other by a coupling or the like (not shown) having flexibility.

The turbine rotation shaft **13** and the first rotation shaft **11** are connected to each other such that the centers of both are aligned. That is, the center line of the turbine rotation shaft **13** and the center line of the first rotation shaft **11** are on the same straight line. That is, the turbine rotation shaft **13** and the first rotation shaft **11** share the axis O as the center line.

Therefore, when the steam turbine **30** rotates the turbine rotation shaft **13**, the first rotation shaft **11** and the second rotation shaft **12** in the compression unit **20** rotate with this rotation. Therefore, the compression unit **20** is driven by the rotation of the steam turbine **30**.

In the present embodiment, the turbine rotation shaft **13** in the steam turbine **30**, the first rotation shaft **11** in the low pressure stage compressor **21**, and the second rotation shaft **12** in the high pressure stage compressor **22** are integrated with each other to form the rotation shaft **10** which is one driving shaft extending in the axial direction Da. That is, the rotation shaft **10** is rotatable about the axis O with the axis O as a center.

The steam G collides with the last stage rotor blade **302***a* and is then exhausted to the outside of the steam turbine **30** via the steam outlet portion in the turbine casing **301***a*. The steam exhaust line **202**, which is a pipe for exhausting the steam G, is connected to the steam outlet portion, and the steam G is introduced into the condenser **90** disposed outside the steam turbine **30** through the steam exhaust line **202**.

(Frequency Conversion Unit)

The frequency conversion unit **60** (variable frequency drive: VFD) is a device that is connected to the power system Gr outside the compressor train **1** for a chemical plant and that performs rotation control of the motor **50**. The frequency conversion unit **60** in the present embodiment is an inverter that is connected to the power system Gr and the motor **50** and converts the direct current power supplied from the power system Gr into three-phase alternating current power to input the alternating current power to the motor **50**.

The first power purchase cable **61***a* and the second power purchase cable **61***b* are connected to the frequency conversion unit **60**. The first power purchase cable **61***a* electrically connects the frequency conversion unit **60** and the motor stator of the motor **50**. The second power purchase cable **61***b* is electrically connected to the frequency conversion unit **60** and the power system Gr.

As a result, the direct current power flowing through the power system Gr is input to the frequency conversion unit **60** via the second power purchase cable **61***b*. The direct current power input to the frequency conversion unit **60** is converted into alternating current power by, for example, a power module or the like provided in the frequency conversion unit **60**, and then is input to the motor **50** via the first power purchase cable **61***a*. Therefore, the motor **50** is driven by purchasing electric power from the power system Gr via the frequency conversion unit **60**.

(Condenser)

The condenser **90** is connected to the steam turbine **30** by the steam exhaust line **202**, for example. The condenser **90** cools and condenses the steam G exhausted from the steam outlet portion of the turbine casing **301***a* through the steam exhaust line **202**. The condenser **90** is connected to the drainage line **170**. The condenser **90** exhausts the water W accumulated inside to the outside of the condenser **90** through the drainage line **170**.

In addition, the condenser **90** is connected to the first suction line **210**. The condenser **90** exhausts the air that flows in from the gap such as a device joint portion to the outside of the condenser **90** from the first suction line **210**. In addition, the condenser **90** is connected to the circulation line **180**. In addition, the circulation line **180** is connected to the drainage line **170**.

In addition, the connection line **160** is connected to the condenser **90**. The connection line **160** connects the steam introduction line **201** and the condenser **90** to each other. Therefore, the connection line **160** can guide the steam G flowing from the steam introduction line **201** toward the steam turbine **30** to the condenser **90**. In addition, the dump valve **250** is disposed in the connection line **160**. The dump valve **250** adjusts its own opening degree by receiving a signal indicating the opening degree transmitted from the control device **150**. The dump valve **250** reduces the pressure of the steam G flowing through the connection line **160** according to the opening degree.

In addition, the governing valve **240** is disposed at a position closer to the steam turbine **30** than the connection point to the connection line **160** in the steam introduction line **201**. The governing valve **240** adjusts its own opening degree by receiving a signal indicating the opening degree transmitted from the control device **150**. Although not shown in detail, the governing valve **240** includes only one valve main body and only one valve body whose posture can be adjusted in the valve main body. That is, unlike the related art, the governing valve **240** does not include a plurality of valve bodies. Therefore, only one guide flow path **333** described above is also disposed in correspondence with only one valve body. In addition, it is desirable that the governing valve **240** is disposed on the steam introduction line **201** but may be integrally attached to the turbine casing **301***a* of the steam turbine **30**.

In addition, the flow rate sensor **290** is disposed at a position closer to the ammonia converter **200** than the connection point to the connection line **160** in the steam introduction line **201**. The flow rate sensor **290** detects the amount of the steam G flowing through the steam introduction line **201**. The flow rate sensor **290** transmits a signal indicating the detected amount of the steam G to the control device **150**.

Furthermore, the main trip and throttle valve (TTV) **280** is disposed between the governing valve **240** and the flow rate sensor **290** in the steam introduction line **201**. The main trip and throttle valve **280** is disposed to immediately block the flow of the steam in the steam introduction line **201** in a case where the system requires an emergency stop. That is, the main trip and throttle valve **280** causes steam to flow in or block the steam.

(Condensate Pump)

The condensate pump **95** is disposed in the drainage line **170**. The condensate pump **95** circulates the water W condensed in the condenser **90** to an external device (not shown) such as a boiler through the drainage line **170**. The first opening and closing valve **260** is disposed at a portion on the downstream side of the condensate pump **95** in the drainage line **170**. In addition, the circulation line **180** that connects the drainage line **170** and the condenser **90** is connected to the drainage line **170**.

The first opening and closing valve **260** is disposed on the downstream side than a connection point to the circulation line **180** in the drainage line **170**. In addition, the second opening and closing valve **270** is disposed in the circulation line **180**. By adjusting the opening degree of the first opening and closing valve **260** and the second opening and closing valve **270**, the inflow amount of the water W from the condenser **90** to the boiler described above and the return amount of the water W to the condenser **90** are adjusted.

(Grand Condenser)

The grand condenser **110** is connected to the steam turbine **30**, for example, via the leak steam line **230**. The grand condenser **110** deaerates the leaked steam that flows out to the outside of the turbine stator **30***a* from a gap between the turbine stator **30***a* and the turbine rotor **30***b* of the steam turbine **30**. The grand condenser **110** in the present embodiment condenses the leaked steam (grand steam) from the gap between the turbine rotation shaft **13** of the turbine rotor **30***b* and an opening portion formed at both ends of the casing main body in the axial direction Da of the turbine stator **30***a*.

Therefore, the inside of the grand condenser **110** communicates with the gap between the turbine rotation shaft **13** and the opening portion of the casing main body through the leak steam line **230**. The grand condenser **110** in the present embodiment is, for example, a shell-and-tube type heat exchanger.

The grand condenser **110** is connected to the condenser **90** via the condensate recovery line **190**. The grand condenser **110** supplies the water W for activation to the condenser **90** when the steam turbine **30** is activated. The grand condenser **110** supplies the leaked steam and the water W obtained by deaerating the condensed water W during the operation of the steam turbine **30** to the condenser **90** through the condensate recovery line **190**. As a result, the grand condenser **110** controls the liquid level of the condenser **90** during the operation of the steam turbine **30**.

(Vacuum Pump)

The vacuum pump **120** is connected to the condenser **90** via the first suction line **210**.

The vacuum pump **120** is driven to suck the air inside the condenser **90**. As a result, the vacuum pump **120** reduces the pressure inside the condenser **90** to a negative pressure. In a case where the steam turbine **30** is not driven, the vacuum pump **120** is driven, so that the air inside the condenser **90** is sucked, and the air inside the steam turbine **30** is sucked into the condenser **90** through the steam exhaust line **202**. As a result, the pressure inside the steam turbine **30** is reduced.

The drain separator **130** is disposed in the first suction line **210** on the downstream side than the vacuum pump **120**. The drain separator **130** further separates the air sucked by the vacuum pump **120** into air and liquid. Each of the liquid phase components and the gas phase components separated by the drain separator **130** into air and liquid is exhausted, for example, to the outside of the compressor train **1** for a chemical plant.

(Vapor Fan)

The vapor fan **125** is disposed in the second suction line **220** connected to the grand condenser. The vapor fan **125** is electrically driven to remove the air in the grand condenser **110** and to maintain the inside of the grand condenser **110** at a slight negative pressure.

(Operation and Effect)

Here, in the chemical plant in the related art, it has been common to mainly use the power of the steam turbine **30** in order to drive the compression unit **20**. However, it is promising to adopt a configuration in which the compression unit **20** is mainly driven by the electric motor (motor **50**) and the power of the motor **50** is assisted by the steam turbine **30**, as in the compressor train **1** for a chemical plant according to the present embodiment. In that case, precise control such as steam flow rate is no longer required for the steam turbine **30**. Therefore, there is a problem that the configuration of the steam turbine **30** in the plant in the related art is over-specified, which leads to an increase in operating costs and maintenance costs. In order to solve the above-described problems, the present embodiment adopts each of the above-described configurations.

With the above configuration, the compression unit **20** is mainly driven by the motor **50**, and the steam turbine **30** is used to assist the driving force of the motor **50**. Therefore, it is not necessary to adjust the rotation speed of the compression unit **20** by the steam turbine **30**. Therefore, it is not necessary to perform precise steam flow rate control in the steam turbine **30**. Therefore, the configuration of the compressor train **1** for a chemical plant can be simplified, so that the manufacturing costs and the maintenance costs of the apparatus can be significantly reduced. As a result, it is possible to reduce the price of the chemical product, which is the final product, and it is possible to use the chemical product in various industries in a large amount and at a low cost.

With the above configuration, the governing valve **240** is disposed between the main trip and throttle valve **280** and the steam turbine **30**. Therefore, by adjusting the opening degree of the governing valve **240**, various types of operation tests and the like related to the steam turbine **30** can be smoothly performed.

With the above configuration, since it is not necessary to precisely adjust the steam flow rate in the steam turbine **30**, it is not necessary to use the valve device having a plurality of valve bodies as in the related art in providing the governing valve **240**. That is, a valve device having only one valve body can be adopted as the governing valve. As a result, the configuration can be further simplified, and the maintenance costs and the manufacturing costs can be further reduced. As a result, it is possible to reduce the price of the chemical product, which is the final product of the compressor train **1** for a chemical plant, and it is possible to promote the widespread use of the chemical product in various industries.

With the above configuration, since it is not necessary to precisely adjust the steam flow rate in the steam turbine **30**, it is not necessary to form a plurality of flow paths communicating with the valve device having the plurality of valve bodies as in the related art in providing the inflow flow path **332** in the casing (turbine casing **301***a*). As a result, the configuration can be further simplified, and the maintenance costs and the manufacturing costs can be further reduced. As a result, it is possible to reduce the price of the chemical product, which is the final product of the compressor train **1** for a chemical plant, and it is possible to promote the widespread use of the chemical product in various industries.

Other Embodiments

While preferred embodiments of the invention have been described and illustrated above, it should be understood that these are exemplary of the invention and are not to be considered as limiting. Additions, omissions, substitutions, and other modifications can be made without departing from the scope of the invention. Accordingly, the invention is not to be considered as being limited by the foregoing description and is only limited by the scope of the appended claims.

For example, in the above-described embodiment, the example is described in which the governing valve **240** is disposed on the steam introduction line **201**. However, a configuration in which the governing valve **240** is not provided can also be adopted. This is because the adjustment of rotation speed of the compression unit **20** can be controlled by the motor **50**, and thus the steam turbine **30**, which is an auxiliary power source, does not need to precisely control the steam flow rate.

With the above configuration, no valve device is provided between the main trip and throttle valve **280** and the steam turbine **30**. As a result, the steam turbine **30** can be operated by a simple method with a simpler configuration. Therefore, since the complexity of the device is avoided, the frequency of maintenance is suppressed, and it is possible to continue to operate the compressor train **1** for a chemical plant more inexpensively and stably. In particular, the risk of failure occurrence is also reduced by reducing the number of parts. Therefore, as described above, it is possible to significantly reduce the frequency of maintenance and the costs required for the maintenance.

APPENDIX

The compressor train for a chemical plant described in each embodiment is grasped, for example, as follows.

(1) The compressor train **1** for a chemical plant according to a first aspect includes a compression unit **20** that compresses a process gas of the chemical plant by being driven, a motor **50** that drives the compression unit **20**, a steam turbine **30** that is rotated by steam G generated in association with treatment of the process gas P of the chemical plant and configured to assist in rotation of the motor **50**, a steam introduction line **201** through which the steam G flows toward the steam turbine **30**, and a main trip and throttle valve **280** that is disposed on the steam introduction line **201** and blocks or causes the steam G to flow into the steam turbine **30**.

With the above configuration, the compression unit **20** is mainly driven by the motor **50**, and the steam turbine **30** is used to assist the driving force of the motor **50**. Therefore, it is not necessary to adjust the rotation speed of the compression unit **20** by the steam turbine **30**. Therefore, it is not necessary to perform precise steam flow rate control in the steam turbine **30**. The manufacturing costs and maintenance costs of the apparatus can be significantly reduced.

(2) A compressor train **1** for a chemical plant according to a second aspect is the compressor train **1** for a chemical plant according to (1), in which another valve device is not disposed between the steam turbine **30** and the main trip and throttle valve **280** on the steam introduction line **201**.

With the above configuration, no valve device is provided between the main trip and throttle valve **280** and the steam turbine **30**. As a result, the steam turbine **30** can be operated by a simple method with a simpler configuration.

(3) A compressor train **1** for a chemical plant according to a third aspect is the compressor train **1** for a chemical plant according to (1), the compressor train further includes a governing valve **240** that is disposed between the steam turbine **30** and the main trip and throttle valve **280** and switches a flow state of the steam G.

With the above configuration, the governing valve **240** is provided between the main trip and throttle valve **280** and the steam turbine **30**. Therefore, by adjusting the opening degree of the governing valve **240**, various types of operation tests and the like related to the steam turbine **30** can be smoothly performed.

(4) A compressor train **1** for a chemical plant according to a fourth aspect is the compressor train **1** for a chemical plant according to (3), in which the governing valve **240** has only one valve body configured to switch a posture between an open state and a closed state.

With the above configuration, since it is not necessary to precisely adjust the steam flow rate in the steam turbine **30**, it is not necessary to use the valve device having a plurality of valve bodies as in the related art in providing the governing valve **240**. As a result, the configuration can be further simplified, and the maintenance costs and the manufacturing costs can be further reduced.

(5) A compressor train **1** for a chemical plant according to a fifth aspect is the compressor train **1** for a chemical plant according to any one of (1) to (4), in which the steam turbine **30** includes a rotor (turbine rotor **30***b*) and a casing (turbine casing **301***a*) that forms a flow path through which the steam G flows by covering the rotor from an outer peripheral side, and the casing includes an inflow flow path **332** that is formed on an upstream side with respect to a first stage stator blade **301***b* in the casing, in which the steam G flows, and has an annular shape centered on a central axis (axis O) of the rotor, and only one guide flow path **333** that connects the inflow flow path **332** and the main trip and throttle valve **280**.

With the above configuration, since it is not necessary to precisely adjust the steam flow rate in the steam turbine **30**, it is not necessary to form a plurality of flow paths communicating with the valve device having the plurality of valve bodies as in the related art in providing the inflow flow path **332** in the casing (turbine casing **301***a*). As a result, the configuration can be further simplified, and the maintenance costs and the manufacturing costs can be further reduced.

EXPLANATION OF REFERENCES

1: compressor train for chemical plant
10: rotation shaft
11: first rotation shaft
12: second rotation shaft
13: turbine rotation shaft
20: compression unit
20*a*: gas introduction line
20*b*: intermediate line
20*c*: gas exhaust line
21: low pressure stage compressor
22: high pressure stage compressor
30: steam turbine
30*a*: turbine stator
30*b*: turbine rotor
40: speed increasing gear
50: motor
51: output shaft

52: motor main body
60: frequency conversion unit
61*a*: first power purchase cable
61*b*: second power purchase cable
62*a*: first power selling cable
62*b*: second power selling cable
90: condenser
90: condensate pump
100: ammonia plant
110: grand condenser
120: vacuum pump
125: vapor fan
130: drain separator
150: control device
160: connection line
170: drainage line
180: circulation line
190: condensate recovery line
200: ammonia converter
200*a*: boiler
201: steam introduction line
202: steam exhaust line
210: first suction line
220: second suction line
230: leak steam line
240: governing valve
250: dump valve
260: first opening and closing valve
270: second opening and closing valve
280: main trip and throttle valve
290: flow rate sensor
301*a*: turbine casing
301*b*: stator blade
302*a*: rotor blade
332: inflow flow path
333: guide flow path
Da: axial direction
G: steam
Gr: power system
O: axis
P: process gas
W: water

What is claimed is:

1. A compressor train for a chemical plant, comprising:

a compression unit comprising a rotation shaft rotatable about an axis as a center and configured to compress a process gas of the chemical plant;

a motor comprising an output shaft rotatable about the axis as a center and configured to drive the compression unit and to adjust a rotation speed of the compression unit;

a steam turbine comprising a turbine rotation shaft rotatable about the axis as a center, rotated by steam generated in association with treatment of the process gas of the chemical plant at a rotation speed equal to or lower than a rotation speed of the motor, and configured to assist rotation of the motor;

a steam introduction line through which the steam flows toward the steam turbine; and

a main trip and throttle valve disposed on the steam introduction line and configured to block or cause the steam to flow into the steam turbine, wherein

the steam turbine is disposed between the motor and the compression unit in an axial direction in which the axis extends, and

the rotation shaft, the turbine rotation shaft, and the output shaft are disposed on a same straight line such that the axis is shared as a center line of the rotation shaft, a center line of the turbine rotation shaft, and a center line of the output shaft.

2. The compressor train for a chemical plant according to claim **1**, further comprising:

a governing valve disposed between the steam turbine and the main trip and throttle valve and configured to switch a flow state of the steam.

3. The compressor train for a chemical plant according to claim **2**, wherein the governing valve has only one valve body configured to switch a posture between an open state and a closed state.

4. The compressor train for a chemical plant according to claim **1**, wherein

the steam turbine comprises:

a rotor; and

a casing configured to form a flow path through which the steam flows by covering the rotor from an outer peripheral side, and

the casing comprises:

an inflow flow path that is disposed on an upstream side with respect to a first stage stator blade in the casing, into which the steam flows, and has an annular shape centered on a central axis of the rotor; and

only one guide flow path connect ing the inflow flow path and the main trip and throttle valve.

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