To provide an apparatus for improving the production efficiency of dry ice of a simple structure, to be mounted easily to the conventional dry ice production apparatus main body, without the risk of choking the conduit or the nozzle with dry ice. This apparatus comprises a first heat exchanging means, a second heat exchanging means and a coolant, with the coolant including an antifreeze. The liquefied carbon dioxide is provided in a supercooled state by transporting cold energy to the coolant by the first heat exchanging means, supplying the liquefied carbon dioxide from the tank to the second heat exchanging means, and transporting the cold energy from the coolant to the liquefied carbon dioxide by the second heat exchanging means, and the liquefied carbon dioxide in the supercooled state is supplied to the nozzle. Owing to little pressure decline of the liquefied carbon dioxide, this apparatus can hardly choke the conduit or the nozzle, and it can be mounted easily to a dry ice production apparatus owing to the simple structure. As a result of the dry ice production test with a dry ice production apparatus mounted with this apparatus, a yield as high as 61 to 70% was achieved.
APPLICANT FOR IMPROVING PRODUCTION EFFICIENCY OF DRY ICE

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a production apparatus for dry ice, more specifically, it relates to an apparatus for improving the production efficiency of dry ice, to be mounted on the former stage of a dry ice production apparatus, wherein a liquefied carbon dioxide is used as the raw material.

[0003] 2. Description of the Related Art

[0004] Dry ice as a solid carbon dioxide is utilized widely in the industrial fields.

[0005] Although the product shape and size varies, the dry ice is produced in general from a liquefied carbon dioxide with the following apparatus.

[0006] Out of the dry ice production apparatus, the structure of the half way between a storage tank for a liquefied carbon dioxide and a dry ice production apparatus main body portion is shown schematically in FIG. 1.

[0007] According to the production apparatus (1), a conduit leads to a dry ice production apparatus main body (8 (8, 8)) from a storage tank (2) via a safety valve (3), a valve (4) to be switched so as to supply the liquefied carbon dioxide from the storage tank (2), a safety valve (5), a pressure gauge (6) for measuring the outlet pressure of the liquefied carbon dioxide, and a valve (7 (7, 7)) to be switched so as to allow passage of the liquefied carbon dioxide to the dry ice production apparatus main body successively.

[0008] In the storage tank (2), a liquefied carbon dioxide is stored at a temperature of about −20° C. is stored. By opening the valve (4) and the valve (7) or the like, the liquefied carbon dioxide is jetted from the nozzle from the storage tank (2) into the chamber of the main body (8) or the like via the conduit so as to provide snow like dry ice of about −70° C. by the adiabatic expansion. By compressing the same with a piston, solid dry ice is obtained.

SUMMARY OF THE INVENTION

[0009] However, at the time of producing dry ice, using the apparatus and the method, a considerable amount of the liquefied carbon dioxide is evaporated at the time of the adiabatic expansion. Since the evaporated carbon dioxide escapes from the discharge opening or the like into the air, it cannot contribute to the product.

[0010] It is preferable to set the temperature, the pressure and the enthalpy such that those of the liquefied carbon dioxide immediately before jetting are on the saturated liquid line as the boundary between the gas-liquid mixed state and the liquid because the dryness of the dry ice after the adiabatic expansion, that is, the ratio of the gaseous carbon dioxide is minimum at the time they are on the saturated liquid line.

[0011] In general, the liquefied carbon dioxide immediately before jetting has about −20° C. temperature and about 2.0 MPa pressure so that the preferable enthalpy value at the temperature and pressure is about 88 kcal/kg. However, even at the preferable temperature, pressure and enthalpy, the dryness to be achieved is about 55% so that the ratio of the carbon dioxide to be utilized as a dry ice product out of the liquefied carbon dioxide (yield) is theoretically about 43% at most.

[0012] Besides, the jetting operation cannot be carried out always in a preferable state. In reality, the yield is further lower and it was only about 32 to 40%.

[0013] Particularly in the case of a small size dry ice production apparatus, a tank lorry is used for supplying the liquefied carbon dioxide. If the yield is low, the total number of the tank lorries used for producing the same amount of the dry ice is larger so that the production cost of the dry ice is raised consequently therefor. Moreover, since a larger amount of the carbon dioxide as the green house effect gas is discharged into the air, an adverse effect is posed also to the global environment.

[0014] Although there is an apparatus for collecting the carbon dioxide, which has not contributed to the product, and again providing a liquefied carbon dioxide, it is expensive. Therefore, in the case the carbon dioxide collecting apparatus is used for a small size dry ice production apparatus, the production cost may be raised instead.

[0015] The official gazette of the Japanese Patent Application Laid Open No. 2003-206122 discloses a technique for improving the yield of the dry ice by reducing the enthalpy of the liquefied carbon dioxide by further supercooling a liquefied carbon dioxide from the saturated liquid line so as to be in a low dryness state, and carrying out the adiabatic expansion.

[0016] However, according to the cooling device for a liquefied carbon dioxide disclosed in the official gazette of the Japanese Patent Application Laid Open No. 2003-206122, the liquefied carbon dioxide is jetted by a nozzle after having its temperature lowered by a plurality of stages using a plurality of heat exchanging devices, further having its temperature lowered once by executing the adiabatic expansion through a metering valve, and passing through a pipe body having about 0.25 MPa resistance so as to have the pressure lowered.

[0017] Therefore, the following problems are generated. Firstly, since the pressure of the liquefied carbon dioxide is lowered drastically before jetting by the nozzle, the liquefied carbon dioxide can easily be frozen in the conduit or the tank so as to be dry ice. Such dry ice prevents the operation of the production apparatus by choking the conduit or the nozzle. For removing the dry ice in the conduit or the nozzle and re-operating the apparatus, enormous cost and time are required.

[0018] Secondly, since the cooling operation is carried out in a plurality of stages using a plurality of heat exchanging devices and a metering valve, the structure of the cooling device is complicated so that it can hardly be mounted to the conventional dry ice production apparatus main body.

[0019] In order to solve the problems, the present application provides an apparatus for improving the production efficiency of dry ice of a simple structure, to be mounted easily to the conventional dry ice production apparatus main body, without the risk of choking the conduit or the nozzle with dry ice by use of an antifreeze as the secondary coolant at the time of supercooling the liquefied carbon dioxide.
To solve above-mentioned problem, the invention provides an apparatus for improving the production efficiency of dry ice, to be mounted between a tank for storing a liquefied carbon dioxide and a device for jetting the liquefied carbon dioxide into a chamber by a nozzle, characterized in that the apparatus comprises a first heat exchanging means, a second heat exchanging means and a coolant, with the coolant including an antifreeze, and the liquefied carbon dioxide is rendered in a supercooled state by transporting cold energy to the coolant by the first heat exchanging means, supplying the liquefied carbon dioxide from the tank to the second heat exchanging means, and transporting the cold energy from the coolant to the liquefied carbon dioxide by the second heat exchanging means, and the liquefied carbon dioxide in the supercooled state is supplied to the nozzle.

According to the apparatus for improving the production efficiency of dry ice of the present invention, since the coolant including the antifreeze is used, the temperature of the liquefied carbon dioxide can be lowered sufficiently to the supercooled state by the cooling operation of one stage. Therefore, the heat exchange of the liquefied carbon dioxide can be one stage without the need of the metering valve. Since the adiabatic expansion by the metering valve is unnecessary, the pipe body for the communication of the metering valve and the nozzle is unnecessary as well so that the means for the purpose of the pressure decline is only the nozzle for jetting. Since the pressure of the liquefied carbon dioxide is sufficiently high (about 1.7 MPa) even immediately before the nozzle, the liquefied carbon dioxide cannot be frozen in the conduit or the nozzle so as not to be snow like dry ice, and thus the operation of the production apparatus cannot be prevented by choking of the conduit or the nozzle. Moreover, since the number of the heat exchanging devices can be reduced and the metering valve and the pipe body are unnecessary, the structure of the apparatus can be simple. Therefore, it can be mounted easily to most of the dry ice production apparatus.

Moreover, to solve above-mentioned problem, the invention provides the apparatus for improving the production efficiency of dry ice, wherein the pressure decline of the liquefied carbon dioxide from the tank for storing the liquefied carbon dioxide to immediately before the nozzle for jetting is about 0.3 MPa or less.

Moreover, to solve above-mentioned problem, the invention provides the apparatus for improving the production efficiency of dry ice, wherein the pressure of the liquefied carbon dioxide immediately before jetting by the nozzle is about 1.7 MPa or more.

Moreover, to solve above-mentioned problem, the invention provides the apparatus for improving the production efficiency of dry ice, comprising only one set of the second heat exchanging means.

Moreover, to solve above-mentioned problem, the invention provides an apparatus for producing dry ice, comprising a tank for storing a liquefied carbon dioxide, a device for jetting the liquefied carbon dioxide into a chamber by a nozzle, and a device for producing solid dry ice by compressing snow like dry ice made from the liquefied carbon dioxide jetted into the chamber.

Further comprising a device for supercooling the liquefied carbon dioxide between the tank for storing the liquefied carbon dioxide and the device for jetting the liquefied carbon dioxide into the chamber by the nozzle,

characterized in that the device for supercooling the liquefied carbon dioxide comprises a first heat exchanging means, a second heat exchanging means and a coolant, with the coolant including an antifreeze, and the liquefied carbon dioxide is rendered in a supercooled state by transporting cold energy to the coolant by the first heat exchanging means, supplying the liquefied carbon dioxide from the tank to the second heat exchanging means, and transporting the cold energy from the coolant to the liquefied carbon dioxide by the second heat exchanging means, and the liquefied carbon dioxide in the supercooled state is supplied to the nozzle.

Moreover, to solve above-mentioned problem, the invention provides the apparatus for producing dry ice, wherein the pressure of the liquefied carbon dioxide immediately before jetting by the nozzle is about 1.7 MPa or more.

Moreover, to solve above-mentioned problem, the invention provides the apparatus for producing dry ice, wherein the pressure decline of the liquefied carbon dioxide from the tank for storing the liquefied carbon dioxide to immediately before jetting by the nozzle is generated substantially only by the resistances of a heat exchanging device, a conduit and a valve.

Moreover, to solve above-mentioned problem, the invention provides the apparatus for producing dry ice, wherein the device for supercooling the liquefied carbon dioxide comprises only one set of the second heat exchanging means.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of the conventional dry ice production apparatus.

FIG. 2 is a schematic diagram of a dry ice production apparatus with an apparatus mounted for improving the production efficiency of dry ice according to the present invention.

FIG. 3 is a schematic diagram of the structure of an apparatus for improving the production efficiency of dry ice according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 2 is a schematic diagram of a dry ice production apparatus, mounted with an apparatus for improving the production efficiency of dry ice according to the present invention. For the same means as in FIG. 1, the same reference numerals are used.

According to the production apparatus (1), a conduit leads to a dry ice production apparatus main body (8 (8', 8'')) from a storage tank (2) via a safety valve (3), a valve (4)
to be switched so as to supply the liquefied carbon dioxide from the storage tank (2), an apparatus (10) for improving the production efficiency of dry ice according to the present invention, a safety valve (5), a pressure gauge (6) for measuring the outlet pressure of the liquefied carbon dioxide, and a valve (7 (7, 7')) to be switched so as to allow passage of the liquefied carbon dioxide to the dry ice production apparatus main body successively. The apparatus (10) for improving the production efficiency of dry ice according to the present invention communicates with a freezing machine (11) by conduits (12, 13) such that a primary coolant flows from the freezing machine (11) to the apparatus (10) via the conduit (12) and it returns from the apparatus (10) to the freezing machine (11) via the conduit (13).

[0037] The production apparatus (1) differs from the conventional dry ice production apparatus shown in FIG. 1 in that the apparatus for improving the production efficiency of dry ice according to the present invention, the freezing machine and the conduits are provided between the valve (4) and the safety valve (5).

[0038] FIG. 3 is a schematic diagram of the structure of the apparatus (10) for improving the production efficiency of dry ice according to the present invention.

[0039] The apparatus (10) includes a first heat exchanging device (21), a second heat exchanging device (22) and a tank (23) for storing a secondary coolant, and the secondary coolant includes an antifreeze (brine). A conduit (24) communicates with the freezing machine (11) by the conduits (12) and (13). A conduit (25) communicates with the storage tank (2) on one side via the valve (4) and the dry ice production apparatus main body (8) or the like on the other side via the safety valve (5). A pump (26) provides the kinetic energy to the secondary coolant passing from the tank (23) through the first heat exchanging device (21) via a conduit (28) so as to return to the tank (23). A pump (27) provides the kinetic energy to the secondary coolant passing from the tank (23) via a conduit (29) through the second heat exchanging device (22) so as to return to the tank (23). In order to absorb the fluctuation of the secondary coolant liquid level inside the tank (23), a dry nitrogen gas is sent into the tank (23) via a conduit (30). Moreover, an expansion tank (31) absorbs the fluctuation of the dry nitrogen gas amount inside the tank (23).

[0040] Preferably, an LCO₂ (liquefied carbon dioxide) exhausting valve (32) is placed on the conduit (25) prior to the second heat exchanging device (22). The LCO₂ exhausting valve (32) is used to exhaust the liquefied carbon dioxide remaining in the conduit (25) when the production apparatus (1) is removed. The LCO₂ exhausting valve (32) is desirably placed prior to the second heat exchanging device (22), because if placed posterior to it, liquefied carbon dioxide could be frozen in the conduit to be snow like dry ice so as to choke the conduit.

[0041] The secondary coolant stored in the tank (23) reaches to the first heat exchanging device (21) via the conduit (28). It receives the cold energy transported from the freezing machine (11) through the conduit (24) via the first coolant at the first heat exchanging device (21), and furthermore, it returns to the tank (23) by the conduit (28). Then, the secondary coolant reaches to the second heat exchanging device (22) via a conduit (29). It passes the cold energy to a liquefied carbon dioxide supplied from the storage tank (2) via the conduit (25) at the second heat exchanging device (22), and furthermore, it returns to the tank (23) by the conduit (29). According to such a circulation of the secondary coolant, the cold energy is transported from the freezing machine (11) to the liquefied carbon dioxide.

[0042] According to the operation, the liquefied carbon dioxide is cooled down immediately to the supercooled state. That is, the means for cooling down the liquefied carbon dioxide other than the apparatus (10) is unnecessary. Preferably, the second heat exchanging device (22) is provided by only one.

[0043] Then the liquefied carbon dioxide in the supercooled state is jetted into the chamber of the production apparatus main body by a nozzle without passing through a means for the purpose of the pressure decline thereof. That is, the pressure of the liquefied carbon dioxide between the storage tank (2) to the nozzle is lowered only by the resistances of the members used for an ordinary dry ice production apparatus, such as a conduit, a heat exchanging device and a valve and the like so that a special member for the purpose of the drastic pressure decline is unnecessary. Preferably, the pressure decline of the liquefied carbon dioxide from the storage tank (2) to the nozzle is about 0.3 MPa or less. Or the pressure of the liquefied carbon dioxide immediately before reaching to the nozzle is about 1.7 MPa or more. The jetted liquefied carbon dioxide becomes snow like dry ice by the adiabatic expansion, and furthermore, it provides solid dry ice by being compressed by a piston.

[0044] According to the apparatus for improving the production efficiency of dry ice according to the present invention, since the secondary coolant including the antifreeze is used, the temperature of the liquefied carbon dioxide can be lowered sufficiently by the cooling operation of one stage. Therefore, the heat exchange of the liquefied carbon dioxide can be executed by one stage without the need of the metering valve. Since the adiabatic expansion by the metering valve is unnecessary, the pipe body for the communication of the metering valve and the nozzle is unnecessary as well so that the means for the purpose of the pressure decline is only the nozzle for jetting. Since the pressure of the liquefied carbon dioxide is sufficiently high (about 1.7 MPa) even immediately before the nozzle, the liquefied carbon dioxide cannot be frozen in the conduit or the nozzle so as not to be snow like dry ice, and thus the operation of the production apparatus cannot be prevented by choking of the conduit or the nozzle. Moreover, since the number of the heat exchanging devices can be reduced and the metering valve and the pipe body are unnecessary, the structure of the apparatus can be simple.

[0045] The apparatus for improving the production efficiency of dry ice according to the present invention has the extremely simple structure. Therefore, by having one side of the conduit (25) of the apparatus communicating with the conduit from the liquefied carbon dioxide storage tank and the other side communicating with the conduit for the jetting nozzle, respectively, it can be mounted easily to most of the dry ice production apparatus. Thereby, the dramatic improvement of the yield of the dry ice can be realized easily in the most of the dry ice production apparatus.
EXAMPLES

Results of the dry ice production test, using a dry ice production apparatus mounted with the apparatus for improving the production efficiency of dry ice according to the present invention are shown.

The test was carried out according to the following description.

The dry ice production machine used for the measurement was serial No.: 99C907 produced by America CO2AIR INC.

As to the measurement method, "Gas flow rate JIS Z8808 (1995) (Pitot tube method)" based on the Japanese Industrial Standard was used.

As the measurement devices, a Pitot tube (double head type C=0.86), a submerged manometer, a manostar gauge (0 to 300 Pa), a digital thermometer (C A couple --100° C. to +1200° C.) were used.

The measurement parameters were as follows.

Atmospheric pressure: 101.4 kPa
Number of the measurement times: 43 (cycles)
The calculation formulae of the measurement results are as follows.

\[ \rho = \frac{M_1X_1 + M_2X_2 + \ldots + M_nX_n}{(1-\sum_{i=1}^{n}X_i)\times 100} \]

\[ Q_x = \frac{v \times 22.4 \times (1 + \frac{0.6079P_a}{R \times T})}{22.4 \times (1 + \frac{0.6079P_a}{R \times 273})} \]

This time, the calculation was carried out with the premise that the exhaust gas composition was CO₂ 100.0% and the moisture content in the exhaust gas was 0.0%.

The meanings of each characters are as follows.

\[ \rho : \text{exhaust gas concentration in the duct (kg/m}^3) \]

\[ \rho_0 : \text{wet exhaust gas concentration converted to } 0°C, 1 \text{ atmosphere (kg/m}^3) \]

\[ T : \text{average value of the exhaust gas temperature (° C.)} \]

\[ P_a : \text{atmospheric pressure (kPa)} \]

\[ P_e : \text{static pressure of the exhaust gas (kPa)} \]

\[ v : \text{flow rate (m/sec)} \]

\[ C : \text{Pitot tube coefficient} \]

\[ P_d : \text{dynamic pressure (kPa)} \]

\[ Q_A : \text{real gas amount (L/sec)} \]

[0046] The measurement results were as follows.

Real gas flow rate \( Q_{A} \) (L/sec) = 38.8
Wet gas flow rate \( Q_{B} \) (L/sec) = 30.2
Dry ice converted value (exhaust gas flow rate) (kg) = 1.97 (per 1 cycle)
Gas temperature \( T \) (° C.) = 82
Gas static pressure \( P_e \) (Pa) = -220
Gas flow rate \( v \) (m/s) = 19.8
Gas composition \( CO_2 \) (%) = 100.0
Gas composition \( O_2 \) (%) = 0.0
Gas composition \( N_2 \) (%) = 0.0
Moisture content \( X_w \) (%) = 0.0
Gas concentration \( p_G \) (kg/m³) = 1.96
Dry ice total production amount (kg) = 134.01 (43 cycles)
Dry ice average production amount (kg) = 3.12 (per 1 cycle)
Production ratio (dry ice production amount/dry ice average production amount/exhaust gas flow rate) × 100 (%) = 61.3

Moreover, the outlet pressure measured by the pressure gauge 6 of FIG. 3 was 1.7 MPa, and the temperature was --52.6°C to --53.3°C.

As heretofore mentioned, as a result of the dry ice production test using a dry ice production apparatus mounted with the apparatus for improving the production efficiency of dry ice according to the present invention, a yield of 61.3% was achieved. Furthermore, as a result of fine adjustment of the machine, a yield of about 70% was achieved. On the other hand, the yield of the conventional dry ice production apparatus was about 32 to 40%. Therefore, the dry ice production apparatus mounted with the apparatus for improving the production efficiency of dry ice according to the present invention realizes the significant production efficiency of two or three times as high as the conventional products.

What is claimed is:

1. An apparatus for improving the production efficiency of dry ice, to be mounted between a tank for storing a liquefied carbon dioxide and a device for jetting the liquefied carbon dioxide into a chamber by a nozzle, characterized in that the apparatus comprises a first heat exchanging means, a second heat exchanging means and a coolant, with the coolant including an antifreeze, and the liquefied carbon dioxide is rendered in a supercooled state by transporting cold energy to the coolant by the first heat exchanging means, supplying the liquefied carbon dioxide from the tank to the second heat exchanging means, and transporting the cold energy from the coolant to the liquefied carbon dioxide by the second
heat exchanging means, and the liquefied carbon dioxide in the supercooled state is supplied to the nozzle.

2. The apparatus for improving the production efficiency of dry ice according to claim 1, wherein the pressure decline of the liquefied carbon dioxide from the tank for storing the liquefied carbon dioxide to immediately before the nozzle for jetting is about 0.3 MPa or less.

3. The apparatus for improving the production efficiency of dry ice according to claim 1, wherein the pressure of the liquefied carbon dioxide immediately before jetting by the nozzle is about 1.7 MPa or more.

4. The apparatus for improving the production efficiency of dry ice according to any of claims 1 to 3, comprising only one set of the second heat exchanging means.

5. An apparatus for producing dry ice, comprising a tank for storing a liquefied carbon dioxide, a device for jetting the liquefied carbon dioxide into a chamber by a nozzle, and a device for producing solid dry ice by compressing snow like dry ice made from the liquefied carbon dioxide jetted into the chamber,

further comprising a device for supercooling the liquefied carbon dioxide between the tank for storing the liquefied carbon dioxide and the device for jetting the liquefied carbon dioxide into the chamber by the nozzle,

characterized in that the device for supercooling the liquefied carbon dioxide comprises a first heat exchanging means, a second heat exchanging means and a coolant, with the coolant including an antifreeze, and

the liquefied carbon dioxide is rendered in a supercooled state by transporting cold energy to the coolant by the first heat exchanging means, supplying the liquefied carbon dioxide from the tank to the second heat exchanging means, and transporting the cold energy from the coolant to the liquefied carbon dioxide by the second heat exchanging means, and the liquefied carbon dioxide in the supercooled state is supplied to the nozzle.

6. The apparatus for producing dry ice according to claim 5, wherein the pressure decline of the liquefied carbon dioxide from the tank for storing the liquefied carbon dioxide to immediately before the nozzle for jetting is about 0.3 MPa or less.

7. The apparatus for producing dry ice according to claim 5, wherein the pressure of the liquefied carbon dioxide immediately before jetting by the nozzle is about 1.7 MPa or more.

8. The apparatus for producing dry ice according to any of claims 5 to 7, wherein the pressure decline of the liquefied carbon dioxide from the tank for storing the liquefied carbon dioxide to immediately before jetting by the nozzle is generated substantially only by the resistances of a heat exchanging device, a conduit and a valve.

9. The apparatus for producing dry ice according to any of claims 5 to 8, wherein the device for supercooling the liquefied carbon dioxide comprises only one set of the second heat exchanging means.

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