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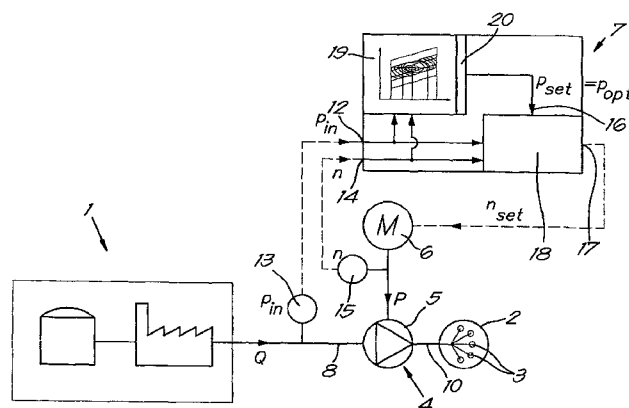
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(54) Title: METHOD FOR REGULATING THE ROTATIONAL SPEED OF A COMPRESSOR AS A FUNCTION OF THE AVAILABLE GAS FLOW OF A SOURCE AND REGULATION THEREBY APPLIED

**Fig. 1**

(57) **Abstract:** Method for controlling the speed (n) of a compressor (4) with a controller (7) as a function of the available gas flow (Q) comprising the following steps: - the setting of a desired value (p_{set}) for the inlet pressure (p_{in}); - the determination of the inlet pressure (p_{in}); - the determination of the speed (n); - the control of the speed (n) of the compressor (4) by reducing or increasing it depending on whether the inlet pressure (p_{in}) is less than or greater than the set desired value (p_{set}) until the inlet pressure (p_{in}) is equal to the set desired value (p_{set}); - the provision of the characteristic data of the compressor (4) relating to the efficiency and/or the SER as a function of the speed (n) and the inlet pressure (p_{in}); - the adjustment of the desired value (p_{set}) of the inlet pressure (p_{in}) on the basis of the aforementioned characteristic data and in such a way that after the aforementioned control of the speed (n) at the adjusted desired value (p_{set}) of the inlet pressure (p_{in}) / the efficiency of the compressor is a maximum or the SER is a minimum.

Method for regulating the rotational speed of a compressor as a function of the available gas flow of a source and regulation thereby applied.

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The present invention relates to a method for controlling the speed of a compressor as a function of the available gas flow originating from a source and a controller and compressor thereby applied.

10

More specifically, the invention is intended for screw compressors, but it is not limited to them.

Due to their high reliability, screw compressors are often
15 used in sectors of industry where gases are produced or extracted such as in the sectors of biogas production, natural gas extraction, CNG applications, CO₂ supplies for the food industry and fertiliser industry, hydrogen supplies and similar.

20

The available flow of gas originating from the source is often highly variable and must be compressed for supply to a downstream network of users, typically up to 18 bara in the event of biogas production.

25

Of course it must be the intention to be able to supply the maximum available flow from the source to the downstream network, but compressors have their limitations with regard to the permissible pressure in the inlet, which by design
30 is limited to between 1 and 4 bara for example.

Various methods are already known for controlling compressors in such applications in which the available gas flow to be compressed varies.

5 For example, a first method is known for compressors with a fixed speed whereby the compressor is switched on and off when the available flow falls below an expected nominal value or rises above an expected value. For compressors with a fixed speed it is also known to bring a bypass into
10 operation in order to bypass the compressor when the available flow is too low. The frequent switching on and off has a negative impact on the lifetime of the compressor.

15 It goes without saying that with such a limited control it does not have the possibilities to set up the most energy-efficient control in all circumstances.

Moreover, with such a control with a fixed speed when the
20 available gas flow rises above the aforementioned nominal value, the inlet pressure will rise until the inlet pressure has reached its maximum permissible value. If in that case the available flow increases further, measures have to be taken with this control to stop the inlet
25 pressure rising further, whereby these measures always come with energy losses. Moreover, as a result the production capacity of the gas source is restricted by the compressor.

A second known method makes use of a compressor with a
30 controllable variable speed, also known as a VSD (Variable Speed Drive) compressor.

This second method comprises the following steps:

- 5 - the imposition of a desired value for the inlet pressure at the inlet of the compressor;
- the determination of the inlet pressure at the inlet of the compressor;
- the determination of the speed of the compressor;
- 10 - the control of the speed of the compressor by reducing the speed when the inlet pressure is less than the set desired value of the inlet pressure, or by increasing the speed when the inlet pressure is greater than the set desired value of the inlet pressure, and this until the inlet pressure is
- 15 equal to the set desired value.

With this method, when the available gas flow increases at a certain speed of the compressor, the inlet pressure at the inlet of the compressor also increases. The

20 aforementioned control of the speed as a function of the inlet pressure will ensure that the speed increases until the inlet pressure recovers to the level of the set desired value. Due to the increase of the speed, the increased available gas flow will be fully compressed by the

25 compressor and supplied to the network. The same logic can be followed in reverse in the event of a decrease of the available gas flow.

This known method provides the advantage that it ensures

30 that, within imposed minimum and maximum limits of the compressor speed, the entire available flow can always be

supplied/sold to the network such that maximum productivity of the gas source can always be ensured.

5 An additional advantage of this second method with control of the speed is that with an available gas flow that is low, the power supplied to the compressor corresponds to the compression capacity of the gas flow, such that all energy supplied to the compressor is usefully utilised for the compression and thus no valuable energy is lost.

10

Another advantage is that the continuous control of the speed prevents the compressor from having to be switched on and off frequently, which is beneficial for the lifetime of the compressor.

15

However, a disadvantage is that the controller will always endeavour to control the speed as a function of the set inlet pressure and to maintain the inlet pressure at the set value, without the controller taking account of a maximum efficiency of the compressor consumption that can be expressed in terms of the compressor efficiency or in terms of the 'SER' (Specific Energy Requirement), which is the ratio of the power supplied to the compressor to the compressed gas flow supplied, and is expressed in
20 Joules/normal litre for, example.

25

Especially when the maximum permissible speed of the compressor is reached with the control for a set inlet pressure, the compressor will operate very inefficiently as
30 in this case an increase of the available gas flow will result in the compressor continuing to run at this maximum

speed and the inlet pressure will rise to its maximum permissible value.

The purpose of the present invention is to provide a solution to one or more of the aforementioned and other disadvantages.

To this end the invention concerns a method corresponding to the second method described above, but whereby the method according to the invention comprises the following additional steps:

- the provision of the characteristic data of the compressor relating to the efficiency and/or the SER (specific energy requirement) as a function of the speed and the inlet pressure;
- the adjustment of the desired value of the inlet pressure on the basis of the aforementioned characteristic data and in such a way that after the aforementioned control of the speed at the adjusted desired value of the inlet pressure, the efficiency of the compressor is a maximum or the SER is a minimum.

This method according to the invention thus combines the advantages of the known method with regard to the full utilisation of the available gas flow for the supply to the network, combined with the continuous aim for the most efficient energy consumption for the drive of the compressor for compressing this entire available gas flow.

For the application of the method according to the invention, the aforementioned characteristic data of the compressor concerned can preferably be determined beforehand, for example during production or already during
5 the design, and then loaded in the memory of the controller.

In the case of a compressor whereby the characteristic data are not known beforehand, it is possible to determine these
10 data experimentally on an ad hoc basis by determining the efficiency and/or the SER for successive steady operating points during the use of the compressor, and storing them in the memory as a function of the speed and the inlet pressure.

15 This can be done during the normal use of the compressor by determining the SER whenever it reaches a steady situation with a certain inlet pressure and speed, and then loading it in the memory for each new steady state or to update
20 existing data.

In this way a graph or table of the characteristic data of the compressor is built up point by point and is continually updated.

25 The controller is thus self-learning such that the data in the memory automatically take account of any signs of wear and other phenomena that affect the efficiency and the SER.

30 Preferably at least during the commissioning of the compressor, the characteristic data of the compressor

concerned are determined over the entire operating region of the compressor and are stored in the memory.

According to a preferred aspect, to determine the
5 characteristic data of the compressor concerned over the entire operating region, the controller is provided with a program to have the compressor operate successively at different discrete operating points within the
10 aforementioned operating region by setting the corresponding desired value of the inlet pressure and the speed for each operating point, for example in incremental steps.

Industrial processes where gas is produced often have to
15 contend with harsh and changeable conditions. In these applications, preference is often given to reliable compressors such as screw compressors, rather than being concerned with efficient energy consumption. Thanks to the invention it is now also possible to choose this type of
20 compressor, not only for its reliability, but also for its efficient application possibilities.

The invention also relates to a controller for controlling the speed of a compressor as a function of the available
25 gas flow originating from a gas source that enables the method according to the invention to proceed autonomously.

To this end the invention concerns a controller that is provided with:

- 30 - an input for a signal that is representative of the inlet pressure p_{in} at the inlet of the compressor;

- an input for a signal that is representative of the speed n of the compressor;
 - a desired value p_{set} to be set for the inlet pressure p_{in} ; and,
 - 5 - an algorithm for controlling the speed (n) of the compressor by reducing the speed n when the inlet pressure is less than the set desired value of the inlet pressure, or by increasing the speed when the inlet pressure is greater than the set desired value
 - 10 of the inlet pressure, and this until the inlet pressure is equal to the set desired value,
- with the characteristic that the controller is further provided with:
- a memory in which the characteristic data of the
 - 15 compressor are stored or can be stored that relate to the efficiency and/or the SER (specific energy requirement) of the compressor as a function of the speed and the inlet pressure; and,
 - an additional algorithm to adjust the aforementioned
 - 20 desired value of the inlet pressure, on the basis of the aforementioned characteristic data in the memory, in such a way that after the aforementioned control of the speed at the adjusted desired value of the inlet pressure the efficiency of the compressor is a maximum
 - 25 or the SER is a minimum.

Preferably the controller is also provided with an algorithm to automatically determine the aforementioned characteristic data of the compressor concerned during the

30 use of the compressor and to store them in the memory of the controller point by point.

This provides the advantage that the controller can be applied to any compressor, even without knowing the characteristic data of the compressor concerned or without
5 these characteristics first having to be determined experimentally.

To this end the controller is provided with an additional input for a signal that is representative of the power
10 supplied to the compressor, whereby this signal can be used by the algorithm to determine the efficiency and/or the SER and to store them in the memory with the characteristic data as a function of the speed and the inlet pressure.

15 Optionally the controller can be provided with a program to allow the compressor to operate autonomously at different successive operating points within the operating region of the compressor by setting the corresponding desired value of the inlet pressure and the speed for each operating
20 point, for example in incremental steps.

For the commissioning of a compressor whose characteristics are not known, this enables these characteristics to be mapped out for the application of the method according to
25 the invention.

Of course the invention also relates to a compressor that is provided with such a controller according to the invention and to the use of such a compressor for the
30 supply of gas originating from a source with a variable available flow with the aim, within certain limits, of

being able to supply the entire available gas flow from the source to a downstream network of users with the highest possible efficiency and/or the lowest possible SER.

5 With the intention of better showing the characteristics of the invention, a few preferred applications of the method according to the invention for controlling the speed of a compressor as a function of the available gas flow and a controller and compressor thereby applied are described
10 hereinafter, by way of an example without any limiting nature, with reference to the accompanying drawings, wherein:

figure 1 schematically shows a perspective view of a
15 compressor according to the invention set up in an industrial environment where biogases are produced to be supplied to a consumer network;

figures 2 to 7 show a few simplified graphs relating to the characteristic data of the compressor of figure
20 1;

figure 8 shows an arrangement such as that of figure 1, but with a variant embodiment of a compressor according to the invention.

25 By way of an example, figure 1 shows a source 1 of gas in the form of an industrial installation 1 for the production of biogas.

It is typical for such an installation that the available
30 produced quantity of gas varies over time and thus also the

available flow Q for the supply of the biogas to a network
2 of consumers 3.

It is of course the intention of the producer of the biogas
5 to be able to sell the entire available flow Q to the
consumers 3 to a maximum.

For the supply of the biogas, this first pressure of this
biogas has to be increased, in this case by making use of a
10 compressor 4 with a compressor element 5 driven by a motor
6 with variable speed and provided with a controller 7
according to the invention for controlling the speed n .

The compressor element 5 is a screw compressor for example,
15 whose characteristics are shown very schematically in the
graphs of figures 2 to 7, which were drawn up
experimentally beforehand, for example, for the compressor
element 5 concerned for different imposed operating regimes
within the operating region of the compressor element 5.

20 This operating region is bounded by a minimum and a maximum
permissible speed, $n_{\min}$ and $n_{\max}$ respectively, and a minimum
and maximum permissible inlet pressure p_{in} at the inlet 8
of the compressor element 5, p_{inmin} and p_{inmax} respectively,
25 for which the compressor element 5 has been designed.

Figure 2 shows, within the aforementioned operating region,
the operating lines 9 of the flow Q as a function of the
inlet pressure p_{in} , each time for a certain speed n of the
30 compressor element 5 and this for a constant outlet
pressure at the outlet 10 of the compressor element.

It follows from this that at a certain speed n the flow Q increases with the inlet pressure p_{in} and that at a certain imposed inlet pressure p_{set} the flow Q increases with the speed n .

For the same compressor element 5, figure 3 shows the graph of the specific energy requirement (SER) as a function of the inlet pressure p_{in} and the flow Q , whereby the concentric rings 11 present the curves of equal SER and whereby the SER increases from the centre ring 11 to the outermost ring 11.

The SER is expressed as being the required power P to be supplied by the motor 6 to compress a flow Q at an inlet pressure p_{in} and is expressed in Joules/normal litre, for example.

It goes without saying that the SER is inversely proportional to the efficiency of the compressor element 5.

In figure 4 the two graphs of figures 2 and 3 have been combined into a single drawing.

With known controllers the speed n of the compressor element 5 is controlled as a function of the available gas flow Q originating from the source 1 by:

- setting a desired value for the inlet pressure, for example the desired value p_{set1} in figure 4, and

- controlling the speed n of the motor 6 by reducing the speed n when the inlet pressure p_{in} is lower than the set desired value p_{set1} , or by increasing the speed n when the inlet pressure p_{in} is higher than this set desired value p_{set1} , and this until the inlet pressure p_{in} is equal to the set desired value p_{set1} .

In this way it can be ensured that the available flow Q is also fully supplied to the network 2.

10

Indeed, if when starting from the operating point I in figure 4 at a flow Q_1 , a speed n_1 and a desired value p_{set1} , the available flow Q supplied by the source 1 increases to Q_2 in figure 4 for example, the inlet pressure p_{in} will increase for a constant outlet pressure.

15

In this case, according to the aforementioned known controller the speed n will increase to n_2 such that a new steady operating point II is reached at a higher flow Q_2 that is equal to the available flow.

20

For a given available flow Q_1 , by setting p_{set} an operating region can be overlapped that is defined in figure 4 by the parallelogram bounded by the aforementioned values p_{inmin} and p_{inmax} and by the operating lines of the speed going through the extreme operating points Q_1, p_{inmin} and Q_1, p_{inmax} .

25

In practice, with known screw compressors two desired values are set for the inlet pressure p_{in} , for example, for example p_{set1} and p_{set2} in figure 4.

30

It is clear that with these desired values the corresponding SER in figure 4 is not optimum and that according to the known control of the speed n as a function of one or two desired values of the inlet pressure p_{in} , it
5 will only operate in optimum conditions of minimum SER by chance as these optimum conditions also depend on the available flow Q .

The invention presents a comparable control as described
10 above, but with the difference that the desired value of the inlet pressure p_{set} is adjusted on the basis of the aforementioned characteristic data and in such a way that after the aforementioned control of the speed at the adjusted desired value p_{set} of the inlet pressure, the
15 efficiency of the compressor is a maximum, or in other words the SER is a minimum.

In the case of figure 4 this adjusted desired value for a flow Q_1 corresponds to the optimum desired value p_{opt} , which
20 in reality is a function of the available flow Q .

In order to enable this control, the controller 7 is provided with:

- an input 12 for a signal that is representative of the
25 inlet pressure p_{in} that originates for example from a pressure sensor 13 at the inlet 8 of the compressor 4;
- an input 14 for a signal that is representative of the
30 speed n of the compressor element 5 or the motor 6 with a controllable variable speed and which for example originates from a tachometer 15;

- a desired value p_{set} for the inlet pressure p_{in} to be set at 16;
- 5 - an output 17 for the control signal n_{set} for the desired speed of the compressor element 5;
- an algorithm 18 for controlling the speed n of the compressor element 5 by reducing the speed n when the
10 inlet pressure p_{in} is lower than the desired value p_{set} of the inlet pressure, or by increasing the speed n when the inlet pressure p_{in} is higher than the desired value p_{set} of the inlet pressure p_{in} , until the inlet pressure p_{in} is equal to the desired value p_{set} ;
- 15 - a memory 19 in which the characteristic data of the compressor element 5 are stored, for example in the form of the graph of figure 4 or in tabular or formula form, whereby this graph is preferably stored in the
20 memory 19 beforehand; and,
- an additional algorithm 20 to determine the value p_{opt} of the desired value p_{set} of the inlet pressure on the basis of the aforementioned characteristic data in the
25 memory 19 and to adjust this accordingly such that the compressor 4, after controlling the speed n using the algorithm 18 with the desired value p_{opt} , consumes the least power P to compress the available gas flow and to supply it to the network 2.

In this way the producer of the gas is assured that the entire available flow of gas can always be supplied to the network 2 and this with the lowest specific consumption.

5 Figures 5 to 7 show an alternative or additional form of the characteristic data of the compressor element 5 that could be stored in the memory 19. In this case in figure 5 these characteristic data are stored in the form of diagrams with an inlet pressure p_{in} and speed n that show
10 the operating curves along which the flow Q and the SER respectively are constant, and in figure 7 both diagrams are shown in one single diagram.

Instead of the SER the efficiency can also form part of the
15 aforementioned characteristic data of the compressor element 5.

Instead of determining or calculating the characteristic data experimentally beforehand, a self-learning intelligent
20 controller 7 can be used that determines these characteristic data, of figure 4 for example, point by point during the use of the compressor 4 and stores them in the memory 19 in the form of a graph or table.

25 To this end the controller 7 can also be equipped with a second additional algorithm 21, as shown in figure 8, to automatically determine the aforementioned characteristic data such as the SER of the compressor 4 concerned during the use thereof and to store them point by point in the
30 memory 19 of the controller.

In this respect the intelligent controller 7 can be provided with an additional input 22 for a signal that is representative of the power P supplied to the compressor element 5 that originates from a transducer 23 for example, whereby this signal is used by the additional algorithm 21 to determine the SER and to store it in the memory 19 with the characteristic data as a function of the speed n and the inlet pressure p_{in} .

To this end, in the second additional algorithm 21 a program can be integrated to allow the compressor 4 to successively operate at different operating points within the operating region of the compressor by setting the corresponding desired value of the inlet pressure and speed for each operating point, for example in incremental steps.

It goes without saying that the algorithm 21 can be used once when commissioning a compressor 4, after which the transducer 23 can be removed, but this algorithm 21 can also be used continually or occasionally during the lifetime of the compressor 4 to continuously update the characteristic data in the memory 19 in order to take account of the effect of wear on the SER for example.

Although the invention is primarily applicable to screw compressors, the method described and the intelligent controller 7 thereby applied can also be used with other types of compressors.

The present invention is by no means limited to the embodiments described as an example and shown in the

drawings, but such a method according to the invention for
controlling the speed of a compressor as a function of the
available gas flow and a controller and compressor thereby
applied can be realised according to different variants
5 without departing from the scope of the invention.

Claims.

1.- Method for controlling the speed (n) of a compressor
5 (4) as a function of the available gas flow (Q) originating from a source (1), whereby the compressor (4) is provided with a controller (7) for controlling the speed (n) and whereby the method comprises the following steps:

- 10 - the setting of a desired value (p_{set}) for the inlet pressure (p_{in}) at the inlet (8) of the compressor (4);
- the determination of the inlet pressure (p_{in}) at the inlet (8) of the compressor (4);
- the determination of the speed (n) of the compressor (4);
- 15 - the control of the speed (n) of the compressor (4) by reducing the speed (n) when the inlet pressure (p_{in}) is less than the set desired value (p_{set}) of the inlet pressure (p_{in}), or by increasing the speed (n) when the inlet pressure (p_{in}) is greater than the set
- 20 desired value (p_{set}) of the inlet pressure (p_{in}), and this until the inlet pressure (p_{in}) is equal to the set desired value (p_{set});

characterised in that the method comprises the following additional steps:

- 25 - the provision of the characteristic data of the compressor (4) relating to the efficiency and/or the SER (specific energy requirement) as a function of the speed (n) and the inlet pressure (p_{in});
- the adjustment of the desired value (p_{set}) of the inlet
- 30 pressure (p_{in}) on the basis of the aforementioned characteristic data and in such a way that after the

aforementioned control of the speed (n) at the adjusted desired value (p_{set}) of the inlet pressure (p_{in}), the efficiency of the compressor is a maximum or the SER is a minimum.

5

2.- Method according to claim 1, characterised in that the aforementioned characteristic data of the compressor (4) concerned are determined beforehand and entered in the memory (19) of the controller (7).

10

3.- Method according to claim 1, characterised in that the aforementioned characteristic data of the compressor (4) concerned are automatically determined during the use of the compressor (4) and are stored in the memory (19) of the controller (7).

15

4.- Method according to claim 3, characterised in that to determine the characteristic data of the compressor (4) point by point during the use of the compressor (4), the efficiency and/or the SER is determined for successive steady operating points and stored in the memory (19) as a function of the speed (n) and the inlet pressure (p_{in}).

20

5.- Method according to claim 4, characterised in that to determine the efficiency and/or the SER, the flow (Q) of compressed gas and the power (P) supplied to the compressor to drive the compressor (4) are determined.

25

6.- Method according to any one of the claims 3 to 5, characterised in that at least during the commissioning of the compressor (4), the characteristic data of the

30

compressor (4) concerned are determined over the entire operating region of the compressor (4) and are stored in the memory (19).

5 7.- Method according to claim 6, characterised in that to determine the characteristic data of the compressor (4) concerned over the entire operating region of the compressor (4), the controller (7) is provided with a program to get the compressor (4) to operate successively
10 at different operating points within the aforementioned operating region by setting the corresponding desired value (pset) of the inlet pressure (p_{in}) and the speed (n) for each operating point, for example according to incremental steps.

15

8.- Method according to any one of the previous claims, characterised in that it is applied to a screw compressor.

9.- Method according to any one of the previous claims,
20 characterised in that it is applied to the supply of gas originating from a source (1) with a variable available flow (Q), in order to be able to supply the entire available flow of gas (Q) from the source (1) to a downstream network (2) of users (3) with the highest
25 possible efficiency and/or with the lowest possible SER.

10.- Controller for controlling the speed of a compressor (4) as a function of the available flow of gas (Q) originating from a source (1), whereby the controller (7)
30 is provided with:

- an input (12) for a signal that is representative of the inlet pressure (p_{in}) at the inlet (8) of the compressor (4);
- an input (14) for a signal that is representative of the speed (n) of the compressor (4);
- a desired value (p_{set}) to be set for the inlet pressure (p_{in}), and,
- an algorithm (18) for controlling the speed (n) of the compressor (4) by reducing the speed (n) when the inlet pressure (p_{in}) is less than the set desired value (p_{set}) of the inlet pressure (p_{in}), or by increasing the speed when the inlet pressure (p_{in}) is greater than the set desired value (p_{set}) of the inlet pressure, and this until the inlet pressure (p_{in}) is equal to the set desired value (p_{set}),

characterised in that the controller is further provided with:

- a memory (19) in which the characteristic data of the compressor (4) are stored or can be stored that relate to the efficiency and/or the SER (specific energy requirement) of the compressor (4) as a function of the speed (n) and the inlet pressure (p_{in}); and,
- an additional algorithm (20) to adjust the aforementioned desired value (p_{set}) of the inlet pressure, on the basis of the aforementioned characteristic data in the memory (19), in such a way that after the aforementioned control of the speed (n) at the adjusted desired value (p_{set}) of the inlet pressure (p_{in}) the efficiency of the compressor (4) is a maximum or the SER is a minimum.

11.- Controller according to claim 10, characterised in that it is additionally provided with an algorithm (21) to automatically determine the aforementioned characteristic data of the compressor (4) concerned during the use of the compressor (4) and to store them point by point in the memory (19) of the controller (7).

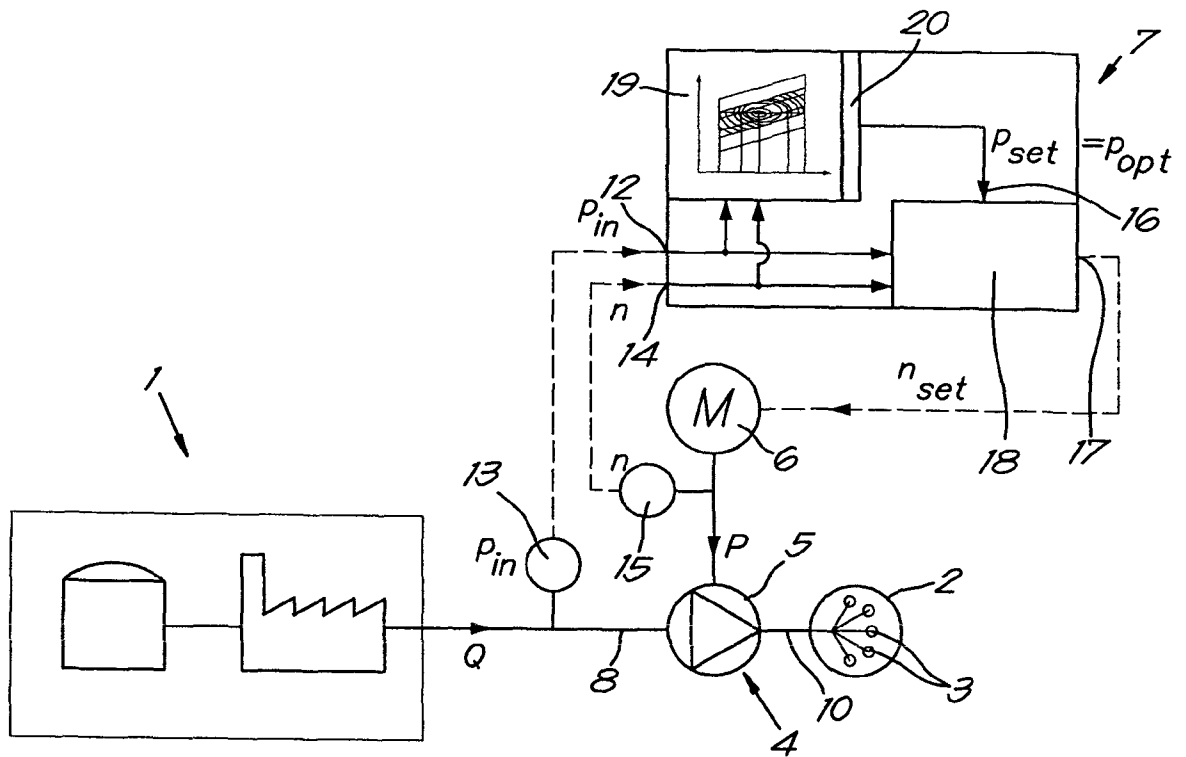
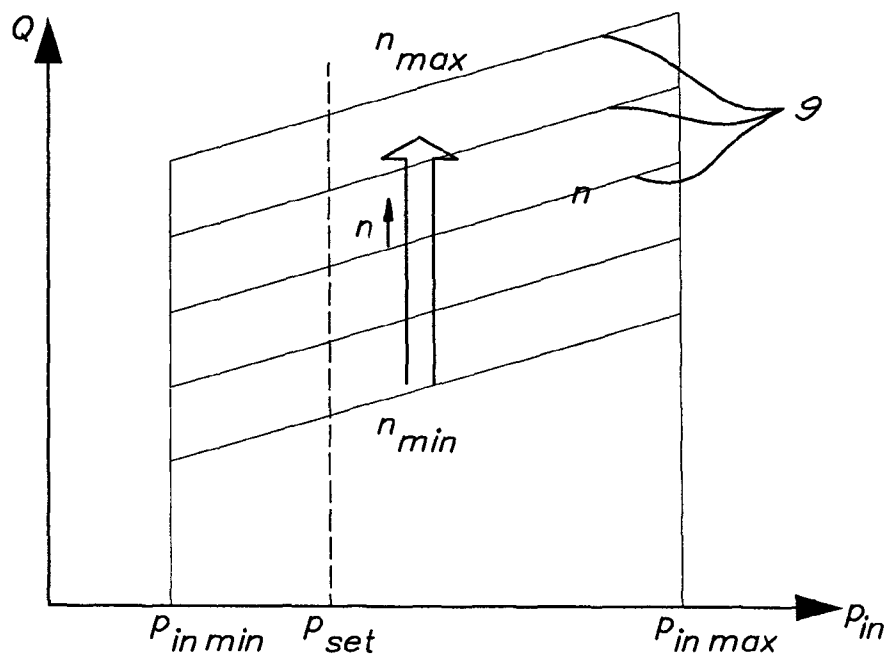
12.- Controller according to claim 11, characterised in that it is provided with an additional input (22) for a signal that is representative of the power (P) supplied to the compressor (4), whereby this signal is used by the algorithm (22) to determine the efficiency and/or the SER and to store or overwrite them in the memory (19) with the characteristic data as a function of the speed (n) and the inlet pressure (p_{in}).

13.- Controller according to any one of the claims 10 to 12, characterised in that it is provided with a program to get the compressor (4) to operate successively at different operating points in the operating region of the compressor (4) by setting the corresponding desired value (p_{set}) of the inlet pressure (p_{in}) and the speed (n) for each operating point, for example in incremental steps.

14.- Compressor, characterised in that it is provided with a controller (7) according to any one of the claims 10 to 13.

15.- Use of a compressor for the supply of gas originating from a source (1) with a variable available flow (Q), characterised in that use is made of a compressor (4)

according to claim 14 or 15 to be able to supply the entire available flow of gas (Q) from the source (1) to a downstream network (2) of consumers (3) with the highest possible efficiency and/or the lowest possible SER.

*Fig. 1**Fig. 2*

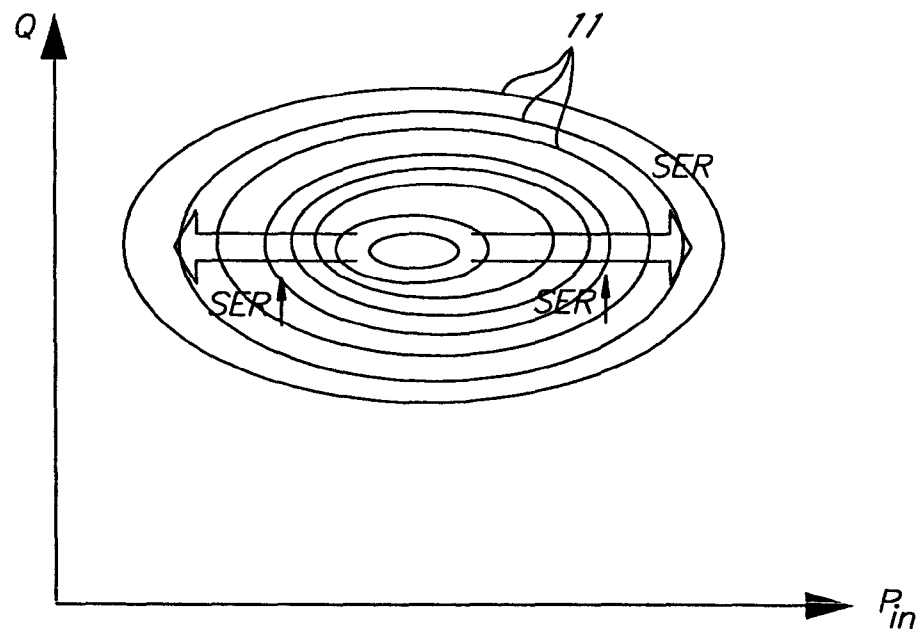


Fig.3

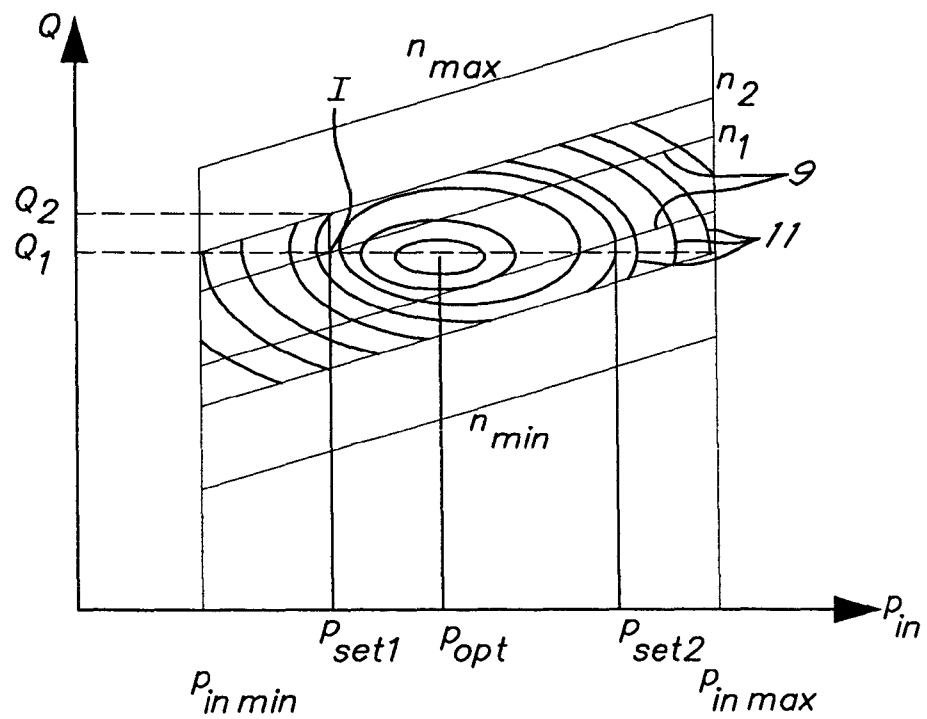
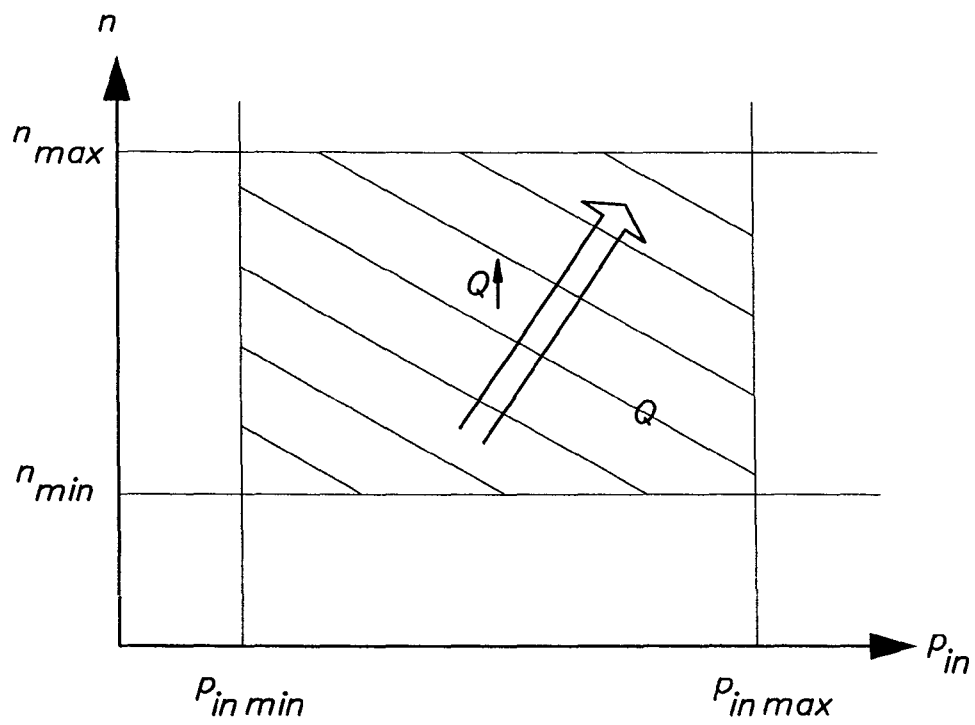
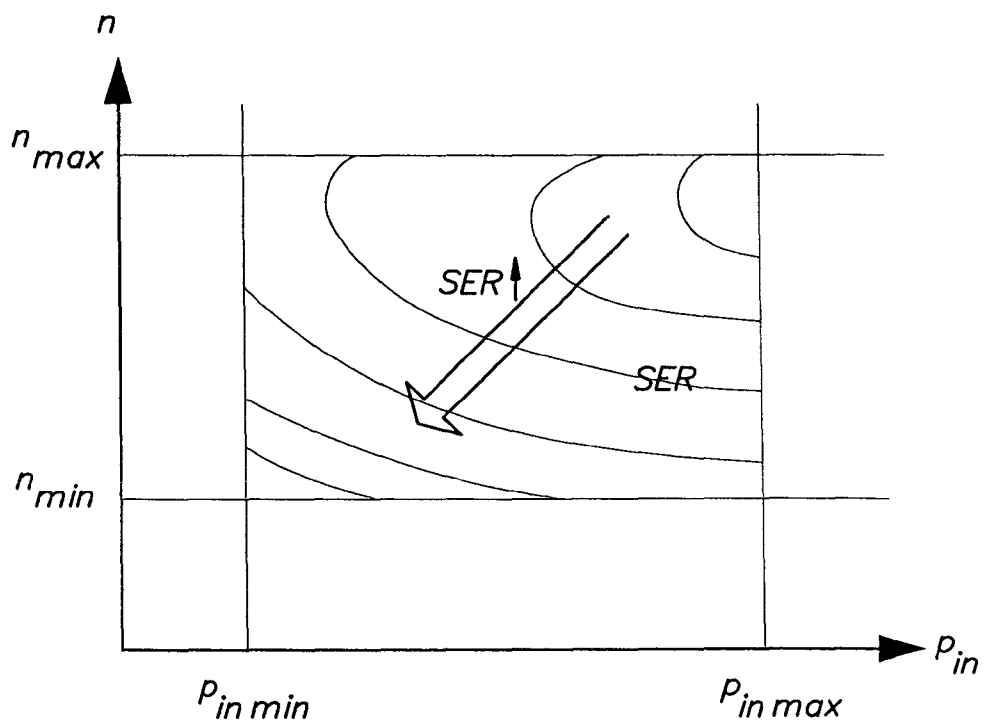


Fig. 4

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*Fig.5**Fig.6*

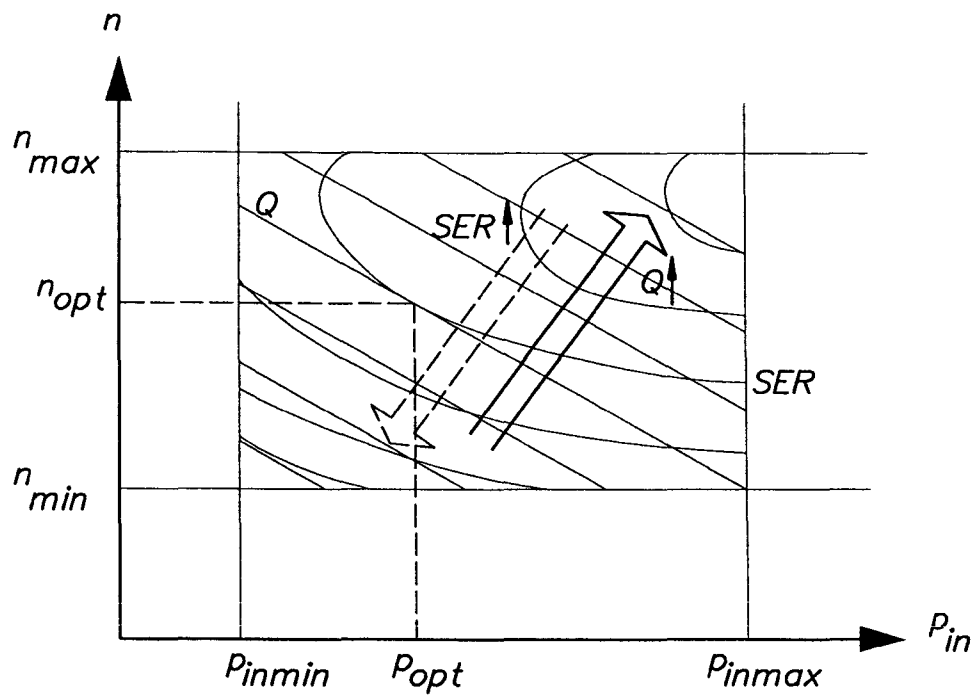


Fig. 7

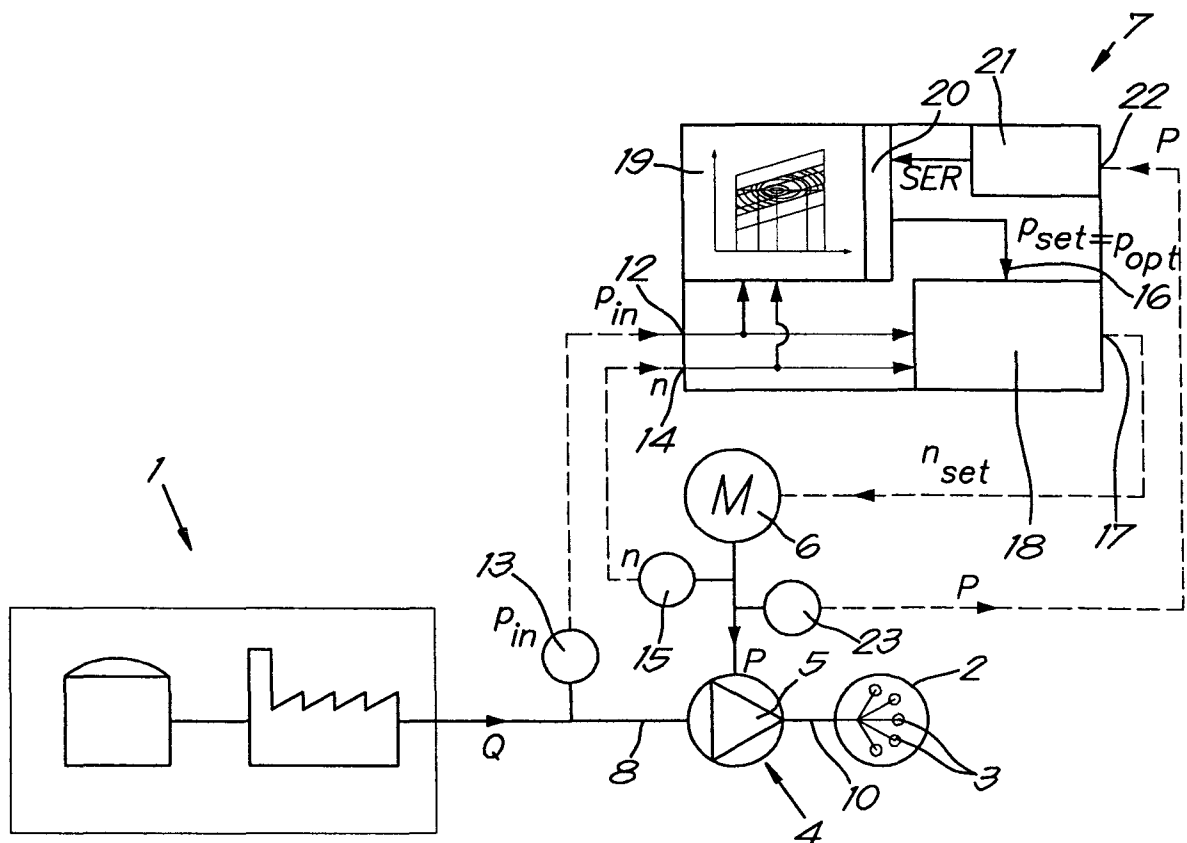


Fig. 8