



(51) International Patent Classification:
F01K 13/02 (2006.01)

(21) International Application Number: PCT/BE2015/000023

(22) **International Filing Date:** 11 May 2015 (11.05.2015)

(25) **Filing Language:** Dutch

(26) **Publication Language:** English

(30) Priority Data:
2014/0380 19 May 2014 (19.05.2014) BE

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM,

DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

— with international search report (Art. 21(3))

— before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

(54) Title: DEVICE AND METHOD FOR EXPANDING A GASFLOW AND FOR SIMULTANEOUSLY RECUPERATING ENERGY FROM THE GASFLOW

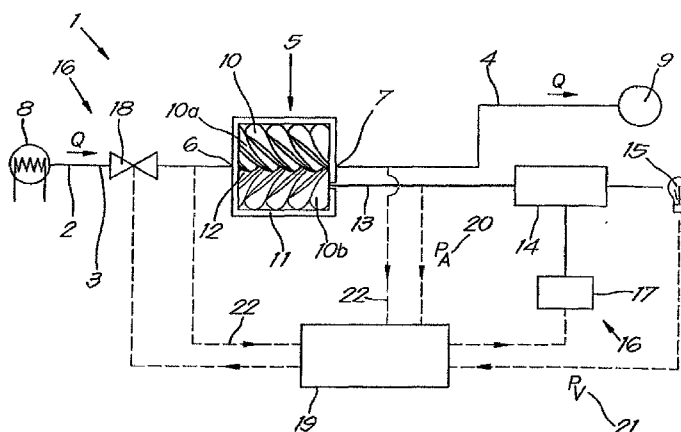


Fig. 1

(57) Abstract: Method for expanding a gas flow (Q) and for the simultaneous recovery of energy by driving the gas flow (Q) through a pressure reducing unit (5) with a rotor (10) with an outgoing shaft (13) for the conversion of energy from the gas flow (Q) into mechanical energy on this shaft (13), whereby the method consists of controlling the pressure (Pu) at the outlet (7) of the pressure reducing unit (5) within a preset operating range between a minimum pressure (Pmin) and a maximum pressure (pmax), taking account of the inlet and outlet conditions and the properties of the pressure reducing unit (5), so that the outgoing power remains constant, remains a maximum, remains a minimum or so that an optimum energy conversion is obtained.

Method and device for expanding a gas flow and for the simultaneous recovery of energy from this gas flow.

- 5 The present invention relates to a method for expanding a gas flow and for the simultaneous recovery of energy from this gas flow.

More specifically, the invention is intended for expanding
10 a gas flow and for the simultaneous recovery of energy from this gas flow by driving the gas flow through a pressure reducing unit with a rotor with an outgoing shaft for the conversion of energy from the gas flow into mechanical energy on this shaft.

15

Gases, for example steam, are often used in industrial processes as a driving force or for the process.

Thereby the gas is first raised to a higher energy level by
20 heating and/or compression to a higher pressure, to then expand the gas in the process to a demanded reduced pressure and temperature, depending on the demanded gas flow downstream, by driving the gas through a pressure reducing unit.

25

It is known that traditional pressure reducing units expand the pressure of the gas flow at the outlet to a preset value.

- 30 This preset value can be fixed or variable and is imposed by the downstream installations for example.

With a variable value a different value for the pressure at the outlet is preset when this is demanded by downstream installations.

5

In both cases a controller will be provided with the operating point of the pressure reducing unit to maintain the instantaneous preset value for the pressure at the outlet.

10

In many of these conventional pressure reducing units energy is also generated by recovering energy from the gas flow that is expanded by means of the installation.

15 However, the control is done entirely on the basis of the requirements of the gas flow.

A disadvantage is that the energy recovery is not always optimum, as no account is taken of the characteristics of
20 the pressure reducing unit itself.

Another disadvantage is that the outgoing power cannot be controlled or kept stable.

25 The purpose of the present invention is to provide a solution to at least one of the aforementioned and other disadvantages.

To this end the object of the present invention is a method
30 for expanding a gas flow and for the simultaneous recovery of energy from this gas flow by driving the gas flow

through a pressure reducing unit with a rotor with an outgoing shaft for the conversion of energy from the gas flow into mechanical energy on this shaft, whereby the method consists of controlling the pressure at the outlet
5 of the pressure reducing unit within a preset operating range between a minimum pressure $p_{\min}$ and a maximum pressure $p_{\max}$ at the outlet, taking account of the inlet and outlet conditions and the properties of the pressure reducing unit so that the outgoing power remains constant, remains a
10 maximum or so that an optimum energy conversion is obtained.

The operating range for the pressure at the outlet can be imposed by the downstream installations for example.

15

An advantage of such a method is that the outgoing power produced by the pressure reducing unit can be controlled as the pressure at the outlet can be freely chosen within this aforementioned operating range, whereby not only is account
20 taken of the requirements of the downstream installation but also of the characteristics of the pressure reducing unit itself, for example, that determine the efficiency of the energy conversion.

25 Preferably the method comprises the step of determining the outgoing power demanded on the outgoing shaft and taking the following steps on the basis of this:

- when there is a demand for outgoing power, adjusting the pressure at the outlet such that either:
30 - according to choice, either the outgoing power is kept constant and equal to the demanded outgoing power, or

it is a maximum by adjusting the pressure to the
aforementioned minimum pressure $p_{\min}$; or

- an optimum energy conversion is obtained whereby the
pressure reducing unit operates at optimum efficiency by
5 taking account of the characteristics of the pressure
reducing unit itself, whereby the pressure at the outlet is
adjusted to a pressure to be determined between $p_{\min}$ and
 $p_{\max}$, whereby the maximum system efficiency is reached;

- when there is no demand for outgoing power,
10 adjusting the pressure at the outlet to the maximum
pressure $p_{\max}$.

This has the advantage that account can be taken of the
energy demand from electricity consumers, for example, that
15 are connected to a generator that is connected to the
outgoing shaft and which converts the mechanical energy
into electrical energy.

Because the outgoing power on the shaft can be kept
20 constant or at a maximum, a specific power can be assured,
and the aforementioned electricity consumers can be
supplied with electric power at all times.

Because the characteristics of the pressure reducing unit
25 itself can be taken into account, the energy conversion can
be kept as optimum as possible, taking account of the
requirements of the downstream installation. In other
words, energy can always be recovered from the gas flow in
the most efficient way.

When no outgoing power is required on the outgoing shaft, the pressure at the outlet will be chosen to be a maximum.

This has the advantage that as much energy as possible
5 remains in the gas flow and in the industrial process.

In a practical embodiment, when the pressure at the outlet is controlled such that the outgoing power on the outgoing shaft remains constant and equal to the demanded outgoing
10 power, the method consists of providing a set of operating curves for different inlet and outlet conditions that define the relationship between the outgoing power on the outgoing shaft and the pressure at the outlet, and whereby the method comprises the step of determining the inlet and
15 outlet conditions and taking the following steps on the basis of this:

- determining the operating curve applicable at that time from the aforementioned set of operating curves;
- determining the operating point on this curve, for
20 which the outgoing power is equal to the demanded outgoing power, and the corresponding pressure at the outlet;
- adjusting the pressure at the outlet to the aforementioned corresponding pressure.

25 This method has the advantage that it is easy to implement.

In another practical embodiment when the pressure at the outlet is controlled such that the outgoing power on the outgoing shaft remains constant and is equal to the
30 demanded outgoing power, the method comprises the step of

determining the outgoing power on the outgoing shaft and taking any one of the following steps on the basis of this:

- when the outgoing power is greater than the demanded outgoing power, increasing the pressure at the outlet;

5 - when the outgoing power is less than the demanded outgoing power, decreasing the pressure at the outlet;

and this until the outgoing power on the outgoing shaft is equal to the demanded outgoing power.

10 As, as is known, there is a monotonic descending relationship between the pressure at the outlet and the outgoing power, such a method is also simple to realise without there being a need for considerable computing capacity.

15

The invention also concerns a device for expanding a gas flow and for the simultaneous recovery of energy from this gas flow, whereby this device comprises a pressure reducing unit with an inlet and an outlet for the gas flow and with

20 a rotor with an outgoing shaft for the conversion of the energy from the gas flow into mechanical energy on this shaft, means for controlling the pressure at the outlet, whereby the device is provided with a controller for the control of the aforementioned means to adjust the pressure

at the outlet within a set operating range between a

25 minimum pressure $p_{\min}$ and a maximum pressure $p_{\max}$ at the outlet, so that, taking account of the inlet and outlet conditions and the properties of the pressure reducing unit

(5), the outgoing power remains constant or such that an

30 optimum energy conversion is obtained.

With the intention of better showing the characteristics of the invention, a few preferred variants of a method according to the invention for expanding a gas flow and for the simultaneous recovery of energy from this gas flow and
5 a device thereby applied are described hereinafter by way of an example, without any limiting nature, with reference to the accompanying drawings, wherein:

figure 1 schematically shows a device according to the
10 invention;

figure 2 schematically shows an operating curve of the pressure reducing unit used in the device of figure 1;

figure 3 schematically shows the operating curve of figure 2 indicating different operating points in the
15 application of a method according to the invention;

figure 4 schematically shows the relationship between the efficiency of the energy conversion and the speed of the pressure reducing unit.

20 The device shown in figure 1 essentially comprises a gas pipe 2 with an inlet pipe 3 and an outlet pipe 4, whereby a pressure reducing unit 5, in the form of an expander with an inlet 6 connection to the inlet pipe 3 and an outlet 7 to which the outlet pipe 4 connects, is provided in the gas
25 pipe 2.

In the example, the inlet pipe 3 is connected to a boiler 8 or any other source of gas at high temperature and/or pressure for the supply of a gas flow Q to the inlet pipe 3
30 of the gas pipe 2 that connects to a downstream installation 9 that uses the gas process-wise as a driving

force or as a process gas for a chemical reaction or similar.

In the following we will assume that the gas is steam.
5 However, it is not excluded that another gas or gas mixture is used.

In the example shown, the pressure reducing unit 5 is constructed as a screw expander with a double rotor 10 that
10 is rotatably affixed in a housing 11 with the aforementioned inlet 6 and outlet 7.

As is known, the double rotor 10 is formed by two helical rotors 10a, 10b with lobes that mesh together, and which
15 together with the housing 11 at the inlet define a gastight chamber 12 that, when the rotors 10a, 10b are turning, moves from the inlet 6 to the outlet 7 and thereby becomes increasingly larger so that the gas trapped in this gastight chamber 12 can expand.

20 One of the two rotors 10b is affixed to an outgoing shaft 13 that extends through the housing 11 to the outside, and which in this case is mechanically coupled to a load 14, for example in the form of a generator that is used for the
25 electricity supply to electricity consumers 15 that are connected thereto and which is schematically shown in the example by a lamp.

The device 1 is provided with means 16 for controlling the
30 pressure p_u at the outlet 7.

A first possibility for controlling the pressure p_u is formed in the example by a variable speed control 17 for controlling the speed of the outgoing shaft 13 that is connected to the load 14 in order to change the counter-
5 torque on the outgoing shaft 13 and thus to influence the speed.

It is not excluded that the speed of the outgoing shaft 13 is controlled in another way than by adjusting the load 14
10 of the resistance-providing torque.

A second possibility for controlling the pressure p_u at the outlet 7 is provided in this example by a variable choke 18, for example in the form of a choke valve that is
15 provided at the inlet 6, and whereby the gas flow 8 that is allowed through the pressure reducing unit 5 can be controlled by closing or opening the choke valve more or less.

20 However, it is also possible that the gas flow Q allowed through the pressure reducing unit 5 is controlled in another way than by means of a choke 13.

Notwithstanding the fact that both the variable speed
25 control 17 and the control of the flow rate by means of the choke 18 are present in the example of figure 1, it is possible to provide only one of the two controls.

The device also comprises a controller 19 that is connected
30 to the variable speed control 17 and the choke 18.

The controller 19 is also connected to means 20 for determining the outgoing power P_A on the outgoing shaft 13 and means 21 for determining the demanded outgoing power P_V .

5

The device 1 is also provided with means 22 for determining the inlet and outlet conditions, the signal from which is connected to the controller 19.

10 The operation of the device 1 is very simple and as follows.

During use the pressure reducing unit 5 will be supplied with steam originating from the boiler 8, for example, to which the inlet pipe 3 is connected. A gas flow Q will be
15 allowed through the pressure reducing unit 5.

As a result the double rotor 10 of the pressure reducing unit 5 is driven, whereby the steam undergoes an expansion
20 and one of the two rotors, i.e. rotor 10b, will drive the outgoing shaft 13 such that the steam energy is converted into mechanical energy on the outgoing shaft 13 to which the generator is connected.

25 The generator will produce electrical energy that can be supplied to the electricity consumers 15.

The expanded steam is removed via the outlet 7 from the pressure reducing unit 5 via the outlet pipe 4 to a
30 downstream installation 9. This steam can also be guided to

a production process or fed back to the boiler 8 in a circuit process.

5 The controller 19 will control the pressure reducing unit 5 such that the pressure p_u at the outlet 7 lies within a preset operating range that is defined by a minimum pressure $p_{\min}$ and a maximum pressure $p_{\max}$.

10 For given inlet and outlet conditions, within this operating range, the outgoing power P_A on the outgoing shaft 13 will vary, as schematically shown in the operating curve of figure 2 by a descending line, which shows an idealised presentation of the monotonic descending relationship between the outgoing power P_A and the pressure p_u at the outlet 7. Upon a change of the inlet and/or outlet conditions the operating curve can move up or down.

15 However, this monotonic descending relationship does not need to be linear, but for simplicity and clarity in this case this relationship is shown by a straight line.

20 In order to determine the pressure p_u at the outlet 7, the controller 19 makes use of the variable speed control 17 and/or the choke 18 at the inlet 6.

25 In order to determine the pressure p_u at the outlet 7, the controller 19 will determine the demanded outgoing power P_v using the means 21 to determine the demanded outgoing power P_v .

When there is no demand for outgoing power, the controller will adjust the pressure p_u at the outlet 7 such that it is a maximum and equal to $p_{\max}$.

- 5 This corresponds to the point X in figure 2 whereby the outgoing power P_A on the outgoing shaft 13 is at least equal to P_X .

As a result as much energy as possible will be maintained
10 in the gas flow Q and in the industrial process and only a minimum of outgoing power P_A will be produced, whereby this outgoing power P_A cannot be usefully used at that time.

When there is a demand for outgoing power, the controller
15 19 can adjust the pressure p_u such that the outgoing power P_A is a maximum by setting the pressure p_u at the outlet 7 equal to $p_{\min}$. This corresponds to the point Y in figure 2.

The pressure reducing unit 5 will then produce the maximum
20 power P_Y possible within the operating range defined by $p_{\min}$ and $p_{\max}$.

It is possible for the controller 19 to adjust the pressure
25 p_u such that the outgoing power P_A is a minimum when there is a demand for outgoing power.

Alternatively, when there is a demand for outgoing power the controller 19 can adjust the pressure p_u at the outlet 7 such that the outgoing power P_A is equal to the demanded
30 outgoing power P_V .

In order to realise this, the controller 19 comprises a set of operating curves for different inlet and outlet conditions, for example, that define the relationship between the outgoing power P_A on the outgoing shaft 13 and the pressure p_u at the outlet 7.

The controller 19 also comprises an algorithm that makes use of the inlet and outlet conditions of the pressure reducing unit, in other words the pressure, temperature and gas flow at the inlet 6 and the outlet 7 that are determined by using the means 22.

On the basis of this the algorithm determines the operating curve applicable at that time from the aforementioned set of operating curves, for example the curve shown in figure 2, corresponding to the prevailing inlet and outlet conditions at that time.

The point Z_1 shows the current operating point of the pressure reducing unit 5, with a pressure p_u at the outlet 7 equal to p_1 and an outgoing power P_A on the outgoing shaft 13 equal to P_1 .

The algorithm determines the operating point on this curve where the outgoing power P_A is equal to the demanded outgoing power P_v and the corresponding pressure p_u at the outlet 7. This operating point can be the point Z_2 for example, as shown in figure 2, whereby the demanded outgoing power P_v is equal to P_2 and the corresponding pressure p_u is equal to p_2 .

The controller 19 will then adjust the pressure p_u at the outlet 7 to the aforementioned corresponding pressure p_2 . As a result the outgoing power P_A will be equal to P_2 and thus equal to the demanded outgoing power P_V under constant
5 conditions at the inlet 6 and the outlet 7.

When the inlet and/or outlet conditions and/or the demanded outgoing power P_V change, the controller 19 will repeat the aforementioned algorithm.

10

In this way the outgoing power P_A can be adjusted to the demanded outgoing power P_V , independently of the inlet and outlet conditions.

15 It is clear that when this algorithm is used, the means 20 for determining the outgoing power P_A can be omitted.

It is clear that another algorithm can be used to adjust the pressure p_u at the outlet 7 such that the outgoing
20 power P_A is equal to the demanded outgoing power P_V , such as an algorithm that is illustrated on the basis of figure 3, for example, which shows the same operating curve as that of figure 2 at the same inlet and outlet conditions.

25 This starts with an operating point of the pressure reducing unit 5 corresponding to the point Z_1 corresponding to a pressure p_u at the outlet 7 equal to p_1 and an outgoing power P_A equal to P_1 .

30 The algorithm is based on the determination of the outgoing power P_A using the means 20.

When this measured outgoing power is less than the demanded outgoing power P_v , the controller 19 will decrease the pressure p_u at the outlet 7.

5

The demanded outgoing power P_v is P_n for example, corresponding to a pressure p_n .

As the outgoing power P_1 is less than the demanded outgoing power P_n , the controller 19 will decrease the pressure p_u at the outlet 7.

The outgoing power P_A will hereby increase. The change in outgoing power P_A is measured by the aforementioned means 20 and the signal is passed on to the controller 19.

The controller 19 will decrease the pressure p_u at the outlet until the outgoing power P_A is equal to the demanded outgoing power P_n . This corresponds to an operating point Z_n whereby the pressure p_u at the outlet 7 is equal to p_n .

When the measured outgoing power P_A is greater than the demanded outgoing power P_n , the pressure p_u at the outlet 7 is now increased.

25

This is schematically in figure 3 by the operating point Z_2 corresponding to a pressure p_u at the outlet 7 equal to p_2 , and an outgoing power P_A equal to P_2 , whereby P_2 is now greater than the demanded outgoing power P_n .

30

The controller 19 will increase the pressure p_u at the outlet such that the outgoing power P_A will decrease. Ultimately the outgoing power P_A will be equal to the demanded outgoing power P_v , corresponding to the operating point Z_n .

It is clear that in this case the means 22 for determining the inlet and outlet conditions can be absent and that the controller 19 does not need to comprise a set of operating curves.

It is possible that a choke 18 is provided at the outlet 7 in the outlet pipe 4 instead of in the inlet pipe 3.

In another case the controller 19 can control the pressure reducing unit 5 such that the pressure p_u at the outlet 7 lies within the operating range defined by the minimum pressure $p_{\min}$ and the maximum pressure $p_{\max}$, whereby the pressure p_u at the outlet is chosen such that an optimum or most efficient energy conversion is always obtained.

The controller 19 will hereby take account of the inlet and outlet conditions and of the machine properties of the pressure reducing unit 5.

The machine properties determine the efficiency E at which the pressure reducing unit 5 will convert steam energy into mechanical energy on the outgoing shaft 13.

Figure 4 shows a curve as an example that shows the relationship between the speed T of the outgoing shaft 13 and the efficiency E of the energy conversion.

- 5 As can be seen in this drawing, the optimum conversion does not occur at the maximum speed, but at the point A at a speed T_A whereby the maximum efficiency E_A is reached.

The controller 19 will consequently select this pressure p_u
10 within the operating range at the outlet, for which the corresponding speed T is as close as possible to the speed T_A .

Such a curve depends on the inlet and outlet conditions
15 just like the operating curves as shown in figures 2 and 3.

In addition, it is possible for the controller 19 to also take account of other properties and characteristics of the pressure reducing unit 5 that can influence the efficiency
20 E .

In this case the choke 18 will change the outlet conditions so that the operating curve of figure 4 is adjusted for example so that the most optimum energy conversion can be
25 obtained, or in other words so that the pressure reducing unit 5 has its most optimum operating point within the imposed operating range, whereby a maximum system efficiency is reached.

30 To realise such a control of the device 1 the controller 19 can be provided with curves that show the efficiency as a

function of machine properties for different inlet and outlet conditions, whereby the controller 19 selects the corresponding curve on the basis of the inlet and outlet conditions applicable at that time, and on the basis of
5 this determines the most optimum operating point.

It is clear that both described algorithms for controlling the pressure p_u at the outlet 7 such that the outgoing power P_A is equal to the demanded outgoing power P_V will
10 enable a stable outgoing power P_A to be generated that is equal to the demanded outgoing power P_V , independently of the inlet and outlet conditions.

It is also clear that it is not excluded that instead of a
15 screw expander, a different type of expander or a turbine or similar is used.

It is also clear that the means 20 for determining the outgoing power P_A , the means 21 for determining the
20 demanded outgoing power P_V , and the means 22 for determining the inlet and outlet conditions can be implemented in all kinds of forms.

The present invention is by no means limited to the
25 embodiments described as an example and shown in the drawings, but a method according to the invention for expanding a gas flow and for simultaneously recovering energy from this gas flow and a device thereby applied can be realised in different variants without departing from
30 the scope of the invention.

Claims.

1.- Method for expanding a gas flow (Q) and for the
5 simultaneous recovery of energy from this gas flow (Q) by
driving the gas flow (Q) through a pressure reducing unit
(5) with a rotor (10) with an outgoing shaft (13) for the
conversion of energy from the gas flow (Q) into mechanical
energy on this shaft (13), characterised in that the method
10 consists of controlling the pressure (p_u) at the outlet (7)
of the pressure reducing unit (5) within a preset operating
range between a minimum pressure (p_{min}) and a maximum
pressure (p_{max}) at the outlet (7), taking account of the
inlet and outlet conditions and the properties of the
15 pressure reducing unit (5), so that the outgoing power
remains constant, remains a maximum, remains a minimum or
so that an optimum energy conversion is obtained.

2.- Method according to claim 1, characterised in that the
20 method comprises the step of determining the demanded
outgoing power (P_v) on the outgoing shaft (13) and taking
any one of the following steps on the basis of this:

- when there is a demand for outgoing power (P_v),
adjusting the pressure (p_u) at the outlet (7) such that
25 either:

- according to choice, either the outgoing power (P_A)
is kept constant and equal to the demanded outgoing power
(P_v), or it is a maximum by adjusting the pressure (p_u) to
the aforementioned minimum pressure (p_{min}) or is a minimum;
30 or

- an optimum energy conversion is obtained whereby the pressure reducing unit (5) operates at optimum efficiency by taking account of the characteristics of the pressure reducing unit (5) itself, whereby the pressure (p_u) at the outlet (7) is adjusted to a pressure to be determined between p_{min} and p_{max} , whereby the maximum system efficiency is reached;

- when there is no demand for outgoing power (P_v), adjusting the pressure (p_u) at the outlet (7) to the maximum pressure (p_{max}).

3.- Method according to claim 2, characterised in that when the pressure (p_u) at the outlet (7) is controlled such that the outgoing power (P_A) on the outgoing shaft (13) remains constant and equal to the demanded outgoing power (P_v), the method consists of providing a set of operating curves for different inlet and outlet conditions that define the relationship between the outgoing power (P_A) on the outgoing shaft (13) and the pressure (p_u) at the outlet (7), and whereby the method comprises the step of determining the inlet and outlet conditions and taking the following steps on the basis of this:

- determining the operating curve applicable at that time from the aforementioned set of operating curves;

- determining the operating point on this curve, for which the outgoing power (P_A) is equal to the demanded outgoing power (P_v), and the corresponding pressure (p_u) at the outlet (7);

- adjusting the pressure (p_u) at the outlet (7) to the aforementioned corresponding pressure.

4.- Method according to claim 2, characterised in that when the pressure (p_u) at the outlet (7) is controlled such that the outgoing power (P_A) on the outgoing shaft (13) remains constant and is equal to the demanded outgoing power (P_V),
5 the method comprises the step of determining the outgoing power (P_A) on the outgoing shaft (13) and taking any one of the following steps on the basis of this:

- when the outgoing power (P_A) is greater than the demanded outgoing power (P_V), increasing the pressure (p_u)
10 at the outlet (7);

- when the outgoing power (P_A) is less than the demanded outgoing power (P_V), decreasing the pressure (p_u) at the outlet (7);

and this until the outgoing power (P_A) on the outgoing
15 shaft (13) is equal to the demanded outgoing power (P_V).

5.- Method according to any one of the previous claims, characterised in that the pressure (p_u) at the outlet (7) is controlled by controlling the speed of the outgoing
20 shaft (13).

6.- Method according to claim 5, characterised in that the speed of the outgoing shaft (13) is controlled by changing the counter-torque on this shaft (13).

25

7.- Method according to any one of the previous claims, characterised in that the pressure (p_u) at the outlet (7) is controlled by controlling the gas flow (Q) that is allowed through the pressure reducing unit (5).

30

8.- Method according to claim 7, characterised in that the control of the gas flow (Q) that is allowed through the pressure reducing unit (5) is done by choking the gas flow (Q) at the inlet (6).

5

9.- Method according to any one of the previous claims, characterised in that it is applied to a gas flow (Q) of steam.

10 10.- Device for expanding a gas flow (Q) and for the simultaneous recovery of energy from this gas flow (Q), whereby this device (1) comprises a pressure reducing unit (5) with an inlet (6) and an outlet (7) for the gas flow (Q) and with a rotor (10) with an outgoing shaft (13) for
15 the conversion of the energy from the gas flow (Q) into mechanical energy on this shaft (13), means (16) for controlling the pressure (p_u) at the outlet (7), characterised in that the device (1) is provided with a controller (19) for the control of the aforementioned means
20 (16) to adjust the pressure (p_u) at the outlet (7) within a set operating range between a minimum pressure (p_{min}) and a maximum pressure (p_{max}) at the outlet (7), so that, taking account of the inlet and outlet conditions and the properties of the pressure reducing unit (5), the outgoing
25 power remains constant, is a maximum or a minimum, or such that an optimum energy conversion is obtained.

11.- Device according to claim 10, characterised in that the device is provided with means (21) to determine the
30 demanded power and that the controller (19) is provided with an algorithm that controls the pressure (p_u) at the

outlet (7), whereby the algorithm is based on the determination of the demanded outgoing power (P_v) using the aforementioned means (21) on the basis of which the controller (19) will control the pressure reducing unit (5), whereby, when there is a demand for outgoing power (P_v), the controller (19) will adjust the pressure (p_u) at the outlet (7) using the aforementioned means (16) such that either:

- according to choice, the outgoing power (P_A) either remains constant and equal to the demanded outgoing power (P_v), or is a maximum by setting the pressure (p_u) at the outlet equal to the minimum pressure (p_{min}), or is a minimum; or

- an optimum energy conversion is obtained whereby the pressure reducing unit (5) operates at optimum efficiency by taking account of the characteristics of the pressure reducing unit (5) itself, whereby the pressure (p_u) at the outlet (7) is adjusted to a pressure to be determined between p_{min} and p_{max} whereby the maximum system efficiency is reached;

and whereby, when there is no demand for outgoing power (P_v), the controller (19) will adjust the pressure (p_u) at the outlet (7) using the aforementioned means (16) such that the pressure (p_u) is equal to the maximum pressure (p_{max}).

12.- Device according to claim 11, characterised in that the device (1) is further provided with means (22) to determine the inlet and outlet conditions and whereby, to control the pressure (p_u) such that the outgoing power (P_A) remains constant and equal to the demanded outgoing power

(P_V), the controller (19) is provided with a set of operating curves for different inlet and outlet conditions that define the relationship between the outgoing power (P_A) on the outgoing shaft (13) and the pressure (p_u) at the outlet (7), and the algorithm is based on the determination of the inlet and outlet conditions using the aforementioned means (22), on the basis of which the controller (19) determines the operating curve applicable at that time from the aforementioned set and determines the operating point on this curve whose outgoing power (P_A) is equal to the demanded outgoing power (P_V) and the corresponding pressure (p_u) at the outlet (7), after which the controller (19) will control the pressure reducing unit (5) so that the pressure (p_u) is equal to the aforementioned corresponding pressure.

13.- Device according to claim 11, characterised in that the device (1) is further provided with means (20) to determine the outgoing power (P_A) on the outgoing shaft (13), whereby, to control the pressure (p_u) such that the outgoing power (P_A) remains constant and equal to the demanded outgoing power (P_V), the algorithm is based on the determination of the outgoing power (P_A) using the aforementioned means (20) on the basis of which the controller (19) will adjust the pressure reducing unit (5), whereby, when the outgoing power (P_A) is greater than the demanded outgoing power (P_V), the controller (19) will increase the pressure (p_u) at the outlet (7), and when the outgoing power (P_A) is less than the demanded outgoing power (P_V) the controller (19) will increase the pressure (p_u) at the outlet (7), and this until the outgoing power

(P_A) on the outgoing shaft (13) is equal to the demanded outgoing power (P_V).

14.- Device according to any one of the claims 10 to 13,
5 characterised in that the means (16) for controlling the pressure (p_u) at the outlet (7) comprise a variable speed control (17) to adjust the speed of the outgoing shaft (13), whereby the variable speed control (17) is connected to the controller (19).

10

15.- Device according to any one of the claims 10 to 14, characterised in that the means (16) for controlling the pressure (p_u) at the outlet (7) comprise a choke (18) at the inlet (6) of the pressure reducing unit (5), whereby
15 the choke (18) is connected to the controller (19).

20

16.- Device according to any one of the claims 10 to 15, characterised in that the pressure reducing unit (5) comprises an expander.

17.- Device according to any one of the claims 10 to 16, characterised in that the pressure reducing unit (5) comprises a screw expander.

25 18.- Device according to any one of the claims 10 to 17, characterised in that the gas is steam.

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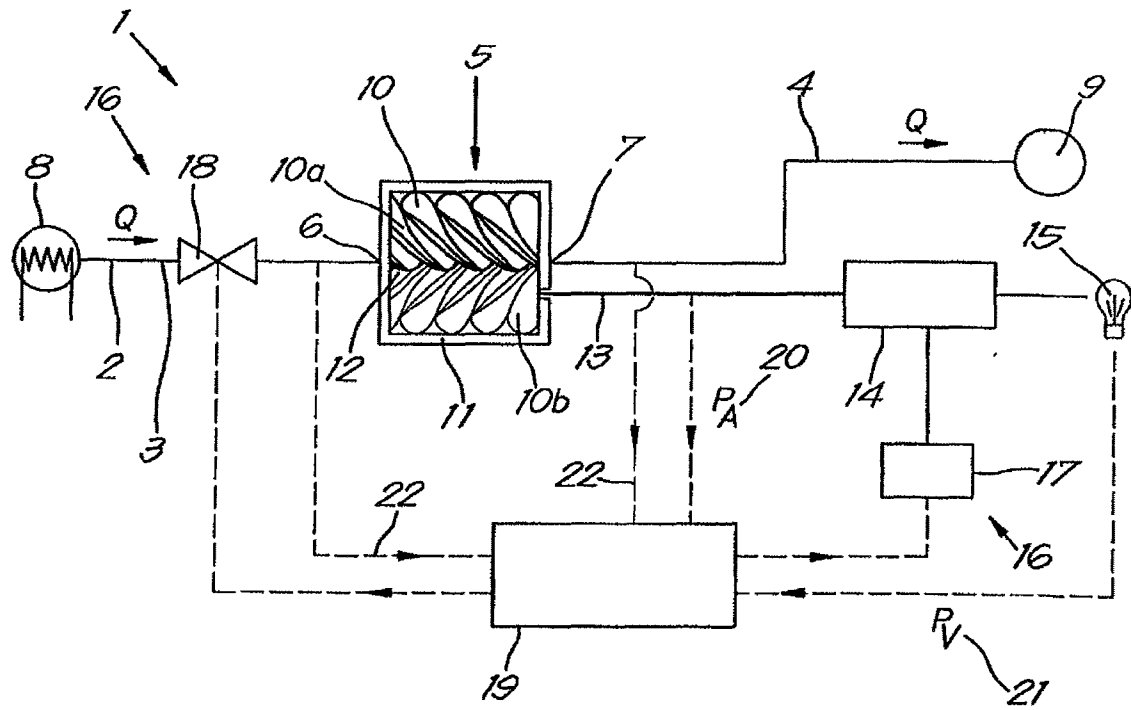
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Fig. 1

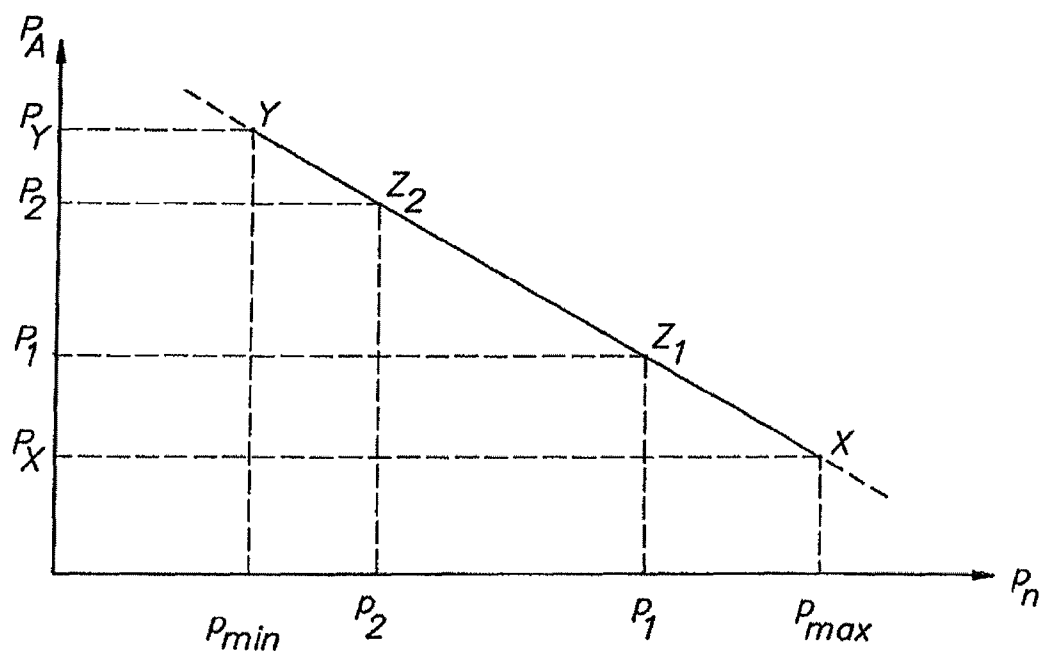
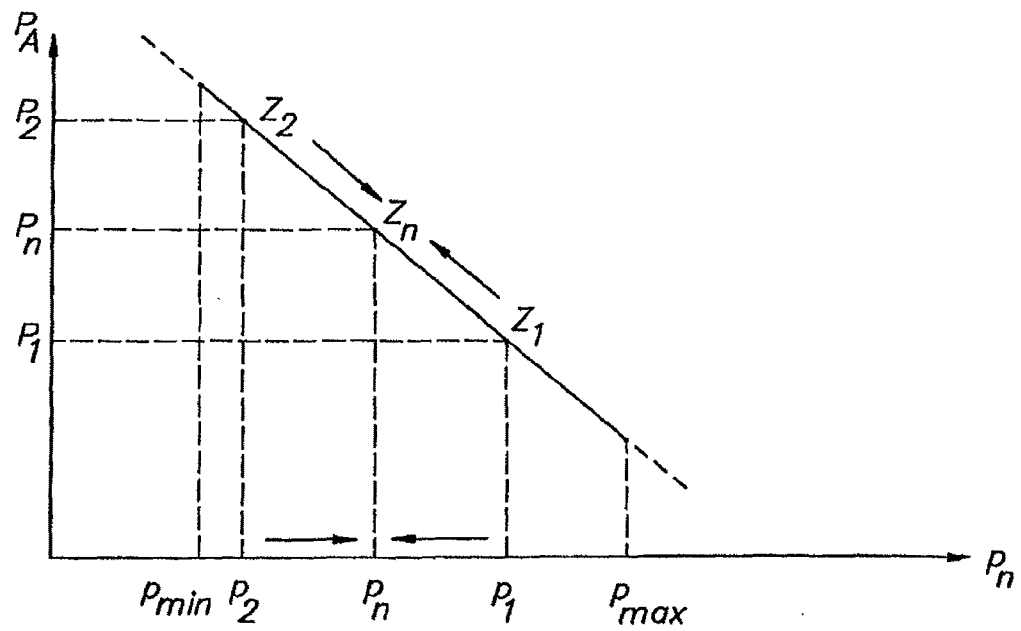
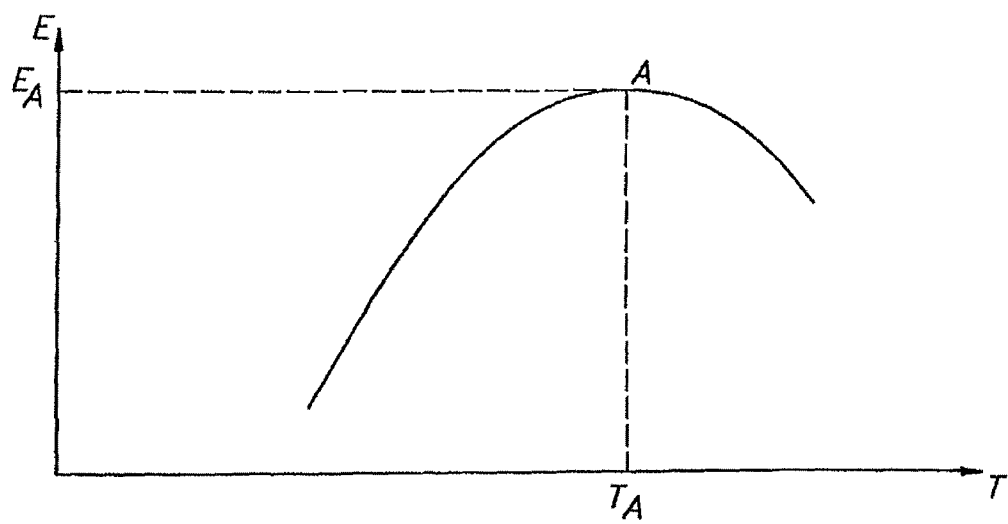


Fig. 2

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*Fig. 3**Fig. 4*

INTERNATIONAL SEARCH REPORT

International application No
PCT/BE2015/000023

A. CLASSIFICATION OF SUBJECT MATTER INV. F01K13/02 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) F01K		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 102 21 594 A1 (KUEHNLE KOPP KAUSCH AG [DE]) 27 November 2003 (2003-11-27) paragraphs [0001], [0006] - [0015], [0023] - [0026], [0036] - [0048], [0061] - [0064], [0079]; figures -----	1-5, 7-14, 16, 18
X	EP 2 540 995 A1 (KOBE STEEL LTD [JP]) 2 January 2013 (2013-01-02) paragraphs [0018] - [0021], [0027] - [0030], [0032], [0038]; figures -----	1,2, 4-11, 13-18
X	DE 103 39 881 B3 (KOEHLER & ZIEGLER ANLAGENTECHN [DE]) 16 December 2004 (2004-12-16) paragraphs [0001] - [0003], [0006]; figures -----	1,2, 7-11, 15-18
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 24 September 2015		Date of mailing of the international search report 02/10/2015
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Henkes, Roeland

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/BE2015/000023

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