ABSTRACT

"ENERGY RECOVERY FROM GASES IN A BLAST FURNACE PLANT"

There is presented a process for recovering energy from blast furnace top gas in a blast furnace plant with top gas recovery turbine system, wherein the blast furnace plant comprises at least one cold blast compressor (12) associated with at least one blast air preheater (14), and wherein a pressurized top gas stream released by the blast furnace (10) is passed through a top gas cleaning unit (24) and fed to an expansion turbine (20) coupled to a load (34). According to the process, heat is extracted from the pressurized cold blast and the extracted heat is transferred, at least in part, to the cleaned top gas upstream of the expansion turbine.

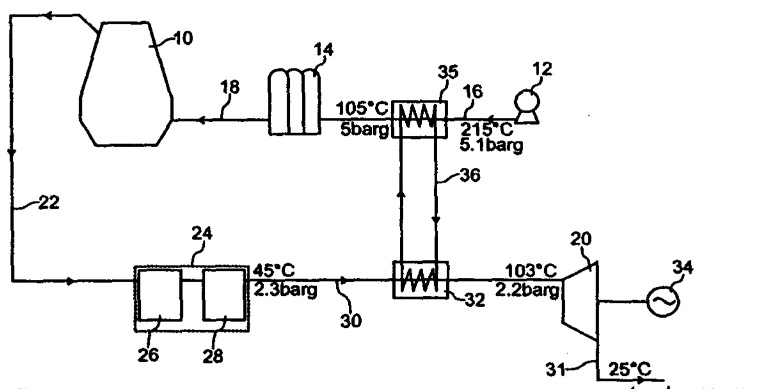

Fig. 1

Claims

1. A process for recovering energy from blast furnace top gas in a blast furnace plant with top gas recovery turbine system, wherein said blast furnace plant comprises at least one cold blast compressor (12) associated with at least one blast air preheater (14), and wherein a pressurized top gas stream released by the blast furnace (10) is passed through a top gas cleaning unit (24) and fed to an expansion turbine (20) coupled to a load (34), **characterized in that** heat is extracted from the pressurized cold blast and the extracted heat is transferred, at least in part, to the cleaned top gas upstream of said expansion turbine.
2. The process according to claim 1, characterized by a pre-heating unit (32) in-between said top gas cleaning unit (24) and said expansion turbine (20), said pre-heating unit (32) comprising: a heat exchanger having a heat-taking side traversed by said cleaned top gas; and a heat-giving side fed with a heat-exchange fluid to which heat extracted from said compressed cold blast has been transferred.
3. The process according to claim 2, characterized by a cold blast heat exchanger (35) in-between said at least one cold blast compressor (12) and said at least one blast air preheater (14), said cold blast heat exchanger (35) having a heat-giving side traversed by said compressed cold blast and a heat-taking side through which said heat-exchange fluid is circulated.
4. The process according to claim 2 or 3, characterized in that heat is added to the heat exchange fluid flowing towards said pre-heating unit upstream of said turbine.
5. The process according to any one of the preceding claims, characterized in that heat is further added to the cleaned top gas stream upstream of the turbine.
6. A blast furnace plant comprising:

a blast furnace (10) connected to a blast air system with at least one cold blast compressor (12) and at least one blast air preheater (14), wherein compressed cold blast formed in said at least one cold blast compressor (12) is heated in said at least one blast air preheater (14) to provide hot blast to said blast furnace (10);

a top gas cleaning unit (24) receiving top gas released from said blast furnace (10);

an expansion turbine (20) having an output shaft coupled to a load (34), said expansion turbine (20) being located downstream of said top gas cleaning unit (24);

a pre-heating unit (32) in between said top gas cleaning unit (34) and said expansion turbine (20) to heat-up the cleaned top gas stream;

characterized by means to extract heat from said compressed cold blast and transfer it, at least partially, to said cleaned top gas in said pre-heating unit (32).

7. The blast furnace plant according to claim 6, characterized in that said pre-heating unit (32) comprises a heat exchanger having a heat-taking side in which said cleaned top gas flows towards said turbine and a heat-giving side configured to receive heat from said cold blast.

8. The blast furnace plant according to claim 7, characterized in that:

   a heat exchanger (35) is installed in said blast air system upstream of the at least one blast air preheater (14)and has a heat-giving side fed with said compressed cold blast and a heat-taking side connected to a heat exchange fluid circuit; and

   said heat exchange fluid circuit (36) is connected to said heat-giving side of said heat exchanger in said pre-heating unit (32).

9. The blast furnace plant according to claim 6, characterized by heat pipes arranged with their condenser section in thermal exchange with said cleaned top gas at said pre-heating unit (32) and their evaporator section in

thermal exchange with said cold blast.

10. The blast furnace plant according to claim 6, 7, 8 or 9, characterized by a further pre-heating unit (42) in the flow of clean top gas in-between said pre-heating unit (32) and said expansion turbine (20).

11. The blast furnace plant according to claim 8 or 10, characterized by a heater unit (40) located in the heat exchange fluid circuit (36) so as to provide additional heat to the fluid flowing to said pre-heating unit (32).

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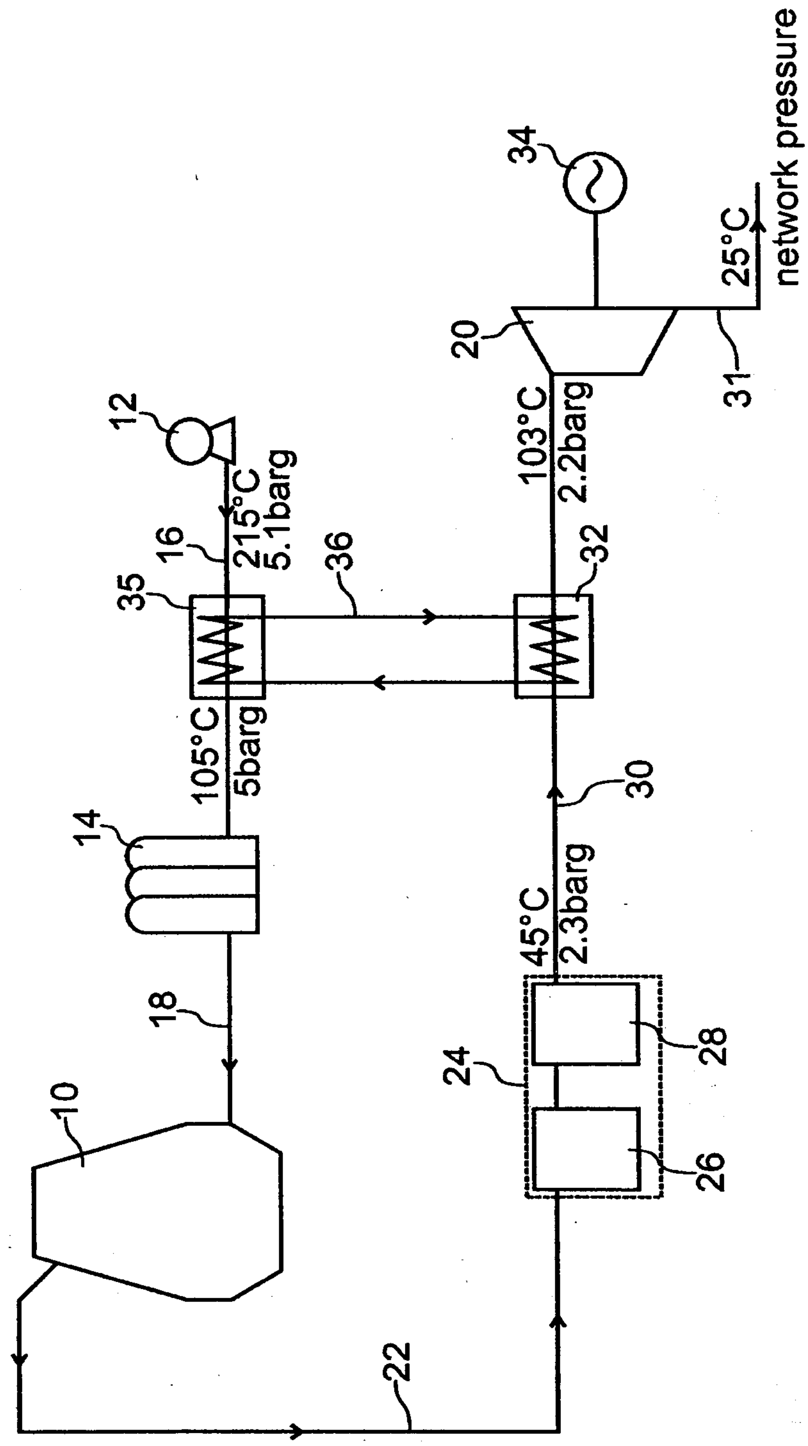

Fig. 1

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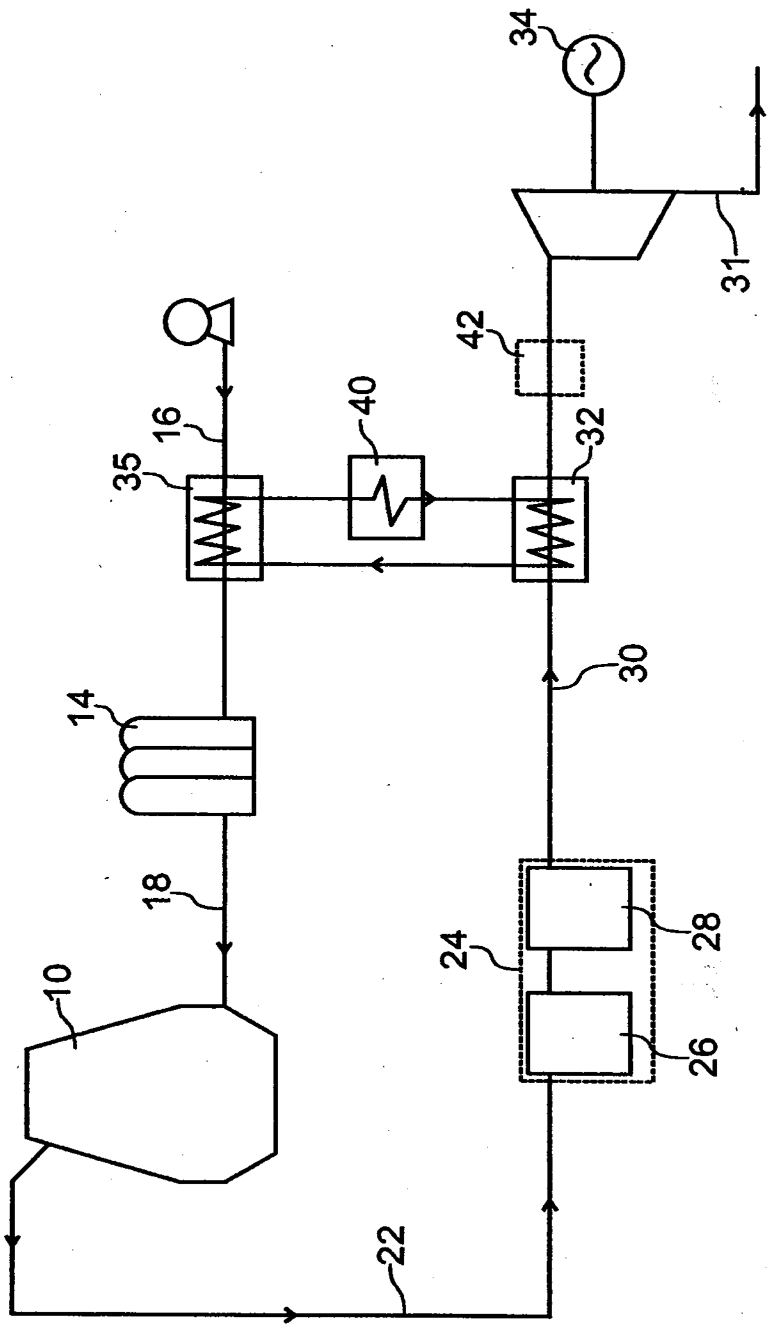

Fig. 2

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ENERGY RECOVERY FROM GASES IN A BLAST FURNACE PLANT

FIELD OF THE INVENTION

The present invention generally relates to the treatment of gases in a blast furnace plant and more specifically to the recovery of energy from blast furnace top gas in an expansion turbine.

BACKGROUND OF THE INVENTION

As it is well known, gases play a fundamental role in blast furnace (BF) operation. A first, essential flow of gas is the air stream (or "blast air") that is blown at the transition between bosh and hearth regions of the blast furnace and that will react with the burden material (iron ore, coke, flux, etc). Before the blast air wind is delivered to the blast furnace tuyeres, it is preheated by passing it through regenerative stoves (also known as Cowper) that are conventionally heated by combustion of the blast furnace offgas. Ambient air admitted upstream of the Cowper forms the "cold blast", while the pre-heated air blast downstream of the Cowper is called "hot blast".

The other main gas flow in a BF is the gas leaving the BF at the top, known as "top gas" or "blast furnace gas", which is a by-product of the blast furnace that is generated when the iron ore is reduced with coke and/or other fuels to metallic iron. BF top gas is commonly used as a fuel within the steel works or in the Cowper, but it can be burnt in boilers and power plants as well. It may also be combined with natural gas or coke oven gas before combustion or a flame support with higher heating value gas or oil is provided to sustain combustion.

As it is also well known, BFs have been operated for decades with an internal overpressure, which —with a proper dimensioning of the furnace— permits a substantial increase in the conversion of materials and energy and thus in the output of pig iron.

Operation under internal overpressure of course also implies considerable additional costs related to equipment and operation. More particularly, it requires producing pressurized air with convenient supply pressure level in a cold blast compressor (or blower) to form the cold blast. Also typical for operation under overpressure is that the gas leaving the top gas is at a pressure substantially above atmospheric pressure. The top gas however still contains combustible components, primarily carbon monoxide, and to a lesser extent hydrogen, and can be used as low heating value combustion gas for producing heat or mechanical and electrical energy.

Top gas leaving the BF also carries along important amounts of solid matter, primarily in dust-like form. Before any subsequent use of the top gas, it is required to remove this solid material. This is conventionally achieved in a gas cleaning sub-plant of the BF plant, which typically comprises a first, dry separation equipment —with a gravity-separator (dust catcher) and/or an axial cyclone— and a subsequent wet, fine cleaning device (wet separator). Due to the wet cleaning, the top gas temperature drops by about 100°C, is saturated with water vapor and includes additional liquid water droplets.

After cleaning, it has been known for long, in addition to the use of the thermal energy of the top gas, to recover the pneumatic energy of the pressurized BF top gas in an expansion turbine. In the turbine, the top gas expands to close to atmospheric pressure while producing mechanical work. The turbine rotor can be coupled e.g. to an electric generator, to the cold blast compressor, or to any other load.

As it is now also known, the efficiency of such expansion turbine (also referred to as Top pressure Recovery Turbine – TRT) can be increased by heating-up the cleaned—and thus cooled—top gas just before it enters the turbine. For this purpose, it has been proposed to preheat the cleaned top gas upstream of the turbine by combustion of expanded top gas. Alternatively, JP 62074009 proposes extracting heat from the slag granulation and transferring this heat to the cool, cleaned top gas upstream of the TRT by means of a heat exchanger.

FR 2 663 685 describes a process for recovering energy from blast furnace gas. The blast furnace gas is passed through fine and/or coarse dust filtration, then in a (pressure recovery) turbine coupled with a power generator and further to a gas line for further utilisation. A proportion of gas (3 to15%, pref ca. 5%) is bypassed, before the expansion turbine (12), if required through a compressor, and burned in a combustion chamber possibly with enrichment by high calorific fuel e.g. natural or coke gas. The combustion gases are then expanded in a gas turbine. The gas turbine may be coupled to its own generator or to the expansion turbine generator via clutch. The temperature of the non-bypassed portion of cleaned blast furnace gas is preferably raised, before injection in the recovery turbine, by thermal exchange with the combustion gases expanded in the gas turbine. A portion of the cold blast stream may be burned in the gas turbine.

OBJECT OF THE INVENTION

The object of the present invention is to provide another, improved way of recovering energy from top gas in a blast furnace plant with TRT.

This object is achieved by a method as claimed in claim 1 and a blast furnace plant as claimed in claim 6.

SUMMARY OF THE INVENTION

The present invention proposes an optimized way of managing gas flows in the blast furnace plant that permits operating the TRT with enhanced efficiency. According to the inventive method, heat is extracted from the compressed cold blast stream upstream of the cold blast pre-heaters (i.e. Cowper and the like) and this heat is then transferred (at least in part) to the cool, cleaned top gas stream upstream of the expansion turbine. The extraction of heat from the cold is preferably performed as it travels in the cold blast main towards the pre-heaters, without consuming such cold blast for the heating purpose of the cleaned top gas.

In doing so, the cold blast temperature can be decreased before the regenerative stoves and, concurrently, the temperature of the cool, cleaned top gas can be increased, improving the efficiency of both the Cowper and TRT. Indeed, it is known that increasing the top gas temperature before the TRT improves efficiency thereof and avoids icing risks, while reducing the cold blast temperature before the Cowper improves the efficiency of this pre-heating step. More specifically, a lower temperature of the cold blast increases the heating capacity of the Cowper.

It shall be appreciated that while in prior art BF plants the energy required to pre-heat the cleaned, top gas was provided by buming or extracted from extraneous media, e.g. slag granulation, and the removed heat of the cold blast was wasted, a merit of the present invention is to have realized that bringing the cold blast and cleaned top gas in heat exchange relationship would be suitable for improved performances of both the cowper and the turbine.

A particularly appreciable aspect of the present invention is that a kind of "self-regulating" thermal exchange between the cold blast and the cool, cleaned top gas is obtained. Indeed, blast air flow conditions upstream of the BF impacts on the top gas flow conditions downstream of the BF (and vice-versa), and it appears that bringing these two streams in heat exchange relationship automatically compensates for variations at one side or the other.

It may be noted that the present process is particularly more simple than the process described in FR 2 663 685, as in the instant process the cold blast gas stream is not affected, except for the heat reduction, and especially is not partially derived to be burnt with top gas in a gas turbine.

As a matter of fact, the present method provides a much simpler and efficient way of preheating cleaned top gas before the TRT, which benefits in the overall plant economics.

The present invention also relates to a blast furnace plant comprising:

a blast furnace connected to a blast air system with at least one cold blast compressor and at least one blast air preheater, wherein compressed cold blast formed in the cold blast compressor(s) is heated in the blast air preheater(s) to provide hot blast to the blast furnace;

a top gas cleaning unit receiving top gas released from the blast furnace;

an expansion turbine having an output shaft coupled to a load, the expansion turbine being located downstream of the top gas cleaning unit;

a pre-heating unit in-between the top gas cleaning unit and the expansion turbine to heat-up the cleaned top gas stream; and

means to extract heat from the compressed cold blast and transfer it, at least partially, to the cleaned top gas in the pre-heating unit.

Preferred embodiments of the present method and blast furnace plant are recited in the respective dependent claims.

It shall be noted that any appropriate technology may be used to extract heat from the compressed cold blast and transfer it, at least partially, to the cleaned top gas. In this connection, one may use any appropriate type of heat exchanger in combination with a heat exchange fluid circuit. A possible type of heat exchange system is the so-called "heat pipe" (either of the straight or loop type), where the evaporator section would be arranged on the cold blast side and the condenser section on the cleaned top gas side.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG. 1: is a schematic diagram of a first embodiment of the present blast furnace plant with gas energy recovery system;

Fig. 2: is a schematic diagram of an alternative embodiment of the present blast furnace plant with gas energy recovery system.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

A first embodiment of the present blast furnace plant is schematically illustrated in Fig.1 (only the air treatment/conditioning equipment is represented). Reference sign 10 indicates a blast furnace to which hot blast wind is fed from a blast air system comprising a blower 12 (or compressor) and a pre-heater unit comprising a set of three regenerative stoves 14, as is conventional in the art. The blower 12 compresses air and forms a cold blast stream that flows through a cold blast main 16 to the regenerative stoves 14. The cold blast stream is heated to temperatures in the order of 900°C to 1300°C in the regenerative stoves 14 and flows through the hot blast main 18 to the tuyeres (not shown) where the hot blast wind is injected into the BF 10.

Top gas released by the BF 10 is directed, at least in part, to a top gas recovery turbine 20 to recover pneumatic energy therefrom. Reference sign 22 indicates an offgas duct that carries top gas to a gas cleaning sub-plant 24. The top gas cleaning sub-plant 24 may comprise a dry separator 26 serially connected with a wet separator 28. Any appropriate type of cleaning technology may be implemented in sub-plant 24.

The cleaned top gas stream is fed to the turbine 20 through a duct 30 via a preheating unit 32, in order to heat-up the cleaned top gas stream that has been cooled down due to the cleaning process in unit 24. In the turbine 20, the cleaned top gas expands to lower pressure and temperature and provides mechanical work to a load 34 (here illustrated as a generator) coupled to the turbine's output shaft. The expanded top gas, downstream of the turbine 20, may then be returned to the clean gas network or conveyed to a user/consumer facility such as e.g. a power station via outlet duct 31.

It shall be appreciated the present BF plant comprises means to extract heat from the compressed cold blast and transfer it, at least in part, to the cleaned top gas in the pre-heating unit 32. This is advantageously achieved by means of a heat exchanger 35 installed on the cold blast main 16 conveying the compressed, cold air to the regenerative stoves 14. In the heat exchanger

35, the cold blast is brought into heat exchange relationship (however without mixing) with a heat-exchange fluid of a heat exchange circuit indicated 36. The heat exchange circuit preferably comprises a pumping system (not shown) that forwards the heat exchange fluid from the heat exchanger 35 to the pre-heating unit 32, where the extracted heat is transferred, at least in part, to the cleaned top gas.

Extracting heat from the cold blast to transfer it to the cleaned top gas provides a very advantageous way of preheating the cleaned top gas before its expansion in the TRT system. This also increases the efficiency of both the regenerative stoves 14 and the turbine 20. Compared to known methods where the cold blast heat was wasted and the preheating of the cleaned top gas required burners or the like, a kind of "self-regulating" effect is obtained. Indeed, the gas flow conditions upstream and downstream of the BF are linked and the following is an example of how this operates.

Example.

The higher the Top Gas Pressure (TGP), the higher is the Hot Blast Pressure (HBP): HBP = TGP + dP, where dP is the pressure loss in the blast line, Blast Furnace (BF) and Gas Cleaning Plant 24 before the turbine 20 (dP is more or less constant depending on BF peculiarities being in the range of 1.0 – 2.5 bar). Also, the higher the TGP, the greater the drop of Top Gas Temperature (TGT) during expansion in the TRT 20.

This is where the pre-heating of the cleaned top gas before the TRT 20 is of interest. If the cleaned top gas is not preheated, the TGT after TRT 20 will be low, leading to risks of TRT icing and decrease in the production of electrical energy in the generator 34. However, if the TGT after TRT 20 is too high, problems also arise such as overheating of the turbine 20 or burning of the sealings in the clean gas network downstream of the TRT.

However, by pre-heating the top gas before the TRT using the heat recovered from the cold blast, an advantageous preheating scheme is achieved that provides an automatic, appropriate heating. If the top pressure in the BF 10 is increased, the blower 12 has to compensate this pressure increase and increased, the blower 12 has to compensate this pressure increase and the cold blast pressure is increased while the cold blast temperature rises accordingly.

At the same time, the pressure difference at the turbine 20 is increased. But icing risks and the like are prevented because the pressure rise downstream of the BF implied the pressure and temperature increase in the cold blast upstream of the BF 10, and thus more heat available for transfer from the cold blast to the cleaned top gas via the heat exchange circuit 36.

Similarly, when decreasing the TGP (e.g. to stop the BF), TGT before the turbine 20 decreases because HBP has also fallen together with HBT, and less heat is required for pre-heating the top gas before TRT. This is convenient, since less heat is available from the cold blast, which pressure has also decreased.

For the sake of exemplification, we have reported temperatures and pressures at different locations of the gas treatment circuit of BF 10 in Fig.1. These values have been calculated. As can be seen, the blower sends into the cold blast main 16 compressed air at a temperature of 215°C and 5.1 barg. After passing through the heat-giving side of heat exchanger 35, the cold blast is at a temperature of 105°C and 5 barg.

After cleaning, the top gas temperature drops to 45°C at 2.3 barg. It then flows through the heat-giving circuit of pre-heater 32 where its temperature raises to 103°C at 2.2 barg. The pre-heated top gas stream then enters the turbine 20 and exits therefrom at 25°C and network pressure.

The transfer of heat from the cold blast to the top gas is carried out by means of the heat exchange circuit 36 that is in fluid communication with the heat-taking side of heat exchanger 35 and the heat-giving side of pre-heating unit 32. It may be noted that in the present example, the temperature of the heat exchange fluid exiting the heat exchanger 35 is 170°C; after the pre-heating unit 32 the heat exchange fluid has given an important part of heat to the top gas and has a temperature of 75°C.

As can be seen from this example, this scheme of operation is sufficient for preheating the top gas before the TRT, by increasing its efficiency and at levels that avoid icing risks and overheating. In other words, the self-regulating effect not only permits heating-up the top gas before the TRT, but it provides a secure and appropriate operation of the TRT system, inside the BF plant but also for users downstream of the TRT.

Although, as shown with respect to Fig.1, the heat extracted from the cold blast may be sufficient under conventional operating conditions, one may want to be able to provide additional heat to the cleaned top gas upstream of the turbine 20. Two alternative or complementary ways of doing this are illustrated in Fig.2, where same reference signs indicate same components of the BF plant.

First, additional heat can be provided by means of a burner or the like, indicated 40, installed in the heat exchange circuit, on the flow of heat exchange fluid from the heat exchanger 35 to the pre-heating unit 32. Furthermore, a preheater 42 can be installed on the cleaned gas ducting 30, in-between the preheating unit and the turbine 20. Any appropriate types of technologies can be used for additional heaters 40 and 42, such as e.g. burners coupled with heat exchangers.

It remains to be noted that the above description is made for exemplary purposes. The term heat exchanger herein encompasses any appropriate type of device where a flow of gas/air can be brought into heat exchange relationship with the another gas or fluid turbine, however without mixing with one another. Any technology compatible with the use in a blast furnace may be used. In particular, heat pipes may be used for the transfer of heat from the cold blast to the cleaned top gas, where the condenser section would be arranged in the pre-heating unit 32 and the evaporator section on the cold blast side. Also for the expansion turbine 20, gas-cleaning sub-plant 24, regenerative stoves 14 or the heat exchange fluid circuit 36 no further description is necessary as the type of equipment and use thereof is known to those skilled in the art.