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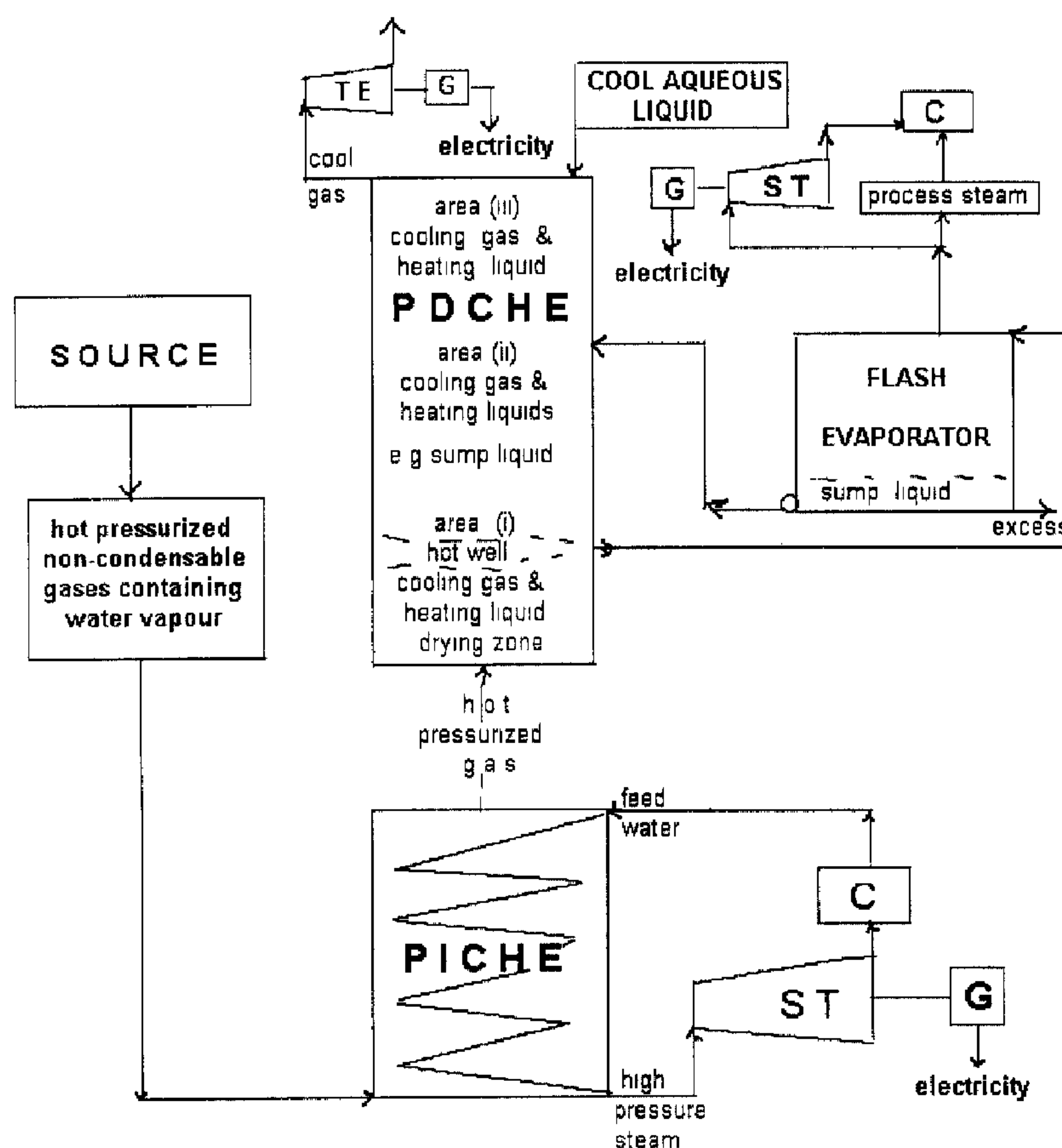
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(54) Titre : PROCESSUS D'ECHANGE DE CHALEUR PAR CONTACT DIRECT SOUS PRESSION

(54) Title: PRESSURIZED DIRECT CONTACT HEAT EXCHANGE PROCESS



(57) Abrégé/Abstract:

Process for converting latent heat of water vapor, appearing with non-condensable gases expelled into the atmosphere, into more useful forms of energy, e.g. process steam / electricity. It uses pressurized direct contact heat exchange systems to



(57) **Abrégé(suite)/Abstract(continued):**

achieve this conversion at high thermal efficiencies. It has application to sources of these gases, such as pressure combustion of wet biomass fuels, where pressures in the range of 250 psia have been used e.g. in the "The Clean Coal Technology Program" sponsored by the US Department of Energy. When pressure combustion is used in combination with pressurized water electrolysis it produces pressurized by-product hydrogen. It can be used to extract methane from methane hydrate ice located below the earth and sea. It has application to the Pulp & Paper Industry, where air-steam exhausts and effluents can be reclaimed and biomass burnt to produce process steam I electricity and water for reuse. It is pertinent to the "greenhouse gas" problem.

ABSTRACT

Process for converting latent heat of water vapor, appearing with non-condensable gases expelled into the atmosphere, into more useful forms of energy, e.g. process steam / electricity. It uses pressurized direct contact heat exchange systems to achieve this conversion at high thermal efficiencies.

It has application to sources of these gases, such as pressure combustion of wet biomass fuels, where pressures in the range of 250 psia have been used e.g. in the "The Clean Coal Technology Program" sponsored by the US Department of Energy.

When pressure combustion is used in combination with pressurized water electrolysis it produces pressurized by-product hydrogen. It can be used to extract methane from methane hydrate ice located below the earth and sea.

It has application to the Pulp & Paper Industry, where air-steam exhausts and effluents can be reclaimed and biomass burnt to produce process steam / electricity and water for reuse.

It is pertinent to the "greenhouse gas" problem.

PRESSURIZED DIRECT CONTACT HEAT EXCHANGE PROCESS.

1. Field of the invention.

This invention relates to sources, which continuously produce hot pressurized non-condensable gases containing water vapor, and which in combination with a pressurized direct contact heat exchange (PDCHE) process, continuously convert the energy in these gases into a more useful form, such as steam / electricity.

2. Description of the Prior Art.

Applicant in two previous patents, i.e. US 3920505 and 4079585 failed to adequately disclose and claim the present invention.

Present processes release large volumes of hot non-condensable gases containing water vapor into the atmosphere resulting in a great loss of energy, especially the latent energy of the water vapor. In the case of the combustion of water laden materials / wastes this results in low thermal efficiencies.

SUMMARY OF THE INVENTION.

A main objective of the present invention is to retain this water within the process and convert it to steam in a more reusable form, and thereby raise the thermal efficiency to a much higher level. This objective is attained by an application of Henry's Law of partial pressures. For example, if the pressure of the gases leaving the PDCHE is 250 psia (and higher) and the gases are cooled to below 200 degrees F, the water content in the gases would approach 0.10 lbs per lb of dry gas, and the thermal efficiency of the process would approach 90%. The pressure of the steam from the flash evaporator at those gas pressures would approach 70 psia.

The basic embodiment of the invention comprises:

(a) providing a source which continuously produces hot pressurized non-condensable gases containing water vapor whose given pressure is commensurate with the steam pressure desired in the following flash evaporating step and with the desired overall thermal efficiency

(b) continuously bringing the hot gases into intimate contact with an aqueous liquid in a pressurized direct-contact heat exchanging process having a hot well, where the gases will flow counter-current to a flow of an aqueous cooler liquid and where water vapor will condense and the gases will become drier, said exchanging process being capable of being divided into at least three areas / sections; (i) the first is one where the evaporative and heating property of, and part of the condensing and heating property of the water vapor in, the hot gas will be utilized to heat the cooler liquid to the highest temperature it could have when in equilibrium with the hot gases at the given pressure, and thereby cool the hot gases; as well as allow heated liquid and condensed water to collect in the hot well within the area, while still maintaining the highest possible hot well temperature; (ii) the second is one where the gas and liquid will continue to progressively exchange heat content and supply heated liquid to the hot well, until the gas approaches the temperature of the liquid coming from the following flash

evaporation step; (iii) and the third is one where the gas and liquid will progressively exchange heat content, until the gas as it cools approaches the temperature of the cool liquid entering at the top of area (iii) and the liquid as it heats, approaches the temperature of the liquid from the flash evaporator.

(c) continuously removing heated liquid from the hot well and flash evaporating it in a flash evaporator at a pressure lower than the pressure corresponding to the equilibrium or hot well temperature to thereby (1) convert some of the water in the liquid into steam and (2) cool the liquid to a temperature corresponding to the pressure of the flashed steam and allow it to collect in a sump in the evaporator.

(d) continuously removing cooled liquid from the flash evaporator and re-introducing it to the direct-contact heat exchange section; at a point in area (ii) where the gas in the area is at about the same temperature.

(e) continuously removing the flashed steam from the flash evaporator for further use;

(f) continuously replenishing the cool liquid entering at the top of area (iii) and continuously removing excess liquid from the flash evaporator, at the appropriate rate in order to keep the liquid in the exchanger and evaporator in balance; as well as for further use;

(g) continuously removing the cooled gases from the top of zone (iii) for further use.

Other embodiments are listed below

BRIEF DESCRIPTION OF THE DRAWINGS.

Symbols used are defined in the next section. While, for compactness, the PDCHE is sometimes shown as a single chamber, the various areas could, were desired, be allotted separate chambers. See FIGS 9 & 10. For similar reasons, valving and other obvious operations are not shown, or labeled e.g. exhaust steam from the ST could go to a condenser; the TC in Fig. 3 could be connected directly to the TE, along with a M; An "o" indicates a pump; particulate removers would be installed when they are required, etc.

The following drawings are schematic representations of the various embodiments / applications of the present invention :

FIG. 1 represents the main embodiment described above in the Summary together with examples of further use for the flashed steam and cool gases.

FIG. 2 represents the situation where a known process (Source) is adapted to produce the gases required for the embodiment shown in FIG. 1

FIG. 3 represents where the gases from a known process (Source) are passed through a TC to produce the pressurized hot gases required for the embodiment shown in FIG. 1

FIG. 4 represents where the liquid from the hot well is heated to a higher temperature indirectly before flashing it in the flash evaporator. The indirect heater could be located within the Source.

FIG. 5 represents where the pressurized gas-steam mixture is heated prior to going to the PDCHE.

FIG. 6 represents where the non-condensable gas content is in the low range and the gases are further pressurized by using a high pressure pump which condenses more of the water vapor prior to going to a secondary PDCHE.

FIG. 7 represents where combustible material is burnt under the earth or sea and the gases processed above the site in the PDCHE.

FIG. 8 represents where gaseous material under the earth or sea can be brought above and processed in the PDCHE.

FIG. 9 represents where a number of the embodiments are involved in an overall process, applicable to the Pulp & Paper Industry.

FIG. 10 involves the electrolysis of water under pressure to illustrate a symbiotic relationship with the invention. Combining it with that of the embodiment of FIG. 9 would illustrate a further symbiotic relationship, in that the Paper Machine Dryers would also contribute further oxygen and steam to the combustion step.

FIG. 11 represents where a PDCHE is combined with a PICHE, located within the source process, to generate high pressure steam, in order to take advantage of the higher efficiency of high pressure, high temperature steam turbines.

FIG. 12 represents where the invention produces greenhouse gases, such as carbon dioxide which can be recycled through its use to accelerate biomass growth. In this embodiment a PDCHE and pressurized combustion is combined with pressurized electrolysis of water to generate pressurized oxygen for the combustion, and hydrogen as a by-product, as well as produce substantially pure carbon dioxide in the flue / exit gases.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS.

The following embodiments are process sequences that provide a wide range of choice to fit a wide variety of circumstances, applications and available technologies. Because of the wide range of process variables involved and technologies to choose from, it is nearly impossible to describe in any detail how a particular embodiment is carried out. In most cases computer simulation will be required to balance the various variables such as the rate of: recirculation of the hot well liquid; cool liquid supply and excess liquid removal.

The embodiments as illustrated and described is such as to obtain maximum thermal efficiency, noting that, the higher the pressure and the lower the temperature of the gas leaving the PDCHE the higher the thermal efficiency. Embodiments involving lower efficiencies should not however, detract from the invention.

Referring to the accompanying drawings and the following text, the symbols used have the following meaning :

G	Generator for electricity	GT	Gas Turbine
TC	Turbine Compressor	TE	Turbine Expander
PR	Particulate Remover	M	Motor electric

ST	Steam Turbine	C	Condenser
P	Pump	PM	Paper Machine
PDCHE Pressurized Direct Contact Heat Exchanger			
PICDHE Pressurized Indirect Contact heat Exchanger			

Thus the following embodiments:

A. Illustrate In FIG 1 that which is expressed in the Summary of the Invention.

Examples of further use for the flashed steam and cool gases are also shown, namely, as process steam and/or as a source of energy for the production of electricity using steam turbines connected to a generator for the flashed steam, and as a source of energy for the production of electricity using a turbo-expander connected to a generator for the cool gases.

The steam and any excess liquid from the system could also be used to heat large living and business complexes especially in remote places. Further use for the cool gases are described below e.g. in Y and AA. Further use for any excess liquid accumulating in the sump / the hot well is described in various embodiments below e.g. J, Q, S.

While the various areas or zones of the PDCHE are shown in one chamber, they could be located in separate chambers or sections Here the hot well is shown near the top of zone, (i) so as to illustrate that the area below it could be used to dry solid materials. Normally it would be near the bottom.

Various technologies are available in determining how the chambers are constructed and the best type of mixer to use, while maintaining maximum heat exchange and minimum pressure drop, e.g. the Field gas scrubber; bubble columns; packed towers; turbo-gas absorber; cascades; collecting the cooler liquid at any point in the PDCHE and recycling it in the exchanger until its temperature approaches that of the gas; etc. While the cooling liquid introduced into areas (i) and (ii) is shown as entering at one point, depending on the mixing technology used, it could be introduced at various points in each area or section.

The whole chamber or any one of the separate chambers could be located within the confines of the Source depending on the process producing the hot gases and other factors. Further elaboration is given in embodiment Q below for this and other embodiments.

Existing high pressure process sources include: pressurized combustion projects in the Clean Coal Technology Program sponsored by the US Department of Energy, where pressures in the range of 200 psia are reached; high pressure char oxidation; processing of wood in digesters; etc.

B. Illustrate In FIG 2, where the Source involves a known process which does not provide the pressurized hot gases required of A, but can be adapted to perform at a substantially elevated pressure and, if feasible, higher temperature.

Examples:

(1) Combustion / incineration of materials that produce water vapor, e.g. wet combustibles. While some emphasis is on biomass fuels, the process could have application to the combustion of (a) solid / liquid fossils fuels; especially those having a high sulphur content such that the acidic sulphur gases produced during combustion can be easily removed in the PDCHE (scrubber) step by making the

circulating fluid alkaline (see L); (b) fuels intermediate between the two i.e. lignite (brown coal), peat, etc, where the high moisture content is a deterrent to their use; (c) diverse fuels, such as Tire Derived Fuel (TDF), and various sludges, etc. where pollutants can be removed in the PDCHE and concentrated.

- (2) Processes that produce other gases such as Lurgi power gas etc;
- (3) Processes operating in the lower pressure range, where the pressure could be increased. e.g. thermomechanical pulping of wood chips; (see M)
- (4) Diverse processes such the smelting of ores; wet oxidation; chemical and metallurgical processes (blast furnaces), and intermediary operations such as: drying; stripping, extraction; boiling and the like.

C. Illustrate in FIG 3 where the increase in pressure and temperature of the source process cannot be carried out, then the gases from the source process are turbo-compressed to the desired pressure, with the temperature increased by the compression. Here where an M drives TC, in step (g), a TE could be used to drive the compressor. For example in the drying of pulp or paper, enormous quantities of air and steam are expelled to the atmosphere, here the air-steam mixture could be turbo-compressed and their heat content recovered in the PDCHE. See embodiments F. & Q. below.

D. is where the steps of, collecting other non-condensable gases containing water vapor (which are outside of the source) and turbo-compressing them to a pressure sufficient to introduce them into the source process, are added prior to step (a). For example, as shown in FIG 9, the air-steam mixture is added to a high pressure combustion process. Other such mixtures include naturally occurring ones such as fog banks, low clouds, mists, steam eruptions from the earth, etc.

E. Illustrate in FIG 4, where the liquid from the hot well is heated indirectly to a higher temperature to thereby increase the steam pressure in the flash evaporator. For example, by passing the liquid through a tube bank within the source process, should it be capable of heating the liquid.

F. Illustrate in FIG 5, where the pressurized gases are further heated prior to going to a PDCHE. For example, by burning oil or gas in the mixture, where it will consume any remaining oxygen or to which additional oxygen may be added. Alternatively, the pressurized gases could be further heated by passing the gases through a tube bank in a hotter zone within the source process.

G. is where the cool gases leaving the PDCHE are heated prior to the TE. For example, by burning oil or gas in the mixture, or by combining the operations of the expander and compressor and introducing inter-stage cooling and heating, as mentioned in embodiment T. This may be necessary to avoid water condensing or freezing in the TE, if the pressure is very high and the temperature low.

H. is where, if the pressure and temperature of the hot gases from the source process are high enough, after removing any particulates, they are passed through a GT connected to a G to produce electricity, before being sent to the PDCHE. This is particularly advantageous for a combustion process where high gas temperatures are achievable as illustrated in FIG 9 & 10. If acidic gases are a problem, they may be removed prior to the GT by passing them through a scrubbing chamber

using a lime or limestone slurry and particulates might be removed using steam scrubbing and the heat content recovered in the PDCHE. It could be important to dry any wet fuels prior to combustion so as to obtain a maximum temperature. The drying could be done using the gases after leaving the gas turbine as shown in Fig 9.

I. is where oxygen, required in any of the embodiments, is supplied by a source under a pressure greater than the pressure required for the source of the pressurized hot gases. This makes the process more efficient by eliminating the need for a TC. The electrolysis of water or steam is one such source, where it is more efficient at the higher pressures, with pressurized hydrogen as a valuable by-product. This is illustrated in FIG 10 and expanded in R below. Alternatively, the oxygen may be supplied in bulk or by air liquefaction with nitrogen as a by-product.

J. is where by using cool liquids, containing dissolved or suspended materials as the cooling liquid, the liquid can be concentrated by the recycling of the liquid through the PDCHE and flash evaporator. Once the concentration of the materials in the circulating liquor reaches the desired level, a portion can be removed at a rate that will prevent further concentration.

If appropriate, the liquid may be used in the source process, e.g. where that process is one of combustion and the material in the liquid is combustible. This is illustrated in FIG 9 & 10. (see Q and R below) Other such liquids are effluents from many other mills, as well as from sewage treatment plants.

Other examples would be (a) the desalination of salt water, the liquor would provide a source of salt and the condensed steam a source of salt-free water suitable for irrigation; (b) concentration of dilute sugar sources, i.e. cane, beet and maple sugars, where any residues or forest biomass can be combusted under pressure to produce the hot gases; water associated with oil from the wells (producer water) when separated from the oil can serve as the cool liquid and when concentrated can be added to the oil and burnt and the noncombustible pollutants removed in the ash for proper disposal; etc.

K. Is where area (i) of step (b) in embodiment A, is used to dry materials.

Here all or a portion of the hot gases would be introduced into a chamber containing the material to be dried. and the drying done in a number of ways, such as flash drying, a fluidized bed, rotary tumble drier, etc, and the dry or partially dried material removed through a screw press or decompression chambers, etc or sent directly to the Source. Various bio-masses, such as peat, lignite, bark, leaves, branches, roots, and many other materials considered as waste can thus be dried or partially dried. The gases after being so used and before the saturation temperature has been reached, would be sent to the rest of the PDCHE.

If the dried material is still considered waste and is combustible and the source process is one of combustion then it can be sent there and consumed. This is illustrated in FIGS 9 & 10.

L. is where undesirable solids and/or gases are present in the hot gases and can be removed in the heat exchanger by maintaining the circulating liquid alkaline for acidic gases and acidic for alkaline gases.

The substances so formed can then be concentrated and removed from the flash evaporator (see J above).

This could allow greater use of fossil fuels containing a high sulphur content. If the solids / gases are very soluble in the water, they could be put through a scrubbing chamber prior to the PDCHE, were a minimum of liquid could reduce their concentration.

M. Illustrate in FIG 6 where the non-condensable gas content is in the low

Range. Here the pressurized hot gases are sent to a primary PDCHE and processed through the first and second areas of step (b) in embodiment A; then they are removed from the exchanger at a temperature close to that of the temperature of the flashed liquid in the evaporator and fed to the suction side of the pump removing the flashed liquid from the flash evaporator, which is capable of pressurizing this removed mixture to a pressure which will condense most of the steam in this removed gas mixture, this pressurized liquid and gas mixture is then sent to a secondary PDCHE where the liquid and gases separate at a temperature corresponding to that of the pump pressure, the separated liquid in the secondary PDCHE is sent to the top of the primary PDCHE at a point where the removed gases exit, the heat content of the separated gases containing a low amount of steam can then be recovered as desired e.g. in a TE, connected to a G, etc.

In certain applications, it is desirable to minimize the presence of the non-condensables in the source process, e.g. in the pressurized thermomechanical pulping of wood chips, by presteaming the chips prior to their entering the refiner.

N. is where if the steam from the flash evaporator is unsuitable for a particular use, or cannot be cleaned by conventional means, it is passed through a reboiler for further use.

O. Illustrate in Fig. 7, where the source process is a combustion process carried out under the earth or sea under pressure, where there is combustible material, where the combustion is supported by a pressurized gas containing oxygen and controlled by water piped to the combustion site from above the site. The pressurized hot gases would be piped to a PDCHE above the site and processed utilizing any of the other embodiments that will give the desired result

P. Illustrate in Fig 8, where the source process is carried out below the earth or sea under pressure, where there is recoverable material, and where the process is activated by high pressure steam, preferably superheated steam, which allows the material to flow to a PDCHE above the site and processed as for any of the other embodiments. As illustrated, high pressure super-heated steam could flow down an insulated pipe to melt the methane hydrate ice and allow it and steam to flow up another pipe to the PDCHE above the site to be dried as in FIG 1. Alternatively, the two pipes could consist of concentric inner and outer pipes, with the steam flowing down the inner pipe to melt the hydrate, which will flow up the outer concentric pipe which is wide enough to trap the methane and in which the pressure is less than that of the liberated methane. Some of the methane could be used in a conventional boiler to produce the steam and the water supplied from the hot well. The end product would be a pressurized, substantially dry methane gas.

This could also be applicable to number of fossil fuels, e.g. unmineable, gassy coal beds containing methane; wells of natural gases, volatile oils, etc after the wells have been somewhat depleted; where the steam will act as a sweep gas.

Q. FIG 9 illustrates how a number of the above embodiments can function within the one process, with particular application to the Pulp and Paper Industry where it forms a somewhat symbiotic relationship.

A collector receives air-steam emissions from the paper and pulp mill, especially those from the drier section of the paper machines (other sources not indicated include those from thermomechanical pulping processes). This air-steam mixture, monitored for the correct amount of air required for combustion, is passed through a TC where it is compressed to a pressure high enough for the process to generate a steam pressure suitable for the dryers of the papermachine, as well as operate a gas turbine e.g. 250

psia. and higher. The compressed air-steam mixture goes to the pressure combustion furnace where combustible wet fuels are burnt to produce hot flue gases. Auxiliary fuel, oil or gas, can be added to the hot gases and burnt to maintain uniform combustion and an optimum temperature for the gas turbine. (see F above)

These hot gases are passed through a PR and a GT and then through a first section or area (i) of the PDCHE, a drier, which dries biomass material, e.g. forest waste and bark including, liquid concentrate from the flash evaporator, to a moisture content amenable to combustion in the pressure combustion furnace. From the drier the flue gases pass to the main second section or area (ii) of the PDCHE, a scrubber, where they come into intimate contact with a liquid concentrate, containing dissolved and suspended solids from paper & pulp effluents. In applications where only an effluent concentrate is to be combusted or the wet fuels are dry enough to combust, the drier would be omitted and the flue gases would pass directly to the PDCHE. The above concentrate would be generated in the initial start-up of the process as the dilute effluent is concentrated in the flash evaporator.

By continuously removing the heated concentrate and evaporating it in the flash evaporator at a pressure lower than that corresponding to the equilibrium or hot well temperature, so as to (a) convert some of the water in the concentrate into steam, (b) further concentrate the liquid, and (c) cool the concentrate to a temperature lower than the hot well temperature, and then returning the cooled concentrate from the flash evaporator to be reheated in the PDCHE; and removing the steam from the flash evaporator, much of the heat content of the flue gases is converted into process steam.

The saturated flue gases from the main PDCHE, after they are cooled to approximately the temperature of the liquid concentrate from the evaporator, are passed through the last section or area (iii) of the PDCHE to come into intimate contact with cool dilute effluent to further cool the flue gases and preheat the effluent;

Thus depending on the temperature of the entering effluent and the efficiency of the PDCHE heater, if the pressure of the flue gases is around 250 psia the water content in the flue gases could be approximately 0.10 lbs per lb of dry flue gas, which is that of the water content of most ambient air, and the thermal efficiency of the process could approach 90% depending on other factors.

Then by continuously removing some of the heated concentrate and adding the required preheated dilute effluent, the proper liquid concentration and balance in the system can be maintained.

The cooled flue gases from the PDCHE heater are passed through a TE to recover some of remaining enthalpy, which is used to compress the air-steam mixture. If necessary they can be put through a PR before going through the TE. Any make-up power for the compression can be supplied by a motor or, while not shown in the drawing, the cooled flue gases can be passed through a combustion chamber in which oil or gas can be burnt to heat the gases to the required temperature before they pass through a TE. (See embodiment G) Any excess power can be used to generate electrical energy by arranging for the M to also act as a G.

To remove any acidic gases from the flue gases, alkaline substances can be added to the liquor circulating in the PDCHE. By a proper choice of substances these will reappear in the ash being removed from the furnace, a portion of which may then be extracted using hot dilute effluent and returned to the PDCHE

The rest of the drawing illustrates how the water from effluents and the steam in the emissions from the paper and pulp mill is recycled back to mill. The steam from the flash evaporator if necessary is passed through a PR or a reboiler and then sent back to the PM dryers, or some used in the pulp mill. Any excess steam can be used to generate electrical energy using condensing steam turbines. The condensate from the dryers is used as clean make-up water at the wet end of the PM. This water reappears again in the white waters from the wet end which are sent to a fiber recovery system, from which they appear in the effluents from that system and are sent to the effluent collector, where they join effluents from the pulp mill. Condensate from the steam turbines can be used similarly in the paper & pulp mill where it will return via the effluents from the mill.

R. FIG 10 further illustrates how flexible the invention is and that it can even enter into further symbiotic relationships with other processes. One such process is the electrolysis of water under pressure (mentioned in embodiment I above) Electrical energy required for the electrolysis is supplied directly by any G adapted to produce the direct current, as converting AC to DC is inefficient. If the pressurized hydrogen, so produced, is not also used in the source process e.g. where CO is produced and this is combined with the H to form methanol, it becomes a very valuable by-product. Alternatively, the oxygen may be supplied as described in I above. If the electrolysis unit is located where further oxygen is required e.g. for pulping and bleaching, this may be a further advantage. Depending on the choice of material being burnt the exit gas will be fairly pure carbon dioxide, another by-product of the process, which has a wide use e.g. for urea, methanol, enhanced oil recovery, refrigeration, etc.

S. This is an embodiment where energy can be removed from the PDCHE for various purposes, and the resulting cooled liquid returned to the DCHE to be reheated. For example, a primary flash evaporator produces steam at the highest possible pressure level, the flashed liquid from the primary is then flashed in a secondary flash evaporator to produce steam at a lower level, if desired this sequence could be continued or, at any stage, the flashed liquid could be used to indirectly heat other media e.g. hot water heating of a building, with the final cooler liquid returned to the PDCHE for re-heating. Similarly, by subdividing the hot well liquid and liquid after flashing and using several independent circulating systems, the rates of circulation, which may depend on the rate of steam production, are not inflexibly tied in with rates and methods of cooling the combustion hot gases.

T. This is an embodiment where the cooled gases from the top of zone (iii) are cooled further, in order to reclaim further latent heat, by bringing them into indirect contact with the cooler gases between expansion stages in the gas expander. This is an example of how inter-stage-cooling and inter-stage-heating could be practiced in a counter-current or parallel arrangement.

U. This is an embodiment where those of H & I can be combined, wherein the electricity produced in H is one of direct current which is then fed directly to the electrolysis of water in I, thereby increasing the efficiency of the overall process. This can also apply to any electricity produced in steps (e) & (g). Similarly, in the case of the electrolysis of steam, the process can supply the direct current as well as the steam.

V. This embodiment where, like some of the above, advantages of other operations can be made use of in the PDCHE process. For example, transportation of materials by pipeline can often be less expensive than that by land or air. Thus, after the appropriate comminution of the material and its suspension in water, it can be pumped to the

primary site, where the wetted material is not a problem and the excess water can be used to cool the gases in PDCHE and any dissolved / suspended material in the water concentrated in the flash evaporator. This could be very useful for pressure combustion processes, where the combustible material (e.g. coal, peat, and various biomasses) can be transported to the combustion site by pipeline.

W. Figure 11 illustrates how the pressurized direct contact heat exchanger (PDCHE) is combined with a pressurized indirect contact heat exchanger (PICHE), by generating high pressure steam in order to take advantage of the higher efficiency of high pressure, high temperature steam turbines. While the PICHE is shown outside the source (for ease of illustration) it would usually be located within the source. While the amount of energy extracted by the PICHE will vary depending on the application, a maximum amount would require that enough energy be left in the hot gases in order to operate the PDCHE so the latent energy of the water vapor in the gases can be extracted in the flash evaporator.

While the PICHE is shown as a separate chamber outside of the SOURCE, it could be located within the confines of the SOURCE depending on the process producing the hot pressurized gases. Where the SOURCE is a combustion process, the PICHE could consist of tube banks located within the combustion chamber.

A PICHE can be introduced into any one of the above embodiments depending on the desired outcome.

X. In certain circumstances it may be possible to maximize the thermal efficiency further by combining both gas and steam turbine technologies with the PDCHE Process, by extracting some of the energy first in a gas turbine, then further energy in a PICHE using high pressure steam turbines (as shown in W. above) and finally the remaining energy in a PDCHE using the steam generated there either as process and / or in lower pressure steam turbines. Where the generation of electrical energy is the prime objective, this embodiment could offer the highest thermal efficiency. This could be the case for generation of electricity from coal, especially high sulphur coals. (See embodiment L)

Y. Another application involves coal bed methane and the sequestering of carbon dioxide, where unmineable, gassy coal beds are swept with pressurized gases containing carbon dioxide which releases the methane and traps the carbon dioxide. The gases containing carbon dioxide are also effective in increasing oil recovery, by reducing its viscosity and providing a driving force towards the wells. The addition of water / steam improves the sweep efficiency and the water can be recovered in the PDCHE.

In these applications, by using the already pressurized gases from the PDCHE the cost of the pressurization of the gases is avoided.

In this technology, while one objective is the removal of the polluting carbon dioxide, in other situations nitrogen is also used to sweep the methane from the coal., so how this application is used could depend on the proportion of carbon dioxide and nitrogen in the gases from the PDCHE as well as the use of the end product of this application, which will be pressurized gases containing methane, e.g. this methane can be used to further heat the hot gases as described in embodiment F.

Z. The present invention also has application to processes which produce gases which on combustion yield hot pressurized non-condensable gases containing water vapor. The following is an example: a pressurized fluidized-bed gasifier transforms coal into a coal gas containing hydrogen and methane (and carbon monoxide), which after suitable cleaning is combusted with a gas turbine to produce electricity, the hot gases containing

water vapor exit the turbine at a pressure sufficient to operate the PDCHE and produce low pressure steam as well as operate a PICHE which can supply high pressure steam to the gasifier, as illustrated in embodiment W above. Whether or not the PICHE produces steam for high pressure steam turbines is a separate consideration. In present systems, the hot gases from the turbine are sent to a conventional heat recovery steam generator, so that the energy in the water vapor is lost to the atmosphere.

AA. FIG. 12 illustrates a way to reduce greenhouse gases, where a pressurized direct contact heat exchanger (PDCHE) and pressurized combustion is combined with pressurized electrolysis of water to generate pressurized oxygen for the combustion, and hydrogen as a by-product. This produces substantially pure carbon dioxide in the flue / exit gases, which is used to accelerate biomass growth in a confined or enclosed space (e.g. an inflated plastic covering, see "solar tower" below). Low pressure steam from the flash evaporator can be used to heat the enclosed space. Part of the carbon dioxide can also be combined with ammonia to make compounds such as urea, which can also be used to accelerate biomass growth as urea.

By creating a false ceiling below the canopy or covering over the enclosed space, the oxygen and water vapour, generated by the biomass, being lighter than the carbon dioxide, can be segregated and removed and used in the PDCHE process (and the carbon dioxide recycled to the enclosed space or "greenhouse")

Some or all of the biomass can be used for combustion / human consumption and any waste from the latter use can be recycled through the combustion cycle.

If air liquefaction is used in place of or in addition to water electrolysis to produce the pressurized oxygen then the nitrogen from the liquefaction can be used along with the hydrogen (in case of the latter) to produce ammonia which can then be used to produce the urea.

A further symbiotic situation is where the above is combined with EnviroMission's (Australian firm) "solar tower" (a vertical wind farm) where a chimney, connected to and surrounded by a shallow, circular, acrylic greenhouse, (7km in diameter) will provide sufficient draft for the hot air generated by the greenhouse, to power turbo-generators to produce electricity.

AB. A special B embodiment is as follows: A fuel cell takes in hydrogen and a gas containing oxygen and generates electricity and expels hot gases laden with water vapour. By operating the fuel cell at elevated pressures and passing the hot gases through the PDCHE the efficiency of the cell is increased. If the gases are not hot enough, pressurized combustible gases / oil can be burnt within the gases to increase their temperature and consume any remaining oxygen or they can be heated by any of the methods described above.

The preceding description of the invention is merely exemplary and is not intended to limit the scope of the present invention in any way thereof.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A process for continuously converting the energy residing in hot pressurized non-condensable gases containing water vapor into a more useful form, comprising the steps of:

(a) providing a source which continuously produces hot pressurized non-condensable gases containing water vapor whose given pressure is commensurate with the steam pressure desired in the following flash evaporating step and with the desired thermal efficiency

(b) continuously bringing the hot gases into intimate contact with a cool aqueous liquid in a direct-contact heat exchanger having a hot well, where the gases will flow countercurrently to a flow of the cooler liquid and where water vapour will condense and the gases will become drier, said exchanger consisting of three areas / sections; (i) the first is one where the evaporative and heating property and part of the condensing and heating property of the hot gas will be utilized to heat the cooler liquid to the highest temperature it could have when in equilibrium with the hot gases at the given pressure, and thereby cool the hot gases; as well as allow heated liquid and condensed water to collect in the hot well at the top of area (i), while still maintaining the highest possible hot well temperature; (ii) the second is one where the gas and liquid will continue to progressively exchange heat content and supply heated liquid to the hot well at the base of the area, until the gas reaches the temperature of the liquid coming from the following flash evaporation step; (iii) and the third is one where the gas and liquid will progressively exchange heat content, until the gas as it cools approaches the temperature of the cool liquid entering at the top of the area and the liquid, as it heats, approaches the temperature of the liquid from the flash evaporator.

(c) continuously removing heated liquid from the hot well and flash evaporating it in a flash evaporator at a pressure lower than the pressure corresponding to the equilibrium or hot well temperature to thereby (1) convert some of the water in the liquid into steam and (2) cool the liquid to a temperature corresponding to the pressure of the flashed steam and allow it to collect in a sump in the evaporator.

(d) continuously removing the cooled liquid from the flash evaporator and reintroducing it to the direct-contact heat exchange section; at a point in area (ii) where the gas in the area is at about the same temperature.

(e) continuously removing the flashed steam from the flash evaporator for further use in a more useful form;

(f) continuously replenishing the cool liquid entering at the top of area (iii) and continuously removing excess liquid from the flash evaporator at the appropriate rate in order to keep the liquid in the exchanger and evaporator in balance;

(g) continuously removing the cooled gases from the top of zone (iii) for further use in a more useful form.

2. The process of claim 1, wherein in step (e) said further use involves its use as process steam and/or as a source of energy for the production of electricity using steam turbines connected to a generator and in step (g) said further use involves its use as a

source of energy for the production of electricity using a turbo-expander connected to a generator..

3. The process of claim 1, wherein in step (a) the source is a know process, but is now adapted to perform at a substantially elevated pressure and, if feasible, higher temperature.
4. The process of claim 1, wherein the gases, from the said source cannot be adapted to perform at a substantially elevated pressure, are turbo-compressed to the desired pressure, with the temperature increased by the compression.
5. The process of claim 1, wherein the steps of, collecting other non-condensable gases containing water vapor and turbo-compressing them to a pressure sufficient to introduce them into the source process, are added prior to step (a).
6. The process of claim 1, wherein the liquid from the hot well is heated indirectly to a higher temperature to thereby increase the steam pressure in the flash evaporator.
7. The process of claim 1, wherein the pressurized gases are further heated prior to going to a direct contact heat exchanger
8. The process of claim 1, wherein in step (g), the cool pressurized gases leaving the top of zone (iii), are heated prior to passing them through a gas turbine expander.
9. The process of claim 1, wherein prior to step (b) and after removing any particulates, the hot gases are passed through a gas turbine connected to a generator to produce electricity.
10. The process of claim 1, wherein the oxygen required is supplied from a source under a pressure greater than that of the source supplying the hot pressurized gases.
11. The process of claims 10 wherein the oxygen required is supplied from the electrolysis of water or steam under a pressure greater than that of the source supplying the hot pressurized gases.
12. The process of claim 1, wherein in step (f), the cool liquid, entering at the top of zone (iii) contains dissolved and/or suspended materials, such that the liquid can be concentrated by the recycling of the liquid through the pressurized direct contact exchanger and flash evaporator.
13. The process of claim 1, wherein area (i) of step (b) is used to dry materials.
14. The process of claim 1, wherein undesirable solids and/or gases present in the hot gases and can be removed in the heat exchanger by maintaining the circulating liquid alkaline for acidic gases and acidic for alkaline gases, the substances so formed can then be concentrated and removed from the flash evaporator.
15. The process of claim 1, wherein the non-condensable gas content is in the low range and the pressurized hot gases are sent to a primary pressurized direct contact heat exchanger and processed through the first and second areas of step (b) then they are removed from the exchanger at a temperature close to that of the temperature of the flashed liquid in the evaporator and fed to the suction side of the pump removing the flashed liquid from the flash evaporator, which is capable of pressurizing this removed

mixture to a pressure which will condense most of the steam in this removed gas mixture, this pressurized liquid and gas mixture is then sent to a secondary pressurized direct contact heat exchanger where the liquid and gases separate at a temperature corresponding to that of the pump pressure, the separated liquid in the chamber is sent to the top of the primary heat exchanger at a point where the removed gases exit, the heat content of the separated gases in the secondary heat exchanger, containing a low amount of steam, can then be recovered as desired.

16. The process of claim 1, wherein the steam from the flash evaporator, unsuitable for a particular use, is passed through a reboiler to recover its heat content for further use.

17. The process of claim 1 wherein the source process is a combustion process carried out under the earth or sea under pressure, at a site where there is combustible material, and where the combustion is supported by a pressurized gas containing oxygen and controlled by water piped to the combustion site from above and where the pressurized hot gases would be piped to a pressurized direct contact heat exchanger above said site and processed to recover its heat content.

18. The process of claim 1, wherein the source process is carried out under the earth or sea under pressure, where there is combustible material, and where the process is activated by high pressure steam, preferably superheated steam, which allows the material to flow to a pressurized direct contact heat exchanger above said site and processed to recover its heat content.

19. The process of claim 1, wherein, a primary flash evaporator produces steam at the highest possible pressure level, the flashed liquid from the primary is then flashed in a secondary flash evaporator to produce steam at a lower level, if desired this sequence could be continued and, at any stage the flashed liquid could be used to indirectly heat other media, with the final cooler liquid returned to the pressurized direct contact heat exchanger for reheating.

20. The process of claim 1, wherein the cooled gases from the top of zone (iii) are cooled further, in order to reclaim further latent heat, by bringing them into indirect contact with the cooler gases between expansion stages in the gas expander.

21. The process of claim 10, wherein some of the electricity produced is one of direct current which is then fed directly to the electrolysis of water or steam.

22. The process of claim 1, wherein the material to be processed at the source is, after the appropriate comminution, suspended in water and pumped to the source, where the wetted material is processed and the excess water used to cool the gases and any un-removed material in the water is concentrated in the flash evaporator.

23. The process of claim 1, wherein high pressure steam is generated, within the source process or by the hot gases after they leave the source, by a pressurized indirect contact heat exchanger, and used to generate electricity using steam turbines, and while the amount of energy extracted by the pressurized indirect heat exchanger will vary depending on the application, the maximum amount would require that enough energy be left in the hot gases in order to operate the pressurized direct contact heat exchanger so that the latent energy of the water vapor in the gases can be extracted in the flash evaporator.

24. The process of claim 23, wherein prior to going to the pressurized indirect contact heat exchanger and after removing any particulates, the hot gases are passed through a gas turbine connected to a generator to produce electricity.

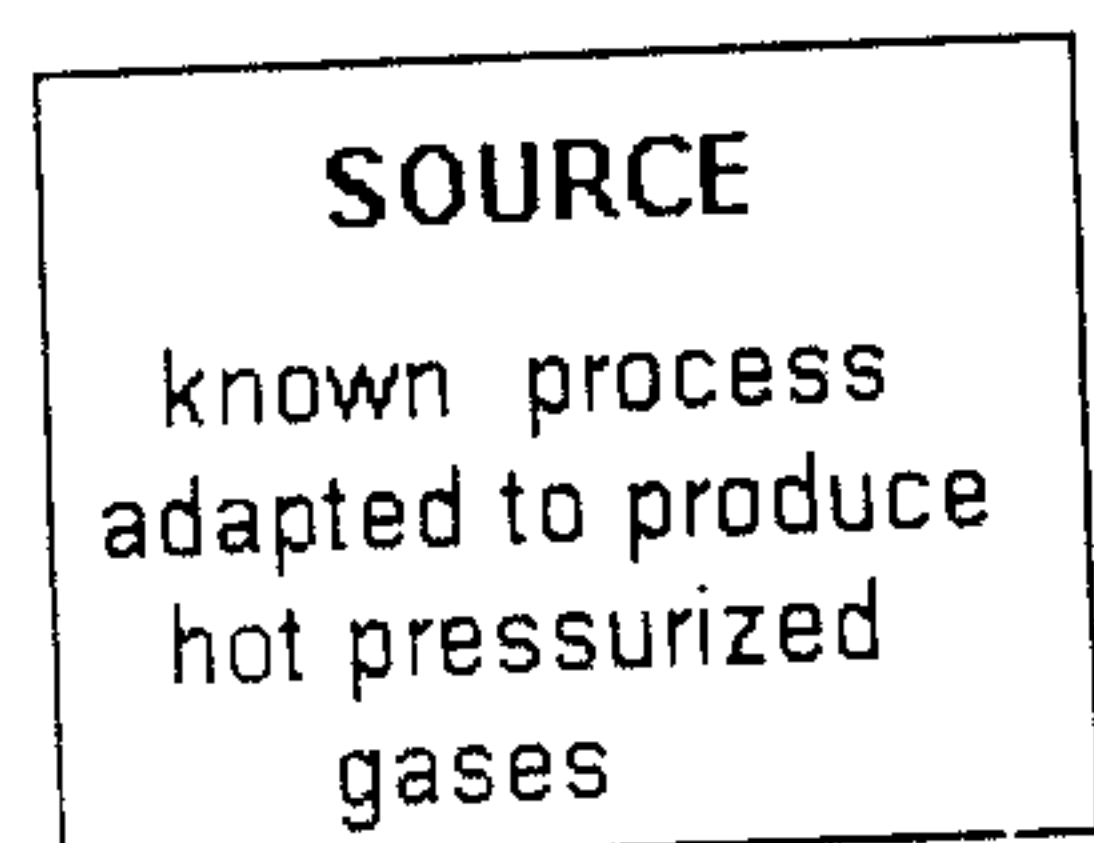
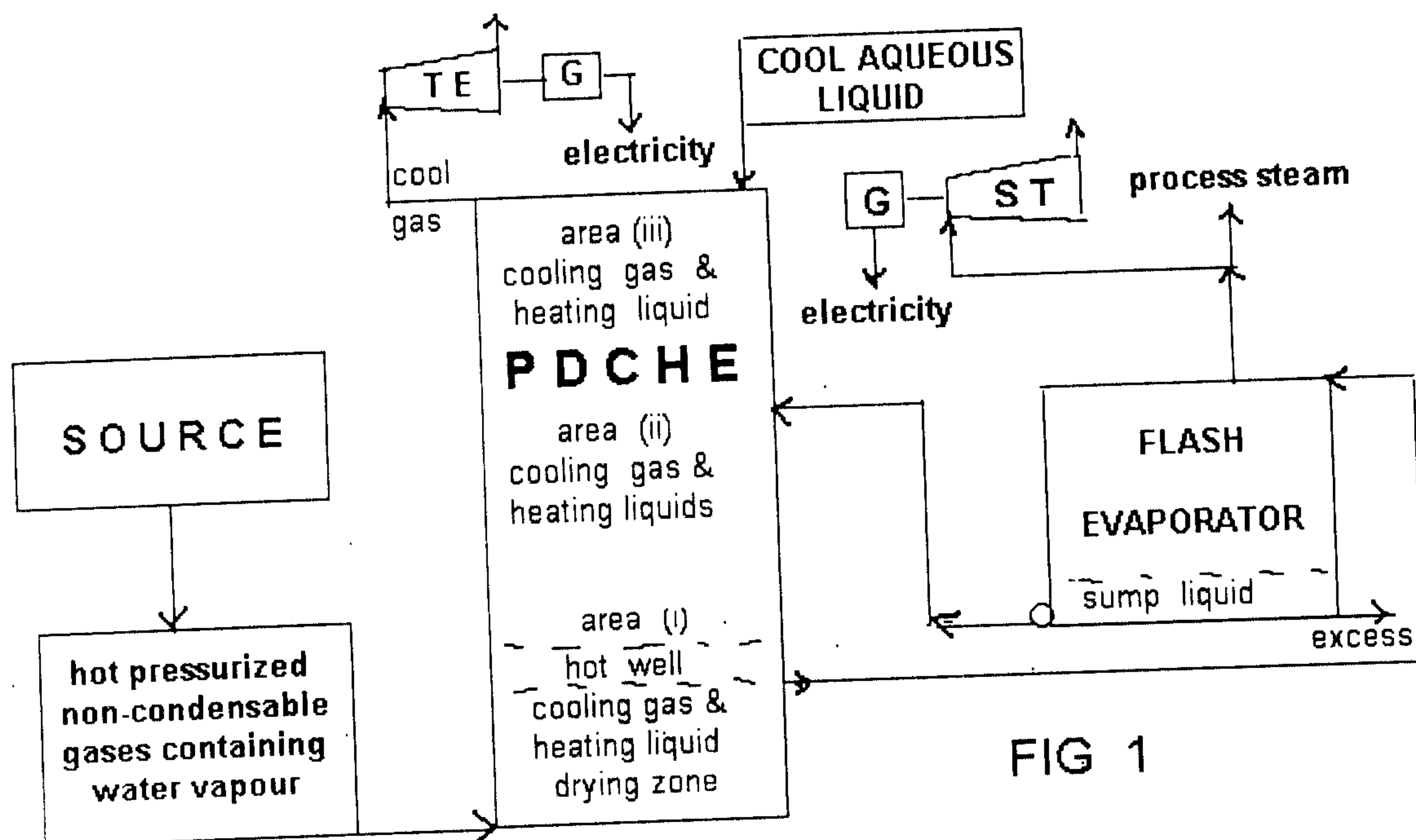
25. The process of claim 1, wherein in step (g) if said cooled pressurized gases contain carbon dioxide and / or nitrogen, said gases are used to sweep gassy coal beds to release the methane contained therein and trap the carbon dioxide and / or nitrogen thereby producing gases containing pressurized methane.

26. The process of claim 10, wherein substantially pure carbon dioxide in the flue gases is used to accelerate biomass growth in an enclosed space .

27. The process of claim 10, wherein by creating a second false ceiling below that enclosing said space, the oxygen and water vapour generated within said enclosed space , being lighter than the carbon dioxide, can be segregated and removed and used in the PCDCHE process and the carbon dioxide recycled to the enclosed space.

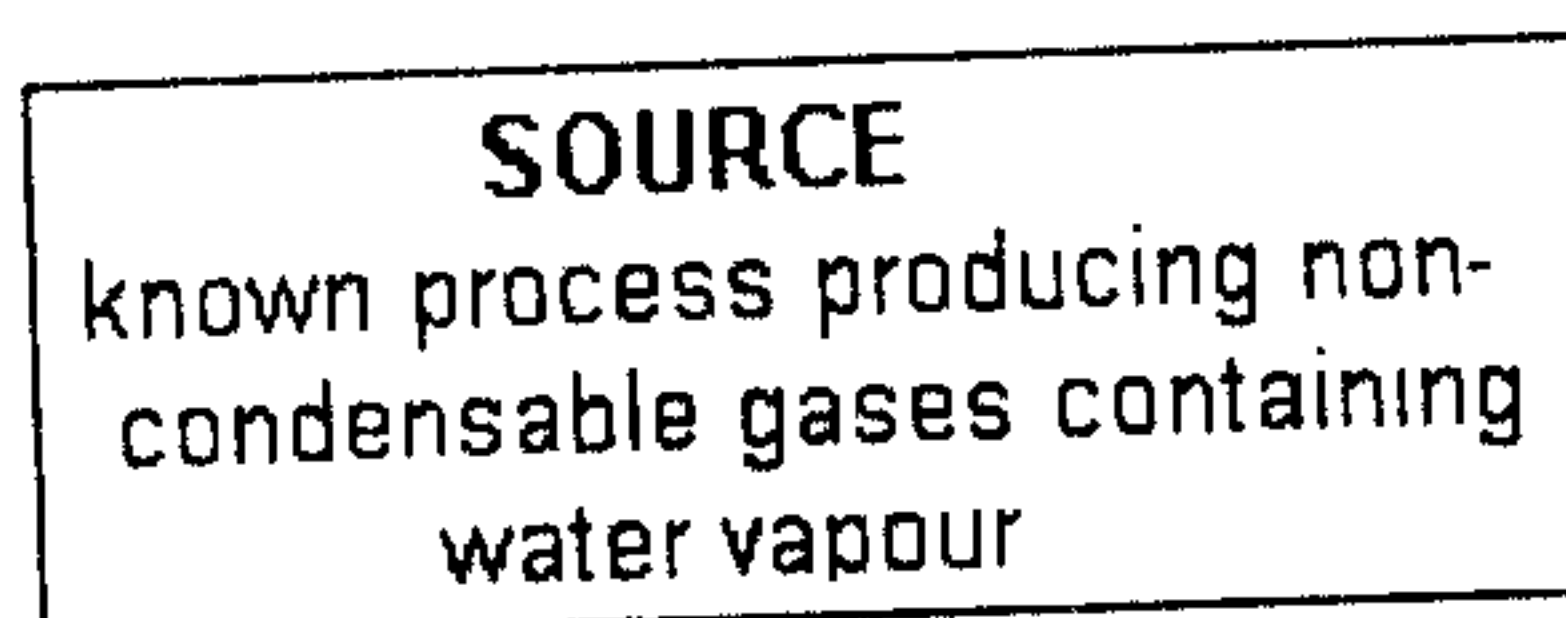
28. The process of claim 26, wherein a chimney is created, connected to and surrounded by said enclosed space, tall enough to provide sufficient draft for the hot air generated in said enclosed space, to power turbo-generators to produce electricity.

29 The process of claim 1, wherein in step (a), the source is a fuel cell, which takes in hydrogen and a gas containing oxygen and generates electricity and expels hot gases laden with water vapour, is now adapted to operate at elevated pressures, and if necessary, prior to step (b) the said gases are heated to a desired temperature



hot pressurized
non-condensable
gases containing
water vapour

see Fig 1
above



TC M

hot pressurized
non-condensable
gases containing
water vapour

see Fig. 1
above

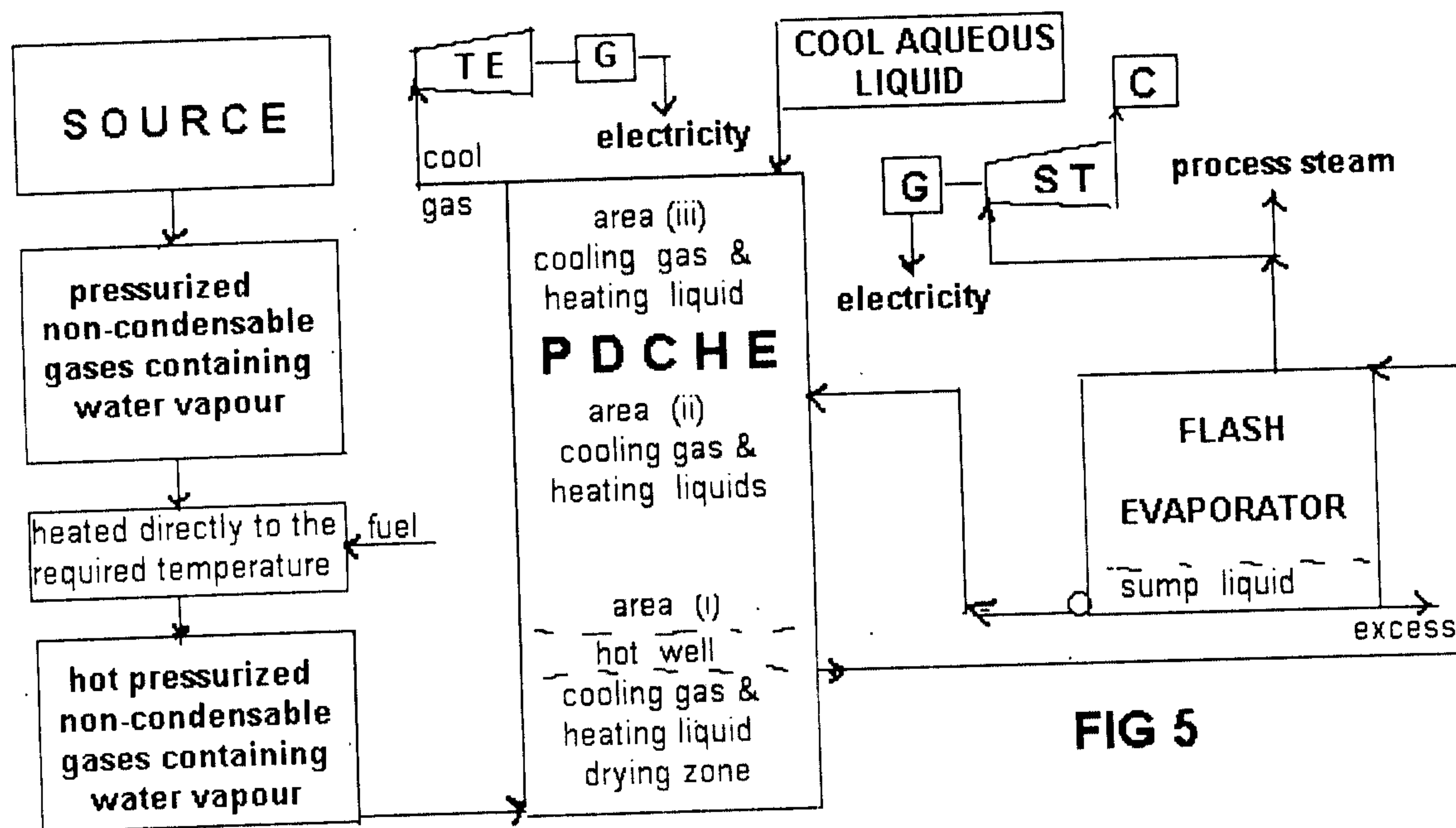
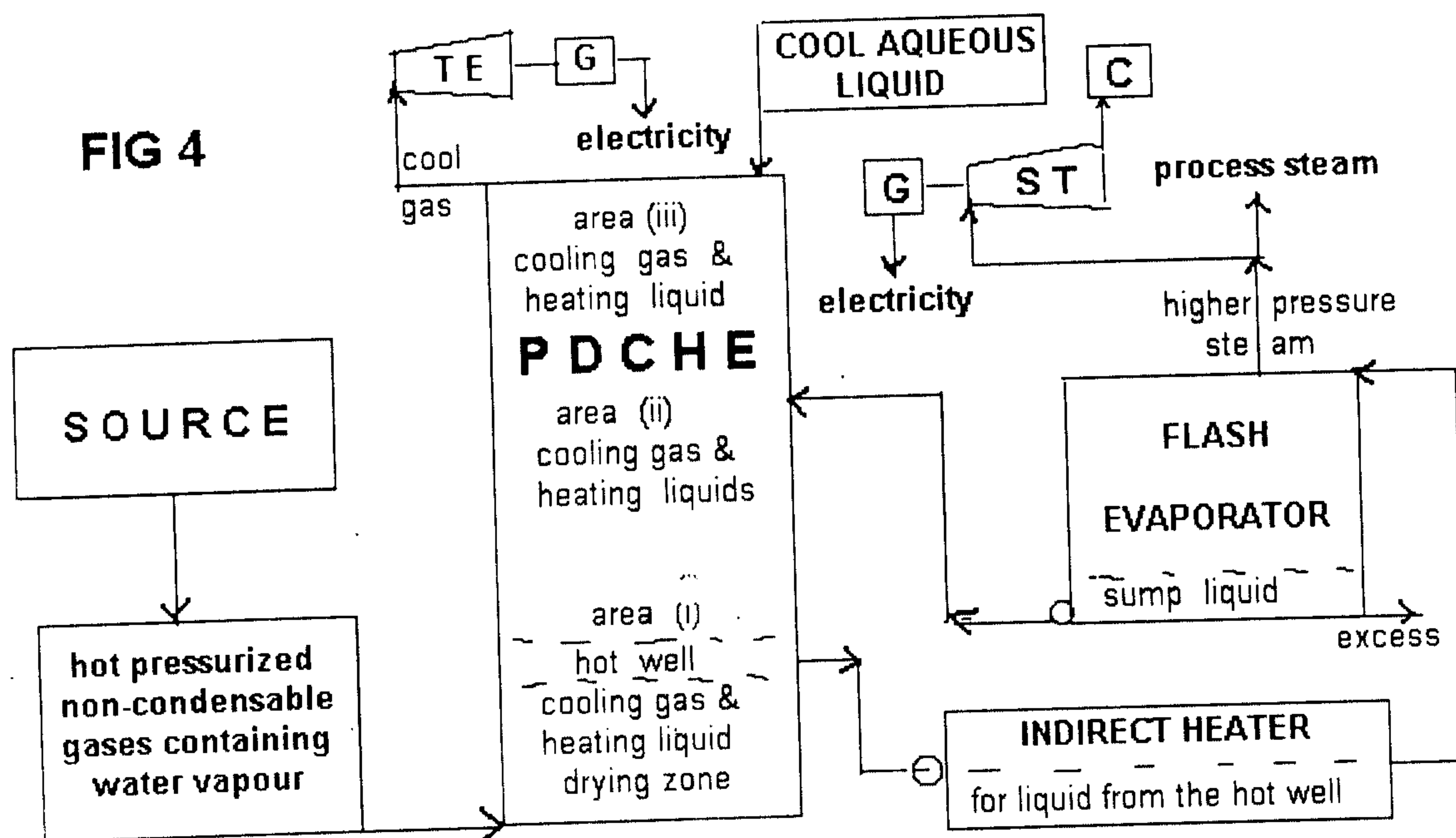


FIG 6

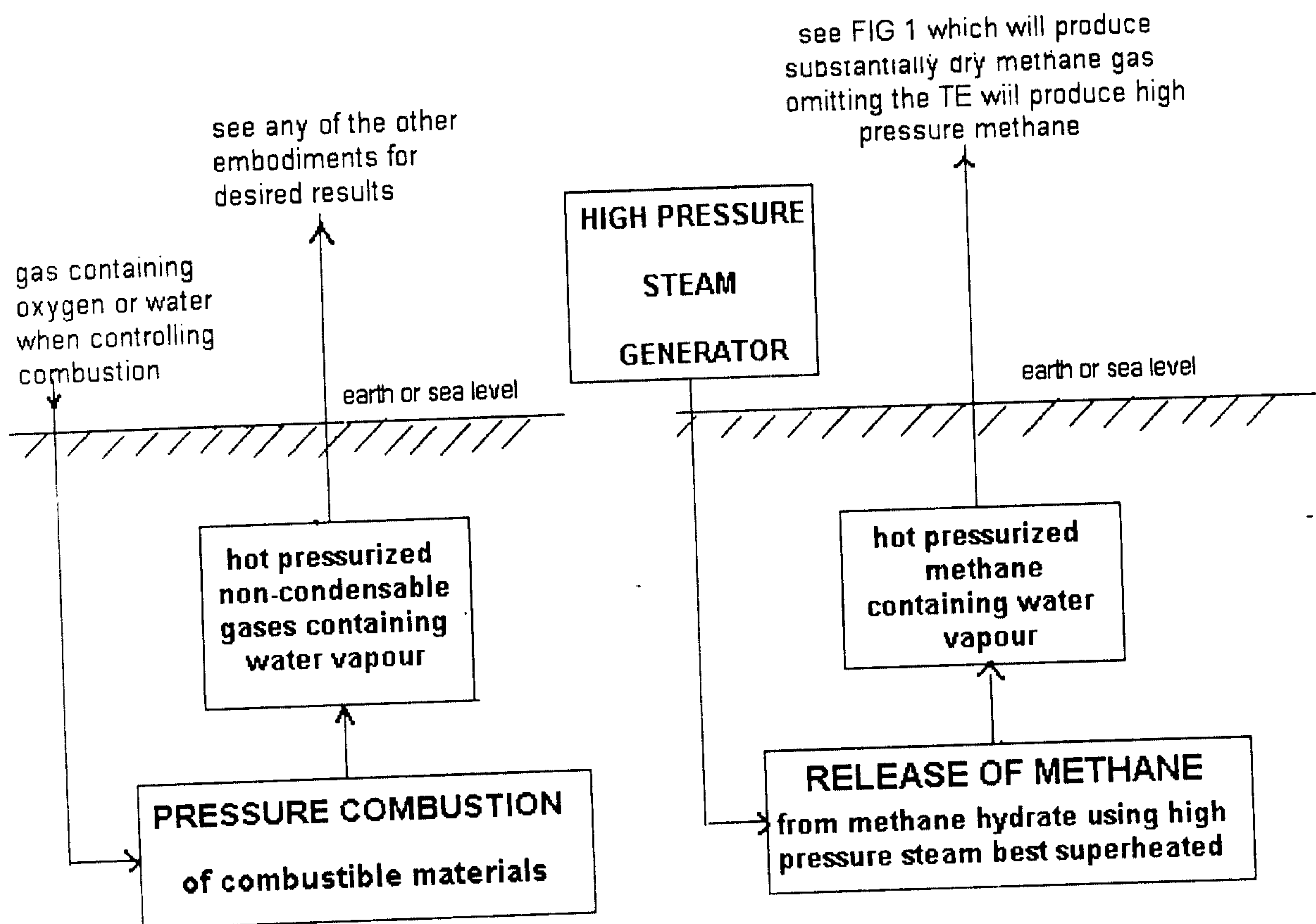
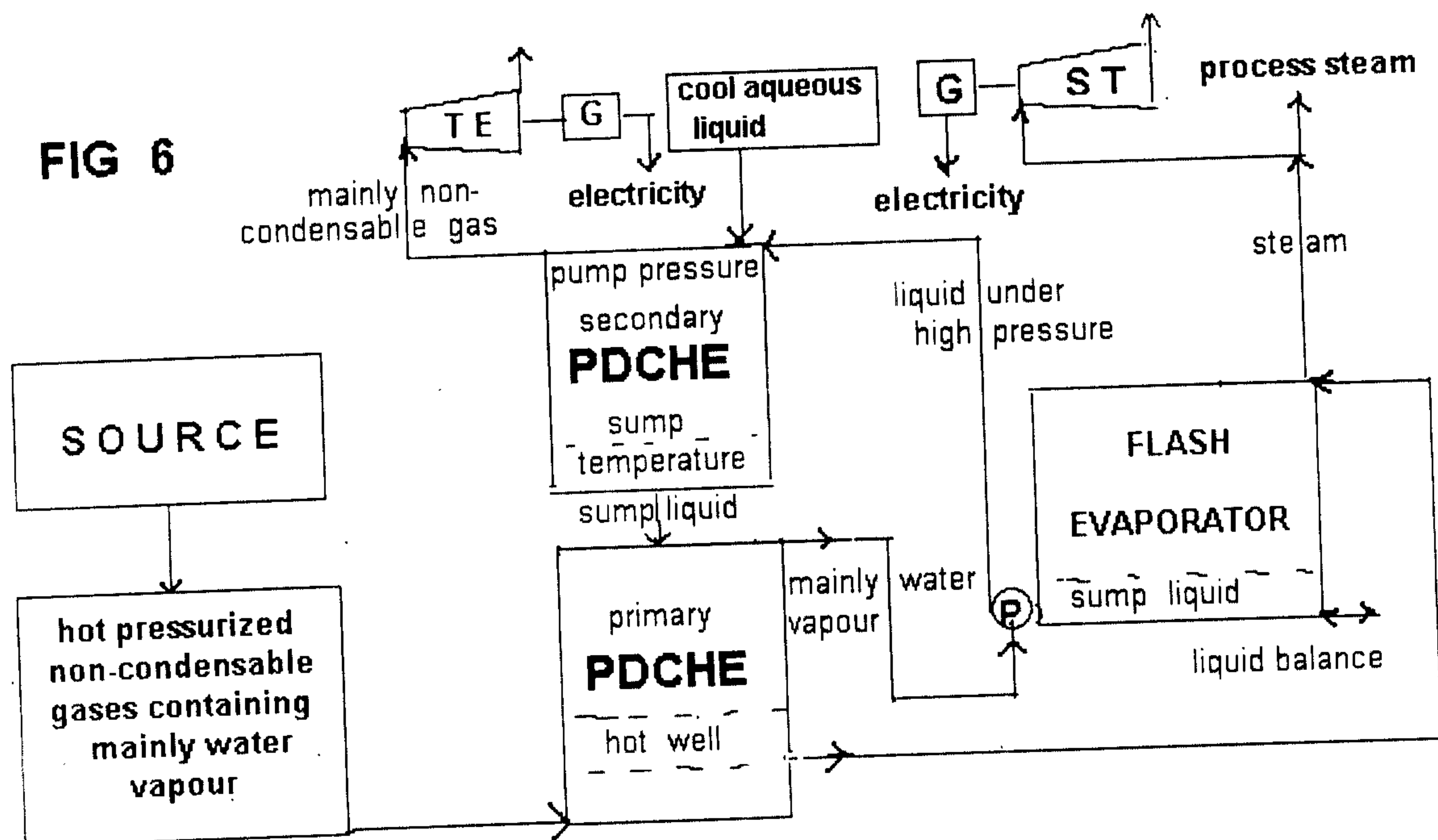


FIG 7

FIG 8

FIG 9

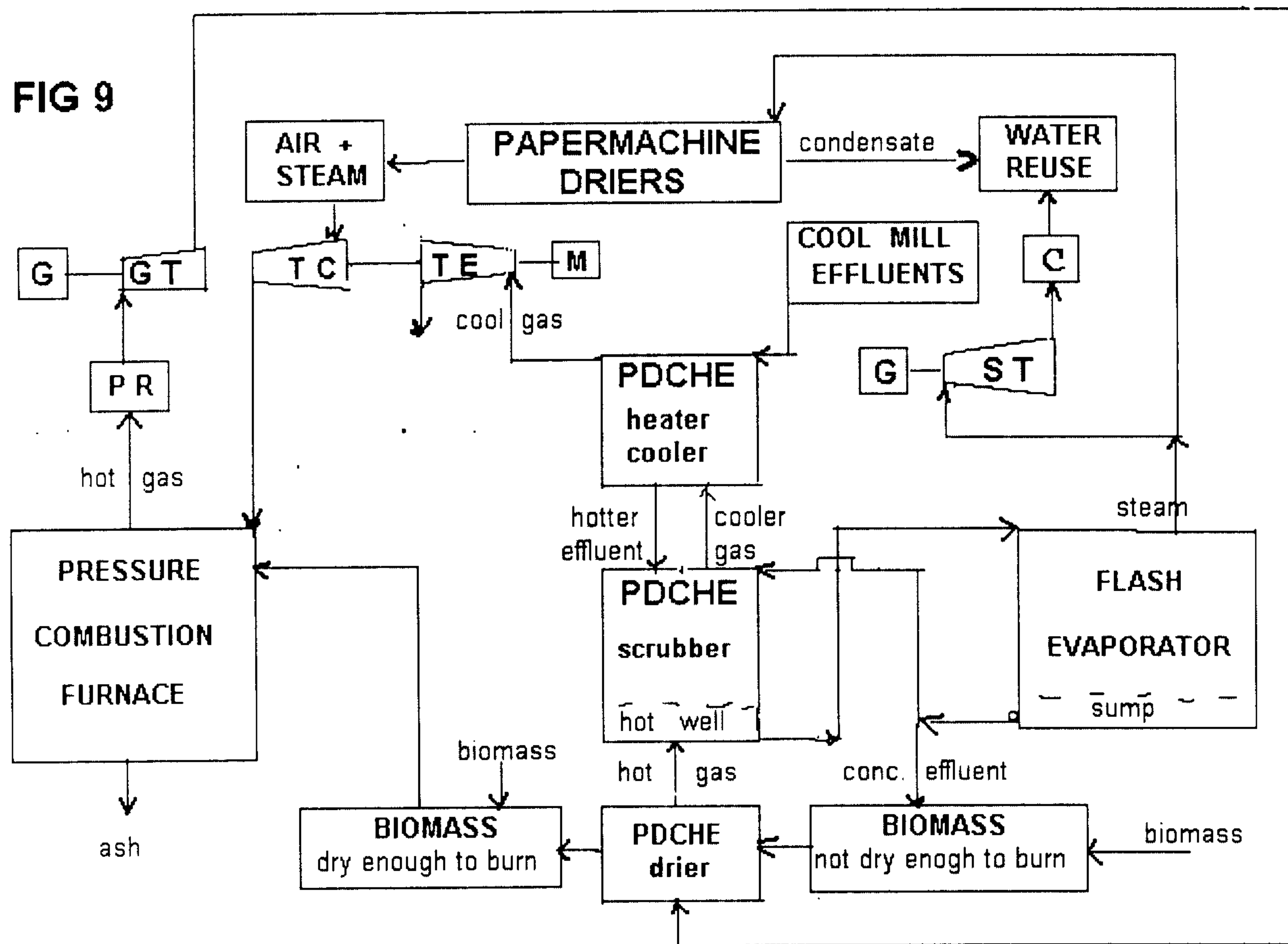
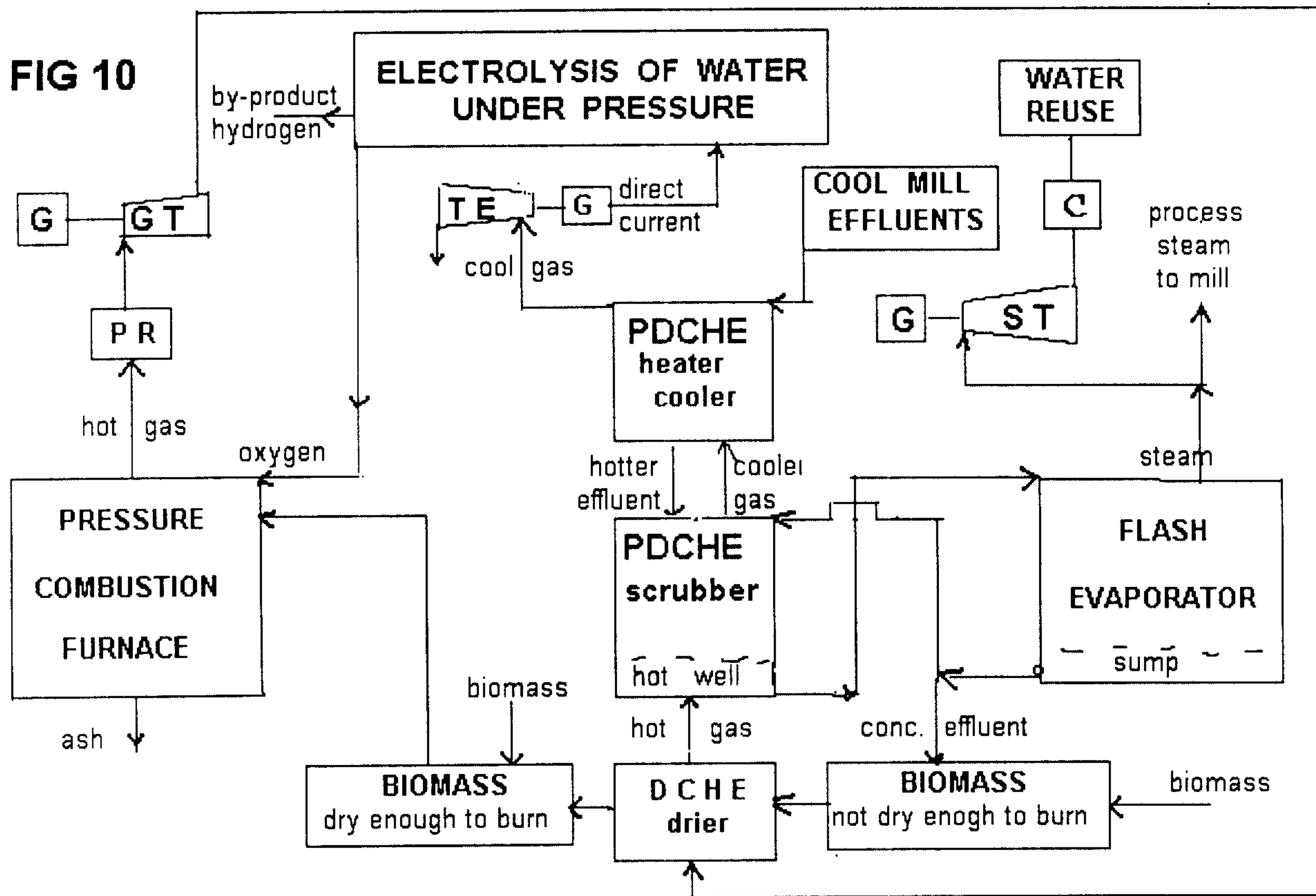


FIG 10



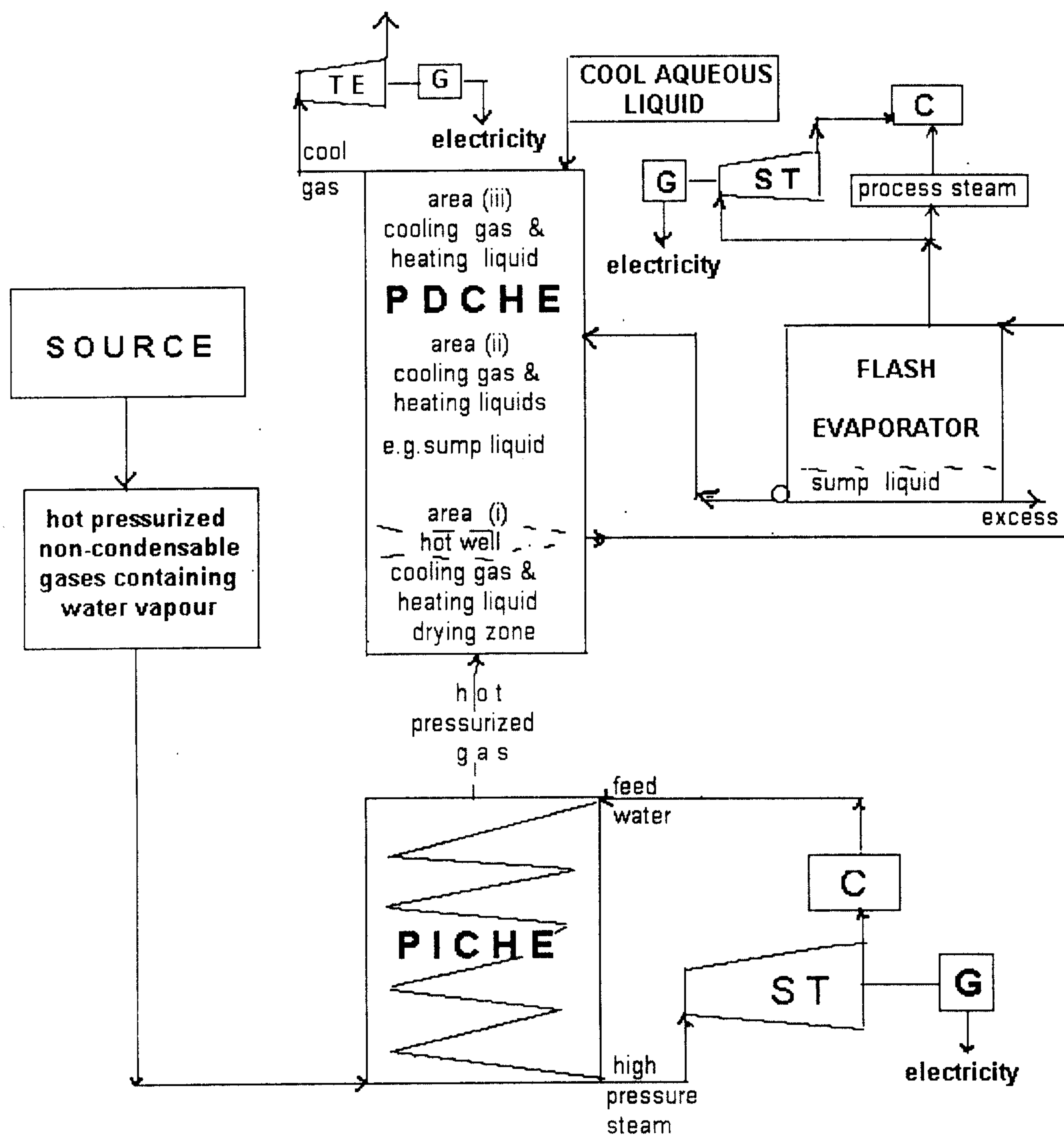


FIG 11

