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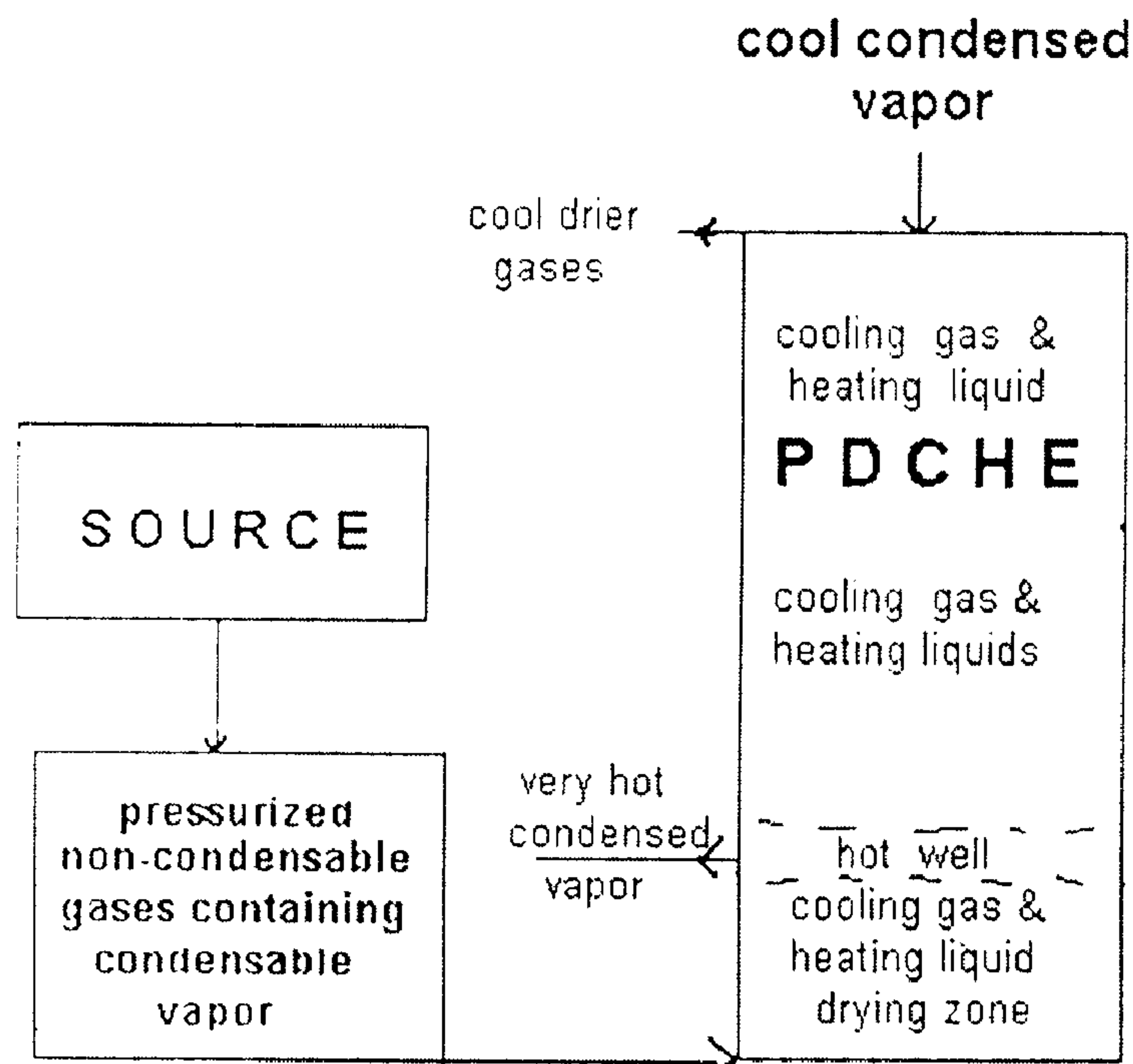
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(54) Titre : METHODE DE RECUPERATION DE L'ENERGIE

(54) Title: ENERGY RECLAIMING PROCESS



(57) **Abrégé/Abstract:**

The invention relates to gaseous sources from which to reclaim energy using a pressurized direct contact heat exchanger, and in particular, those sources containing a condensable vapor. While the main applications involve water as the condensable vapor, the process is applicable to other vapors, e.g. those in the chemical and petroleum industries where various organic solvents are used. The reclaimed energy can be in the form of a hot fluid, process steam and or electricity. It has particular application to: a pressure combustion furnace and the DOE's Clean Coal Technology; the combustion of wet fuels (biomass, peat); pulp & paper; electrolysis of alumina or water; detoxidation, thermal depolymerization, enhanced oil recovery (and sequestering of carbon dioxide), phytotechnology,

A B S T R A C T

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ENERGY RECLAIMING PROCESS

FIELD OF THE INVENTION

The invention relates to gaseous sources from which to reclaim energy using a pressurized direct contact heat exchanger. In particular, those sources containing a condensable vapor. While the main applications involve water as the condensable vapor, the process is applicable to other vapors, e.g. those in the chemical and petroleum industries where various organic solvents are used.

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If the source is not already under pressure, the invention converts it to a higher pressure.

DESCRIPTION OF THE PRIOR ART

Present processes release large volumes of gas into the atmosphere, resulting in a loss of energy, especially the latent heat of any condensable vapor, resulting in low thermal efficiencies.

While various direct contact heat exchange systems have been proposed to recover this energy, all of them operate at close to atmospheric pressure and recover mainly the sensible heat and the temperature of the recovered fluids are near or below the boiling point of the fluid at the recovered pressure.

US Patents 3,920,505 and 4,079,585 are previous disclosures relating to the recovery of waste sulfite liquors using a pressurized heat exchange process.

SUMMARY OF THE INVENTION

The basis embodiment of the invention comprises:

- (a) providing a source from which to reclaim any additional energy from pressurized gases, continuously being produced within and/or emanating from the source, and if necessary, converting the source to a higher pressure, so that pressurized gases are produced;
- (b) continuously bringing the pressurized gases into intimate contact with a cooler liquid, in a pressurized direct-contact heat exchanger, a vertical vessel consisting of various sections, including a hot well, where the gases will enter at the bottom, flow counter-current to a flow of the cooler liquid and where any condensable vapor will condense and the gases will become drier, and leave at the top where the cooler liquid enters, said exchanger being capable of being divided into several areas / sections; the first area being where any evaporative and heating property of the gases could be used to dry materials, a second area where part of the condensing and heating property of any vapor in the gas will be utilized to heat the cooler liquid to the highest temperature it could have when in equilibrium with the gases at the given pressure, and thereby cool the gases; as well as allow heated liquid and condensed vapor to collect in the hot well within the area, while still maintaining the highest possible hot well temperature, and continuously removing liquid from the hot well as reclaimed energy for further use or alternatively, continuously removing the liquid in the hot well and sending it to a flash chamber to produce vapor and the cooler flashed liquor reintroduced into this second area to cool further gases; and the third area is 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 cool liquid entering at the top.

(c) continuously replenishing the cool liquid entering at the top of the exchanger

(d) continuously removing the cooled gases from the top of the exchanger as reclaimed energy for further use.

Other embodiments are listed below

BRIEF DESCRIPTION OF THE DRAWINGS.

To avoid complexity, valving and other obvious operations are not always shown, or labeled e.g. exhaust steam from steam turbines could go to a condenser; the gas compressor in Fig. 3 and elsewhere could be connected directly to the turbine expander, along with an electric motor. 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:

Figure 1 illustrates the main embodiment described above The figure shows two “cooling gas and heating liquid “areas, as the liquid in the hot well can alternatively be sent to a flash chamber and the cooler flashed liquor reintroduced into the second area to cool further gases, see Figure 1B.

Figure 1A illustrates schematically how Carson’s Fluidized Spray Tower can be incorporated in the present invention.

Figure 1B illustrates an embodiment where the liquid in the hot well is sent to a flash chamber / evaporator to produce steam and the cooler flashed liquor reintroduced into the second area to cool further gases.

Figure 1C illustrates an embodiment where the hot water from the hot well is sent through a pressurized indirect contact heat exchanger, heated by the hot gases, to produce high temperature, high pressure steam, for use as process steam and / or to generate electricity using high efficiency steam turbines.

Figure 1D illustrates an embodiment where the steam from the flash chamber is sent through a pressurized indirect contact heat exchanger, heated by the hot gases, to produce superheated steam.

Figure 2 illustrates an embodiment where a known process (Source) is adapted to produce the gases required for the embodiment shown in Figure 1

Figure 3 illustrates an embodiment where the gases from a known process (Source) are passed through a gas compressor to produce the pressurized hot gases required for the embodiment shown in Figure 1.

Figure 4 illustrates an embodiment 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.

Figure 5 illustrates an embodiment where the pressurized gas-steam mixture is heated prior to going to the pressurized direct contact heat exchanger.

Figure 6 illustrates an embodiment 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 pressurized direct contact exchanger.

Figure 7 illustrates an embodiment where combustible material is combusted under the earth or sea and the gases processed above the site in the pressurized direct contact exchanger.

Figure 8 illustrates an embodiment where gaseous material under the earth or sea can be brought above and processed in the pressurized direct contact exchanger.

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

Figure 10 illustrates an embodiment where the electrolysis of water under pressure supplies oxygen to a pressure combustion furnace and illustrating a further symbiotic relationship with the invention. Combining it with that of the embodiment of Figure 9 would illustrate a further symbiotic relationship, in that the Paper Machine Dryers could also contribute further oxygen, present in the air and steam, to the combustion step.

Figure 11 illustrates an embodiment where a pressurized direct contact exchanger is combined with a pressurized indirect heat contact exchanger, (which could be located within the Source), to generate high pressure high temperature steam, in order to take advantage of the higher efficiency of high pressure, high temperature steam turbines.

Figure 12 illustrates an embodiment where greenhouse gases, such as carbon dioxide, are produced which can be recycled through its use to accelerate biomass growth. In this embodiment a pressurized direct contact exchanger 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, when the fuel is essentially carbon.

Figure 13 illustrates an embodiment where by operating a fuel cell at elevated pressures and temperature and passing the hot gases through the pressurized direct contact exchanger, the efficiency of the cell is increased,

Figure 14 illustrates an embodiment where energy is reclaimed from a process involving the electrolysis of alumina

Figure 15 illustrates an embodiment where energy is reclaimed from a process involving the electrolysis of water.

Figure 16 illustrates an embodiment where energy is reclaimed from a process involving the electrolysis of steam using the Ceramtec Process and combined with other embodiments illustrated above. The steam from the flash evaporator could be processed as illustrated in Figure 1C.

Figure 17 illustrates an embodiment where the electrolysis of water or steam is combined with other processes and embodiments and the results used in various applications e.g. oil enhancement, phytotechnology .

Figures 18 & 19 illustrate an embodiment where various substances are processed in a pressure reactor and the reacting materials are handled in two different ways to produce steam.

Figure 20 illustrates an embodiment where thermal depolymerization is carried out.

Figures 21 & 22 illustrate embodiments where gases existing at lower pressures can produce hot fluids (which in the case of water can produce high pressure steam and / or electricity).

Figure 23 illustrates an embodiment where further energy can be reclaimed in pressure combustion projects in the Clean Coal Technology Program sponsored by the US Department of Energy.

Figure 24 illustrates an embodiment where further energy can be reclaimed in gasification projects in the Clean Coal Technology Program sponsored by the US Department of Energy.

Figures 25 and 26 illustrate an embodiment where the invention can be applied to the recovery of bitumen (i.e. oil) from Oil Sands, including the recovery of energy and water.

Figure 27 illustrates an embodiment where the invention can be applied to a new paper technology referred to as Impulse Drying.

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. For example, while many of the embodiments below will use water as the condensable vapor it will be understood that wherever feasible there embodiments can be used for other condensable vapors, such as the many organic solvents used in the chemical industry. In most cases computer simulation will be required to balance the various variables such as the rate of recirculation of the hot well liquid through the flash chamber; the cool liquid supply; the excess liquid removal, which can be done at the appropriate location: etc.

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 pressurized direct contact heat exchanger, the lower the vapor content of the exit gases and the higher the thermal efficiency. Embodiments involving lower pressures are also being included, see Figures 21 & 22.

Referring to the accompanying drawings, 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	<u>Note:</u> TC also represents a rotary blower	
PICHE	Pressurized Indirect Contact Heat Exchanger		

Referring to the drawings in greater detail.

Figure 1 shows the basic embodiment described above.

The gases can contain two components of heat, sensible heat and latent heat. If there is little or no condensable vapor in the gases, it will essentially be all sensible heat and the cooler liquid will extract heat and become hotter. If there is condensable vapor the cooler liquid will condense the vapor and the resulting heat will be absorbed by the cooler liquid and become hotter

Examples of further use for the condensed vapor in the hot well are numerous and well known in the trades in which a particular condensed vapor is involved, and which will also depend on the temperature of the condensed vapor in the hot well, which is determined by the pressure of the hot gases and the vapor pressure of the condensed liquid.

For example, if the condensed vapor is water and the pressure of the gases in the heat exchanger is 200 psia the temperature in the hot well will be somewhat below 195 C (382 F) depending on the efficiency of the heat exchange, Similarly, further use of the gases will depend on the type of non condensable gas involved and the dryness of the gas will depend on the pressure and temperature of the exiting gases, i.e. Henry's Law of Partial Pressures. For example, using the following equation for gas saturated with water vapor at t°F:

$$\frac{\text{lb.mols H}_2\text{O} / \text{lb.mols dry gas}}{M} = \frac{\text{vapor pressure of water at t}^\circ\text{F} / \text{total pressure}}{1 - \text{vapor pressure water at t}^\circ\text{F} / \text{total pressure}}$$

we find that at 100°F & 250 psia M=0.0038 which is way below that of a normal ambient condition, so if this temperature was attainable for the exiting flue gases, it would greatly improve the overall thermal efficiency, especially if the air being fed into the turbine compressor had a high water vapor content. Even at 160°F & 250 psia M = 0.0193 & at 200 psia M = 0.0243 & at 150 psia M = 0.0326, all within a normal ambient range.

These higher pressures are required when higher hot well temperature are desired and / or when the invention is used in connection with a flash evaporator / chamber to produce fairly high steam pressures and to concentrate effluents. The lower end of pressure spectrum, e.g. in the range of that produced by a rotary blower, can be used to reclaim the energy as illustrated below in Figures 21 & 22.

The cool dry pressurized gases are source of energy for the production of electricity using a turbo-expander connected to a generator.

Where water is the condensed liquid in the hot well it could obviously be used to heat large living and business complexes especially in remote places. Further use for the cool gases and water in the hot well are described in the various embodiments below.

While the various areas or zones of the pressurized direct contact exchanger are some times shown in one chamber, they could be located in separate chambers or sections Here the hot well is shown near the top of lower zone 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 heat exchanger 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 pressurized exchanger and recycling it in the exchanger until its temperature approaches that of the gas; etc. While the cooling liquid introduced into various areas 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. To increase the dwell time of contact between the gas and the cooler liquid, a portion of the descending liquid may be withdrawn from the top section and re-circulated back through the gas This procedure may be repeated at any place in the exchanger where it seems appropriate. The top location could be the best place to remove any liquid in order to maintain a water balance as its heat content would be the least.

A particular heat exchange process used for gases at atmospheric pressure is the “Fluidized Spray Tower” technology, recently developed by William D. Carson and disclosed in US Patent Application 20030015809). The disclosure of which is hereby incorporated by reference, as embodiments of that Process, designed to recover heat from non-condensable gases containing a condensable vapor, are directly pertinent to this

invention, designed to recover heat from gases at pressures and temperatures greatly higher than presently attempted.

As illustrated schematically in FIGS 1A, using water as the condensable vapor, the pressurized hot gases enter at the lower end of the First Tower and if necessary can be scrubber clean of solid material and leave with the waste condensate; Water (heated) in the Second Tower enters the First Tower to be further heated and accumulate in the “reservoir” i.e. hot well; the still hot gases from the First Tower are introduced into the Second Tower to be further cooled and dried by the very cool water entering the Second Tower. For gases at lower temperatures, one Tower would suffice, possibly using the single chamber embodiment, and for very high temperatures possibly more than two Towers may be necessary.

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 various embodiments below.

Existing high pressure process sources include: (a) pressurized combustion projects in the Clean Coal Technology Program sponsored by the US Department of Energy, where pressures up towards 250 psia are reached using combustion furnaces developed by such firms as Foster Wheeler, ABB (now Alstom Power), & Babcock & Wilcox; (b) high pressure char oxidation; processing of wood in digesters; etc.

In Figure 2, the Source involves a known process which does not provide the pressurized gases required, but can be adapted to perform at a substantially elevated pressure and, if feasible, higher temperature as was done above for coal.

Examples:

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; (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.

(2) Diverse processes such the smelting of ores; wet oxidation; chemical, electrochemical, metallurgical processes (blast furnaces), and intermediary operations such as: drying; stripping, extraction; boiling and the like.

In Figure 3, there is shown an arrangement wherein the increase in pressure 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. 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 pressurized exchanger. See embodiments below.

It is also possible, to collect 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. For example, in the above paragraph the air-steam mixtures could be turbo-compressed and introduced into a combustion furnace. Other such mixtures include naturally occurring ones such as fog banks, low clouds, mists, steam eruptions from the earth, etc.

In most of the following embodiments, water will be the “condensed vapor“ used in the examples. Embodiments involving the flash evaporator will generally also be used along with the use of low pressure steam turbines but it is understood that wherever there

is need to increase the thermal efficiency of the turbines the above embodiments shown in Figures C & D can be used.

The following embodiment involves expanding the alternative use of the hot well liquid of the main embodiment as follows:

continuously removing heated liquid from the hot well and flash evaporating it in a flash chamber 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 flash chamber, continuously removing cooled liquid from the flash chamber and re-introducing it to the direct contact heat exchange section; at a point in the second area where the gas in the area is at about the same temperature as that of the liquid in the sump, so as to cool further gases, and where the gas and cooled liquid will progressively exchange heat content, until the gas as it cools approaches the temperature of the liquid from the flash chamber; continuously removing the flashed steam from the flash chamber for further use;

This further embodiment is illustrated in FIG 1B, and 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.

As mentioned above the temperature of the water in the hot well will depend on the pressure in the exchanger and correspondingly this will determine the pressure of the steam from the flash chamber. As mentioned, at 200 psia the temperature in the hot well

will be somewhat below 195 C (382 F) so this could produce steam pressures in a range somewhere below 200 psia depending on the flashing potential used and several other factors, including the enthalpy of the gases,

It should be noted that the pressurized direct contact heat exchanger in combination with a flash chamber / evaporator can concentrate cool effluents containing solids, used to cool the gases, which if combustible can be burnt in a combustion furnace. Examples are given below. Another feature of this combination, is that when the efficiency of lower pressure steam turbines has been significantly increased, it will not be necessary to use the embodiments illustrated in Figures 1C & 1D, and so avoid the high cost and maintenance of pressurized indirect contact heat exchangers

Figure 1C illustrates how the hot well water can be upgraded, especially where the temperature of the hot gases is high enough, as it would be, for example, when the gases come from a high pressure combustion furnace. This means that the hot water can now be turned into high temperature, high pressure steam, and used in high efficiency steam turbines to produce electricity, by passing it through a pressurized indirect heat exchanger i.e. boiler. In Figure 1C it is shown separately but can be located within the source e.g. a pressure combustion furnace. Alternatively, if the Source is not pressurized, the hot well water can be upgraded by passing it through a conventional atmospheric boiler.

Figure 1D illustrates how the medium to low pressure steam from the flash chamber can be upgraded in order to improve the efficiency of the lower pressure steam turbines, should their efficiency not be high enough. Here the lower pressure steam is superheated by passing it through a pressurized indirect contact heat exchanger, before passing through the lower pressure steam turbines. The pressurized indirect heat

exchanger i.e. a super-heater is shown separately but can be located within the source e.g. a combustion furnace. Similarly, as mentioned above the low pressure steam can be upgraded by passing it through a conventional atmospheric boiler.

Figures 9 & 10 illustrate how the overall efficiency of the process can be upgraded by passing the pressurized hot gases through a gas turbine connected to a generator to produce electricity, before they are sent to the pressurized direct contact heat exchanger. In this case, the pressure of the gases from the turbine should still be high enough to operate the exchanger satisfactorily. The gases from the turbines could also go to a pressurized indirect contact heat exchanger before going the direct contact exchanger, as illustrated in Figures 1C & 1D.

Which of the above embodiments is chosen could depend on which is less expensive approach.

Figure 4 illustrates an arrangement 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.

Figure 5 illustrates an embodiment where the pressurized gases are further heated prior to going to a pressurized direct contact heat exchanger, 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, one can also heat the cool gases leaving the pressurized direct contact heat exchanger prior to them entering the turbine expander. 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 one

embodiment below. This may be necessary to avoid water condensing or freezing in the turbine expander, if the pressure is very high and the temperature low.

As previously mentioned, a further arrangement 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 gas turbine connected to a generator to produce electricity, before being sent to the pressurized direct contact heat exchanger.

This is particularly advantageous for a combustion process where high gas temperatures are achievable as illustrated in Figure 9 & 10. 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 Figure 9.

Oxygen, if 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 turbine compressor. 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 Figure 10 and expanded below. Alternatively, the oxygen may be supplied in bulk or by air liquefaction with nitrogen as a by-product.

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 pressurized direct contact heat exchanger 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 Figures 9 & 10. (see 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.

It is also possible that the first area of step (b) in the embodiment of FIG 1, 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 pressurized direct contact heat exchanger. 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 Figures 9 & 10.

Undesirable solids and/or gases present in the hot gases 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 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 pressurized direct contact heat exchanger, where a minimum of liquid could reduce their concentration.

Illustrated in Figure 6 is where the non-condensable gas content is in the low range. Here the pressurized hot gases are sent to a primary pressurized direct contact heat exchanger and processed through the first and second areas of the main embodiment, 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 which is 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 secondary pressurized direct contact heat exchanger is sent to the top of the primary pressurized direct contact heat exchanger 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 turbine expander connected to a generator, 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.

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.

As illustrated in Figure 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 pressurized direct contact heat exchanger above the site and processed utilizing any of the other embodiments that will give the desired result

Illustrated in Figure 8 is an embodiment 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 pressurized direct contact heat exchanger 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 pressurized direct contact heat exchanger above the site to be dried as in Figure 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.

Figure 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 turbine compressor where it is compressed to a pressure high enough for the process to generate a steam pressure suitable for the dryers of the paper machine, 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 above)

These hot gases are passed through a particulate remover and a gas turbine and then through a first section or area of the pressurized direct contact heat exchanger, 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 of the pressurized direct contact heat exchanger 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 pressurized direct contact heat exchanger. 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 pressurized direct contact heat exchanger; 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 pressurized direct contact heat exchanger, after they are cooled to approximately the temperature of the liquid concentrate from the evaporator, are passed through the last section or area of the pressurized direct contact heat exchanger 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 pressurized direct contact heat exchanger 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 pressurized direct contact heat exchanger heater are passed through a turbine expander to recover some of remaining enthalpy, which is used to compress the air-steam mixture. If necessary they can be put through a particulate remover before going through the turbine expander. 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 turbine expander. (See the above embodiment) Any excess power can be used to generate electrical energy by arranging for the motor to also act as a generator.

To remove any acidic gases from the flue gases, alkaline substances can be added to the liquor circulating in the pressurized direct contact heat exchanger. 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 pressurized direct contact heat exchanger.

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 particulate remover or a reboiler and then sent back to the paper machine 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 paper machine. 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. To increase the efficiency of the steam turbines the steam from the evaporator can be processed as illustrated in Figure 1D.

Figure 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 the embodiment above) Electrical energy required for the electrolysis is supplied directly by any generator adapted to produce the direct current, as converting alternating current to direct current is inefficient. If the pressurized hydrogen, so produced, is not also used in the source process e.g. where carbon monoxide is produced and this is combined with the hydrogen to form methanol, it becomes a very valuable by-product. 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.

In a further embodiment energy can be removed from the pressurized direct contact heat exchanger for various purposes, and the resulting cooled liquid returned to the pressurized direct contact heat exchanger 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 pressurized direct contact heat exchanger 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.

In an embodiment the cooled gases from the top of zone 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.

One can combine various embodiments wherein the electricity produced is one of direct current which is then fed directly to the electrolysis of water, 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 as illustrated in Figure 16.

In some arrangements, advantages of other operations can be made use of in the pressurized direct contact heat exchanger 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 pressurized direct contact heat exchanger 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.

Figure 11 illustrates how the pressurized direct contact heat exchanger is combined with a pressurized indirect contact heat exchanger, by generating high pressure steam in order to take advantage of the higher efficiency of high pressure, high temperature steam turbines. While the amount of energy extracted by the pressurized indirect contact heat exchanger 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 pressurized direct contact heat exchanger so the latent energy of the water vapor in the gases can be extracted in the flash evaporator.

While the pressurized indirect contact heat exchanger 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 pressurized indirect contact heat exchanger could consist of tube banks located within the combustion chamber.

A pressurized indirect contact heat exchanger can be introduced into any one of the above embodiments depending on the desired outcome.

In certain circumstances it may be possible to maximize the thermal efficiency further by combining both gas and steam turbine technologies with the pressurized direct contact heat exchanger Process, by extracting some of the energy first in a gas turbine,

then further energy in a pressurized indirect contact heat exchanger using high pressure steam turbines (as shown in the above) and finally the remaining energy in a pressurized direct contact heat exchanger 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 above)

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 pressurized direct contact heat exchanger.

In these applications, by using the already pressurized gases from the pressurized direct contact heat exchanger 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 pressurized direct contact heat exchanger 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 above.

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 pressurized direct contact heat exchanger and produce low pressure steam as well as operate a pressurized indirect contact heat exchanger which can supply high pressure steam to the gasifier, as illustrated in an embodiment above. Whether or not the pressurized indirect contact heat exchanger 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.

Figure 12 illustrates a way to reduce greenhouse gases, where a pressurized direct contact heat exchanger 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 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 pressurized direct contact 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, (7 km in diameter) will provide sufficient draft for the hot air generated by the greenhouse, to power turbo-generators to produce electricity.

A special 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 pressurized direct contact heat exchanger 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. Figure 13 illustrates this.

Possibly combining this with pressurized water electrolysis other efficiencies might develop. See below. If only hydrogen & oxygen are used, any residual hydrogen & oxygen could also be recycled back to the fuel cells, rather than put through a turbine

expander to produce electricity. If air is used in place of the oxygen the energy in the residual pressurized nitrogen would be recovered in the turbine expander.

Other embodiments involve electrochemical processes where the “overvoltage”, etc generates heat, which is generally dissipated, thereby decreasing the efficiency of the process.

One such embodiment involving electrolysis is illustrated in Figure 14, where the electrochemical process is that of the electrolysis of alumina and the hot non condensable gas is mainly carbon monoxide, and where the carbon monoxide content of the gas can be increased by combining the process with the pressurized direct contact heat exchanger as well as taking advantage of the high solubility of the carbon dioxide in water and the corresponding very low solubility of the carbon monoxide. Here the gas is sent to Solution Chamber where cool water absorbs the carbon dioxide, which when sent to a Gas Separator under atmospheric pressure or a slight vacuum, releases the carbon dioxide and is returned to the solution chamber to absorb more carbon dioxide. The energy of the carbon monoxide enriched gas is recovered by combustion in a Heat Recovery Steam Generator and steam generated used for process or to produce electricity using steam turbines

It should be noted that the proportion of carbon monoxide in the hot gas depends on the alumina content in the hot bath. By carefully controlling this content (e.g. keeping track of the cell voltage) this proportion can be kept to a maximum and the carbon dioxide to a minimum and the carbon monoxide bleed off.

A further embodiment involving electrolysis is that of the electrolysis of water, which was mentioned above in a general way in a symbiotic association with other processes.

In particular it relates to those hydrogen-oxygen generators that operate at relatively high pressures, e.g. high pressure water electrolysis presently allow the generation of hydrogen at pressures up to 5 MPa. (750 psi). One such unit under development / available is made by GHW (Gesellschaft für Hochleistungswasserelektrolyseure). Generally these operate at normal temperatures, however by a similar choice of material, these can be made to operate at fairly high temperatures as was done in the Ceramtec process mentioned below.

Figure 15 illustrates how a pressurized high temperature oxygen-hydrogen generator can be combined with the pressurized direct contact heat exchanger. In previous embodiments the pressurized direct contact heat process was generally involved with a source having a single stream of hot pressurized non-condensable gases containing water vapor. Since in the present embodiment there are two streams, they are represented side by side.

Where necessary present oxygen-hydrogen generators are cooled to keep the temperature below 100 C (e.g. 65-60 C) mainly to avoid the formation of too much water vapor. In the present embodiment, since the temperature is much higher, a fair amount of steam will pass along with the gases, as illustrated in Figure 15

Most of the rest of Figure 15 has been explained and described in more detail in many of the previous embodiments and need not be repeated here. Since normally nearly pure water is used to replenish that used up in the electrolysis, water here is taken from

steam turbine condensate. Some of the generated steam is used to help preheat this water, prior to being pumped to the generator, with the possible additional use of a jet pump. To further heat this water to the operating temperature of the cell and to heat the electrolyte at start-up, as well as help keep an even temperature in the cell, an alternating current could be superimposed on the direct current or used within a separate circuit.

Figure 15 shows the use of a single flash chamber for both gases, however, if there is too much cross contamination of the gases, each should have its own flash chamber. Also to reduce a loss of gas with the steam from the flash chamber, an inert substance can be dissolved in the re-circulating liquid to reduce the solubility of each gas in the liquid.

When the above embodiment is combined with pressure combustion (see embodiment above) only one stream of gas would be involved as illustrated in Figure 10 i.e. that of hydrogen, as the pressurized oxygen from the generator would pass directly to the pressure combustion furnace. Similarly, the pressurized oxygen could be used in anyone of the many other oxidation processes involving oxygen e.g. as mentioned in an embodiment above: in the pulp & paper industry for pulping and bleaching and in the manufacture of sulfuric acid by the contact process, where the higher pressure and temperature could be of benefit.

It should be noted that the above embodiment, Figure 12, leads (i) to a nearly pure source of pressurized carbon dioxide which can be more readily used commercially or disposed of than the present gases emanating from the various power combustion plants all over the country, e.g. biomass growth and oil enhancement Figure 17 (a) and (ii) to easily attained higher combustion pressures (by using high pressure oxygen) thereby allowing for greater use of the higher efficiency gas turbine technology.

Figure 16 illustrates how the present invention can improve the recently developed Ceramic process (mentioned above) for the high temperature electrolysis of steam. Besides improving the efficiency of the process it also shows how the high pressure, high temperature steam that is needed for the generator can be generated in the Combustion Furnace.

Further examples of symbiosis are illustrated in Figure 17, where the process illustrated in Figure 15 or Figure 16 can be located in various locations.

(a) Here the process in Figure 17 is located at a depleted oil source where the oil could used to fuel the high pressure combustion and the pressurized carbon dioxide could serve as a working fluid in enhanced oil recovery (Figure 17 (a)). In addition, the (i) carbon dioxide would be sequestered (ii) hydrogen would serve as a means of storing electricity for use in fuel cells; (iii) which in turn be used to decrease pollution arising from other activities producing carbon dioxide. Being pressurized the plant would be very compact and could be moved from one depleted oil well to another,

(b) A further example is Phytotechnology (Figure 17 (b)) which was mentioned above, where carbon dioxide is supplied as a nutrient for accelerated growth of biomass crops (Figure 12) as well as use up the CO₂. The biomass is produced in a closed-atmosphere, controlled-environment that provides complete control of an enriched CO₂ atmosphere from 1000 to 3000 PPM. The Phytotechnology process enhances the plant photosynthesis to achieve higher rates of CO₂ conversion into biomass, including BIOFUEL (and food, etc) and mass-cell-culture and algae culture for energy. Normally the process is carried out at normal pressure, however if done at higher pressures the large amount of water vapor produced could be sent directly along with the biomass to the

furnace and its energy recovered. Presumably the EnviroMission firm, mentioned above in connection with Figure 12 uses higher pressures. Using oxygen for combustion, the water content of the biomass could be quite high and still burn.

A further embodiment involves the general processing of substances in a reactor under high pressure as illustrated in Figure 18. The configuration of the equipment will depend on the process used. If the heat developed is time dependent, then to insure that the hottest part of the aqueous medium is located where the medium leaves the reactor with a minimum of mixing, various reactor shapes and baffles can be used e.g. an elongated baffled vertical chamber. While the make-up water could come from the condensed steam, hotter water would of course be preferable. By regulating its use the concentration of the reactants in the circulating aqueous medium can be increased / controlled.

Any gas produced in the reactor can be separated from the aqueous medium in a special separator chamber, as shown in Figure 18, where the separated gas and steam goes to the pressurized direct contact heat exchanger, with the hot well water being returned to the gas separator, and the hot aqueous medium to a flash evaporator where it can be concentrated and returned to the reactor. Such an arrangement is necessary to avoid excessive gas being released in the flash chamber, which could lower the efficiency of a condensing steam turbine. Energy in the gas and steam is recovered in a turbine expander. Alternatively, it may be used to heat the make-up water and reactants. To maintain a sealing level of liquid in the separator, a portion of the degassed medium can be recirculated back to the separator (with the proper controls).

An example of a reactor process is that of wet oxidation (combustion), where substantial steam is present with the gas that is produced, and the heat content of the gas and steam is recovered more efficiently, by passing the cool make-up water (e.g. condensed steam) through the pressurized heat exchanger. A dry cool gas is also produced, the energy of which is recovered in a turbine expander.

Alternatively, if the gas is pressurized carbon dioxide (a) it could be used for oil enhancement as shown in Figure 17 (a); or where after de-pressurizing in the expander, it can be used in the production of biofuel as shown in Figure 17 (b).

Reactants include compressed air or pressurized oxygen and any oxidizable material, including inorganics, with a COD. Examples are: (a) Caustic streams: refinery spent caustic and soda pulping liquor; (b) Dangerous, obnoxious and toxic substances: effluents containing cyanide, phenols, etc. (c) Waste biological sludges.

Figure 19 illustrates where the gas separator can be eliminated by sending the hot aqueous medium directly to the pressurized direct contact heat exchanger

Which of the embodiment in Figures 18 & 19 is used will depend on the nature of the wet oxidation.

The embodiment illustrated in Figure 20 could be used in various pressurized thermal depolymerization reactions involving two Reactors. Here the medium from the First Reactor goes to the first Gas Separator and the liquid from the first Gas Separator goes to a Fraction Separator and the top fraction goes to a Second Reactor, and the medium from that Reactor goes to a second Gas Separator, with the hot gases from there joining the gases from the first Gas Separator on their way to the pressurized heat exchanger, and the liquid from the second Gas Separator going to Conventional

Distillation Column to yield the required Products, the hot gases from which, if pressurized, could join those going to the pressurized heat exchanger. the bottom fraction in the Fraction Separator is returned to the first Reactor for further processing.

The number of reactors will depend on the substances being depolymerization

The following embodiment illustrated in Figure 21, covers the situation where lower hot well temperatures are produced and a flash evaporator / chamber is not required. Here lower pressures are used, i.e. higher than that which are used presently, and are pressurized using a rotary blower (see below for attainable pressures) and sent to the pressurized direct contact heat exchanger to reclaim the energy as described above.

Figure 22 illustrates where the condensable vapor is water. The pressure chosen depends on the temperature desired for the water in the hot well, which depends on the vapor pressure of the water being used to cool the gases, as well as the pressures obtainable using rotary blowers, which are less expensive than turbine compressors. For example, a pressure of about 30 psia (15psi) corresponds to a hot well water temperature of about 120 C (250 F) and thermal efficiency would depend on the temperature of the cooled gases. The pressurized gases can be passed through a turbine expander connected to the rotary blower.

Here the hot water could be sent to a boiler (possibly located in the Source) to produce very high pressure, high temperature steam for process or for generating electricity using highly efficient steam turbines. If cool enough the steam condensate could be recycled back to the pressurized heat exchanger. The hot water could of course be used for other purposes. In terms of Carson's Fluidized Spray Tower illustrated in Figure 1A, one Tower or chamber should suffice for this embodiment.

The present invention could have particular application to existing high pressure combustion projects in the Clean Coal Technology Program sponsored by the US Department of Energy, (mentioned above).

(a) In various projects, a water paste of coal and limestone and compressed air are fed to pressurized circulating fluidized-bed combustor where combustion takes place at a pressure of about 200 psig, the hot flue gas pass through equipment to remove the particulates, etc, then through a gas turbine and the heat in the gas from the turbine is recovered in a conventional steam generator, in which case the latent heat of any water vapor in the final flue gas is lost.

Figure 23 illustrates how the present invention can increase the thermal efficiency of that process. Here the water paste of coal and limestone and compressed air are fed to pressurized circulating fluidized-bed combustor where combustion takes place at a pressure of about 200 psig, the hot flue gas pass through equipment to remove the particulates, etc, then through a gas turbine and some of the heat in the gas from the turbine is recovered in a pressurized indirect contact heat exchanger (i.e a boiler), to generate very high pressure and high temperature steam with which the generate electricity using high efficiency stream turbines using the hot well water from the pressurized direct heat exchanger, the pressurized hot gases from the boiler go to the pressurized direct contact heat exchanger to reclaim essentially all the remaining energy in the gases. as described above in various embodiments.

Various details are left out since they vary from one type of process to the other. Since the limestone removes about 95% of the sulfur and the ash content in the hot gas is low, the hot well water should be suitable to produce the high pressure high temperature

steam for the steam turbines. Here (Figure 23) the pressurized indirect contact heat exchanger (boiler) is shown after the gas turbine, while in Figure 24 it is shown before, whichever is selected may depend of various factors. The pressure of the gases leaving the turbine should be high enough so as to reclaim the latent heat in the gasses in the heat exchanger. If desired the turbine gas could be left out to simplify and reduce the cost of the process.

(b) In another series of projects, a pressurized gasifier is supplied with steam, oxygen, and a water paste of coal and limestone to produce a fuel gas rich in hydrogen and carbon monoxide, which is cleaned and used to fire a gas turbine. Again it appears that the latent heat of any water vapor in the final flue gas is lost, which could be high since hydrogen is one of fuel gas components.

Figure 24 illustrates how the present invention can increase the thermal efficiency of that process. The process is essentially the same as described above for Figure 23, except the fuel gas goes to a pressure combustion furnace, containing a pressurized indirect contact heat exchanger (i.e a boiler), where the hot well water is used to generate the high pressure steam before the gases go through the gas turbine. The pressure of the gases leaving the turbine should be high enough so as to reclaim the latent heat in the gasses in the heat exchanger.

As a further example of symbiosis, a high pressure electrolysis of water plant (see Figure 15) could be located nearby to supply the requires pressurized oxygen. The gas turbine could be left out and the hot gases from the fuel gas combuster could go directly to the pressurized exchanger. In some processes air is used in place of oxygen.

In another embodiment, Figure 25 illustrates how the invention can be applied to the recovery of bitumen (i.e. oil) from Oil Sands, including the recovery of energy and water.

Here the process is concerned with the present technique of using high pressure steam to lower the viscosity of the bitumen in the sands so that it will flow towards a well which will raise it above the ground. In the present embodiment care is taken to collect as much steam and gas as possible emanating from the oil well and compress it to the same gas pressure as that for the gases coming from a pressurized combustion furnace, which will also contain water vapor. Both gases are combined and processed through the pressurized direct contact heat exchanger to recover the heat energy in the gases as well as produce very hot well water which is used to make the high pressure steam in a boiler in the pressurized furnace.

This high pressure steam can also be used to produce electricity with which to operate the system, using high efficiency condensing steam turbines. The condensate can then be used to cool the gases in the heat exchanger. Where it is introduced could depend on its temperature. As indicated the coolest water available is introduced at the top of the heat exchanger and its temperature will determine the thermal efficiency of the process.

Depending on the type of fuel used to fire the furnace, it may be necessary to clean the gases before they go to the heat exchanger so as to ensure that hot well water is suitable for the production of the high pressure steam. The gas cleaning technology is well known and used in the Clean Coal Program sponsored by the US Department of Energy. To that end it might be desirable to mix limestone with the fuel so as trap any sulfur compound in the fuel so that they will exit with the ash and not the gas steam. The

pressure in the furnace will depend on the temperature that is desired for the hot well water, as well as the degree of thermal efficiency desired, as was explained above.

Figure 26 illustrates how the hot well water can be used in the present technique of using hot water to separate the bitumen from the Oil Sands. The water fraction can then be cleaned and sent back to the heat exchanger at the proper location, depending on its temperature, to cool further gases.

The present invention can also be used to break the bitumen down into various fractions using the any of the above embodiments, one of which is illustrated in Figure 20.

As an alternative to the above the gas and steam from the oil well can be processed as described in Figures 21 & 22.

Other embodiments involving lower pressures are situations where drying (and boiling) is involved e.g. web drying. Here the drying could be accelerated by subjecting the web to a mild vacuum using either the suction side of rotary blower or a vacuum pump and the steam and any entrained air could go a pressurized direct contact heat exchanger, such as the fluidized spray tower mentioned above, where some of the steam would be condensed using the water in the hot well of the second heat exchanger as cooling water. The water in the hot well can be sent to a high pressure boiler to produce high pressure steam.

The remaining steam containing low amounts of air can then to connected to the suction side of a high pressure water pump being fed cooler water e.g the condensate from the steam turbines and then sent to a pressurized direct contact heat exchanger as disclosed above in connection with Figure 6 , where more steam will condense and the

energy in the pressurized air can be recovered in turbine expander, which can be used to power the rotary blower or vacuum pump.

This embodiment can be very effectively used with a new paper technology referred to a Impulse Drying where a very hot roll is heated by either very hot steam or a gas flame or magnetic induction This is illustrated in Figure 27, where a vacuum chamber encloses the hot roll. Details of how the roll is heated and how the webs are introduced and removed from the Chamber are not shown as they are well understood in the trade. By insulating the Vacuum Chamber not will the heat content of the gases involved be reclaimed but also that from the heating process used for the roll. In this latter aspect, magnetic induction is recommended especially that involving a new type of roll called “Optimized Heated Roll” presently being marketed by Comaintel Inc.

While alternatively a low pressure chamber could be used, the above low vacuum chamber would seem more advantageous.

It should be noted to avoid cleaning gases using expensive equipment one can by using an indirect heat exchanger use the unclean hot well water to heat the condensate from the steam turbines and send this now clean hot water to the boiler to make high pressure steam.

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 an invention in which an exclusive property or privilege is claimed is defined as follows:

1. A process for continuously reclaiming any additional energy residing in hot pressurized non-condensable gases containing a condensable vapor, produced when processing material, and converting said energy into a more useful form, comprising the steps of:

a) providing a source from which to reclaim said additional energy from said gases continuously being produced within and or emanating from the source, and if necessary, converting the source to a higher pressure, so that hot pressurized gases are produced;

b) continuously bringing the pressurized gases into intimate contact with a cooler liquid, in a pressurized direct-contact heat exchanger, a vertical vessel consisting of various sections, including a hot well, where the gases will enter at the bottom, flow counter-current to a flow of the cooler liquid and where any condensable vapor will condense and the gases will become drier, and leave at the top where the cooler liquid enters, said exchanger being divided into several areas; a first area being where any evaporative and heating property of the gases could be used to dry materials, a second area where part of the condensing and heating property of any vapor in the gas will be utilized to heat the cooler liquid to the highest temperature it could have when in equilibrium with the gases at the given pressure and thereby cool the gases as well as allowing heated liquid and condensed vapor to collect in the hot well within the area while still maintaining the highest possible hot well temperature, and continuously removing liquid from the hot well as reclaimed energy for further use or alternatively, continuously removing the liquid in the hot well and sending it to a flash chamber to

produce vapor with the cooler flashed liquor reintroduced into said second area to cool further gases; and a third area wherein 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 cool liquid entering at the top;

c) continuously replenishing the cool liquid entering at the top of the exchanger

d) continuously removing the cooled gases from the top of the exchanger as reclaimed energy for further use.

2. The process of claim 1 comprising the steps of continuously removing heated liquid from the hot well and flash evaporating it in a flash chamber 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 flash chamber, continuously removing cooled liquid from the flash chamber and re-introducing it to the direct contact heat exchange section; at a point in the second area where the gas in the area is at about the same temperature as that of the liquid in the sump, so as to cool further gases, and where the gas and cooled liquid will progressively exchange heat content, until the gas as it cools approaches the temperature of the liquid from the flash chamber; continuously removing the flashed steam from the flash chamber for further use;

3. The process of claim 1 wherein in step (a) the source is a known 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 are turbo-compressed to the desired pressure, with the temperature being increased by the compression.
5. The process of claim 1 wherein said condensable vapor is water and said further use of said water from the hot well comprises sending the water through a pressurized indirect heat exchanger to convert the water into high temperature high pressure steam for use in a process or to generate electricity using high efficiency steam turbines.
6. The process of claim 2 wherein said further use of the flashed steam involves its use as process steam or in the production of electricity using steam turbines connected to a generator and said further use of the cooled gases in step (d) involves its use in the production of electricity using a turbine expander connected to a generator.
7. The process of claim 2 wherein said further use of the flashed steam from the flash evaporator involves sending said steam through a pressurized indirect heat exchanger to superheat it to a higher temperature so as to generate electricity using higher efficiency steam turbines.
8. 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 operate the pressurized direct contact heat exchanger and to introduce them into the source process prior to step (a).
9. The process of claim 2 wherein the liquid from the hot well is heated indirectly to a higher temperature to thereby increase the steam pressure in the flash evaporator
10. The process of claims 1, wherein the pressurized gases are further heated prior to going to a direct contact heat exchanger

11. The process of claim 1 wherein in step (g), the cool pressurized gases are heated prior to passing them through a gas turbine expander.
12. The process of claims 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.
13. The process of claim 1 wherein oxygen required is supplied from a source under a pressure greater than that of the source supplying the hot pressurized gases.
14. The process of claim 13 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.
15. The process of claim 2 wherein the cool liquid entering at the top. 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.
16. The process of claim 1 wherein the area below the hot well is used to dry materials.
17. The process of Claim 2 wherein undesirable solids and/or gases are present in the hot gases and are removed in the heat exchanger by maintaining the circulating liquid alkaline for acidic gases and acidic for alkaline gases, the substances so formed then are concentrated and removed from the flash evaporator.
18. The process of claim 2 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) , said hot gases are

then removed from the exchanger at a temperature close to that of the temperature of the flashed liquid in the evaporator and fed to a suction side of a 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, the 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.

19. The process of claim 2 wherein the steam from the flash evaporator, is passed through a reboiler.

20. The process of claim 1 wherein the source process is a combustion process carried out underground under pressure, 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 ground and where the pressurized hot gases would be piped to a pressurized direct contact heat exchanger above ground and processed utilizing any of the other embodiments that will give the desired result

21. The process of claim 1 wherein the source process is carried out underground 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 ground and processed as for any of the other embodiments.

22. The process of claim 2 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.
23. The process of claim 1 wherein the cooled gases from the top of zone 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.
24. The process of claim 15, wherein the electricity produced is one of direct current which is then fed directly to the electrolysis of water.
25. The process of claim 2 wherein the material to be processed at the source is after the appropriate comminution is 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 in the material in the water concentrated in the flash evaporator.
26. The process of claim 1 wherein high pressure steam is generated within the source process, by a pressurized indirect contact heat exchanger, and used as desired, and while the amount of energy extracted by the pressurized indirect heat exchanger 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 pressurized direct contact heat exchanger so that the latent energy of the water vapor in the gases can be extracted in the flash evaporator.

27. The process of claim 1 wherein prior to going to the pressurized indirect heat exchanger and after removing any particulates, the hot gases are passed through a gas turbine connected to a generator to produce electricity, and while the amount of energy extracted by the gas turbine 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 pressurized direct contact heat exchanger so that the latent energy of the water vapor in the gases can be extracted in the flash evaporator.

28. The process of claim 1 wherein in step (d) if the cooled pressurized gasses 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.

29. The process of claim 1 wherein in step (d) if the cooled pressurized gasses contain carbon dioxide, said gases are used to accelerate biomass growth in an enclosed area.

30. The process of claim 29 wherein by creating a second enclosed area below said enclosed area, the oxygen and water vapor generated within the first enclosed area, being lighter than the carbon dioxide, will accumulate and can be removed and pressurized and used in the pressurized direct contact heat exchanger to generate more carbon dioxide which can be recycled to the first enclosed area.

31. The process of claim 1 wherein the source involves an electrochemical process under pressure.

32. The process of claim 31 wherein said electrochemical process involves the electrolysis of water and cool dry oxygen and cool dry hydrogen are produced

33. The process of claim 32 wherein the source involves the electrolysis of steam under pressure using the Cerametek process and cool dry oxygen and cool dry hydrogen are produced.

34. The process of claim 33 wherein said electrolysis is combined with a pressure combustion furnace so that the hot well water can be sent to said furnace to produce high temperature pressurized steam for the Cerametek process.

35. The process of claim 32 where said electrochemical process is the electrolysis of water or steam, and where said electrolysis produces two streams of gas which results in (a) pressurized oxygen containing water vapor, which is used directly in any other pressurized process requiring oxygen and (b) pressurized hydrogen containing a minimum of water vapor.

36. The process of claim 35 where the other pressurized process requiring oxygen is a combustion process.

37. The process of claim 32 where an alternating current is used to (a) heat the make-up water to electrolytic cell up to the operating temperature of the cell and (b) heat the electrolyte at start-up, and (c) help keep an even temperature in the cell,

38. The process of claim 32 wherein the electrochemical process involves the electrolysis of alumina .

39. The process of claim 38 wherein the hot non condensable gas is mainly carbon monoxide and the carbon monoxide and carbon dioxide can be separated using a solution chamber and a gas separator and the energy of the carbon monoxide enriched gas recovered by combustion in a heat recovery steam generator and the steam generated used for process or to produce electricity using steam turbines.

40. The process of claim 1 wherein various substances can be processed in a reactor under high pressure.
41. The process of claim 40 wherein any gas produced in the reactor can be separated from the aqueous medium in a special separator chamber,
42. The process of claim 41 wherein the process is one of wet oxidation.
43. The process of claim 42 wherein if the gas is pressurized carbon dioxide, it could be used for oil enhancement, or where after de-pressurizing in the expander, it can be used in the production of biofuel.
44. The process of claim 40 wherein the reaction is one of thermal depolymerization.
45. The process of claim 44 wherein the thermal depolymerization can involve more than one reactor.
46. The process of claim 2 wherein the source involves a pressurized fuel cell and if only hydrogen & oxygen are used, any residual hydrogen & oxygen could also be recycled back to the fuel cells, rather than put through a turbine expander.
47. The process of claim 1 wherein the pressure is at a low level, but higher than is presently used, and a rotary blower is used to bring the gases to the desired pressure.
48. The process of claim 2 wherein the pressure is at a low level, but higher than is presently used, and a rotary blower is used to bring the gases to the desired pressure and the condensable vapor is water.
49. The process of claim 47 wherein the hot water can be sent to a boiler to produce very high pressure, high temperature steam for process or for generating electricity using highly efficient steam turbines.

50. The process of claim 1 wherein boiling liquids, extracting materials with steam, drying materials, stripping, etc are processes that supply the pressurized gases.

51. The process of claim 1 wherein the source is a pressure combustion furnace, which is being fed air and a water paste of coal and limestone, which produces hot gases, which are cleaned and sent to a gas turbine to generate electricity, with the pressure of the gases leaving the turbine high enough so as to reclaim the latent heat in the gases in the pressurized direct contact heat exchanger, then they are sent to a pressurized indirect contact heat exchanger, and then to the pressurized direct contact heat exchanger to create hot well water, which is used to generate high pressure high temperature steam in the pressurized indirect contact heat exchanger (a boiler), said steam being used to generate electricity using steam turbines.

52. The process of claim 1 wherein the source is gasifier which is being fed oxygen or air and a water paste of coal and limestone, which produces hot gases, which are cleaned and sent to a pressure combustion furnace, which is being fed air, to produce hot gases, which are cleaned and sent to gas turbine to generate electricity, such that the pressure of the gases leaving the turbine should be high enough so as to reclaim the latent heat in the gases in the heat exchanger, then they are sent to the pressurized direct contact heat exchanger to create hot well water, which is used to generate high pressure high temperature steam in a boiler within the pressure combustion furnace, said steam being used to generate electricity using steam turbines.

53. The process of claim 1 wherein the source of the gases is a oil well reclaiming bitumen from the oil sands.

54. The process of claim 19 wherein the source is an impulse drying process.

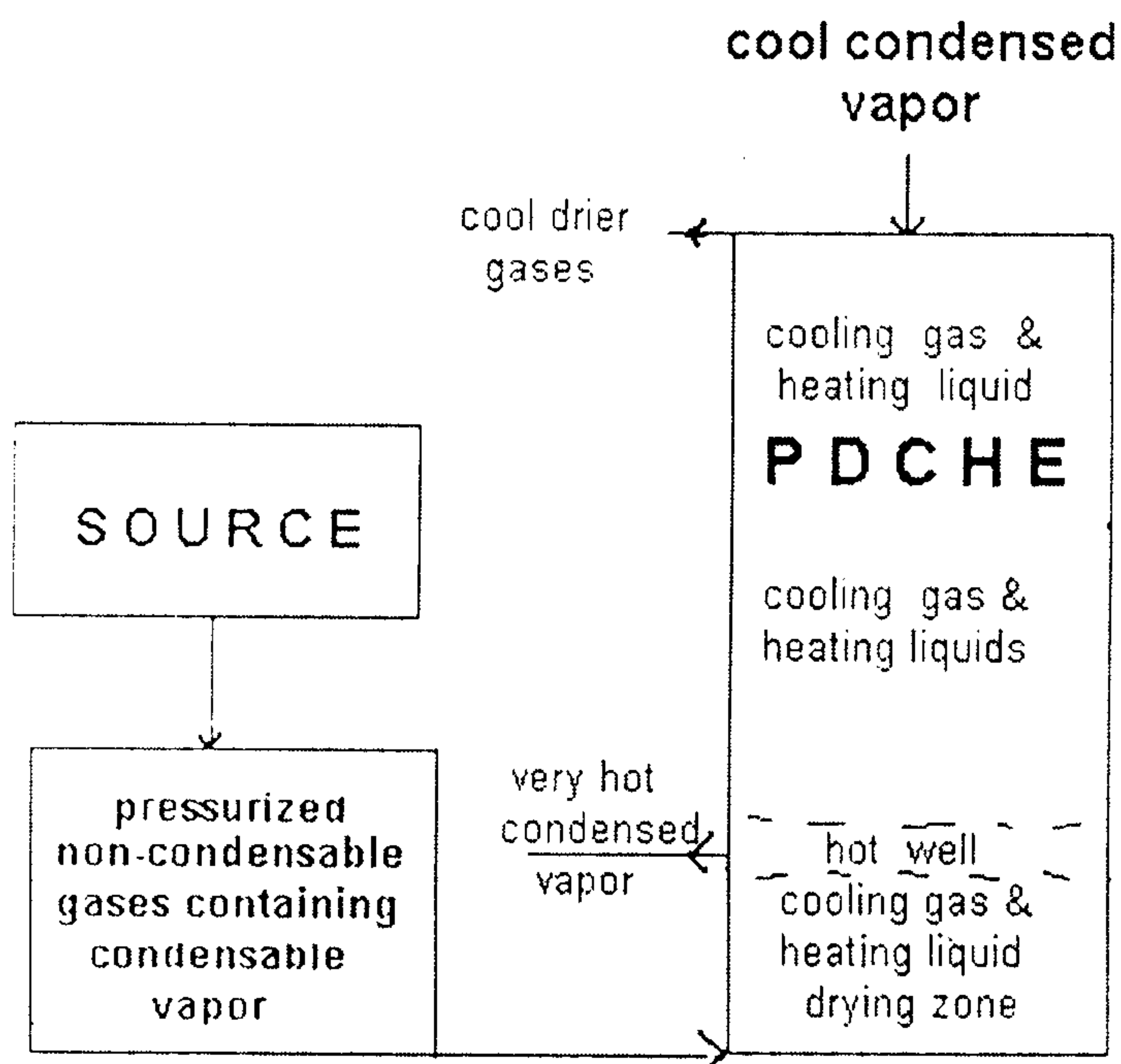


FIG 1

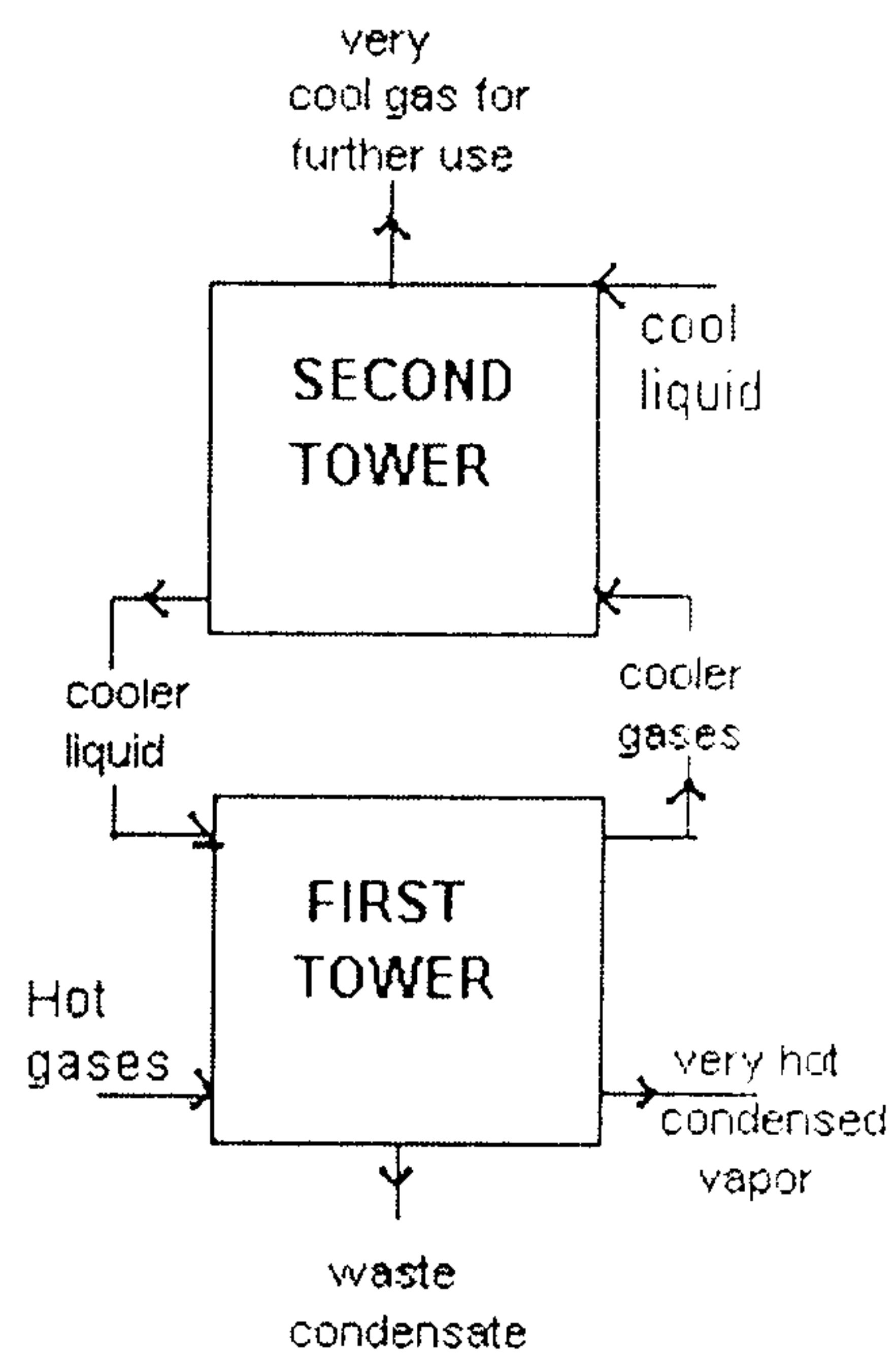


FIG 1 A

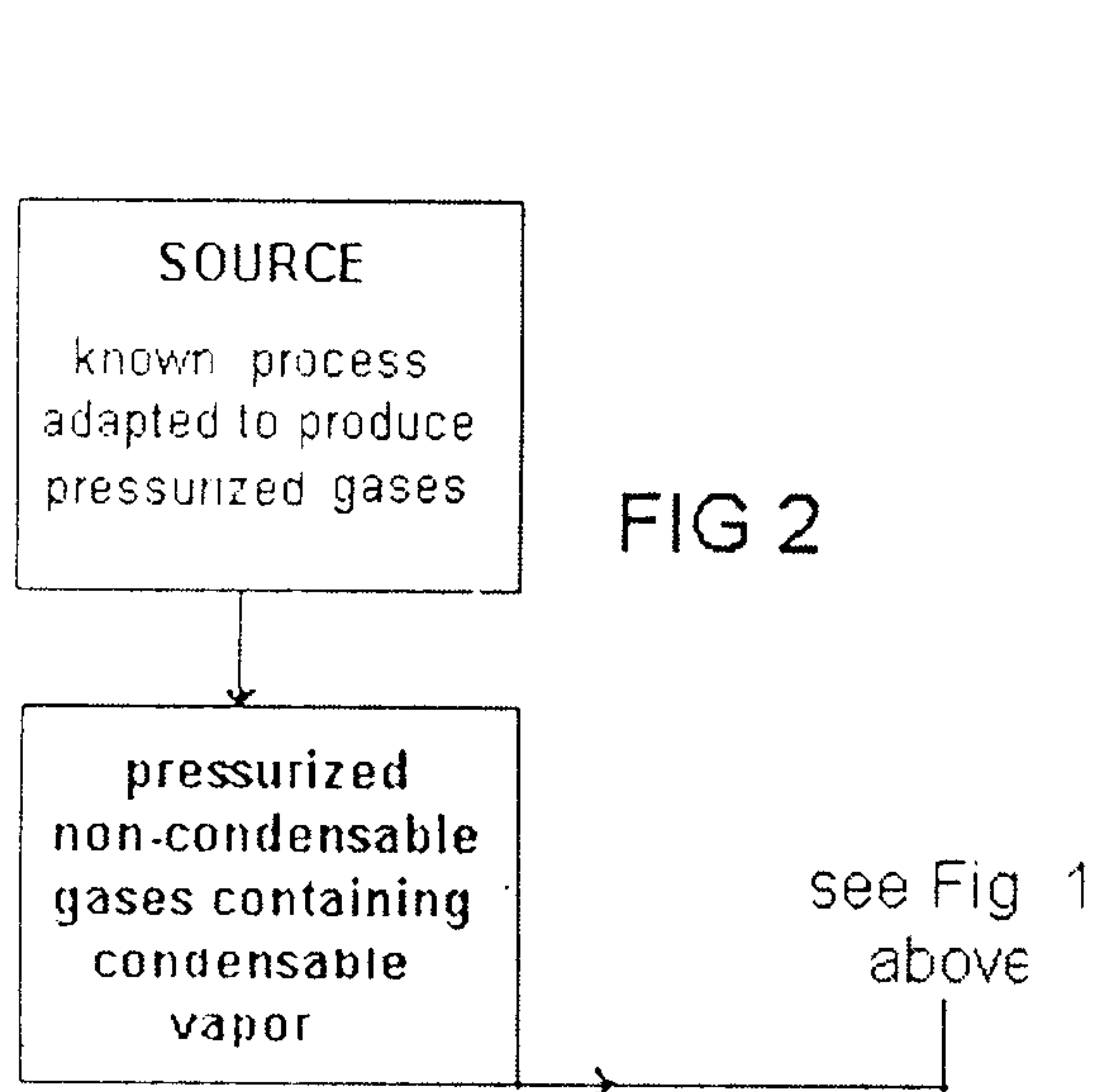


FIG 2

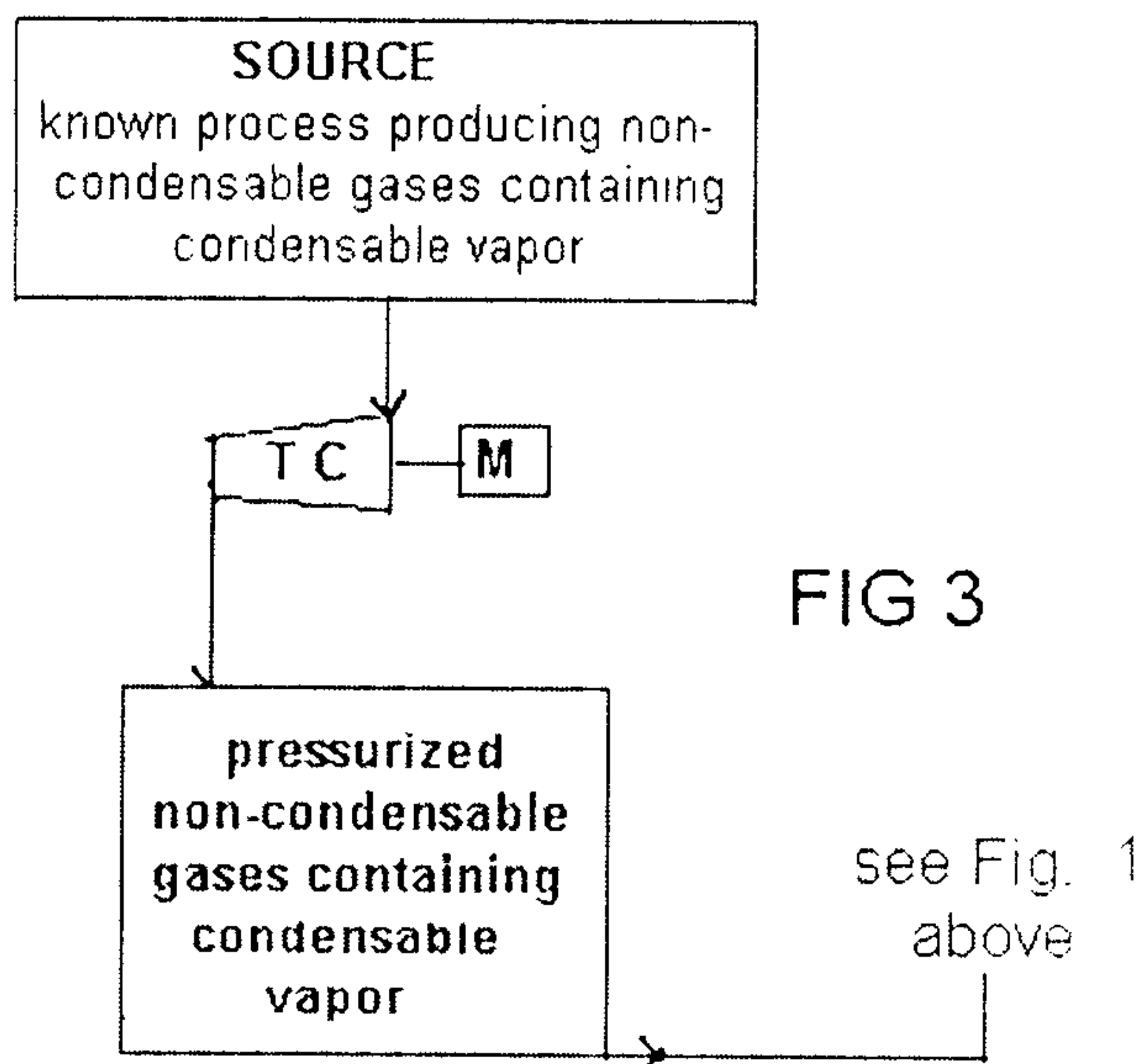


FIG 3

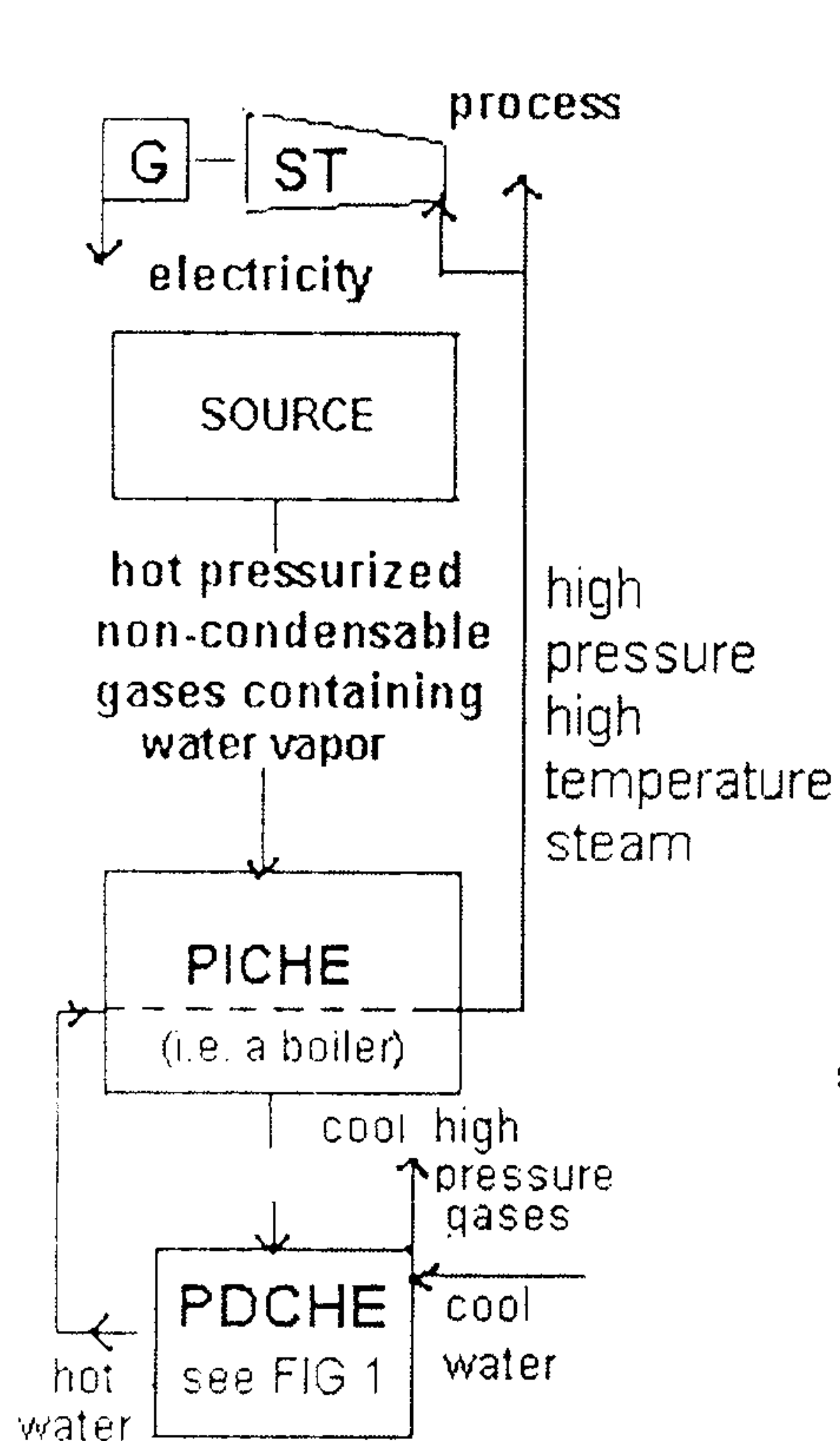


FIG 1C

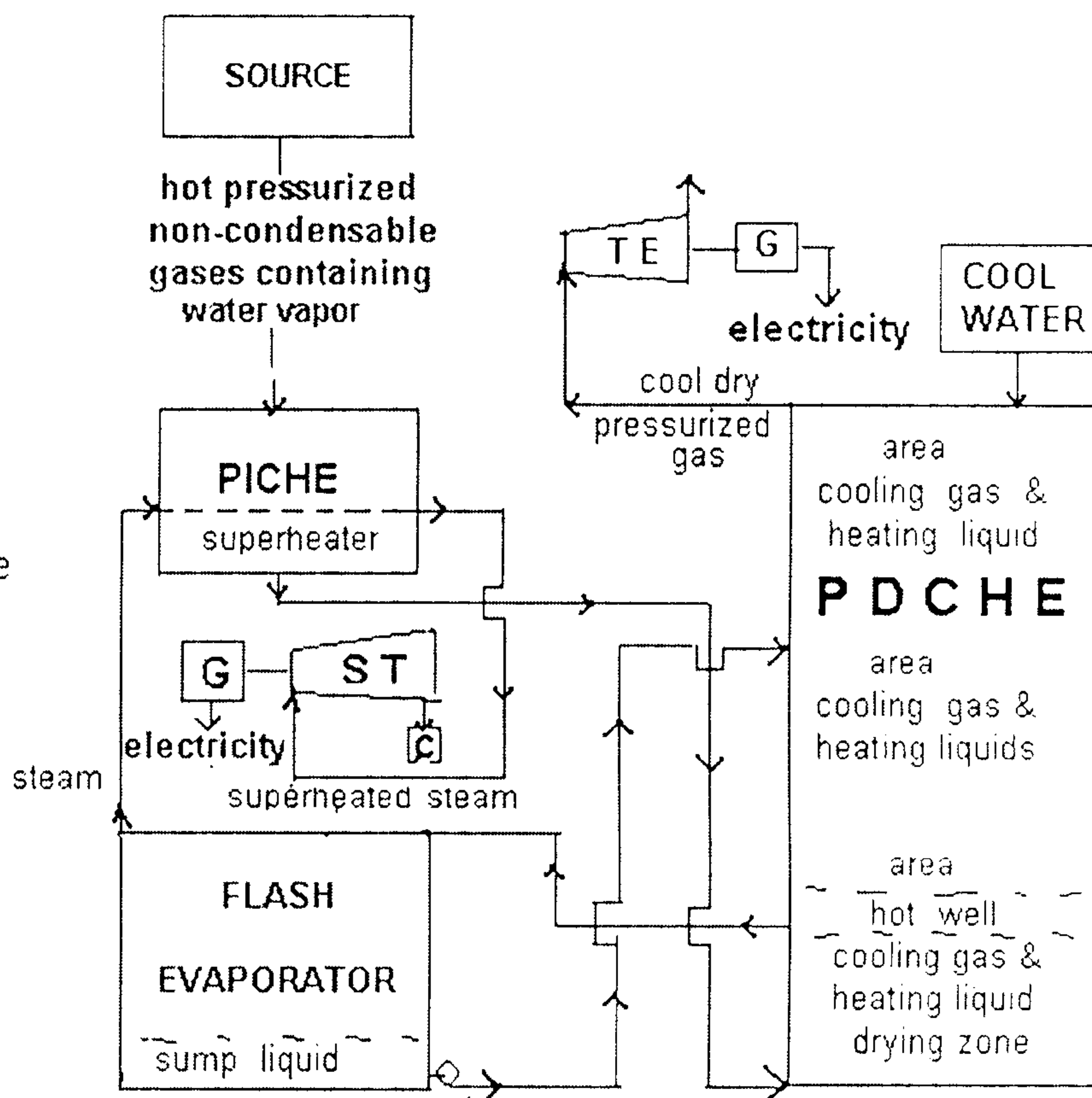


FIG 1D

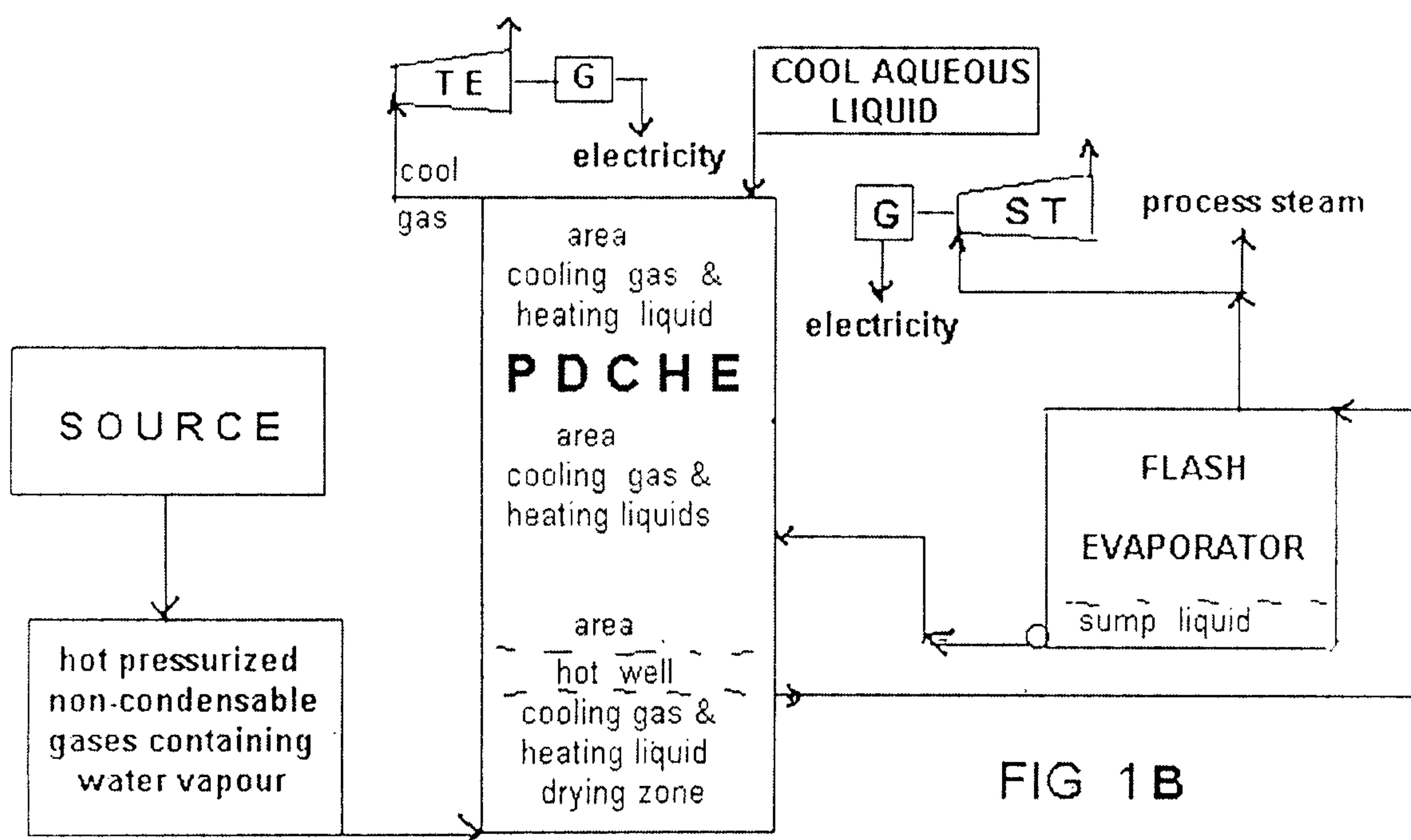


FIG 1B

FIG 4

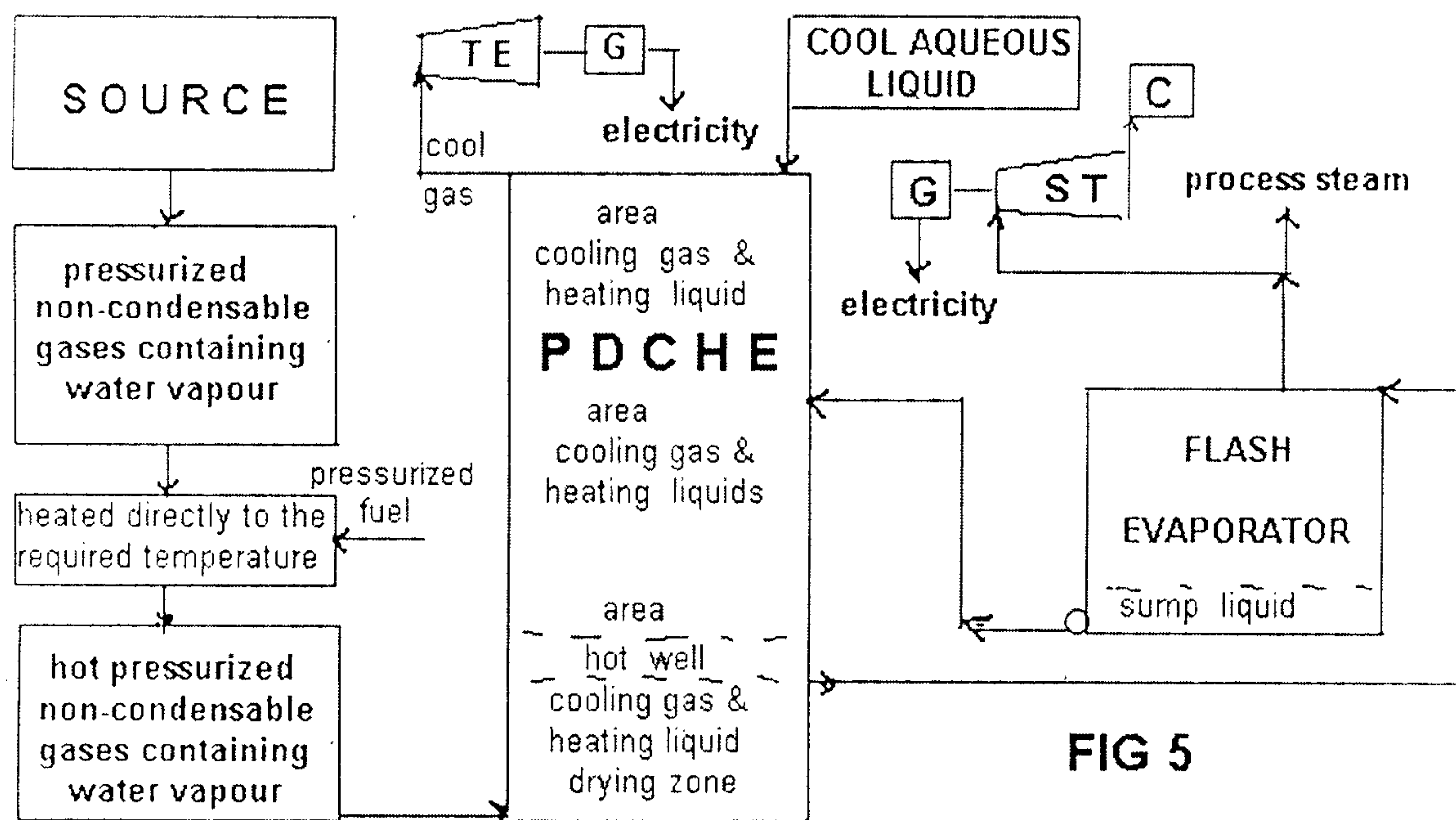
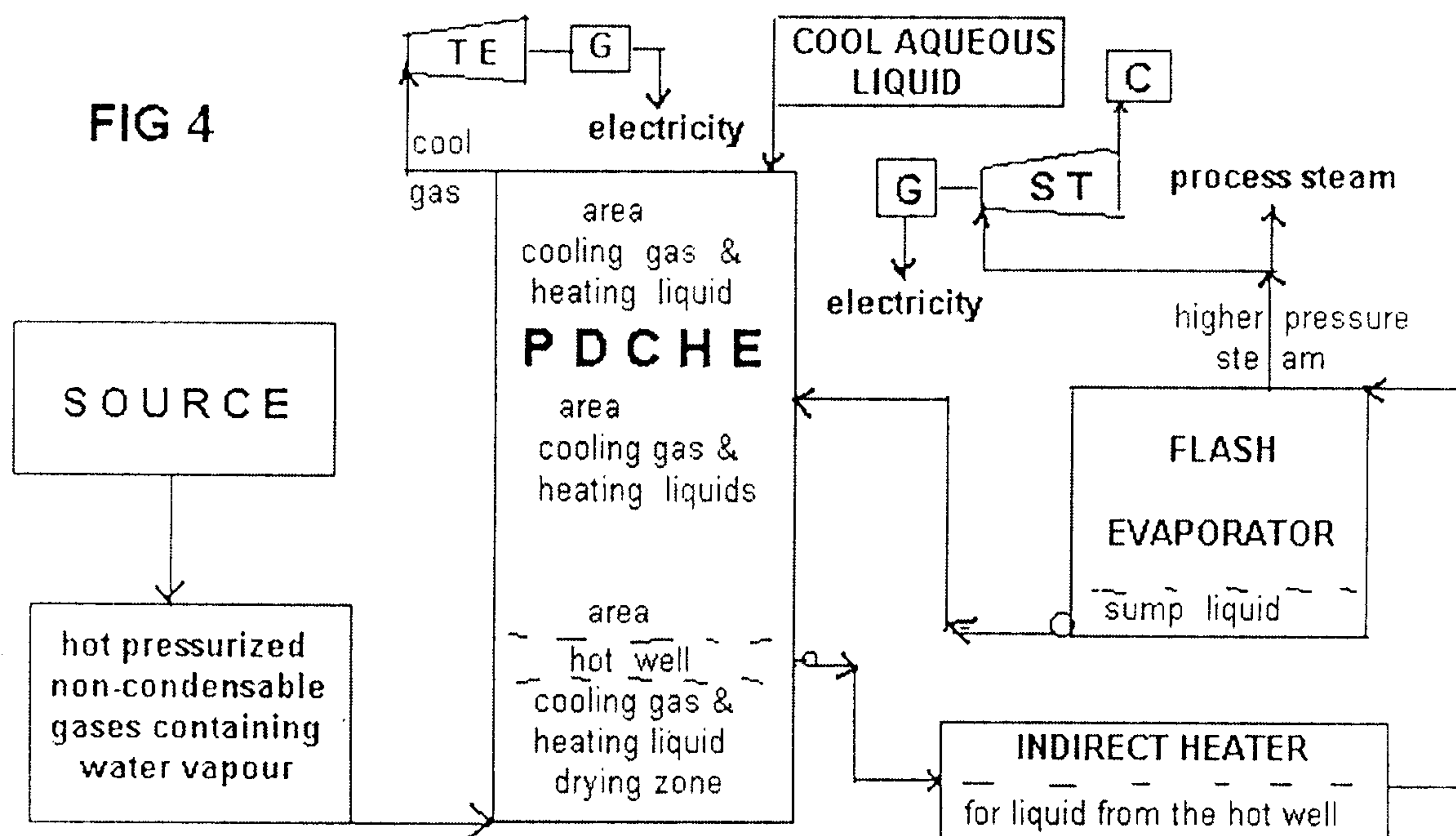


FIG 5

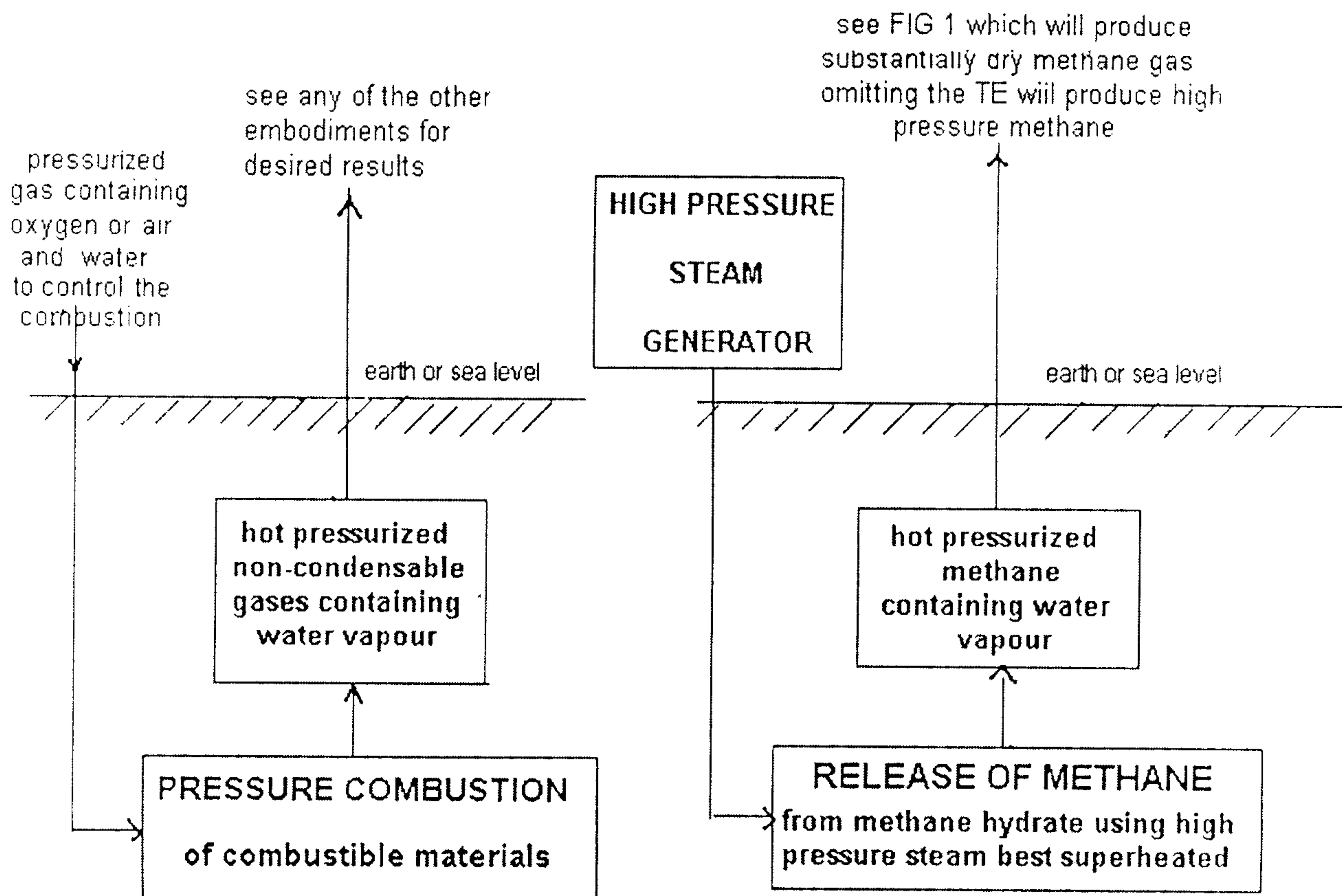
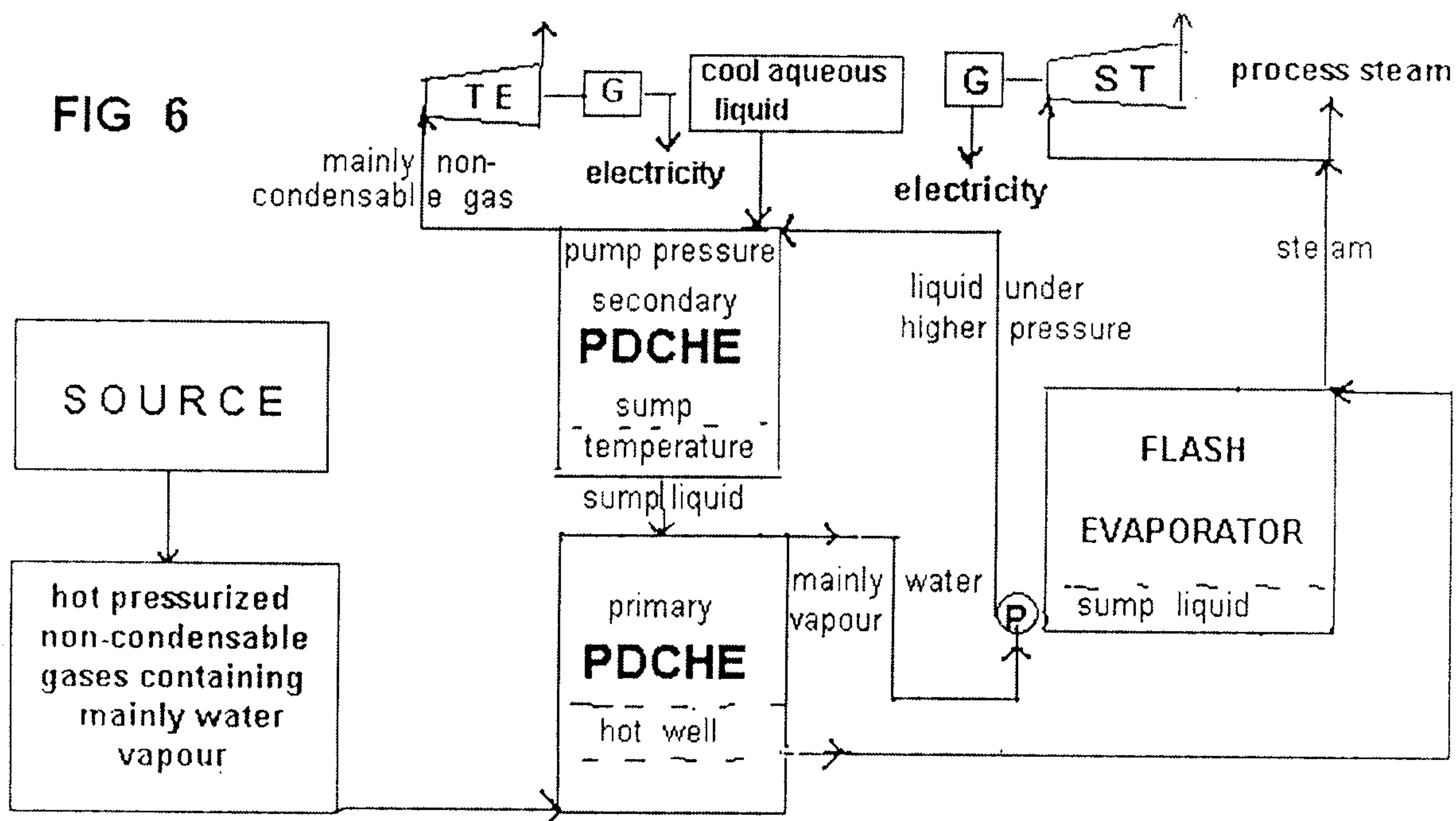


FIG 7

FIG 8

FIG 9

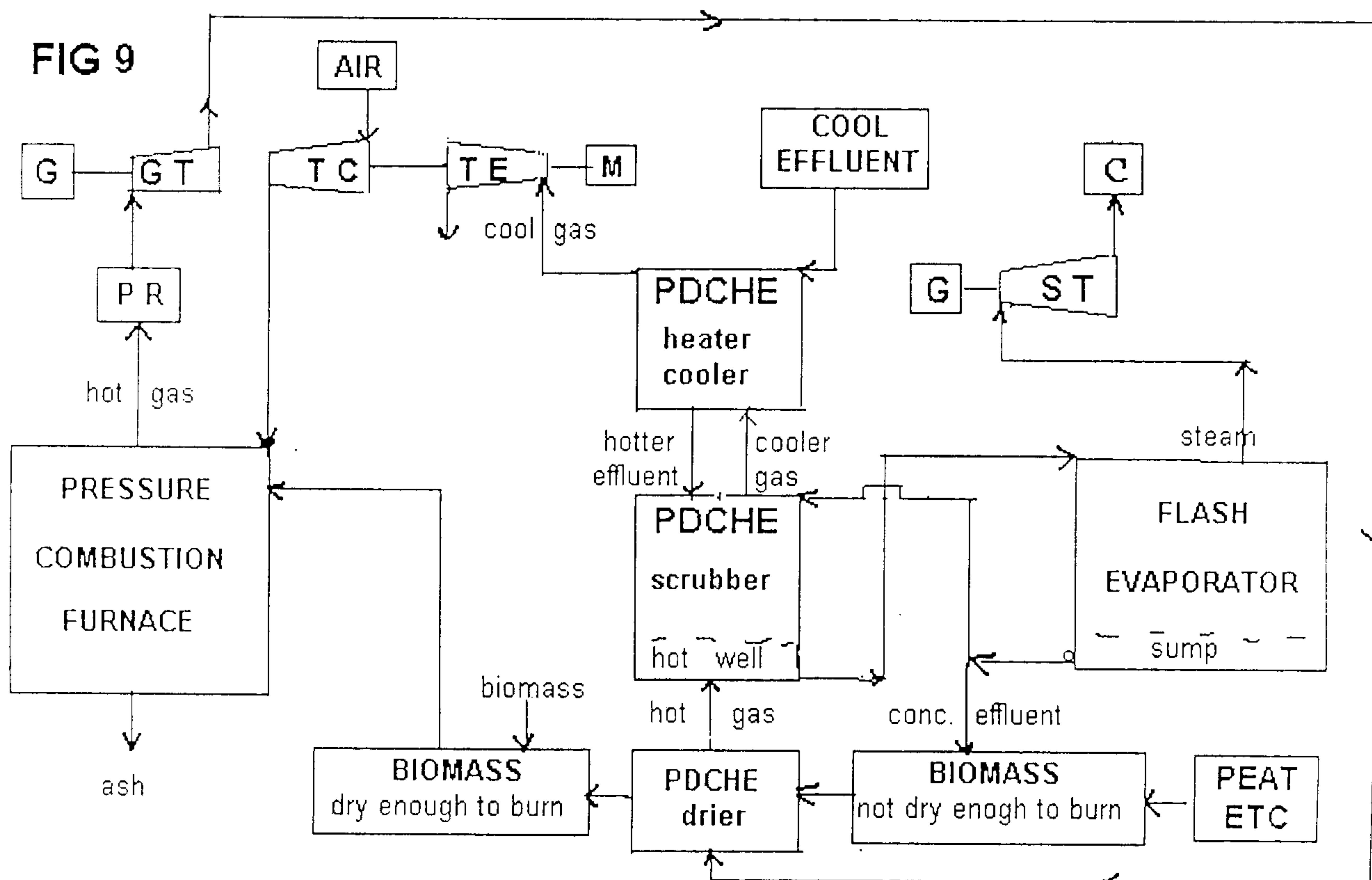
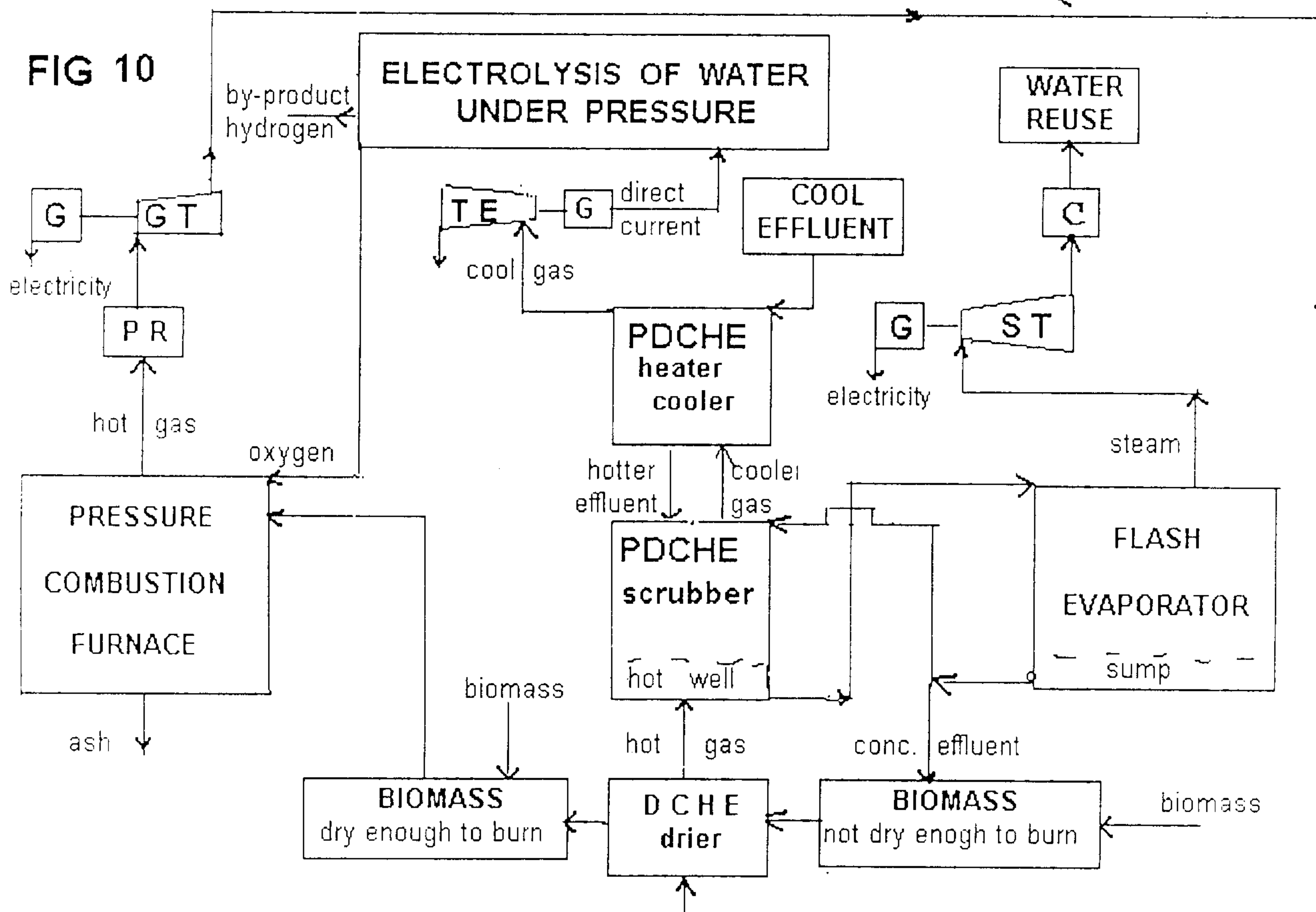


FIG 10



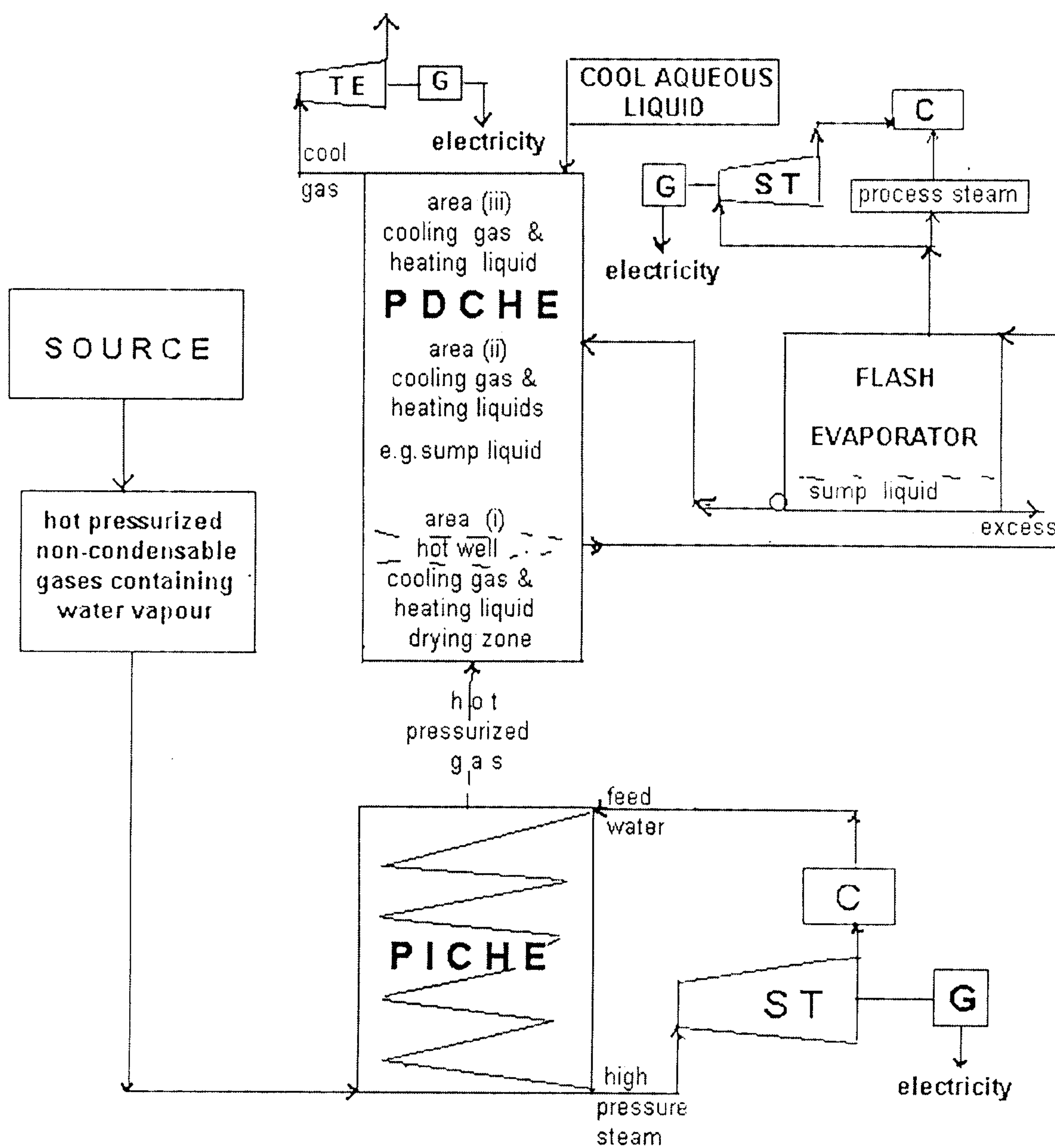
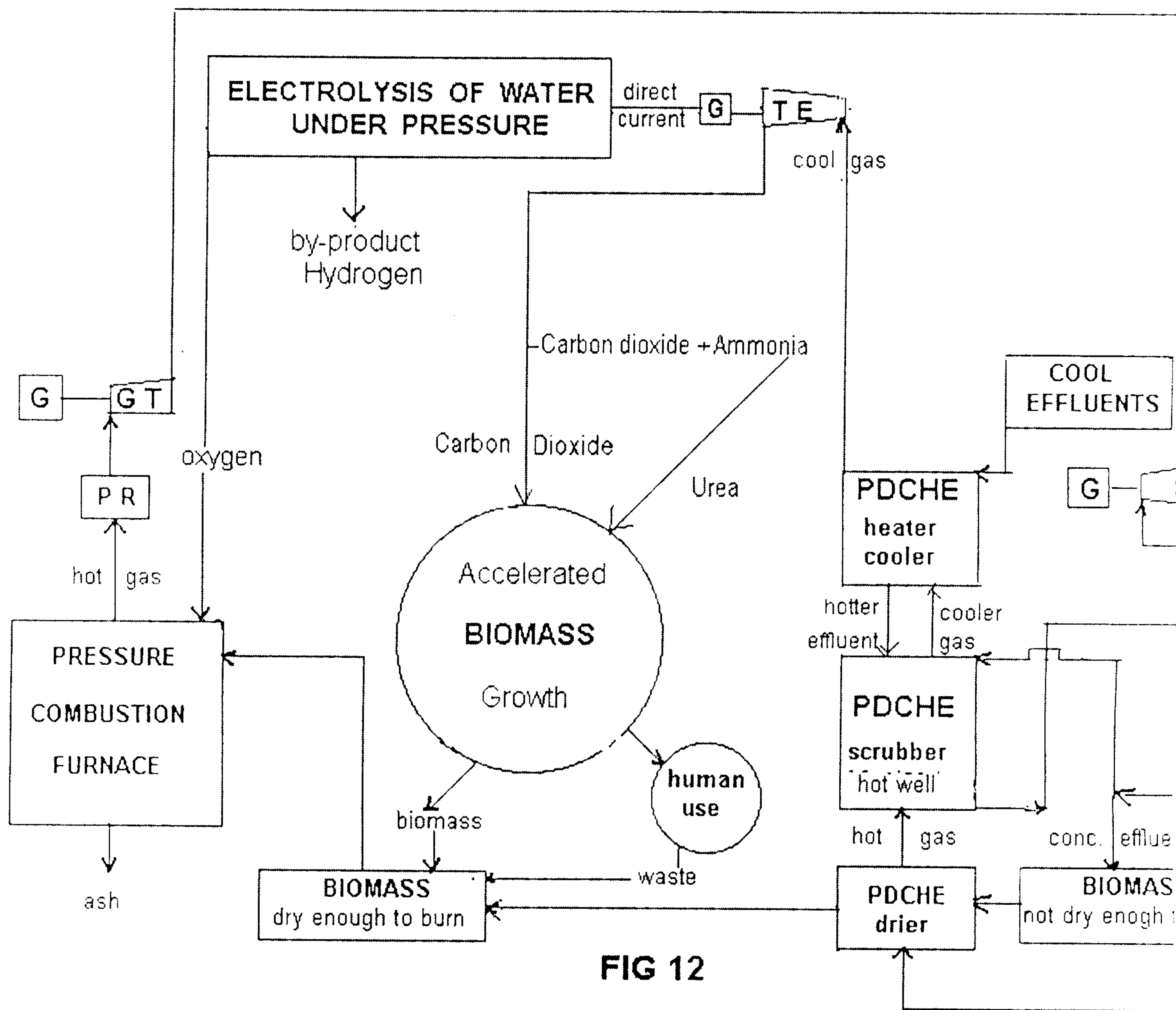
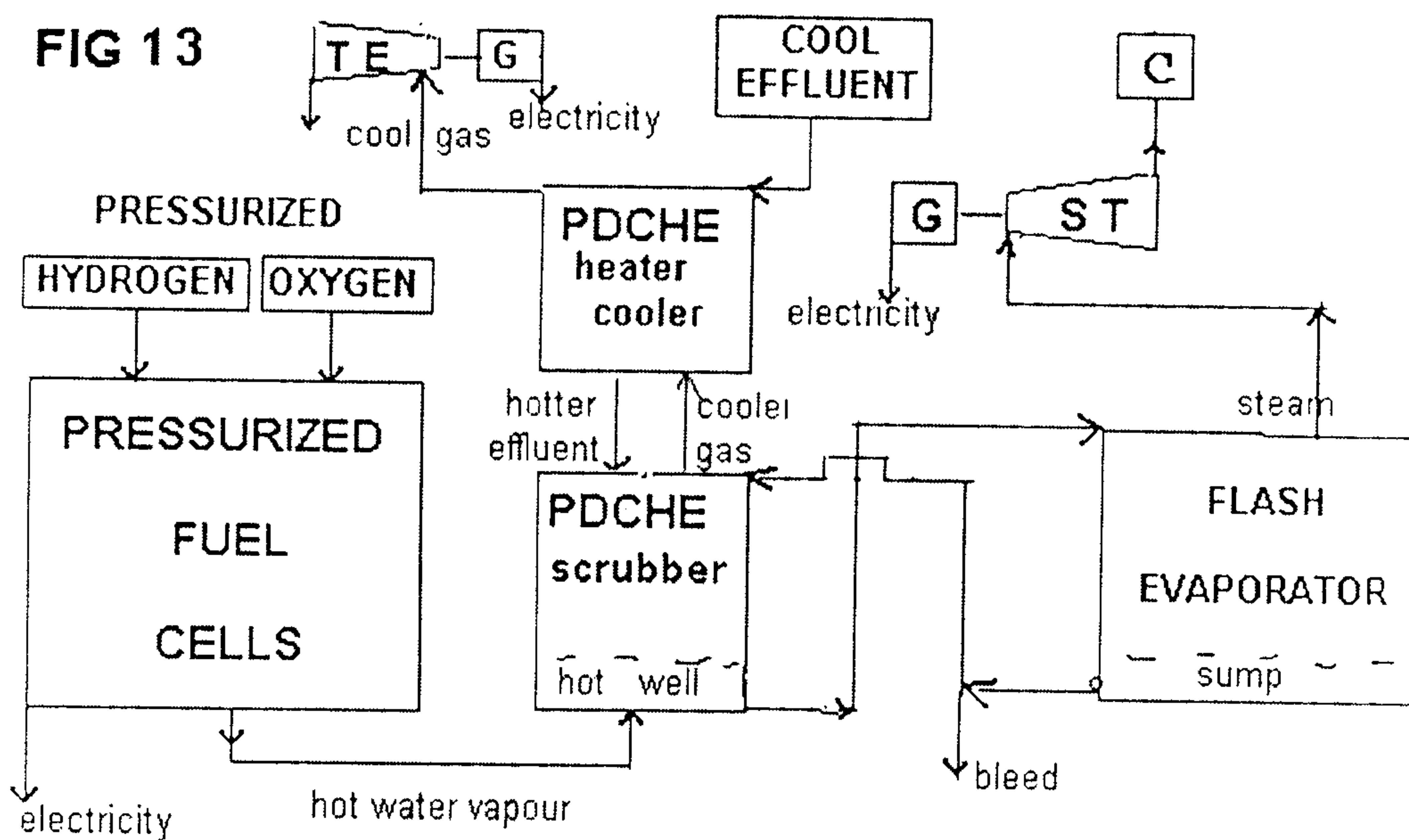
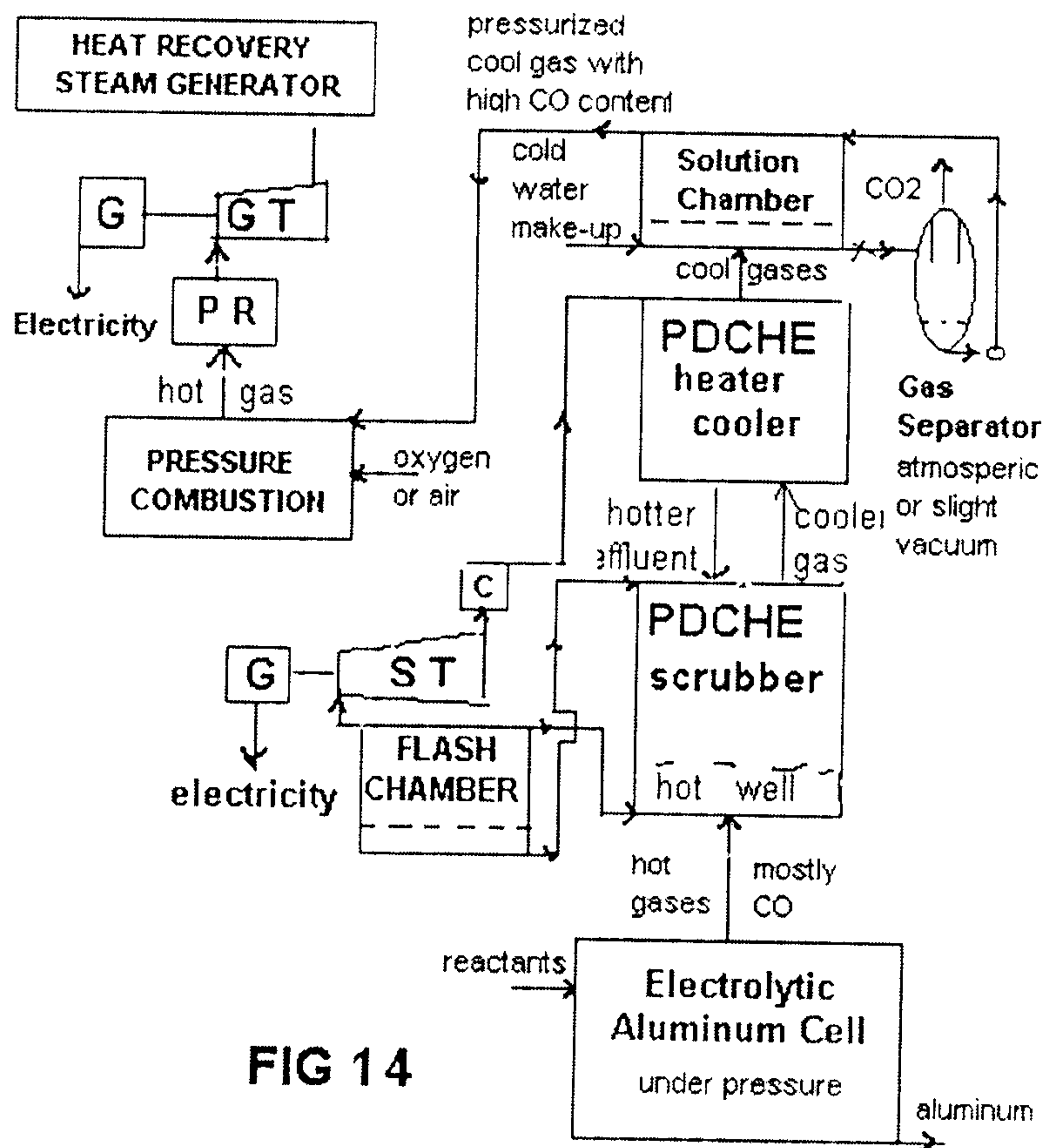


FIG 11





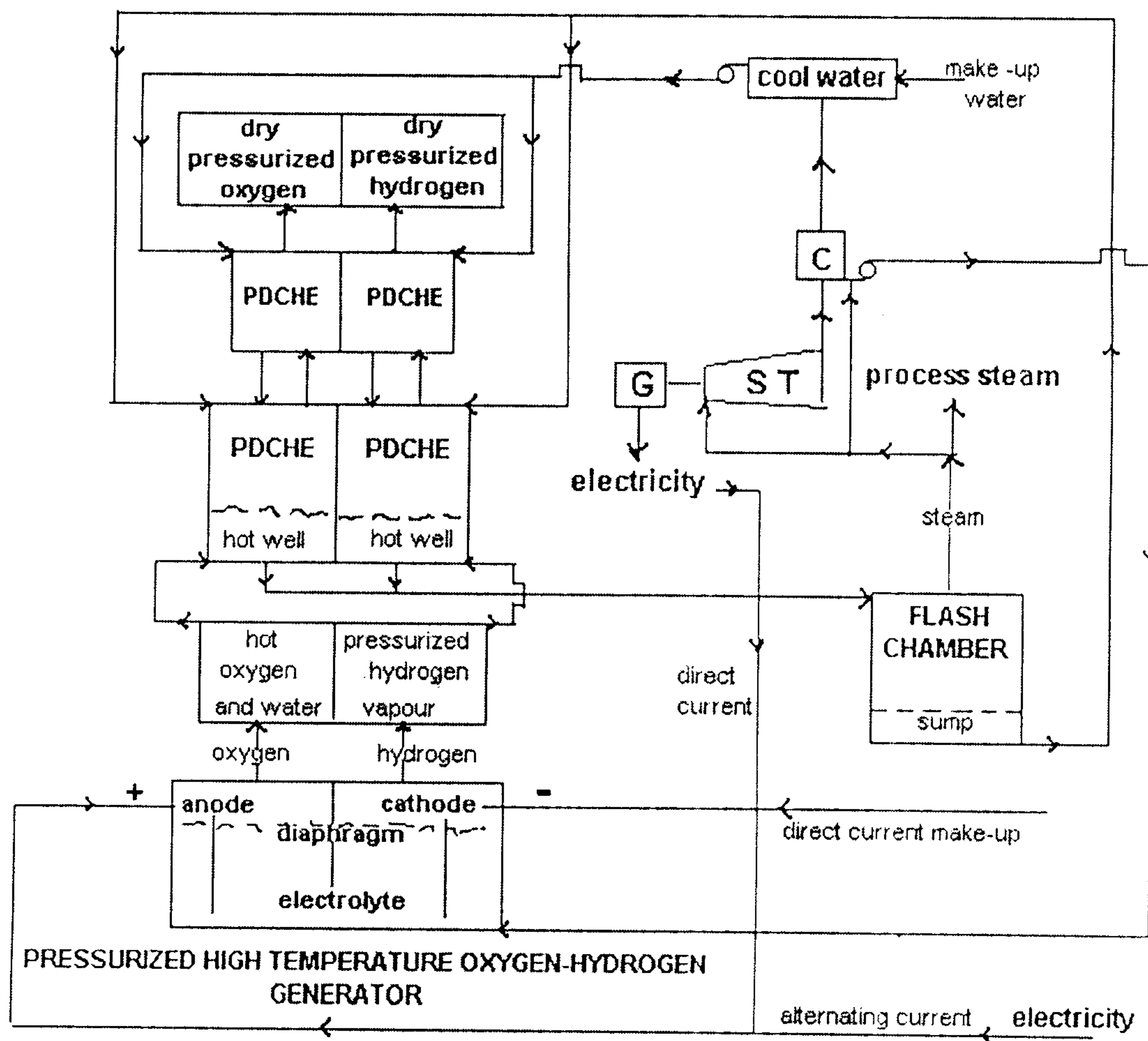
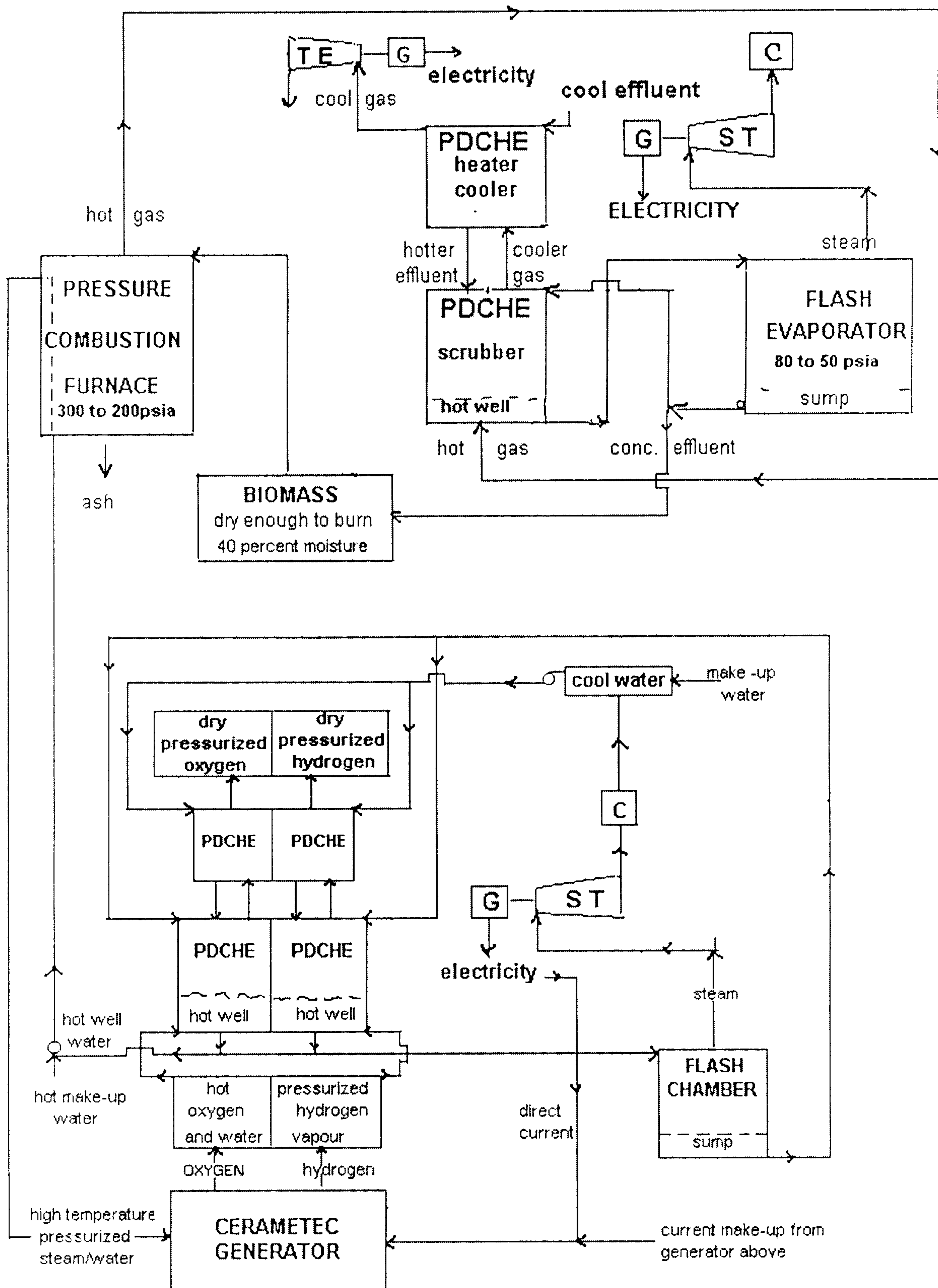


FIG 15



HIGH PRESSURE & TEMPERATURE OXYGEN-HYDROGEN
GENERATOR

FIG 16

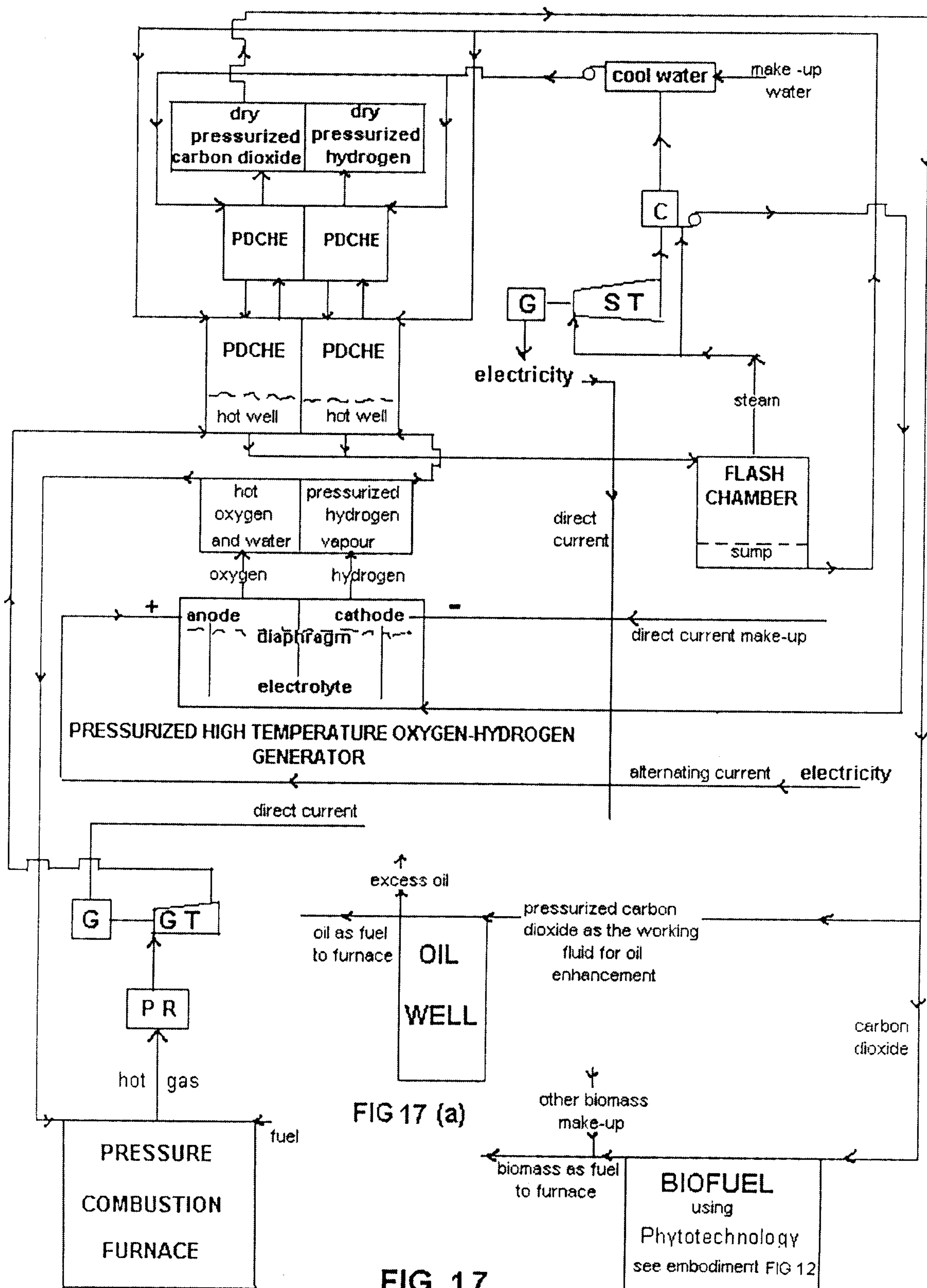
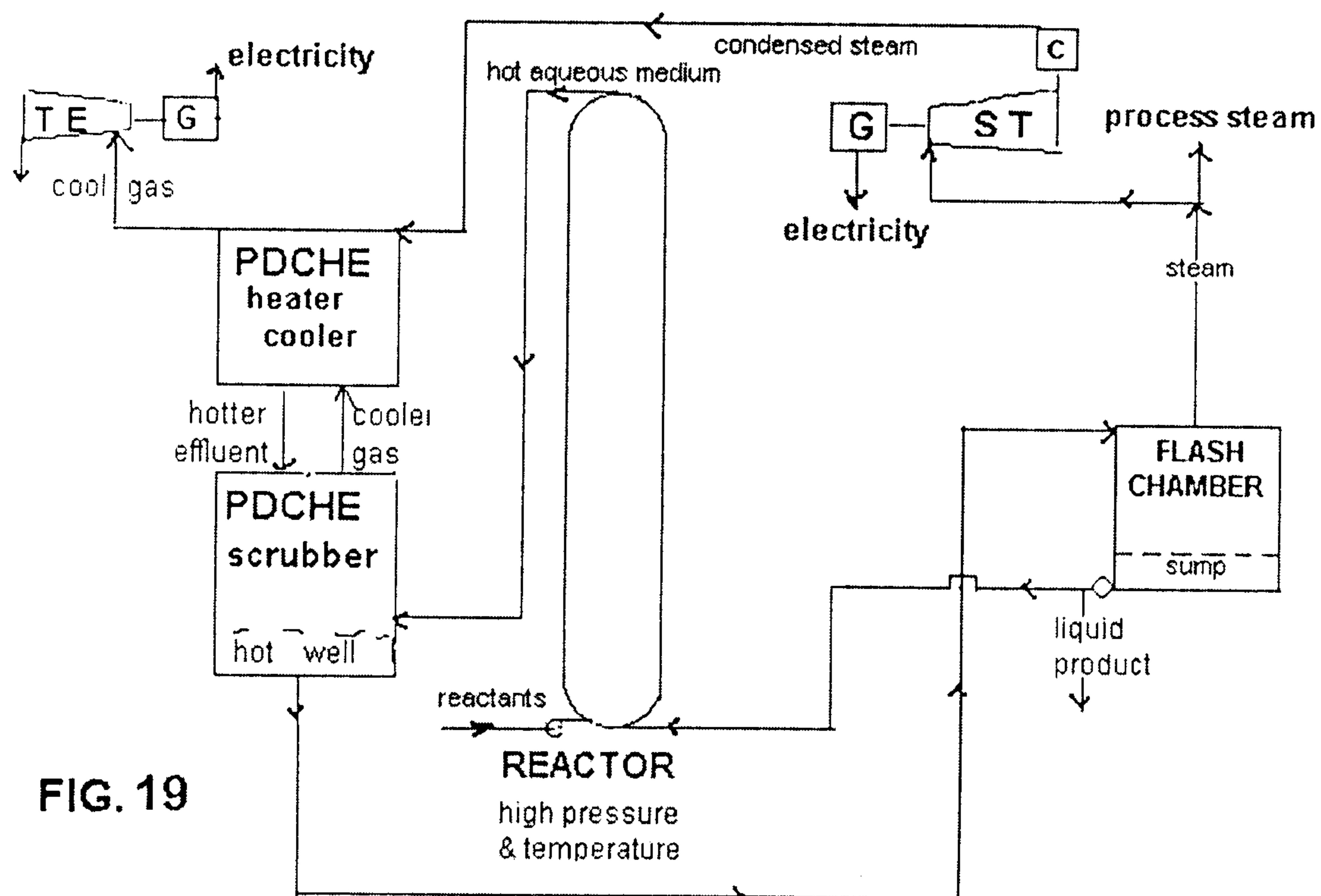
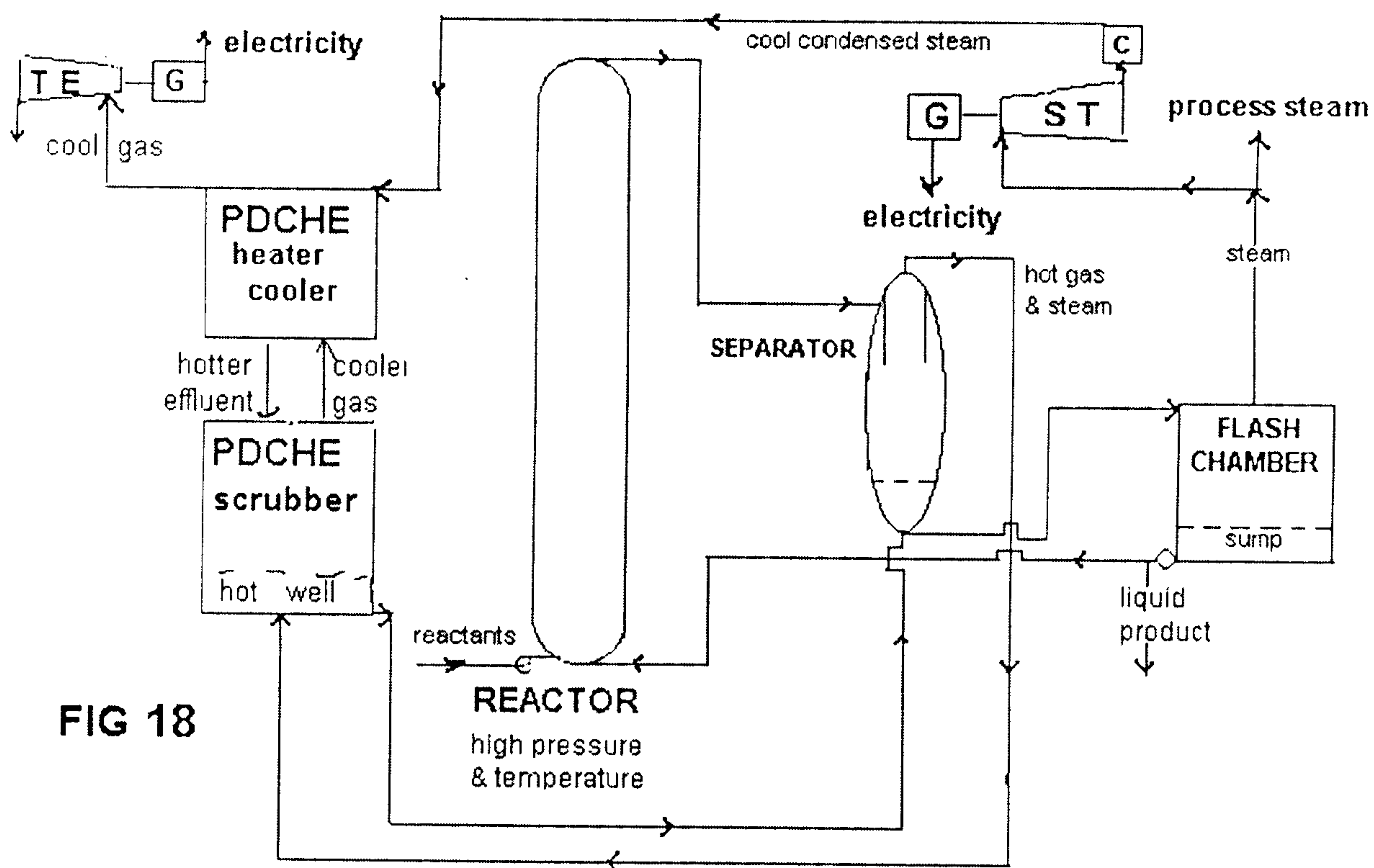


FIG 17

FIG 17 (b)



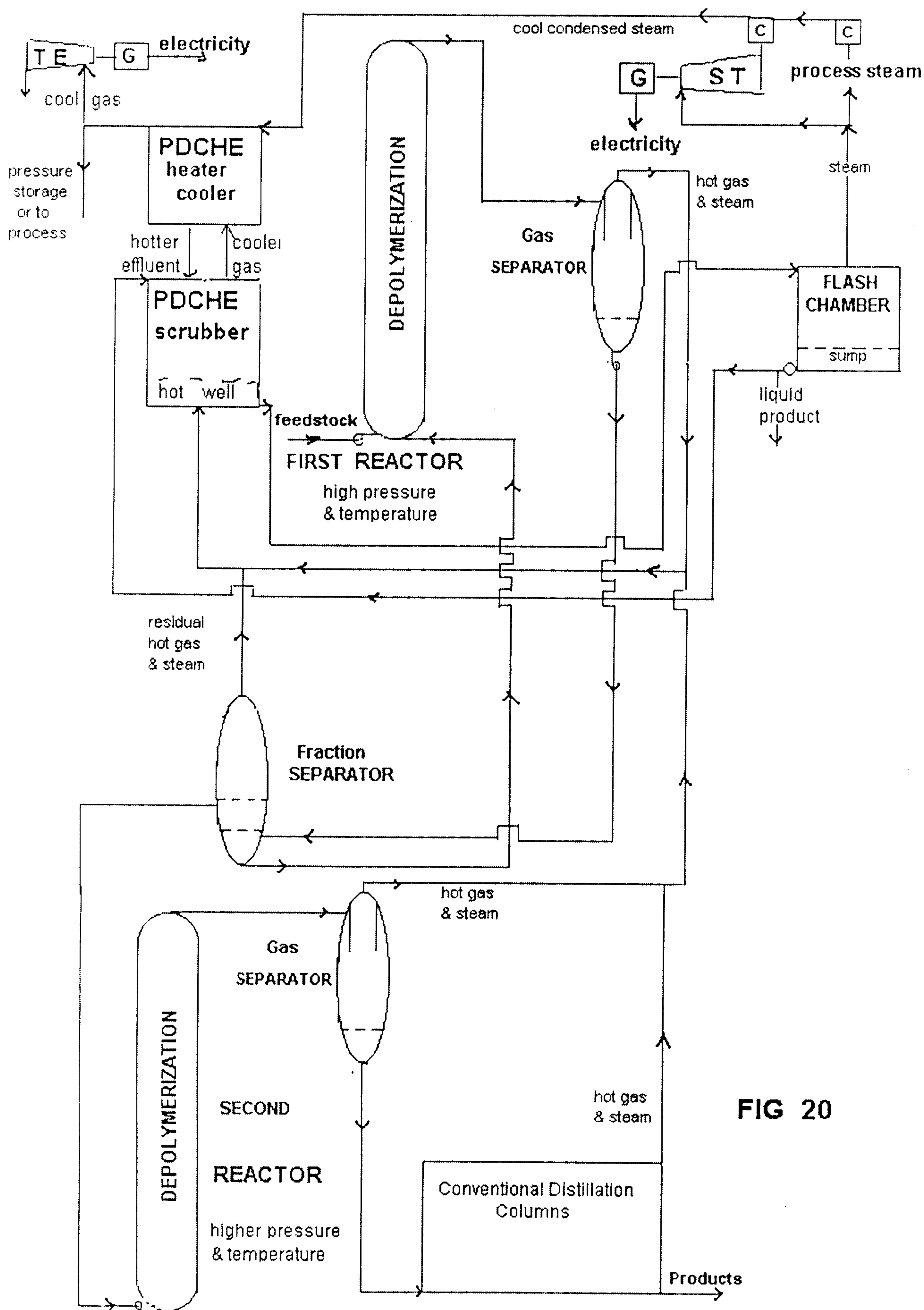


FIG 20

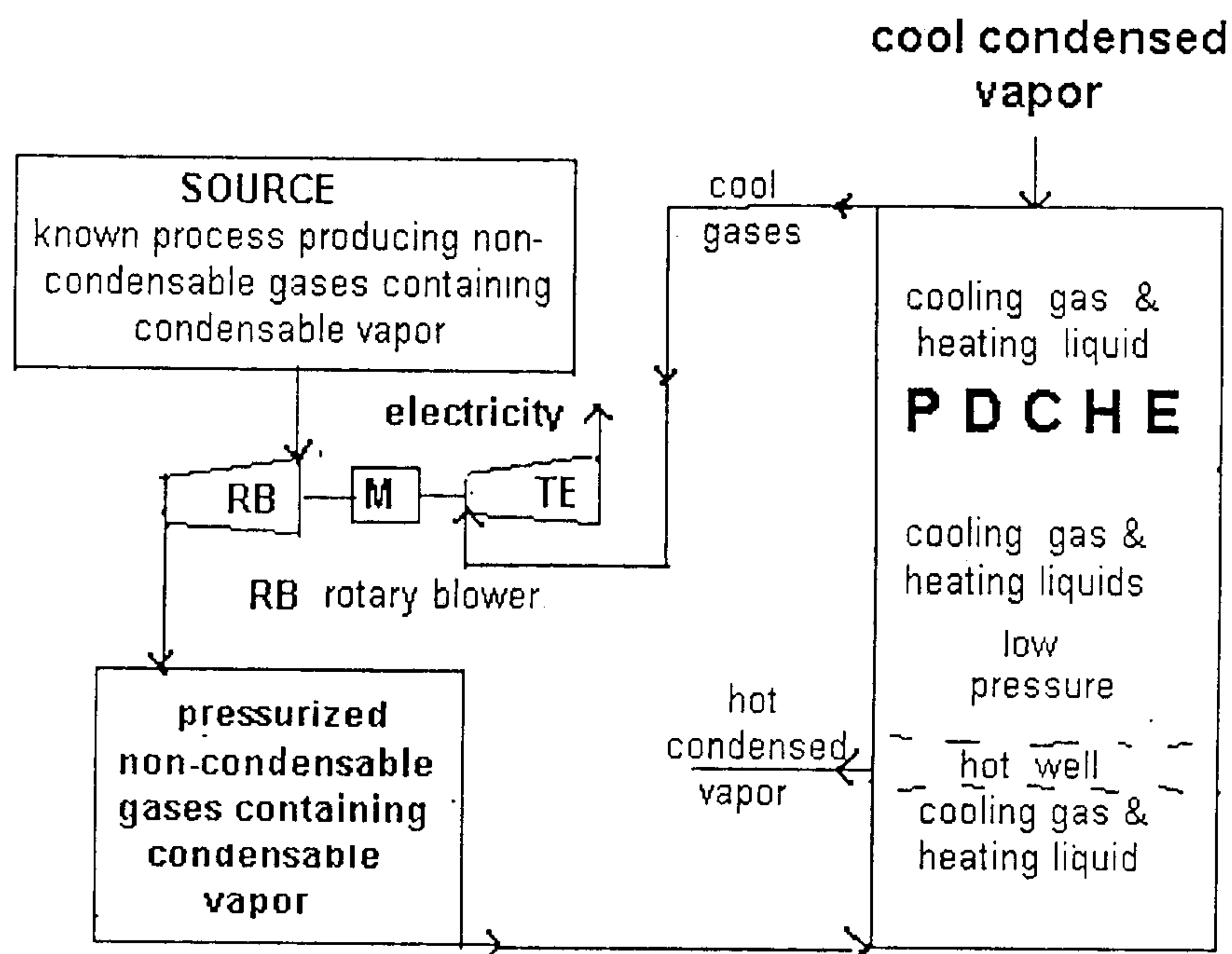


FIG 21

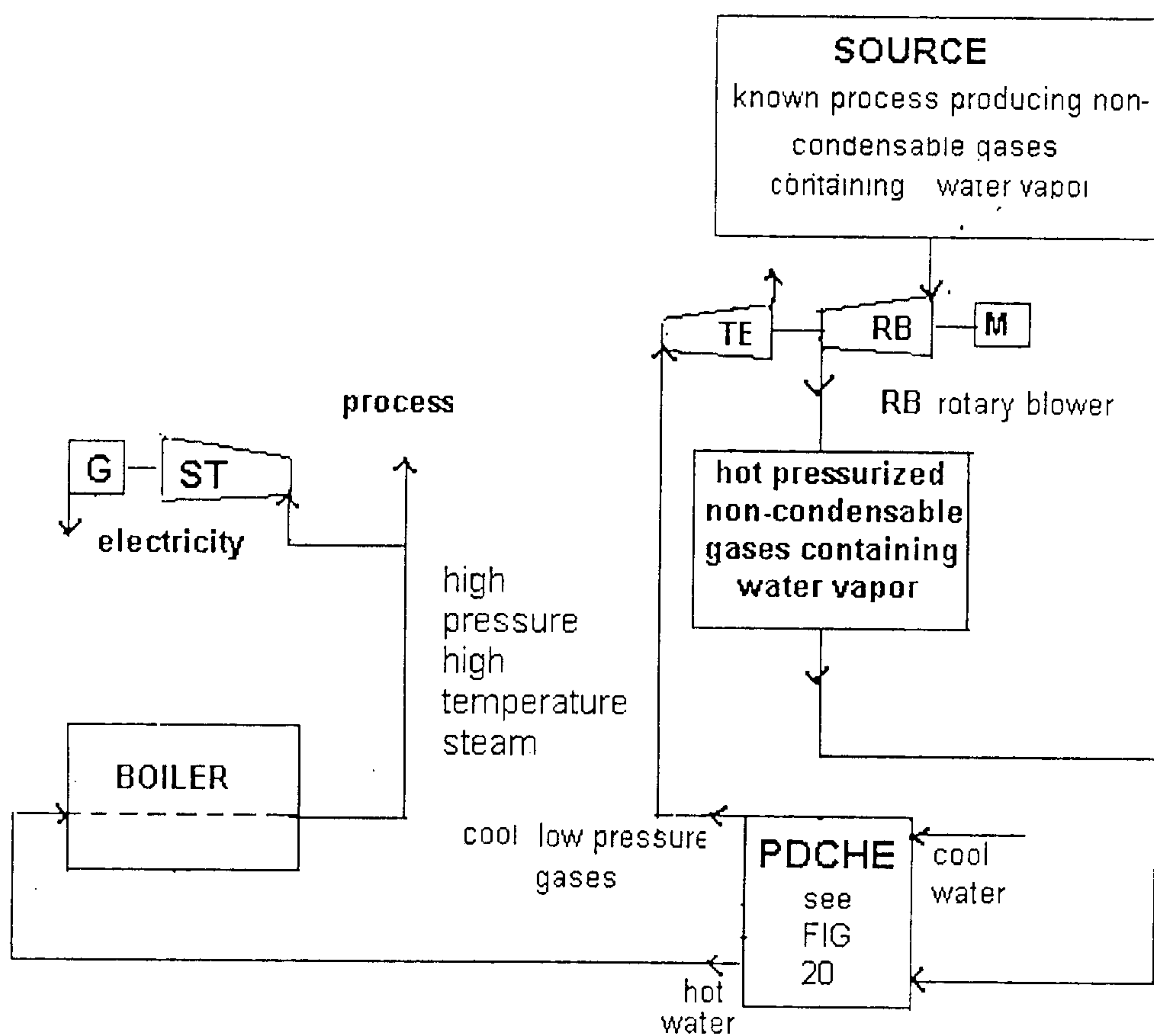


FIG 22

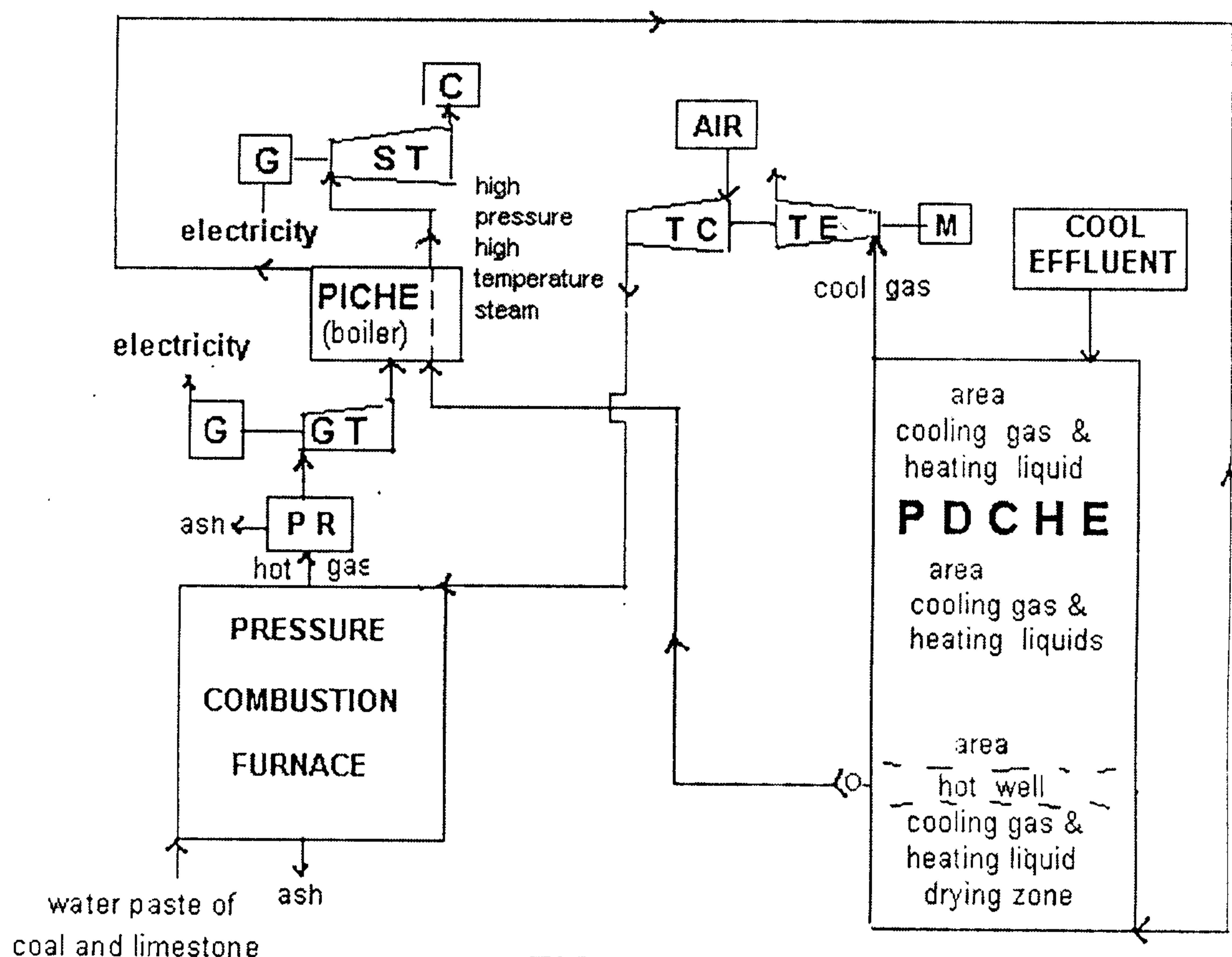


FIG 23

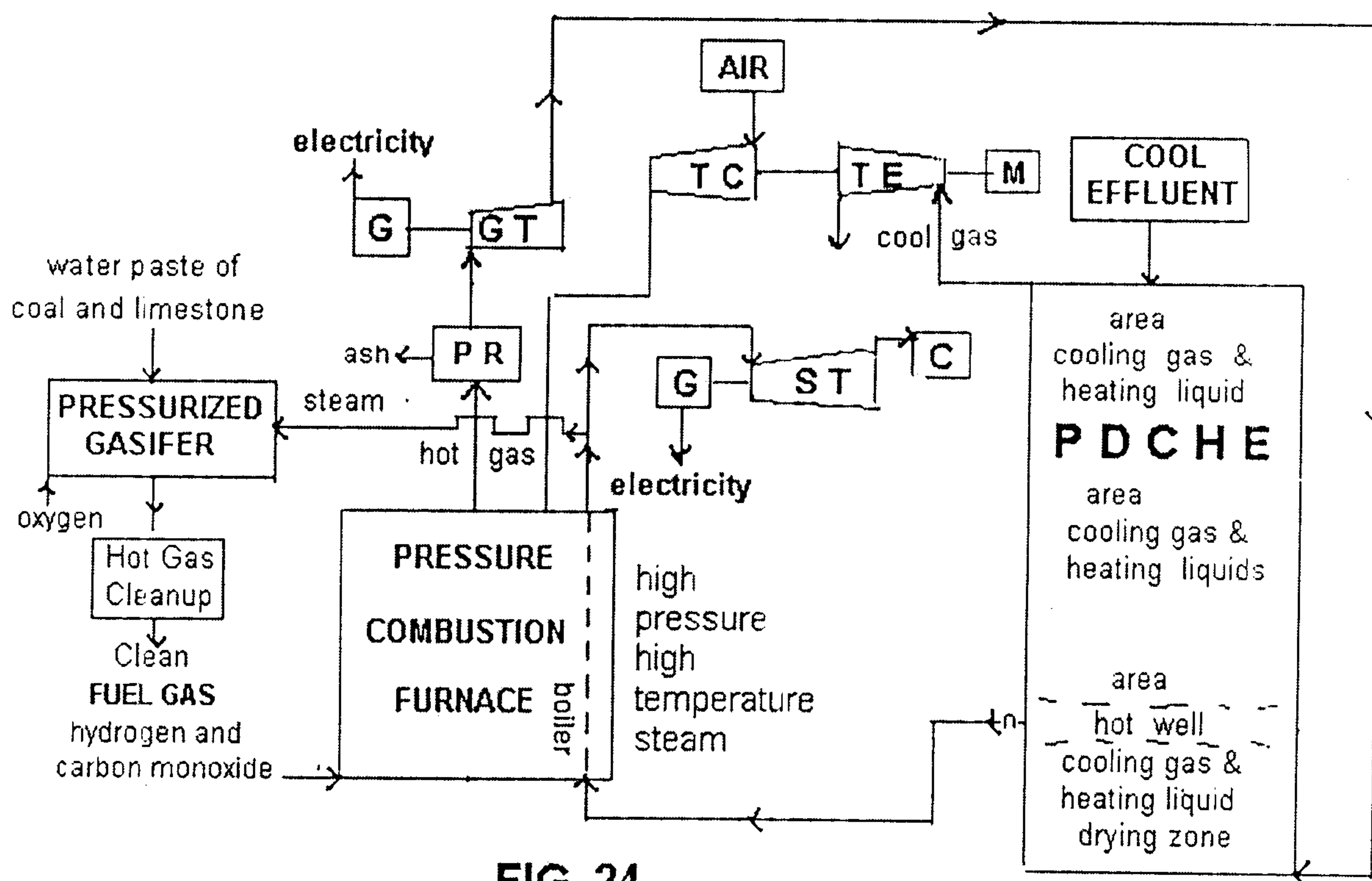


FIG 24

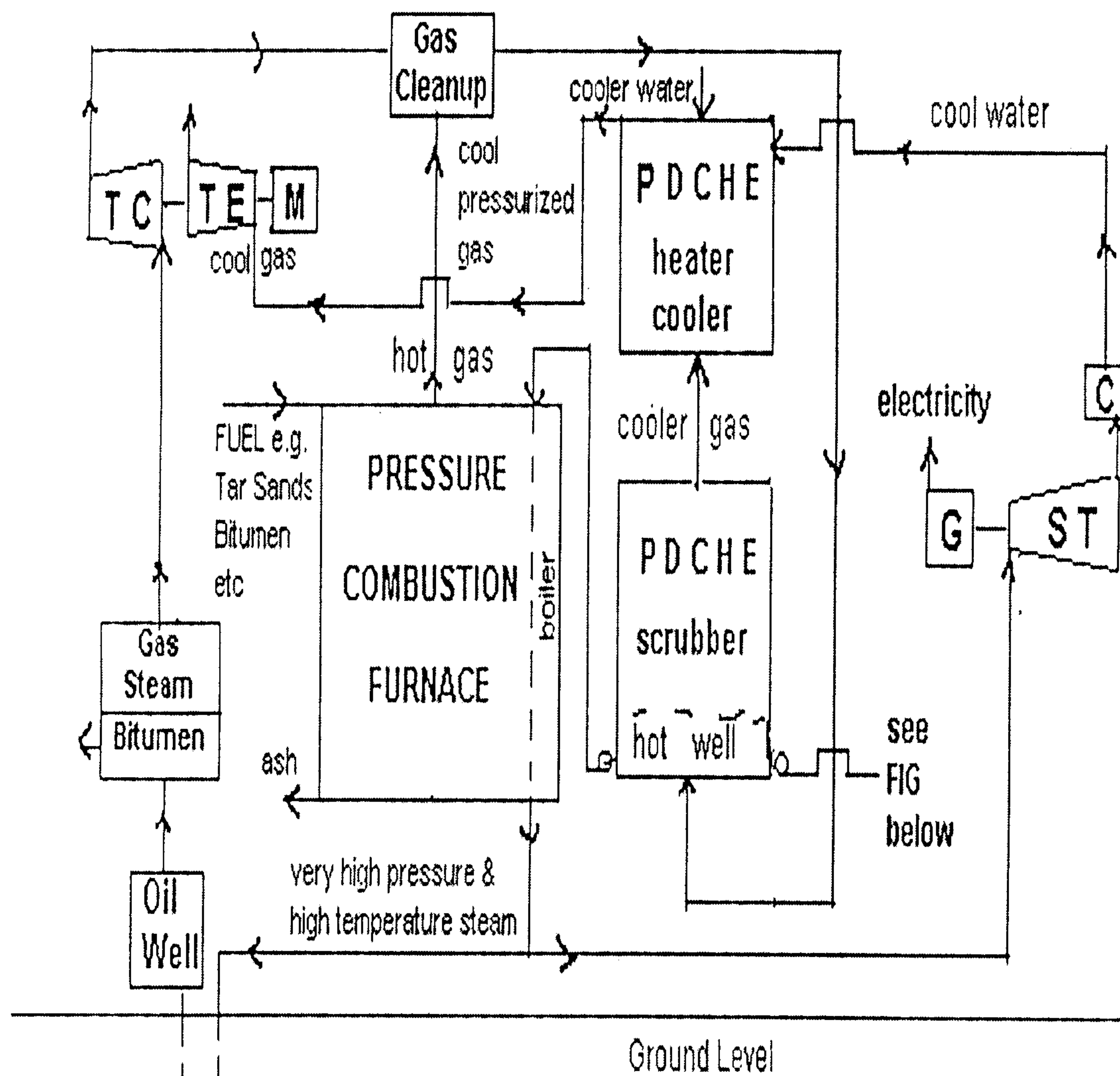


FIG 25

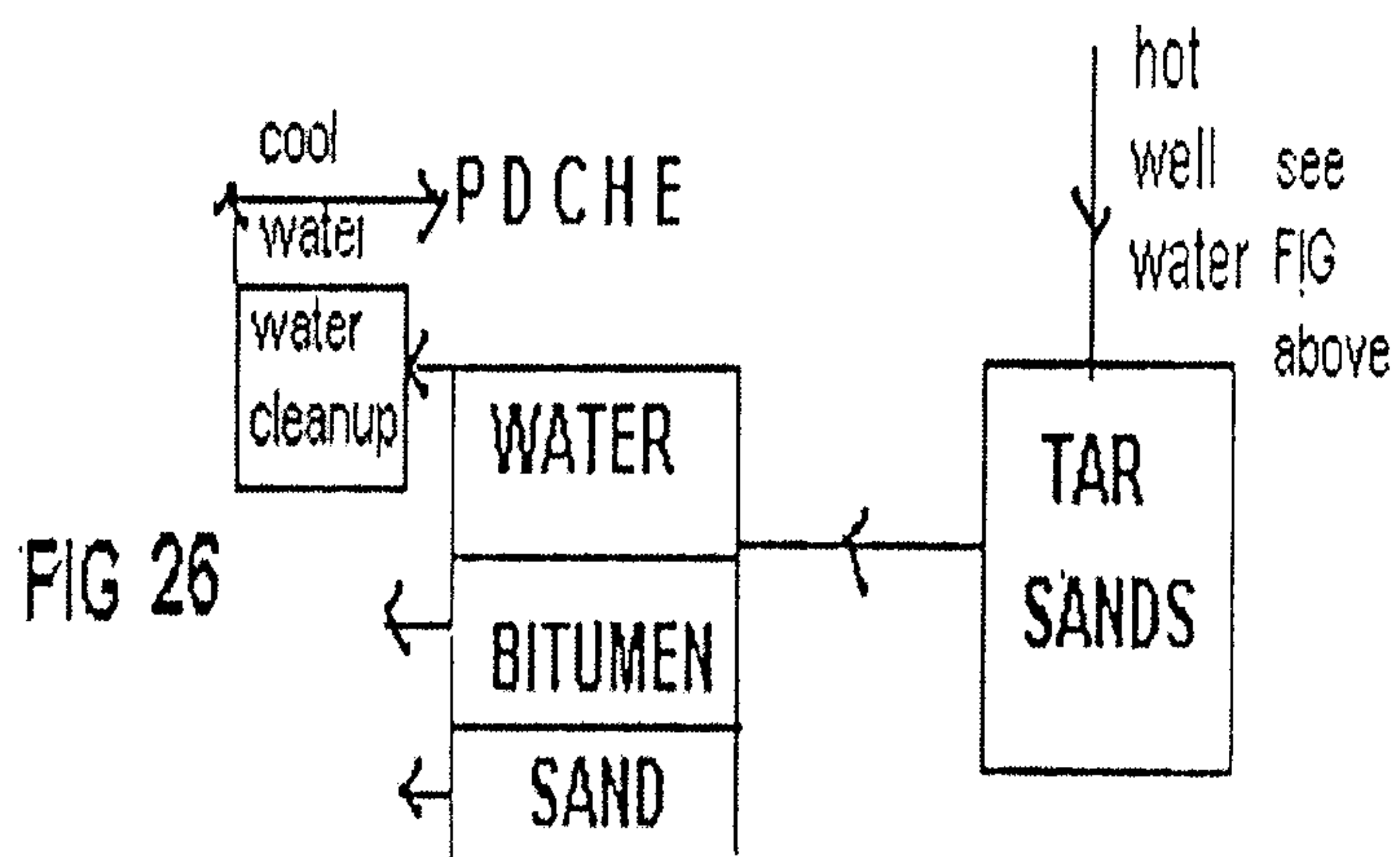


FIG 26

