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METHOD FOR THE ARRANGEMENT OF
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The present invention relates to a method and apparatus for the arrangement of thermodynamic relations in technological processes in connection with chemical reactions which must be carried out under predetermined optimum conditions of temperature and pressure.

In order to ensure such optimum conditions, it is often necessary to supply a considerable quantity of heat during the working cycle and then to withdraw heat from the system, with the quantity of heat supplied from a source outside the system having an important bearing on the cost of the whole manufacturing process. The recovery of heat in such cases is effective only to a small degree or is not possible at all because of the pressure or temperature levels in the system.

An example of a chemical reaction normally occurring under unsatisfactory conditions is the pressure conversion of carbon monoxide with steam to hydrogen, such reaction being one of the basic processes in the production of synthetic liquid fuels. During this conversion the optimum temperature amounts to about 450° C. and an excess of steam, amounting to several times the stoichiometric quantity, is required for the process. A part of the steam is produced by direct evaporation of the circulating water heated by the heat of gases which have undergone the reaction. Only a part of the heat of the gases which have undergone the reaction is thus returned to the cycle by the production of steam when the usual devices are employed, whereas a large portion of the heat is lost. It is however necessary to introduce into each of the cycles from the outside a quantity of heat which is of the same order as the quantity of heat lost during the cycle and this additional heat has to be supplied in the form of steam.

On the other hand, in order to remove the heat which, with the existing devices, cannot be recovered, great quantities of cooling water are needed. The reason why the heat of the reacted gases cannot all be returned to the cycle and most of the required steam is not obtained by direct evaporation of water in the working cycle, is to be found in the fact that this heat has a lower temperature level than the temperature level of substances entering the reaction.

The above disadvantages of the known systems or devices are removed by the present invention. Contrary to the known systems, the arrangement according to the invention permits the return to the cycle of the major portion of the heat of the gases which have undergone the reactions, thereby to reduce the amount of heat that needs to be supplied from outside the reaction cycle.

In accordance with a primary feature of the invention, the temperature levels in the various parts of the system are arranged so as to make possible a transmission of heat in the required direction to the greatest possible extent. By suitably changing the pressures in the various parts of the system, the temperature levels are arranged so as to achieve values permitting an increased recovery of heat, and at least one component required for the reaction, that is, steam, is obtained either entirely or

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partially by the evaporation of its liquid phase by the heat of the reaction products. In this way favourable conditions are created for carrying out the reaction.

The invention will be further explained with reference specifically to a process for the conversion of CO with steam, and wherein water is used as a heat exchange medium and the temperature levels are arranged at the required values by an increase of the pressure level of the gases which have been subjected to the reaction.

The accompanying drawing shows by way of example an arrangement for carrying out the process according to the present invention.

Water gas containing CO and compressed, for example, to a pressure of 9 atmospheres is supplied through a conduit 8 to an exchanger-saturator 1, where it is heated and wetted or humidified by countercurrent contact with hot water introduced into the top part of the saturator. The humidified and heated gas is compressed by a blower 4 to a suitable pressure, for example, to 12.5 atmospheres, after leaving the saturator and, if need be, the compressed gas is additionally humidified with steam admitted from the outside through a conduit 9. The gas is further conveyed through a surface heat exchanger 5 to a reactor 6, where the actual water gas shift reaction takes place, i.e., $\text{CO} + \text{H}_2\text{O} = \text{CO}_2 + \text{H}_2$. In order to make the reaction proceed at suitable temperatures, cooling condensate is supplied to the reactor through a conduit 12. The gas enriched with hydrogen flows from the reactor 6 through the exchanger 5, where it heats the humidified water gas from the blower 4, and then through a pre-cooler 7, where the hydrogen enriched gas is cooled and heats the water to be introduced into the top portion of the saturator 1. The pre-cooled gas then flows through an exchanger-cooler 2, where it is further cooled by water-quenching, prior to discharge through a conduit 13. The conduit 13 may, for example, extend into a pressure medium for further treatment in the latter of the cooled gas.

The water-quenching of the gas in the cooler 2 is effected by countercurrent contact of the gas with fresh cool water, introduced from the outside to the upper part of the cooler through a conduit 10. In addition to the water supplied through conduit 10, water taken from intermediate points of the water gas saturator 1 is pumped by pumps 3, 3' to several intermediate points of the gas cooler 2, in the present example to two points. The water is heated in the cooler 2 by the gases which have undergone the reaction and is conveyed from the lower portion of the cooler by suitable pressure through the gas pre-cooler 7, in which the temperature of the water is further increased prior to feeding of the water to the top portion of the water gas saturator 1, as described above.

It is apparent from the above that the transmission of heat is effected by means of water in closed cycles, with the pre-cooler 7 as well as the cooler 2 of the gases, which have undergone the reaction, operating behind the compressor 4, that is at an elevated pressure and temperature level of the gases. In this way the required temperature gradient for the transmission of heat from the gases in the cooler 2 to water is achieved, the water being transmitted to the water gas saturator 1 by way of the pre-cooler 7, as described above. Only a small portion of the cooled water leaves the bottom portion of the saturator 1 through the outlet 11, so that the described arrangement according to the invention reduces the quantity of waste heat by as much as about 90% as compared with some known arrangements.

In the illustrated example the heat exchange medium consists of water, and the steam formed from such water is used as one of the reaction components. The steam consumed by the reaction is replaced by the supply of fresh steam from the outside through the conduit 9 or

by the supply of fresh water from the outside through the conduit 19 or in both ways simultaneously.

It is obvious that for another type of reaction another liquid may be used instead of water, when the vapours of that other liquid are needed for the reaction. The vapours of the liquid may be used either as a reaction component or as a catalyst. It is also possible to provide a system embodying the invention wherein liquids are evaporated to produce the vapours which have to be introduced into the reaction, but these liquids are not used at the same time as the heat exchange medium. The evaporation of such liquids can be achieved with a surface heat exchanger with one or more stages, while the reaction products are cooled down in the heat exchanger and, if required, the vapours which have not undergone the reaction may be condensed and the condensate fed back into the initial substances for the reaction.

A series of systems according to the invention may be devised in various more or less complex combinations. Thus, for example, the reaction products may be cooled by various combinations of surface exchangers and contact exchangers, while the changes of the pressures in the individual parts of the system may be effected by various suitable devices for the compression or expansion of gaseous substances which are interposed in the working process at a suitable point during the evaporation or after the same.

None of such possible arrangements exceeds the scope of the present invention as far as it is based on the fundamental principle consisting in the adjustment of temperature levels to a suitable relation.

The present invention may be advantageously used in connection with any processes employed for chemical reactions, and in which complete utilisation of heat has an important bearing on the manufacturing cost. The invention can also make possible the profitable conversion of CO from lighting gas for the purpose of reducing or even eliminating its poisonous properties or the conversion of poor gases for the purpose of increasing their caloric value by simultaneous washing of CO₂.

We claim:

1. In a process for producing hydrogen from a gaseous substance containing carbon monoxide, the steps of contacting said gaseous substance in a saturating zone at a predetermined pressure with hot water so as to heat said gaseous substance, to vaporize a portion of said water, and to cool the remaining portion of said water; conducting said gaseous substance and said vaporized water to a reaction zone to form therein a hydrogen enriched reaction gas containing water vapor; increasing the pressure of said gas over said predetermined pressure by substantially 39%; contacting said reaction gas at said increased pressure in a cooling zone with said cooled remaining water portion so as to condense a portion of said water vapor, to heat said water portion, and to cool said reaction gas; and conducting the heated water and condensed water vapor to said saturating zone for contact with said gaseous substance.

2. In a process for producing hydrogen from a gaseous substance containing carbon monoxide, the steps of contacting said gaseous substance along a path in a saturating

zone at a predetermined pressure with countercurrent hot water so as to heat said gaseous substance, to vaporize a portion of said water, and to cool the remaining portion of said water; withdrawing the cooled remaining water portion from said saturating zone in a plurality of streams at spaced points along said path; conducting said gaseous substance and said vaporized water to a reaction zone to form therein a hydrogen enriched reaction gas containing water vapor; increasing the pressure of said gas over said predetermined pressure by substantially 39%; contacting said reaction gas at said increased pressure along a path in a cooling zone countercurrent with said plurality of streams of said cooled remaining water portion so as to condense a portion of said water vapor, to heat said water portion, and to cool said reaction gas, said plurality of streams being introduced into said cooling zone at spaced points along said path therein; and conducting the heated water and condensed water vapor to said saturating zone for contact with said gaseous substance.

3. A process for producing hydrogen from a gaseous substance containing carbon monoxide, comprising the steps of heating and humidifying the gaseous substance by contacting the latter with hot water in a saturating zone, thereby allowing said hot water to cool, conducting the heated and humidified gaseous substance to a reaction zone where it reacts to form a hydrogen enriched gas, contacting the reaction gas with cool water in a cooling zone at a pressure higher by substantially 3.5 atmospheres than the pressure in said saturating zone, thereby cooling the reaction gas and heating the cool water, said pressure in the cooling zone being maintained at a value causing the temperature at least at the top, bottom, and an intermediate point of said cooling zone to correspond to the temperatures in said saturating zone at the bottom, top, and an intermediate point, respectively, of the saturating zone, conducting the heated water from the bottom of said cooling zone to the top of said saturating zone, and conducting water from intermediate points of said saturating zone to intermediate points of said cooling zone having corresponding temperature levels.

4. A process as set forth in claim 3, including indirectly contacting the heated and humidified gaseous substance being conducted to the reaction zone with the reaction gas prior to the cooling of the latter.

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