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PROCESS FOR REMOVING THE SUBSTANCES CONDENSED IN COLD ACCUMULATORS IN THE COOLING OF GASES

Jean Le Rouge, Boulogne-sur-Seine, France; vested in the Alien Property Custodian

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This invention relates to a process for removing by sublimation or vaporization the substances which have been condensed in the cooling of a gas, which in the following will be called the "incoming gas," by another gas to be warmed up, which will be called the "outgoing gas," this cooling taking place through the passage of the incoming gas through a cold accumulator, that is, a container enclosing a suitable filling substance, for instance aluminium, in which the cold of the outgoing gas has been accumulated; the two gases are alternately flowing, each in a direction opposed to that of the other, through the accumulator, and in order to allow a continuous operation, a pair of accumulators is utilized.

The removal of the substances condensed in the cooling of the incoming gas in the accumulator is in principle effected by the flow therethrough of the outgoing gas, and, in order to lower the difference of temperature between the two gases and consequently facilitate this removal, for instance the sublimation of the carbon dioxide contained in the air to be separated into its components, it has already been proposed to pass through the cold accumulator, either over its entire length or over its colder part, that is, that part in which the carbon dioxide deposits, a quantity of the separated components larger than that of the incoming air to be separated.

The process according to the present invention enables the difference of temperature between the incoming and the outgoing gas to be lowered more than does the known process. Moreover it is applicable to the removal of water vapour whereas the known process is not.

The process of this invention consists in subjecting at least one of the two gases, in at least one of the two parts of its path which are situated on both sides of the place where the separation of the condensible substance begins, to a thermal action which is distinct from that to which it is submitted by the other gas through the intermediacy of the accumulator, and brings its temperature nearer to the temperature prevailing in the part of its path other than that in which the thermal action is applied.

Thus, if the thermal action is applied in that part of the accumulator in which the condensible substance to be removed is not yet depositing and which will be called in the following, for simplicity's sake, the "warmer part" of the accumulator, the thermal action will consist in a cooling; it will on the contrary consist in a heating if it is applied in that part of the accumulator in which the condensible substance deposits and which will in the following be called the "colder part" of the accumulator.

If the deposition of the condensible element to be removed only begins in the vicinity of the cold end of the accumulator, as in the case of the carbon dioxide contained in the air, it is in practice necessary to exert a cooling action; if on the contrary this element begins depositing in the vicinity of the warm end of the accumulator, as in the case of water vapour, a heating will be exerted. The cooling will be preferably exerted in the immediate vicinity of the place where the condensible element to be removed begins depositing; again the heating will be preferably exerted at the place where the condensible element no longer deposits in a troublesome amount. If moreover these cooling and heating are simultaneously exerted for the same substance to be removed, at two places of the accumulator in the localized manner above defined, the power outlay is lowered to the most.

The above mentioned thermal action may be performed in any suitable manner. Thus it may be obtained by direct contact of an agent of a suitable temperature with the gas to be heated or cooled. In the case of a heating a small quantity of the outgoing gas, formerly warmed up to the surrounding temperature and which has been brought back to its pressure at the place where the addition takes place, is added to the outgoing gas as it flows through the cold accumulator. In the case of a cooling there is added to the incoming or outgoing gas a gas colder than the same or a liquefied gas, which it will generally be useless manufacturing in a special plant because they will be found either in the accumulators or in the apparatus, such as liquefaction and rectification apparatus, to which the cold accumulators are appended. For instance in the case of the separation into its constituents of air which has not formerly been freed from its carbon dioxide, a small quantity of liquid air, which, according to the pressure of the incoming air and the degree of perfection of the accumulators, is generally comprised between ⅕% and 1% of the bulk of the treated air, is added to the incoming air, in the region of the accumulator where a temperature of about −140° C. is prevailing. Again there may be added to the outgoing component a small quantity of that same component in the liquid state taken from the separating apparatus. The liquefied air or component will for instance consist of a part of the liquid formed in a liquefier by putting air under pressure or a given amount of the component under pressure in heat exchange with the incoming air or the outgoing component taken at the cold end of the cold accumulators.

It is to be noted that this addition, to the entering or outgoing gas, of a cooling or heating agent modifies the quantity of these gases which flow through the accumulator. It may result therefrom that the difference of temperature between the two gases, while being suitable at the place of the addition, is no longer suitable in another part of the accumulator. This drawback is removed by withdrawing from that gas which has been subjected to the addition, near the place where the addition takes place, a quantity of gas which approximates that of the added agent, and which will preferably be conveyed back to a place of the plant where a temperature near that of the withdrawn gas and a pressure lower than that of this gas are prevailing; again the quantity of the gas which is not subjected to the addition may be increased over a portion of its path through the cold accumulators. In both cases substantially equal quantities of incoming and outgoing gas are flowing through all parts of the accumulators.

When the cooling agent is added to the incoming gas or the heating agent to the outgoing gas, that is, when the thermal action exerted on the gas is of the same sense as that exerted thereon on the other hand by the gas with which it is in heat exchange through the intermediacy of the accumulator, it is in particular in the region of the accumulator in which the condensed substance deposits in a troublesome amount that the addition of the cooling or heating agent tends to cause the difference of temperature between the two gases to vary along the accumulator: for equal specific heats of the incoming and outgoing gases, this difference increases as one, in this region, gets farther from the place of the addition. In order to keep this difference substantially constant in this region, one or more secondary thermic actions of the same sense as the main one may be exerted in said region. For instance a part of the cooling or heating agent may be added at one or several places disposed along this region. When the thermal action according to this invention consists in the addition, in the warmer part of the accumulator, of a cooling agent to the incoming gas, this addition is then accompanied by the addition of another portion of the cooling agent in that portion of the colder part of the accumulator which is nearest to the warmer part, the latter cooling being itself, if desired, accompanied by a heating exerted in the remaining portion of the colder part, that in which the deposition of the condensible substance is too slight to be still troublesome.

The thermal action, instead of being applied directly, may also be applied by means of an indirect contact, which will preferably be effected by means of an auxiliary fluid flowing in a closed cycle between the place where the thermal action is to be applied and a source of heat or cold. The auxiliary fluid will consist of a gas under high pressure, so as to have a great capacity under a small volume, or preferably of a fluid under such a pressure as to be alternately in the gaseous state at the higher and in the liquid state at the lower of the two temperatures between which it is circulating. When the treated gaseous mixture is air and the condensible element to be sublimated carbon dioxide, the auxiliary fluid will for instance consist of oxygen, argon or krypton circulating in a closed cycle between a heat exchanger located within one cold accumulator in the region where the temperature of about −140° C is prevailing and a second heat exchanger located either in the same or in the other cold accumulator of the pair, at a place where a lower temperature, say −160° C or −170° C, is prevailing. If then the cold end of the accumulators is placed at the top, and a U-shaped tube, with descending vertical branches, between the two heat exchangers between which the fluid circulates, the same will from itself circulate continuously according to the thermo-siphon principle, without it being necessary to utilize a circulation pump.

Another remark respecting the difference of temperature between the incoming and the outgoing gas in the different parts of the accumulators should be made. As known, for all the gases which are more compressible than taught by the law of Boyle-Mariotte, thus in particular for air and its components, the specific heat of the gas increases at the same time as the pressure, especially at low temperature so that, when both gases are in equal quantities and when the outgoing gas is under a lower pressure than the incoming one, which is generally the case, the difference of temperature between the incoming and the outgoing gas increases as the temperature falls. It results therefrom that the difference of temperature between the incoming and the outgoing gas may have been rendered small enough by the process of the invention at the place where the condensible element begins depositing and remain however too great at the cold end of this region, even when the quantities of the two gases in heat exchange are kept equal over the whole length of the accumulator in one of the above described manners. In that case a part of the cooling agent may be added in the colder part of the accumulator in the manner above described, or the process of the invention may be combined with the known process mentioned at the beginning of this specification which consists in increasing the quantity of the outgoing gas in proportion to that of the incoming one. This will for instance take place, in the case of a thermal action effected by direct contact, by taking the added agent and the withdrawn gas in quantities which are no longer equal, as assumed hereinbefore, but on the contrary unequal.

JEAN LE ROUGE.