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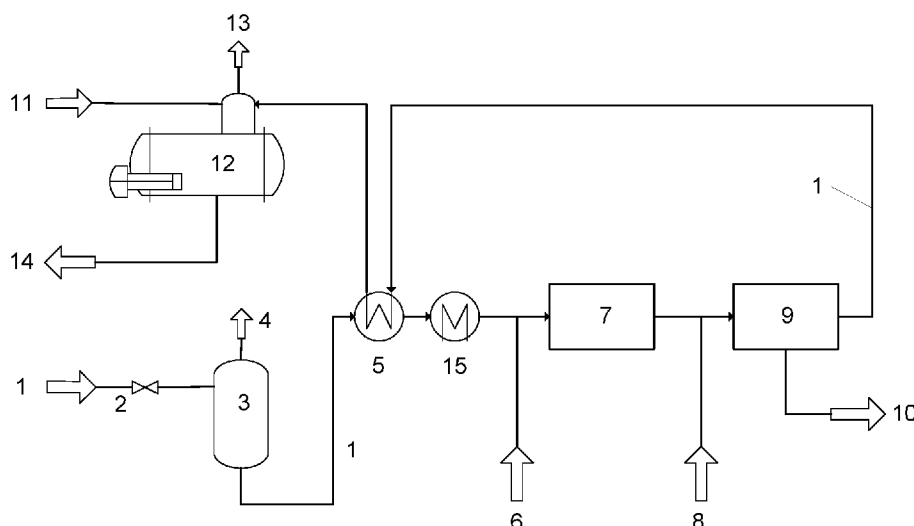


Fig. 1

(57) Abstract: A plant and a process for the purification of process condensate (1) from the catalytic steam reformation of a hydrocarbonaceous feed gas by using UV light (7) and reverse osmosis (9).



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10                    **Process and Plant for the Purification of Process Condensate from the  
                         Catalytic Steam Reformation of a Hydrocarbonaceous Feed Gas**

**Field of the Invention**

15                    This invention relates to a process and a plant for the purification of process  
condensate which has been separated from synthesis gas produced by catalytic  
steam reformation of a hydrocarbonaceous feed gas.

**Prior art**

20                    Such processes and plants are known per se. The underlying process for the  
catalytic steam reformation of a hydrocarbonaceous feed gas is described for  
example in Ullmanns Encyclopedia of Industrial Chemistry, Sixth Edition, Vol. 15,  
Gas Production, Chapter 2. The feed gases, a hydrocarbonaceous gas, such as  
e.g. natural gas and steam, are passed through externally heated reactor tubes  
filled with catalyst at elevated pressure, e.g. at 20 to 35 bar, and high  
25                    temperature, e.g. 800 to 950 °C. In the process, the feed gases are converted into  
synthesis gas rich in hydrogen and carbon monoxide.

30                    For the economy of the process it is very important to employ the heating energy  
used for heating the feed gases and for carrying out the, in total, endothermal  
reforming reactions as far as possible for steam generation. The steam used  
together with the hydrocarbonaceous feed gas is referred to as process steam. It  
is obtained by re-evaporating the condensate formed and deposited from the

synthesis gas upon cooling thereof. The heat content of the synthesis gas and of the flue gas however exceeds the heat quantity required for generating the process steam. To make good use of this excess heat, the same is utilized for generating so-called export steam, which chiefly is used outside the steam reforming process.

The purity requirements of the export steam often are very much higher than those of the process steam. The process condensate contains impurities, such as methanol, ammonia, carbon dioxide, formic and acetic acid, which render a direct use of the condensate for the generation of export steam impossible. In practice, the two kinds of steam therefore often are generated in separate degassing and steam boilers, wherein fresh boiler feed water is used for the generation of export steam. This twofold configuration of the evaporation systems however increases the costs of the plant.

The European patent specification EP 2 456 721 B1 therefore presents a process in which the process condensate is purified to such an extent that it can be evaporated together with boiler feed water, in a common evaporation system, and can then be used both as export steam and as process steam. This process is characterized in that the process condensate, after other purification stages, is subjected to a reverse osmosis and, as last stage, to an electrodeionization. By the reverse osmosis minerals and salts are separated, and by the electrodeionization organic acids and carbonate ions are removed.

For the treatment of drinking water the combination of reverse osmosis and treatment with UV light also is known, as described e.g. in the German document DE 40 08 458 A1. The UV light serves for the sterilization of the water.

It is the object of the invention to provide an alternative process and the concept for a corresponding plant for the purification of process condensate, whereby the process condensate can be purified to such an extent that it is also suitable for the generation of export steam.

**Description of the Invention**

The object is solved by a process according to the features of claim 1 and by a plant according to the features of claim 4.

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Process according to the invention:

A process for the purification of process condensate from the catalytic steam reformation of a hydrocarbonaceous feed gas, comprising the process steps:

- a) provision of a process condensate under elevated pressure, which has  
10 been separated from the synthesis gas produced during the steam reformation,
- b) depressurization of the process condensate to atmospheric pressure, mechanical separation and discharge of the depressurizing gas for the further treatment outside the process,
- c) heat exchange between the process condensate and the permeate from  
15 step f),
- d) cooling of the process condensate to a temperature which is suitable for the subsequently used UV lamps,
- e) irradiation of the process condensate with UV light,
- f) treatment of the process condensate with a reverse osmosis process,  
20 wherein a purified permeate is formed and wherein a concentrate containing impurities is separated and discharged for the further treatment outside the process,
- g) thermal degasification of the permeate treated in step c),
- h) transfer of the permeate to the steam generation.

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The UV light here serves to as far as possible destroy all organic constituents which still are contained in the process condensate after depressurization and outgassing, wherein they are converted into organic acids, carbon dioxide and water. The UV light conditions the impurity by a subsequent reverse osmosis such  
30 that it is particularly suitable for the separation from the process condensate.

A preferred embodiment of the process according to the invention is characterized in that between steps c) and d) of claim 1 hydrogen peroxide and/or ozone and

titanium dioxide is fed into the process condensate. By means of this measure hydroxyl ions are produced in the process condensate and the effect of the subsequently used UV light, which likewise produces hydroxyl ions, thereby is intensified.

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Another preferred embodiment of the process according to the invention is characterized in that between steps d) and e) of claim 1 a basic substance is fed into the process condensate. By means of this measure the dissociation of acids and salts in the process condensate can be promoted and the efficiency of the subsequent reverse osmosis can be improved thereby. The ions obtained by the  
10 dissociation form a surrounding sphere of water molecules and thereby are prevented from passing through the membrane of the reverse osmosis module.

Plant according to the invention:

15 A plant for the purification of process condensate from the catalytic steam reformation of a hydrocarbonaceous feed gas, comprising the plant sections:

a) Means for the provision of a process condensate under an elevated pressure, which has been separated from the synthesis gas produced during the steam reformation.

20 b) Apparatus for the depressurization of the process condensate. The synthesis gas, and hence also the process condensate, initially are under the process pressure of the steam reforming process, which frequently lies between 20 and 35 bar. The purification of the process condensate and the subsequent thermal degasification are carried out just above the atmospheric pressure. These  
25 process pressures are above the atmospheric pressure only to such an extent that pressure losses are compensated for the transport of the condensate through the purification stages.

c) Separator for the mechanical separation of depressurizing gas from the process condensate. The separator in essence can be a container, comprising an  
30 inlet for the inflow of the depressurized mixture of process condensate and steam, an outlet at the bottom for the liquid phase, and an outlet for the mixture of depressurizing gas and steam.

d) Heat exchanger for the heat exchange between process condensate and permeate. . This heat exchanger for example can be a tube bundle or plate heat exchanger.

e) Cooler for lowering the temperature of the process condensate.

5 f) Unit for irradiating the process condensate with UV light. The lighting elements are positioned such that the process condensate is irradiated uniformly and with sufficient intensity.

g) Reverse osmosis unit for the treatment of the process condensate. The quality of the membrane of this unit is adjusted to the type of impurities to be  
10 separated.

h) Boiler for the thermal degasification of the permeate produced in part f). The boiler is designed so large that it can also be used for degassing the boiler feed water which is admixed to the purified process condensate. The boiler is equipped with a heating element and with a stillhead filled with packings. The  
15 stillhead is configured such that via the same the process condensate and the boiler feed water are introduced into the boiler and the gases expelled from the waters are discharged, which results in a stripping effect for the purification of the waters flowing in via the stillhead and the packing.

h) Conduit for the transfer of the permeate to the steam generation.

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A preferred embodiment of the plant according to the invention furthermore comprises means for feeding hydrogen peroxide and/or ozone and titanium dioxide into the process condensate between plant sections e) and f). In this plant section hydroxyl ions are produced in the process condensate and the effect of  
25 the subsequently used UV light, which likewise produces hydroxyl ions, thereby is intensified.

Another preferred embodiment of the plant according to the invention furthermore comprises means for feeding a basic substance into the process condensate  
30 between plant sections f) and g). In this plant section the dissociation of acids and salts in the process condensate can be promoted and the efficiency of the subsequent reverse osmosis can be improved thereby. The ions obtained by the

dissociation from a surrounding sphere of water molecules and thereby are prevented from passing through the membrane of the reverse osmosis module.

### **Exemplary embodiment**

5 Further features, advantages and possible applications of the invention can also be taken from the following description of an exemplary embodiment and the drawing. All features described and/or illustrated form the subject-matter of the invention per se or in any combination, independent of their inclusion in the claims or their back-reference.

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The process according to the invention will be explained below with reference to Fig. 1 of the drawing, in which:

15

Fig. 1 shows a flow diagram of an exemplary embodiment of the plant according to the invention.

#### Fig. 1:

The process condensate 1 separated from the synthesis gas is depressurized to almost atmospheric pressure in the expansion device 2 and introduced into the separator 3. Due to the resulting steam formation the process condensate 1 is cooled to approximately 100 °C. The mixture 4 of depressurizing gas and steam, which is separated from the condensate in the separator 3, is discharged from the process for the further treatment. In the heat exchanger 5 heat is exchanged between the hot, unpurified process condensate and the cooled, purified process condensate. By means of the cooler 15 the temperature of the process condensate is lowered to about 40 °C, so as not to expose the succeeding UV lamps to too high temperatures. To the cooled process condensate a stream 6 of hydrogen peroxide or ozone, each with titanium dioxide as catalyst, is added. In the unit 7 the process condensate is irradiated with UV light. By the hydrogen peroxide, the ozone and the UV light protons are produced, which decompose the impurities contained in the condensate. To dissociate the decomposition product more strongly, a base 8 subsequently is introduced. The process condensate

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treated in this way is introduced into the reverse osmosis module 9. There, the impurities are separated as concentrate stream 10 and discharged from the process for the further treatment. The purified process condensate (permeate of the reverse osmosis process) together with boiler feed water 11 is introduced into  
5 the boiler 12, after the heat exchange in 5, for the thermal degasification. The gas 13 expelled thereby is discharged from the process for the further treatment. The degassed water 14 is supplied to the steam generation (not shown).

### **Industrial Applicability**

10 Due to the invention it is possible to carry out the generation of process and export steam in a common steam generation system and hence save investment and operating costs. The invention therefore is industrially applicable.

**List of Reference Numerals**

- 1 Process condensate, in various states of purity
- 5 2 expansion valve
- 3 separator
- 4 mixture of depressurizing gas and steam
- 5 heat exchanger
- 6 hydrogen peroxide/ozone/titanium dioxide
- 10 7 unit for irradiation with UV light
- 8 base
- 9 reverse osmosis module
- 10 concentrate stream
- 11 boiler feed water
- 15 12 boiler for thermal degasification
- 13 expelled gas
- 14 degassed water for steam generation
- 15 cooler

20

**Claims:**

1. A process for the purification of process condensate from the catalytic steam reformation of a hydrocarbonaceous feed gas, comprising the process steps:
  - 5 a) provision of a process condensate under elevated pressure, which has been separated from the synthesis gas produced during the steam reformation,
  - b) depressurization of the process condensate to atmospheric pressure, mechanical separation and discharge of the depressurizing gas for the  
10 further treatment outside the process,
  - c) heat exchange between the process condensate and the permeate from step f),
  - d) cooling of the process condensate to a temperature which is suitable for the subsequently used UV lamps,
  - 15 e) irradiation of the process condensate with UV light,
  - f) treatment of the process condensate with a reverse osmosis process, wherein a purified permeate is formed and wherein a concentrate containing impurities is separated and discharged for the further treatment outside the process,
  - 20 g) thermal degasification of the permeate treated in step c),
  - h) transfer of the permeate to the steam generation.
2. The process according to claim 1, characterized in that between steps d) and  
25 e) of claim 1 hydrogen peroxide and/or ozone and titanium dioxide is fed into the process condensate.
3. The process according to claim 1 or 2, characterized in that between steps e) and f) of claim 1 a basic substance is fed into the process condensate.
- 30 4. A plant for the purification of process condensate from the catalytic steam reformation of a hydrocarbonaceous feed gas, comprising the plant sections:

- a) means for the provision of a process condensate under elevated pressure, which has been separated from the synthesis gas produced during the steam reformation,
  - b) apparatus for the depressurization of the process condensate,
  - 5 c) separator for the mechanical separation of depressurizing gas from the process condensate,
  - d) heat exchanger for the heat exchange between process condensate and permeate,
  - e) cooler for lowering the temperature of the process condensate,
  - 10 f) unit for irradiating the process condensate with UV light,
  - g) reverse osmosis unit for the treatment of the process condensate,
  - h) boiler for the thermal degasification of the permeate produced in part f),
  - i) conduit for the transfer of the permeate to the steam generation.
- 15 5. The plant according to claim 4, furthermore comprising means for feeding hydrogen peroxide and/or ozone and titanium dioxide into the process condensate between plant sections e) and f).
- 20 6. The plant according to claim 4 or 5, furthermore comprising means for feeding a basic substance into the process condensate between plant sections f) and g).

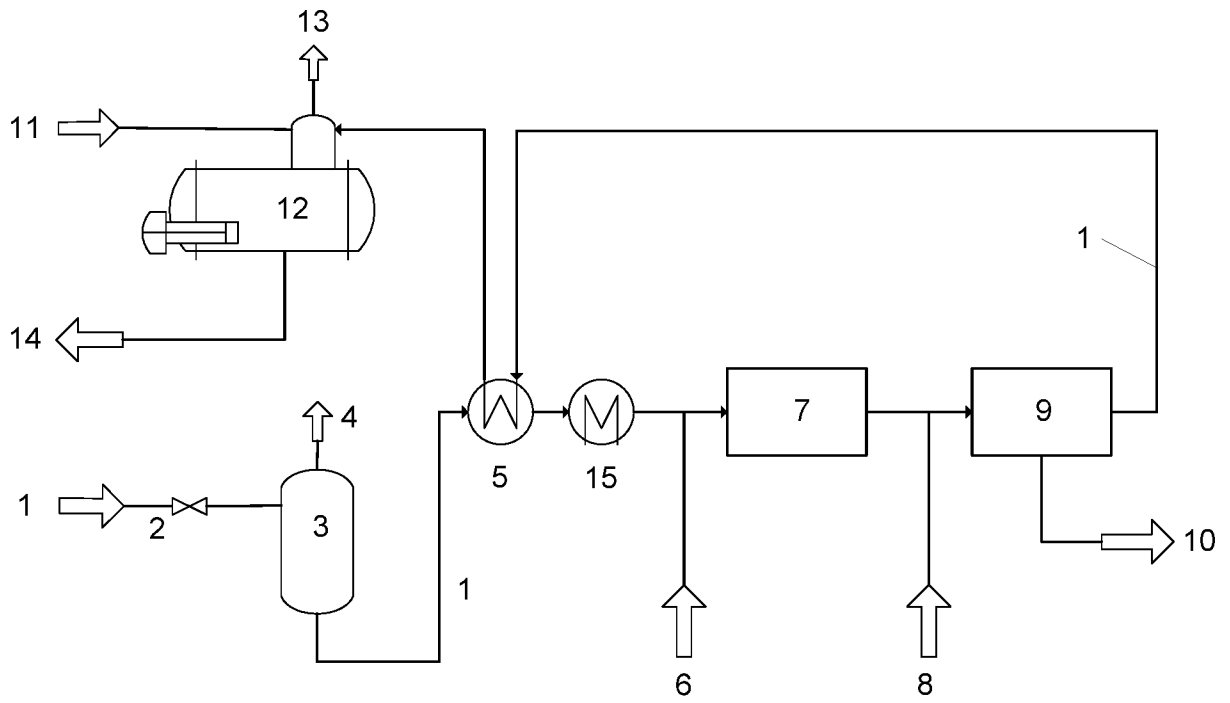


Fig. 1

**INTERNATIONAL SEARCH REPORT**

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A. CLASSIFICATION OF SUBJECT MATTER					
INV.	C02F9/00				
ADD.	C02F1/32	C02F1/44	C02F1/20	C02F1/02	C02F101/30
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According to International Patent Classification (IPC) or to both national classification and IPC					

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols) C02F C10K C01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
EPO-Internal, WPI Data

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Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"O" document referring to an oral disclosure, use, exhibition or other means	
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Date of the actual completion of the international search	Date of mailing of the international search report
8 June 2017	20/06/2017

Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer  One1 Inda, Santiago
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