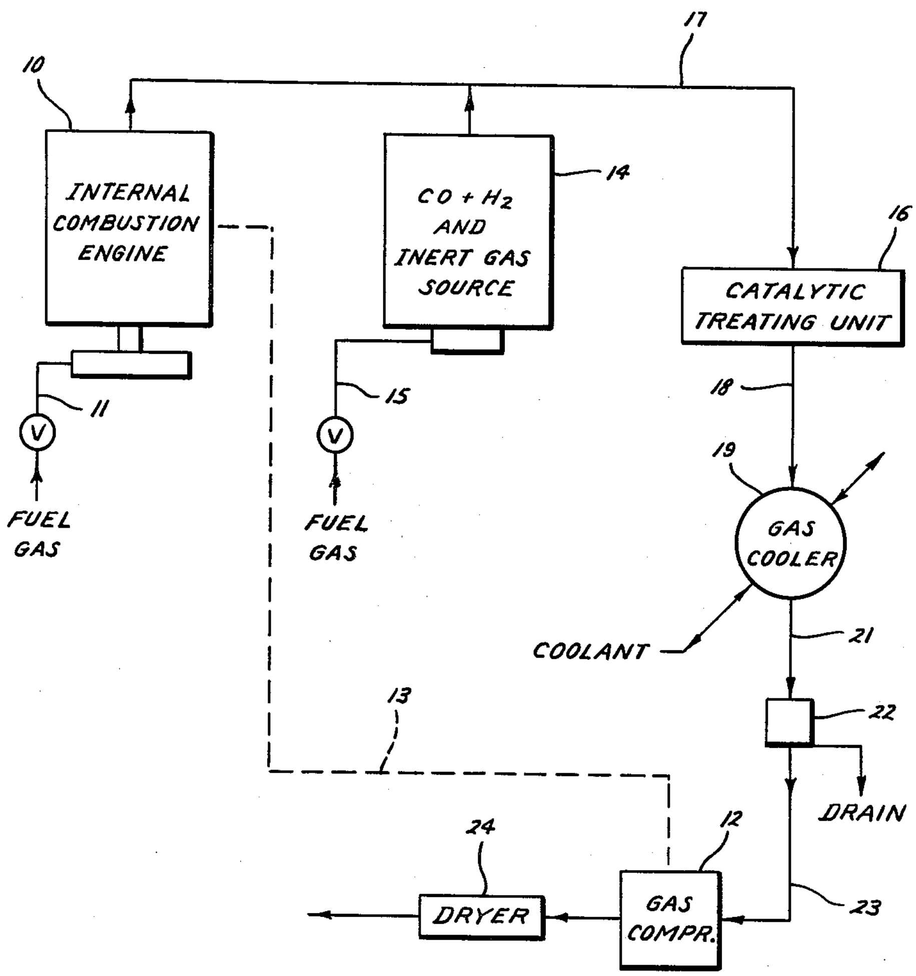
Sept. 19, 1961 W. F. BARSTOW 3,000,707

PROCESS FOR GENERATING INERT GAS

Filed May 29, 1959



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3,000,707

Patented Sept. 19, 1961

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3,000,707

PROCESS FOR GENERATING INERT GAS

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Filed May 29, 1959, Ser. No. 816,911
3 Claims. (Cl. 23—281)

This invention relates to systems and processes for generating inert gas, and more particularly to systems and processes utilizing the exhaust gases of an engine as a portion of the total gas flow.

While inert gas is used in a variety of situations, and gas produced by the systems and processes of this invention may be used in any desired situation, the systems and processes were developed in connection with inert gas injection into a subsurface hydrocarbon producing formation and will be explained in conjunction with this use of the systems and processes.

There are many instances where injection of an inert gas in an earth formation may be utilized to increase its productivity of hydrocarbons, such as programs for attic oil recovery, miscible phase displacement, gas cap displacement and formation repressurizing. The volume of gases used for this purpose is extremely large, and it is pertinent that the gas should be inert to prevent damage to the compression system, to the injection well and to the formation itself.

In the past, natural gas has been injected for the purposes discussed above in large volumes. It has been known that inert gas is useful for this purpose. As natural gas is generally available in the oil fields, the compressor for injection systems may be driven by an internal combustion type gas engine. However, the exhaust gas of the usual internal combustion gas engine used for compressing the gas to be injected has not been considered very suitable as a source of inert gas due to its content of the oxides of nitrogen and free oxygen. If these undesirable gases were removed, a ready source of inert gas would be provided.

It is therefore an object of this invention to provide a system and process for using the exhaust gases from an internal combustion gas engine for injection into earth formations without setting up highly corrosive conditions.

Another object is to remove the acid forming compounds from the exhaust of internal combustion gas engines.

Another object is to provide an economical system and process for injecting inert gas in which the exhaust from an internal combustion gas engine is mixed with certain compounds and the mixture treated to remove undesirable compounds from the engine exhaust gases.

Another object is to provide a system and process as in the preceding object in which an additional source of inert gas is provided to utilize the full efficiency of the internal combustion engine.

Another object is to provide an economical system and process for injection of earth formations with inert gas by combining the output of an inert gas generator with the exhaust of an internal combustion gas engine which drives the gas compressor of the injection system and treating the mixed gases to remove substantially all acid forming compounds therefrom.

Other objects, features and advantages of this invention will be apparent from the drawing, the specification and claims.

In accordance with this invention, either carbon monoxide or hydrogen, or both, are admixed with the exhaust of an internal combustion gas engine. The admixed gases are reacted in the presence of either a platinum or palladium catalyst to remove substantially all of the oxygen and oxides of nitrogen from the gases. Preferably, the internal combustion engine gases are admixed with the output of a gas or liquid fuel fired inert gas generator, and the combined gases passed over a palladium or platinum catalyst. The inert gas generator provides both carbon monoxide and hydrogen for reducing the oxides of nitrogen and oxygen in the exhaust gases of the gas engine. The gas engine may drive a gas compressor which raises the pressure of the gas to permit it to be injected into a well for displacement purposes or to increase or maintain the formation pressure.

Referring now to the drawing, the single figure is a diagrammatic flow of a system for providing inert gas for injecting into a well.

The internal combustion engine **10** uses as fuel any desired gas such as natural gas, propane, butane, etc., which is delivered to the engine through line **11**. As natural gas is generally present in the oil fields, natural gas is preferred as fuel.

The internal combustion engine **10** drives the compressor **12** as indicated by the dashed line **13** interconnecting these pieces of equipment. The compressor raises the pressure of the gas to the desired value for injecting into the formation.

The exhaust gases of the engine provide a gas for injecting into the well which is inert with the exception of small quantities of free oxygen and the oxides of nitrogen. For instance, a convention internal combustion gas engine producing 34565 standard cubic feet per hour (dry) of exhaust gases will have approximately the following composition:

N_2	percent	87.18
CO_2	do	11.82
O_2	do	1.00
Oxides of nitrogen	p.p.m.	300
H_2O	pounds/hr.	369.8

"Oxides of nitrogen" is defined herein as nitric oxide and nitrogen dioxide which are believed to be the only oxides of nitrogen present in the exhaust of gas engines.

With the removal of the free oxygen, the oxides of nittrogen and preferably the water, it will be seen that the acid forming compounds will be removed and the injection gases will be substantially inert. If the oxides of nitrogen content of the gas is completely removed, the water might be left in the gas, but it is preferred to additionally remove the water as the water will combine with oxides of nitrogen content, if any happens to be present, and form nitric acid. While only a small amount of nitric acid would be formed per hour with only a few parts per million of nitrogen present, it is desired to reduce the possibility of formation of nitric acid to an absolute minimum as these systems are operated over extended periods of time, and even small amounts of nitric acid passing through the equipment and injection well is objectionable.

In order to remove the oxygen and oxides of nitrogen content of the exhaust gases, they are mixed with either carbon monoxide or hydrogen as reducing agents. While these compounds could be obtained from any desired source, they are preferably provided by the output of a gas fired inert gas generator. The gas fired inert gas generator will provide both carbon monoxide and hydrogen as well as additional inert gas for injection purposes. In general, the internal combustion gas engine is capable of compressing more gas than the exhaust gases which the engine generates. For instance, in a typical installation ¾ of the injection gas might be furnished by the internal combustion engine and ¼ of the injection gas furnished by the inert gas generator. With this relationship of volumes, an excess amount of carbon monoxide and hydrogen will be formed to insure the presence of sufficient reducing agents for combining with the acid forming elements of the engine exhaust gas.

While natural gas might provide additional injection gas to be mixed with the exhaust of the gas engine and bottled carbon monoxide or hydrogen used as a reducing agent, the inert gas generator is preferred as one volume of natural gas burned in the inert gas generator will produce approximately nine volumes of inert gas. Obviously, the use of inert gas is much more economical. The inert gas generator might be provided by any desired type of generator, but the gas fired exothermic, combustion type generator is preferred due to its economy of operation, and to the fact that natural gas is generally always available in the oil fields. By comparison, the natural gas fired generator is more economical than the water gas generator using coal or coke, and therefore the inert gas generator is preferably of the gas fired type.

The source of carbon monoxide or hydrogen and inert gas is indicated at **14**, and, as noted above, is preferably gas fired inert gas generator which receives natural gas through line **15**.

A typical gas fired inert gas generator if operated "rich" (insufficient air for stoichiometric perfect combustion) will produce the following output gas analysis (dry basis):

N_2	percent	81.0
CO_2	do	9.0
CO	do	5.0
H_2	do	5.0
Oxides of nitrogen		Trace
H_2O	pounds/hr	76.3
Output (Dry)	s.c.f.h	8500

It will be noted from the analysis given for the gas engine and the gas generator that approximately ¼ of the total gas is furnished by the gas generator. When the two gases combine in line **17** they will have approximately the following analysis (dry basis):

N_2	percent	86.0
CO_2	do	11.2
CO	do	1.0
H_2	do	1.0
O_2	do	0.8
NO	p.p.m.	240
H_2O	pounds/hr	446.1

The output of the internal combustion engine and the inert gas generator are fed to a catalytic treating unit **16**. Preferably, the two gases are combined and delivered to the catalytic treating unit through a common input line **17** to permit their mixing while en route to the treating unit.

In the catalytic treating unit there is provided a bed of catalytic material which will catalyze the reaction between oxygen and the oxides of nitrogen from the engine exhaust and carbon monoxide and hydrogen from the generator. It is believed that the oxygen combines with the carbon monoxide to provide the inert gas carbon dioxide and with the hydrogen to form water and the oxides of nitrogen are broken down catalytically and the oxygen combines with carbon monoxide and hydrogen to provide carbon dioxide and water and free nitrogen.

It is desired to remove substantially all of the oxides of nitrogen and free oxygen. It has been found that by employing either a platinum or a palladium catalyst that this objective will be accomplished.

The palladium or platinum catalyst may take any desired form. As will be understood by those skilled in the art, only a very small amount of palladium or platinum is needed if it is spread over a large surface area. For this reason, it is preferred to deposit the platinum or palladium on a suitable carrier such as gamma alumina which has a very large surface area per volume. Palladium is preferred over platinum as its cost is much less than platinum.

The temperature in the catalytic treating unit **16** influences the degree to which the oxygen and oxides of nitrogen are removed from the input gas. For instance, in a typical installation handling the feed as above defined with anywhere from 100 to 500 parts per million undesirable gases in the feed, it will be found that if the catalytic treating unit is operated at around 850 degrees F. that substantially all undesirable gases can be removed. Under continuous operating conditions, the undesirable gases can be reduced to less than 5 parts per million, and sometimes they can be reduced to 2 parts per million, or less. If the temperature in the catalytic treating unit is dropped to around 700 degrees F. the undesirable gases and the output from the treating unit will climb to around 10 parts per million. As the temperature continues to decrease, the content of the undesirable gases increases. It is extremely desirable to maintain the undesirable gases in the output gases of catalytic treating unit at 10 parts per million, or less, so that substantially all of the acid forming gases will be removed.

The desired temperature of 850 degrees input gas to the catalytic treating unit may be obtained in operating the gas compressor and inert generator in the volumes given in the preceding gas analysis by regulating the engine exhaust gas to maintain a temperature of 1100 degrees F., and the inert gas generator to maintain an output gas temperature of 140 degrees F. This will give a gas temperature at the inlet of the catalytic treating unit of about 850 degrees. As the reaction in the catalytic treating unit is exothermic, it may be desirable to cool the catalytic treating unit with any desired cooling system to maintain the heat at the desired level. This level might be defined as sufficient to carry the reaction between the oxygen, oxides of nitrogen and the carbon monoxide and hydrogen to completion.

A typical dry gas analysis of the output of the catalytic treating unit employing a palladium type catalyst deposited on a carrier of gamma alumina with an input gas temperature of 850 degrees F. is as follows:

N_2	percent	87.7
CO_2	do	11.9
CO	do	0.2
H_2	do	0.2
O_2		less than 2 p.p.m.
NO		less than 2 p.p.m.

It is desirable to reduce the temperature of injection gas to below about 350 degrees F. before it reaches the gas compressor. Above this temperature difficulty in compressor lubricants is experienced. Therefore, the output line **18** from the catalytic unit preferably conducts the output gases to a gas cooler **19** wherein the temperature of the gas is reduced to below 350 degrees F. The gas cooler may be a conventional water tower. The stream from the gas cooler is conducted by line **21** to a separator or scrubber **22** to remove any condensed water in the stream.

After leaving the scrubber **22**, the stream above defined from the catalytic treating unit will have a throughput of 42200 s.c.f.h. (dry). It will be water saturated at the stream temperature and pressure.

From the scrubber **22** the gas passes through line **23** to the compressor **12** where it is compressed to the desired pressure.

The gas may be injected directly from the gas compressor into the injection well. However, if any oxides of nitrogen and oxygen remain in the stream, the water present will result in the formation of nitric or nitrous acid. Therefore, it is preferred to remove substantially all of the water present in the stream. For this purpose, the output from the catalytic treating unit is passed through a desiccant dryer **24** which, in handling the stream above defined, will remove water from the stream to less than 5 parts per million. Of course, the dryer might be placed anywhere in the stream downstream of the scrubber 22.

With the above system it is possible to remove free oxygen and the oxides of nitrogen down to less than 5 and 10 parts per million, respectively. Running under optimum operating conditions, it is possible to remove both undesirable compounds to a level of approximately 2 parts per million, or lower.

The foregoing disclosure and description of the invention is illustrative and explanatory thereof and various changes in the size, shape and materials, as well as in the details of the illustrated construction, may be made within the scope of the appended claims without departing from the spirit of the invention.

What is claimed is:

1. The process of manufacturing inert gas suitable for injecting into earth formations comprising, burning hydrocarbon gases in an internal combustion engine to provide engine exhaust gases, adding to said exhaust gases additional exhaust gases from a hydrocarbon gas-fired inert gas generator, said additional exhaust gases containing compounds selected from the group consisting of carbon-monoxide and hydrogen, and reacting said combined exhaust gases over a catalyst selected from the group consisting of platinum and palladium.

2. The process of manufacturing inert gas suitable for injecting into earth formations comprising, burning hydrocarbon gases in an internal combustion engine to convert the heat energy of the gases into mechanical energy in the engine and to provide engine exhaust gases, adding to said exhaust gases additional exhaust gases

from a hydrocarbon gas-fired inert gas generator, said additional exhaust gases containing compounds selected from the group consisting of carbon monoxide and hydrogen, reacting said combined exhaust gases over a catalyst selected from the group consisting of platinum and palladium, and compressing the reacted gases with the mechanical energy delivered by said internal combustion engine.

3. The process of manufacturing inert gas suitable for injecting into earth formations comprising, burning hydrocarbon gases in an internal combustion engine to convert the heat energy of the gases into mechanical energy in the engine and to provide engine exhaust gases, adding to said exhaust gases additional exhaust gases from a hydrocarbon gas-fired inert gas generator, said additional exhaust gases containing compounds selected from the group consisting of carbon monoxide and hydrogen, reacting said combined exhaust gases over a catalyst selected from the group consisting of platinum and palladium, cooling said reacted gases, and compressing the cooled reacted gases with the mechanical energy delivered by said internal combustion engine.

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