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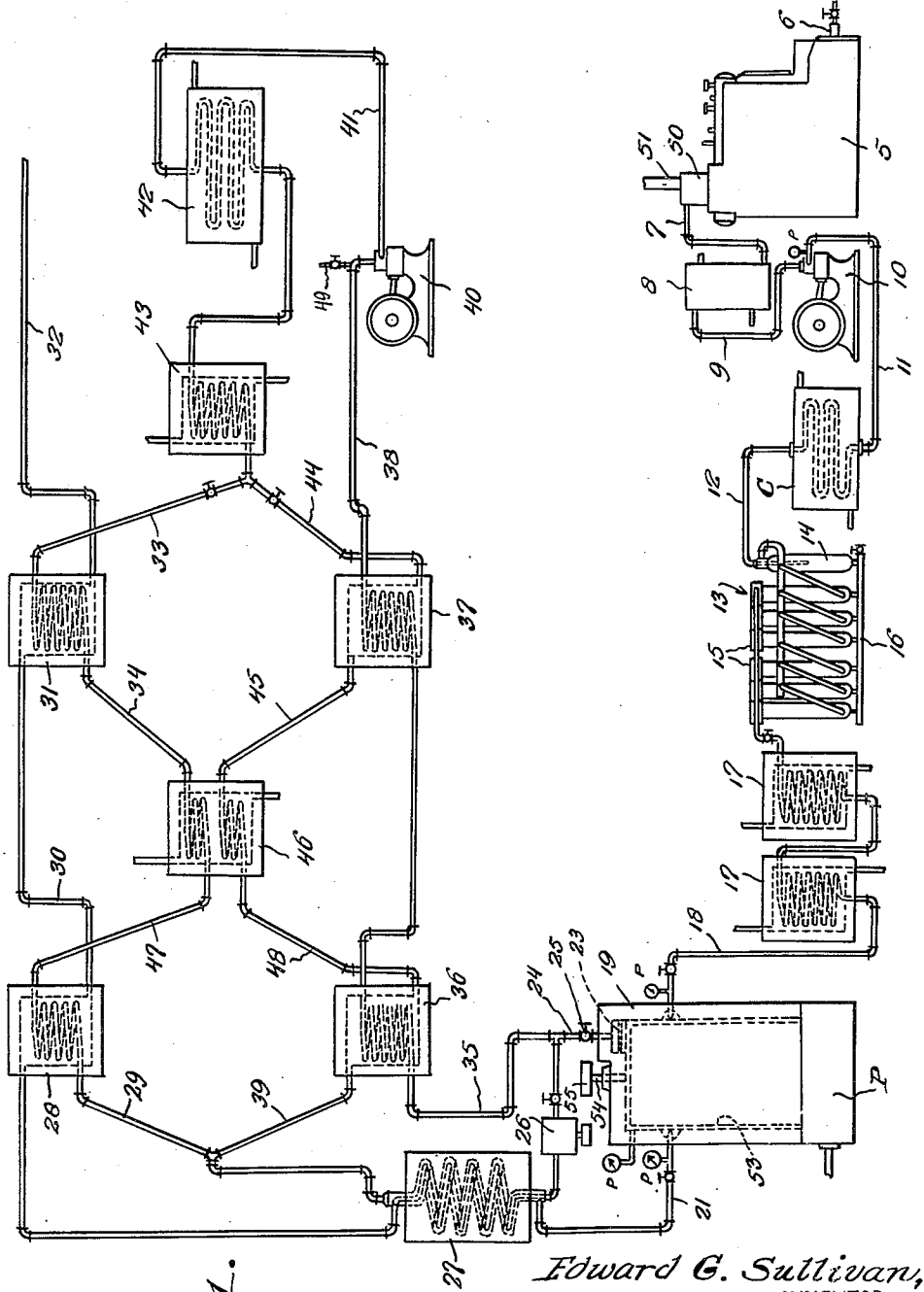
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PROCESS OF AND APPARATUS FOR PRODUCING SOLID CARBON DIOXIDE

Filed Feb. 17, 1931

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Fig. 3.

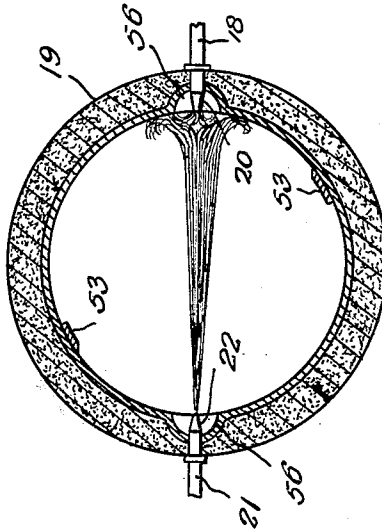
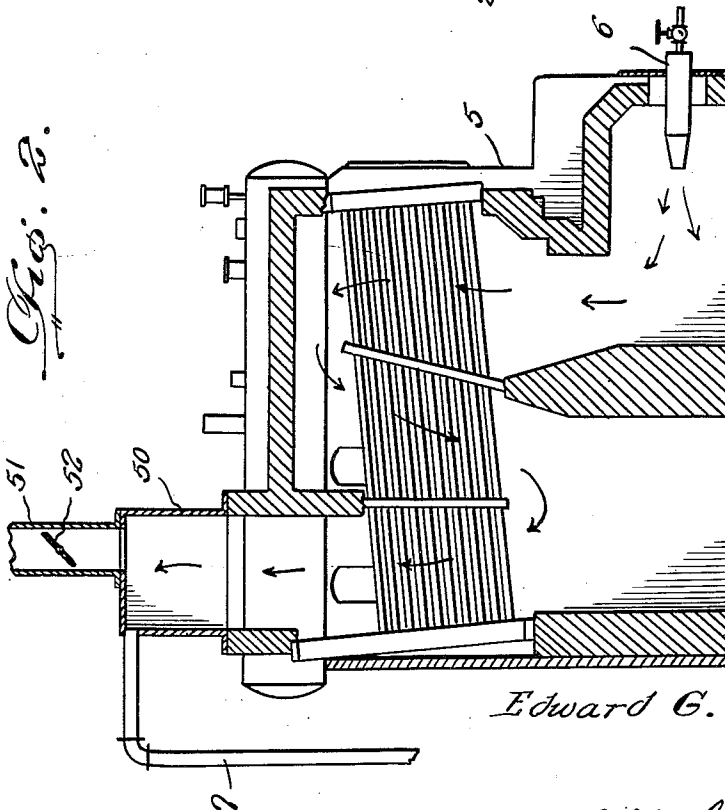


Fig. 2.



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PROCESS OF AND APPARATUS FOR PRODUCING SOLID CARBON DIOXIDE

Application filed February 17, 1931. Serial No. 516,491.

This invention relates to a process of and apparatus for producing solid carbon dioxide from flue gases occasioned by burning natural gas with air and composed of about 10% carbon dioxide gas and about 90% nitrogen.

As shown in the pending application of Joseph S. Belt and Hamilton P. Cady, Ser. No. 424,655 filed January 30, 1930, it has heretofore been proposed to highly compress and cool flue gases and then expand them into a snow or converting chamber having external supercooling or refrigerating means, whereby a comparatively large percentage of the carbon dioxide gas contained in the flue gases is converted to solid or snow form.

The present invention differs from the prior apparatus and method referred to above in that the flue gases are compressed to a moderate pressure after being dried and moderately cooled, and nitrogen highly compressed and cooled to a state of partial liquefaction is discharged together with these flue gases and expanded within a snow or converting chamber in conflicting jets so that the flue gases and nitrogen are thoroughly mixed to utilize the cold temperature of the nitrogen in facilitating transition of the carbon dioxide gas in the flue gases directly to a solid or snow, the snow falling to the bottom of the converting chamber for being readily collected and pressed into cake form for commercial use.

A specific object of the present invention is to provide an improved process and apparatus of the character indicated above wherein provision is made for utilizing the residual nitrogen in the flue gases after being expanded into the converting chamber for assisting in cooling and partially liquefying the nitrogen prior to its expansion into the converting chamber.

Other objects and features of the invention will be apparent from the following description when considered in connection with the accompanying drawings, in which:

Figure 1 is a somewhat diagrammatic elevation of an apparatus suitable for carrying out the process of the present invention.

Figure 2 is an enlarged vertical longitudinal section of the boiler furnace for gener-

ating the flue gases and forming part of the apparatus shown in Figure 1; and

Figure 3 is an enlarged horizontal section of the converting chamber.

Referring in detail to the drawings, 5 indicates a furnace which has a burner 6 supplied with natural gas from a suitable source, and also supplied with sufficient air to furnish the necessary oxygen for substantially complete combustion of the hydrocarbon constituents of the natural gas. A pipe 7 conducts the flue gases from the furnace 5 through a scrubber and cooler 8, in which acids and odors are removed from the flue gases, and in which the water vapor of the hot flue gases is condensed. The gases pass from the scrubber and cooler 8 through a pipe 9 to a conventional multiple stage compressor 10 having the usual intercoolers and after cooler, and in which some moisture is expressed from the gases and drawn off as necessary in any well known or preferred manner. The compressed and cooled gases are then conducted by a pipe 11 to a preliminary cooler —C— where they are reduced somewhat in temperature. From the cooler —C—, the gases are conducted by a pipe 12 into a dehydrator 13 by means of which any water remaining in the gases is removed, and by means of which such gases are effectively dried. As shown, this dehydrator may include a settling tank 14 in which the water is removed from the gases, and a battery of absorbent dryers 15 through which the gases are conducted from the settling chamber 14 for having any remaining moisture effectively extracted therefrom. Water collecting in the chamber 14 and dryers 15 drains into a manifold 16 from which it may flow to any suitable point of discharge or disposal.

The compressor 10 places the flue gases under a pressure of 294 pounds per square inch, and after the flue gases are dried, they are passed through successive coolers or refrigerators 17 for being cooled to a temperature of substantially -76° Fahrenheit. The flue gases pass from the final coolers or refrigerators 17 by way of pipe 18, discharging

into a snow or converting chamber 19 through a nozzle 20 in a jet transversely of the converting chamber 19 as shown in Figure 3.

A pipe 21 which terminates in a nozzle 22 opening into the converting chamber 19 in opposed relation to the nozzle 20, leads from a source of supply of partially liquefied nitrogen under a pressure of approximately 2940 pounds per square inch and at a temperature of about -251° Fahrenheit. As the nitrogen discharges into the converting chamber 19 from the nozzle 22, it emerges in a jet transversely of the chamber 19 so that the jets of flue gases and nitrogen conflict and effect thorough mixture of the nitrogen and flue gases. As the cold nitrogen expands to a pressure of 294 pounds per square inch which is maintained within the converting chamber 19, it exerts a freezing influence upon the carbon dioxide gas contained in the flue gases, so that nearly 100% of the carbon dioxide gas is converted to a solid or snow which falls to the bottom of the converting chamber into a press—P—for being pressed or compacted and subsequently cut into cake or block form for commercial use. The converting chamber 19 has a top screened outlet chamber 23 from which leads a pipe 24 having a control valve 25, and by means of which the remaining nitrogen, consisting of the nitrogen introduced as such and the residual flue gases, are allowed to escape from the converting chamber at a pressure of slightly less than 294 pounds per square inch and at a temperature of about -251° Fahrenheit.

Of the exhaust nitrogen from the converting chamber 19, a portion equal to the residual nitrogen from the flue gases, less system leakage, is expanded through an adiabatic engine 26 to one atmosphere pressure, whereupon it passes to a heat exchanger for finally cooling the high pressure nitrogen immediately prior to its expansion into the converting chamber 19. This heat exchanger is, as shown, preferably of the countercurrent type as generally illustrated at 27. In passing through the heat exchanger 27, this portion of the nitrogen is heated from -321° Fahrenheit to -251° Fahrenheit, and cools the high pressure nitrogen to about the latter temperature before passing through the pipe 21 into the converting chamber. The low pressure nitrogen then passes through a further heat exchanger 28 for cooling the high pressure nitrogen to about -225° Fahrenheit before the latter passes to the pipe 29, the low pressure nitrogen being thereby heated to -35° Fahrenheit before passing into the pipe 30. The low pressure nitrogen then passes from pipe 30 to still another heat exchanger 31 where it is heated to about 45° Fahrenheit and then exhausts through pipe 32 to the atmosphere. In the heat exchanger 31, the low pressure nitrogen cools a portion of the high pressure nitrogen from 62° Fahrenheit to

-22° Fahrenheit, the high pressure nitrogen being supplied to this heat exchanger by pipe 33 and passing therefrom by way of pipe 34.

The exhaust nitrogen from the converting chamber 19 which is not passed through the engine 26 is conducted by pipe 35 through heat exchangers 36 and 37 at a pressure of 294 pounds per square inch. When leaving the heat exchanger 37, the low pressure nitrogen passes to pipe 38 at a temperature of about 45° Fahrenheit. After passing through the heat exchangers 37 and 36, the high pressure nitrogen passes to pipe 39 at a temperature of about -225° Fahrenheit, and the pipes 29 and 39 connect together for passing through the heat exchanger 27 to the pipe 21. The low pressure or exhaust nitrogen passes from pipe 38 to a compressor 40 where its pressure is raised from 294 pounds per square inch to about 2940 pounds per square inch. This compressor 40 is preferably of the two stage type having an intercooler and an after cooler, and the compressed nitrogen leaves the aftercooler of this compressor at about 80° Fahrenheit, whereupon it is conducted by pipe 41 to a water cooler 42 and an ammonia cooler 43 for being cooled to about 62° Fahrenheit. The high pressure nitrogen then passes partly to the heat exchanger 37 by way of pipe 44 and partly to the heat exchanger 31 by way of pipe 33. In passing through the heat exchangers 31 and 37, the nitrogen is cooled to about -22° Fahrenheit, after which it passes by way of pipes 34 and 45 to a common ammonia cooler for being cooled to about -37° Fahrenheit. The nitrogen then passes from the ammonia cooler 46 to the heat exchangers 28 and 36 by way of pipes 47 and 48 for being cooled to the temperature of -225° Fahrenheit before passing to the final heat exchanger 27, as hereinbefore mentioned.

In operation, the partially liquefied nitrogen is expanded through nozzle 22 into the converting chamber 19 from a pressure of 2940 pounds per square inch to 294 pounds per square inch and at a temperature of -251° Fahrenheit. As this jet of cold expanding nitrogen strikes the jet of cooled dried and compressed flue gases issuing from the nozzle 20, the carbon dioxide gas in the flue gases is brought to a sufficiently low temperature to cause solidification of substantially all of the same. The pressure maintained within the converting chamber 19 by suitable means including valve 25 is just slightly lower than 294 pounds per square inch so that the flue gases may be discharged into the converting chamber at this pressure. By means of the apparatus described a continuous supply of highly compressed and cooled nitrogen is had together with a continuous supply of flue gases, the residual nitrogen of the flue gases being effectively

utilized in cooling and partially liquefying the nitrogen used in the converting operation. Additional nitrogen may be supplied to the system as required from time to time in any suitable or preferred way, preferably adjacent the inlet of compressor 40 as indicated at 49.

In the operation of a plant of the present character, it will be necessary to burn considerably more gas than can be used in the process, in order to generate sufficient steam as required for power purposes. The furnace 5 is accordingly provided with a dome 50 for receiving the flue gases and from which leads the pipe 7 and also a stack or chimney 51 that opens to the atmosphere. This stack 51 has a suitable damper 52 by means of which the desired portion of the flue gases may be diverted through the pipe 7 for use in the process.

In producing the snow or solid carbon dioxide within the converting chamber 19, considerable of the snow will stick or adhere to the inner surface of the converting chamber. In order to free this snow from the surface as it forms thereon, I provide within the converting chamber a U-shaped scraper 53 formed to contact the top and side walls of the converting chamber and carried at the top by an operating shaft 54 having an operating pulley 55. In this way the scraper 53 may be operated by power to continuously scrape the snow from the walls of the converting chamber as it adheres thereto or forms thereon. This snow will fall to the bottom of the converting chamber into the press —P— along with such snow as does not adhere to the inner surface of the converting chamber.

In order that the nozzles 20 and 22 may not interfere with the rotation of the scraper 53, they are preferably located within suitable recesses 56 provided in opposed portions of the side walls of the converting chamber 19 so that the nozzles 20 and 22 may terminate entirely outside the inner face of the side walls of the converting chamber.

From the foregoing description, it is believed that the present process and apparatus will be clearly understood by those skilled in the art, as well as its objects and features appreciated. While I have specified certain details of construction and exact temperatures and pressures which are deemed most practical, it is understood that minor changes may be made or practiced with regard to details of the process without departing from the spirit and scope of the invention as claimed.

What I claim as new is:

1. The process of making carbon dioxide snow which includes discharging moderately compressed and cooled dried flue gases containing carbon dioxide gas into a converting chamber, and precipitating the carbon di-

oxide in the form of snow from the flue gases by subjecting the latter to the cooling action of a jet of expanding highly cooled nitrogen.

2. The process of making carbon dioxide snow which includes discharging moderately compressed and cooled dried flue gases containing carbon dioxide gas into a converting chamber, and precipitating the carbon dioxide in the form of snow from the flue gases by subjecting the latter to the cooling action of a jet of expanding highly cooled nitrogen, and maintaining a pressure in the converting chamber slightly below the pressure of the flue gases during the precipitating operation.

3. The process of making carbon dioxide snow which consists in discharging dried flue gases containing carbon dioxide gas into a converting chamber at a pressure of approximately 294 pounds per square inch and at a temperature of approximately -76° Fahrenheit, and precipitating the carbon dioxide from the flue gases in the form of snow by subjecting the flue gases to the cooling action of partially liquefied nitrogen expanding from a pressure of approximately 2940 pounds at a temperature of approximately -251° Fahrenheit.

4. The process of making carbon dioxide snow which consists in discharging dried flue gases containing carbon dioxide gas into a converting chamber at a pressure of approximately 294 pounds per square inch and at a temperature of approximately -76° Fahrenheit, and precipitating the carbon dioxide from the flue gases in the form of snow by subjecting the flue gases to the cooling action of partially liquefied nitrogen expanding from a pressure of approximately 2940 pounds at a temperature of approximately -251° Fahrenheit, and utilizing the residual nitrogen in the flue gases in the partial liquefaction of the nitrogen used in the precipitating operation and as a component part of the nitrogen so used.

5. The process of making carbon dioxide snow which includes discharging moderately cooled and compressed dried flue gases containing carbon dioxide gas and highly compressed and cooled nitrogen in conflicting jets within a converting chamber, and permitting material expansion of the nitrogen as it is discharged, whereby the cooling action of the expanding nitrogen on the flue gases causes precipitation of the carbon dioxide from the flue gases in the form of snow.

6. In an apparatus for making carbon dioxide snow, a converting chamber, means for continuously supplying said converting chamber with moderately compressed and cooled dried flue gases containing carbon dioxide gas, means for supplying highly compressed and cooled nitrogen to the converting chamber in an expanding jet which conflicts with the incoming flue gases to mix

therewith, means for conducting the nitrogen from the converting chamber and for utilizing the same in cooling the nitrogen prior to its discharge into the converting
5 chamber.

7. In an apparatus for making carbon dioxide snow, means for partially liquefying nitrogen, a converting chamber, means for discharging the partially liquefied nitrogen
10 into the converting chamber so as to expand within the later, means for supplying the converting chamber with dried moderately cooled and compressed flue gases containing carbon dioxide gas so as to mix with the in-
15 coming expanding nitrogen for utilizing the cooling action of the latter and precipitating the carbon dioxide in the flue gases to snow form, means to conduct the expanded nitrogen from the converting chamber, means
20 for utilizing a portion of the escaping nitrogen in an amount approximating the residual nitrogen in the flue gases for power purposes and for cooling action upon the nitrogen supplied to the converting chamber, and means
25 for returning the remaining nitrogen to be again partially liquefied and expanded into the converting chamber.

8. In an apparatus for making carbon dioxide snow, a converting chamber, means for
30 supplying the converting chamber with conflicting jets of expanding partially liquefied nitrogen and dried moderately compressed and cooled flue gases containing carbon dioxide gas, and means to remove snow from
35 the walls of the converting chamber.

In testimony whereof I affix my signature.

EDWARD G. SULLIVAN.

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