

PATENT SPECIFICATION

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(54) A PROCESS OF CONVERTING SOLID WASTE INTO A COMBUSTIBLE PRODUCT GAS

(71) We, SYNGAS RECYCLING CORPORATION, a corporation of Canada located at Suite 2120, The Thomson Building, 65 Queen Street W., Toronto, Ontario, Canada, do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed to be particularly described in and by the following statement:—

This invention relates to a process of converting solid waste into a combustible product gas and to a combustible product gas when made thereby.

In view of the increasing amount of solid wastes, for example, refuse and sewage sludge, produced by an ever expanding and consumer-orientated population, waste disposal is rapidly becoming a national problem of major importance. Present waste disposal systems, such as incineration and landfilling cannot be employed indefinitely. Incineration produces no useful by-product and increasingly pollutes the atmosphere. Landfilling is becoming increasingly difficult and more costly as suitable land becomes scarce. Further, leaching of filled areas eventually may cause water pollution. Thus, there is a growing need to develop alternative waste disposal systems.

An additional dilemma is the fact that in the not too distant future, an energy shortage may exist, and it may soon be essential that alternative energy sources are developed.

According to the present invention there is provided a process of converting solid waste to a combustible product gas, said solid waste consisting of any one or more of municipal refuse, municipal sewage sludge, and carbohydrate-containing, agricultural and farming wastes, the process including the steps of contacting the solid waste in a reaction zone with a reaction gas composed of at least 90 mole percent hydrogen at a reaction pressure of between 1000 psig and 3000 psig, the solid waste and the reaction gas being contacted at a temperature between 500°C and 675°C; removing from

said reaction zone the resulting carbonaceous residue free of liquid hydrocarbon products; and removing from said reaction zone a product gas at a pressure of at least 1000 psig, said product gas being substantially free of condensable or entrained hydrocarbon products and including methane, carbon monoxide, carbon dioxide and water vapour.

As used throughout the specification the phrase "municipal sewage sludge" means the sludge material removed from sewage in a municipal sewage primary treatment system, while the phrase "municipal refuse" means the garbage, trash, etc. collected from homes, businesses, institutions, etc. in a community, which material is commingled in the collection process and usually dumped in designated refuse areas in such a commingled state.

Said reaction temperature may be between 550°C and 650°C.

The reaction pressure may be between 1000 psig and 1500 psig.

The product gas may contain ethane.

The process preferably includes subsequently cooling said product gas to condense the water vapour, removing the carbon dioxide and methanating the carbon monoxide.

The reaction temperature is preferably 550°C.

In the practice of the present invention solid wastes are introduced into a reaction zone preferably in a shredded state to enhance the speed of the reaction. Also, if desired, glass and metal objects are first removed.

A reaction gas, consisting of at least 90 mole percent hydrogen is introduced into the reaction zone at a pressure of between 1000 psig and 3000 psig, preferably between 1000 psig and 1500 psig. The other gaseous constituents of the reaction gas, if present, are inert substances or compounds such as carbon monoxide and carbon dioxide.

The reaction temperature in the reaction zone is maintained at between 500°C and

675°C, preferably between 550°C and 650°C. Since the reaction is highly exothermic, solid wastes with a high moisture content can be converted to combustible product gas without addition of external heat. In fact, such solid wastes with a high moisture content will, in many instances, enable the reaction to proceed autothermically.

The product gas, at a pressure of at least 1000 psig, from the reaction zone is essentially composed of methane (and usually ethane), carbon monoxide, carbon dioxide, and water vapour, and usually hydrogen. Small amounts of nitrogen can also be present plus whatever other gaseous constituents were present in the reaction gas. When the fact that solid wastes have a high oxygen content is considered, the product gas contains carbon monoxide in unexpectedly low amounts, usually less than 4 mole percent.

As the product gas is cooled to room temperature (i.e. 20°C to 25°C), the water vapour condenses so that a substantially dry product gas is obtained. The carbon dioxide is scrubbed or absorbed therefrom in the conventional manner and the carbon monoxide is methanated by reacting it with hydrogen in the presence of a catalyst. The hydrogen used may be that contained in the product gas.

Since the carbon monoxide is present in the product gas in a relatively low amount and since virtually all of it is methanated, it is not necessary to convert some of it to

carbon dioxide by the water gas shift reaction.

The product gas is still at a pressure of at least 1000 psig after the removal of the water vapour, and carbon dioxide and so can be added to pipeline gas for supply to industries and homes for heating, cooking and power generation purposes.

By controlling the degree of carbon conversion in the reaction zone, the product gas, in a dry state and after methanation, can have a heating value of at least 900 Btu./cu.ft. Further, the reaction is essentially free of liquid hydrocarbon products and therefore no expensive and time consuming separation steps are required. Still further, ethane can be produced in significant amounts, especially at a reaction temperature of about 550°C.

If desired, any dry carbonaceous residue from the reaction zone may be employed to produce hydrogen for the reaction zone. More specifically, the carbonaceous residue is employed as fuel to produce synthesis gas, e.g. a gas consisting of carbon monoxide, carbon dioxide, hydrogen and water, in the conventional manner by, for example, passing oxygen and steam over the heated residue, or by passing steam over the residue in an electrogasifier.

The following examples illustrate the process according to the present invention as practiced on a particular shredded municipal refuse which has been standardised by HEW* for incineration tests and which have the following composition:

Composition of Standard Municipal Refuse

Component		Wt %	Approximate Ultimate Analyses	Wt %
75	Cardboard	23	Carbon	45.2
	Newspaper	22	Hydrogen	6.1
	Magazines	17	Oxygen	41.1
	Brown paper	5	Nitrogen	0.5
	Waxed paper	5	Sulphur	0.2
80	Plastic coated paper	5	Ash	6.9
	Raw Potatoes	23		
Total		100	Total	100.0
			Moisture	23%

Example 1

Varying amounts of samples of the above standard municipal refuse were separately tested in a 1000 ml batch autoclave. In each test, a reaction gas containing 98 mole percent hydrogen was charged to the autoclave and the reaction proceeded at 650°C for one

hour. No liquid hydrocarbon products were formed. The results were as follows:

*United States Department of Housing, Education and Welfare, now the U.S. Environmental Agency.

	Test A	Test B	Test C
Weight of sample (gms)	10.00	20.00	80.00
Hydrogen charge (moles)	.87	.87	.46
Final operating pressure (psig)	1200.00	1500.00	2750.00
5 Percent conversion of carbon in solid charge to gas	60.00	66.40	45.80
Percent conversion of carbon in solid charge to hydrocarbons	43.40	49.70	23.30
10 Percent conversion of carbon in solid charge to carbon monoxide	8.00	5.00	8.00
Percent conversion of carbon in solid charge to carbon dioxide	8.80	11.50	14.60

Analysis of product gas in mole % on a water-free, carbon-dioxide free basis

15	Hydrogen	80.90	68.80	25.30
	Nitrogen	2.00	1.50	.80
	Carbon Monoxide	3.00	3.10	1.00
	Methane	12.10	23.00	71.10
	Ethane	2.00	3.60	1.00

20 As can be seen from these tests the product gas becomes richer in methane as the hydrogen-to-sample ratio is decreased. Also, the degree of conversion of the carbon in the sample generally decreases as the hydrogen-to-sample ratio decreases. In many instances a lower carbon conversion is desirable in that the carbonaceous residue will then be rich in carbon and can therefore be readily employed as fuel to produce the synthesis gas for the process in which case the only external feeds for the whole process will be air, water, and solid waste.

25 With further regard to Example 1, it can be seen that a product gas containing more than 3.5 mole percent ethane can be produced at a reaction temperature of 650°C. In a continuous operation wherein gas-solid contact times are substantially reduced in comparison to the batch operation of Example 1, production of the more valuable ethane can be further increased in that shorter contact times prevent any ethane product from being subsequently converted to methane while still in the reaction zone.

45 Example 2

A sample consisting of 80 grams of the above standard municipal refuse was charged to the batch autoclave of Example 1 with 0.46 moles of hydrogen. The same was heated for 60 minutes at 550°C. The average pressure in the autoclave was 1300 psig. No liquid hydrocarbon products were formed. 53.3%, by weight of the carbon in the sample was converted to product gas, which, on a water-free and a carbon dioxide-free basis, consisted of 32.8 mole percent hydrogen, 3.4 mole percent carbon monoxide 52.6 mole percent methane and 11.2 mole percent ethane. After methanation of the carbon

monoxide the gas consisted of 25.2 mole percent hydrogen, 62.3 mole percent methane and 12.5 mole percent ethane with a heating value of 936 Btu/cu.ft.

As can be seen from Example 2, at a relatively low reaction temperature of 550°C the product gas becomes enriched with ethane which has a relatively high heating value. Yet the product gas is still free of liquid hydrocarbon products. In comparison, at such a relatively low temperature, it is practically impossible to hydrogasify coal at pressures of 1000 psig and higher.

In a further more general comparison to high pressure hydrogasification of coal wherein the product gas is all gaseous with no condensible oils and tars, the present invention will be seen to operate at a much lower temperature.

Other solid wastes as above defined such as carbohydrate-containing agricultural and forming wastes, including corn stalks and cow manure, can be converted to gas having a relatively high heating value by the process of the present invention.

WHAT WE CLAIM IS:—

1. A process of converting solid waste to a combustible product gas, said solid waste consisting of any one or more of municipal refuse, municipal sewage sludge and carbohydrate-containing, agricultural and farming wastes, the process including the steps of contacting the solid waste in a reaction zone with a reaction gas composed of at least 90 mole percent hydrogen at a reaction pressure of between 1000 psig and 3000 psig, the solid waste and the reaction gas being contacted at a temperature between 500°C and 675°C; removing from said reaction zone the resulting carbonaceous residue free of liquid

(17)

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25 With further regard to Example 1, it can be seen that a product gas containing more than 3.5 mole percent ethane can be produced at a reaction temperature of 650°C. In a continuous operation wherein gas-solid contact times are substantially reduced in comparison to the batch operation of Example 1, production of the more valuable ethane can be further increased in that shorter contact times prevent any ethane product from being subsequently converted to methane while still in the reaction zone.

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1. A process of converting solid waste to a combustible product gas, said solid waste consisting of any one or more of municipal refuse, municipal sewage sludge and carbohydrate-containing, agricultural and farming wastes, the process including the steps of contacting the solid waste in a reaction zone with a reaction gas composed of at least 90 mole percent hydrogen at a reaction pressure of between 1000 psig and 3000 psig, the solid waste and the reaction gas being contacted at a temperature between 500°C and 675°C; removing from said reaction zone the resulting carbonaceous residue free of liquid



hydrocarbon products; and removing from said reaction zone a product gas at a pressure of at least 1000 psig, said product gas being substantially free of condensable or entrained hydrocarbon products and including methane, carbon monoxide, carbon dioxide and water vapour.

2. A process as claimed in claim 1 in which said reaction temperature is between 550°C and 650°C.

3. A process as claimed in claim 1 or 2 in which the reaction pressure is between 1000 psig and 1500 psig.

4. A process as claimed in any preceding claim in which the product gas contains ethane.

5. A process as claimed in any preceding claim including subsequently cooling said

product gas to condense the water vapour, removing the carbon dioxide, and methanating the carbon monoxide.

6. A process as claimed in any preceding claim in which the reaction temperature is 550°C.

7. A process as claimed in claim 1 and substantially as herein described.

8. A combustible product gas when made by the process as claimed in any preceding claim.

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