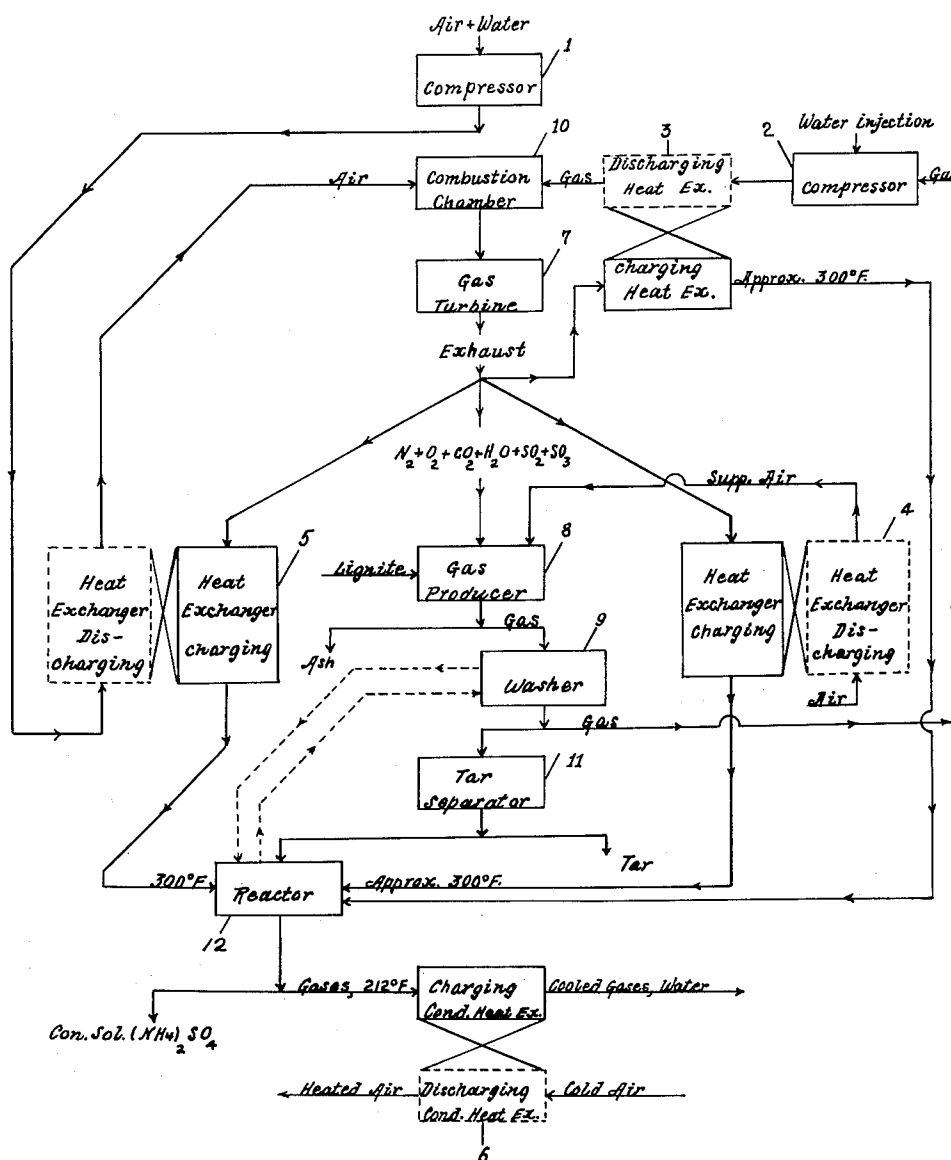


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METHOD OF IMPROVING THE THERMAL EFFICIENCY
OF A GAS PRODUCER-GAS TURBINE ASSEMBLY
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As of today the gas turbine, so-called, relies upon either a gaseous or a liquid fuel. In spite of much hope expressed for powdered coal as a future fuel, the fact remains that all large scale trials have ultimately ended in failure. For this reason it is not remarkable that much attention has been given to the gas producer as the means of converting solid fuel to gaseous fuel and thus automatically solving the difficulty but the inherent fault of low over-all conversion of heat content of the fuel into mechanical energy presents difficulties which require something besides conventional practice. The gas turbine, by itself, is somewhat below the conventional steam turbine and boiler in over-all efficiency and if the losses and costs of gas producer be superimposed upon this deficiency then the conventional steam unit easily wins. It is the aim and object of my invention to so combine gas producer practice and the gas turbine into an economic whole that it will have an efficiency well over that of the conventional steam unit.

I, therefore, wish to make it quite clear that I do not claim any originality for the concept of first gasifying a solid fuel and then using the resultant gas in a turbine. That concept is quite old. But I do claim that a combination of certain steps which I shall now describe are new and novel and that the efficiency of the combination warrants its use upon a wide variety of fuels.

In the attached drawing I have illustrated all these steps and combined them into a composite whole, it being at once apparent that it would be impossible to separate the producer from the gas turbine and consider each one by itself. Without the innovations that I have introduced both in the turbine circuit and in the producer circuit, the entire concept becomes inoperative in so far as the claimed efficiency is concerned. Contrariwise, as a single process for converting the heat value of the fuel into mechanical energy, it has specific merit and simultaneously does serve to obtain some by-products that also have commercial value.

For the purpose of such explanation I will take as a specific example a lignite having a heat value of 7600 B.t.u., and the following composition. Moisture, 32.69%; volatile matter, 29.25%; fixed carbon, 28.76%; ash, 7.6%; sulphur, 1.12% and nitrogen, 0.8%, as specified subsequently. The washed gas has a heat value of 149 B.t.u. per cu. ft., and the temperature of the gas leaving the producer was 840° F., due to the large amount of moisture in the fuel. Further details will be given later on as pertinent to the specific items elucidated. The inlet temperature to the turbine is held at a little below 1450° F. by a corresponding large excess of combustion air. Turbine exhaust will not vary much from 1000° F. and will obviously consist chiefly of nitrogen and unconsumed oxygen. Lower temperatures after passing heat accumulators and reactor are given in the drawing.

I will commence my description with the exhaust from said turbine indicated by the number 7. It will be seen that I have divided this into four parts in the following manner. Owing to the large oxygen content, a large fraction can be used in place of air for the producer indicated by the number 8 but the actual amount cannot be accurately determined as it depends on the amount of water vapor and carbon dioxide simultaneously present and the ability of the producer to convert such material

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into combustible gases. Any deficiency is readily made up by heating the balance of the needed air to about 100° F. less than the exhaust, by heat exchange, with said turbine exhaust. This is plainly indicated as "supplementary air" entering into the gas producer, after passing through the discharging phase of heat exchanger indicated by the number 4.

The remainder of the unused exhaust from the turbine is indicated as used to heat the air for combustion supplied to the combustion chamber of the gas turbine by passing through the discharging phase of heat exchanger indicated by the number 5, after initial compression in compressor number 1, and to heat the washed gas from the producer by passage through the compressor, indicated by the number 2, and the discharging phase of the heat exchanger, indicated by the number 3, just before its entrance into the same combustion chamber, indicated by the number 10. All such heat exchange is illustrated as accomplished by means of "heat accumulators" rather than the conventional tube assemblies. These are far more efficient and permit of an approach to a regenerator of "infinite" surface. In practice this simply means that the technique is borrowed from the open hearth of the steel maker instead of from the heat exchangers of the power station. It is, of course, subject to the disadvantages of said system but it is gaining a steadily greater importance in the chemical industries because of its far lower cost per unit of transferred heat. In the calculations herein it is assumed that a differential of 100° F. is an adequate allowance for said accumulator when receiving and discharging heat. Inasmuch as this device is entirely conventional no more adequate description appears necessary. Personally, I have used a cylindrical vessel filled with iron rods of 1/4 in. dia. or less, the flow of gas being, obviously, along the rods.

To elucidate another portion of my process I now turn to the top center of the drawing and the item called a "compressor" indicated by the number 1. Assuming a 5 to 1 ratio of compression of the needed combustion air and allowing for the turbulence feature of the axial compressor we have in actual performance a rise in temperature to 540° F. from a normal of 60° F. To combat this I introduce water as an atomized mist before the air enters said compressor, and, as needed, at any intermediate point. Inasmuch as a pound of dry air at 180° F. will absorb over 0.6 pound of moisture, allowing for the reduction in volume and the specific heat of air, it will be seen that said temperature of 540° can be reduced to 180° by the volatilization of approximately 0.1 pound of injected water. Furthermore, that said air can be so reduced in temperature without reaching actual saturation. It follows that while I cannot reach a truly iso-thermal compression in this manner I can approach it, and as all work performed by the compressor is negative all such gain in power input is direct gain in output.

But there is a further gain involved. The relatively humid air has larger mass and larger volume which gain is likewise directly obtained at no expense for consumed power and thus results in another net gain. Finally, the moisture laden air ultimately arrives in large part as a direct contribution to the efficiency of the gas producer. All this, and the added heat supplied to combustion zone of the gas producer, represents a transfer of energy from the exhaust of the turbine into potential chemical work in the producer. So far I have been considering only the air and water vapor supplied to the combustion chamber of the turbine but it is obvious that the same technique applies to the fuel gas entering the combustion chamber and I have illustrated that at the right hand of said combustion chamber by showing water injection into the compressor indicated by the number 2.

I now wish to describe that part of my drawing placed

below the gas producer which is indicated by the number 8. This device receives fuel and produces ashes and gas respectively. The gas is represented as entering a washer indicated by the number 9, a conventional device, where by condensation and scrubbing it is cleaned and cooled, the separated product being ammoniacal liquor in which tar is disseminated. The cooled, purified gas, as already referred to previously, goes to a compressor indicated by the number 2, an accumulator heater indicated by the number 3, and then to the combustion chamber indicated by the number 10. The ammoniacal liquor passes through a tar separator indicated by the number 11 and then to the "reactor," a non-conventional phase indicated by the number 12. Here intimate contact is achieved between the partially cooled exhaust gases from the turbine, after passage through the various heat accumulators, and said ammoniacal liquor. It is in effect a scrubber. The ammonia in the liquor is present in part as carbonate and in part as sulphide. The sulphur dioxide and trioxide present in the exhaust react with the ammonia compounds to produce ammonium sulphate and separated sulphur. Simultaneously, as said gases leave at a lower temperature than they enter they are able to produce much evaporation.

Now all lignite contains some nitrogen, and in the instant case said nitrogen is present to the extent of 0.8%. In gasification, as the temperature is kept low by the presence of so much water vapor and carbon dioxide, about half of this nitrogen appears as ammonia. However, as there is also so much moisture in the fuel the ammoniacal water becomes very dilute. It is, therefore, of prime importance that, simultaneously with the chemical effect present in the reactor, there is also this advantageous feature of attendant concentration. It is also desirable to keep as low a concentration of the volatile ammonia salts as possible in the scrubbing liquor so, by the double-dotted lines connecting washer and reactor, I have indicated a commingling, at will, of the liquors used in both devices, thus reducing volatile ammonia salts to a minimum.

The products leaving the reactor are indicated on the drawing as a concentrated solution of ammonium sulphate and gas at approximately 212° F., leaving the total water content in said gas in the form of vapor. The actual temperature is optional but it is obvious that to obtain maximum concentration in the liquid scrubbing medium in the reactor the gas in contact with said liquid must be at the proper temperature to cause evaporation in place of condensation.

The final step in the drawing is devoted to the reclamation of such water as may be desired from the gases leaving the reactor. In many places where adequate fuel is available, water is quite scarce, hence fuel is generally brought to the source of more abundant water. Whenever enough water is present to permit the use of a conventional condenser, said recovery of water becomes unnecessary, but in isolated localities it may become quite important. If such moisture laden gas is passed through the charging phase of a simple heat accumulator, indicated by the number 6, consisting of a bed of pebbles, then much water will be condensed for a while until the pebbles become unduly warm. The current is then cut off and sent to another accumulator. Meanwhile cold air enters the heated accumulator and effectively removes the stored heat to such an extent that it may once more be used as a condenser, after which the cycle is repeated.

Although such use of a heat accumulator is truly conventional in many industries and hence needs no specific description, nevertheless because of the importance of this device to my process a few words, and a further explanation of the legend I have used on the drawing, may be useful. Throughout, I have represented such use of a heat accumulator in heat exchange by placing two rectangles side by side connected by an X-bridge to show that they form a part of one system. I have used an

unbroken line in the rectangles denoted as receiving heat.

Contrariwise, the discharging phase of the accumulator is represented by the rectangle consisting of dotted lines. In each and every case I have presented said accumulator as consisting of a single pair, that being the minimum number to constitute an operative unit and to illustrate the principle. However, in practice, such devices will always be used in multiple so as to smooth the transition on reversal of flow. Thus, there should always be present as a minimum two accumulators receiving, and simultaneously two discharging heat. Obviously, in any design the greater the number of devices employed the less will the inevitable fluctuation induced when any accumulator is taken from the "charging" line and put "on stream" in the discharging line.

While in this specific description of my process I have used lignite as fuel and submitted the over-all picture of inter-relations, temperatures, and gas compositions, it is obvious that my process will be equally applicable to any type of carbonaceous fuel from anthracite dust to bituminous coal. Similarly, to take even lower grades of fuel, we may employ peat or any type of forest-waste in the manner herein described. It is even possible to use the urban waste of our great cities, as a means of disposal of such objectionable material, as gas producer fuel. The great objection to incineration has always been the objectionable products sent into the atmosphere and of which we are now so conscious as originators of "smog." It is obvious that in my process perfect combustion is attained and hence little if any contamination of the atmosphere becomes possible. All such uses of my process to a great variety of fuels I consider as within the scope of this disclosure as long as the theme involved contains the simultaneous use of a gas producer and a gas turbine inter-connected into a composite whole in the manner herein described for lignite.

Inasmuch as I have used lignite as my fuel in the specific illustration represented on the drawing and thus used it to point out clearly the operation of my process, I wish it specifically understood that I do not attribute any special importance to lignite over and above extended use of other fuels. Having thus fully described my process.

I claim:

1. The method of improving the thermal efficiency of a gas producer-gas turbine assembly operating upon a fuel, selected from the group consisting of anthracite, bituminous coal, and lignite, containing both sulphur and nitrogen, which comprises; dividing the hot gas of the turbine exhaust, which consists of a mixture of nitrogen, oxygen, carbon dioxide, oxides of sulphur, and water vapor, into two portions; utilizing one portion as the air of combustion required by the gas producer thus converting the sensible heat contained therein into additional chemical energy as it passes through said fuel, and by its water content improving the conversion of the nitrogen of said fuel into ammonia; passing the second portion of the exhaust through heat accumulators, thus storing the sensible heat resident therein, and subsequently imparting said stored heat to traversing, relatively cool, gas and air, respectively, required in the operation of turbine and producer, by reversal of flow through said heat accumulators; injecting water into air and gas before said traverse through said heat accumulators thus enriching said gases in water vapor and improving the over-all efficiency of turbine and producer with increased yield of ammonia; washing the producer gas with water to remove, in part, said ammonia with attendant removal of tar and sulphur; separating the tar from the resulting ammoniated water and commingling said ammoniated water with the exhaust gas from the turbine after partial cooling of same by passage through the heat accumulators, thus converting said ammonia together with attendant sulphur into ammonium sulphate with simultaneous evaporation of water thus increasing the concentration of ammonium sulphate in said water; and further increasing said concentration by the

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re-use of said water solution of ammonium sulphate in the removal of ammonia and sulphur from producer gas.

2. The method of improving the thermal efficiency of a gas producer-gas turbine assembly set forth in claim 1, with the added step that the moisture laden gases, constituting the final gaseous reject from the operation, then pass through a relatively cold heat accumulator with attendant condensation of a part of said moisture, the heat thus stored in said accumulator being subsequently discharged and the accumulator cooled by the passage of air, 10

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at ambient temperatures, the condensed water simultaneously formed being suitable for re-use wherever required in the process.

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