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# Communal Solid Waste as Fuel for Gas Turbine Power Plants

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The growth of the worlds population accompanied by the increase of the energy intensity (Wt/person) leads to the rapid usage of oil, gas and mineral coal, the reserves of which in the entrails of Earth are not infinite. According to the UN expert assessments the world community may face serious deficiencies of Energy resources in the next 25-30 years. The world fuel crisis of the 1970-ies was the signal to the development of power plants for alternative fuels, including municipal sold waste.

An inhabitant of a large city forms as a result of life about 300-360 kg/year of municipal solid waste per person. A municipal territory with a population of 1 million people annually generates more than 300.000.000 kg municipal solid waste which has to be removed. Most of them are removed to special landfill sites to be disposed in the ground for the period of 15-20 years (the service fee is up to 80$/per ton communal solid waste).

Communal solid waste is an effective energy carrier with the calorific value equivalent to the same of wood, peat or oil shale. The main contemporary method of communal solid waste chemical energy utilization is the direct combustion in the boiler furnace of a steam turbine power plant, based in a remote isolated territory. For example 60 such installations in the suburbs of Paris generate approximately 80% of the city power consumption.

An example of a combustion gas-turbine plant is the American CPU-400 for a municipal territory with the population of 400.000 people. The utilization technology of communal solid waste includes a sequence of operations. The communal solid waste is pre-treated and separated into combustible and non-combustible fractions. The non-flammable mass is then directed for further separation by the flotation method. The combustible mass is burned under pressure in a fluidized bed Combustor.. The Combustor is supplied with air from a gas-turbine unit compressor. The toxic components of combustion products are displayed in the slag with the help of special additives. To prevent the erosion damage of the gas-turbine blades the combustion materials are cleaned in cyclones to the dust content rate of not more than 5 mgr/m$^3$ with the particle size less than 10 mKm. The installation is self-supporting. For 1 spent dollar (capital cost, maintenance cost, depreciation of equipment etc.) the commercial product costing

1.25 dollars is produced (electric energy, secondary raw material e.g. ferrous and non-ferrous metals, glass, ceramics, etc.). The “ecologically” clean composition of flue gasses allows to place this installation in the territory of service. This allows to minimize costs of gathering and transportation of municipal solid waste and leads to an additional economic effect.

The essential fault of the scheme is the presence of a cyclone in the high-temperature line before the turbine. The cyclone brings gas pressure loss and heat waste. The reduced performance of the cyclone at high temperatures limits the temperature level after the combustion chamber (accordingly before the turbine). The installations with such a scheme did not get a further development.

The Russian Academy Institute of Chemical Physics Problems (ИПХФ РАН) , The Federal Plant «Salut», Bauman Moscow State Technical University joint efforts aim was to develop the Installation with gas turbine energy convertor for recycling of Solid Waste by Gasification. The installation is based on a counterflow reactor-gasifier atmospheric type with steam-air blowing, developed by ИПХФ РАН.  For effective transfer the heat from one working zone into another special inert material with high specific heat is used.  This allows to maintain the required temperature field at the reactor height. This inert  material circulate throw reactor from up to downt. As a result the temperature at the gasification zone is up to 1450…1500 K, thus allowing to gasify and neutralize the waste of medical facilities. The temperature of the producer  gas at the reactor exit is not more than 370 K. The cold conclusion of enerta, ash and slag is realized through the lower gateway. The performance factor of the gasification process is more than 96%.

The development of the gas-turbine unit is based on the well-known schema with the location of the combustion chamber after the  turbine. The atmospheric pressure chamber is well  conformed with the atmospheric pressure reactor-gasifier: to enter the fuel gas into the combustion chamber the use of a low-pressure circulator is sufficient. The use of puer air for the turbine operation excludes erosion damage of the turbine blades. The air is heated to the working temperature before the turbine in an air-gas heat-exchanger. The source of heat are the thermal gases, flowing out of the combustion chamber. The high temperature air-gas heat-exchanger acts as a regenerator with a regeneration rate of 100% (due to the fact that the temperature of the air at the entrance of the combustion chamber equals to the temperature of the air after the turbine) and as a combustion chamber, raising the temperature at the regenerator exit  to the temperature before the turbine. To implement the process of heat transfer the temperature in the combustion chamber exceeds the temperature before the turbine on the value of the limit temperature difference. The heat resistant alloy of the ВЖ-98 type allows to raise the temperature before the heat-exchanger matrix up to 1300 K and the air temperature at the turbine entrance to 1200…1250 K accordingly. The gas-turbine unit schema is of a regeneration type. Intercooler is introduced between compressors to improve efficiency and specific power. The principal schema of gas-turbine unit and gas turbine cycle are given in figure 1.

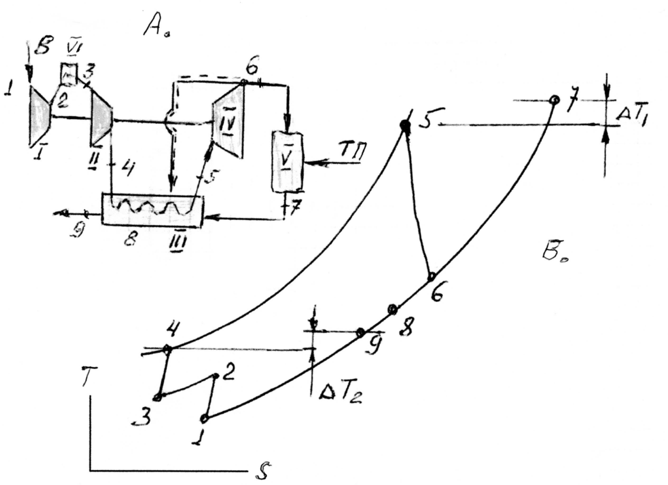

Fig.1 Principal schema and Gas Turbine Cycle: A – schema, B – cycle, 1 –Low ..pressore compressor, 11- high pressure compressor, 111- air heat exchanger, 1У –turbine. У –combustion chamber, (all another figures correspond each others.

The characteristics of the generation gas of municipal solid waste gasification

| Indicator name | Identification | unit | value |
|---|---|---|---|
| Fractional composition (by weight) | H2O<br>H2<br>CO<br>C H4<br>C2 H5<br>C O2<br>N2 | %<br>%<br>%<br>%<br>%<br>%<br>% | 36,619<br>0,844<br>9,188<br>0,823<br>1,096<br>14,488<br>37,822 |
| Lower heating value | QHP | kJ/kg | 2866 |
| Stoichiometric coefficient | L0 | Kg/kg | 0,818 |
| Gas constant | Rnc | J/kg.K | 378,47 |

The stoichiometric coefiicient L is determined by the elemental composition of the generator gas. Air fuel ratio α depends on the composition of the gas, the air temperature $T_a$ at the entrance of the combustion chamber, the air temperature $T_g$ at the exit of the combustion chamber, the heat capacity of the combustion products and is calculated through the solution of the combustion equation. Based on the combustion equation solution nomograms and tables, used in engineering calculations, are made for industrial fuels with stable composition and properties (gasoline, natural gas, etc.). The combustion equation solution for the fuel with arbitrary composition is made using a specially developed computer system. The equation solution for fuel composition (table 1) in graphic form is given in Fig.2.

The features of the combustion process of the low-calorie generator gas are demonstrated on a concrete example of a gas-turbine unit (Fig. 1) using the following data: air temperature after the high-pressure compressor $T_4$= 416K, air temperature before the turbine $T_5$= 1173K, air temperature after the turbine $T_6$= 750K, gas temperature after the combustion chamber $T_7$= 1273K, stoichiometric coefficient L=0,819, excess-air coefficient α=3,0, heat capacity of gas $C_p$ =1275 J/kg.K, heat capacity of air $C_p$ =1070 J/kg.K, fuel gas consumption $G_T$ =1 kg/sec. The computing results are given below.

Heat power to increase air temperature from 416 to 1173 K 1987715 w,

Gas temperature at heat exchanger exit 821.64 K,

Non-used gas temperature potential 821,64 –416 =405,64 K,

Taken for use temperature potential 405,64 – 100=305,64 K,

Gas heat power to be used for heating excess air 1343174 w,

Excess airflow, which may be heated by gas 1,685 kg/c

The excess air has to be used for additional power production. It flows through compressors, air heater, air turbine and directed then to the gas duck of the air heater, as it shown by dash-line on fig 1.

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Д.А. Скибин Расчет показателей процесса сгорания углеводородного топлива произвольного элементного состава в камере сгорания газотурбинной установки. Молодежный научно-технический вестник. ФГБОУ ВПО МГТУ им.Н.Э. Баумана. Эл.№ФС77-51038. 03 март 2012 г.