



CONVERSION OF 2-PROPANOL TO SYNGAS VIA PARTIAL OXIDATION IN FILTRATION COMBUSTION



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Introduction

In the world a large number of various types of liquid combustible wastes are concentrated, among which: spent organic solvents and various combustible-lubricating materials. When they are stored for a long time or improperly destroyed, very dangerous substances form from an ecological point of view.

For effective processing of such liquid combustible wastes, the process of filtration burning in a countercurrent mode can be used. By filtration combustion we mean the process of oxidation of fuel during filtration through it or a layer of inert material of a gaseous oxidant. In the case of filtration combustion, the phenomenon of "superadiabatic heating", due to the concentration of released heat in the combustion zone due to internal heat exchange between the gas and condensed phases, can be observed. The accumulation of heat in a relatively narrow combustion zone can be so great that the temperature in the front of the combustion wave can repeatedly exceed the adiabatic combustion temperature of the mixture calculated on the assumption that the initial temperature of the reagents is equal to the ambient temperature and the thermal oxidation effect of the fuel is distributed throughout the reactor volume. The heat concentration is due to the fact that in the case of counter flow of reagents, the inert components of the system are a very effective coolant, thanks to which both the fuel and the oxidant can be heated to the maximum efficiency before reaching the zone of chemical reactions. In the regime of filtration combustion with countercurrent of reagents, such an important characteristic as the burning rate due to the high temperature is determined not by the speed of chemical reactions, but only by the flow of reagents into the combustion zone (filtration rate) and stoichiometry of the process. This method can be carried out both with an excess of the oxidant with the combustion of combustible liquids to CO₂ and H₂O, and with a lack of oxidizer, when the conversion of the initial fuel to the synthesis of a gas predominantly containing CO and H₂ takes place. One of the reagents (liquid fuel or oxidizing gas) is supplied from the end of the reactor filled with a porous non-flammable charge, and the other into its middle part. In this case, the inert material charged to the top of the reactor at room temperature is heated in countercurrent combustion products. The inert material discharged from the reactor (and at the same time the equal volume is pumped into the upper part, so that the bed in the reactor is kept constant), heated in the upper part gives heat to the gaseous reagent supplied from below. Thus, the inert is discharged from the reactor in the cool condition, and the gaseous reactant is supplied to the reaction zone at a high temperature. Such a heat exchange scheme can be used in a reactor with a moving layer of a solid inert, which will allow to operate in a continuous mode.

Experimental setup

In laboratory studies we used quasi-continuous heat-insulated 65-mm id vertical quartz reactor (fig. 1) with a rotary grate to controllably discharge granular solid (porcelain Raschig rings 5×10 mm) to the discharge bin. The bulk of the reactor was filled with a granular inert solid. The air was supplied from below. As a model hydrocarbon fuel, 2-propanol (chemically pure) was used in the experiments, which is a clear, colorless, flammable liquid with a characteristic odor with a gross formula C₃H₈O. Combustion was ignited in the reactor on the level of TC3 and 2-propanol was supplied there with a constant supply rate ~6 ml/min. The discharge of granular solid was controlled to maintain the temperature on TC1 for the established regime at a constant value. Fresh solid was charged atop to maintain constant charge level. Syngas was withdrawn from the upper part of the reactor and analyzed using a gas chromatograph.

The characteristic temperature profiles of the 2-propanol combustion wave are presented in Fig. 2. In the plot, the thermocouples are numbered along the reactor length from bottom to top. The initial instant of time corresponds to charging of the ignition charge into the reactor. After the inert charge was heated (in front of the liquid fuel delivery pipe) to more than 1000°C and the ignition charge burned out, the liquid fuel started to be delivered. The instants of beginning and terminating the fuel delivery are shown by vertical solid lines. The temperature fluctuations in this time interval correspond to discharges of the inert material and charging of new portions into the top of the reactor to maintain the high temperature zone opposite to the fuel delivery pipe. In this experiment the liquid fuel was delivered during ~30 min. The maximum combustion temperature in a run was ~1000°C.

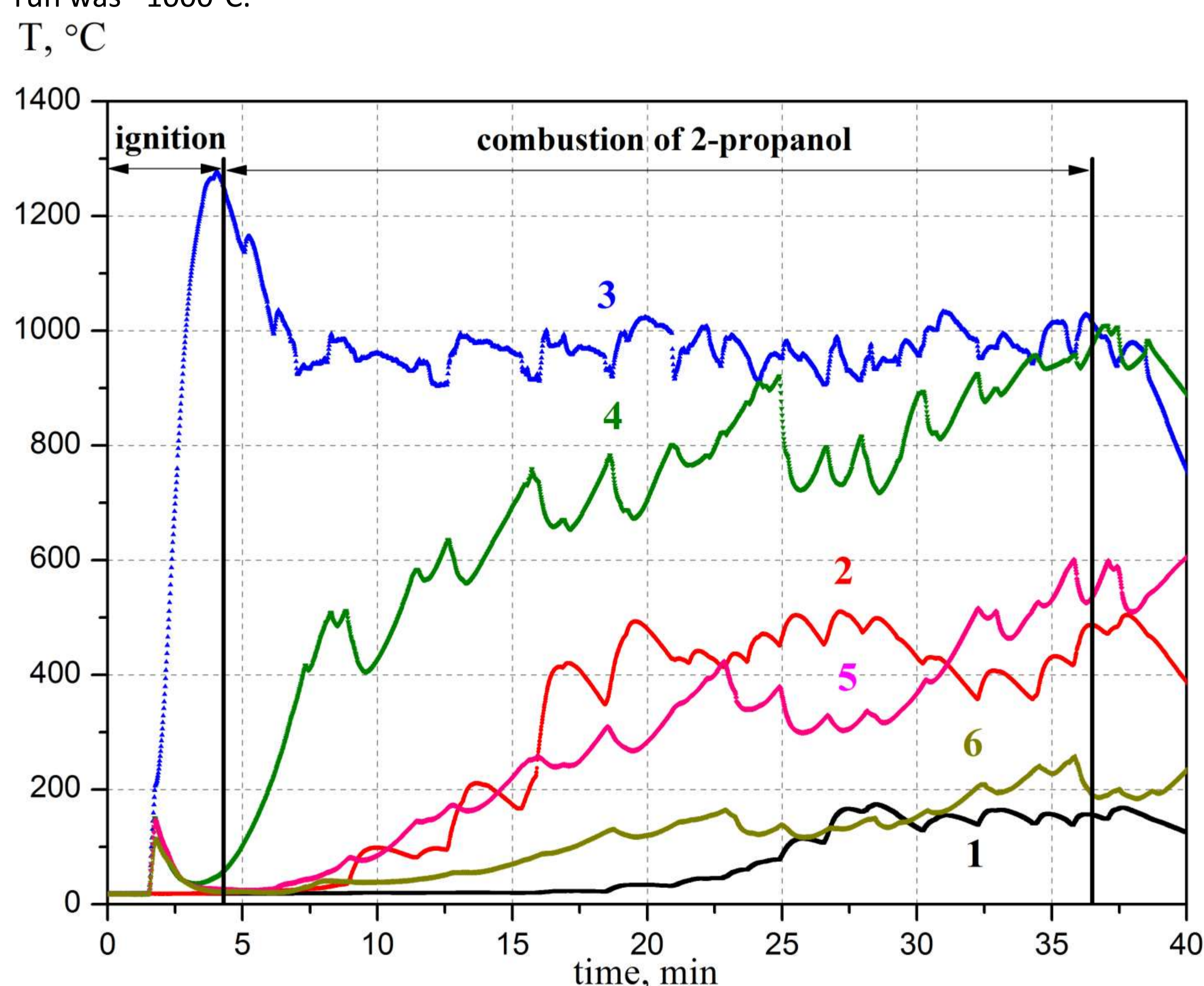


Figure 2. Typical temperature plots for an experiment of 2-propanol combustion. The numbers at curves correspond to those of thermocouples (from bottom upwards).

Conclusions

Conversion of liquid organic fuels in the filtration combustion mode in a reactor with a moving bed of an inert granular heat carrier is a promising way of processing various types of hazardous liquid hydrocarbon waste (waste oil, paint and varnish waste, refinery waste, and others). The advantages of burning liquid fuels (or wastes) in the filtration combustion mode are a high energy efficiency and independence from a catalyst usually used in the reforming of liquid hydrocarbon fuels.

Experiments with a model fuel (isopropyl alcohol) with varied oxidant to fuel ratio have shown that in oxygen-deficient combustion regime, a combustible gas (a mixture of carbon monoxide, hydrogen and lower hydrocarbons) with a calorific value of up to 9 MJ/m³ can be obtained, which can be used to produce thermal and/or electric energy, and also as a syngas. The char formed in pyrolysis of the liquid fuel plays an important role in the process as an intermediate product but does not accumulate as it is consumed with the flow of preheated oxidant gas.

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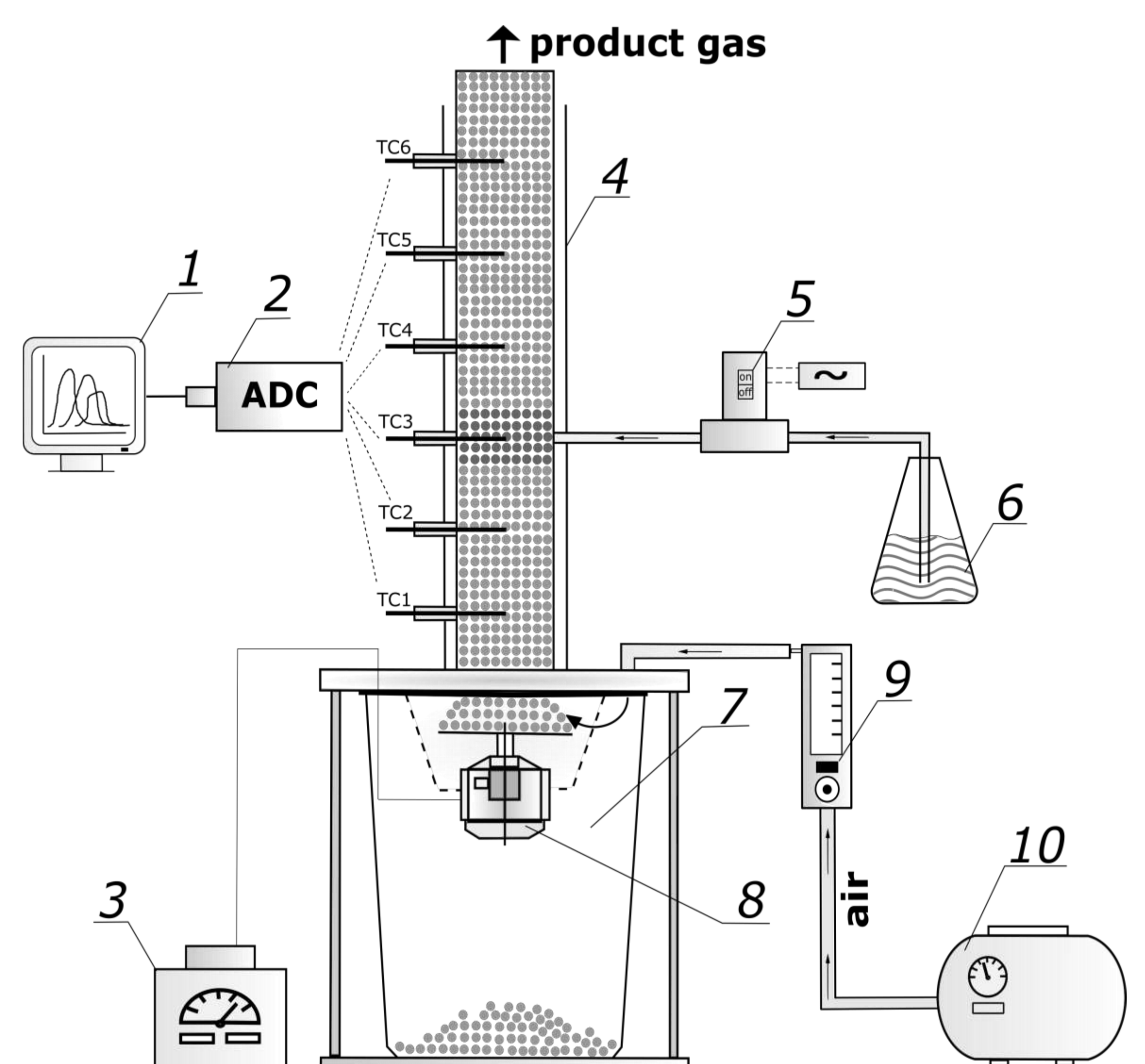


Figure 1. Schematic of the experimental reactor. 1 - PC, 2 - ADC, 3 - laboratory transformer, 4 - quartz reactor, 5 - peristaltic pump, 6 - fuel tank, 7 - discharge bin for inert solid, 8 - rotary grate, 9 - flowmeter, 10 - air compressor, TC1-TC6 - thermocouples.

Major characteristics of 2-propanol conversion depending on oxygen excess ratio

α	Concentration of gases, % vol.							Q_g , MJ/m ³	T_c , °C
	CO ₂	CO	O ₂	C ₃ H ₆	C ₂ H ₄	CH ₄	H ₂		
0.34	7.47	15.4	-	4.5	1.8	4.61	3.73	8.64	923
0.52	8.17	14.2	-	1.43	1.25	2.19	1.7	4.55	990
0.61	11.8	13.6	-	1.21	1.05	1.74	1.11	3.96	1005
0.80	6.84	9.48	8.29	1.21	0.68	1.1	1.11	2.03	1050
1.69	2.76	7.53	16.2	0.02	0.15	0.25	0.21	1.10	1070
1.95	1.8	7.29	17.8	0.02	0.08	0.12	0.11	0.97	1060