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## Emission of oxygen dissolved in fuel at aircraft climb

*Change of oxygen concentration in tanks space above fuel as a function of aircrafts rate of climb and the ratio of gas and liquid phases studied*

The concentrations of oxygen and nitrogen in the tank space above fuel during the flight of the aircraft are changed as a result of the emission of air dissolved in the fuel. Numerous tests had shown that the fuel in the RT under normal conditions contains about 16 % of dissolved air, while oxygen concentration is about 5.25 % by volume and the nitrogen concentration -10.75 % (V.) At aircraft altitude raising the dissolved air is released, and the oxygen concentration in the tank space above the fuel can theoretically reach 33 % (V.) via a lower solubility of oxygen in hydrocarbons of fuel compared to nitrogen.

Experimental tests regarding to the amount of dissolved gases in the RT- fuel as a function of the altitude of the aircraft had shown that under static conditions at rate of climb close to the performance, there arises a significant disagreement between the amount of allocated dissolved gases and those calculated in accordance with Henry's law. During the experiment was observed the growth (Fig. 1) of gas emissions delay, and at the increase of the rate of climb this delay had grown too.

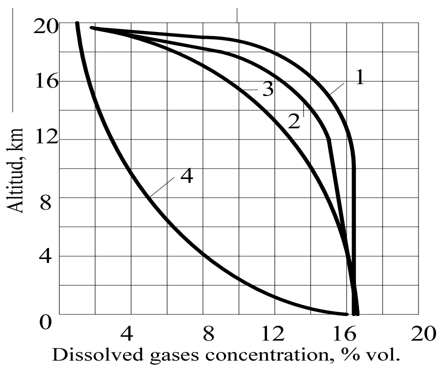



Fig. 1. Dependence of the dissolved air amount in the RT fuel, altitude and aircraft rate of climb (Vy): 1 - Vy=75 m/s; 2 - Vy=45 m/s; 3 - Vy=15 m/s; 4 – according the Henry's law.

It should be noted that at actual flight real conditions, in presence of aircraft evolution and vibration, the delay of release of dissolved gases from fuel while having a complex character generally decreases. There is opportunity to determine theoretically the dependence of the oxygen content in the formerly dissolved gases that were released depending on the ratio of the fuel volume and over fuel space volume as a function of aircraft climb altitude. In this case we assume that the temperature of fuel and gas are constant.

Then the amount of dissolved gases that are released when changing pressure according to Henry's law, is:

$$Vi = V_o \cdot ( 1 - P_f / P_o ), \qquad (1)$$

)

where $V_o$ - initial volume of dissolved gas, $m^3$; $P_o$, $P_f$ - the initial and final pressure, kPa.

At an aircraft climb to altitude proceeds the expanding of escaping gases, the volume of which is equal to:

$$V_i = V_o \cdot ( P_o / P_f - 1 ) \qquad (2)$$

Quantity of oxygen in space above fuel in tank can be determined by the formula:

$$C \cdot V_t = 21 \cdot V' + 33 \cdot V'_t , \qquad (3)$$

where C, 21, 33 - the oxygen concentration in the gas,% vol .;

$V_t$ - total above fuel space, $m^3$ ;

V '- part of the air space of the tank, $m^3$ ;

$V'_t$ – part of above fuel space occupied by the gas released from the fuel, $m^3$.

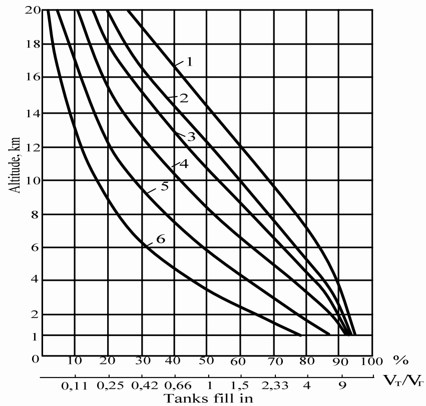



Fig. 2. Theoretical dependence of oxygen concentration in the space above fuel from the volume of the tank filled with fuel and altitude of an aircraft: *1* - $O_2$ – 33 %; *2* - $O_2$ – 29 %; *3* - $O_2$ – 27 %; *4* - $O_2$ – 25 %; *5* - $O_2$ – 23%; *6* - $O_2$ – 22 %

Assuming that under normal conditions, the amount of air in the RT-fuel reaches 16% , I.e.$_t$ $V = 0.16\ V_f$ and $V' = V_i - V'_i$, and using equation (2) represented by formula (3), after transformations we obtain the oxygen concentration in mixture:

$$C = 21 + 1{,}92 \cdot V_i/Vt \cdot (P_0/P_f - 1), \quad (4)$$

Fig. 2. demonstrates the theoretical dependence of oxygen content above fuel in the space of the aircraft tank as a function of tank fuel filling in and of altitude. At 70% filling of the fuel tank with climbing it to altitude of 10000 m in above fuel space oxygen concentration reaches 33 % vol.

At 20 % the fuel tank filling (the ratio $Vgas/V_{fuel}$ =4) and at the rate of climb 5 m/s an increase of oxygen concentration occurs above 21 % (vol) after altitude of 4000 m (Fig. 3a). This suggests that the release of dissolved air from the fuel does not occur immediately after take-off of the aircraft, but during the subsequent ambient pressure drop.

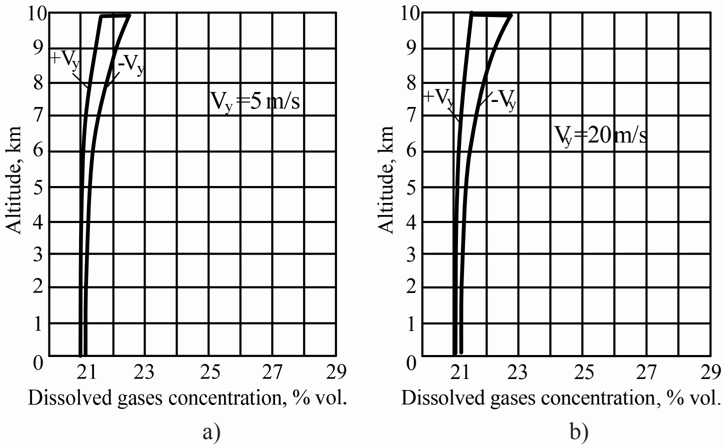



Fig. 3. Change of oxygen concentration in the space above fuel as the tank is risen to the altitude and at 20 % fuel tank filling

Further tests with various fuel tank filling and at different aircraft rate of climb also indicate an air release delay from the fuel at lift to the designed altitude. With the achievement altitude 10000 m oxygen concentration in the above fuel space increases to 21.7 %. While maintaining the tank for 30 minute at this altitude, the oxygen concentration is increased to 22.3 %. At lowering of aircraft altitude oxygen concentration in the tanks is reduced, there proceeds a dilution of the gas mixture as a result of the inflow of outside air into space over fuel. At reaching altitude of 4000 m the concentration of oxygen is leveled to 21 % Vol.

With the rate of climb 20 m/s (3b) from altitude 4000 m to 10000 m the oxygen concentration above over fuel space increases to 21.5 %.

With the rate of climb increasing is released some smaller amount of air dissolved in the fuel, and when it reaches an altitude of 10000 meters, therefore occurs a smaller concentration of oxygen in the space above fuel. But when tank exposed to the altitude 10000 m, the oxygen concentration is increased to 22.5% vol.

At 40 % filled fuel tank (the ratio $V_i/Vt = 3/2$) and the rate of climb 5 m/s an increase in the concentration of oxygen up to 22.5 % occurs from altitude 4000 m to 10000 m (Fig. 4a). Keeping tank at an altitude of 10,000 meters, there proceeds further release of dissolved gases and the oxygen concentration increases to 24.3 % (vol.). By reducing the altitude from 10,000 meters to the ground level, the oxygen content is reduced to about 21.1 %. A similar result was obtained with a chosen rate of climbing of tank equal 20 m/s (Fig. 4b). However, at maintaining the tank at an altitude of 10000 meters the oxygen concentration increases by a larger amount - from 22.2 to 24.3 % vol.

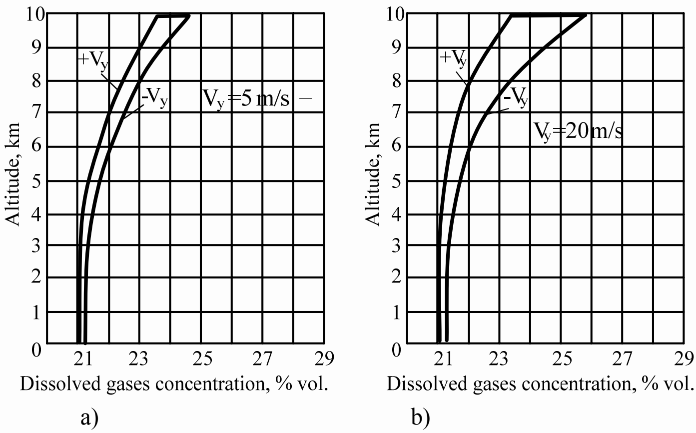
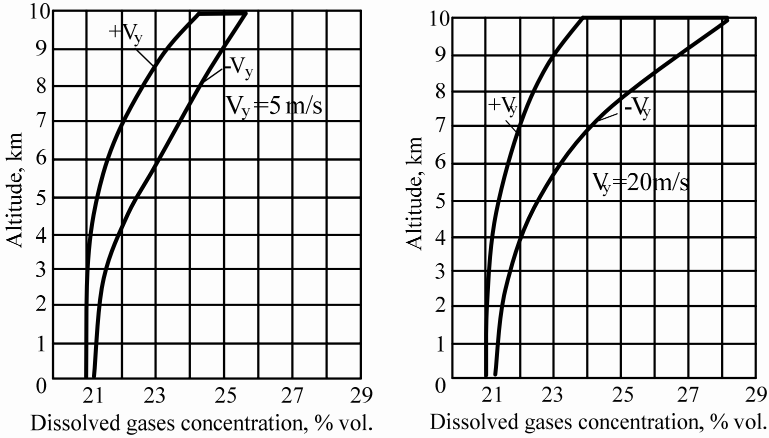



Fig. 4. Change of oxygen concentration in the space above fuel as the tank is risen to the altitude and at 40% fuel tank filling

For altitudes from 4000 m to 10000 m, at 70% fuel tank filling and at the rate of climb 5 m/sec the oxygen concentration in the above fuel space increases to 24.3 %, (Fig. 5). By maintaining the tank at altitude of 10,000 m the oxygen concentration increases to 25.8 % (vol.). At aircraft descending, the oxygen concentration is reduced to 21.3 %(vol.), (Fig. 5a). With the aircraft rate of climb 20 m/s while maintaining the fuel tank at altitude 10000 m the oxygen content is increased from 23.8 % to 28 vol. (Fig. 5b).




a) b)

Fig. 5. Change of oxygen concentration in the space above fuel as the aircraft tank is risen to the altitude and at 70 % fuel tank filling

## Conclusions

Thus, at aircraft climbing at definite altitude in the tanks space above the fuel proceeds increasing the oxygen concentration owing to the emission of gases dissolved in the fuel. The intensity and the magnitude of this increase depends on the degree of the fuel tank filling, on altitude and the rate of climb.

Based on these studies, the staff of the National Aviation University had developed technical solutions that allow to influence on the oxygen content in the space above the fuel in the tanks of aircraft that will increase fire and explosion safety and also the reliability of the fuel system.

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