



Elaboration of the continuous method for degassing hydrocarbon fuels and the installation for its implementation

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ABSTRACT

Oxidation of hydrocarbon fuels with oxygen of dissolved air leads to the loss of its quality and, ultimately, to the abnormal operation of facilities using it, determining the need to elaborate a method for fuel degassing. On the basis of hydrocarbon fuel degassing process regularities, a theoretical analysis of gas desorption from liquids upon degassing was carried out, a mathematical model for calculating the degassing process under static vacuum conditions, as well as a mathematical model of liquid degassing with the method of forced gas boiling under dynamic conditions were proposed. Based on the carried out experimental and theoretical studies and calculations, an efficient method of continuous degassing of hydrocarbon fuels and a scheme of the installation for its implementation were proposed. Results of the experimental studies which confirm the high efficiency of the proposed degassing method are reported.

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1. Introduction

Upon storage, transportation, pumping and fueling, hydrocarbon fuels (hereinafter hydrocarbon fuels shall mean jet propulsion fuels, diesel fuels, automotive and aviation gasolines) change their quality as a result of physical and chemical processes. The quality change intensity depends on physical and chemical properties of hydrocarbon fuels, as well as conditions of their production, transportation, storage and application.

Basic physical processes proceeding in hydrocarbon fuels are the following: evaporation, stratification, contamination with impurities (gaseous, liquid, and mechanical), settling of high-melting components during cooling, as well as mixing in tanks and hauling equipment, mixing during serial pipeline transfer of hydrocarbon fuels of various groups and grades.

Basic chemical processes proceeding in hydrocarbon fuels are the following: oxidation, decomposition, polymerization, and condensation [1].

It should be noted that upon pumping, open jet discharging, liquid mixing during transportation, and discharge-and-filling operations, fuels are aerated due to the mechanical involvement of air together with water vapor into the liquid volume. Air and its components penetrate into the liquid in the form of bubbles of various sizes. In a steady fuel state of fuel, gas bubbles float up and escape from it, but their volume decreases due to the partial gas dissolu-

tion in fuel. Dissolution of up-floating bubbles in liquid is a diffusion process.

Upon storage, transportation, pumping and fueling, certain conditions shall be provided which exclude or minimize the ingress of gaseous, liquid and mechanical impurities. Non-compliance with these conditions is usually associated with the poor state of technical facilities and depends on the qualification and responsibility of the personnel.

Upon the contact of the hydrocarbon fuel surface with air, dissolution of the latter in fuel is observed.

Dissolved air negatively affects a number of performance characteristics of hydrocarbon fuels [2].

It should be noted that oxygen solubility in hydrocarbon fuels is higher than nitrogen solubility (by 6–7% under normal conditions). This negatively affects the application of fuels. Upon contact with air, fuel is enriched with oxygen, therefore, oxygen concentration in the liquid phase increases. Oxygen dissolved in fuels is a reason for oxidation process development leading to sediment formation, decrease in the storage time, deterioration in the thermal oxidation stability, filterability, and other performance characteristics, as well as corrosion and wear of construction materials. In order to preserve the quality of fuels, it is necessary to isolate fuels from the air environment during production, transportation, storage and operation, or elaborate efficient methods of its degassing [2].

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Nomenclature

Abbreviations

SS sampling system
 GCLC CD control device for the gas content in low concentrations
 IR-spectra infra-red spectra

Designations

C concentration of gas in liquid, kg/m³
 κ gas solubility in liquid, kg/(m³ MPa)
 P gas partial pressure in the gas phase, MPa
 P_p equilibrium gas pressure in the gas phase, MPa
 m mass, kg
 $\Sigma F, F$ mass transfer surface, m²
 β mass transfer coefficient, m/s
 τ time, s
 r bubble radius (average), m
 M molecular mass of gas, kg/kmol
 R gas constant, J/(kmol K)
 T temperature, K
 D diffusion coefficient of gas in liquid, m²/s
 d_n diameter of up-floating bubbles, m
 Pe Peclet number
 dm/dt gas dissolution rate, kg/s
 ΔC difference of concentrations, kg/m³
 κ constant of gas solubility in liquid, kg/(m³ MPa)
 n mole fraction of gas in mixture
 ρ density, kg/m³
 σ surface tension, N/m
 C_p specific thermal capacity, J/(kg K)

K dimensionless group
 α dimensionless parameter
 ξ fill factor
 g gravitational acceleration, m/s²
 Q heat of vaporization, J
 Re Reynolds number
 NA Avogadro constant
 μ molecular dipole moment
 H Henry's Law constant

Indices

g gas
 0 initial value
 τ current value
 f final value
 res residual value
 eq equilibrium value
 atm atmospheric
 bar barometric
 vac vacuum
 sep separated
 unsep unseparated
 l liquid
 cav cavity
 i any gas
 mix gas mixture
 Δ difference

2. Preparation technology for degassed hydrocarbon fuels

Removal of retained gases from high-boiling liquids is usually performed in the most intensive desorption regime, i.e. vapor boiling. The essence of technologies is either in boiling of liquids $P_s > P_{bar}$, or their preliminary heating (to increase the initial pressure of saturated vapors) and subsequent joining of the free tank volume with the degassed component and the area of low back pressure (provided by vacuum systems). Such methods require significant power consumption and are distinguished by an increased substance entrainment from systems upon their degassing.

The patent [3] describes an installation for removal of dissolved gases from the hydrocarbon liquid medium. The installation comprises a feed pipeline with a nozzle unit, a cylindrical channel to provide the supersonic flow of the liquid mixture with liberated gases, a main pipeline for removal of gaseous impurities and a discharge pipeline for the purified medium. The nozzle unit is designed in the form of a multi-tube nozzle, hermetically fixed in the pipeline. The ratio between the nozzle cross-section and the total area of nozzle openings is [6–12]:1. Downstream of the cylindrical channel, a diffuser with the opening angle of 4–6°, followed by a separation chamber and the main pipeline for removal of gaseous impurities, is installed. A hydraulic lock in the form of a bended pipe section is installed in the discharge pipeline. The installation ensures efficient removal of hydrogen sulfide and other dissolved gases from sour oil.

In the patent [4], a method for liquid degassing and a device for its implementation are proposed. Liquid degassing lies in the following: a rotational motion is imparted to the liquid mass, exposing it to an acoustic field in the tangential or tangential-longitudinal direction relative to the axis of liquid mass rotation, by means of which the gas and liquid phases are separated.

Degassing is performed in a device which contains a chamber for the degassed liquid, gas and liquid mixture supply inlets and a liquid discharge outlet; the chamber is equipped with acoustic radiators, the active surface of which is fixed in the tangential or tangential-longitudinal direction (with the displacement relative to each other in the longitudinal direction of the chamber). The degassing chamber is also equipped with an additional acoustic radiator, the active surface of which is installed in the longitudinal direction relative to the axis of the degassing chamber.

Our experience in preparation of degassed liquids shows the relevance of their conditional division into two groups. The first group includes high-boiling liquids with relatively high pressure of saturated vapors ($P_s > 0.01$ Pa at $T = 293$ K), while the second group includes low-boiling liquids with low pressure of saturated vapors ($P_s < 0.01$ Pa at $T = 293$ K).

The issues of dissolved gas removal become complicated for the second group of liquids due to the small value of P_s . This circumstance increases power consumption for the arrangement of vapor boiling (boiling-up) of liquids, and also leads to noticeable changes in the fractional composition of a number of hydrocarbon liquids. The use of heating elements is unacceptable for many liquids due to a sharp increase in the rate of thermal decomposition of working substances, accompanied by intensive release of gaseous constituents from decomposed products.

As for operative tasks of degassing large masses of hydrocarbon liquids, it is necessary to develop new, highly efficient technologies combining the intensity of gas desorption out of liquids in the vapor boiling regime and minimum losses of the product during its preparation. Efficiency of processing operations shall be preserved at different initial thermal conditions of liquids (± 50 °C) up to crystallization temperatures. In combination with the requirements to high rates for preparation of degassed fuels and

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