# Normalization of hydrocarbon emissions in Germany

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**Abstract.** In connection with the integration of the Russian Federation into the European space, many technical regulations and methodologies are being corrected. The work deals with the German legislation in the field of determining of hydrocarbon emissions and the methodology for determining the emissions of oil products from vertical steel tanks. In German law, the Emission Protection Act establishes only basic requirements. Mainly technical details, which have importance for practice, are regulated in numerous *Orders on the Procedure for the Implementation of the Law* (German abbr. – *BimSchV*). Documents referred to by *the Technical Manual on the Maintenance of Clean Air* are a step below on the hierarchical ladder of legislative and regulatory documentation. This set of documents is represented by numerous DIN standards and VDI guidelines. The article considers the methodology from the guidance document VDI 3479. The shortcomings and problems of applying the given method in Russia are shown.

## 1. Introduction

The basis of environmental legislation of Germany is the Federal Law on Protection from Emissions (German *Bundes-Immissionsschutzgesetz*), adopted in 1974, which full name is the Law on Protection from Harmful Environmental Effects due to Air Pollution, Noise, Vibration and Similar Processes. The law was developed with the influence of its predecessor – the Clean Air Act, adopted in the United States in 1970. The Law on Protection against Emissions itself establishes only basic requirements. The technical details, which are of great importance for practice, are mainly regulated in numerous **Resolutions on the Procedure for Enforcement of the Law** (*German:* BImSchV), two of which, related to hydrocarbon emissions, can be singled out in relation to the regulation of hydrocarbon emissions from vertical steel tanks:

- **20. BImSchV** – *The regulation on the limitation of emissions of volatile organic compounds during transshipment and storage of gasoline* is directed to equipment used for storage, filling and empting operations and transport of gasoline. The main objective of the Resolution is to reduce emissions through the introduction of vapor recovery systems (Gaspendelsysteme). This resolution does not apply to refueling vehicles at gas stations. The specified area is regulated by the Resolution 21. BImSchV.

- **21. BImSchV** – *The regulation on restriction of hydrocarbon emissions when refueling the motor vehicles* prescribes the equipping of fuel dispensers with special devices (Gasrückführungseinrichtungen), returning gasoline vapor generated during the refueling operation, back to the filling station tank, and automatic control devices that interrupt the fuel supply if the vapor recovery system is not rectified within 72 hours.

The lower level of documentation is the level of normative and technical acts containing specific technical requirements for the implementation of the requirements of the above-mentioned Federal Law on Protection against Emissions. It is presented in the *Technical Manual on Air Cleanliness* (*German*: *Technische Anleitungzur Reinhaltungder Luft*[1], *abbr.:* ***TA Luft***). The first version of this Manual appeared in 1964 even before the adoption of the Federal Law on Protection against Emissions, and then the document was revised in 1974, 1983, 1988 and 2002. The technical regulation performs a low concretizing function, explaining the general and vague concepts that are used in the above mentioned Law, prescribing specific requirements for emissions, their measurements, etc. In judicial practice, guidance is recognized as being compulsory performed in most cases.

It should be noted that for liquid organic compounds, guidance **TA Luft** regulates the use of vertical tanks with a fixed roof, connected to a vapor collection system or to an installation for the purification of emissions. However, if the volume of the tank is more than 20,000 m$^3$ and if it is equipped with a floating roof and an effective sealing gate or pontoon under a fixed roof, such tanks are allowed to be used for oil storage provided that the reduction of emissions is at least 97 percent compared to similar tanks not equipped with a pontoon stationary roof.

A step below on the hierarchical ladder of legislative and regulatory documentation, the documents are referred to by the *Technical Manual on the Maintenance of Clean Air.* This set of documents is represented by numerous DIN standards and VDI guidance documents, integrated into the constantly updated and updated VDI/DIN Standards Guide for Air Purity (***VDI/DIN-Handbuch „ReinhaltungderLuft"***).

The methodology for calculating the loss caused by evaporation discussed in this paper was taken from the **Regulation Document of the German Association of Engineers VDI**[2] **3479** *Monitoring the emissions from tank farms that are not located in oil processing areas* (German ***VDI-Richtlinie 3479. Emissionsminderung – Raffenerieferne Mineralöltanklager***).

## 2. Application area of VDI 3479
Guidance document VDI 3479 is applied to new tank farms remote from oil refinery sites where the following products are stored and transshipped:
- raw oil,
- motor gasolines,
- diesel fuel,

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[1]Technical Manual (German *Technische Anleitung*) is a document, that is so-called the General Administrative Order (Allgemeine Verwaltungsvorschrift), aimed at ensuring the uniform application of regulations by relevant institutions. For example, the receipt or non-receipt of a permit which is regulated by the Federal Emission Control Act (German *Bundes-Immissionsschutzgesetz*) may depend on compliance with the requirements of ***TALuft.***

[2]**German Engineers Association (VDI e. V),** founded in 1856, is the largest association of engineers and research scientists in Germany. One of the goals of the Association is to represent the interests of its engineers and researchers. In addition, the German Engineers Association (VDI) is a member ASIIN e. V. (Akkreditierungsagentur für Studiengänge der Ingenieurwissenschaften, der Informatik, der Naturwissenschaften und der Mathematik e. V. – Agency for the accreditation of educational programs, preparing students for engineering specialties, informatics, natural science disciplines and mathematics) and takes part in the accreditation of educational programs for engineering specialties in German universities. The Association of German Engineers, as well as other norm-setting organizations, the most famous of which is DIN (Deutsches Institut für Normung – German Institute for Standardization) is a commercial structure. Its main activity is development of standards and other normative documentation. At the moment, there are more than 1,700 standards created by the Association of German Engineers, the so-called VDI Guidelines (VDI-Richtlinien) covering different fields of methods and technology.

- fuel oil,
- aviation fuel,
- kerosene,
- special solvent gasolines,
- additives,
- fuel components.

When verifying the possibility of using the measures specified in VDI 3479 to reduce losses from the evaporation of oil and petroleum products in relation to old tank farms, it is necessary to take into account the existing technical conditions, as well as the environmental conditions and the proportionality of the proposed activities to these factors.

The document refers to the current legislative and regulatory acts, orders and regulations in the field of construction and operation of tank farms. It is emphasized that the rules and regulations for safety in VDI 3479 are not included. It is also mentioned that for important security elements, according to 12. BImschV[3], in some cases additional measures can be required not described in the document in question.

All values of the gas volumes in VDI 3479 are given for the state under normal conditions (273 K, 1013 hPa) after the deduction of the water vapor content.

Guidance document VDI 3479 is not applied to oil tank farms in oil refineries (for this, see VDI 2440) or petrochemical plants. It also can not be applied to petrol stations and reserve stores for end users. This document is not applied to fuels with a predominant share of the biological component, such as E85 and biofuels for diesel engines. In addition, the document is not applied to the storage and transshipment of liquid gases.

## 3. Calculation procedure for VDI 3479

Guidance document VDI 3479 presents a methodology for calculating hydrocarbon emissions from tanks with fixed and floating roofs.

The methodology for calculating for tanks with a fixed roof was developed based on the data obtained during the joint project BMI[4] and DGMK[5] 4590-01 – 4590-12 "Measurement and determination of hydrocarbon emissions during storage, transshipment and transportation of fuels and verification of methods for regulating these emissions"[6].

VDI 3479 states that the total emissions of the tank farm are formed not only of evaporation losses from tanks, but also of emissions from a vapor recovery unit and emissions from dispersed sources, which in turn are formed from the sum of losses in pumps, seals and etc., as well as vapor leakage due to leaks (see VDI 3479, Table 8 - 10).

Further, in this review, attention will be focused solely on evaporation losses from tanks.

*Average annual evaporation losses $L_{Tank}$ from tank*

Average annual losses, $L_{Tank, a}$(kg/year), are calculated taking into account certain factors assigned

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[3]Zwölfte Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes(Störfall-Verordnung – **12. BImSchV**) vom 8. Juni 2005 (BGBlI, 2005, Nr. 33, S. 1599–1620) / № 12 Resolution No. 12 on the execution of the Federal Emission Act dated 8 June 2005.

[4]BMI (Bundesministerium des Inneren) – Federal Ministry for Interior of Germany.

[5]DGMK (Deutsche Wissenschaftliche Gesellschaft für Erdöl, Erdgas und Kohle e. V – Scientific Society of Germany on oil, gas and coal.

[6]BMI-DGMK Gemeinschaftsprojekt 4590-01 bis 4590-12 „Messen und Ermittlung von Kohlenwasserstoff-Emissionen bei Lagerung, Umschlag und Transport von Ottokraftstoffen und Prüfen von Verfahren zur Beherrschung dieser Emissionen", Teil 1: Zusammenfassender Bericht des Gesamtprojekts Teil 2: Berichte zu den Teilobjekten.

to the time period of one year.

The following formula is used for the calculation:

$$L_{Tank,a} = (1 - \eta_{SD}) \cdot ((1 - \eta_{VD}) \cdot f \cdot L_{A,a} + L_{B,a})$$

(1)

where:

$\eta_{SD}$ – pontoon efficiency (minimum 0.95);

$\eta_{VD}$ – efficiency of the breathing valve;

f – color ratio (is determined according to Table 7 of VDI 3479 - see Table 1 below);

$L_{A, a}$ - losses as a result of evacuation of the product from the reservoir and respiration (kg/year);

$L_{B, a}$ - losses when filling the tank (kg/year).

**Table 1.** Coating ratios

| Color | Coating ratio |
|---|---|
| White | 1.0 |
| Aluminum silver | 1.1 |
| Light gray | 1.3 |
| Shingle gray | 1.4 |
| Mouse gray | 1.6 |
| Green | 1.6 |

*Evaporation losses from atmospheric (freely ventilated) tanks with a fixed roof*

Average daily loss from breathing, $L_{A, d}$ (kg/day), is calculated using the following formula:

$$L_{A,d} = f_A \cdot c_n \cdot V_n$$

(2)

$f_A$ – saturation degree (this is the ratio of the concentration reached to the saturation concentration),

$c_n$ - saturation concentration of hydrocarbons in the air-vapor space above the liquid surface (kg/m$^3$),

$V_n$ – average daily volume of evaporation (m$^3$/day).

$$V_n = \frac{T_n}{p_n} \cdot \left( \frac{p}{T_1} - \frac{p}{T_2} \right) \cdot V_G \cdot \frac{1}{t}$$

(3)

$T_n$ – normal temperature in Kelvin ($T_n$ = 273 K);

$p_n$ – normal pressure (in hectopascals) ($p_n$ = 1013 hPa);

p – ambient pressure (hPa);

$T_1$ – the average minimum temperature in the gas space (in Kelvin) (averaging time: from 1 to 11 hours, average values are determined by Table 2);

$T_2$ – average maximum temperature in the gas space (in Kelvin) (averaging time: from 11 to 16 hours, average values (determined by Table 2);

t – application time (t = 1 day);

$V_G$ – the volume of gas space above the product in the tank (in m$^3$) is determined by the formula from Table 2, depending on the type of use of the tank (for transshipment or storage). The storage tank, according to VDI 3479, is a tank with a turnover frequency of about 1 per year. All other tanks are transshipment ones.

To calculate the volume of gas space above the product in the tank in Table 12 of the standard VDI 3479 (see Table 2 below), it is proposed to use the following formulas:

for a transshipment tank, m$^3$, $V_G = 0,5 \cdot V$

for a storage tank, m$^3$,

$V_G = 0,075 \cdot V$

where V – tank volume.

*Average annual losses when breathing and pumping out the product from the reservoir,*

$$L_{A,a}(kg/year).$$

The calculation takes into account the summer and winter period and uses the following formula:

$$L_{A,a} = L_{A,S} \cdot d_S + L_{A,W} \cdot d_W , \tag{4}$$

or:

$$L_{A,a} = f_{A,S} \cdot c_n \cdot V_{n,S} \cdot d_S + f_{A,W} \cdot c_n \cdot V_{n,W} \cdot d_W , \tag{5}$$

where:

$L_{A,S}$ – average daily loss in breathing in summer (kg/year),

$L_{A,W}$ – average daily loss in breathing in winter (kg / year),

$f_{A,S}$ - the saturation degree in summer; it is determined by the formula from Table 2,

$f_{A,W}$ - the saturation degree in winter; it is determined by the formula from Table 2,

$c_n$ – concentration of hydrocarbons saturation in the air-vapor space above the liquid surface $(kg/m^3)$,

$d_s$ – number of summer days in a year,

$d_w$ – the number of winter days per year (in the note it is pointed out that the summer period is from May to September for the latitudes of Central Europe: $d_s$ = 153 153 days per year, and the winter one is from October to April: $d_w$ = 212 days per year)

$V_{n,S}$ – average daily volume of evaporations in summer $(m^3/day)$, ·

$V_{n,W}$ – average daily volume of evaporations in winter $(m^3/day)$.

**Table 2.** Data for tanks used for transshipment and storage.

| | The average temperature of the product in the tank, in K | | The temperature of the gas space, in K | | Saturation degree $f_A$ | | Volume of gas space $V_G$, in $m^3$ |
|---|---|---|---|---|---|---|---|
| | in summer | in winter | in summer | in winter | in summer $f_{A,S}$ | in winter $f_{A,W}$ | |
| Tank for transshipment | 287 | | T1=286.5 T2=303.5[a)] | 278 286 | 0.63 | 0.57 | 0.5*V[c)] |
| Storage tank | 291 | 280 | b) | b) | 1 | 1 | 0.075*V[c)] |

a)   The average maximum temperature of the gas space measured in summer can be at the upper limit of the possible values, if it is taken into account that this temperature was determined at a distance of only approximately 1 m under the dome, with a gas space height of 5.7 m.

b)   There are no data for storage tanks, therefore, the gas temperature values given for the transshipment tanks can be applied.

c)   Tank volume is measured in $m^3$.

**Note**: Due to the fact that procedures for measuring the temperature of gas space T1 and T2, the average product temperature in tank T and the degree of saturation $f_A$ are very labor-intensive, the averaged values based on real measurements can be used for approximate calculations. It should be noted that these values were obtained as a result of measurements on the fuel storage tank, the color ratio of which was 1.1. For tanks with a different color factor, it should be substituted in the formula for calculating evaporation $L_A$ in relation to 1.1.

*Evaporation losses from breathing and pumping from tanks with a fixed roof equipped with breathing valves*

To determine the emissions from a fixed roof tank equipped with breathing valves, the losses for total breath $L_A$ of a freely ventilated tank are multiplied by the coefficient of the breathing valves (1 − ηVD) (see formula (1)).

**4. Conclusion**

As can be seen from the description, the methodology for calculating oil losses from evaporation from tanks with fixed roofs from the Guideline Document of the German Engineers Association VDI 3479 (Germany), and the Russian methodologies equally include the main components of the total evaporation losses: "large" and "small breaths" (while in Germany they operate with the concepts: *loss at work, loss during storage*), but differently evaluate the importance of factors affecting the process of loss occurrence. First of all, this is reflected in the initial data, which are necessary for calculation.

In particular, the German technique operates with three basic formulas and offers most of the data relating to the product temperature, the gas space of the reservoir, the saturation degree of the gas space, etc., based on the data in the table, which gives the average values obtained on test tanks in climatic conditions of Germany. And if this can be permissible for Germany, and even, to some extent, for Europe, then, for example, for Russia such approach in determining the initial data due to the large extent of the territory and the significant difference in the climate between its individual parts would be absolutely unacceptable.

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