Application Note

Gas Factor Calculation

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Table of Contents

1. SCOPE

This document explains the need for using Gas Factor in ultrasonic level meters and the ways of calculating it.

2. OBJECTIVES OF THIS APPLICATION NOTE

- Familiarize the user with various gases/vapors effects when measuring distance.
- Acquaint the user with Gas Factor calculation methods.

Notes:

1. No/wrong Gas Factor ⇒ Level measurement deviation.

2. Correct use of Gas Factor ⇒ Accurate level measurement.

3. BACKGROUND THEORY

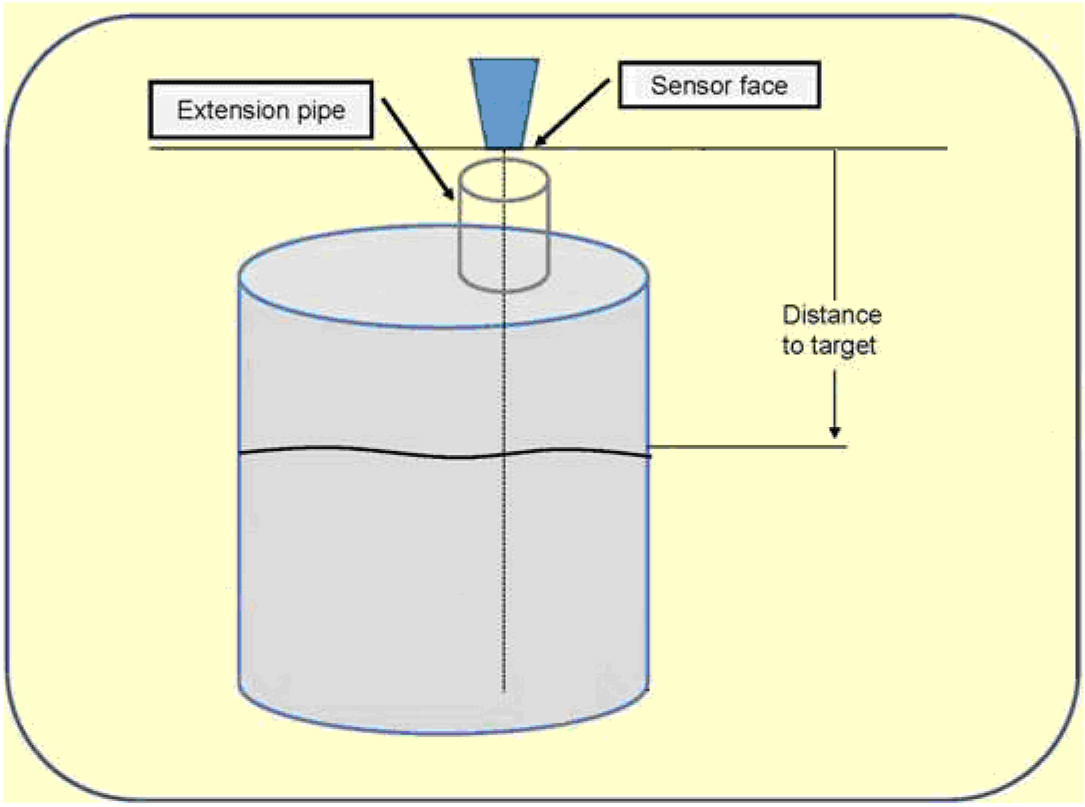
- Ultrasonic level measurement is based on the propagation of an acoustic wave in dry air media between the sensor face and the target surface and then back to the sensor face.
- The propagation speed is known as "the speed of sound" and is about 343m/sec in air at 20°C (331m/sec at 0°C). When the air is filled with vapors, or when the medium between the sensor face and the target surface is gas, the medium's density is different than that of dry air, thus the speed of sound within the medium is different. This results in measurement deviations (the target seems to be farther away or closer to the sensor, depending on the gas type).
- "Gas Factor" is the ratio between the speed of sound in the specific medium that is being used in the application and the speed of sound of dry air at the same temperature.
- SolidAT level meters employ a manual Gas Factor compensation mechanism. The Gas Factor needs to be configured by the customer in accordance with the specific application's medium. The measurement reading is then corrected by the Gas Factor value.

4. GAS FACTOR – CALCULATION METHODS

This chapter describes two empirical ways for Gas Factor calculation.

4.1 Distance Measurement

In this method, the customer is requested to physically measure the distance between the sensor face and the liquid's surface inside the tank and to compare it with the level meter's distance reading in the presence of gas/vapor as exists during the process.



Than:

$$\text{Gas Factor} = \frac{\text{Physical distance}}{\text{Measured distance}}$$

It is advised to repeat this action at several different levels and to set the Gas Factor to an average value.

Advantage: Fits best to the specific application (tank size and medium's composition).
Disadvantage: Physical measurement is not always possible.

Ethanol (C_2H_6O) example:

When measuring a sealed tank that employs Ethanol, and the physical distance is 1m from the sensor face, and the medium between the sensor face and the liquid surface is filled with Ethanol vapors, the measured distance (unless compensated for) will be longer (1.41m) since that the Speed of Sound in Ethanol vapors is slower than in dry air. In this case, the Gas factor will be as follows:

$$\text{Gas Factor} = \frac{\text{Physical distance}}{\text{Measured distance}} = \frac{1\text{m}}{1.41\text{m}} = 0.71$$

4.2 Theoretical Calculation

In this method, the Gas Factor is calculated by a derivates formula that uses the medium chemical parameters:

$$Gas\_Factor = \frac{1}{V}\sqrt{\frac{\gamma RT}{M}}$$

Where:

V = Speed of Sound in dry air = 331m/s @ 0°C
γ = Adiabatic Constant (or Specific heat ratio)
R = Universal Gas Constant = 8.314 Joule / K^0 / mol
T = Temperature = 273.15°K (= 0°C)
M = Molar Mass in kg/mol

Nitrogen (N_2) example:

γ = 1.4
R = 8.314
T = 273.15
M = 0.014 = 0.028
V = 331

$$\frac{\gamma RT}{M} = 113{,}548$$

$$\sqrt{\frac{\gamma RT}{M}} = 337$$

$$Gas\_Factor = \frac{1}{V}\sqrt{\frac{\gamma RT}{M}} = \frac{337}{331} = 1.02$$

Ethanol (C_2H_6O) example:

$\gamma = 1.13$
R = 8.314
T = 273.15
M = 0.046
V = 331

$$\frac{\gamma RT}{M} = 55{,}702$$

$$\sqrt{\frac{\gamma RT}{M}} = 236$$

$$Gas\_Factor = \frac{1}{V}\sqrt{\frac{\gamma RT}{M}} = \frac{236}{331} = 0.71$$

Advantage: No physical measurement is required.
Disadvantages: Requires some information from the Internet (Engineering tables or Wikipedia). Vapors composition and density may not always be easily calculated.

Notes:

(1) Each change of 6℃ (or6°K) deviates the distance measurement by -1% . This deviation is automatically corrected in SolidAT level meters.

(2) Presences of gases and vapors affect the dead-zone distance.

(3) Gas Factor may be exploited by the users to compensate for any type linear deviation that may occur in the application.

Appendix A: Gas Factors list

Gas	Alternative Names	Formula	CAS No.	Molar Mass [kg*mol-1]	Adabiatic Constant	Speed of Sound [m/sec]	Gas Factor	Remarks
Acetic Acid	Ethanoic acid Acetyl hydroxide Hydrogen acetate	$C_2H_4O_2$	64-19-7	0.060	1.15	209	0.63	
Acetone	Propanone 2-propanone	C_3H_6O	67-64-1	0.058	1.11	208	0.63	
Acetaldehyde	Acetaldehyde Ethanal	C_2H_4O	75-07-0	0.044	1.14	242	0.73	
Acetyl Chloride	Ethanoyl chloride	C_2H_3COCl	75-36-5	0.079	1.12	180	0.54	
Acetylene	Ethyne	C_2H_2	74-86-2	0.026	1.23	328	0.99	
Ammonia	Azane Hydrogen nitride	H_3N	7664-41-7	0.017	1.31	418	1.26	
Argon		Ar		0.040	1.67	308	0.93	
Benzene	Benzol Cyclohexa-1	C_6H_6	71-43-2	0.078	1.12	180	0.55	
Bromine		Br_2		0.160	1.28	135	0.41	2 atoms
Bromochlorodifluoromethane	Halon 1211 Freon 12B	$CBrClF_2$	353-59-3	0.165	1.13	125	0.38	
Butanone	Butan-2-one Methyl ethyl ketone Methylpropanone	C_4H_8O or $CH_3CH(OH)CH_2CH_3$	78-93-3	0.072	1.08	184	0.56	
Carbon Dioxide	Carbonic acid gas	CO_2	124-38-9	0.044	1.29	258	0.78	
Carbon Monoxide	Carbonic oxide	CO	630-08-0	0.028	1.40	337	1.02	
Carbon Tetrachloride	Tetrachloromethane Tetrachloromethane Halon 104	CCl_4	56-23-5	0.154	1.11	128	0.39	
Chlorine		Cl_2		0.071	1.36	208	0.63	2 atoms
Dimethyl Ether	Methyl ether Methoxymethane Dimethyl oxide	C_2H_6O or CH_3OCH_3	115-10-6	0.046	1.11	234	0.71	
Ethane		C_2H_6	74-84-0	0.030	1.19	299	0.90	

Ethanol	Ethyl alcohol Hydroxyethane Ethyl hydrate	C_2H_6O	64-17-5	0.046	1.13	236	0.71	
Ethylene	Ethene	C_2H_4	74-85-1	0.028	1.24	317	0.96	
Ethyl Acetate	Ethyl ethanoate Ethyl ester Ester of ethanol	$C_4H_8O_2$	141-78-6	0.088	1.08	167	0.50	
Helium		He		0.004	1.63	962	2.91	
Hexan	n-Hexane	C_6H_{14}	110-54-3	0.086	1.06	167	0.50	
Hydrochloric Acid	Muriatic acid Spirit of Salt Chlorane	$HCl (+H_2O)$	7647-01-0	0.036	1.40	295	0.89	
Hydrogen		H_2		0.002	1.41	1258	3.80	2 atoms
Hydrogen Sulfide	Sulfane Sulfuretted hydrogen Hydrosulfuric acid	H_2S	7783-06-4	0.034	1.30	294	0.89	
Isopropyl Alcohol	IPA Propan-2-ol 2-propanol	C_3H_8O	67-63-0	0.060	1.11	204	0.62	
Methane	Methyl hydride	CH_4	74-82-8	0.016	1.30	430	1.30	
Methanol	Methyl alcohol Hydroxymethane Methyl hydrate	CH_4O	67-56-1	0.032	1.20	292	0.88	
Methyl Hydrazine	Monomethylhydrazine	CH_6N_2 or $CH_3(NH)NH_2$	60-34-4	0.046	1.11	234	0.71	
Neon		Ne		0.020	1.64	430	1.30	
Nitrogen		N_2		0.028	1.40	337	1.02	2 atoms
Nitromethane	Nitrocarbol	CH_3NO_2	75-52-5	0.061	1.17	209	0.63	
Oxygen		O_2		0.032	1.40	315	0.95	2 atoms
Propane		C_3H_8	74-98-6	0.044	1.13	241	0.73	
Propanol	Propan-1-ol Propyl alcohol n-propanol	C_3H_8O	71-23-8	0.060	1.09	203	0.61	
Tetrahydrofuran	Oxacyclopentane Butylene oxide Tetra-methylene oxide	C_4H_8O	109-99-9	0.072	1.13	189	0.57	
Toluene	Phenylmethane Methylbenzene Toluol	C_7H_8 or $C_6H_5CH_3$	108-88-3	0.092	1.09	164	0.50	