

# Scientific Paper

## Humidity-Measuring-Technology for medical gases

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# **Humidity measuring technology for medical gases**

## **1. Introduction**

At present the subject „Compressed air quality for medical gases“ is fiercely being discussed in the trade journals. The trigger for this fierce discussion has been an annex to the European Pharmacopeia.

After expiry of the transitional deadline on 01<sup>st</sup> August 2001 the medical compressed air is subject to the pharmaceutical law. So far medical compressed air has been condensed ambient air, which has been used for artificial respiration as well as for the actuation of respirators as well as for other instruments. The requirements for this compressed air were regulated in the DIN 13260-1 and DIN EN 737-Part 3.

**Herewith the comparison of the quality characteristics according to the old standard and Pharmacopeia.**

<b>Components</b>	<b>DIN 13260-1 and DIN EN 737-Part 3</b>	<b>European Pharmacopeia</b>
Öl	0,5 mg/m <sup>3</sup>	0,1 mg/m <sup>3</sup>
H <sub>2</sub> O	pressure dewpoint +5 °C (Atm. TP -25 °C)	67ppm (Atm. TP -46 °C)
CO	5ppm (ml/m <sup>3</sup> )	5ppm
CO <sub>2</sub>	1000ppm (ml/m <sup>3</sup> )	500ppm
Solid matters	filter class P3 according to EN 143	no data
SO <sub>2</sub>	no data	1ppm
NO NO <sub>2</sub>	no data	2ppm

As you can see from the comparison, the limit value of the dewpoint and pressure dewpoint has been decreased drastically.

How can it be physically understood now, if the DIN 13260-1 and the DIN EN 737-Part 3 use a pressure dewpoint of +5 °C and the European Pharmacopeia 67 ppm (V/V), and -46 °C dewpoint atmospherical? This scientific paper is going to inform you about this.

## 2. Physical basic factors of compressed air technology.

### 2.1 Physical parameters

#### Max. humidity $f_{\max}$ [g/m<sup>3</sup>]

→ is the max. quantity of water vapour, which 1 m<sup>3</sup> air contains at a specific temperature.

#### Absolute humidity $f$ [g/m<sup>3</sup>]

→ is the actually contained quantity of water vapour in 1 m<sup>3</sup> air.

#### Relative humidity $\phi$ [% RH]

→ is the ratio of the absolute to the max. humidity.

#### Atmospheric dewpoint [°Ctd]

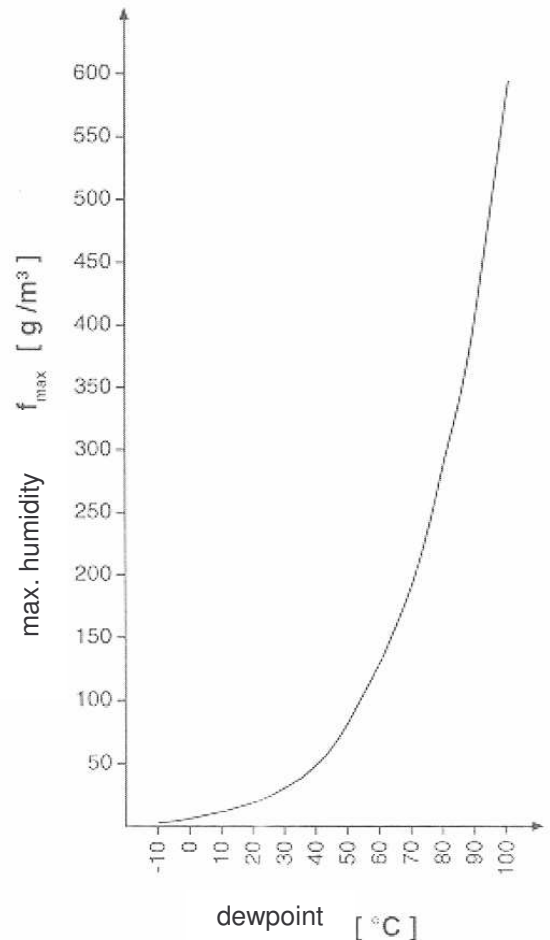
→ is the temperature, to which **atmospheric** air (1 bar<sub>abs</sub>) can be cooled down to, without penetration of water.

#### Pressure dewpoint [°Ctpd]

→ is the temperature, to which condensed air can be cooled down to, without penetration of condensate. The pressure dewpoint depends on the reference ultimate pressure. With decreasing pressure the dewpoint decreases as well.

#### ppm (V/V)

→ The meaning of ppm (V/V) is „parts per million“. It is the ration of water vapour parts to the parts of the total humid air, regarding the volume.



## 2.2 Overview ratios of dewpoint, absolute humidity and water content

dew-point in °C	Absolute humidity in g/m <sup>3</sup>	water content in Vol.-%	dew-point in °C	Absolute humidity in g/m <sup>3</sup>	water content in Vol.-%	dew-point in °C	Absolute humidity in mg/m <sup>3</sup>	water content in ppm (V/V)	dewpoint in °C	Absolute humidity in mg/m <sup>3</sup>	water content in ppm (V/V)
100	588,1	100,0	40	51,08	7,29	5,0	6794	8611	-27,1	455	504
90	418,5	69,3	39	48,57	6,91	4,0	6357	8029	-28,1	415,22	458
85	349,9	57,1	38	46,17	6,55	3,0	5945	7481	-29,0	378,98	416
80	290,8	46,8	37	43,87	6,20	2,0	5557	6967	-29,9	345,61	378
75	240,1	38,1	36	41,67	5,87	1,0	5191	6485	-30,8	314,90	343
70	196,9	30,8	35	39,56	5,56	0,0	4846	6032	-31,8	286,66	311
69	189,1	29,5	34	37,55	5,26	-0,9	4522	5608	-32,7	260,73	282
68	181,6	28,2	33	35,62	4,97	-1,8	4216	5210	-33,6	236,93	255
67	174,3	27,0	32	33,78	4,70	-2,6	3930	4838	-34,6	215,10	230
66	167,2	25,8	31	32,02	4,44	-3,5	3660	4489	-35,5	195,10	208
65	160,4	24,7	30	30,34	4,19	-4,4	3407	4163	-36,5	176,79	188
64	153,8	23,6	29	28,74	3,96	-5,3	3169	3858	-37,4	160,05	169
63	147,4	22,6	28	27,21	3,73	-6,2	2946	3573	-38,3	144,76	152
62	141,3	21,6	27	25,75	3,52	-7,1	2737	3307	-39,3	130,79	137
61	135,4	20,6	26	24,35	3,32	-8,0	2541	3059	-40,2	118,06	123
60	129,7	19,7	25	23,03	3,13	-8,9	2358	2828	-41,2	106,46	111
59	124,2	18,8	24	21,76	2,95	-9,8	2187	2612	-42,1	95,90	99,3
58	118,8	17,9	23	20,56	2,77	-10,7	2026	2411	-43,1	86,30	88,9
57	113,7	17,1	22	19,41	2,61	-11,6	1876	2224	-44,0	77,58	79,6
56	108,8	16,3	21	18,32	2,46	-12,5	1736	2050	-45,0	69,66	71,2
55	104,0	15,6	20	17,28	2,31	-13,4	1606	1889	-45,9	62,49	63,5
54	99,5	14,8	19	16,30	2,17	-14,3	1484	1739	-46,9	55,99	56,7
53	95,0	14,1	18	15,36	2,04	-15,2	1370	1599	-47,8	50,12	50,5
52	90,8	13,5	17	14,47	1,91	-16,1	1264	1470	-48,8	44,81	45,0
51	86,7	12,8	16	13,62	1,79	-17,0	1166	1350	-49,8	40,01	40,0
50	82,8	12,2	15	12,82	1,68	-17,9	1074	1239	-50,7	35,69	35,5
49	79,0	11,6	14	12,06	1,58	-18,8	989	1137	-55,5	19,80	19,2
48	75,4	11,0	13	11,34	1,48	-19,8	910	1042	-60,4	10,64	10,1
47	71,9	10,5	12	10,65	1,38	-20,7	837	954	-65,3	5,53	5,12
46	68,5	10,0	11	10,01	1,30	-21,6	769	873	-70,2	2,77	2,50
45	65,3	9,47	10	9,39	1,21	-22,5	706	798	-75,1	1,33	1,17
44	62,2	8,99	9	8,81	1,13	-23,4	647	729	-80,1	0,62	0,53
43	59,3	8,54	8	8,26	1,06	-24,3	593	666	-85,2	0,27	0,23
42	56,4	8,10	7	7,75	0,989	-25,3	543	607	-90,2	0,11	0,09
41	53,7	7,69	6	7,26	0,923	-26,2	497	553	-95,2	0,05	0,04
40	51,1	7,29	5	6,79	0,861	-27,1	455	504			

Fig.1: equivalents

Calculation according to Wexler, IST 90.

## 2.3 Diversion of atmospheric dewpoint to pressure dewpoint at different pressures.

The new pharmaceutical law prescribes a water content of 67 ppm (V/V) atmospheric. As you can see in fig. 1, this equals an atmospheric dewpoint of  $-46\text{ }^{\circ}\text{C}$ . As during relaxation the dewpoint decreases, this limit value equals ( $-46\text{ }^{\circ}\text{C}$  dewpoint atmospheric) at e. g. 12 bar a pressure dewpoint of  $-21\text{ }^{\circ}\text{C}$ tpd. The table shows, which pressure dewpoint at which pressure is required to attain  $-46\text{ }^{\circ}\text{C}$ td atmospheric.

line pressure in bar	pressure dewpoint at line pressure in °Ctpd	atmospheric dewpoint in °Ctpd	ppm (V/V)*
12	-21	-46	67
11	-22	-46	67
10	-23	-46	67
9	-24	-46	67
8	-25	-46	67
7	-27	-46	67
6	-29	-46	67
5	-31	-46	67
4	-33	-46	67
3	-35	-46	67
2	-39	-46	67

Fig. 2

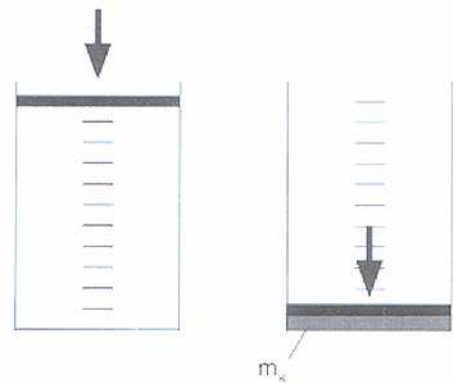
\* according to 1013 mbar and 25 °C

### 3. How does water get into compressed air?

Air has got the capability to set water vapour. The higher the temperature, the more vapour air can set and vice versa. The bigger the air volume, the bigger the quantity of vapour air can contain and vice versa. That results into the fact, that the capability to set water vapour is lower with condensed air.

#### 3.1 Example:

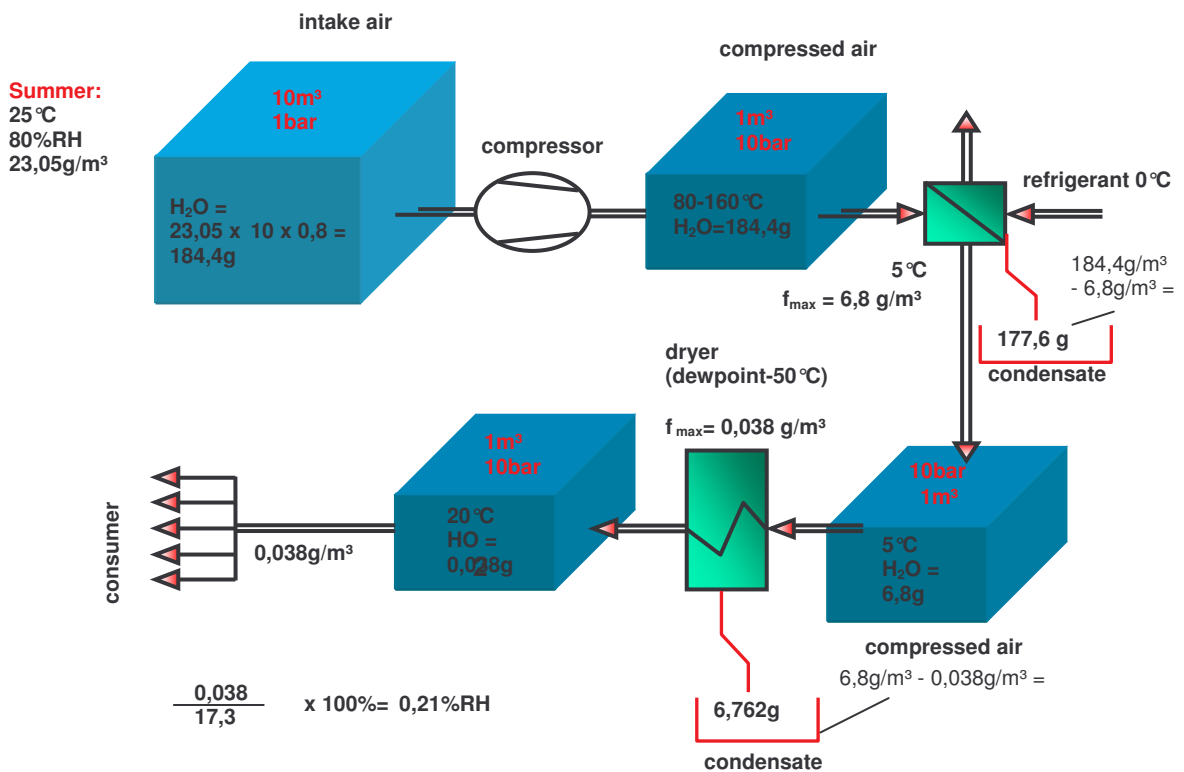
A compressor with a working pressure of 7 bar condenses ambient air to  $\frac{1}{7}$  of its volume, the capability of the air to set water decreases to  $\frac{1}{7}$ . At a specific point of the compression process the water content of the air exceeds the reduced capability of the air to set water. The air is saturated and part of the water vapour condenses, settles as liquid. As only the water settles, which cannot be accumulated, the relative air humidity  $\varphi$  of the condensed air always increases to 100%. By lowering the temperature more water vapour condenses.



The following simple example will show, how a compressed air plant especially works in summer. Within summer especially the hot and humid days are critical for a working compressed air drying plant, the example clearly proves this.

### 3.2 Field example of a compressed air plant with refrigeration cooler and adsorption dryer

On a hot summer day with 25°C and 80% humidity, the air can store a max. of 23,05 g/m<sup>3</sup>. 10 m<sup>3</sup> intake air is compressed to 1 m<sup>3</sup>. The pressure increases from 1 bar to 10 bar. The air content of 1 m<sup>3</sup> equals 184,4 g. During the compression a temperature between 80°C and 160°C can be reached, depending on the type of compressor. There will be no saturation at this temperature, as at this temperature the air is able to accumulate all the water. The pressure dewpoint equals 70°C<sub>tpd</sub>. If now the humidity with a pressure dewpoint of 70°C flows undried into a compressed air plant, a considerable amount of water would condense.



A cooling dryer is topped to the compressor, which cools the flowing compressed air to approx. 2°C – 5°C via a cooling agent. When cooling down 177,6g water condenses. The air with a pressure of 10 bar has got a pressure dewpoint of 5°C, which equals an absolute humidity of 6,8 g/m<sup>3</sup>.

As you can see in the example the limit value is +5 °C<sub>tpd</sub>, which is required by the old standard, which can easily be achieved.

Therefore the limit value of the European Pharmacopeia of 67 ppm (V/V) (atmospheric –46°C dewpoint) can only be reached via an additional drying stage. Obviously adsorption and membrane dryers can be used, which dry air, already pre-dried in a cooling dryer. It is possible here to reach the dewpoints of –46°C atmospheric dewpoint and 67 ppm required in the new pharmaceutical law.

#### **4. Filter and water separators**

By retrofitting additional filter, cooling dryer and adsorption dryer, they try to “get ready” for the new law. However it should be guaranteed to actually reach the required pressure dewpoint. This can only be guaranteed in connection with reliable measuring technology and an alarm in case of a defect.

Erroneously there is the misbelief in the hospital field as well as in the industrial field, that with additional filters and water separators a further drying can be achieved. Additional filter as well as water separators can only divert arising condensation water. Drying compressed air cannot be achieved.

#### **5. Cooling dryer**

Mainly cooling dryers are only monitored by the cooling temperature on a display. This is often regarded as the pressure dewpoint, which leads to a misadjustment of the monitoring. Even if the cooling temperature is in order, the following errors lead to an increased pressure dewpoint within the compressed air systems:

- Condensate at the cooling dryer is not let off (steam trap faulty or dirty).
- Compressed air bypass within the cooling dryer / heat exchanger close up, corrode, etc.
- Compressed air bypass in ambient air piping (valve faulty or not closed).
- Condensate overload of the cooling dryer due to scarce condensate prefractionator.

#### **6. Adsorption dryer**

Pressure dewpoint monitoring only for bigger adsorption dryers or for special applications. No display at smaller adsorption dryers, perhaps there is a colour indicator. Therefore a too high pressure dewpoint does not trigger an alarm. The following faults can occur with adsorption dryers:

- Adsorption agent used up (standard endurance between 3 and 5 years). The endurance can considerably be reduced by overload or lack of condensate and oil prefractionation.
- No sufficient regeneration (nozzle clogged, heater faulty, etc.)
- No change-over (control or valves faulty).

## 7. Why is stationary humidity measurement with alarm important and necessary?

Within the practice it has to be ensured, that the quality of medical gases is constant. As described in chapter 4 to 6, there are several faults, which can lead to condensation or ingress of water within compressed air.

With **aseptic filters** condensation has to be avoided in any case, as those have to be exchanged in case of a defect. This results in considerable costs, as beside the exchange of the filter the piping has to be dried. These possible risks have to be avoided with a reliable measuring instrument.

**Important is a fast response time, in order to react very fast in case of a damage.**

## 8. Practical hints

In order to keep the strict limit values within the hospital field, a stationary measurement in practical operation is necessary, e. g. the FA 200



Technical data FA 410	
Measuring range:	-80...20 °C <sub>d</sub> resp. 20...50 °C <sub>d</sub>
Accuracy:	+ 1°C at 20...20 °C <sub>d</sub> + 2°C at -20...50 °C <sub>d</sub> + 3°C at -50...80 °C <sub>d</sub>
Pressure range:	-1...50 bar special version up to 350 bar
Power supply:	24 VDC (16...30 VDC)
Protection class:	IP 65
EMC:	according to DIN EN 61326
Operating temp.:	-20...70 °C
Connection:	M12, 5-pole
PC connection:	S01 interface
Analogue output:	4...20 mA - -80...20 °C <sub>d</sub> resp. 4...20 mA - -20...50 °C <sub>d</sub>
Burden for analogue output:	< 500 Ohm
Screw-in thread:	G1/2"
Dimensions:	8 30 mm, length approx. 130 mm
Via service software:	- choose units: % RH, °C <sub>d</sub> , g/m <sup>3</sup> , mg/m <sup>3</sup> , ppm V/V - scaling: change 4...20 mA
Special version:	4...20mA, 2-wire technology

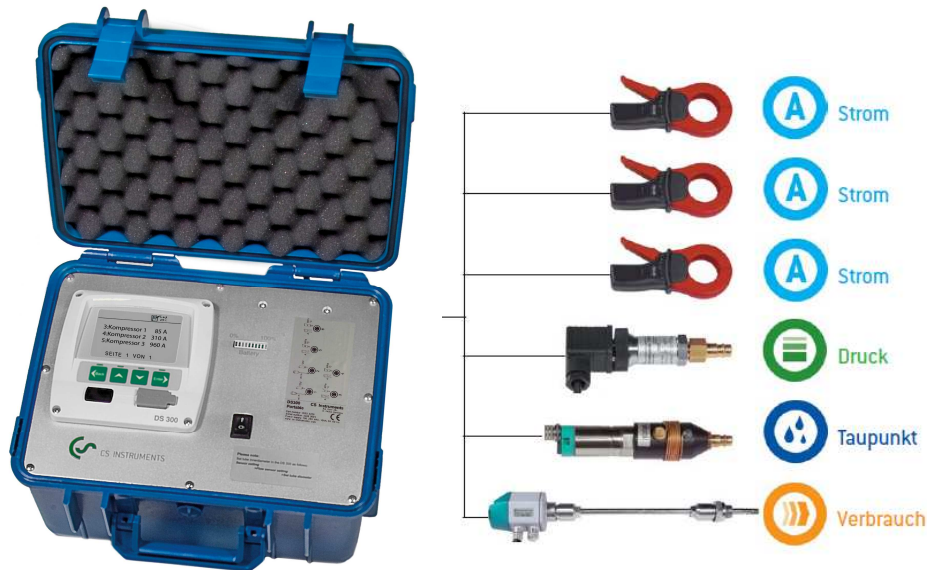
Technical data DS 300	
Dimensions:	118 x 115 x 93 mm, IP 65 (wall housing) 92 x 92 x 70 mm, IP 65 (panel mounting)
Inputs:	2 digital inputs for FA 410 resp. VA 400
Interface:	USB
Keypad:	4 keys
Power supply:	100...240VAC, 50/60 Hz
Accuracy:	see FA 410 page 6
Alarm outputs:	2 relays, 230 VAC, 3 A
Operating temp.:	0...50 °C
Transport temperature:	-20...70 °C
OPTIONS	
Data logger:	1 million meas. values start/stop time, meas. rate freely adjustable

### Special features of the FA 410 dew point set

- Measuring range -80...20 °C<sub>d</sub>
- System ready for plug-in: Everything completely wired
- No time-consuming studying of the instruction manual
- 2 alarm contacts (230 VAC, 3 A), pre- and main-alarm freely adjustable
- 4...20 mA analogue output
- Optical alarm: Red flashing
- Parallel indication % RH, °C, °C<sub>d</sub>

## 9. Mobile measurement

Energy analysis - consumption measurement - leakage calculation at compressed air systems



With the **instrument DS 300 portable** compressed air stations can be analysed. Up to 4 clamp-on ammeters measure the current consumption of the single compressors. Optionally also 4 pressure sensors, temperature sensors or any analogue sensors can be connected.

Additionally, DS 300 measures the actually generated compressed air quantity in m<sup>3</sup>/h, m<sup>3</sup> and the dew point temperature in °Ctd at the same time.

The **integrated data logger** stores up to 1 million measured values.

The operation is very easy.

The **CS Analysis Software** enables a graphic and statistic evaluation of the stored data at the PC. The stored current curves serve for calculation of the **costs in € for the energy consumption (kWh)** as well as **load and non-load times** of every single compressor including switch-on/switch-off cycles.

From the actually consumed compressed air quantity the costs per m<sup>3</sup>, the total costs per year in € are calculated. A special leakage calculation **determines** the cost share of the leakage in the total costs in €.

At the push of one button the user will obtain a DIN A 4 graphic printout as daily and weekly view of each compressor **for documentation of the measured value**.

The additional printout of the statistic values contains all necessary data for a complete analysis of the compressor stations.

The issuing of complex Excel calculations and reports is not applicable.

Each service company can issue a report with the own logo for the end customer.