

FAT

**Forschungsvereinigung
Automobiltechnik**

**Effects of Gaseous Carbon Dioxide on the
Human Organism - A Literature Study**

Speaker:
Dr.-Ing. M. Arndt

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Motivation

CO₂ MIK Value in **Germany** (Source VDI 2310 BI12)

- MIK 3.000ppm (5,4g/m³)

CO₂ limits in **Germany** (Sources: TRGS¹ 900, BMWA)

- MAK²: 5.000ppm (9,1g/m³)
- Spitzenwert³: 10.000ppm (18,2 g/m³)

CO₂ limits in the **US** (Sources: OSHA⁴ 1910.1000, NIOSH⁵, ACGIH⁶)

- PEL⁷: 5.000ppm (9,1g/m³), TWA
- STEL⁸: 30.000ppm (54,0g/m³)
- EDLH 40.000ppm (72,0g/m³),

- Present legal limits focus more on long time CO₂ exposition at work places with respect to potential health risks
- R744 leaks can lead to a short time exposition of the car passengers

What kind of effects on the passengers may result from an elevated CO₂-concentration of the air inside the vehicle ?

¹ Technische Regeln für Gefahrstoffe, Bundesminister für Wirtschaft und Arbeit (BMWA)

² Maximale Arbeitsplatzkonzentration (maximale mittlere Konzentration bei regelm. 8 stündige Exposition ohne Beeinträchtigung der Gesundheit)

³ Maximale mittlere Konzentration innerhalb eines 15 min. Zeitraumes

⁴ Occupational Safety and Health Administration

⁵ National Institute of Occupational Safety and Health

⁶ American Conference of Governmental Industrial Hygienists

⁷ Permissible Exposure Limit (Time weighted average TWA, wie 2)

⁸ Short Time Exposure Limit (wie 3)

Organisation of the Study

Literature Study „Effects of Carbon Dioxide on the Human Organism“

Contractors:

- 1) Staatliches Wissenschaftliches Forschungs- und Versuchsinstitut der Militärmedizin des Ministeriums für Verteidigung der Russischen Föderation, Prof. Buchtijarow, Prof. Stepanow, Prof. Chomenko, Moskau
- 2) Akademie für Militärmedizin , beim Verteidigungsministerium der Russischen Föderation Prof. Dr.med.S.Matwejew, St. Petersburg
- 3) Ministerium des Gesundheitswesens der Russischen Föderation, Institut für Toxikologie, Prof. S. Netschiporenko, Sankt Petersburg

Coordination: DaimlerChrysler RTOM, Moskau

Funding: Corporation funded Research Project

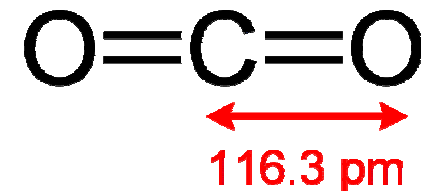
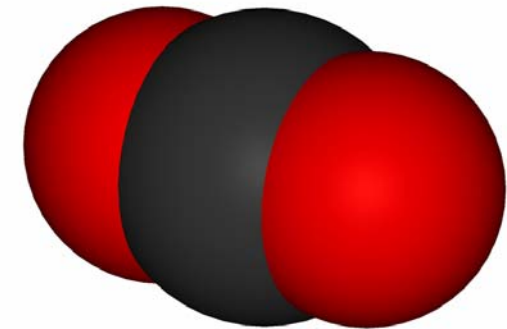
Period: 01.07.2004 to 31.12.2004

Summary and presentation of the results of the literature studies, presentations and discussions with the contractors:

J. Wertenbach (DaimlerChrysler), S. Wiedemann (BMW), M. Arndt (RB)

History

- In the 15th century Leonardo da Vinci described that no animal can live in an **atmosphere** in which a flame does not burn.
- In the 17th century described Van Helmont a substance which appears with a combustion. He named this substance "**Gas**".
- In 1875 two pilots of the airship "Zenith" died at a height of 8.000 meters of oxygen starvation. This was the beginning of the **aviation physiology**.
- In the 20th century a lot of investigations were done on this topic concerning **submarines and spaceships**. Many of those were carried out in the former sowiet union.



This literature study is based on the "20th century" investigations.

Set up of the cited Experiments

Cited Types of Experiments:

- Various Types of Experiments

Main Areas of Research:

- Aerospace Research
 - Airtight Cabins
 - Protective clothing
- Military Research

Several reports on the effects of gas mixtures with elevated carbon dioxide content on the **physiological condition** and **working ability** of humans.

Summary:

The cited literature primarily describes **short time effects**. Stable physiological conditions were not achieved in the experiments. However, the experiments offer the possibility to evaluate the effects of gaseous carbon dioxide on the **human*** or animal **organism**.

*predominantly young, healthy men

Essay from the literature survey (1/7)

CO₂ Concentration < 4%

0% 4% 6% 10% 20%



1. Short stay (some days) in air with carbon dioxide content $\leq 3\%$

- Physical and intellectual working ability was maintained
- No complaints by the tested persons
- Physiological Effects:
 - Moderate increase of the CO₂-content in the alveolar air
 - Breathing-air volume doubled at stable breathing frequency
 - Heart rate and blood pressure constant
 - PH-value of the blood reduced

2. Gaspreferendum Experiments

- Declining reactions to a gas mixture with CO₂-content higher than 3.7%
CO₂ were cited in the studies

Essay from the literature survey (2/7)

CO₂-Concentration between 4% and 6%

0% 4% 6% 10% 20%



1. **60 Minutes stay in 5% to 6% results in:**

- Breathing-air volume increases by a factor of 2.5 to 3.0
- Breathing rate increases moderately
- Very low change of heart rate and blood pressure
- Effects on intellectual working ability could be compensated by the tested persons

2. Feeling and condition (at rest) while breathing **5 % CO₂** was satisfying. A change to **6 % CO₂** was strongly noticed

3. **Moderate physical activity** (e.g. standing up) resulted in strong changes of the physiological condition (heart rate, blood pressure)

4. In the cited literature it is stated, that breathing a concentration of **6% CO₂ for 60 minutes** sets a limit, at which no heavy effects can be expected. This statement is based on experimental data.

Essay from the literature survey (3/7)

CO₂-Concentration between 7% and 9%

0% 4% 6% 10% 20%



1. Stay in CO₂ concentrations between 7 % and 9 %:

- Considerable change in physical condition and feeling
- Headache and heaviness feeling
- Tolerance depends on tested person
- Breathing-air volume increases by a factor of 3.5

2. 14% of the tested persons lost their spacial and visual perception at **7.5% CO₂**

Essay from the literature survey (4/7)

3. Bearing of 8% CO₂ at rest:

- 10% of the tested persons abandoned the 1h-test after 14 minutes
- Well-feeling was rapidly impaired
- Noticeably cramped position
- Breathing-air volume increased by a factor of 4.5
- 25% Increase in heart rate
- Increased blood pressure

4. Bearing of 8% CO₂ at light physical work:

- Physical working ability decreased noticeably in contrast to that at 7% CO₂
- Breathing-air volume and breathing rate increased
- Heart rate and blood pressure increased

0% 4% 6% 10% 20%

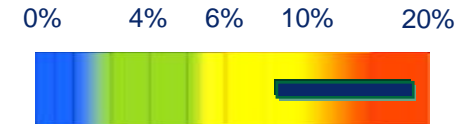


Essay from the literature survey (5/7)

Singular Case Reports about effects at concentrations between 9% und 10% CO₂:

- Increasingly cramped position
- Impaired mobility
- Feeling like having fever
- Heavy headache
- Sweating
- Giddiness
- Visual perception impaired (foggy, misty)
- Increased breathing rate
- Breathing-air volume increased by a factor of 6
- Heart rate increased by +50%
- Increased blood pressure
- Working ability is lost

For CO₂ concentrations of 15% an ability to breathe of some seconds is stated
At CO₂ concentrations of more than 20% cramping of the glottis can occur



Essay from the literature survey (6/7)

Rapid changes of the CO₂-concentration

- Experimental results show that a rapid decrease of the CO₂ concentration of the breathing-air from a high level to a normal level may result in a worse condition.
- It is proposed to decrease the CO₂ concentration slowly, if higher concentrations were present for more than 15 minutes.

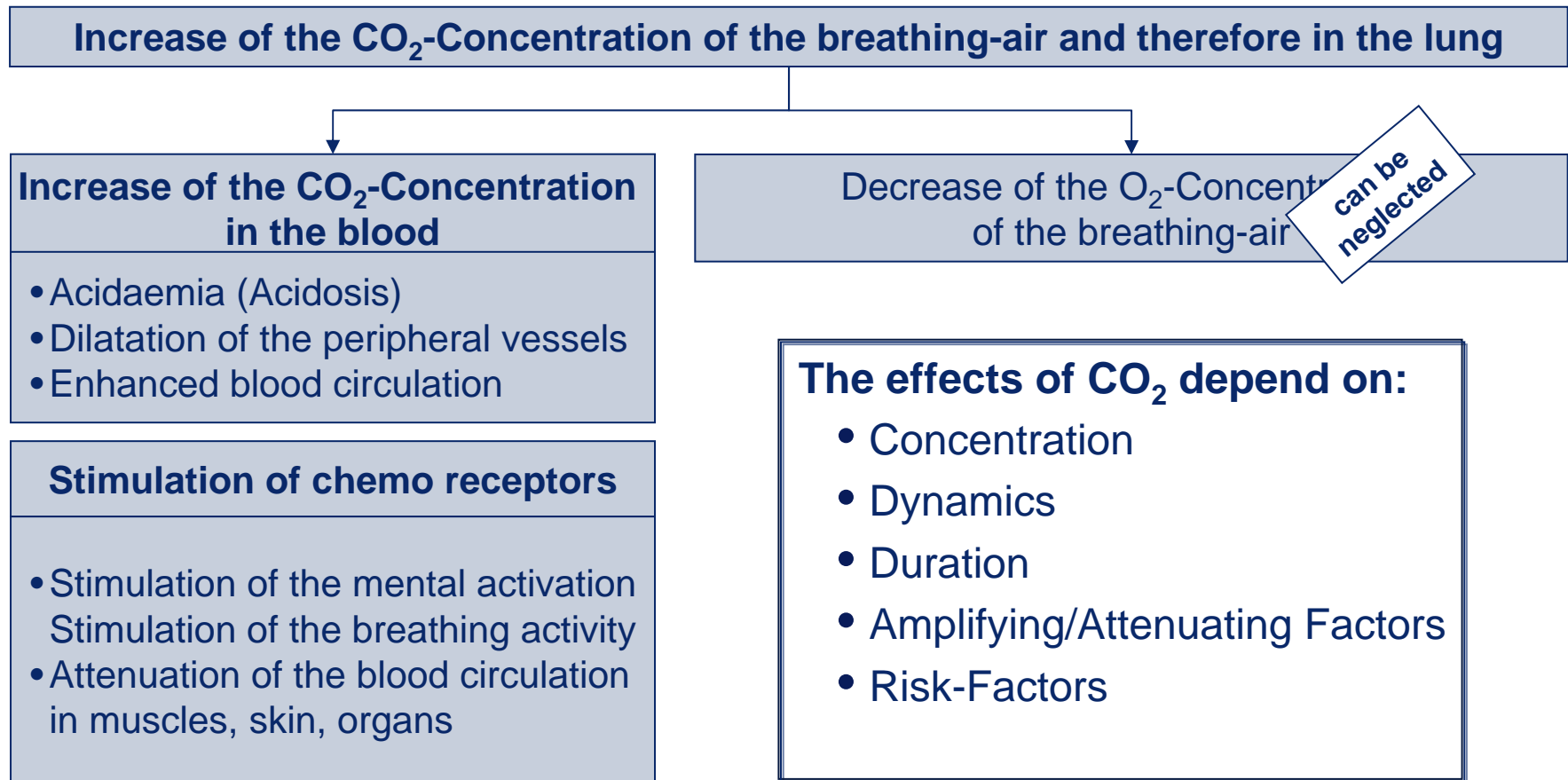
Essay from the literature survey (7/7) – Groups at Risk

The cited experiments were mainly carried out with young, healthy men (Age between 18 and 45 Years)

Groups at risk from a medical point of view are:

- Persons with pulmonary diseases
(e.g. Emphysema, Bronchitis)
- Persons with vascular diseases
(e.g. Coronary-sclerosis, Arteriosclerosis)
- Persons with diseases of the blood system
(z.B. Drepanocythemia)

Summary – Physiological Effects



**The authors would like to say thank you to the
sponsors of this literature study**

Thank You for Listening !