



BGI 690

Leaflet for the treatment of illnesses in compressed air

(Diving and compressed air work)

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Introduction

Decompression illness can occur when working under hyperbaric conditions (compressed air work, diving). As a rule, special therapeutic tables are used to treat the conditions that fall under the general heading of decompression illness (DCI). These tables contain data based on physical laws and the experience gained over decades with the use of specific therapies and treatment methods. The information provided here is based on these tables and clinical data. The purpose of this leaflet is to give doctors, medical advisors, medical assistants and technical staff a practical guide to the common forms of DCI, effective treatment methods for DCI and also to familiarise physicians and health carers with the most important basic principles of treatment.

It is presumed that readers of this leaflet will be familiar with the occupational medical check-up procedures detailed in the G 31 "Compressed Air" Principles published by the German Employers' Liability Insurance Association (BG). Attention is also drawn to the list of relevant publications (see Section 6) provided in the Principles. As a comprehensive overview of the pathophysiology of decompression illness is already provided in the Principles, this leaflet does not go into the topic.

Work in hyperbaric conditions (compressed air and diving) is regulated by the following sets of regulations:

- Regulations on Work in Compressed Air (DruckLV), first published on 4 October 1974 and last updated on 19 June 1997, in conjunction with the announcement published by the Federal Ministry of Labour and Social Affairs dated 26 October 1994 (IIIb2-34572-2, Bundesarbeitsblatt (Federal Labour Gazette) 12/1994, p 52)
- Accident Prevention Regulation on Diving (BGV C23 / formerly VBG 39) in conjunction with Accident Prevention Regulation on Preventive Occupational Health Examinations (BGV A4 / formerly VBG 100).

1 The unit of pressure

1 bar gauge ') is equivalent to the pressure at a depth of 10 metres of water.

1 bar = 100 kPa (= old German unit: 1.019 atü or kp/cm²)

') 1 bar gauge is equivalent to 2 ata (= 200 kPa)

2 Preliminary Measures

2.1 Briefing

Prior to the commencement of compressed air or hyperbaric construction projects, the medical advisor should brief the on-site technical supervisors, or other personnel with sufficient experience to oversee work in compressed air, about the precise details of all technical and medical aspects of work in compressed air, including the effect of hyperbaric pressures, symptoms of all potential decompression-related illnesses and details of how to treat them.

The following issues should be addressed:

- The advantages of breathing oxygen during recompression in an airlock and during treatment (please also refer to Section 3.2.3)
- Emergency care and transportation of patients (including details of how to move casualties in constricted environments)
- The precise location of the operating controls, gauges and communication instruments in the treatment chamber, all of which should, if possible, be in the vicinity of the observation window
- Preparing disposition, contingency and emergency plans
- Provision of a basic treatment kit, including drugs, medicines and instruments

2.2 First Aid Station

Major construction sites involving work in compressed air are required to employ two auxiliary helpers in accordance with § 18 Section 1 No. 6 of the Work in Compressed Air Regulations (DruckLV). Additionally, it is recommended that a first aid station is set up and a medical orderly is appointed. The duties of the medical orderly are to communicate with the doctor and to initiate and carry out first aid treatment in the event of decompression illness. The medical orderly should receive specific instructions on how to recognise symptoms and treat decompression illness.

2.3 Planning additional emergency procedures

To be prepared for serious accidents and/or cases of acute decompression illness it is advisable to contact the nearest suitable hospital to ensure that there is an emergency hyperbaric doctor on duty. It is strongly advised that an emergency drill is conducted.

2.4 Emergency card

It is recommended that all employees are issued with an Emergency Card (please refer to Appendix 1 for a sample).

2.5 Basic kit for treating decompression illness caused by hyperbaric work

An emergency medical kit for treating decompression illnesses and barotraumas must be provided. The kit should be stored in a central location and must be accessible at all times. It should contain a full range of the medication, medicines and instruments required to treat

hyperbaric conditions, e.g., decongestant nose drops and spray, a Politzer balloon, painkillers and infusion solutions.

It is advised that the local conditions for rapid emergency treatment, e.g., the amount of time required for an ambulance to reach the site, the location of the nearest suitable hospital, are taken into consideration when selecting the contents of the basic emergency treatment kit.

Additional information can be provided by the local state physician responsible for health and safety.

3 Treatment management

3.1 Treating barotrauma

Barotraumas occur when insufficient pressure equalisation causes the pressure of the air in the body's cavities to change, resulting in pain and damage to the surrounding tissues. These traumas occur far more frequently during pressure increases than decreases. Barotrauma can affect the lungs, sinuses, middle ear, the skin beneath a face mask or a dry-diving suit, damaged teeth and the intestines. Usually, pressure in the middle ear can be equalised by opening the mouth wide, swallowing, yawning and pressing while keeping the nose and mouth firmly closed (the Valsalva manoeuvre). Slight reductions in pressure and a slower rate of pressurisation are generally an effective method of pressure equalisation. Decongestant nose drops or spray can be applied if the tissues in the nasal passages or the sinuses remain swollen, except when diving. If the subject still experiences pain after

trying these methods then he/she must refrain from working in compressed air until the symptoms have disappeared entirely; failure to do this could result in tissue bleeding or a perforated eardrum.

Exception: recompression to treat decompression illness (please refer to Section 3.2.2).

In the event of a severe barotrauma (perforation of the ear drum, haematotympanum, lung oedema, lung squeeze) specialist medical assistance must be sought immediately.

3.2 Treating decompression illness

3.2.1 General information about decompression illness and accidents Decompression sickness or “caisson” disease

Decompression illness is caused by bubbles of gas in the blood or tissues; these impede the flow of blood and can cause temporary microembolisms and local anoxia, particularly in bradytrophic and fatty tissues (bones, joint cartilage, fatty tissue, central nervous system). The pressure exerted by bubbles on nerve endings can cause severe local pain. Life-threatening complications can arise if the bubbles affect the central nervous system, the circulation and the lungs.

The site and frequency of decompression illness can vary considerably (please refer to Section 6.3 of the G 31 “Compressed Air” Principles published by the German Employers’ Liability Insurance Association).

Decompression illness can be exacerbated by a number of factors at the work place, e.g., low temperatures, wet environment, vibration, pressure fluctuations, physical exertion, as well as personal disposition, e.g., excess body weight, fatigue and alcohol.

As a rule, symptoms will occur in the first few hours after airlocking or surfacing; in certain circumstances, however, occurrence may be delayed and the symptoms can appear many hours later.

Over-expansion of the lungs

Failure to exhale during a rapid drop in pressure – particularly in low pressures – can lead to a dangerous over-expansion of the lungs and ultimately a ruptured lung or pulmonary barotrauma. This condition can occur regardless of the amount of time spent in the hyperbaric environment.

Workers who are decompressed too fast in an airlock are particularly threatened by this condition, as are divers who ascend too fast (emergency ascent). Over-expansion of the lungs can result in pneumothorax, mediastinal emphysema or air embolisms in the major vessels (potentially causing cardiac arrest, damage to the central

nervous system and peripheral damage). Pneumothorax and mediastinal emphysema are treated according to standard clinical procedures; if indicated, these conditions can also be treated in a hyperbaric chamber.

3.2.2 Recompression treatment

The definitive treatment for decompression sickness is immediate recompression in a designated chamber. It is essential that recompression is initiated as soon as any symptoms of decompression illness are detected. Recompression time will depend on the hyperbaric pressure the casualty was exposed to and the time spent at this pressure (please also refer to Section 3.2.7). It is essential that the doctor treating the patient takes these factors into consideration when planning emergency treatment. Effective first aid will greatly increase the chances of subsequent recovery, especially if recompression is likely to be delayed or the patient fails to seek immediate medical treatment. The doctor in charge will decide whether recompression treatment is necessary. In diving accidents the patient should be given 100% oxygen through a tight-fitting face mask until medical treatment can be initiated. In serious cases the doctor should make arrangements for the patient to be treated in a hyperbaric chamber.

Should the doctor be delayed then a helper or medical orderly should remain with the casualty in the hyperbaric chamber until the doctor arrives. Both the doctor and the helper must be fit to work at hyperbaric pressures.

In most cases, additional therapies are not required to treat a patient suffering from decompression illness, e.g. physical therapy or medication. In emergency cases or serious cases of decompression illness (for instance, cases involving dizziness or faintness), however, it may be necessary to administer medication, infusions (the drop rate must be monitored carefully, as it will alter as the pressure changes) or start resuscitation.

If the patient exhibits symptoms of middle ear barotrauma during recompression then the treatment methods outlined in Section 3.1 of this leaflet should be applied as appropriate to the severity of the case. Alternatively, one or a combination of the following can be used:

- Politzer balloon
- Analgesics
- Myringotomy or punctuation of the tympanum in the anterior inferior quadrant, e.g., with a cannula

In the event of life-threatening decompression illness it may be necessary to continue recompression regardless of any middle ear pain experienced by the casualty or the immediate risk of tympanic perforation.

3.2.3 **Recompression treatment with oxygen**

Ventilation with oxygen during recompression can help to shorten treatment time and it also reduces the risk of the patient suffering a relapse. Treatment chambers must always be equipped with oxygen breathing apparatus. It should be taken into consideration that oxygen narcosis may occur, depending on the duration of the treatment and the pressure at which it is carried out. Symptoms of oxygen narcosis are visual abnormalities (tunnel vision), dizziness, nausea, breathing difficulties, and muscular twitching in the face and hands.

General convulsions may also occur without warning. If these symptoms occur, interrupt the supply of oxygen immediately and remove the breathing mask. For this reason it is imperative that a second person is present in the hyperbaric treatment chamber if the oxygen pressure is higher than 1.0 bar.

3.2.4 **Treating relapses**

If the patient still exhibits symptoms of decompression illness after recompression, or if such symptoms recur after the conclusion of the treatment, then recompression should be repeated. Additionally, the patient can be given medication to increase the microcirculation.

3.2.5 **Transferring the patient to a hyperbaric treatment centre**

If possible, casualties should be treated in an on-site treatment chamber at the construction site (if the site is required to provide such a chamber by the Regulations on Work in Compressed Air (DruckLV) or UVV "Diving Work" (VGB 39)). Transfer to a hyperbaric treatment centre should only take place in absolute emergencies.

If the construction site is not required to provide a treatment chamber or medical airlock then the patient should be transferred to the nearest suitable hyperbaric treatment centre. During transfer 100% oxygen at atmospheric pressure should be administered through a tight-fitting breathing mask.

The following centres can provide specialised treatment for decompression illness (last updated: May 1996):

Schiffahrtmedizinisches Institut der Marine

(German Navy Institute of Marine Medicine)

Kopperpahler Allee 120

24119 Kronshagen, Germany

Emergency phone number:

+49 431 5409-1715

(Staff sergeant will put the call through)

Daytime phone number:

+49 431 5409-1782

(Hyperbaric Doctor on duty)

+49 431 5409-1760

(Group Leader for Diving and Hyperbaric Medicine)

+49 431 5409-1720

(Division Leader for Diving and Hyperbaric Medicine)

Bundeswehrkrankenhaus Ulm

(Military Hospital)

Intensive Care Department

Oberer Eselsberg 40

89079 Ulm/Donau, Germany

Tel.: +49 731/171-2285 or -2286

3.2.6 List of hyperbaric treatment chambers

For a complete list of hyperbaric treatment chambers in Germany, please contact the Tiefbau-Berufsgenossenschaft (employer's liability insurance association for the German civil engineering industry), Am Knie 6, 81241 Munich, Germany, tel.: ++0049 89 8897-01.

It is strongly advised that the time required to mobilise any of the chambers on this list is ascertained prior to sending a patient in for treatment.

3.2.7 Treatment tables

The treatment tables for treating decompression illness and caisson disease can be found in Appendix 2.

When applying these tables it is important to differentiate between mild forms of decompression illness (skin symptoms, pain in joints and arms and legs) and severe forms (neurological and cardiorespiratory symptoms) or lung embolisms.

After hyperbaric treatment has been concluded it is strongly recommended that the patient be examined by a specialist in hyperbaric medicine. All patients, regardless of the severity of the decompression illness symptoms experienced, must pass an occupational medical examination in accordance with G 31 “Compressed Air” Principles published by the German Employers’ Liability Insurance Association (BG) before being permitted to resume work.

3.2.8 **Waiting time after recompression**

After treatment the doctor should specify the number of hours the patient must spend in the vicinity of the treatment chamber; the exact length of time depends on the severity of the illness and the duration of recompression treatment, but as a rule the patient will be required to wait for at least six hours. If the patient plans to spend time at high altitude or fly at any point after treatment, then the waiting time should be extended after consultation with the doctor in charge. After mild forms of decompression illness the patient must allow a surface interval of at least 24 hours to elapse after the last recompression treatment before carrying out further work in compressed air.

Severe forms of decompression illness (e.g. after diving accidents) may require the patient to allow a period of several days or weeks to elapse before returning to diving.

3.3 **Treatment reports**

The manifestations, course and prescribed treatment of all cases of decompression illness must be fully documented (please see Appendix 3 for a sample form).

3.4 **Emergency exit / emergency ascent**

In cases of emergencies, e.g., when serious injuries require urgent emergency surgery, it is important to observe correct decompression procedures and ensure that professional emergency medical care is available throughout the procedure. In medical or other emergencies it may be necessary for workers or divers to decompress or ascend rapidly without adhering to the applicable tables. In such cases the patient must be recompressed in a treatment chamber immediately after first aid has been provided.

Appendix 1

Emergency Card printed on red cardboard
(Format: DIN A 7)

Front:

Emergency Card
for compressed air worker / diver

Mr / Ms / Mrs.....

Date of birth.....

is occupationally exposed to compressed air.

This should be taken into account in the event of pains in the joints or arms and legs, or any other acute symptoms which could be an indication of decompression illness.

Reverse

The doctor providing first aid/emergency care is urgently requested to contact the appointed hyperbaric doctor on

telephone number

Construction site.....

to make all necessary arrangements for transferral to and treatment in a hyperbaric chamber.

Appendix 2

Notes on how to use the treatment tables

Introduction

In order to use the tables effectively it is first necessary to diagnose and classify the DCI symptoms the patient is exhibiting. This examination may only be carried out by an experienced hyperbaric or diving doctor. The symptoms can be classified in two general groups:

Type 1 (mild form): marbling of the skin, joint or limb pain

Type 2 (severe form): dysfunction or breakdown of the central nervous system or the cardiorespiratory system; abdominal symptoms may also present

In many cases the “mild” symptoms, e.g., severe pain in the joints, can mask the first manifestations of a severe case of decompression illness, e.g., paraesthesia or muscular weakness. In such cases the patient’s symptoms should be classified as “severe”.

Depending on the therapy required one of the following treatment tables should be applied:

- S1/S2 (S = standard) for standard therapy
- L1/L2 (L = Luft, the German for air) for emergency tables in cases where pure O₂ cannot be
- D1/D2 (D = Druckluft, the German for compressed air) for shortened treatment time for compressed air work

Standard therapy (see illustrations)

Table S1 presents the standard therapy for all cases of decompression illness. Table S2 should be used to treat severe cases of decompression illness, particularly following an emergency ascent (suspected lung embolism). The S2 Table may only be applied by an experienced hyperbaric or diving doctor.

Emergency tables for oxygen toxicity

If the patient starts to exhibit symptoms of oxygen toxicity during treatment then Table L2 may be used as an alternative; Table L1 can be used to treat mild forms of decompression illness (only for workers who have been working in compressed air no deeper than 15 metres).

If it is known before treatment starts that the patient cannot be given pressurised oxygen then oxygen at normal pressure should be administered through a mask while the patient is taken to the nearest hyperbaric treatment centre.

TAB \ msw	50	42	36	30	24	18	15	12	9	6	3	Total time in hours
L1 (in min)				30	12	30	30	60	60	120		07:00
L2 (in min)	30-120	30	30	30	30	360	360	360	720	120	120	38:55

Shortened treatment for work in compressed air (breathing oxygen)

The times given in Table S1 can be shortened if the patient presents only mild symptoms of decompression illness, but only for work in compressed air up to a maximum depth of 15 metres (Table D1); alternatively, Table D2 can be applied. This Table uses a treatment depth of 12 metres (e.g., for O2 intolerance). Tables D1 and D2 schedule regular 5 minute breaks from oxygen during which air is breathed.

TAB \ msw	18	12	9	0	Total time in hours
D1 (in min)	2x(25+5)	30	25+5	30	02:30
D2 (in min)		4x(25+5)		30	02:30

Table S 1

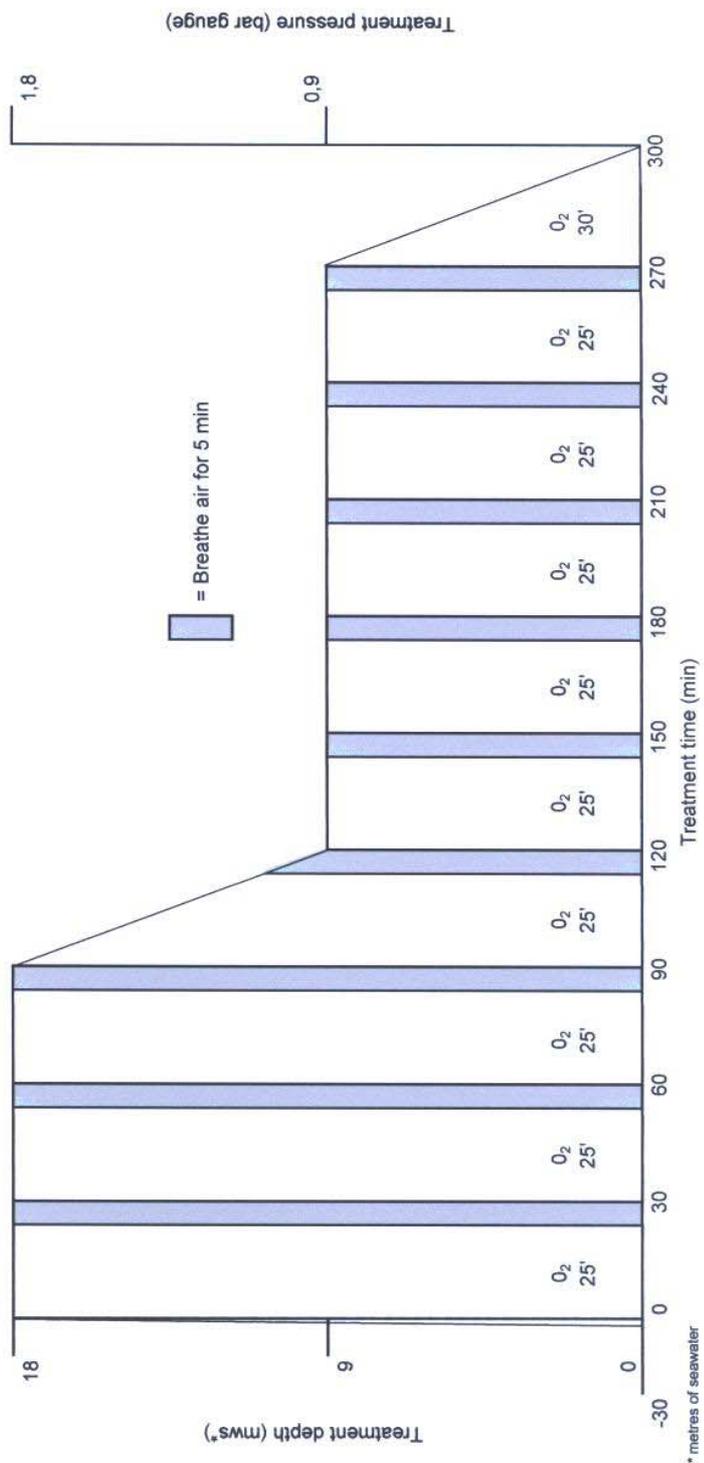
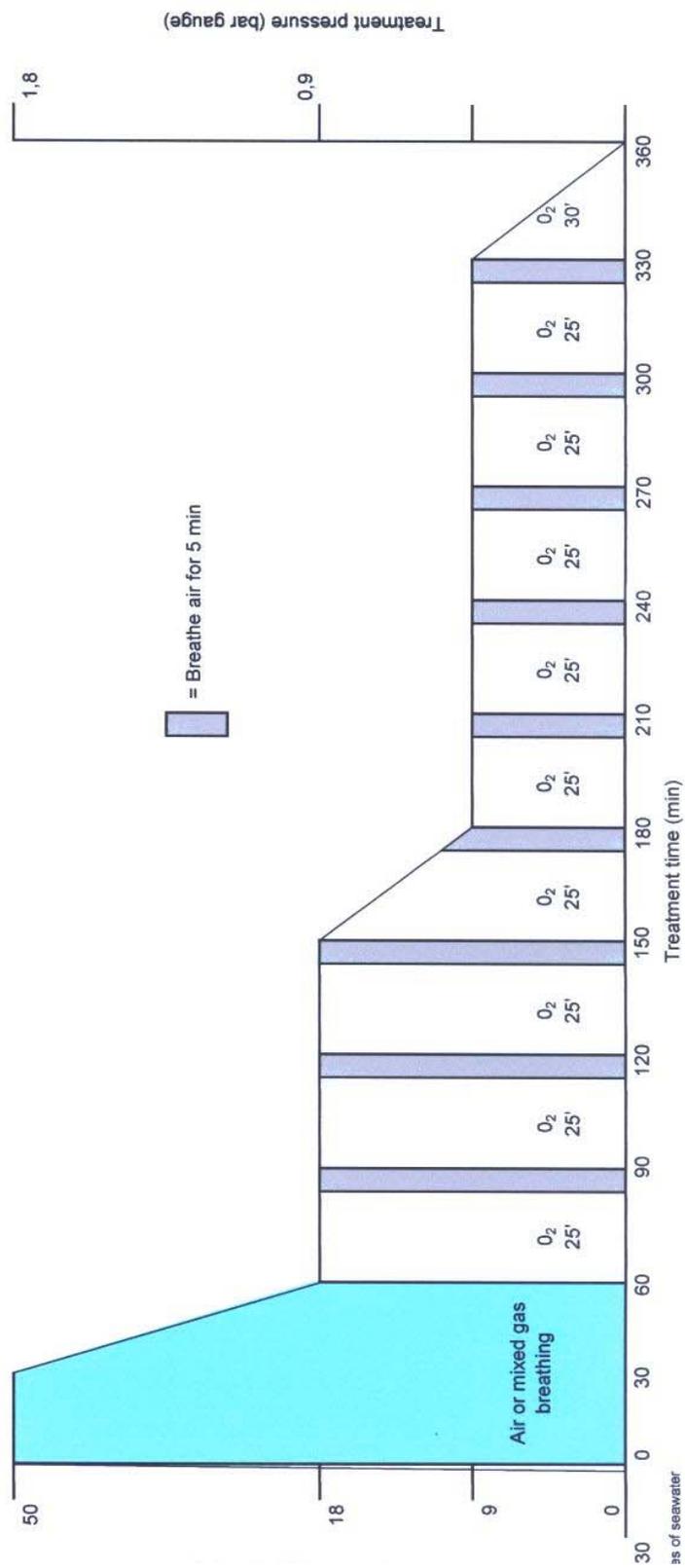


Table S 2



Appendix 3

Consultation, Examination and Treatment Record for a Decompression-Related Illness

No.: / on:(Relapse, see Record No.....)

Name: born on:.....

Working hours on..... from.....to.....hrs (completion of airlocking/ ascent)

Time spent in compressed air/dive duration.....hours

Working pressure..... bar

Airlocked with / without oxygen.....mind')

Work performed during the shift:.....

Details of any particular difficulties: (e.g., humidity, work performed in cramped conditions, noise, vibration)

Details of principle symptoms (type and site).....

When did the symptoms occur?.....

(hours after airlock /ascent)

Medical practitioner Dr.....

advised at time: date.....

Initial medical instructions given by doctor:

Treatment according to column / table:

Recompression from.....tohrs

Time spent in the chamber after completion of treatment.....min

Comments / special occurrences:.....

Please give details if a standard treatment procedure was not used:.....

Pressure (bar).....duration (min)..... time.....

Additional comments:.....

Further instructions given after recompression.....

No further symptoms after treatment /relapse, see record No.....

Form completed by

) only for compressed air work

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