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Welding activities with chromium and nickel alloyed filler and base metal

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Contents

Foreword

The present brochure is mainly addressed to the employer and intends to be of assistance during fulfilment of his/her duties specified in national occupational health and safety regulations, accident prevention regulations and rules, where applicable, and to show possibilities for the prevention of occupational accidents, occupational diseases and occupational health hazards.

The present BG Information Booklet has been prepared with the assistance of the working committee "Schadstoffe in der Schweißtechnik" (Hazardous substances in welding and allied processes) in the expert committee "Metall und Oberflächenbehandlung" (metal and surface treatment), department "Safety and Health" (SiGe) of the German Social Accident Insurance - DGUV (formerly: the Central Office for Safety and Health – BGZ of the Central Federation of the BGs) and is published by the Vereinigung der Metall-Berufsgenossenschaften (association of industrial statutory accident insurance bodies for the metallurgical and metalworking industry).

The Deutsche Verband für Schweißen und verwandte Verfahren (DVS, German association for welding and allied processes) contributed valuable information from practical experience.

The present BGI contains information on the safe evaluation of the welder's exposure to hazardous substances and describes the necessary protective measures, which shall be taken to eliminate or minimise possible hazards during welding activities with chromium and nickel alloyed filler and base metals.

When observing the recommendations contained in the present BG Information Booklet, especially the exemplary possible solutions, the manufacturer can assume that the protection objectives required in TRGS 528 "Welding activities" and in chapter 2.26 "Welding, cutting and allied processes" of BGR 500 "Use of work equipment" are generally complied with. This is, however, also true for other solutions than those described here, provided they achieve at least the same protection level. If technical rules have been determined by the committees established for this purpose in order to substantiate national occupational health and safety regulations, these shall be given priority.

1 General

In clause 3.5 "Auswahl von Verfahren und Arbeitspositionen" (Choice of processes and working positions) of chapter 2.26 "Welding, cutting and allied processes" of BGR 500 and in clause 3.2 of TRGS 528 "Welding activities" it is pointed out that during welding with high alloy welding consumables (filler metal), carcinogenic fractions are released in the welding fume.

Research results (see clause 8) verify that during manufacturing and processing of high alloy chromium nickel steels, high alloy chromium alloys, nickel and nickel alloys by welding, chromium(III) compounds, chromium(VI) compounds, nickel oxides and mixed oxides (spinels) are formed – besides other inhalable components. The amount and the fraction of these substances in the welding fume depend on the welding processes and materials used.

Epidemiological studies (see clause 8) were carried out with regard to health hazards for arc welders (MMA, MAG, MIG, TIG) during welding of non alloyed/low alloy and high alloy chromium nickel steel. Overall, a slightly increased lung cancer risk which was, however, not statistically significant, resulted for arc welders.

The present brochure deals with welding and allied processes during use of chromium and nickel alloyed filler and base metals, e.g.

- high alloy chromium nickel steels,
- high alloy chromium steels,
- nickel and nickel alloys

in considerably more detail than presented in chapter 2.26 "Welding, cutting and allied processes" of BGR 500 and in the TRGS 528. This BG Information Booklet describes the health hazards arising from different welding processes and gives recommendations and information on necessary protective measures on the basis of the results from specific studies (see clause 8).

2 Legal regulations

2.1 BGR 500, chapter 2.26 "Welding, cutting and allied processes"

Clause 3.5
"Choice of process and working position" states:

Clause 3.5.1
"The employer shall select welding, cutting and allied processes with low release of health hazardous substances.

Independently from the selection of the welding processes (Figure 2-1), the employer shall take appropriate ventilations measures in compliance with the Hazardous Substances Ordinance taking processes, materials and conditions of use into account. If these measures are not feasible or their effect is insufficient, additional appropriate respiratory protective equipment shall be made available and used.

Process	Ventilation measures for filler and base metals from stainless steel and non ferrous materials (with the exception of aluminium materials)	
	short-time	long-time
Manual metal arc welding	A	A
MAG, MIG welding	A	A
TIG welding with tungsten electrodes free from thorium oxide	F	T
TIG welding with tungsten electrodes containing thorium oxide	A	A
Submerged arc welding	T	T
Laser beam welding and cladding	A	A
Laser beam cutting	A	A
Plasma arc cutting	A	A
Thermal cutting	A	A
F = free (natural) ventilation T = technical (mechanical) room ventilation A = extraction in the area where hazardous substances are generated		

Figure 2-1: Ventilation in rooms during processes with/without filler metal on the basis of tables 1 and 2 of chapter 2.26 BGR 500

Clause 3.5.2
The employer shall ensure that operating positions, where the effect of health hazardous substances on the insured persons is low, have to be taken.

Clause 3.5.3
Paragraphs 1 and 2 may be deviated from for urgent technical reasons.“

In clause 3.5.1, ventilation measures for the processes and materials used are given, which generally ensure sufficient compliance with the requirements of clause 3.5.

2.2 German Hazardous Substances Ordinance (GefstoffV)

Under the conditions given therein, the ventilation measures described in clause 2.1 satisfy clause 3.5 of chapter 2.26 "Welding, cutting and allied processes" of BGR 500 and thus also comply with the ventilation measures according to §§ 7 to 11 of the German Hazardous Substances Ordinance.

The risk assessment is of special importance and will also be taken into account in the following clauses of the present BGI.

2.3 Technical Rules for Hazardous Substances (Technische Regeln für Gefahrstoffe TRGS)

2.3.1 TRGS 900
In the Technical Rules for Hazardous Substances „Arbeitsplatzgrenzwerte“ (TRGS 900; Limit values at the workplace), technical guidance concentrations (TRK) for carcinogenic substances, including the above chemical compounds, are no longer given in compliance with the new Hazardous Substances Ordinance.

2.3.2 TRGS 905
The TRGS 905 only lists substances which are not specified accordingly by other regulations. Thus, the classification of chromium(VI) compounds and nickel oxides is not included in TRGS 905. A complete list of all substances assessed as carcinogenic, mutagenic or toxic to reproduction can be found under www.baua.de (>Gefahrstoffe>Einstufung und Kennzeichnung>CMR Gesamtliste).

2.3.3 TRGS 402
For the identification and evaluation of the concentrations of hazardous substances at the workplace, TRGS 402 is used.

It describes the proceedings for the evaluation of the inhalation exposure, the exposure assessment and the efficiency of protective measures. The exposure evaluation may either be carried out by means of workplace measurements or by equivalent evaluation methods.

The exposure assessment for substances with occupational limit values is done by comparison with the limit values. For substances without occupational limit values like chromium(VI) compounds or nickel oxides, other criteria are given, e.g. VSK, BG/BGIA recommendations. Here, the values to the state of the art (see as well Table 2 of TRGS 528 and Figure 5-1 on page 17 shall be observed. Even if these values are complied with, a cancer risk may be present. Therefore, measures for exposure minimisation should be aimed at.

For the "Evaluation of substance mixtures in the air at the workplace" during welding and allied processes, reference is made to the "Simplified evaluation procedure based on key components" (see as well BGI 593 clause 3).

If the valid limit value(s) for the key component(s) or the value(s) according to the state of the art (e.g. Cr(VI), Ni) are not reached in the breathing zone of the welder, the concentrations of all other hazardous substance in the hazardous substances mixture are below their relevant limit values.

The result of the evaluation refers to "protective measures sufficient/insufficient". The efficiency control of the protective measures is used for verification of the result.

2.3.4 TRGS 528

Clause 3.3 "Hazard evaluation" of TRGS 528 "Welding activities" indicates welding activities, where carcinogenic substances may be released, especially when welding high alloyed materials.

Measures for the minimisation of the exposure shall therefore be aimed at in order to further reduce a remaining cancer risk.

3 High alloy filler and base metals: Formation, toxicity, classification

3.1 Formation of chromium(VI) compounds

During **manual metal arc welding** with high alloy covered electrodes, the welding fume contains up to 16% of chromium compounds (total chromium), mainly in the form of chromium(VI) compounds.

The high proportion of chromium(VI) compounds of up to 90% of the total chromium is due to the alkali and alkaline earth compounds contained in the cover.

For basic electrodes, chromium in the welding fume is mainly present in the form of chromium(VI) compounds. The chromium(VI) proportion is lower for rutile electrodes than for basic electrodes.

The **gas shielded process MAG** with high alloy flux-cored wires also leads to high amounts of chromium(VI) compounds of up to 60% of the total chromium.

During the processes mentioned above, chromium(VI) compounds mainly occur in the form of chromates, e.g. sodium chromate (Na_2CrO_4), potassium chromate (K_2CrO_4) and calcium chromate ($CaCrO_4$).

The chromium proportion in the welding fume during gas shielded arc welding MAG with high alloy solid wires is as high as that during manual arc welding, the proportion of the chromium(VI) compounds, however, is much lower.

During **plasma arc cutting** with pressurized air and during **laser beam cutting** of high alloy steel (chromium nickel steel), considerable amounts of chromium(VI) compounds were also measured. Chromium(VI) compounds may as well be formed in high quantities during **thermal spraying** with high chromate content of the spraying materials. Here, chromium(VI) compounds are assumed to occur in the form of chromium trioxide. Chromium(VI) compounds are also formed during welding over of formerly common zinc chromate containing shop primers (repair welding).

3.2 Formation of nickel oxides

Nickel oxides (NiO, NiO_2, Ni_2O_3) are mainly formed during

- welding with nickel and nickel alloys as filler metals (especially during MIG welding),
- plasma cutting of high alloy chromium nickel steel or of nickel and nickel alloys,
- thermal spraying with nickel and nickel alloys as spraying materials.

The nickel proportion in the fume - as compared to the nickel proportion in the filler metal - is extremely low for manual metal arc welding with high alloy covered electrodes (1% to 3% nickel oxide in the fume). Here, mainly mixed oxides (spinels) are formed.

During MAG welding of high alloy chromium nickel steel, the welding fume contains up to 5% of nickel oxide.

During MIG welding with nickel and nickel alloys the nickel oxide content in the welding fume may achieve values of 30% to 84%.

During TIG welding of high alloy chromium nickel steel, nickel and nickel alloys, the proportions of chromium(VI) compounds and nickel oxide in the welding fume are negligible.

3.3 Hazard classification of the emissions of chromium(VI) compounds and nickel oxides

The findings from clauses 3.1 and 3.2 are summarized in Figure 3-1. On this basis, the identified hazards may be classified into a three stage hazard sequence (relatively high, medium and low emission of chromium(VI) compounds and nickel oxides). This classification allows for graded protection measures.

Filler and base materials	Hazard classification of emissions of chromium(VI) compounds and nickel oxides for different welding processes			
	MMA	MAG	MIG	TIG
High alloy Cr-Ni steel Cr 5 ... 30 % and Ni 0 ... 30 %	h due to Cr(VI)-compounds	solid wire m due to NiO, possibly Cr(VI)-compounds flux-cored wire h due to Cr(VI) compounds	- - -	n as Cr(VI) compounds and NiO[1])
Nickel and nickel alloys Ni > 30 %	h mainly due to NiO (also mixed oxides)	h mainly due to NiO	h mainly due to NiO	n as NiO[2])

h = relatively high emissions of chromium(VI) compounds or nickel oxides
m = medium emissions of chromium(VI) compounds or nickel oxides
n = low emissions of chromium(VI) compounds or nickel oxides

[1]) only occur in negligible quantities

[2]) only occurs in negligible quantity

Figure 3-1: Hazard classification with respect to the relative amount of emissions of chromium(VI) compounds and nickel oxides for different welding processes

As already mentioned, also plasma arc cutting and laser beam cutting and thermal spraying produce relatively high emissions of chromium(VI) compounds and nickel oxides so that here as well a classification of the hazard into range "h" is justified.

3.4 Toxicity of chromium(VI) compounds and nickel oxides

Chromium(VI) compounds are of special importance under occupational medical aspects, since they may have a carcinogenic effect on humans.

The chromium(VI) compounds may be divided into

- water soluble (e.g. mono-chromates and di-chromates of sodium and potassium) and
- water insoluble (e.g. zinc chromates, calcium chromate, lead chromate, barium chromate, chromium trioxide.)

compounds.

Water soluble chromium(VI) compounds may cause irritations of the respiratory tract and damages to kidneys and liver. Water insoluble chromium(VI) compounds were found to have a carcinogenic effect on the human organism (lung cancer).

On the other hand, chromium(III) compounds have a low toxicity and are therefore harmless under occupational medical aspects.

At present, there are no data on the effects of mixed oxides (spinels). Therefore, no statement on their toxicity is possible at the moment.

Nickel oxides are water insoluble compounds, which may have a carcinogenic effect on humans and are therefore of importance under occupational medical aspects comparable to chromium(VI) compounds.

3.5 Classification of chromium(VI) compounds and nickel oxides

Chromium(VI) compounds are classified as follows in Annex I of the EU Directive 67/548/EEC (TRGS 905 no longer lists these substances):

carcinogenic: category 1[1])

- zinc chromate
- zinc potassium chromate
- chromium trioxide (M:2, R_F: 3)

[1]) Substances known to be carcinogenic to humans

carcinogenic: category 2[2])

- chromium(VI) compounds, e.g. potassium chromate (M: 2), potassium dichromate (M: 2, R_F: 2, R_E: 2), sodium chromate (M: 2, R_F: 2, R_E: 2), sodium dichromate (M: 2, R_F: 2, R_E: 2), calcium chromate

  (with the exception of e.g. zinc chromate, zinc potassium chromate, lead chromate)

[2]) Substances which should be regarded as being carcinogenic to humans

carcinogenic: category 3[3]):

- lead chromate

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[3]) Substances, which give rise to concern due to possible carcinogenic effects on humans

M = mutagenic
R_F = toxic to reproduction
R_E = teratogenic

(Categories 1 - 3 in accordance with Annex VI of Directive 67/548/EEC)

Nickel oxide is classified as follows:

Category 1

- nickel monoxide
- nickel dioxide
- dinickel trioxide

These substances may cause malignant tumours in humans.

For limit values, see as well clause 2.3.1

3.6 Hazard identification, results of workplace measurements

A large number of measurements were carried out within the framework of a measuring program by the Berufsgenossenschaften (see clause 8). Personal measurements (in the welder's breathing zone) as well as stationary measurements (in the room) were effected. They yielded the following results:

Chromium steels and chromium nickel steels

It has to be assumed that the values 0,1/0,05 mg/m³ (indicative values with respect to the state of the art, Dec. 2004) for the concentration of chromium(VI) compounds in the breathing zone of welders working with high alloy filler metals without ventilation measures are

- always exceeded during **manual metal arc welding with covered electrodes**,
- often exceeded during **MAG welding with flux-cored wire**,
- often not reached during **MAG welding with solid wire**,
- always far from being reached during **TIG welding**,
- often exceeded during **plasma arc cutting, laser beam cutting** and **thermal spraying**.

For nickel oxide the concentration in the breathing zone of welders working with high alloy chromium nickel filler metal is in most cases below 0,5 mg/m³ (indicative value with respect

to the state of the art, Dec. 2004) during manual metal arc welding and MAG welding with solid wire and is always and significantly below that value during TIG welding.

During **manual metal arc welding** of chromium nickel steel with high alloy covered electrodes, the concentration of nickel oxide is nearly always lower than 0,5 mg/m³ even without special protective measures.

During **MAG welding** with solid wire and **without** ventilation measures, the exposure to nickel oxides in many cases exceeds the concentration value of 0,5 mg/m³.

During cutting of chromium nickel steel with the processes **plasma arc cutting** or **laser beam cutting,** the concentration of nickel oxide considerably exceeds the value of 0,5 mg/m³ without relevant ventilation measures; the same is true for thermal spraying.

Nickel and nickel alloys

During manual metal arc welding and especially during **MIG welding** of nickel and nickel alloys, high exposure of the welder to nickel oxide is found. In this case it has to be assumed that without relevant protective measures the concentration of nickel oxide will always exceed the value of 0,5 mg/m³.

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During **tungsten inert gas welding** of nickel and nickel alloys, the concentration of nickel oxide is always found to be below 0,5 mg/m³.

The results of workplace measurements for chromium(VI) compounds and nickel oxide are summarized in Figure 3-2.

The tables in figure 3-1 (see page 9) and 3-2 (page 13) show that the welders working without ventilation measures, especially as **manual metal arc welders** with high alloy covered electrodes or as **MAG welders with high alloy flux-cored wire** are subject to a relatively high exposure to **chromium(VI) compounds** and thus to an increased hazard. For these groups of persons, an increased cancer risk cannot be excluded. Some investigations, however, indicate a slightly increased risk of cancer for welders in general.

A relatively high **exposure to nickel oxide** and a correspondingly increased hazard can be assumed for welders who especially carry out **metal inert gas welding (MIG) of nickel and nickel alloys**. During **plasma arc cutting, laser beam cutting** and **thermal spraying without** ventilation measures, an increased hazard may also be assumed.

For the **TIG welder,** the hazard caused by chromium(VI) compounds or nickel oxides is found to be **very low** during welding with high alloy chromium nickel steel and with nickel and nickel alloys.

During **resistance welding**, e.g. spot welding, of high alloy material, a hazard caused by chromium(VI) compounds or nickel oxide is practically excluded.

During **submerged arc welding** with high alloy filler metals, a hazard caused by chromium(VI) compounds or nickel oxide **is improbable.**

Process	Exposure to chromium(VI) compounds for chromium steels and chromium nickel steels		Exposure to nickel oxide for chromium nickel steels		Exposure to nickel oxide for nickel and nickel alloys	
	above 0,1/0,05 [1)]	below 0,1/0,05 [1)]	above 0,5 [2)]	below 0,5 [2)]	above 0,5 [2)]	Below 0.5 [2)]
Manual metal arc welding with covered electrodes	always	–	–	nearly always	–	nearly always
MAG welding with solid wire	–	often		often	nearly always	–
MAG welding with flux-cored wire	often	–	–	nearly always	–	–
MIG welding	–	–	–	–	nearly always	–
TIG welding	–	always	–	always	–	nearly always
Plasma arc cutting	often	–	always	–	always	–
Laser beam cutting	often	–	always	–	always	–
Thermal spraying	often	–	always	–	always	–

[1)] Indicative value for chromium(VI) compounds with respect to the state of the art December 2004 (0,1 mg/m³ for manual metal arc welding; 0,05 mg/m³ for all other processes)

[2)] Indicative value (0,5 mg/m³ for all processes) for nickel oxide with respect to the state of the art December 2004

Figure 3-2: Exposure at the workplace to chromium(VI) compounds and nickel oxide without ventilation measures or for insufficient efficiency of ventilation measures

4 Non alloyed and low alloy filler and base metals

During welding with non alloyed or low alloy filler metals (chromium or nickel proportion below 5%), a hazard caused by chromium(VI) compounds or nickel oxides is improbable.

Here as well, however, results of more recent studies indicate a slightly increased cancer risk rate for welders in general.

5 Evaluation of results, protection measures and preventive occupational medical examinations

In order to minimise exposure of the welders during welding activities with chromium and nickel alloyed filler and base metals - especially when carcinogenic substances like chromium(VI) compounds and nickel oxide are generated - the measures based on the results described in clauses 3 and 4 shall be taken in the order given below.

5.1 Protective measures for range „h“ Relatively high emissions of chromium(VI) compounds and nickel oxide

1. Use of high alloy covered electrodes with low content of sodium and potassium or their substitutes which reduces the formation of chromates.

2. Conversion of welding with high alloy covered electrodes to gas shielded arc welding (MAG welding only with solid wire or TIG welding), if technically possible, see clause 3.5 "Selection of processes and working positions" of chapter 2.26 "Welding, cutting and allied processes" of the BG Rule "Use of work equipment".(BGR 500) and clause 4.2 of TRGS 528. During MAG welding, only a small amount of chromium(VI) compounds is generated; during TIG welding, chromium(VI) compounds and nickel oxide are negligible.

3. Optimizing the process specific parameters, e.g. current, voltage, cutting rate, which generally is achieved by compliance with the values given by the manufacturer; on the whole, this leads to lower fume emission.

4. Use of pulsed arc welding techniques during MAG welding, as far as technically possible; on the whole, this leads to lower fume emission.

5. Effective extraction of the welding fumes in the area of generation, e.g. torch integrated extraction during MAG/MIG welding and under-table extraction for plasma arc cutting (see as well clause 4.4 TRGS 528); if an effective extraction of the fumes in the area of generation (a local extraction) is not possible for technical reasons, another type of ventilation, e.g. room ventilation shall be chosen. For other ventilation measures see as well BG Rule “Arbeitsplatzlüftung - Lufttechnische Maßnahmen” (BGR 121) (Ventilation at the workplace - ventilation measures), DVS/VDI Directive 6005 “Lüftungstechnik beim Schweißen und bei verwandten Verfahren” (Ventilation techniques during welding and allied processes) and BG Information Booklet "Schadstoffe beim Schweißen und bei verwandten Verfahren" (Hazardous substances in welding and allied processes) (BGI 593).

6. The capture element should always be placed as close as possible to the fume generation area.

7. Favourable working position, in which the breathing zone is mainly kept free from welding fumes: e.g. no bending over the welding location. Appropriate positioning of the workpiece (see as well chapter 2.26, clause 3.5 BGR 500 and clause 4.7 TRGS 528).

8. Water cover or water protection device for plasma arc cutting.

9. Booths for thermal spraying, see BGI 593.

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10. Use of respiratory protective devices supplementary to the protective measures mentioned above in areas like vessels, containers, ship access floor cells or other areas with restricted air exchange, see clause 3.5 "Selection of processes and working positions" of chapter 2.26 "Welding, cutting and allied processes" of BG Rule "Use of work equipment" (BGR 500) and clause 4.7 TRGS 528 § 4 para. 2 of the accident prevention regulation "Principles of prevention" (BGVA1), BG Rule "Einsatz von Atemschutzgeräten" (Use of respiratory protective equipment) (BGR 190) and BG Information Booklet "Zertifizierte Atemschutzgeräte" (Certified respiratory protective devices) (BGI 693).

5.2 Protection measures for range „m“: Medium emission of chromium(VI) compounds and nickel oxide

1. Use of pulsed arc welding techniques during MAG welding, as far as technically feasible (see clause 5.1, paragraph 4).

2. Optimizing the process specific parameters, e.g. current and voltage, which is generally achieved by compliance with the values given by the manufacturer (see clause 5.1, paragraph 3).

3. Effective extraction of the welding fumes in the area of generation, e.g. torch integrated extraction during MAG/MIG welding, if an effective extraction of the fumes in the area of generation is not possible for technical reasons, another type of ventilation, e.g. room ventilation shall be chosen (see clause 5.1, paragraph 5).

4. The capture element should always be placed as close as possible to the fume generation area.

5. Favourable working position, in which the breathing zone is mainly kept free from welding fumes, e.g. no bending over the welding location; appropriate positioning of the workpiece.
   See chapter 2.26, clause 3.5 BGR 500 and clause 4.7 TRGS 528,

6 Use of respiratory protective equipment supplementary to the protective measures mentioned above in areas like vessels, containers, ship access floor cells or other areas with restricted air exchange. See chapter 2.26, clause 3.5 BGR 500 and clause 4.7 TRGS 528, BGR 190 and BGI 693.

5.3 Protection measures for range „n“ Low emissions of chromium(VI) compounds and nickel oxide

No special measures as in clauses 5.1 and 5.2 required.
See chapter 2.26, clause 3.5 BGR 500, BGI 790-012 and clauses 3.2 and 4 of TRGS 528.

Optimizing the process-specific parameters and favourable working positions are also useful in this case (see explanations in 5.1 and 5.2).

5.4 Additional information on risk assessment

If the employer realises that the welding workplace to be assessed is not described by the cases contained in Figure 3-1 (process, materials and ventilation measures), or that it deviates from the protection measures for the ranges "h" and "m", a new evaluation of the

workplace on the basis of §§ 7 to 11 of the German hazardous substances ordinance in combination with TRGS 402 followed by an appropriate specification of ventilation measures required has to be effected.

In accordance with TRGS 528, clause 3.2 "Risk assessment" and the related Table 1 "Assessment of processes on the basis of emission rates taking into account workplace specific factors or effects; assignment to hazard classes" welding processes like MMA, MAG and MIG, the welding fumes of which contain carcinogenic substances, shall be assigned to the hazard category "high" and thus the protective measures given in TRGS 528 shall be implemented.

Table 5-1 represents the state of the art on the basis of exposure data for welding activities.

The data are based on workplaces with fume extraction.

<table>
<tr><th>Process</th><th>Welding consumable or material</th><th>Welding fume in mg/m³</th><th>Chromium(VI) compounds in mg/m³</th><th>Nickel and its compounds in mg/m³</th><th>Ozone in mg/m³</th><th>Nitrogen oxides in mg/m³</th></tr>
<tr><td>Gas welding (autogenous welding)</td><td>Non-alloyed, low alloyed steels</td><td colspan="3">Particulate emissions insignificant</td><td>Not assign-able[1])</td><td>Not assign-able[1])</td></tr>
<tr><td rowspan="2">MMA</td><td>Non-alloyed, low alloyed steels</td><td>≤ 3(A)
≤ 10 (E)</td><td colspan="2">insignificant</td><td rowspan="2">Not assign-able[1])</td><td rowspan="2">Not assign-able[1])</td></tr>
<tr><td>High alloy steels</td><td>≤ 3 (A)
≤ 10 (E)</td><td>≤0,03 (E)</td><td>≤ 0,05 (E)</td></tr>
<tr><td rowspan="2">MAG/MIG</td><td>Non-alloyed, low alloyed steels</td><td>≤ 3 (A)
≤ 10 (E)</td><td colspan="2">insignificant</td><td rowspan="2">≤ 0,2</td><td rowspan="2">Not assign-able[1])</td></tr>
<tr><td>High alloy steels</td><td>≤ 3 (A)
≤ 10 (E)</td><td>≤ 0,02 (E)</td><td>≤ 0,1 (E)</td></tr>
<tr><td>Submerged arc welding</td><td></td><td>≤ 1 (A)</td><td colspan="2">insignificant</td><td colspan="2">insignificant</td></tr>
<tr><td>TIG welding[2])</td><td></td><td>≤ 1 (A)
≤ 2 (E)</td><td>≤ 0,01 (E)</td><td>≤ 0,01 (E)</td><td>≤ 0,1</td><td>Not assign-able[1])</td></tr>
<tr><td>Resistance welding</td><td></td><td>≤ 2 (A)
≤ 4 (E)</td><td colspan="2">insignificant</td><td colspan="2">insignificant</td></tr>
<tr><td>Thermal spraying (flame, arc, plasma spraying)</td><td></td><td>≤ 2 (A)
≤ 10 (E)</td><td>≤ 0,01 (E)</td><td>≤ 0,05 (E)</td><td>Not assign-able[1])</td><td>Not assign-able[1])</td></tr>
<tr><td>Thermal cutting</td><td></td><td>≤ 3(A)
≤ 10 (E)</td><td colspan="2">insignificant</td><td>Not assign-able[1])</td><td>NO: ≤ 2,5
NO_2: ≤ 2</td></tr>
<tr><td colspan="7">[1]) State of the art not assignable as data for the specification of a value are not available in sufficient quantity. Number 5.1, paragraph 9 shall be applied
[2]) see as well BGI 790-012</td></tr>
</table>

Figure 5-1: Overview on the state of the art based on Table 2 of TRGS 528 (state 2009)

5.5 Preventive occupational medical examinations

According to the ArbMedVV (German ordinance on preventive occupational medical care), preventive occupational medical examinations shall be carried out for the ranges specified in clauses 5.1 to 5.4 in compliance with the DGVU Grundsatz für arbeitsmedizinische Vorsorgeuntersuchungen (Principle of the DGUV for preventive occupational medical examinations)

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if 3 mg/m³ of A dust is exceeded. For a welding fume concentration not exceeding 3 mg/m³ for A dust, these preventive examinations shall be offered.

For exposures to carcinogenic substances such as chromium(VI) compounds and nickel oxide, preventive occupational medical examinations in accordance with Part 1 of the Annex to the ArbMedVV depending on the exposure level shall be arranged for or a regular offer has to be provided (G15 "Chromium(VI) compounds", G38 "Nickel or its compounds"). In this context see as well clause 6 auf TRGS 528.

Also for the use of respiratory protective equipment, obligatory examinations in accordance with Part 4 of the Annex to the ArbMedVV are required for respiratory equipment of groups 2 and 3 and offered examinations are required for respiratory protective equipment of group 1. These examinations shall be carried out in compliance with G 26 „Respiratory protective equipment" (for respiratory protective equipment weighing more than 3 kg and with breathing resistance).

5.6 Other protective measures, efficiency verification

If additional measures exceeding those given in clauses 5.1 to 5.4 are required, e.g. marking duty, prohibition against eating and drinking, the relevant regulations of the German hazardous substances ordinance (GefStoffV), especially §§ 5, 16, and 19 shall be applied.

Efficiency of the protective measures taken shall be verified (see § 8 GefStoffV). Technical protective measures, e.g. ventilation and extraction systems shall be regularly inspected for their functioning and efficiency at least once a year (see clause 5, TRGS 528).

In accordance with the German hazardous substances ordinance, the following additional measures are required:

- information of the employees involved, the works council and employee committee concerned (§ 19 para2),

- notification of the responsible authority.

In addition, employment restrictions according to the Mutterschutzrichtlinienverordnung (directive ordinance on maternity protection) (§ 5) and the Jugendarbeitsschutzgesetz (youth employment protection act) (§ 22) shall be observed, if necessary.

6 Instruction and training Operating instruction

On the basis of the operating instruction, the employees shall be orally instructed prior to start of work and at regular intervals, but at least once a year.

For welding and allied processes with high alloy filler and base metals an operating instruction corresponding to the workplace shall be prepared in compliance with clauses 3.1.1 and 3.1.2 chapter 2.26 "Welding, cutting and allied processes) (BGR 500) in connection with § 14 "Unterrichtung und Unterweisung der Beschäftigten" (Instruction and information of the employees) Hazardous Substances Ordinance and the Technical Rules for Hazardous Substances "Betriebsanweisung und Information der Beschäftigten" (Operating instruction and information of the employees) (TRGS 555).

The operating instruction is based on the risk assessment carried out and shall be observed by the employees.

It has to be adapted to new findings and to be updated according to the state of the risk assessment.

According to TRGS 555, especially for activities with carcinogenic substances such as chromium(VI) compounds and nickel oxide, an occupational medical and toxicological consultancy and additional information duties are required and extended measures shall be taken.

As shown in the enclosure to TRGS 555 - Scheme "From the safety data sheet to the operating instruction", the contents of the safety data sheets generally present a good basis for the preparation of an operating instruction.

The model shown in Annex 1 may serve as an example for an operating instruction. In this model (container construction = confined spaces) also hazards, e.g. caused by electric current, noise, are considered which are not dealt with in the present BG Information.

Annex 2 shows the example of an operating instruction in accordance with § 14 GefStoffV.

7 Regulations and Rules

In the following, the main pertinent regulations and rules to be observed are listed:

7.1 Ordinances and Technical Rules

- Verordnung zum Schutz vor gefährlichen Stoffen (Gefahrstoffverordnung - GefStoffV)
- Verordnung zur arbeitsmedizinischen Vorsorge (ArbMedVV)
- Verordnung über Sicherheit und Gesundheitsschutz bei der Benutzung persönlicher Schutzausrüstungen bei der Arbeit (PSA-Benutzungsverordnung – PSA-BV),
- TRGS 400 "Gefährdungsbeurteilung für Tätigkeiten mit Gefahrstoffen
- TRGS 402 „Ermitteln und Beurteilen der Gefährdungen bei Tätigkeiten mit Gefahrstoffen: Inhalative Exposition“,
- TRGS 500 „Schutzmaßnahmen, Mindeststandards“,
- TRGS 528 "Schweißtechnische Arbeiten"
- TRGS 555 „Betriebsanweisung und Information der Beschäftigten“,
- TRGS 900 „Arbeitsplatzgrenzwerte“,
- TRGS 905 „Verzeichnis krebserzeugender, erbgutverändernder oder fortpflanzungsgefährdender Stoffe“,
- DVS/VDI Richtlinie 6005 „Lüftungstechnik beim Schweißen und bei den verwandten Verfahren“.

Source of supply: Bookselling trade or Carl Heymanns Verlag KG, Luxemburger Straße 449, 50939 Köln

7.2 Accident prevention regulations, BG Rules and BG Information Booklets

- „Grundsätze der Prävention“ (BGV A1)
- „Arbeitsmedizinische Vorsorge“ (BGV A4),
- „Arbeitsplatzlüftung - Lufttechnische Maßnahmen“ (BGR 121),
- „Benutzung von Atemschutzgeräten“ (BGR 190),
- "Betreiben von Arbeitsmitteln" (BGR 500
- "Handlungsanleitungen für die arbeitsmedizinische Vorsorge" (BGI/GUV-I 504)

- "Chrom(VI)-Verbindungen“ (BGI 504-15),
- „Atemschutzgeräte“ (BGI 504-26),
- "Nickel oder seine Verbindungen“ (BGI 504-38),
- „Schweißrauche“ (BG! 504-39),
- „Schadstoffe beim Schweißen und bei verwandten Verfahren“ (BGI 593),
- „Zertifizierte Atemschutzgeräte“ (BGI 693).

Source of supply: responsible Berufsgenossenschaft or Carl Heymanns Verlag KG, Luxemburger Straße 449, 50939 Köln

7.3 Principles of the DGUV for preventive occupational medical examinations

- G 15 Chrom(VI)-Verbindungen,
- G 26 Atemschutzgeräte,
- G 38 Nickel oder seinen Verbindungen,
- G 39 Schweißrauche.

Source of supply: Gentner Verlag, Abt. Buchdienst, Postfach 10 17 42, 70015 Stuttgart.

8 Other publications

Epidemiological studies

- Becker N.: „Epidemiologische Follow-up-Studie zur Krebsmortalität unter Chrom-Nickel-exponierten Lichtbogenschweißern“ (1997). Dritter Follow-up (1989 - 1995), Deutsches Krebsforschungszentrum, Abteilung Epidemiologie, Im Neuenheimer Feld 280, 69120 Heidelberg.

- Danielsen E., Langård S., Andersen A., Knudsen Q. “Incidence of cancer among welders of mild steel and other shipyard workers” (1993). Br. J. Ind. Med. 50.

- Hansen K. S., Lauritsen J. M., Skytthe A.: „Cancer incidence among mild steel and stainless steel welders and other metal workers“ (1996). AM. J. Ind. Med. 30.

- Sjögren B., Hansen K. S., Kjuus H., Persson P. G. „Exposure to stainless steel welding fumes and lung cancer: a meta-analysis“ (1994). Occup. Environ. Med. 51.

Studies on hazardous substances generation

- Eichhorn, F., u. T. Oldenburg: „Untersuchung der Schweißrauchentstehung beim Schweißen mit mittel- und hochlegierten Zusatzwerkstoffen“. (1986) Forschungsberichte Humanisierung des Arbeitslebens der Schweißer, Bd. 13. DVS-Verlag, Düsseldorf.

- Holzinger, K.: „Untersuchungen zur Schadstoffentstehung beim MIG-Schweißen von Nickel- und Nickelbasislegierungen“, Abschlussbericht (1996), Institut für Schweißtechnische Fertigungsverfahren der RWTH Aachen.

- Dennis, J.H.: "Control of Occupational Exposure to hexavalent Chromium and Ozone in Tubular Wire Arcwelding Processes by Replacement of Potassium by Lithium of by Addition of Zinc" 2001

- Dr. Lausch, H.: Untersuchungen der Zusammensetzung und Struktur von oxydischen Komponenten in freigesetzten Stäuben in der Arbeitsluft bei der Herstellung und Verarbeitung nickelhaltiger metallischer Werkstoffe - nickelhaltige Stäube", Final report (1999), HVBG Sankt Augustin.

Measurements at the workplace

- Grothe, Kühnen und Pfeiffer: „Betriebliche Messungen von Schweißrauchen unter Berücksichtigung von Nickel und Chromaten“. (1984) DVS-Berichte Band 90, Deutscher Verlag für Schweißtechnik, Düsseldorf.

Occupational safety and health protection

- Kraume, G., u. A. Zober: „Arbeitssicherheit und Gesundheitsschutz in der Schweißtechnik“. (1989) Fachbuchreihe Schweißtechnik, Bd. 105. DVS-Verlag, Düsseldorf.

- Spiegel-Ciobanu, V.-E.: „Chrom und Nickel in der Schweißtechnik“ in „Gesund und

Sicher“ 3/1996, Norddeutsche Metall-Berufsgenossenschaft, Hannover.

- Spiegel-Ciobanu, V.-E.: „Schadstoffmessungen beim Metall-Schutzgasschweißen (MIG/MAG) mit Nickel-Zusatzwerkstoffen“ in „Gesund und Sicher“ 8/2000, Norddeutsche Metall-Berufsgenossenschaft, Hannover.

- Spiegel-Ciobanu, V.-E.: „Schadstoffe beim Schweißen: Ergebnisse betrieblicher Untersuchungen und Bewertung der Gefährdung“, DVS-Berichte „Schweißen und Schneiden“ Bd. 209, DVS-Verlag, Düsseldorf.

Annex 1 - Operating Instruction

(Company name)	**OPERATING INSTRUCTION** [1]	No. **...**

1. SCOPE

WORK AREA: Chemical apparatus construction	WORKPLACE: Container construction ACTIVITY: Manual metal arc welding with covered electrodes containing chromium and nickel inside the container

2. HAZARDS TO MAN AND ENVIRONMENT

Electric current: increased electrical hazard by:

- welding voltage used
- operational voltage of electrical devices used

Heat:

- catching of fire of clothing, especially if dirty
- burning by hot parts, ejected splash, welding sputter and hot slag

Hazardous substances:

- inhalation of welding fume with carcinogenic proportions (chromium(VI) compounds/nickel oxides)
- allergic reactions of the skin (nickel oxide)
- irritation of the respiratory tract or damage to kidneys and liver (some chromium(VI) compounds)
- irritations of the mucous membranes of stomach and respiratory tract by fluorides (basic electrodes)

Noise: due to arc, seam preparation, plastering works, ventilation/extraction

Arc radiation: intensive glare (visible light); "arc eye", burning of unprotected parts of the skin (UV radiation)

Mechanical / chemical effects on the skin: sharp edges, corners, sweating in gloves or shoes

3. PROTECTIVE MEASURES AND RULES OF BEHAVIOUR

Visual examination of electric appliances and cables for operational safety before starting work

Use only tested electric equipment (observe test badge)

- use suitable welding current sources (S) , place outside of container
- install clamps for welding return cables as close as possible to the welding location
- use electric appliances (electric tools, lamps) only with protective extra-low voltage or protective disconnection
- always take care of faultless insulation of electric cables and equipment (also welding cables)
- only lay down electrode holder in insulated state
- use electrically insulating intermediate layers
- replace soaked, dirty (oiled) clothes, gloves by dry, clean ones
- effectively extract hazardous substances in the area of generation (correct positioning of capture element, continuous follow-up)
- additional forced ventilation (air supply and exhaust) [2])
- use respiratory protective equipment independent from the ambient air (self-contained closed-circuit devices); preventive occupational medical examinations according to G 26 “Respiratory protection” [2])[3])
- Preventive occupational medical examinations according to G 15 “Chromium”, G 38 “Nickel”, G 39 “Welding fumes in general” [2])

- use welder's shields or screens having protection levels 11 to 14 (appropriate setting of switchable electro-optical helmets)
- wear dry, heavily flammable protective garments, do not wear easily melting synthetic fibre underwear
- wear closed work clothes, use neck protection
- use leather gauntlets
- wear protective shoes with undamaged insulating sole
- wear heavily flammable hearing protection
- use knee pads during kneeing activities
- take up favourable posture, observe welding plume
- preventive occupational medical examinations according to G 20 “Noise”
- do not eat, drink and smoke at the workplace
- clean face and hands before breaks and after end of shift
- use skin protection, cleaning and care products in compliance with skin protection scheme
- preventive occupational medical examinations according to G 24 "Dermatoses"

4. BEHAVIOUR IN CASE OF DYSFUNCITIONS AND DANGER

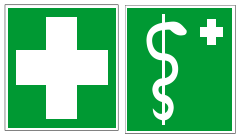
emergency call: ... [4])

In case of dysfunctions interrupt work and inform superior
Only re-start work after elimination of dysfunction

- In case of damage to electric cables and equipment interrupt mains connection , initiate exchange (repair only by electrical specialist)
- In case of failure of ventilation/extraction stop working, leave container

5. BEHAVIOUR IN CASE OF ACCIDENTS, FIRST AID

emergency call: ... [4])



In case of accidents interrupt work immediately, report accident (.....)[4])
Current accident:

- set system to zero potential
- salvage injured person
- start recovery chain
- immediate measures (mouth to mouth resuscitation, cardiac massage)

Irritation of respiratory tract and mucous membranes:

- go into fresh air
- see the doctor (Dr. ...[4])

Other accidents/injuries:

- see first aid appointed person ...[4]) (even in case of minor injuries)

6. MAINTENANCE, DISPOSAL

- Do not use electric equipment, the testing of which is overdue and initiate testing by an electrical specialist
- Dust free change of filters for extraction systems
- Thorough cleaning of extraction systems before repair or test works
- Dust-tight packing of filter and filter dust for disposal (hazardous/industrial waste)

7. CONSEQUENCES OF NON-OBSERVANCE

- Injuries, diseases, other damages to health
- Consequences related to labour legislation

Date:	Signature / release:	Shop steward:

[1]) - This operating instruction is an example and shall be adapted to the relevant requirements.
[2]) - These measures are necessary, as long as the use of extraction equipment is insufficient or impossible. According to TRGS 402 they are not necessary if compliance with the limit values is verified.
[3]) - If the selection criteria according to BGI 504-26 / BGR 190 are complied with.
[4]) - To be determined before start of work and recorded in the operating instruction by the employer. Instruct employees.

Annex 2 - Example of an operating instruction in accordance with § 14 of the German Hazardous Substances Ordinance, on the basis of TRGS 528, enclosure 4, page 26

(Company name)

OPERATING INSTRUCTION [1]

NO. …

acc. to § 14 of the German Hazardous Substances Ordinance

1. Scope

Work area/work-place/activity:
Ship building, chemical apparatus construction

Activity: Manual metal arc and MAG welding of chromium nickel steels

2. Designation of hazardous substance

- Welding fume with carcinogenic proportions of chromium(VI) compounds and nickel oxides

3. Hazards to man and environment

- Inhalation of these welding fumes may cause cancer
- Irritation of the respiratory tract (sputum, shortage of breath, bronchitis) and the gastric mucosa
- Allergic reactions of the skin due to chromium(VI) compounds and nickel oxide

4. Protective measures and rules of behaviour

- Always extract welding fumes in the area of generation
- Place capture element above the welding location and always follow-up
- Only work in ventilated rooms
- Use forced-air ventilated welder's helmet
- Dust-free filter exchange for extraction systems
- Thorough cleaning of the extraction systems prior to repair and test activities
- Do not eat, drink or smoke at the workplace
- Clean face and hands and change polluted work clothing before breaks and after end of shift
- Only clean workplace by means of vacuum cleaning (no sweeping!)

5. Behaviour in case of emergencies — Emergency call:…

- In case of failure of the extraction, ventilation or the forced-air ventilated helmet stop working immediately and leave the work zone
- Inform superior
- Only re-start working after remedy of the failure

6. First Aid — Emergency call:…

- In case of allergic reactions or irritations of the respiratory tract
- stop working without delay and consult physician

7. Adequate disposal

- Dust proof packing of filter and filtering dust (hazardous industrial waste)

Date:	Signature/Approval:

[1] This operating instruction is an example and shall be adapted to the relevant need of the case

Notes